A

TREATISE

ON

SHIP-BUILDING,

WITH

EXPLANATIONS AND DEMONSTRATIONS

RESPECTING

The Architectura Navalis Mercatoria.

BY

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TRANSLATED INTO ENGLISH

WITH EXPLANATORY NOTES, AND A FEW REMARKS ON THE CONSTRUCTION OF SHIPS OF WAR,

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TO

The Translation.

THE works of FREDERICK CHAPMAN, the Swedish Naval Architect, have always been held in very great estimation on the continent by every person at all interested in the construction of ships. It is hoped, therefore, that the following translation of his first treatise on this subject, will not be an unacceptable present to the young English ship-builder. Those notes by the French translator Vial Du Clairbois, which seemed most worthy of notice, have been printed with it; some others also have been given by the English translator, which he trusts will not be found altogether unimportant. At the end a few general remarks on the construction of ships of war have been added, which are more particularly intended to serve as a guide, in their exercises, to the students at the School of Naval Architecture in Portsmouth Dock-yard.

The observations of Chapman in this, and all his other treatises, are the more valuable, as coming from a person, who united vast experience as a ship-builder to considerable scientific attainments. As some proof of this, we need only give a brief outline of his life. He was born at Gottenburgh on the 9th of May 1721. His father, a native of England, was an officer of some rank in the Royal Swedish Navy. His mother was the daughter of a Mr. Colson, a ship-builder in London.

Chapman was educated with a view to his becoming a ship-builder, for which profession he seems to have formed an early and decided predilection. When a young man he left Sweden, and travelled abroad for the purpose of gaining information in the different modes of construction and actual building. In England he entered himself and wrought some time in Deptford yard as a common ship-wright; after which he visited Brest and Toulon in the same character, and with the same view.

On his return to Sweden he first brought himself into public notice and esteem by constructing flat-bottomed vessels to be used with the army on the coasts of the Baltic. During the Pomeranian war he particularly distinguished himself by the activity and skill he evinced in the difficult and important charge, which he had as ship-builder to the army; and obtained the marked approbation of Field Marshal Count Ehrenswärd. Soon after he was placed at Carlscrona as Chief Ship-builder of the Swedish Navy; in which situation he remained to the time of his death in about 1810.

When ship-builder to the army in 1772 he was ennobled by the King (Gustavus III.) and made a Knight of the Royal Order of the Sword. He obtained the rank of Colonel in the Swedish Navy in 1777, and that of Rear Admiral in 1783.

His principal writings are as follows:

1. A folio book of plates, containing constructions of merchant ships, and entitled Architectura Navalis Mercatoria, published in 1768.

2. A Treatise on Ship-building, with explanations and demonstrations on the Architectura Navalis Mercatoria; published in 1775.

3. An account of Experiments made at Carlscrona to determine the resistance to Ships; published in 1795.

4. A Treatise concerning the true method of finding the proper area of the Sails for Ships of the Line, and from thence the length of the Masts and Yards; published about 1793, and translated into English 1794.

5. A small Treatise on the Management of Ships for the use of Naval Officers; date of publication unknown.

6. Investigation to determine, for Ships of the Line, their right size and form; the same for Frigates and smaller armed vessels; published in 1806.

From the above short sketch of his life, it is sufficiently evident that Chapman possessed, when young, an uncommon zeal in the prosecution of his studies, and in the pursuit of professional knowledge, wherever it could be found. In the application of the knowledge he thus acquired he had peculiar advantages. He was placed in situations in which he had opportunities of planning and building almost every species of vessels; and he lived long enough to observe how far his different constructions succeeded. He was thus enabled to bring his ideas on every branch of Naval Architecture to the test of actual experiment, and, if necessary, to make from time to time such alterations, as his farther experience suggested.

These considerations, in addition to the acknowledged eminence of

Chapman abroad, will be some inducement to the young English ship-builder to study his writings; from which he may expect to derive considerable benefit. He will certainly thereby acquire true notions on the nature, extent, and real difficulty, of the subject; and what is equally important, he will be put on his guard against the many erroneous conclusions, that persons not thoroughly conversant with it, are so apt to fall into.

In justice to the Swedish writer, it seems necessary to state that this translation has been made chiefly from the French of Clairbois; compared however, in every doubtful passage, with the original Swedish. And it is presumed, that there are few, if any passages, in which the sense of the Author is not sufficiently clear; which probably is as much as the reader will require in a work of this kind.

The translator begs to thank the SYNDICS of the University Press at Cambridge, for the assistance they have generously afforded him in printing this work. It will give him great pleasure, should this proof of their wish to facilitate the study of Naval Architecture be productive of public benefit. He embraces this opportunity of making his acknowledgments also to the Right Honourable Viscount Melville, First Lord of the Admiralty, for the steady and flattering encouragement and support he has received from him on this, and every other occasion, on which he has endeavoured to give effect to his Lordship's views in the improvement of the system of Naval Architecture in this country.

THE AUTHOR'S

Preface.

If we were to take a view of the immense number of ships that have been built, since mankind first began to navigate upon the ocean, and note all the different steps, which have been taken in improving their construction, we should at first sight be inclined to believe, that the art of ship-building had, at length, been brought to the utmost perfection. An opinion that would receive additional force from a consideration of the few essential considerations, which have been introduced either in their form or rigging, during our own age.

Yet when we recollect the different kinds of ships and vessels, that are used in Europe, it will appear less surprising to us, if there should be good grounds for asserting that their very great variety, equally with other causes, have prevented ship-builders and riggers from discovering either the true figure and shape of ships, or the best mode of rigging them, either generally, or, for each species of vessel in particular.

In order to form a decisive opinion in both these points of view, on the degree of perfection to which ships in general have arrived, we will divide those of all nations into two classes; comprising in one, all small vessels, or those used in short voyages and narrow waters; in the other, all larger ships, or those employed in distant voyages, and calculated for going out to sea.

The first class consists of the vessels, that different natives make use of in their coasting trade, or in their commerce with neighbouring countries. As the climate, the extent and depth of the seas, the position of the countries with respect to the sea and to each other, also their productions, are different in different countries, the proportion and form of these vessels, as well as the mode of rigging them, must necessarily depend upon these circumstances. Thus a species of perfection may be found in the circumstance, that they are dissimilar in the same degree as their objects differ.

On the contrary, if we consider the ships comprehended in the second class, even though of different countries, we shall find that being built for the same purposes, they are similar in their essential parts. As to their proportions, we find that the breadth is between one-third and one-fourth of the length; that the least have usually greater breadth in proportion to their length than the largest; that the draught of water is something greater or less than the half breadth. The height out of the water has also limits, which depend on the particular destination of the ship. The accommodations, moreover, in these ships, among all nations have a great similarity; they differ only in matters of small importance, in which each follows the plan that appears most convenient.

With respect to form, we see that all ships have their greatest breadth a little before the middle; that they are leaner aft than forward; that those designed for ships of burthen are fuller in the bottom; that those built for sailing are leaner there; that the stem and stern-post have a rake; that they have a greater draught of water aft than forward, &c. With regard to the rigging, most vessels have three masts, others two, and some only one; which depends on their size. These masts with respect to the ships and the manner of rigging them, have nearly the same proportions and the same place. They are also generally rigged in the same manner, except that some may have more or less sail, according to the judgment of the owner. All ships have their center of gravity a little before the middle of their length, and the center of gravity of the sails always before the center of gravity of the ship.

In this manner all ships designed for navigating in the open sea are constructed; and as this mode of construction is the result of an infinite number of trials and experiments, and of alterations made in consequence thereof, it would be improper to infringe on limits so established.

But although ships are thus confined as to their proportions, within certain limits, still however they admit of such variations in their form, as to produce an infinite number of qualities more or less good, or more or less bad.

There are ships possessing all the qualities, which we can reasonably wish for, and there are others, which, although within the above-mentioned limits, have nevertherless a great many faults.

In the construction of ships, people usually make attempts at different times to improve the form, each person according to his own experience; thus after the construction of one ship, which has been tried and found to possess such or such a bad quality, it seems possible to remedy this defect in another. But it often (not to say generally) happens, that the new ship possesses some fault equally as great, and frequently even that the former defect, instead of being removed, is increased. And we are unable to determine, whether this fault proceeds from the fault of the ship, or from other unknown circumstances.

It thus appears, that the construction of a ship with more or less good qualities, is a matter of chance and not of previous design, and it hence follows, that as long as we are without a good theory on ship-building, and have nothing to trust to beyond bare experiments and trials, this art cannot be expected to acquire any greater perfection, than it possesses at present.

It becomes a matter of importance then, to discover what may bring this knowledge to greater perfection. Seeing that ships, the proportions of which lie within the same limits, nay, which have the same form, differ greatly from each other in respect to their qualities, and even that with a small alteration in the form, a ship acquires a quality immediately opposite to the one we wish to give it, we must conclude that this arises from certain physical causes; and that the art of constructing ships cannot be carried to greater perfection, till a theory has been discovered, which elucidates these causes.

In every art or science there exists a hidden theory, which is the more or less difficult to be found out, as the art or science depends more or less on physical causes.

Into the theory of a common oar, even Archimedes made researches, and many others after him; notwithstanding which, this theory is not yet fully explained. If such difficulties occur in this investigation, how great must those be which attend the theory of ship-building, where so many other circumstances are combined!

It is true, that the oar is made use of to great advantage in rowing, the cannon in firing; an infinite number of machines are in like manner used, without considering it absolutely necessary to investigate to the bottom their theory. We see how little these machines can be advanced towards perfection by its assistance. The question may be perhaps concerning some inches more or less in the length of the oar, concerning a twentieth part less matter for a cannon of the same force; so that the theory for these objects is not so necessary as for ships.

For ships, we have to fear an infinity of bad qualities of the greatest consequence, which we are never sure of being able to remove, without understanding the theory.

At the same time the construction of ships and their equipment, are attended with too great expense, not to endeavour beforehand to insure their good qualities and their suitableness for what they are intended for. The theory then which elucidates the causes of these different qualities, which determines whether the defects of a ship proceed from its form, or from other causes, is truly important; but as the theory is unlimited, practice must determine its limits. We may consequently farther conclude, that the art of ship-building can never be carried to the last degree of perfection, nor all possible good qualities be given to ships, before we at the same time possess in the most perfect degree possible, a knowledge both of the theory and practice.

To possess this theory in all its extent seems to exceed the force of the human understanding. We are obliged therefore to content ourselves with a part of this vast science; that is, with knowing sufficient of it to give to ships the principal good qualities, which I conceive to be:

1. That a ship with a certain draught of water, should be able to contain and carry a determinate lading.

2. That it should have a sufficient and also determinate stability.

3. That it should be easy at sea, or its rolling and pitching not too quick.

4. That it should sail well before the wind, and close to the wind, and work well to windward.

5. That it should not be too ardent, and yet come easily about.

Of these qualities one part is at variance with another; it is necessary therefore to try so to unite theory and practice, that no more is lost in one object than is necessary in order to secure another, so that the sum of both may be a maximum.

This is the subject of this short treatise. Whether I have succeeded or not, will be seen by the reader. There will be found in it some things both in theory and practice, which have not hitherto been treated of, and which may be worthy the attention of persons who are desirous of applying themselves to this science; it will be seen moreover, that the principles laid down admit of demonstration, although they are of the most difficult nature.

Still however it must be confessed, that this science has one great difficulty, in which it probably differs from all others; namely, that even after following the theory with the greatest exactness, and executing the work, according to its rules, with the greatest care, the constructor may notwithstanding suffer in point of professional reputation. For although a ship may have been built in conformity with all the rules which both theory and practice prescribe, its yards have got their true proportions, and the masts their true place and position; so that there appears to be the greatest certainty of its possessing all the best qualities; it may nevertheless happen, that such a vessel will answer very ill for the following reasons:

1. Although the rigging of the ship (when the masts and yards are put in their place, and are in due proportion) is not a matter of such great difficulty, but that every seaman knows how to give the proper proportions, it happens, notwithstanding, that too stout cordage and too large pullies are frequently used, which renders the weights aloft too considerable. It may happen also that the sails are badly cut, on which account the ship may lose the advantage of sailing well close to the wind, of coming about, &c. whence great inconveniences may result, with which the form of the ship has nothing to do.

2. The ship is liable also to become ungovernable, to lose its good qualities in every way by the bad disposition of the stowage. If the lading

be too low, the moment of stability will become too great, which will occasion violent rolling. On the contrary, if the weight of the lading be too much raised, the ship will not carry sail well when the wind blows fresh; neither will it be able to work off a lee shore; if the lading be too heavy towards the extremities, it will produce heavy sending and pitching, whence the ship may become the worst possible sailer, with other inconveniences which are not the fault of the ship itself.

3. The good performance of a ship depends also on the manner in which it is worked; for if the sails be not well set, with respect to the direction of the wind and the course, it will lose in point of sailing; it will become slack so as to miss stays, which often places a ship in a critical situation. The person who works the ship is also charged with an attention to the draught of water; and to the manner of setting up the shrouds and stays, upon which the qualities of the ship greatly depend. Furthermore, to work the ship well is of greater consequence in a privateer, than in a merchant ship. One who understands the management of his ship, knows how to give it all the good qualities it is capable of; he knows how to employ those qualities to his advantage, and when he is engaged with an enemy, he thereby makes himself master of the attack; but he who blunders in the working of his ship, may thereby not only be reduced to the necessity of acting solely on the defensive, but seldom if ever escapes falling an easy prey to the enemy, although his ship is ever so carefully and well built.

Thus an owner may suffer considerable losses, in a thousand ways, less through the defects of his ship, than the ignorance of the commander.

It is even frequently observed, that a ship exhibits the best qualities, during one cruize, and the very worst during another.

Lastly, it is evident from all that has been said, that a ship of the best form, will not shew its good qualities, except it is at the same time well rigged, well stowed, and well worked by those who command it.

ERRATA.

PAGE 31 line 19 for *than* read *as*.
—— 56 — 13 for *size and length* read *breadth and height*.
—— 66 — 15 for *mizen top-sail* read *spanker*.
—— ib. — 16 for *Mizen top-gallant sail* read *Mizen top-sail*.
—— 95 — 7 for $A^{\frac{2}{8}}$ read $A^{\frac{2}{7}}$.
ib. for (*Note* 47.) read (*Note* 46.)
99 in Table, for *sills* read *ports*.
—— 101 line 9 for $\frac{2}{3}\int y^3\, d\dot{x}$ read $\frac{2}{3}\int y^3\, \dot{x}$.
—— 109 — 8 from bottom, for *girth of the yard is* read *yard arms are*.
—— 112 last line, after *ship* add *top sail-yard* 0,8 × *main-yard*.
—— 129 line 9 from bottom, for *after edge* read *square*.
—— 174 — 8 for *by contract* read *on speculation*.
—— 188 — 4 from bottom, for *beer* read *butter*, and for *ditto* read *quarts*.
—— ib. — 5 from bottom, for *beer* read *butter*, and for *quarts* read *pounds*.
—— 237 — 5 for W and w read Z and z; and for Z and z read W and w.
—— 240 — 12 for $nw \times z + mw \times y$ read $mw \times z + nw \times y$.

CHAPTER I.

ON THE DISPLACEMENT OF A SHIP, AND THE CENTER OF GRAVITY OF THAT DISPLACEMENT.

(Art. 1.) The displacement is the volume of water, which the weight of a ship causes it to displace, when it lies in still water.

The more heavily a ship is laden, the greater will be the immersion and consequent displacement; and the weight of the ship is equal to that of the volume of water it displaces.

The weight of the hull and rigging being known, if the displacement be known also, the weight of the lading is determined; and *vice versâ.*

Hence appears the importance of rightly ascertaining the displacement of a ship from its projected draught, in order that one may neither build a larger ship than the object in view requires, which would be attended with great and unnecessary expence, nor on the other hand suffer loss by building one too small and therefore useless. This is the more important in ships of war and privateers, as the nature of the lading, with the space occupied by and the distribution of their stores, is more accurately determined; it is a necessary consideration also, in order to give the ship the proper qualities in stability and sailing, which depend greatly thereon.

The imperfect nature of the methods hitherto made use of to calculate the displacement, has induced me to give the following one, and to illustrate it by examples, in order that persons engaged in the construction of ships, seeing its simplicity, may no longer embarrass themselves with the long calculations which other methods require.

To find the area of a curvilinear plane figure.

(2.) Let $HIKLO$ (Fig. 1.) be a portion of a parabolic curve. Draw the lines AH, BI, CK, &c. perpendicular to the line AG (NOTE 1.) and at equal distances from each other; draw afterwards the straight line HK; then IR is a diameter, and HR, RK, ordinates of the parabola HIK. Let AH, BI, CK, DL, &c. $= a, b, c, d, e, f, g$; and $AB = BC$, &c. $= m$. Then the area of the trapezium $AHKC = m \times (a + c)$, and the area of the parabolic part $HIKRH = \frac{2}{3} \times \left(b - \frac{a+c}{2}\right) \times 2m = \frac{4b - 2a - 2c}{3} \times m$ (NOTE 2.). Consequently the area of the surface $AHIKC = m \times (a + c) + \frac{4b - 2a - 2c}{3} \times m = \frac{a + 4b + c}{3} \times m$..

It is seen in the same manner that the area $CKLME = \frac{c + 4d + e}{3} \times m$, and $EMNOG = \frac{e + 4f + g}{3} \times m$; consequently the whole area $AHLOG$ is equal to the sum of these three quantities, that is, to

$$\frac{a + 4b + 2c + 4d + 2e + 4f + g}{3} \times m.$$

COROLLARY.

(3.) In this manner the area of any curvilinear plane figure is found; that is to say, ordinates being drawn at equal distances (the less that distance the more exact the result), being drawn also perpendicular to the axis, which axis is supposed to be divided into an even number of parts, so that the number of ordinates may be odd, the coefficient of the first and last is 1; of the second and last but one 4; of the third and last but two 2; and so on alternately, 4 and 2 as far as the middle term, which has, according to this order, 2 or 4, for its coefficient. The sum of these functions of the ordinates is multiplied by one-third the distance between them. This method of finding the areas of curvilinear plane figures, is sufficiently exact for practice, which appears from the following example (NOTE 3.).

(4.) Let AFL (Fig. 2.) be a quadrant of a circle, the radius $AL = AF = 8$, and AF, BG, CH, DI, EK, five ordinates; the distance between them AB, BC, CD, &c. $= 1$; it is required to find the area of $AFHKE$.

AF being equal to 8, from the nature of the circle, $BG = \sqrt{63} = 7{,}937254$; $CH = \sqrt{60} = 7{,}74596$; $DI = \sqrt{55} = 7{,}4162$; $EK = \sqrt{48} = 6{,}9282$, and the area $AFHKE$, according to the corollary, is $= \frac{1 \times 8 + 4 \times 7{,}937254 + 2 \times 7{,}74596 + 4 \times 7{,}4162 + 1 \times 6{,}9282}{3} = 30{,}611312$ (NOTE 4.) Whence is easily found the area of the quadrant of a circle. For by subtracting from the area $AFHKE = 30{,}611312$ the area $AKE = 13{,}8564$, there remains $16{,}7549$ for the area of the sector AFK; and as $AE = EL$, it follows that this quantity $16{,}7549$ multiplied by 3, will be the area $AFKL = 50{,}2647$ (NOTE 5.). This calculation is exact to the fifth place.

To find the center of gravity of a plane (NOTE 6.).

(5.) The distance of the center of gravity of the trapezium $AHKC$ (Fig. 1.) from the line $AH = \frac{2}{3} m \times \frac{a + 2c}{a + c}$ (NOTE 7.), and that of the center of gravity of the surface of the parabolic part $HIKRH$ from the same line $= m$; consequently, the distance of their common center of gravity $=$

$$\frac{\frac{2}{3} m \times \frac{a + 2c}{a + c} \times (a + c) \times m + \frac{2}{3} m \times (2b - a - c) \times m}{(a + c) \times m + \frac{2}{3} m \times (2b - a - c)} = m \times \frac{4b + 2c}{a + 4b + c}.$$

In the same manner the distance of the center of gravity of the area $CKME$ from the line $CK = m \times \frac{4d + 2e}{c + 4d + e}$, and from the line $AH = m \times \frac{2c + 12d + 4e}{c + 4d + e}$; and lastly the distance of the center of gravity of the area $EMOG$ from the line $EM = m \times \frac{4f + 2g}{e + 4f + g}$, and from the line $AH = m \times \frac{4e + 20f + 6g}{e + 4f + g}$; consequently the distance of the common center of gravity of these three spaces from the line $AH =$

$$\frac{4b + 4c + 12d + 8e + 20f + 6g}{a + 4b + 2c + 4d + 2e + 4f + g} \times m =$$

$$\frac{0 \times a + 1 \times 4b + 2 \times 2c + 3 \times 4d + 4 \times 2e + 5 \times 4f + 6g}{a + 4b + 2c + 4d + 2e + 4f + g} \times m.$$

COROLLARY.

(6.) The center of gravity of a plane is found, therefore, by means of the expression for the area of a plane; by multiplying the function of the first ordinate by 0, of the second by 1, of the third by 2, of the fourth by 3, &c.; by dividing the sum of these products by the sum of the functions; and by multiplying the quotient by the distance between the ordinates (NOTE 8.).

To find the solid content and center of gravity of solids.

(7.) Let ADC (Fig. 3.) be a solid formed by the revolution of the curve AFD round its axis AB; required the solid content, and the center of gravity of the part $CMFD$ of this solid.

Through the point G draw the line NE, which is perpendicular to the axis AB. Produce the lines CD and MF, which are parallel to NE; let p be the area of a circle, whose diameter is 1. Suppose a line LKI drawn so that the ordinates HL, GK, BI, may be equal to the area of the corresponding sections $p \times MF^2$, $p \times NE^2$, $p \times CD^2$; then it is manifest that the area of the plane $HLIB$ will express the solidity of the body $MFDC$.

Hence we see that the formula for measuring areas (Art. 3.), serves also for finding the content of solid bodies; and that the formula for the calculation of the center of gravity of the same areas, serves in a similar manner for finding the center of gravity of solids (NOTE 9.).

COROLLARY.

(8.) When $BG = GH$, then the area $HLIB$ (Art. 3.) $=$ $(BI + 4GK + HL) \times \frac{BG}{3}$; consequently, the solidity of $CMFD =$

$(CD^2 + 4NE^2 + MF^2) \times \frac{p \times BG}{3}$, and if $BH = AH$, it follows that the solidity of the whole body $AFDCMA = (CD^2 + 4MF^2) \times p \times \frac{BH}{3}$.

When the solid is a cone, $4MF^2$ is equal to CD^2; when it is a paraboloid, $4MF^2$ is equal to $2CD^2$; when the solid is a hemispheroid, it is equal to $3CD^2$; when a cylinder, to $4CD^2$. The contents of these bodies are respectively as the numbers $2 : 3 : 4 : 6$.

The distance of the center of gravity, in the last case, is expressed by $\frac{4HL + 2BI}{4HL + BI} \times AH = \frac{4MF^2 + 2CD^2}{4MF^2 + CD^2} \times AH$, which gives for each of these four kinds of solids the distance of the center of gravity from $A = \frac{3}{4}, \frac{2}{3}, \frac{5}{8}$ and $\frac{1}{2} AB$ (NOTE 10.).

To calculate the displacement of a ship; and the position of the center of gravity of that displacement, with respect both to length and depth.

(9.) For example, to find the displacement, &c. of the privateer (Fig. 43, 44 and 46.)

Upon the sheer-plan or plan of elevation (Fig. 43.) ϕ, 3, 6, 9, 12, &c. C, F, I, &c. represent the projections of sections perpendicular to the keel, and at equal distances from each other.

The figure of these sections is represented upon the body-plan or plan of projection, (Fig. 44.); ϕ is the main section; to the left are represented the transverse sections abaft ϕ; they are denoted by 3, 6, 9, 12, &c.; to the right are represented the sections afore the same section; they are denoted by C, F, I, M, &c.

On the sheer-plan or plan of elevation (Fig. 43.) is drawn a line, which marks the draught of water, the ship being completely equipped; it is called the load water-line. This line is not parallel to the keel, when ships have a greater draught of water abaft than forward.

At equal distances, taken at pleasure, other water-lines are drawn under, and parallel to, the load water-line. These water-lines afterwards are transferred to the body-plan, by setting off their heights on the corresponding sections; by which means are formed the line marked 1 and the dotted lines 2, 3, 4, 5, 6, 7. The figure 1 denotes the load water-line, 2 denotes the second; 3, the third, &c. Each section or moulding edge of the frame, has then seven ordinates or breadths, which are known; the length of each of these ordinates is measured on a decimal scale, and written down in order, as in the following table. The ordinates are multiplied successively by 1, 4, 2, 4, 2, 4, 1, (Art. 3.), and the sum of the products is again multiplied by one-third of the distance between the water-lines.

The distance between these water-lines = 1,62 feet, of which the third = 0,54; the sum therefore is multiplied by 0,54. The triangle which is between the last water-line 7 and the keel, being added to this quantity, we have the area of the half frame; the operation is as follows.

HALF AREA OF EACH SECTION.

Water-lines.	Ord.	Section 27.	Ord.	Section 24.	Ord.	Section 21.
1	4,67	1 = 4,67	8,88	1 = 8,88	11,14	1 = 11,14
2	2,16	4 = 8,64	6,16	4 = 24,64	9,14	4 = 36,56
3	1,25	2 = 2,50	3,60	2 = 7,20	6,58	2 = 13,16
4	0,86	4 = 3,44	2,18	4 = 8,72	4,02	4 = 16,08
5	0,62	2 = 1,24	1,47	2 = 2,94	2,47	2 = 4,94
6	0,45	4 = 1,80	0,97	4 = 3,88	1,48	4 = 5,92
7	0,40	1 = 0,40	0,67	1 = 0,67	0,87	1 = 0,87
		22,69		56,93		88,67
		0,54		0,54		0,54
		9076		22772		45468
		11345		28465		34335
		12,2526		30,7422		47,8818
Part towards the keel		0,52		0,87		1,045
	Area...	12,77	Area...	31,61	Area...	48,92

Water-lines.	Ord.	Section 18.	Ord.	Section 15.	Ord.	Section 12.
1	12,46	1 = 12,46	13,30	1 = 13,30	13,91	1 = 13,91
2	11,00	4 = 44,00	12,36	4 = 49,44	13,19	4 = 52,76
3	8,90	2 = 17,80	10,72	2 = 21,44	11,98	2 = 23,96
4	6,24	4 = 24,96	8,37	4 = 33,48	10,10	4 = 40,40
5	3,81	2 = 7,62	5,51	2 = 11,02	7,33	2 = 14,66
6	2,11	4 = 8,44	2,98	4 = 11,92	4,26	4 = 17,04
7	1,10	1 = 1,10	1,37	1 = 1,37	1,78	1 = 1,78
		116,38		141,97		164,51
		0,54		0,54		0,54
		46552		56788		65804
		58190		70985		82255
		62,8452		76,6638		88,8354
Part towards the keel		1,32		1,507		1,958
	Area...	64,16	Area...	78,17	Area...	90,79

Water-lines.	Ord.	Section 9.	Ord.	Section 6.	Ord.	Section 3.
1	14,35	1 = 14,35	14,61	1 = 14,61	14,75	1 = 14,75
2	13,81	4 = 55,24	14,18	4 = 56,72	14,39	4 = 57,56
3	12,81	2 = 25,62	13,30	2 = 26,60	13,64	2 = 27,28
4	11,30	4 = 45,20	12,01	4 = 48,04	12,40	4 = 49,60
5	9,01	2 = 18,02	10,04	2 = 20,08	10,66	2 = 21,32
6	5,75	4 = 23,00	7,00	4 = 28,00	7,90	4 = 31,60
7	2,14	1 = 2,14	2,63	1 = 2,63	2,98	1 = 2,98
		183,57		196,68		205,09
		0,54		0,54		0,54
		73428		78672		82036
		91785		98340		102545
		99,1278		106,2072		110,7486
Part towards the keel		2,14		2,367		2,384
	Area...	101,27	Area...	108,57	Area...	113,13

Water-lines.	Ord.	Section ϕ.	Ord.	Section C.	Ord.	Section F.
1	14,80	1 = 14,80	14,79	1 = 14,79	14,57	1 = 14,57
2	14,40	4 = 57,60	14,36	4 = 57,44	14,06	4 = 56,24
3	13,67	2 = 27,34	13,53	2 = 27,06	13,17	2 = 26,34
4	12,48	4 = 49,92	12,30	4 = 49,20	11,80	4 = 47,20
5	10,78	2 = 21,56	10,53	2 = 21,06	9,81	2 = 19,62
6	8,05	4 = 32,20	7,72	4 = 30,88	6,75	4 = 27,00
7	3,00	1 = 3,00	2,78	1 = 2,78	2,40	1 = 2,40
		206,42		203,21		193,37
		0,54		0,54		0,54
		82568		81284		77348
		103210		101605		96685
		111,4668		109,7334		104,4198
Part towards the keel		2,4		2,24		1,68
	Area...	113,87	Area...	111,97	Area...	106,10

Water-lines.	Ord.	Section I.	Ord.	Section M.	Ord.	Section P.
1	14,16	1 = 14,16	13,43	1 = 13,43	12,10	1 = 12,10
2	13,55	4 = 54,20	12,58	4 = 50,32	10,82	4 = 43,28
3	12,48	2 = 24,96	11,14	2 = 22,28	8,98	2 = 17,96
4	10,81	4 = 43,24	9,15	4 = 36,60	6,83	4 = 27,32
5	8,55	2 = 17,10	6,72	2 = 13,44	4,58	2 = 9,16
6	5,38	4 = 21,52	3,88	4 = 15,52	2,53	4 = 10,12
7	2,08	1 = 2,08	1,57	1 = 1,57	1,10	1 = 1,10
		177,26		153,16		121,04
		0,54		0,54		0,54
		70904		61264		48416
		88630		76580		60520
		95,7204		82,7064		65,3616
Part towards the keel		1,456		0,95		0,66
	Area...	97,18	Area...	83,66	Area...	66,02

Water-lines.	Ord.	Section *S*.	Ord.	Section *W*.
1	9,49	1 = 9,49	5,00	1 = 5,00
2	7,80	4 = 31,40	3,73	4 = 14,92
3	5,97	2 = 11,94	2,59	2 = 5,18
4	4,10	4 = 16,40	1,70	4 = 6,80
5	2,68	2 = 5,36	1,05	2 = 2,10
6	1,55	4 = 6,20	0,60	4 = 2,40
7	0,77	1 = 0,77	0,30	1 = 0,30
		81,36		36,70
		0,54		0,54
		32544		14680
		40680		18350
		43,9344		19,8180
Part towards the keel		0,385		0,15
		Area . . . 44,32	Area . . . 19,97	

(10.) To find the solid content of the displacement and its center of gravity, the areas of the sections are made use of, as we have just made use of the ordinates (Art. 3. 9.). The distance between the sections = 6,27 feet, one-third of which = 2,09. To the result of the calculations are added the solid contents of the parts, which are situated between the section *W* and the stem, and between the section 27 and the sternpost. The sum is half the displacement, which multiplied by 2, gives the total displacement to the outside of the timbers, not including the planking, the sternpost, the stem, and the keel.

(11.) To get the distance of the center of gravity from the section 27, the functions of the areas of the sections are multiplied; the first, or the area of the section 27, by 0; the second by 1; the third by 2; &c. (Art. 6.) Dividing the sum of these products by the sum of the functions of the areas of the sections, the quotient multiplied by the distance between the sections, will be the required distance of the center of gravity for that part of the bottom, which is contained between the section 27 and *W*, from the section 27. The operation is as follows.

Sections.	Areas of the sections.	Multipliers.	Products.	Multipliers.	Products.
27	12,77	1	12,77	0	
24	31,61	4	126,44	1	126,44
21	48,93	2	97,86	2	195,72
18	64,16	4	256,64	3	769,92
15	78,17	2	156,34	4	625,36
12	90,79	4	363,16	5	1815,80
9	101,27	2	202,54	6	1215,24
6	108,57	4	434,28	7	3039,96
3	113,13	2	226,26	8	1810,08
Φ	113,87	4	455,48	9	4099,32
C	111,97	2	223,94	10	2239,40
F	106,10	4	424,40	11	4668,40
I	97,18	2	194,36	12	2332,32
M	83,66	4	334,64	13	4350,32
P	66,02	2	132,04	14	1848,56
S	44,32	4	177,28	15	2659,20
W	19,97	1	19,97	16	319,52

3838,40

$\times\ \frac{1}{3}$ the dist. between the frames = 2,09

3454560
767680

8022,2560 = $\frac{1}{2}$ the displacement betw. 27 & *W*.
between *W* and the stem = 60
between 27 and the sternpost = 23

8105 = $\frac{1}{2}$ the displacement.
2

16210 = total displacement.

$\frac{32115,56}{3838,40} = 8,3669$

6,27 = dist. between the frames.

585683
167338
502014

52,460463 = the distance from the center of gravity to the frame 27, for the part which is between 27 and *W*.

(12.) Now to find the common center of gravity of the three parts; that which is between 27 and *W*= 8022,256 cubic feet; that between *W* and the stem = 60; and that between 27 and the sternpost = 23; the center of gravity of the part forward is 2 feet before the section *W*; and from 27 to *W* there are 16 distances of 6,27 feet each, consequently, the whole distance from 27 to *W*= 100,32; add thereto the 2 feet, and the distance of the center of gravity of the part forward from the section 27 will be 102,32 feet. The center of gravity of the part between 27 and *W* is 52,46 feet, also before the section 27; the center of gravity of the part aft is 1,2 feet behind the same section 27; then

$$\frac{102{,}32 \times 60 + 52{,}46 \times 8022{,}256 - 1{,}2 \times 23}{60 + 8022{,}256 + 23} = \frac{426959}{8105} = 52{,}678 = \text{the distance}$$

which the center of gravity of the whole displacement is before the section 27; consequently, it is 2,518 before the section 3.

To find the distance of the center of gravity of the same displacement, from the plane of the load water-line.

(13.) To do this, the same rule is used; we easily find the area of the seven water-lines, which are used in the calculation in the same manner as we have made use of the areas of the sections. The same ordinates serve again, but they are arranged in another order, so that those which are in the plane of the load water-line, form one column; those of the second water-line, another column; and so on successively.

Each water-line has 17 ordinates; they are multiplied by 1, 4, 2, 4, &c. the last by 1; the sum of these products is multiplied by one-third of 6,27, the distance between the sections; that is by 2,09.

To the areas of the water-lines are added respectively those of the triangles, which are near the stem and sternpost.

Half Areas of the Water-lines.						
Sections.	Ord.	Load water-line.	Ord.	Second water-line.	Ord.	Third water-line.
27	4,67	1 = 4,67	2,16	1 = 2,16	1,25	1 = 1,25
24	8,88	4 = 35,52	6,16	4 = 24,64	3,60	4 = 14,40
21	11,14	2 = 22,28	9,14	2 = 18,28	6,58	2 = 13,16
18	12,46	4 = 49,84	11,00	4 = 44,00	8,90	4 = 35,60
15	13,30	2 = 26,60	12,36	2 = 24,72	10,72	2 = 21,44
12	13,91	4 = 55,64	13,19	4 = 52,76	11,98	4 = 47,92
9	14,35	2 = 28,70	13,81	2 = 27,62	12,81	2 = 25,62
6	14,61	4 = 58,44	14,18	4 = 56,72	13,30	4 = 53,20
3	14,75	2 = 29,50	14,39	2 = 28,78	13,64	2 = 27,28
Φ	14,80	4 = 59,20	14,40	4 = 57,60	13,67	4 = 54,68
C	14,79	2 = 29,58	14,36	2 = 28,72	13,53	2 = 27,06
F	14,57	4 = 58,28	14,06	4 = 56,24	13,17	4 = 52,68
I	14,16	2 = 28,32	13,55	2 = 27,10	12,48	2 = 24,96
M	13,43	4 = 53,72	12,58	4 = 50,32	11,14	4 = 44,56
P	12,10	2 = 24,20	10,82	2 = 21,64	8,98	2 = 17,96
S	9,49	4 = 37,96	7,80	4 = 31,20	5,97	4 = 23,88
W	5,00	1 = 5,00	3,73	1 = 3,73	2,59	1 = 2,59
		607,45		556,23		488,24
$\frac{1}{3}$ dist. between frames		= 2,09		= 2,09		= 2,09
		546705		500607		439416
		121490		111246		97648
		1269,5705		1162,5207		1020,4216
between *W* and stem		= 15,00		= 11,19		= 7,77
—— 27 and sternpost		= 9,34		= 4,32		= 2,50
total area		= 1293,91		1178,03		1030,69

Half Areas of the Water-lines.

Sections.	Ord.	Fourth water-line.	Ord.	Fifth water-line.	Ord.	Sixth water-line.
27	0,86	1 = 0,86	0,62	1 = 0,62	0,45	1 = 0,45
24	2,18	4 = 8,72	1,47	4 = 5,88	0,97	4 = 3,88
21	4,02	2 = 8,04	2,47	2 = 4,94	1,48	2 = 2,96
18	6,24	4 = 24,96	3,81	4 = 15,24	2,11	4 = 8,44
15	8,37	2 = 16,74	5,51	2 = 11,02	2,98	2 = 5,96
12	10,10	4 = 40,40	7,33	4 = 29,32	4,26	4 = 17,04
9	11,30	2 = 22,60	9,01	2 = 18,02	5,75	2 = 11,50
6	12,01	4 = 48,04	10,04	4 = 40,16	7,00	4 = 28,00
3	12,40	2 = 24,80	10,66	2 = 21,32	7,90	2 = 15,80
Φ	12,48	4 = 49,92	10,78	4 = 43,12	8,05	4 = 32,20
C	12,30	2 = 24,60	10,53	2 = 21,06	7,72	2 = 15,44
F	11,80	4 = 47,20	9,81	4 = 39,24	6,75	4 = 27,00
I	10,81	2 = 21,62	8,55	2 = 17,10	5,38	2 = 10,76
M	9,15	4 = 36,60	6,72	4 = 26,88	3,88	4 = 15,52
P	6,83	2 = 13,66	4,58	2 = 9,16	2,53	2 = 5,06
S	4,10	4 = 16,40	2,68	4 = 10,72	1,55	4 = 6,20
W	1,70	1 = 1,70	1,05	1 = 1,05	0,60	1 = 0,60
		406,86		314,85		206,81
$\frac{1}{3}$ dist. between frames		= 2,09		= 2,09		= 2,09
		366174		283365		186129
		81372		62970		41362
		850,3374		658,0365		432,2329
between *W* and stem		= 5,1		= 3,15		= 1,8
——27 and sternpost		= 1,7		= 1,2		= 0,8
total area		= 857,14		662,39		434,83

Half Areas of the Water-lines.

Sections.	Ord.	Seventh water-line.
27	0,40	1 = 0,40
24	0,67	4 = 2,68
21	0,87	2 = 1,74
18	1,10	4 = 4,40
15	1,37	2 = 2,74
12	1,78	4 = 7,12
9	2,14	2 = 4,28
6	2,63	4 = 10,52
3	2,98	2 = 5,96
Φ	3,00	4 = 12,00
C	2,78	2 = 5,56
F	2,40	4 = 9,60
I	2,08	2 = 4,16
M	1,57	4 = 6,28
P	1,10	2 = 2,20
S	0,77	4 = 3,08
W	0,30	1 = 0,30
		83,02
$\frac{1}{3}$ dist. between sections		= 2,09
		74718
		16604
		173,5118
between *W* and the stem		= 0,9
between 27 and sternpost		= 0,8
		Area 175,21

(14.) To find the distance of the center of gravity from the plane of the load water-line, the areas of the water-lines are used in the same manner as the areas of the sections, in finding the distance of the center of gravity from the section 27.

Water-lines.	Areas of the water-lines.	Multipliers.	Products.	Multipliers.	Products.	
1	1293,91	1	1293,91	0		
2	1178,03	4	4712,12	1	4712,12	
3	1030,69	2	2061,38	2	4122,76	
4	857,14	4	3428,56	3	10285,68	
5	662,39	2	1324,78	4	5299,12	
6	434,83	4	1739,32	5	8696,60	
7	175,21	1	175,21	6	1051,26	
			14735,28		34167,67	= 2,3187
$\frac{1}{3}$ the distance between the water-lines . . . . =			0,54		14735,28	1,62 = dist. between the water-lines.
			7957,0512			3,756294 = the distance of the center of gravity, below the plane of the load water-line, for the part which is between the load water-line and the seventh water-line.
between the seventh water-line and the keel . . . . =			147,95			
			8105 = $\frac{1}{2}$ the displacement			
			2			
			16210 = total displacement			

The distance of the center of gravity of the part, which is between the seventh water-line and the keel, from the said seventh water-line = 0,4 feet; between the seven water-lines, there are six distances, which make together 9,72 feet; and 9,72 + 0,4 = 10,12; then

$$\frac{3{,}756 \times 7957 + 10{,}12 \times 147{,}95}{7957{,}05 + 147{,}95} = \frac{31383{,}93}{8105} = 3{,}872,$$ which is the distance of the center of gravity of displacement, from the plane of the load water-line.

CHAP. II.

ON THE STABILITY, OR THE RESISTANCE TO HEELING.

(15.) It is well known that the resultant of the force of the water, in supporting a ship, and in resisting its heeling, passes through the center of gravity of the displacement; and that the direction of this effort is perpendicular to the surface of the water: for this reason, if a vessel be free and at rest, its center of gravity (Note 11.) must be in the mean direction, or resultant, of the force of the water which supports it. When the ship heels, it ought to have a tendency of itself to resume the position it had when at rest; that is to say, the center of gravity ought to be so situated, that the effort of the weight of the ship may concur with that of the water to right it (Note 12.)

This union of efforts is called *stability*, and the *point of stability* or *metacenter* is that point in the vertical longitudinal section, which divides the ship into two equal and similar parts, below which the center of gravity of the ship must necessarily be situated, in order that it may be able to float upright.

To find the point of stability, or metacenter.

(16.) Let E (Fig. 4.) be the center of gravity of the displacement of a ship; ADB a vertical section passing through the point E; AB the water-line when the ship is upright, let GD be a perpendicular to the water-line passing through the point E.

As the resultant of the force of the water to support the ship, is in the line GD, it follows necessarily, that the center of gravity of the ship must also be in the same line.

Suppose the vessel to incline through an infinitely small angle of heeling without increasing or diminishing the displacement, and let ab be the load water-line after the inclination; then the triangles CBb and CAa, one of which has been raised out of the water, and the other has been immersed in it, will be similar and equal. Let M and N be respectively the centers of gravity of the triangles, and F the center of gravity of the displacement after the inclination; draw from the point F the line FG perpendicular to the line ab; it will meet the line DG in some point G; G is the point of stability or metacenter. For when the center of gravity is below this point, the ship will keep itself upright, or will tend to right itself; on the contrary, when it is above this point, the ship will upset. If the center of gravity be at the same point with that of the displacement E, then the weight of the ship acts at the whole distance FE against the inclination.

As the sides of the triangle GFE are perpendicular to the sides of the triangles CAa, CBb, it follows that it is similar to each of the latter triangles; and consequently it is easy to find its side, or the distance EG, that is, when all the ordinates CB of the load water-line are supposed known, as also the distance between them. Let $CB = AC = y$; let the length of the water-line be denoted by x, the fluxion of which is $\dot{x}$; $Bb = Aa = b$; the displacement of the ship $= D$; hence $NC = CM = \frac{2}{3}y$, and the solid content of the small prisms $CBb = \frac{by\dot{x}}{2}$.

But the places of the centers of gravity of the small parts, which are raised out on one side and immersed on the other, are at the distance from each other of $NM = \frac{4}{3}y$; consequently the moments

$\frac{by\dot{x}}{2} \times \frac{4}{3}y$ and $D \times EF$ are equal (Note 13.); hence $EF = \int \frac{2}{3} \times \frac{by^2\dot{x}}{D}$. But $b : y :: \frac{2}{3} \times \frac{by^2\dot{x}}{D} : \frac{2}{3} \times \frac{y^3\dot{x}}{D}$, of which the fluent is $\int \frac{\frac{2}{3}y^3\dot{x}}{D} = GE =$ (Note 14.) the distance of the center of gravity of the displacement from the metacenter. If this quantity be multiplied by the displacement D, we have $GE \times D = \int \frac{2}{3} \times y^3\dot{x}$, which will be the moment of the stability, when the center of gravity of the ship is in the center of gravity of that displacement (Note 15.).

To find the situation of the metacenter, with relation to the center of gravity of displacement.

(17.) We make use of the rule (Art. 3.), which was employed to find the area of a plane, with this difference that we use here the cubes of the ordinates instead of simply the ordinates (Note 16.). With respect to the small triangles, which are found at the extremities of the load water-line, which are not included in the calculation, the formula $\int y^3\dot{x}$ indicates, that for such triangles, it is necessary to multiply the cube of the base by one-fourth of the height; the result of which is added to the quantity, which we have found for the principal part between the extreme ordinates.

Ordinates of the load water-line.	Cubes of the ordinates.	Multi-pliers.	Products.
4,67	101,85	1	101,85
8,88	700,23	4	2800,92
11,14	1382,47	2	2764,94
12,46	1934,43	4	7737,72
13,30	2352,64	2	4705,28
13,91	2691,42	4	10765,68
14,35	2954,99	2	5909,98
14,61	3118,53	4	12474,12
14,75	3209,05	2	6418,10
14,80	3241,79	4	12967,16
14,79	3235,22	2	6470,44
14,57	3092,99	4	12371,96
14,16	2839,16	2	5678,32
13,42	2422,30	4	9689,20
12,10	1771,56	2	3543,12
9,49	854,67	4	3418,68
5,00	125,00	1	125,00

107942,47
$\frac{1}{3}$ the dist. between the sections = 2,09

97148223
21588494

225599,7623
Triangle before W 188,00
Triangle abaft 27 101,85

225889,6123 $= \int y^3 \dot{x}$
2

451779,2246 $= 2\int y^3 \dot{x}$

$\frac{1}{3} \times 451779{,}22 = 150593{,}07 = \frac{2}{3}\int y^3 \dot{x}$, which divided by the displacement

$16210 = 9{,}29 = \int \frac{\frac{2}{3} y^3 \dot{x}}{D}$. If from this quantity the distance of the center of gravity of the displacement, from the plane of the load water-line be subtracted, there will remain 5,418, which the metacenter is above the surface of the water, when the ship is fitted for sea.

(18.) We have just said that the formula $\int y^3 \dot{x}$ denotes for the triangles, that it is necessary to multiply the cube of the base by one-fourth of the height, we shall now prove this.

Let ABC (Fig. 5.) be a rectilinear triangle; DE parallel to the base AB; $CD = x$, and $DE = y$.

Then $dD : eF :: \dot{x} : \dot{y} :: CA : AB$, whence we see that $\dot{x} = \frac{CA \times \dot{y}}{AB}$ and $\int y^3 \dot{x} = \int \frac{CA \times y^3 \dot{y}}{AB}$; it thence follows that $\int y^3 \dot{x} = \frac{CA \times y^4}{4\,BA}$: but if $x = CA$ then $y = BA$, and $\int y^3 \dot{x} = \frac{1}{4}\, CA \times BA^3$.

The same thing may be shewn, by using the rule given (Art. 3.). Make $AD = DC$; and let $AB = 2$; then $DE = 1$. Let AD and DE each equal 1;

$$\begin{array}{l|l} 2^3 = 8 & 8 \times 1 = 8 \\ 1^3 = 1 & 1 \times 4 = 4 \\ 0^3 = 0 & 0 \times 1 = \underline{0} \\ & \qquad\quad \frac{12}{3} = 4 = \int y^3 \dot{x} \text{ for triangle } ABC. \end{array}$$

The cube of the base $= 8$, being multiplied by $AC = 2$, we have 16, of which the fourth is $4 = \int y^3 \dot{x}$.

(19.) When the center of gravity of the whole vessel is situated in the very same point as the center of gravity of the displacement, in that case the moment of stability is rightly expressed by $\frac{2}{3} \int y^3 \dot{x}$. But it is very unlikely to happen that the center of gravity of the whole system, the weight of the hull and rigging, and other heterogeneous weights, as a greater or less weight of guns, &c. with which a ship is laden, should be in the center of gravity of the displacement; it is to be expected that this point will be either lower or higher, on which account the ship becomes more or less stiff.

(20.) Suppose the weight of the ship with all that it contains, to be divided into two parts; let the center of gravity of one of these parts be in the center of gravity of the displacement, and let the center of gravity of the other be in H (Fig. 6.).

Let ADB be a vertical section of the ship, EH the middle line of this section; E the center of gravity of the displacement, when the ship is upright, and F the center of gravity of the displacement, when it is inclined.

If from F a vertical line FG be drawn perpendicular to AB, which is supposed to be the load water-line, this line will meet the line EH in some point G; then G will be the metacenter. From H a vertical line HI is let fall, and from E and G the lines EF, GI are drawn perpendicular to GF, HI.

Let the weight in $E = P$, and the weight in $H = Q$; the moment of stability will be $EF \times P - GI \times Q$; but on account of similar triangles we may also rightly express the moment of stability by $EG \times P - GH \times Q$, that is to say, $(P+Q) \times EG - EH \times Q$; now $(P+Q) \times EG = \int \frac{2}{3} y^3 \dot{x}$; (Art. 16.) consequently the moment of stability is expressed by $\int \frac{2}{3} y^3 \dot{x} - EH \times Q$.

(21.) When the weight P is not situated in the center of gravity of the displacement E, but lower down in some point L; from L draw a line LK (Fig. 6.) perpendicular to GF, so that the moment of stability $= LK \times P - GI \times Q$ or $GL \times P - GH \times Q = (GE + EL) \times P - GH \times Q = GE \times (P+Q) + EL \times P - EH \times Q =$ (Art. 19.) $\int \frac{2}{3} y^3 \dot{x} + EL \times P - EH \times Q$, from which we deduce this general rule, by which the moments of stability of two ships may be compared very exactly, although their magnitude and form are different, and the weights are not of the same kind, provided the position of these weights is known in regard to height.

(22.) *When the moments of the weights are calculated, with relation to the center of gravity of the displacement, all those which are placed below this center, form positive quantities, and those which are above form negative quantities; their sum added to the expression* $\int \frac{2}{3} y^3 \dot{x}$, *gives the moment of stability.*

On the augmentation of weights put at the bottom of a ship, and on the increase of displacement, which corresponds thereto; to find the effect, which they produce on the moment of stability, and in what place the addition in the displacement should be made.

(23.) Suppose that the space $ARDSB$ (Fig. 7.) represents the displacement $= D$, of which the center of gravity is in E, the metacenter is in G; let the space or the augmentation of displacement $ARDTA + BSDOB = P$, and let its center of gravity be in I.

Let the half breadth of the ship $= y$, $GE = a$, $GI = b$; then the distance between the metacenter (NOTE 17.) and the center of gravity of the displacement after the augmentation $= \frac{aD + bP}{D + P} = GK$. Let the weight above the water $= Q$, and its center of gravity be in H; make $GH = c$; let the new weight, which is equal to the augmentation of displacement $= P$, and let its center of gravity be in L; make $KL = z$. Then the moment of stability of $ARDSB = \int \frac{2}{3} y^3 \dot{x} - (a + c) \times Q$ (Art. 20. NOTE 18.); but the moment of stability of the ship after the augmentation $ATDOB$ with the weight in $L = \int \frac{2}{3} y^3 \dot{x} + zP - \frac{aD + bP}{D + P} \times Q - cQ$ (Art. 22.). Striking out the common quantities from these two expressions there remain $-aQ$ and $zP - \frac{aD + bP}{D + P} \times Q$, upon which the relative stability entirely depends. Suppose $-aQ = zP - \frac{aD + bP}{D + P} \times Q$; and consequently $z = (b - a) \times \frac{Q}{D + P}$; then if z be greater than this quantity, the stability will be greater. And the more this distance $b - a$ or EI is diminished, the greater must be the effect of the new weight to give stability; and if the augmentation of displacement be situated so that its center of gravity is in E, in that case the moment of stability is increased by $EL \times P$. If, on the contrary, z be less than $(b - a) \times \frac{Q}{D + P}$, the stability is less; a thing which happens when the augmentation of displacement is low down, or near the keel.

Hitherto we have supposed the center of gravity L of the weight P constant, and the load water-line the same; but if z be supposed to be lengthened, $b - a$ to be constant, and the center of gravity L to descend, the stability will increase because z will be of greater length; but it will be less on another account, in as much as HK is longer than HE.

(24.) *We conclude from hence, that as it is proper to give to a ship all the stability which is possible, it is right to enlarge it near the load water-line, so as to raise the center of gravity of the displacement. Paying less regard to the placing of the ballast; particularly because the ballast is supposed to be of such a specific gravity that it takes up little room. This is a thing to be attended to principally in ships, which have great weights in their upper works.*

CHAP. III.

ON THE CENTER OF GRAVITY OF THE SHIP CONSIDERED AS A HETEROGENEOUS BODY.

(25.) ONE may lay down an axiom, that a body put in motion turns round its center of gravity, as long as it is not prevented by any external force, and provided the effort by which it is first put into motion, does not force it to move round any other point. Let us see in the first place the effect, which the force situated in the center of gravity, produces on the pitching and rolling of a ship.

(26.) For this purpose suppose ADB (Fig. 8.) to be a section of a ship; AB the load water-line, E the center of gravity of the whole ship; and G the metacenter. Suppose also that a weight, or any other force, acts at B in the direction BH, against the side of the ship, so as to give it the inclination ab. The moment of the effort, which produces the inclination, is in proportion to the distance EH, and the moment of the effort, which tends to restore the ship to its upright position, is in proportion to the distance EG (Art. 16.); and as these efforts act in contrary directions, there results from thence a motion, which is called rolling; and the effect of the forces, which produce it, is as the sum of EH and EG. But the ship during the inclination is supposed to revolve round its center of gravity; and its weight or its displacement is supposed to be the same, when it is inclined, as when it is upright, which cannot happen unless the ship, and consequently its center of gravity E, is raised

(Note 19.) by the quantity Ee equal to the versed sine of the angle Geg to the radius EG. It follows, that the effort, which has produced the inclination, having ceased, the ship will fall with its whole weight in the perpendicular through a height Ee; which fall is accelerated by the pressure of the fluid against the metacenter G. And as the rolling may extend as far as thirty degrees to each side, the distance eE then becomes considerable, and the rolling exceedingly violent (Note 20.).

Rolling seldom takes place, unless the wind is aft; and then the ship rolls most, when, a little before, the wind has blown from a different quarter: as the waves continue to go in the latter direction, the vessel rolls, although there does not appear to be much sea. But the vibrations are not very violent, and are performed nearly in equal times.

(27.) If the center of gravity E (Fig. 9.) of the ship were in the plane of the load water-line and the distance EG the same as before, the rolling would be less in extent, and less violent, than when this point is lower, for the two following reasons:

In the first place EH is less; so that the effort, which acting at B in the direction BH lifts the side of the ship, cannot produce so great an inclination as if the center of gravity were lower down, since the sum of EH and EG is less.

Secondly, the center of gravity E being in the plane of the load water-line, the ship rolls without either the ship or the center of gravity being raised or lowered; in which case those shocks, which we have just mentioned, do not take place.

We conclude, therefore, that the motion of rolling is more uniform and more free from sudden shocks, when the center of gravity of the ship is in or near the plane of the load water-line. And as this position of the center of gravity has the same effect in regard to pitching, which is rolling length-ways, it follows that this is the situation in which it is proper to place it.

But if other circumstances do not admit of the center of gravity's being in the plane of the load water-line, it is proper to endeavour to bring it as near thereto as possible.

(28.) We may further add to this, that as the keel and the lower parts forward and aft, which are the cleanest, contribute greatly to the diminution of the rolling by the direct opposition of their surface to the water, the farther these parts are from the axis of rotation, the greater will be the effect they produce in diminishing the rolling; and for this reason, likewise, when the center of gravity is in the plane of the load water-line, the ship should roll less.

And moreover, as the rolling depends partly on EH, the form of the side of the ship near the load water-line will influence its motion; when the form is such, that BH cuts the middle line in a point more elevated, the ship will roll more, which experience confirms.

(29.) The angular motion of a vessel round its center of gravity, being stopt at the point g (Fig. 8, 9. Art. 26.) by an effort, which acts in the direction Fg, and is equal to the weight of the displacement or of the whole ship, it is sufficiently clear that the metacenter g or G may be considered as the center of percussion; but as the vessel, without farther opposition, is supposed to roll back round its center of gravity E, this oscillation may be considered as the movement of a pendulum, oscillating in the same time as the ship. Wherefore the point G may be considered as the center of oscillation, particularly as the two points (the center of oscillation and the center of percussion) are in the same place, in relation to the center of gravity, which is also the center of rotation or point of suspension. The centers of percussion and oscillation are not always in the same point, but as here the moments of the weights round these centers are absolutely the same, we may without running the risk of making any great mistake, consider this movement either way, as circumstances require (Note 21.)

(30.) Let ABD be a plane without weight. Suppose several weights

P, Q, R, S, fixed in that plane; that their common center of gravity is in G; the point of suspension in O; and the center of oscillation in C. Then the length of the pendulum $OC =$
$\frac{P \times OP^2 + Q \times OQ^2 + R \times OR^2 + S \times OS^2}{OG \times (P + Q + R + S)}$, OC is also equal to
$OG + \frac{P \times GP^2 + Q \times GQ^2 + R \times GR^2 + S \times GS^2}{OG \times (P + Q + R + S)}$, whence $CG =$
$\frac{P \times GP^2 + Q \times GQ^2 + R \times GR^2 + S \times GS^2}{OG \times (P + Q + R + S)}$, (SIMPSON'S *Fluxions*, Tom. I. p. 215, 216.); the same expressions belong also to the center of percussion.

(31.) From these expressions for OC, the length of the pendulum, we see that they become greater, the more distant the weights P, Q, R, S, are from the middle.

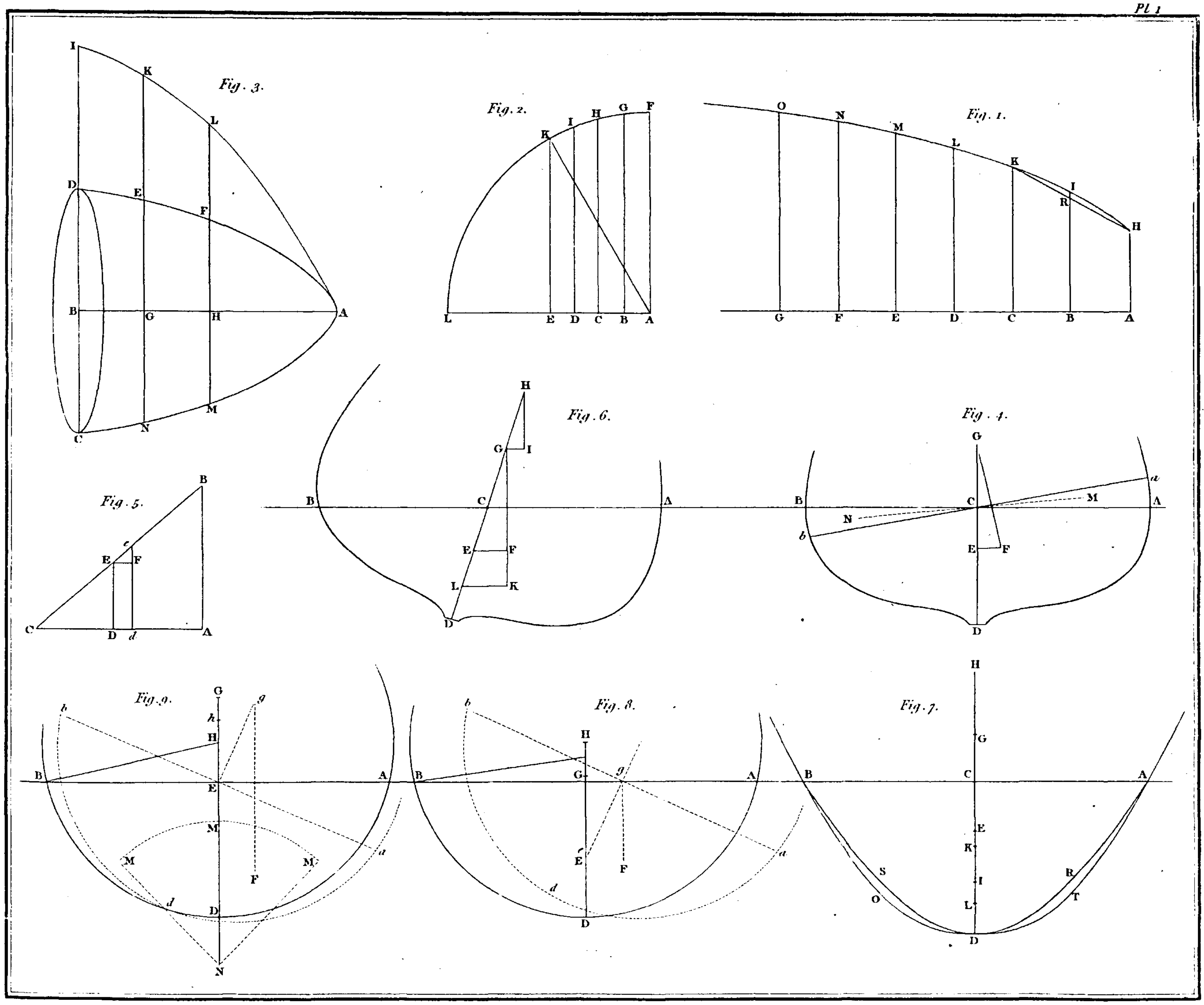
(32.) From the second and third expressions it appears, that although a body revolves round its center of gravity, the center of oscillation nevertheless remains in the same place.

(33.) And we may observe from the last expression, that the distance between the center of gravity and the point of suspension is always in the inverse ratio of the distance between the centers of gravity and oscillation. As the ship is moved round its center of gravity E, (Fig. 8, 9.) and the center of oscillation is in the metacenter G, it is manifest one may conceive some point as N to be the point of suspension, and that the distance of this point from the center of gravity E, is equal to the quotient of the sum of the products of each weight multiplied by the square of its distance from the center of gravity E, divided by the product of the sum of all the weights, or the displacement, multiplied by the line EG, the distance between the center of gravity and the metacenter.

(34.) Wherefore the farther the weights are placed from the center of gravity, or which is the same thing, the nearer they are placed to the sides of the ship, (without at the same time changing the position of the center of gravity of the ship with respect to the metacenter *G*), the greater will be the distance *NE*; consequently, the rolling motion will be the more slow. And the whole length *NG*, the distance between the point of suspension and the center of oscillation, is equal to the quotient which arises from dividing the sum of the products of each weight multiplied into the square of its distance from the point of suspension, by the product of the sum of all the weights, or the displacement, multiplied into *NE*, the distance of the center of gravity from the point of suspension; so that the weights *M, M,* which are placed at the same distance from the point *N*, produce the same effect on the rolling of the ship. Considering now the metacenter *G* or *g* as the center of percussion, it is manifest the greater *EG* or *Eg* is, the greater will be the force to restore the equilibrium of the ship. But if the metacenter approach the center of gravity *E*, for example, if it be found in *h*, the distance *NE* will be altered in the inverse proportion of *EG* to *Eh*; that is to say, *the nearer the center of gravity is to the metacenter, the longer will* NE *be; consequently the slower and less violent will be the rolling.*

(35.) The investigation, upon these principles, of the distance of the point of suspension from the center of gravity or from the metacenter, would lead to very long calculations, since it would be necessary to take into account the masting, rigging, &c. Besides the investigation is not particularly necessary; it is sufficient to know the causes, which render the rolling more or less violent, and the manner, if they cannot be removed altogether, of at least lessening their effect in part.

(36.) It is exceedingly difficult to construct a ship, so as to have at the same time sufficient stability, and roll easily, because the augmentation of the distance *EG*, which increases the stability, contributes also to increase the motion of rolling (Note 22.). And the difficulty is still greater to do this in ships of burthen, in which there is required, beside attention to



Lowry Sculp.

economy in construction, the property of carrying the greastest possible cargo. Ships of this kind should be very full below, and have but little height above the water in proportion to their breadth. A ship of this construction will have its center of gravity of displacement very low; consequently the metacenter will be so too. On this account it is necessary to bring the center of gravity of the cargo as low as possible, in order that the ship may have sufficient stability. The consequence is that the common center of gravity of the ship and cargo being very low, the ship will be subject to quick rolling and violent shocks, (Art. 26.) which however may be partly alleviated by winging the weights as much as may be possible.

(37.) There is another means of easing the movement of rolling in ships of burthen. As it is necessary, in order to save expence, to navigate them with as few men as possible, they require a small quantity of sail; a circumstance which allows less distance to be given between the center of gravity and the metacenter.

(38.) On the contrary, ships which are not constructed for burthen, for instance ships of war, as frigates, &c. (which are built for sailing and have no occasion for great capacity below), may have length, breadth, and be constructed so that the center of gravity may be higher.

The metacenter ought therefore to have such a height above the water, that the common center of gravity of the ship and of the weights, may be brought to the plane of the load water-line or very nearly; and that the ship may still be sufficiently stiff in resisting heeling, so that the rolling will solely depend on the situation of the metacenter, whose distance from the center of gravity of the whole ship (to give it sufficient stability) need not, even in the largest ships of the line, be more than six feet, with which distance the motion of rolling will be sufficiently easy (Note 23.).

(39.) In the foregoing Articles we have seen, that the center of gravity of the ship, in regard to height, should be either in the plane of the load water-line, or as near to it as possible. It remains to consider its position with respect to length.

(40.) As the length of the ship is very great in proportion to the breadth, the metacenter with regard to the former dimension will be considerably elevated; particularly in ships which have a full load water-line, and are very lean under the water fore and aft. In consequence, the length of the pendulum, of which the oscillations are isochronous with those of the ship, will be exceedingly great, especially if by placing the weights near the extremities, the point of suspension is situated very low.

But if we consider the center of oscillation or the metacenter also as the center of percussion, the extremities of the ship are scarcely plunged in the sea, before they are thrown back with great vivacity, and this motion ceases almost immediately.

(41.) The ship has still however a rolling according to its length, such that its extremities rise and fall; but this motion is only the raising by a wave, of the forepart of the ship, which falls again when the wave has passed. This motion would cease immediately, if another wave did not succeed to raise the forepart of the ship again. When a ship is close to the wind, and meets the waves, and it happens after a sea has passed the forepart, that it falls suddenly and raises itself with difficulty upon the following wave, in that case the ship is said to *pitch*. This fault not only impedes greatly the sailing, but the shocks also strain prodigiously the masting. When it is the after part which falls heavily, the ship is said to *send*. This motion may arise from a similar cause, and has the same inconveniencies.

The body of the ship suffers greatly, as much from pitching and sending as from quick rolling; all the parts labour, and have a tendency to separate. It is an inconveniency which ought to be obviated.

(42.) The reason of the pitching and sending motion is easily seen.

When a wave has passed the forepart of the ship, and is got near the middle, there is left a great void space under the bows, where the ship is not supported. It precipitates itself therefore with a certain momentum, which is the product of the weights in the fore part, multiplied by their distance from the point, where the ship is sufficiently supported.

(43.) This kind of motion is greater in ships, which are very full near the load water-line fore and aft, and very lean below; but if the weights in the forepart are carried nearer the middle, the momentum with which the ship plunges itself in this part will be less, and not only this motion becomes less quick, but moreover the following waves which meet the forepart of the ship, have less difficulty in raising it again: the same observation may be made on the aft part. Thus it is seen that all the weights should be brought as near as possible to the middle of ship, from which we may conclude that the center of gravity ought to be, with respect to the length, at the middle point (NOTE 24.). But there is a circumstance, which prevents the placing of the center of gravity at the middle point of the length, namely, the weight of the foremast and its rigging, the bowsprit, the anchors, &c.; these weights can be placed no where so conveniently than where they are; the center of gravity, therefore, is necessarily before the middle point, *but not more than between a hundredth and a fiftieth of the length* (NOTE 25.).

(44.) We should not forget to observe, that the center of gravity of the load water-line and that of the ship should be in the same vertical line; for when the ship sails close to the wind and is inclined on one side, if the load water-line is fuller aft than forward, since the ship must preserve the same quantity of displacement, it will have an inclination also forward. (NOTE 26.) It is true, it will gain something in point of stability, by this augmentation of the load water-line, as appears from the expression $\int \frac{2}{3} y^3 \dot{x}$ (Art. 16.); but this inclination forward being an inconveniency, which it is proper to avoid, any augmentation of the breadth, if it be necessary, should rather be made in the middle. After all it is not a great fault, although the center of gravity of the load water-line be a little abaft the center of gravity of the ship, or of the displacement.

We shall now investigate the place where the center of gravity ought to be, considering its influence upon the property of steering well.

(45.) When a ship sails by the wind, that is, when the wind is on the side of the ship or more a-head, then almost all vessels have such a form, that they will of themselves, without the use of the rudder, turn the stem more towards the wind, because the mean direction of the water's resistance passes usually a little before the center of gravity of the ship.

If this resultant passed too far a-head, it would be an inconveniency, which might be remedied by giving a greater draught of water aft. The greater the velocity of the ship, the more sensibly this effect is felt, and the vessel can then be kept to her course only by the constant use of the rudder.

(46.) It is well known, that if a body receive an impulse between one of its extremities and its center of gravity, it turns round a point which is on the other side of the center of gravity (NOTE 27.) Thus, when the ship feels the effect of its rudder more than that of the water on the side forward, it turns round a point, which is before the center of gravity. But if the rudder be not applied, and the effect of the impulse of the water be before the center of gravity, the center of rotation will be behind this center of gravity; and if the resistance of the water forward and its action on the rudder act together to turn the vessel in the same direction, which takes place when the ship is tacking, the center of rotation is then in the perpendicular passing through the center of gravity; or very near it, before or behind it, as one or the other of the efforts has the preponderancy. If then the center of gravity were exactly in the middle, and the ship of itself ardent, the rotatory movement would be most prompt, for the resistance which the two extremities experience from the water, whilst the ship is going round, is in proportion to the squares of their distances from the center of rotation; and this quantity is a *minimum* when the center of rotation is at the middle.

CHAP. IV.

ON THE RESISTANCE, WHICH A SHIP IN MOTION MEETS WITH FROM THE WATER.

(47.) WHEN a ship is at rest, the pressure of the water upon each of its extremities is the same; but as soon as it is impelled by any force, the pressure is increased at the end opposite to the impulse, and is diminished at that end where it acts: this we shall explain hereafter.

(48.) If a plane is moved in the water, the resistance is the most forcible, when the direction of motion is perpendicular to the plane, and becomes less if the plane assumes a position oblique to the line of motion.

Thus bodies of different forms and convexities, with equal bases, experience different resistances.

(49.) It is by no means difficult to express the resistance, which one body meets with in striking another: but it is not equally easy to express the effect which a medium produces on bodies, which are moved therein. The effect of the impact of bodies on each other is subject to known mechanical laws, but that of mediums upon bodies depends on physical causes, with which we are unacquainted.

(50.) To surmount this difficulty, fluids have been supposed to consist of globular particles, infinitely small, which follow each other very closely, and strike the body in succession; as for example:

(51.) Let ABC (Fig. 11.) be a right-angled triangle, suppose the fluid, or a particle of the fluid, to strike the side AB of this triangle in a direction parallel to AC, from A to C, with the velocity ED.

If ED denote the perpendicular resistance against the base BC, it may be resolved into two others, EF perpendicular and FD parallel to AD; as the effect in the direction FD is nothing, inasmuch as the fluid glides along AB, therefore EF alone acts on the triangle, and in a direction perpendicular to AB; in like manner this force may be resolved into two others, GF perpendicular and EG parallel to AC; GF is the lateral force, which impels the triangle from B to C, but EG denotes the direct force, which acts on the side AB, and consequently the resistance: thus the absolute or perpendicular resistance at the point D is to the relative resistance as ED to EG; but $DE : EG :: DE^2 : EF^2$; and since the number of particles, which can strike the side AB in the direction ED are in proportion to BC, and from similar triangles DEF, ABC we have $DE : EF :: AB : BC$, the direct resistance against the whole triangle is as $\frac{BC^2}{AB^2} \times BC$.

(52.) Upon this principle the known curve GFB (Fig. 12.) of least resistance has been investigated, which is of such a nature, that by revolving round its axis AD it generates a solid $AGBD$, which experiences less resistance from the water than any body whatever of the same length AD and the same base BC. As this problem is treated on by several authors, I shall here only give the construction of the curve.

If $AE = x$, $EF = y$, the equation will be $y\dot{y}^3\dot{x} = a \times (\dot{x}^2 + \dot{y}^2)^2$ (see Simpson's Fluxions, Art. 413.).

The angle AGF has been found to be a right angle and a half, or 135°. (NOTE 28.) Let $v = \frac{\dot{x}}{\dot{y}}$; then $\dot{x} = v \times \dot{y}$, and $\dot{x}^2 = v^2 \times \dot{y}^2$. Substituting the value of $\dot{x}^2$ in the equation, we have $vy\dot{y}^4 = a \times (v^2\dot{y}^2 + \dot{y}^2)^2$, or $vy = a \times (v^4 + 2v^2 + 1)$; hence $y = a \times \left(v^3 + 2v + \frac{1}{v}\right)$

and $\dot{y} = a \times \left(3v^2\dot{v} + 2\dot{v} - \frac{\dot{v}}{v^2}\right)$ and therefore $\dot{x} = a \times \left(3v^3\dot{v} + 2v\dot{v} - \frac{\dot{v}}{v}\right)$ of which the fluent or $x = a \times \left(\frac{3}{4}v^4 + v^2 - \text{log. } v\right) + C$. When $v = 1$, then $x = 0$ by the above-mentioned property, whence $\frac{7}{4}a + C = 0$; and $C = -\frac{7}{4}a$; hence $x = a \times \left(\frac{3}{4}v^4 + v^2 - \frac{7}{4} - \text{log. } v\right)$. Supposing $a = 1$, the least ordinate AG will be equal to 4 (NOTE 29.). If, beginning with 1, we give successive values to v, and substitute them in the equation of x and y, we shall have the following values of x and y.

$v = 1{,}0 \begin{cases} x = 0 \\ y = 4 \end{cases}$	$v = 1{,}06 \begin{cases} x = 0{,}262 \\ y = 4{,}254 \end{cases}$	$v = 1{,}1 \begin{cases} x = 0{,}453 \\ y = 4{,}440 \end{cases}$
$v = 1{,}2 \begin{cases} x = 1{,}053 \\ y = 4{,}961 \end{cases}$	$v = 1{,}3 \begin{cases} x = 1{,}820 \\ y = 5{,}566 \end{cases}$	$v = 1{,}4 \begin{cases} x = 2{,}655 \\ y = 6{,}258 \end{cases}$
$v = 1{,}5 \begin{cases} x = 3{,}892 \\ y = 7{,}042 \end{cases}$	$v = 1{,}6 \begin{cases} x = 5{,}255 \\ y = 7{,}921 \end{cases}$	$v = 1{,}7 \begin{cases} x = 6{,}873 \\ y = 8{,}901 \end{cases}$
$v = 1{,}8 \begin{cases} x = 8{,}775 \\ y = 9{,}987 \end{cases}$	$v = 2 \begin{cases} x = 13{,}557 \\ y = 12{,}500 \end{cases}$	$v = 2{,}2 \begin{cases} x = 19{,}900 \\ y = 15{,}502 \end{cases}$

(53.) Let $AE = x$, $EF = y$ (Fig. 13.); then from A the values of x are set off on AD, and on the corresponding ordinates AG, EF, &c. the values of y, we shall have the line GFB, which as we have said, by revolving round its axis AD, will generate a solid, which will experience less resistance than any other body of the same length AD, and of the same base BD. If this solid be terminated by a cone AHG whose base$=AG$, the resistance by that means will be considerably diminished.

We shall see by the following Articles the quantity of resistance, which a body like this meets with from the fluid.

Fig. 11.

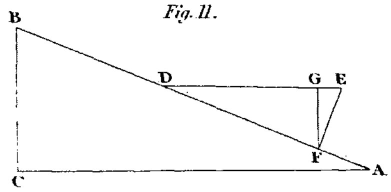


Fig. 12.

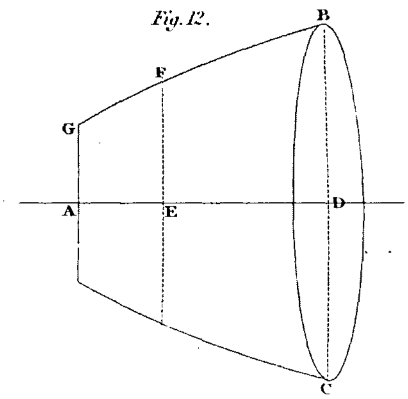


Fig. 10.

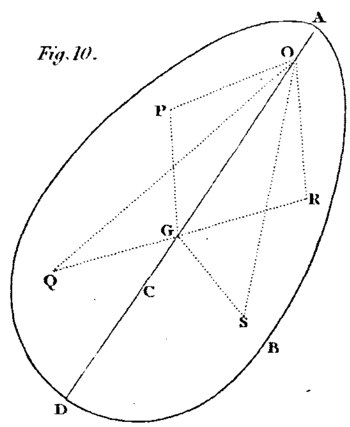
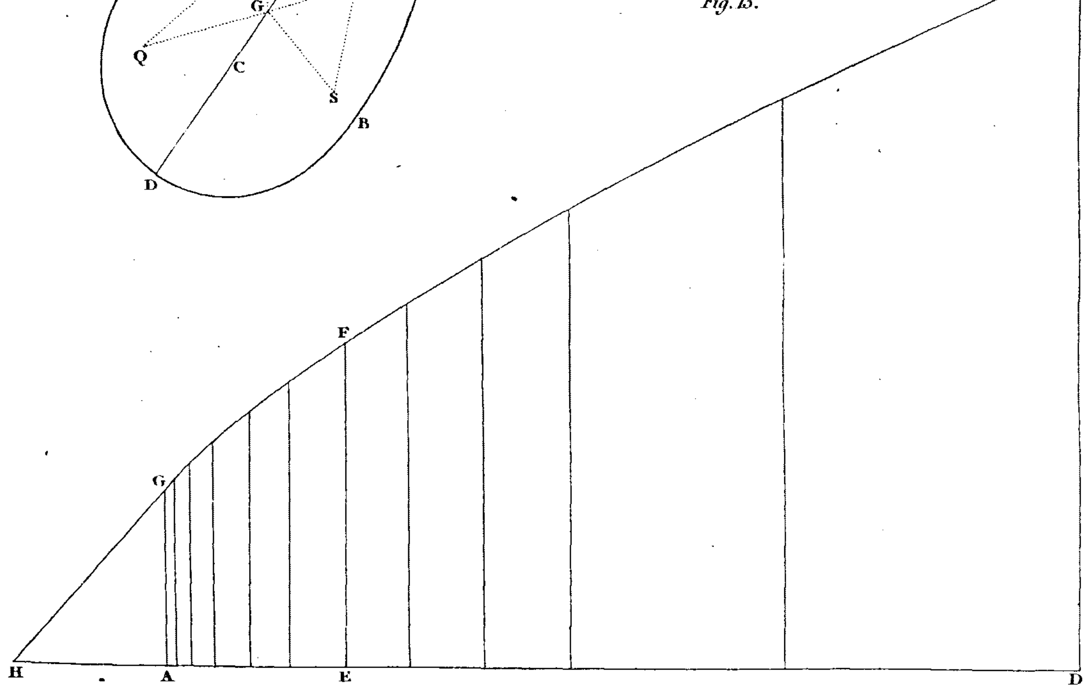


Fig. 13.



Lowry sculp.

(54.) When a body is at rest in the water, it receives a pressure at every point of the part immersed, which is perpendicular to its surface, and its force proportional to the depth of the part pressed.

This is a fact derived from experience, which it is necessary not to lose sight of: but before we go farther into the investigation of the expression for the resistance, which a body meets with when impelled through a fluid, it is necessary to notice the circumstances which occur, when a ship sails forward, or when a ship by means of any force whatever is drawn through the water.

(55.) When a ship ABC (Fig. 14.) is put in motion in still water with any velocity, it always happens that the water upon the extremity A before the greatest breadth C, rises against this part above the surface F. This elevation is perceptible to some distance before the ship in the direction of its course; it also extends laterally towards PQ; but past the greatest breadth C, the water falls again, so that between C and B it is below its proper level, until it meets in D the part of the fluid, which constantly follows the ship with the same velocity as the ship has itself, in order to fill up the void space, which it would leave behind. But as the water, which glides along the side of the ship, has already filled this space, there is a collision of this fluid in EE, which produces what is called eddy water. This is a thing remarked more in small vessels, which draw little water; but in great vessels, the elevation of the water afore is not perceptible till they have attained a velocity of 4 or 5 feet in a second. This water, which is before the greatest breadth, is driven forward with the ship, and so moves in the same direction; and as it is higher afore the greatest breadth than abaft, it flows down a declivity, so as to acquire a velocity in a direction contrary to that of the ship; and the greater velocity the ship has, the greater is this declivity.

(56.) All this is sufficiently observable, when a ship is navigated in a sea little agitated, where there are no waves: but when a ship sails or is drawn along a channel, where there is not more than three or four times the breadth of the ship between it and the side of the channel, this effect is much more perceptible, however small may be the velocity.

(57.) There necessarily results from what we have just observed; first, that the resistance a ship sailing with a given velocity meets with, is increased on account of the water's rising before the greatest breadth, and because the ship has to propel a more elevated body of water before it, than at the commencement of its motion; although this column thus elevated and driven a-head, by acting on the water in the direction of its motion, before the body of the ship gets to the same point, (NOTE. 30.) in some degree diminishes the resistance. Secondly, that the resistance is farther increased, because the water is lower behind the greatest breadth, and because this water has, moreover, lost in regard to its pressure against the after part of the ship, a force which depends on the velocity of the ship, and also on that with which the fluid flows along the after part of the ship, in running from the greatest breadth of the ship to the stern-post.

After the observations and remarks which have been made, let us form an equation, which expresses the resistance that a body meets with when impelled through the water.

(58.) A difficulty occurs however, which arises from the circumstance of its being necessary to compare the pressure of the water with the effect arising from the velocity of the body, two forces, which are of very different kinds. But since we may neglect in the expression the perpendicular pressure of the water against the surface of the ship when at rest, (the effect being the same, whatever be the extremity of the body that moves forward), we may observe that the force in question expresses only the effect of the inequality of the pressure on the two extremities of the ship during the motion, or the resistance, which is thereby occasioned, and which depends as to its amount on the velocity of the ship.

(59.) Let $ACBQ$ (Fig. 15.) be formed of two wedges joined together at their base CQ; let the pressure of the water, perpendicular to the surface in every point, be denoted by FG, FG.

Suppose this body to be moved with the velocity FH in a direction parallel to the middle line AB, from B to A; complete in the usual manner the parallelogram $FGIH$, and draw the diagonal IF. Then we have the resultant of this velocity with the pressure of the water in the direction IF. If from the point K, where the line IH meets the line AC or CB, we draw the line KL perpendicular to GI, IL will be the resistance, which the body experiences in the direction BA, and LI is a force on the hinder part of the body CB, which impels it forward in the direction in which it moves.

(60.) Let CM be perpendicular to AB; $CD = DM$, and DN be perpendicular to the surface $ACBM$. Let $FG=m$, $FH=n$; the area of the plane $CE=A$, the area of the plane $CP=B$, and lastly the area of the plane $CN=C$.

From the similar triangles ACD, FHK, KIL, we have $KH=\frac{DC}{AC}\times n$, and hence $IK=\frac{DC}{AC}\times n+m$, and also $IL=\frac{DC}{AC}\times\left(m+\frac{DC}{AC}\times n\right)$. IL represents the resistance at the point F, which is produced by the forces FG (m), HF (n). But the number of pressures FG is to the number of pressures FH, as the area A is to the area C; consequently $A\times\frac{DC}{AC}\times m+C\times\frac{DC^2}{AC^2}\times n$ represents the effect of the water on the forepart. In the same manner we get $B\times\frac{DC}{BC}\times m-C\times\frac{DC^2}{BC^2}\times n$ for the effect of the water on the aft part.

Subtracting this last expression from the first, the resistance against this body moved in the direction AB, will be expressed by $A\times\frac{DC}{AC}\times m+C\times\frac{DC^2}{AC^2}\times n-B\times\frac{DC}{BC}\times m+C\times\frac{DC^2}{BC^2}\times n$, and as $A\times\frac{DC}{AC}\times m=B\times\frac{DC}{BC}\times m$, the expression for the resistance is reduced to $C\times\frac{DC^2}{AC^2}\times n+C\times\frac{DC^2}{BC^2}\times n$; whence we see, so long as the velocity is not sufficient to produce an elevation of the water afore, and a depression abaft the greatest breadth, so as to increase the fore resistance and diminish that aft, that the body will experience the same resistance, whether the sharp or obtuse extremity moves forward; and yet that the resistance will be the least when the two extremities are equal, or what is the same thing, when the greatest breadth CM is in the middle.

But if we suppose that the water runs a-head of the ship before its greatest breadth with a velocity v, and that it has acquired a velocity w in a direction opposite to that of the body abaft this greatest breadth, then the velocity forward $=n-v$, and aft $=n+w$; and as the resistance is in proportion to the squares of the velocities, it will be expressed definitively by $C' \times \frac{DC^2}{AC^2} \times (n-v)^2 + C \times \frac{DC^2}{BC^2} \times (n+w)^2$, where we suppose C' to be greater than C, inasmuch as the water before the greatest breadth is more elevated than behind it.

Hence it is seen, whatever proportion there is between n, v, and w, the body meets with less resistance, when the obtuse end is forward, than when the acute end is forward; and that it depends on the quantities $n-v$, and $n+w$, how far the main breadth should be before the middle point, so that the resistance may be less, than if its situation were any where else.

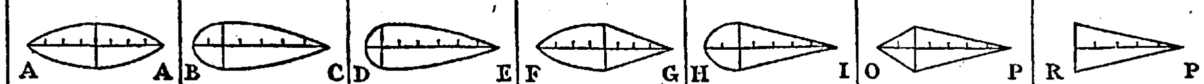
We see also that the greater v and w are with respect to n, the more the greatest breadth should be carried before the middle to render the resistance least.

It never can happen that $v=n$, for in this case, the water would run forward with the same velocity as the ship, which is not possible. v is very small with respect to n, when the velocity is little; so that when n is very small $v=0$. It is the same also in respect to the water abaft the greatest breadth; when the velocity is small and the body has its greatest breadth very far aft, the water follows the body to fill up the void space which it leaves; from which cause a part of the water follows the same direction as the body, so that the velocity of the body in relation to the water is $n-w$, whence it follows that the expression for the resistance ought to have this form

$$C' \times \frac{DC^2}{AC^2} \times (n - v)^2 + C \times \frac{DC^2}{BC^2} \times (n \pm w)^2 \text{ (Note 31.)}$$

If this expression for the resistance be not exact, at least what results from it is confirmed by the following experiments.

(61.) In a large and deep pond (Fig. 16.) were placed a hundred feet from each other two poles *A, B,* and two piles *C, D,* to which were fitted two copper pullies, and through these were reeved ropes to support the weights; the whole as is represented in the figure. The lines *E* and *G* were attached to the body used in the experiment. On the line *E* a weight was placed, to give motion to the body in the water, and on the other line *G* there was also a weight, but less than the first, to keep the body in a straight line from which it would have deviated without it; to the line *E* were tied two small pieces of red cloth *I, K,* at the distance of 74 feet from each other. To measure the time a stop-watch shewing seconds was used. When the mark arrived at *L* the stop-watch was let go, and when the mark *I* was come to the same point, the watch was stopped. It then shewed the number of seconds which the body *F* took up to pass over the space of 74 feet. The bodies, on which the experiments were made, were of wood, and were 28 inches in length; the transverse sections under the water were circular. Their diameters at the greatest breadth were $\frac{2}{7}$ of the length, or 8 inches; the water-lines were either straight or conic parabolas, and the vertex of the parabolic line was at the greatest breadth. As these bodies were lighter than water, lead was run in, until their specific gravity was nearly equal to that of sea water, so that they only just floated (Note 32.), having their axes parallel to the surface of the water. The weight on the line *E* to put the body in motion, was varied according as it was required to increase or diminish the velocity; but the retarding weight was always the same. The bodies N°. 1, 2, and 3 had the same weight, but the others were lighter in proportion as the solidity of a cone is less than that of a paraboloid.

		N°. 1.	N°. 2.		N°. 3.		N°. 4.		N°. 5.		N°. 6.		N°. 7.	
Weight of the bodies....		27 pounds	27 pounds		27 pounds		22 pounds		$19\frac{3}{4}$ pounds		$16\frac{3}{4}$ pounds		12 pounds	
Form of the bodies.......														
Moving weights	Retarding weights	Time the bodies have been describing the space of 74 feet, in seconds.												
		Seconds.	Seconds.		Seconds.		Seconds.		Seconds.		Seconds.		Seconds.	
		A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*O*	*P*	*R*	*P*
$\frac{3}{4}$ the weight of the body	$\frac{1}{2}$ the weight of the body	$25\frac{1}{2}$	$26\frac{1}{4}$	$24\frac{3}{4}$	$27\frac{3}{4}$	$26\frac{1}{2}$	$25\frac{3}{4}$	$25\frac{1}{2}$	$27\frac{1}{4}$	$24\frac{1}{4}$	30	$29\frac{3}{4}$	45	$29\frac{1}{2}$
The weight of the body	$\frac{1}{2}$ the weight of the body	14	14	$14\frac{1}{2}$	$14\frac{1}{2}$	$16\frac{1}{2}$	$13\frac{3}{4}$	$13\frac{3}{4}$	15	16	$24\frac{1}{2}$	$24\frac{1}{4}$	38	24
$1\frac{1}{2}$ weight of the body	$\frac{1}{2}$ the weight of the body	11	$10\frac{1}{2}$	$11\frac{1}{2}$	$10\frac{1}{2}$	$13\frac{1}{2}$	11	11	$10\frac{1}{4}$	$11\frac{1}{2}$	$12\frac{1}{2}$	$17\frac{1}{4}$	$30\frac{3}{4}$	$19\frac{1}{4}$
37 pounds in all	12 lb. and $\frac{1}{3}$ in all	$12\frac{1}{2}$	lost		11	14	$10\frac{3}{4}$	11	10	$11\frac{1}{4}$	12	16		

The Bodies:

N°. 1. has its greatest breadth at the middle, and its two extremities formed by parabolic lines.

N°. 2. has its greatest breadth at $\frac{2}{7}$ of its length from the point *B*; the two extremities are also parabolic.

N°. 3. has its greatest breadth $\frac{1}{7}$ of the length from the point *D*; the two extremities still parabolic.

N°. 4. has its greatest breadth at the middle; the extremity *F* parabolic, the other *G* conic.

N°. 5. has its greatest breadth $\frac{2}{7}$ of the length from the point *H*; the extremity *H* parabolic, the other *I* conic.

N°. 6. has its greatest breadth $\frac{2}{7}$ of the length from *O*; the two extremities conic.

N°. 7. wholly conic, having the greatest breadth equal to that of the other bodies, and its length twice and an half the breadth.

To understand these experiments take N°. 2., where the moving weight is equal to that of the body, and the retarding weight is half of it. With the extremity *B* first, the body passes over 74 feet in 14 seconds; if on the contrary the extremity *C* be first, the body is $14\frac{1}{4}$ seconds in passing over the same space.

Each of these experiments was repeated six times, and a mean taken of the results, which for the most part were nearly equal; and where there was any difference, it did not exceed half a second. We do not find in the velocities, the proportions we are led to expect from a consideration of the weights; which arises from a motion produced at the surface of the water by a division of the fluid too near the surface. The number of pullies over which the line passes, renders the experiments less exact on account of friction. But as the friction is equal for all the experiments, the variation of velocity ought to be of the same kind.

(62.) The inferences which we may draw from all this are; first, that when the motion is slow, the body has greater velocity when the sharp end is forward than when the full; secondly, that when the velocity is increased to a certain degree, the body passes over the same distance in equal times, with either extremity forward; thirdly, that when the velocity becomes still greater, the body is less time in passing over the same distance, when the obtuse end is forward. Thus it is the velocity of the body which should determine the place of the greatest breadth, to render the resistance least.

M. Camus, in his Treatise on Moving Forces, speaks of experiments which he made to determine this point. We find likewise (Murray's Treatise on Ship-building) some experiments, which agree with the above sufficiently well; differing however from them in this, that whether the velocity is great or little, the body always experiences less resistance when the fullest end is forward, a circumstance which arises from the experiments having been made in a canal formed on purpose, in proportion to the breadth of which that of the body was considerable; so that the water could not pass it without rising before, and consequently being lower behind. This water must therefore have had a current on each side of the body, so that however slowly the body was moved in the canal, the effect of the water was the same, as when in the above experiments it was moved with the greatest velocity.

These experiments are agreeable to the expression for the resistance which was given in Article 60. The only question is to find the value of v and w relatively to n, and to see when we ought to employ the signs + and − in $n \pm w$. We know from what was said in Article 60. that the sign − in $n \pm w$ is not to be used in the expression for the resistance, except when the velocity and the form behind the greatest breadth are such, that the water, which acts on the after part, moves in the same direction as the ship.

(63.) By the expression for the resistance, we see (Fig. 15.) that this force on account of $n - v$ and $n + w$, is greater or less according to the proportion there is between the lines AC and BC; consequently, that there is a certain distance from the one or the other extremity, where the greatest breadth CM ought to be placed to render the resistance a *minimum:* it is required therefore to determine the distance AD, which will make the expression for the resistance a *minimum.* To do this, multiply $C \times \frac{DC^2}{AC^2} \times (n - v)^2 + C \times \frac{DC^2}{BC^2} \times (n + w)^2$ by the unknown quantity $\frac{AC^2 \times BC^2}{C \times DC^2}$. The relation of the terms will be the same. We shall then have $(BC^2) \times (n - v)^2 + AC^2 \times (n + w)^2$, which is to be a *minimum* (NOTE 33.).

Let $AB = a$, $AD = x$; then $BD = a - x$; make $DC = 1$; $n - v = p$ and $n + w = q$, and you will have $AC^2 = x^2 + 1$ and $BC^2 = a^2 - 2ax + x^2 + 1$ Then the quantity, which is to be a *minimum,* will be $(x^2 + 1) \times q^2 + (a^2 - 2ax + x^2 + 1) \times p^2$. Take the fluxion $2q^2 x\dot{x} - 2ap^2\dot{x} + 2p^2 x\dot{x} = 0$; whence $(p^2 + q^2) \times x = ap^2$ from which we have this proportion, $\overline{(n + w)}^2 + \overline{(n - v)}^2 : \overline{(n - v)}^2 :: AB : AD$; so that the greater w and v are in proportion to n, which takes place in proportion as the velocity becomes more considerable, the less will AD become. When w and v are supposed $= 0$, which may take place, when the velocity is small, then $AD = \frac{1}{2} AB$. It is on w and v then that the determination of the place, where the midship bend ought to be, depends. But these are precisely the two quantities, which cannot be determined, since they vary with the velocity. It seems to follow, that to render the resistance always a *minimum,* the place of the greatest breadth ought to vary; a thing which is not possible.

(64.) We can conclude nothing therefore from this, except that the greatest breadth ought to be something before the middle. Supposing the place of the midship bend to be determined for a certain velocity, the problem will not be therefore solved, since the determination will only be founded on one supposition.

(65.) For example, let a vessel sail with great velocity, so as to run 20 feet a second. Let the water in this case, be one foot more elevated at the head, than at the stern. As it will be at the lowest only near the stern-post, it may be supposed that at the middle between the stern-post and the stem, it will be half a foot lower than at the stem; the current of water then has a velocity equal to that which a body would acquire in falling from the height of half a foot, namely, a velocity which would carry it $\sqrt{33}$ feet in one second. This only takes place at the surface. The velocity decreases according to the depth as far as the keel, where it is nothing; we may therefore suppose in order to have a mean, a velocity of 3 feet a second. It ought to be further diminished, because the water which is raised up before the greatest breadth, has a motion in a contrary direction, that is in the same direction with the ship. All this does not take place unless the ship sails in smooth water; if there be any sea, the elevation or depression of the fluid will be reduced to nothing or to very little. On this account I shall suppose that when the velocity of the ship is 20 feet *per* second, that of the water in the contrary direction and abaft the greatest breadth, is one foot *per* second, and that before in the direction of the ship it is half a foot *per* second; on this supposition we have $n = 20$, $w = 1$, $v = 0{,}5$; then $n + w = 21$; $n - v = 19{,}5$, consequently $(n + w)^2 = 441$, and $(n-v)^2 = 380{,}25$. Now if AB or a be supposed $= 100$, AD or x will be $= 46$, that is, the greatest breadth will be in this case $\frac{1}{25}$ of the length before the middle.

It must be again confessed that this calculation being founded only upon certain suppositions, we cannot derive any conclusions from it, except that the main breadth should be placed a little before the middle, as has been shewn before. However the exact place of the main breadth, to produce the desired effect, does not require the most rigorous determination, since the resistance may also be diminished by the form of the water-lines afore and abaft the main breadth. We shall find hereafter certain means of determining with more exactness the place, where it is proper to place the midship bend.

(66.) We may however draw another advantage from these attempts; since $n-v$ and $n+w$ express the velocity, with which the ship meets the water, and the effect of the resistance is for the fore part as $(n-v)^2$, and for the after part as $(n+w)^2$, these two quantities may be considered as absolute forces, which act against the ship, and which are always greater on the after part than on the forepart; and if we suppose all ships to have the same velocity, the numbers 380,25 and 441 may be considered for all, as given coefficients of the resistance. But these quantities being invariable, it would be better to employ for this purpose lower numbers in the same proportion, as 6 and 7; then the expression for the resistance on the forepart, will be $6 \times \frac{DC^2}{AC^2} \times C$, and for that on the aft part $7 \times \frac{DC^2}{BC^2} \times C$. The numbers 6 and 7 are always founded on certain suppositions; for if w had been equal to 2 or to $\frac{1}{2}$, then instead of 7 the given coefficient of the resistance for the after part would have been 7,7 or 6,6; but mathematical precision not being required in practice, it is better to have an expression in some degree erroneous, provided there be nothing absurd in it, than to want one altogether.

As it still remains to apply these expressions, and since from the absolute resistance is derived not only the relative direct resistance, but also the lateral and vertical, we shall give the following construction, which will serve to find the value of these three forces.

(67.) Let $ACDB$ (Fig. 17.) be a plane inclined to the horizon (Note 34.). Suppose that it is met by a fluid with a force EF, in a horizontal direction from E to F.

From F draw the line FI parallel to the horizon; from E drawn EG perpendicular to the plane: EG will express the force, which acts perpendicularly to this plane. From G draw GH perpendicular to EF; EH is the relative direct force. From E draw the line EI perpendicular to FI, and draw GI; then the triangle EIG will be perpendicular to the horizon. From G a perpendicular GK is let fall to EI or to the horizon, and GK will be the relative vertical force. Draw a line from K to H; it will be perpendicular to EF, and the distance KH will represent the relative lateral force. So that the relative direct, vertical, and lateral forces, which act at the point F, are expressed by EH, GK and KH. To apply this to the body of the ship; let $aacd$ (Fig. 18.) be the fore part of this body; aa, bb, cc, &c. the water-lines at equal distances from each other, and AK, BL, MN, &c. the vertical sections, which are also at equal distance.

To find the direct, vertical, and lateral forces, which act on the fore part of the ship, divide all the spaces $CABD$, $DBMO$, &c. into triangles, which is done in $CABD$ by means of the diagonal AD.

From D and A draw the lines DF, AE perpendicular to AC, DB; and from F and E draw in like manner EH, FG perpendicular to aa, bb.

Draw the two parallel lines RS, PQ (Fig. 19.) at a distance from each other equal to that of the vertical sections. To these two lines draw the perpendicular RP produced; transfer the distance DF from P to T; draw TR; from T draw TU perpendicular to TR.

If UR express the absolute force, UP will express the relative direct force, FG (Fig. 18.) the vertical, and GD the lateral force, which act on the triangle ACD. But as the absolute force is constant, we may take for this force, the distance between the sections. Wherefore draw PW (Fig. 19.) perpendicular to the line RT; from W draw WX perpendicular to RP, and PX will be the relative direct force.

Set off the distance FG (Fig. 18.), which is the vertical force when the absolute force is RU, from Z to Y, so that the line ZY may be perpendicular to PQ (Fig. 19.).

As the force RU has been reduced to RP, the one ZY ought to be diminished in the same proportion. Draw therefore the line TX. Then $YZ : Y\beta :: RP : RX :: RU : RP$; consequently $Y\beta$ will be the relative vertical force on the triangle ACD (Fig. 18.).

Fig. 14.

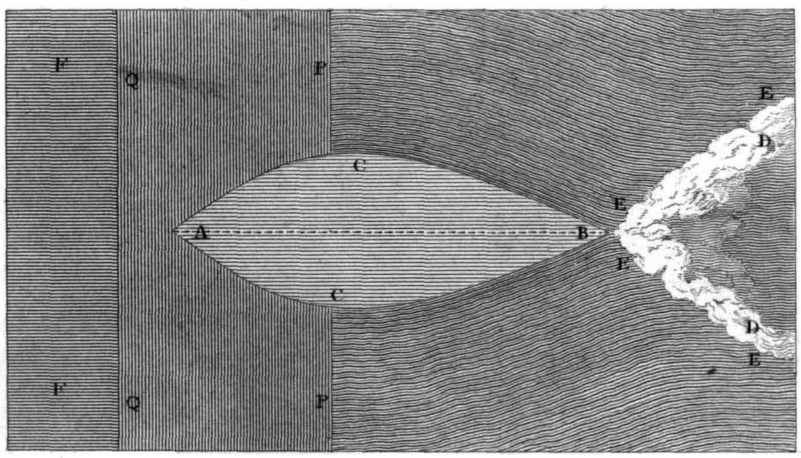


Fig. 15.

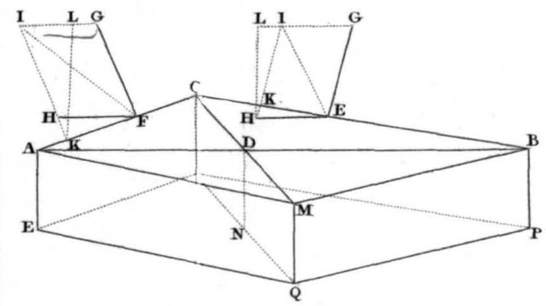


Fig. 16.

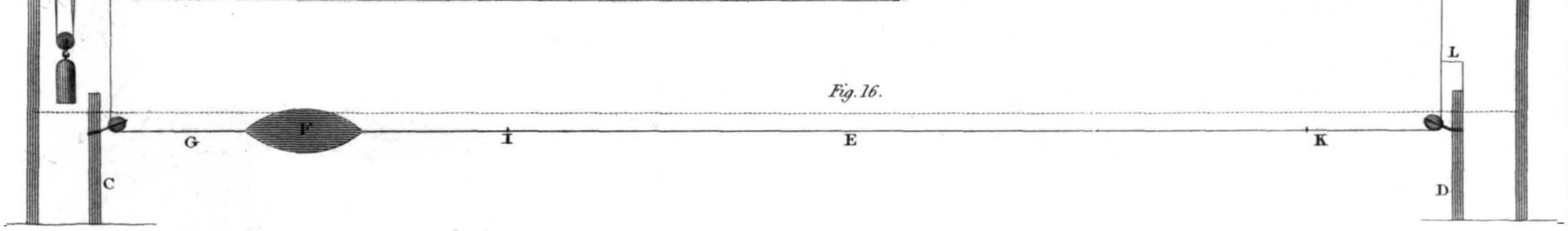


Fig. 17.

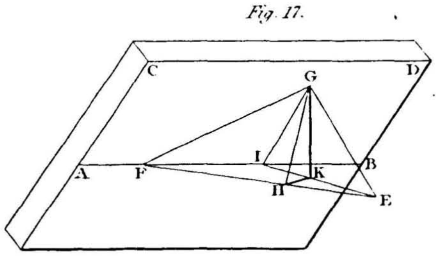


Fig. 18.

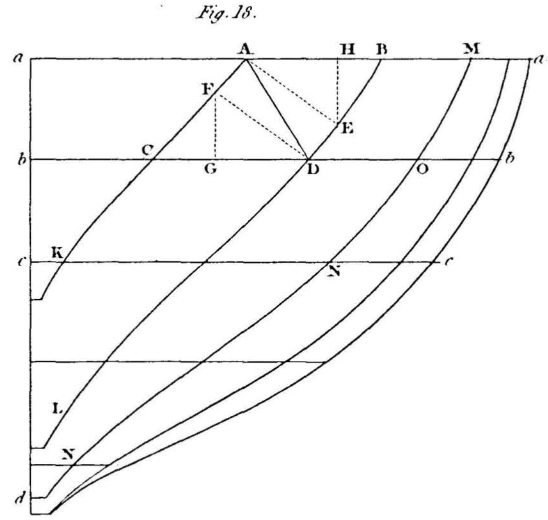
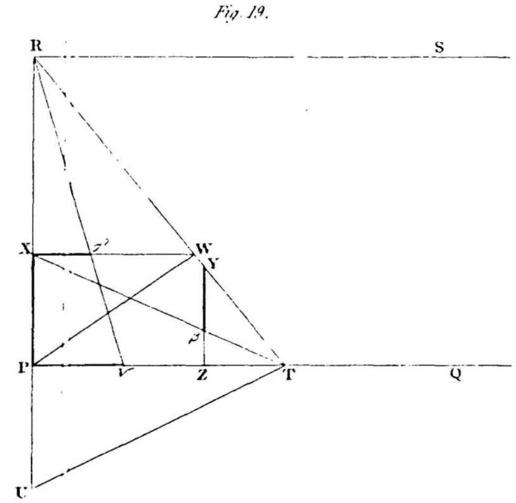


Fig. 19.



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Transfer DG from P to γ (Fig. 19.); draw γR. It is seen in the same manner that δX is the lateral force on the same triangle; and consequently, the relative direct, vertical, and lateral forces are expressed by Px, βY and δX, when RP is the absolute force. We get the effect of these forces by multiplying them by the triangle ACD. The same operation does for the triangle ADB, and so for the others.

(68.) Now if we have the resistance on the fore part equal M; that on the aft equal N; the whole resistance according to the last article, will be proportional to $6M + 7N$; but as we have taken for the absolute force, the distance between the sections, which may be greater in one plane than in another, the relative force on one ship cannot be compared with that which acts on another. It is necessary then to find a plane figure, which being moved in the water with the same velocity as the ship, meets with the same resistance; this is called the *plane of resistance*. If the distance between the sections $= m$, the plane of resistance will be $= \frac{6M + 7N}{13m}$ (NOTE 35.). For example, let $M = 18$, $N = 16$, $m = 5$; then we shall have $\frac{6M + 7N}{13m} = 3{,}38$; that is to say, the ship meets with the same resistance as a plane would of 3,38 feet area, when moved with the same velocity as the ship. Thus the plane of resistance is 3,38 square feet.

(69.) To find the direct resistance, or the plane of resistance for the Privateer (Fig. 47, 48, and 49.).

To obtain with the greatest exactness the construction and calculation of the forces, we have made the vertical plan of the body on a larger scale.

The sections which are at equal distances, are represented by π, β, Z, X, u, &c. afore ϕ, and by 32, 30, 28, &c. abaft ϕ; 11 is the load water-line, when the ship is fitted. Below this line are drawn others, 22, 33, 44, &c. all which are parallel to the load water-line, and at equal distances from each other. By this means, the whole surface of the body is divided into spaces like $B\pi\beta E$; these spaces are divided triangularly by the diagonals AB, πE, &c.

From A draw the line AC perpendicular to $B\pi$; from π and E, the line πI, EF perpendicular to $E\beta$, $B\pi$. From C draw CD perpendicular to the water-line. From F and I draw the lines FH and IG also perpendicular to the water-lines, and so on for the other spaces.

This construction being made, draw two parallel lines IK, LM, (Fig. 21.) at a distance from each other equal to that between the sections; draw NO perpendicular to them.

Set off AC (Fig. 20.) from N to P (Fig. 21.); make NQ equal to the distance of the section π from the stem; draw PQ. But as the distance between the first section π and the stem is less than that between the sections, and as this latter distance is taken for the perpendicular effect of the forces on every space, draw from O the line OR parallel to PQ.

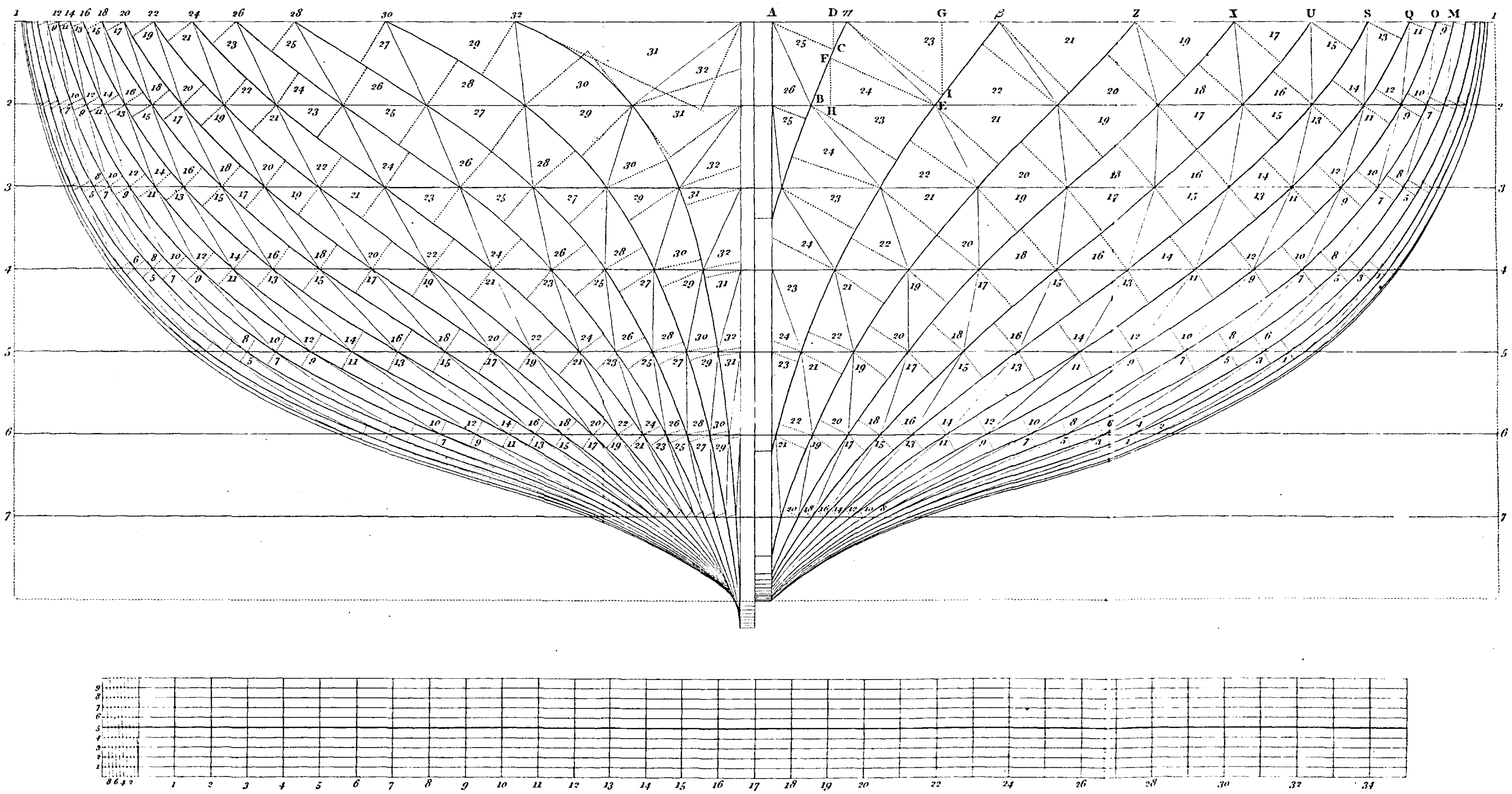
Set off DC (Fig. 20.) from U to W (Fig. 21.) perpendicular to NR; from N and through the point W, draw the line NX; again, from N let fall on OR the perpendicular NS, and from S upon NO the perpendicular ST. It will follow by the last article, that NT will be the relative direct force, which acts against the triangle $AB\pi$.

Draw RT (Fig. 21.); from X draw XY perpendicular to LM; XY is the vertical force, which acts against the same triangle; and in this manner are found the direct and vertical forces, which act against the triangle 25 (Fig. 20.).

To find the direct and vertical forces, which act on the triangle 24, we proceed as has been just explained in the last article. Make ab (Fig. 21.) perpendicular to LM, set off the distance EF (Fig. 20.) from a to c (Fig. 21.), from a draw ad perpendicular to bc, from d draw de perpendicular to ab; ae will be the direct force. Draw ce, and set off the distance FH (Fig. 20.) from the line bc (Fig. 21.) to the line LM perpendicular to the latter; fg will be the vertical force on the triangle 24 (Fig. 20.).

The product of these forces multiplied by the area of the triangles, gives the effect on each of them. The same operation does for all the spaces.

Fig. 20.



W. Lowry Sc.

Fig. 21.

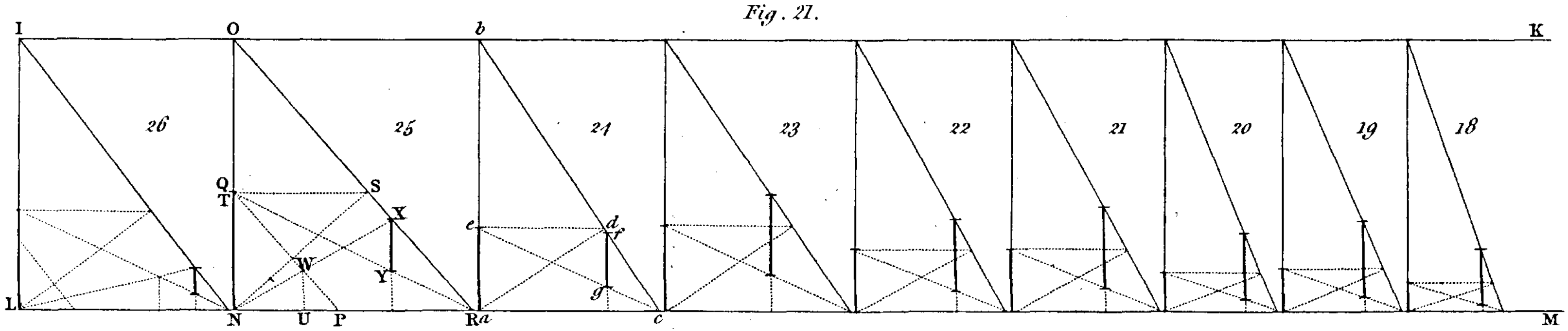
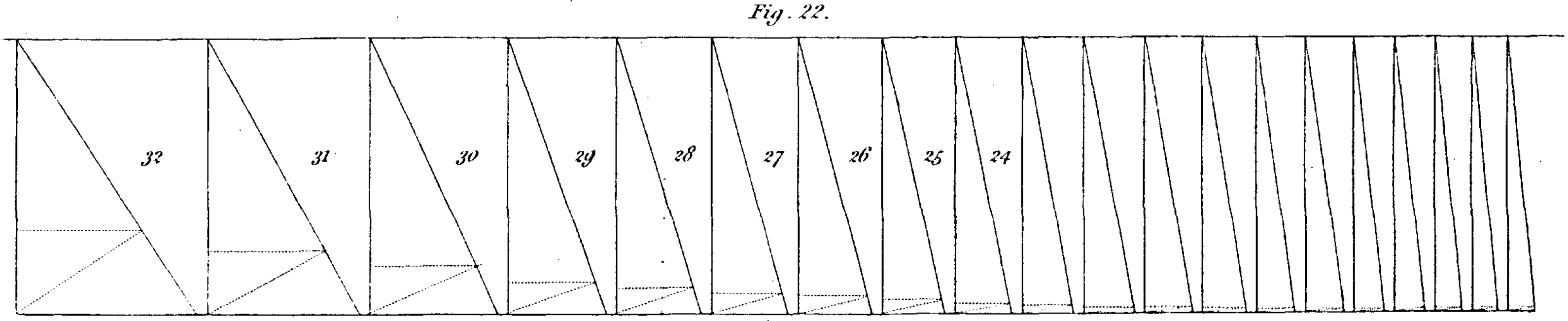


Fig. 22.



Lowry Sculp.

(70.) In the same manner the forces on the after part are found. The construction for it is represented in Fig. 22. The value of all these forces is taken on a decimal scale, and a table of them made in the following manner. As at present we only seek the direct forces, the effects of these forces alone are put down.

The distance between the sections = 4,95 feet. The distance between the water-lines = 2,25 feet = 2 feet and a quarter, half of which = 1 foot and an eighth.

Direct Resistance to the Privateer, (Fig. 47, 48, 49.) *before* ϕ.

Between the 1st and 2d water-lines.

Triangles. No.	Base.	Direct resistance.	This force × by the base.	Triangles. No.	Base.	Direct resistance.	This force × by the base.
25	2,02	2,11	4,16	26	1,07	1,83	1,95
23	4,25	1,53	4,70	24	3,40	1,42	4,82
21	3,74	1,15	4,30	22	3,37	1,12	3,77
19	2,83	0,75	2,12	20	2,79	0,72	2,00
17	2,12	0,53	1,12	18	2,39	0,53	1,26
15	1,62	0,36	0,58	16	1,90	0,38	0,72
13	1,07	0,21	0,22	14	1,39	0,25	0,34
11	0,72	0,10	0,07	12	1,06	0,15	0,16
9	0,53	0,07	0,03	10	0,72	0,11	0,07
7	0,33	0,03	0,01	8	0,48	0,06	0,02
5	0,25	0,02	0,00	6	0,31	0,03	0,01
3	0,14	0,01	0,00	4	0,20	0,02	0,00
1	0,10	0,00	0,00	2	0,15	0,01	0,00
			17,31				15,12
× by ½ height of trian.			$1+\frac{1}{8}$				$1+\frac{1}{8}$
Effects.			19,47				17,01

Between the 2d and 3d water-lines.

Triangles. No.	Base.	Direct resistance.	This force × by the base.	Triangles. No.	Base.	Direct resistance.	This force × by the base.
25	1,07	1,67	1,78	26			
23	3,40	1,17	3,97	24	2,64	1,02	2,69
21	3,37	0,93	3,13	22	2,72	0,89	2,42
19	2,79	0,63	1,75	20	2,47	0,57	1,40
17	2,39	0,51	1,21	18	2,47	0,49	1,21
15	1,90	0,36	0,68	16	2,12	0,37	0,78
13	1,39	0,23	0,32	14	1,73	0,26	0,44
11	1,06	0,19	0,20	12	1,34	0,19	0,25
9	0,72	0,10	0,07	10	1,02	0,14	0,14
7	0,48	0,05	0,02	8	0,67	0,08	0,05
5	0,31	0,03	0,01	6	0,47	0,04	0,01
3	0,20	0,02	0,00	4	0,30	0,02	0,00
1	0,15	0,01	0,00	2	0,22	0,01	0,00
			13,14				9,39
			$1+\frac{1}{8}$				$1+\frac{1}{8}$
			14,78				10,56

Between the 3d and 4th water-lines.

Triangles. No.	Base.	Direct resistance.	This force × by the base.	Triangles. No.	Base.	Direct resistance.	This force × by the base.
23	2,64	0,86	2,27	24	1,73	0,57	0,98
21	2,72	0,74	2,01	22	2,07	0,65	1,34
19	2,47	0,50	1,23	20	1,92	0,44	0,84
17	2,47	0,45	1,11	18	2,12	0,40	0,84
15	2,12	0,37	0,78	16	2,01	0,33	0,66
13	1,73	0,28	0,48	14	1,84	0,27	0,49
11	1,34	0,19	0,25	12	1,61	0,19	0,30
9	1,02	0,14	0,14	10	1,29	0,14	0,18
7	0,67	0,08	0,05	8	0,96	0,10	0,09
5	0,47	0,04	0,01	6	0,72	0,07	0,05
3	0,30	0,03	0,01	4	0,46	0,04	0,01
1	0,22	0,02	0,00	2	0,34	0,03	0,01
			8,34				5,79
× by ½ height of trian.			$1+\frac{1}{8}$				$1+\frac{1}{8}$
			9,38				6,51

Between the 4th and 5th water-lines.

Triangles. No.	Base.	Direct resistance.	This force × by the base.	Triangles. No.	Base.	Direct resistance.	This force × by the base.
23	1,73	0,61	1,05	24	0,81	0,44	0,35
21	2,07	0,51	1,05	22	1,50	0,40	0,60
19	1,92	0,38	0,72	20	1,46	0,32	0,46
17	2,12	0,37	0,78	18	1,50	0,30	0,45
15	2,01	0,31	0,62	16	1,58	0,23	0,36
13	1,84	0,23	0,42	14	1,58	0,18	0,27
11	1,61	0,19	0,30	12	1,64	0,18	0,29
9	1,29	0,15	0,19	10	1,40	0,13	0,18
7	0,96	0,09	0,08	8	1,13	0,11	0,12
5	0,72	0,06	0,04	6	0,93	0,07	0,06
3	0,46	0,04	0,01	4	0,73	0,04	0,02
1	0,34	0,02	0,00	2	0,55	0,03	0,01
			5,26				3,17
			$1+\frac{1}{8}$				$1+\frac{1}{8}$
			5,91				3,56

Direct Resistance to the Privateer before φ.

Between the 5th and 6th water-lines.

Triangles. No.	Triangles. Base.	Direct resistance.	This force × by the base.	Triangles. No.	Triangles. Base.	Direct resistance.	This force × by the base.
23	0,81	0,35	0,28				
21	1,50	0,34	0,51	22	1,00	0,20	0,20
19	1,46	0,28	0,40	20	0,97	0,17	0,16
17	1,50	0,23	0,34	18	0,90	0,14	0,12
15	1,58	0,18	0,28	16	0,93	0,11	0,10
13	1,58	0,16	0,25	14	0,97	0,09	0,08
11	1,64	0,14	0,22	12	1,10	0,07	0,07
9	1,40	0,11	0,15	10	1,13	0,06	0,06
7	1,13	0,08	0,09	8	1,08	0,05	0,05
5	0,93	0,06	0,05	6	0,90	0,04	0,03
3	0,73	0,04	0,02	4	0,82	0,03	0,02
1	0,55	0,02	0,01	2	0,79	0,02	0,01
			2,60				0,90
× by $\frac{1}{2}$ height of trian.			$1+\frac{1}{8}$				$1+\frac{1}{8}$
			2,92				1,01

Between the 6th and 7th water-lines.

Triangles. No.	Triangles. Base.	Direct resistance.	This force × by the base.	Triangles. No.	Triangles. Base.	Direct resistance.	This force × by the base.
21	1,00	0,19	0,19	22	0,30	0,05	0,01
19	0,97	0,16	0,15	20	0,50	0,07	0,03
17	0,90	0,11	0,09	18	0,40	0,06	0,02
15	0,93	0,08	0,07	16	0,35	0,05	0,01
13	0,97	0,07	0,06	14	0.40	0,04	0,01
11	1,10	0,06	0,06	12	0,40	0,03	0,01
9	1,13	0,05	0,05	10	0,40	0,02	0,01
7	1,08	0,04	0,04	8	0,40	0,02	0,01
5	0,90	0,03	0,02	6	0,39	0,01	0,00
3	0,82	0,02	0,01	4	0,35	0,01	0,00
1	0,79	0,01	0,00	2	0,28	0,00	0,00
			0,74				0,11
			$1+\frac{1}{8}$				$1+\frac{1}{8}$
			0,83				0,12

Direct Resistance to the Privateer abaft φ.

Between the 1st and 2d water-lines.

Triangles. No.	Triangles. Base.	Direct resistance.	This force × by the base.	Triangles. No.	Triangles. Base.	Direct resistance.	This force × by the base.
31	6,22	1,14	7,09	32	3,13	1,52	4,75
29	3,50	0,58	2,03	30	3,00	0,85	2,55
27	2,40	0,37	0,88	28	2,62	0,42	1,10
25	1,72	0,28	0,48	26	2,31	0,31	0,71
23	1,20	0,18	0,21	24	1,72	0,24	0,41
21	1,08	0,19	0,20	22	1,47	0,21	0,30
19	0,75	0,09	0,06	20	1,12	0,13	0,14
17	0,64	0,07	0,04	18	0,91	0,11	0,10
15	0,51	0,07	0,03	16	0,76	0,09	0,06
13	0,39	0,05	0,02	14	0,56	0,06	0,03
11	0,35	0,04	0,01	12	0,50	0,06	0,03
9	0,31	0,03	0,01	10	0,43	0,04	0,01
7	0,26	0,02	0,00	8	0,34	0,04	0,01
5	0,17	0,02	0,00	6	0,26	0,02	0,00
3	0,15	0,01	0,00	4	0,20	0,02	0,00
1	0,11	0,00	0,00	2	0,14	0,01	0,00
			11,06				10,20
× by $\frac{1}{2}$ height of trian.			$1+\frac{1}{8}$				$1+\frac{1}{8}$
			12,44				11,47

Between the 2d and 3d water-lines.

Triangles. No.	Triangles. Base.	Direct resistance.	This force × by the base.	Triangles. No.	Triangles. Base.	Direct resistance.	This force × by the base.
31	3,04	0,95	2,88	32	1,73	0,60	1,03
29	3,00	0,64	1,92	30	2,01	0,60	1,20
27	2,62	0,45	1,17	28	2,05	0,50	1,02
25	2,31	0;35	0,57	26	2,07	0,35	0,72
23	1,72	0,25	0,43	24	2,02	0,28	0,56
21	1,47	0,21	0,30	22	1,65	0,22	0,36
19	1,12	0,15	0,16	20	1,61	0,27	0,33
17	0,91	0,13	0,11	18	1,21	0,15	0,18
15	0,76	0,11	0,08	16	1,00	0,12	0,12
13	0,56	0,07	0,03	14	0,81	0,10	0,08
11	0,50	0,05	0,02	12	0,68	0,07	0,04
9	0,43	0,04	0,01	10	0,56	0,05	0,02
7	0,34	0,03	0,01	8	0,45	0,04	0,01
5	0,26	0,02	0,00	6	0,31	0,03	0,01
3	0,20	0,01	0,00	4	0,23	0,02	0,00
1	0,14	0,00	0,00	2	0,16	0,01	0,00
			7,69				5,68
			$1+\frac{1}{8}$				$1+\frac{1}{8}$
			8,65				6,39

Direct Resistance to the Privateer abaft ϕ.

Between the 3d and 4th water-lines.

Triangles. No.	Triangles. Base.	Direct resistance.	This force × by the base.	Triangles. No.	Triangles. Base.	Direct resistance.	This force × by the base.
31	1,73	0,48	0,83	32	1,07	0,29	0,31
29	2,01	0,48	0,96	30	1,35	0,29	0,39
27	2,05	0,40	0,82	28	1,40	0,29	0,40
25	2,07	0,31	0,64	26	1,49	0,27	0,41
23	2,02	0,26	0,52	24	1,69	0,26	0,43
21	1,65	0,21	0,34	22	1,61	0,21	0,33
19	1,61	0,20	0,32	20	1,70	0,19	0,32
17	1,21	0,12	0,14	18	1,50	0,16	0,24
15	1,00	0,11	0,11	16	1,34	0,14	0,18
13	0,81	0,08	0,06	14	0,98	0,09	0,08
11	0,68	0,07	0,04	12	0,88	0,08	0,07
9	0,56	0,04	0,02	10	0,74	0,06	0,04
7	0,45	0,03	0,01	8	0,63	0,05	0,03
5	0,31	0,02	0,00	6	0,39	0,03	0,01
3	0,23	0,01	0,00	4	0,31	0,02	0,00
1	0,16	0,00	0,00	2	0,19	0,01	0,00
			4,81				3,24
× by $\frac{1}{2}$ height of trian.			$1+\frac{1}{8}$				$1+\frac{1}{8}$
			5,41				3,64

Between the 4th and 5th water-lines.

Triangles. No.	Triangles. Base.	Direct resistance.	This force × by the base.	Triangles. No.	Triangles. Base.	Direct resistance.	This force × by the base.
31	1,07	0,27	0,28	32	0,70	0,16	0,11
29	1,35	0,28	0,37	30	0,88	0,16	0,14
27	1,40	0,26	0,36	28	0,93	0,16	0,14
25	1,49	0,25	0,37	26	1,00	0,16	0,16
23	1,69	0,24	0,40	24	1,11	0,16	0,17
21	1,61	0,19	0,30	22	1,23	0,16	0,19
19	1,70	0,18	0,30	20	1,24	0,15	0,18
17	1,50	0,13	0,19	18	1,30	0,14	0,18
15	1,34	0,12	0,16	16	1,37	0,13	0,17
13	0,98	0,10	0,09	14	1,17	0,12	0,14
11	0,88	0,09	0,07	12	1,13	0,09	0,10
9	0,74	0,06	0,04	10	0,91	0,07	0,06
7	0,63	0,05	0,03	8	0,76	0,05	0,03
5	0,39	0,04	0,01	6	0,62	0,03	0,01
3	0,31	0,02	0,00	4	0,40	0,02	0,00
1	0,19	0,01	0,00	2	0,26	0,01	0,00
			2,97				1,78
			$1+\frac{1}{8}$				$1+\frac{1}{8}$
			3,34				2,00

Between the 5th and 6th water-lines.

Triangles. No.	Triangles. Base.	Direct resistance.	This force × by the base.	Triangles. No.	Triangles. Base.	Direct resistance.	This force × by the base.
31	0,70	0,15	0,10	32	0,41	0,08	0,03
29	0,88	0,15	0,13	30	0,56	0,08	0,04
27	0,93	0,15	0,13	28	0,61	0,08	0,04
25	1,00	0,15	0,15	26	0,62	0,08	0,04
23	1,11	0,15	0,16	24	0,64	0,08	0,05
21	1,23	0,15	0,18	22	0,75	0,08	0,06
19	1,24	0,14	0,17	20	0,78	0,08	0,06
17	1,30	0,13	0,16	18	0,83	0,08	0,06
15	1,37	0,12	0,16	16	0,83	0,05	0,04
13	1,17	0,10	0,11	14	0,88	0,05	0,04
11	1,13	0,07	0,07	12	0,95	0,05	0,04
9	0,91	0,05	0,04	10	0,76	0,04	0,03
7	0,76	0,04	0,03	8	0,76	0,04	0,03
5	0,62	0,03	0,01	6	0,76	0,03	0,02
3	0,40	0,02	0,00	4	0,54	0,02	0,01
1	0,26	0,01	0,00	2	0,38	0,01	0,00
			1,60				0,59
× by $\frac{1}{2}$ height of trian.			$1+\frac{1}{8}$				$1+\frac{1}{8}$
			1,80				0,66

Between the 6th and 7th water-lines.

Triangles. No.	Triangles. Base.	Direct resistance.	This force × by the base.	Triangles. No.	Triangles. Base.	Direct resistance.	This force × by the base.
31	0,41	0,07	0,02	32	0,22	0,05	0,01
29	0,56	0,07	0,03	30	0,29	0,04	0,01
27	0,61	0,07	0,04	28	0,32	0,04	0,01
25	0,62	0,07	0,04	26	0,31	0,03	0,01
23	0,64	0,07	0,04	24	0,31	0,03	0,01
21	0,75	0,07	0,05	22	0,31	0,02	0,00
19	0,78	0,07	0,05	20	0,31	0,02	0,00
17	0,83	0,06	0,04	18	0,31	0,02	0,00
15	0,83	0,05	0,04	16	0,31	0,01	0,00
13	0,88	0,04	0,03	14	0,31	0,01	0,00
11	0,95	0,04	0,03	12	0,28	0,01	0,00
9	0,76	0,03	0,02	10	0,26	0,01	0,00
7	0,76	0,03	0,02	8	0,25	0,00	0,00
5	0,76	0,02	0,01	6	0,24	0,00	0,00
3	0,54	0,02	0,01	4	0,23	0,00	0,00
1	0,38	0,01	0,00	2	0,21	0,00	0,00
			0,47				0,05
			$1+\frac{1}{8}$				$1+\frac{1}{8}$
			0,53				0,06

Recapitulation of the direct Resistances between the lines of floatation.

For the part afore ϕ		*For the part abaft ϕ*	
Between the 1st and 2d water-lines.......	= 36,48	Between the 1st and 2d water-lines.......	= 23,91
Between the 2d and 3d	= 25,34	Between the 2d and 3d	= 15,04
3d and 4th	= 15,89	3d and 4th	= 9,05
4th and 5th	= 9,47	4th and 5th	= 5,34
5th and 6th	= 3,93	5th and 6th	= 2,46
6th and 7th	= 0,95	6th and 7th	= 0,59
Against the stem.....	= 13,16	Against the rudder....	= 20,00
Whole resistance afore ϕ	= 105,22	Whole resistance abaft ϕ	= 76,39

(71.) According to Article 68, the plane of resistance $= \frac{6M + 7N}{13m}$. In this example $M = 105{,}22$, $N = 76{,}39$, and $m = 4{,}95$; then the half area of the plane of resistance $= \frac{6 \times 105{,}22 + 7 \times 76{,}39}{13 \times 4{,}95} = \frac{1166{,}05}{64{,}35} = 18{,}12$. Consequently this frigate will meet with, from the fluid, a resistance equal to that which a plane would meet with of 36,24 square feet or a perfect square of 6 feet, moved with a velocity equal to that of the vessel.

CHAP. V.

ON THE CENTER OF EFFORT OF THE WIND ON THE SAILS, AND THEIR MOMENT ROUND THE SHIP'S CENTER OF GRAVITY.

(72.) The effect of the wind on the sails is that force, which gives the ship head-way, and which is proportional to the size of the sails; so that a greater surface of the sails ought to cause a greater velocity in the ship. On this account people endeavour to make the sails as large as possible: but as the length of the ship determines the breadth of the sails, they cannot become very large without being of considerable height.

But very large sails, and particularly very high sails, cause a great inclination; and since with a certain force of wind, the inclination ought not to be more than a certain determinate degree, it becomes necessary to restrain the size and length of the sails within certain limits, which may be determined in the following manner.

(73.) By referring to Article 59, we shall see that when a body is in motion, the pressure of the water on the after part produced by this motion, is a negative quantity, and this not only in regard to the direct resistance, but also in regard to the vertical and lateral resistances. Suppose then AB (Fig. 23.) a ship moved from B towards A with a certain force, in a resisting fluid.

Let DG be the direct force of the water against the head of the ship, the direction of which is from D to G; let IE be the direct force of the water on the after part, the direction of which is from I to E; let GH

be the vertical force of the water upon the head, the direction of which is from G to H, and KI the same force on the after part, the direction of which is from K to I. We shall have DH for the resultant of the forces on the fore part, the direction of which is from D to H; and KE for the resultant of those on the after part, the direction of which will be from K to E.

Produce the lines DH, EK to meet in F. Make FN, $FO = DH$, EK; complete as usual the parallelogram of the forces $FNPO$; draw the diagonal PF and produce it. From the center of gravity of the ship C draw CL, CM, and CQ, perpendicular to DH, EK, and PF. We shall have $FN \times CL + FO \times CM = FP \times CQ$; consequently, if PF is the force and the direction of the wind, and the center of gravity of the sails is in the line PF, the surface of the sails being perpendicular to the same line, the ship would go a-head without the elevation or depression of either of its extremities. But the direction of the wind must be considered as horizontal; wherefore from C, N and F draw the lines CW, NS perpendicular, and FR parallel to the horizon, and through P the line TR parallel to NS; then $FS + NT = DG + IE = FR =$ the whole direct resistance.

The triangles CQW and FRP being similar, $CQ : CW :: FR : FP$, and hence $CQ \times FP = CW \times FR$.

As the horizontal effort of the wind on the sails is necessarily equal to the horizontal effort of the water on the hull of the ship, the point W will be the proper height of the center of gravity of the sails, the direction XY of the wind on the sails being parallel to the horizon.

(74.) If the center of gravity of the sails is not situated in the line XY or in W, but for example in α, then the ship will incline towards the head. If on the contrary the center of gravity be in β, the after part will be farther immersed. Wherefore, that a ship may not have any motion of this kind, either forward or aft, by means of the sails, the center of effort of the wind on the sails should be situated in some part of the line XY.

Hence we see of what consequence it is to have this center at the proper height, when the ship sails with the wind aft. For if it is situated in α, or in β, a greater quantity of sail would not increase the sailing proportionally to the surface (NOTE 36.), because one or other of the extremities of the ship would be depressed, by which the resistance would be increased.

(75.) In a ship full at the load water-line forward, and lean below, the resultant of the effort of the water rises very much; to sail well therefore it ought to have high sails: on the other hand, in a ship the forepart of which is very full under the water, the resultant will not rise much: consequently, to sail well, it ought to have sails less high. The after part of the ship is equally to be considered in the determination of the center of effort of the sails.

This proves that two ships of the same length, breadth, and tonnage, may have the same stability, and yet require different heights of the sails to sail equally well with the wind aft.

(76.) We cannot determine from the last articles the surface which the sails ought to have; for the proper height of the center of effort of the wind on the sails being once determined, it would be convenient with the wind aft to give the sails the greatest possible surface, without affecting the condition in regard to the height. But it is not the same when the ship is on a wind. This center will then be much higher than the resultant of the force of the water on the side of the ship, and as soon as the wind acts on the sails the vessel assumes an inclination, which ought not to exceed a certain degree, the moment of the sails, and the force of the water being given.

(77.) To determine the surface proper to be given to the sails, from the knowledge which we have of the effect of the wind on planes or sails, with different velocities in different directions, it would be necessary to enter upon long calculations of great difficulty, and yet of little importance. We may compare plans of ships and of their rigging, which are tried and known, and nothing will be required further than to be guided by those ships, which have the best proportion of canvass, with respect to the center of effort of the wind on the sails and the stability; which will be seen by what follows:

Let ABC (Fig. 24.) be a ship inclined by the effort of the wind HG. Let AB be the load water-line; D the center of gravity of the ship; E the center of gravity of the displacement, and G the height of the center of effort of the wind on the sails. If from E we draw a vertical line EF, F will be the metacenter. From D draw DK perpendicular to EF, make the force of the wind, which acts perpendicularly to the line $GD = U$; that which acts in the line EF (which is equal to the displacement) $= D$.

(78.) As the rotatory motion is round the center of gravity (Art. 25.), the moment of the sails to incline the ship, will be equal to $DG \times U$; the moment of the ship to resist the inclination $= DK \times D$. But since, whatever be the length of FD, it preserves a constant proportion to KD at equal inclinations (Note 37.), we may always express the moment of the ship to resist inclination by $FD \times D$, which moment ought to have a certain proportion to $DG \times U$, in order that the degree of inclination may be the same, DG being considered as an arm of a lever of the second or third order.

The wind acting in the direction HG, the ship is impelled from B towards A, and the resistance of the water will act in the line IL, which passes either above or below the center of gravity D. If IL pass above the center of gravity, the stability will be increased; if below it, the stability will be diminished.

(79.) It requires considerable labour to calculate on the plan of each ship, the direction of the resistance of the water on the side; and it may be sufficient to know that the mean direction of this resistance rises less in ships, the hulls of which are very lean, as well towards the extremities as towards the keel, than in those ships which are full throughout. As this however cannot produce a considerable effect on the stability, we may suppose, without running the risk of making a great error, that this mean direction passes through the center of gravity of the ship. So that the moment of the sails, relatively to the center of gravity of the ship, should always have a certain proportion to the whole weight of the ship, multiplied by the distance of the center of gravity D from the metacenter F; that is to say, the moment of the sails in all ships is equal to $m \times DF \times D$. The value of the coefficient m can only be determined by experience.

(80.) I have calculated the moment of the sails for several ships in use, and I have found, if the length of the ship, from the stem to the sternpost $= x$, that the quantity $m = \frac{35{,}5}{x^{\frac{1}{3}}}$ nearly. So that the absolute moment of the sails for all ships, as well privateers as merchant ships, $= \frac{35{,}5}{x^{\frac{1}{3}}} \times DF \times D$ (NOTE 38.). If now the center of gravity of all frigates of war and privateers, as also smaller vessels, which are built only for sailing, down to the smallest pleasure boat, be supposed to be situated in the plane of the load water-line (a supposition which may be made with great safety, since it cannot be far from thence) the moment of the sails will be reckoned from the same plane of the load water-line. We are the more authorized to do this in such ships, because the lading for those of the same kind is always the same, and the weights, which affect the stability, are similarly placed in them.

(81.) It is not the same for ships engaged in commerce; they take various cargoes, which may differ greatly in specific gravity; whence it follows, that the center of gravity may be situated either higher or lower, notwithstanding the vessel is brought down to the same draught of water.

When the cargo consists of merchandize of little specific gravity, we may lower the center of gravity, by putting ballast in the bottom of the ship; but as little ballast is taken as possible, particularly when the cargo is bulky. Whence the ship necessarily loses stability. If the cargo consist of several kinds of merchandize of different specific gravity, a skilful arrangement of the heaviest at the bottom, and the lightest above, may give the necessary stability. It also sometimes happens that these ships sail with only ballast.

Hence we see that the center of gravity of a ship with its cargo is not always in the same point; wherefore the moment of stability varies, and consequently that of the effort of the sails.

The expression however for the moment of the sails, in all these variations, is equally correct with relation to the displacement, and the position of the center of gravity of the ship and lading.

We have seen in the preceding articles the manner of determining the height of the center of effort of the wind on the sails, when the wind is aft; here is found the product of the area of the sails, multiplied by the distance of their common center of gravity from the load water-line, or from the center of gravity of the ship.

(82.) It appears from the investigation of these two points that the sails cannot be proportioned so as to conduce most to make the ship sail well, by any other method, than by determining the height of the center of gravity of the sails, from the mean direction of the water, when the ship sails before the wind, and the product of the area of the sails multiplied by this height, from the stability of the ship. It hence follows, that if we have two ships of the same length, and resisting heeling with the same force, but such that the mean direction of the water in one, rises more than in the other, the former ought to have higher masts and shorter yards than the latter. But one cannot always thus proportion the sails; for in a ship where the mean direction of the water rises very little, if the moment of the sails is to preserve a proper proportion to the stability, their center of gravity will necessarily be higher than that which this direction gives; for the yards cannot have beyond a certain length, lest they should lock in bracing, or the sails becalm each other. It follows, that all other circumstances being the same, when these two ships sail with top-gallant sails set, the former ought to have the advantage; but if a reef be taken in their top-sails, the latter ought to sail the better.

It is impossible then to proportion the surface and height of the sails, so as to obtain in every case the fastest rate of sailing.

(83.) That the moment of the sails ought to be proportional to the cube of the length of the ship, appears to me to rest on no foundation, particularly as the force of the wind, on planes of different extent, is proportional to their surface. In fact, small vessels have often more canvass in proportion to their stability, than large ones; but this arises solely from the circumstance of its being desirable to sail as fast in small craft as in large ships; the small ones have often occasion even to sail the faster.

There is less danger besides in giving too much sail to small ships than to great ones, because the time taken up in working them, is nearly proportional to the homologous sides of the sails: so that a sail twice as broad, and twice as high as another, requires twice as much time to work it. Whenever therefore a sudden squall takes the ship, the necessary manœuvre to prevent dangerous consequences, is executed in less time in a small vessel; on which account, people venture to give them a little greater moment of sail in proportion to their stability.

The sails, which are comprised in the calculation of their moments, are the courses, the top-sails, the top-gallant sails, the main top-mast stay-sail, the jib, and fore top-mast stay-sail.

(84.) We cannot find, except by the method of trial, the surface of canvass from the moment of the sails. A draught is made of the rigging, in which the masts and yards are placed in their usual proportions. The sails are there also represented in the proper form and size. The area of each sail is calculated, and its center of gravity is determined. The product of the area of a sail, multiplied by the distance of its center of gravity from the line of floatation, is called its moment. If the sum of the moments of all the sails be equal to the given moment, the object of research is found. If it be greater or less, the draught must be altered till we obtain this equality, the sails still preserving their proportion to each other. By dividing afterwards the sum of all these moments, by the sum of the area of the sails, we get the distance of the center of gravity of the sails from the load water-line.

(85.) The position of the center of gravity of the canvass, with respect to the length of the ship, contributes greatly to render the ship a good sailer. It is to be determined by the mean direction of the water, the ship being close to the wind; and this direction depends on the shape of the bottom, according to which it passes before or behind the center of gravity of the ship. In a well constructed ship, it ought to pass through this center of gravity, or a very little before it; so that, if a sudden squall take the ship, it may have a disposition to come to the wind, which will not take place, when the direction passes behind this center.

In ships which are more lean forward in proportion than they are aft, the mean direction passes more before the center of gravity, than in those ships which are fuller in this part; on this account, the center of gravity of the sails ought also to be more forward. But in this there is one inconvenience; which is, that the ship inclined by the force of the wind is more immersed forward, whence the resistance increases; besides in a rough sea the pitching will be more considerable, which must prodigiously retard the sailing.

Experience has led to the discovery of a method of lessening the fault of being too ardent; which is, by giving a greater draught of water aft than forward, and this difference of draught of water should be greater in ships which are lean forward, than in those which are full; by which means, when the ship is close to the wind, the mean direction of the water is carried farther aft. Hence the ship becomes less ardent, and the center of gravity of the sails may be carried farther aft, taking care however, that it still remains at one-twentieth of the length of the ship, before the center of gravity of the ship. Without which upon an inclination of the ship, the direction of the wind on the sails (the manner in which they are trimmed by the wind being considered) would pass too far behind the center of gravity of the ship, whence it would still remain too ardent; and, on the other hand, this center of gravity of the sails cannot be situated more than one-tenth of the length of the ship before the center of gravity, without producing a great deal of pitching occasioned by too much head sail.

When a ship is too ardent, this ardency may be diminished by putting in more after ballast; but such a remedy will be attended with the inconvenience that the ship will become a worse sailer, particularly if it has full quarters; moreover when it has come about in plying to windward, it will fall off too much.

When a ship is too little ardent, it is necessary to carry more ballast forward. But the ship on that account will pitch the more, and when it goes about and the head sails are a-back, it will not be brought round easily.

The rudder may remedy the fault of being too much or too little ardent; but by its resistance to the water, it will lessen the rate of sailing.

An important conclusion which results from all this is, that it is necessary to give to a ship a form of body, such that it may neither be too much nor too little ardent; and to effect this, one should endeavour to make the mean resistance of the water, in sailing close to the wind, pass a little before the center of gravity of the ship, as we have said heretofore.

(86.) Before we proceed to the application to which the preceding rules and remarks lead, it will doubtless be useful to give the methods

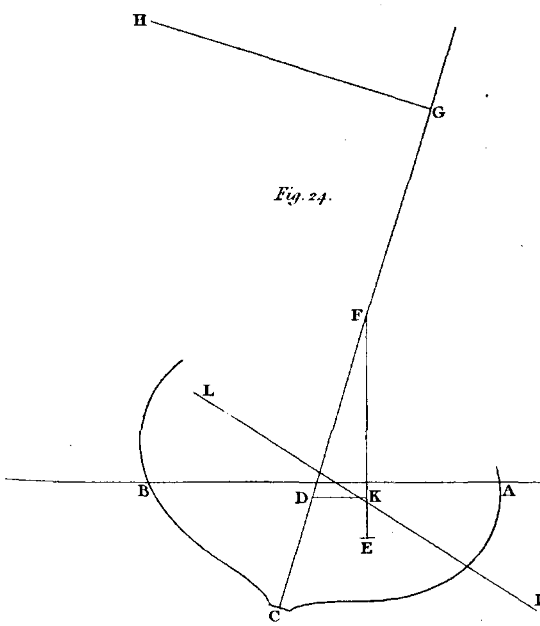


Fig. 24.

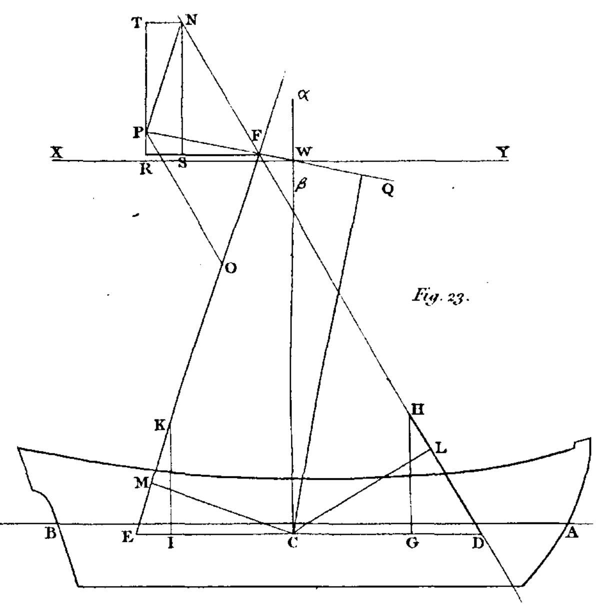


Fig. 23.

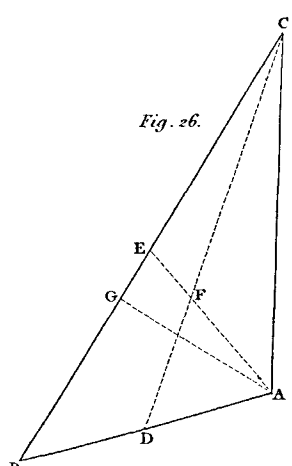


Fig. 26.

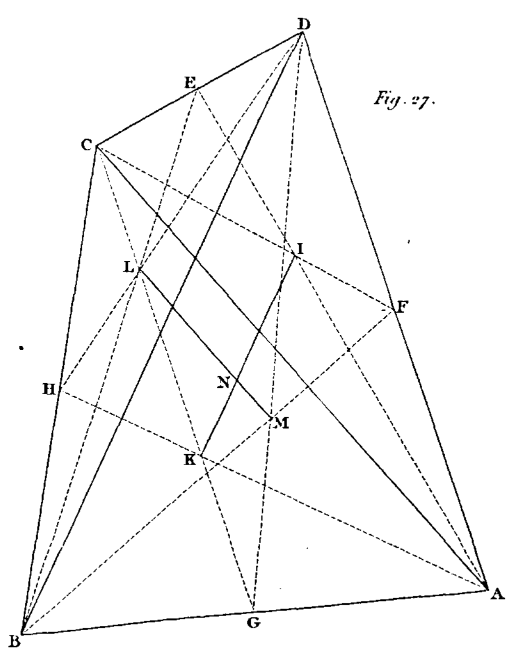


Fig. 27.

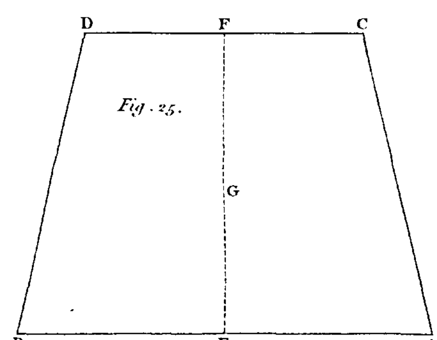


Fig. 25.

Lowry sculp.

of finding, in the easiest manner, the center of gravity of sails of every form, with a view to calculate their moment as well as their area.

The area of a square or rectangular sail, is simply the product of its height by its base (Fig. 25.). Its center of gravity is at the point of intersection of the diagonals. But for the top-sails, which have the form of a trapezium $ABCD$, if $AB = a$, $CD = b$, and $EF = m$, we shall have the area $= m \times \frac{a + b}{2}$; and if the center of gravity be in G, the distance FG will be $= m \times \frac{2a + b}{3 \times (a + b)}$.

The area of a stay-sail, as ABC (Fig. 26.), is found by multiplying its base BC by half its height AG, and its center of gravity is found, by bisecting two of its sides, for example in D and E, and drawing straight lines to the opposite angles; these will meet in the point, which is the center of gravity. The area of a spanker sail, as the trapezium $ABCD$ (Fig. 27.), is found by dividing it into two triangles by the line AC; the sum of these two triangles ADC and ACB gives the area of the trapezium.

To find its center of gravity, each of its four sides is divided into two equal parts in E, F, G, H; from E a line EA is drawn, from F the line FC, which meet in I; in the same manner from G the line GC is drawn, from H the line HA, which cut each other in K; join KI. From E draw EB, and from H, HD, which meet in L; from F draw FB, and from G, GD, which meet in M; join LM, which meets KI in N. Then N will be the center of gravity of the trapezium $ABCD$.

(87.) Now suppose a Frigate to have 138 feet length from the stem to the stern-post, 35 feet and a half breadth; DF (Fig. 24.) or the height of the metacenter above the level of the water 5,93 feet; and the displacement 29000 cubic feet; then the moment of the sails computed from the plane of the load water-line, by the rule given in Art. 80, should be $\frac{35{,}5 \times 5{,}93 \times 29000}{(138)^{\frac{1}{3}}}$.

$$\text{Log of} \begin{cases} 35{,}5 = 1{,}5502284 \\ 5{,}93 = 0{,}7732110 \\ 29000 = 4{,}4623980 \\ \hline \quad\quad 6{,}7858374 \end{cases} \qquad \text{Log of} \begin{cases} 138 = 2{,}1398791 \\ 138^{\frac{1}{3}} = 0{,}7132930 \end{cases}$$

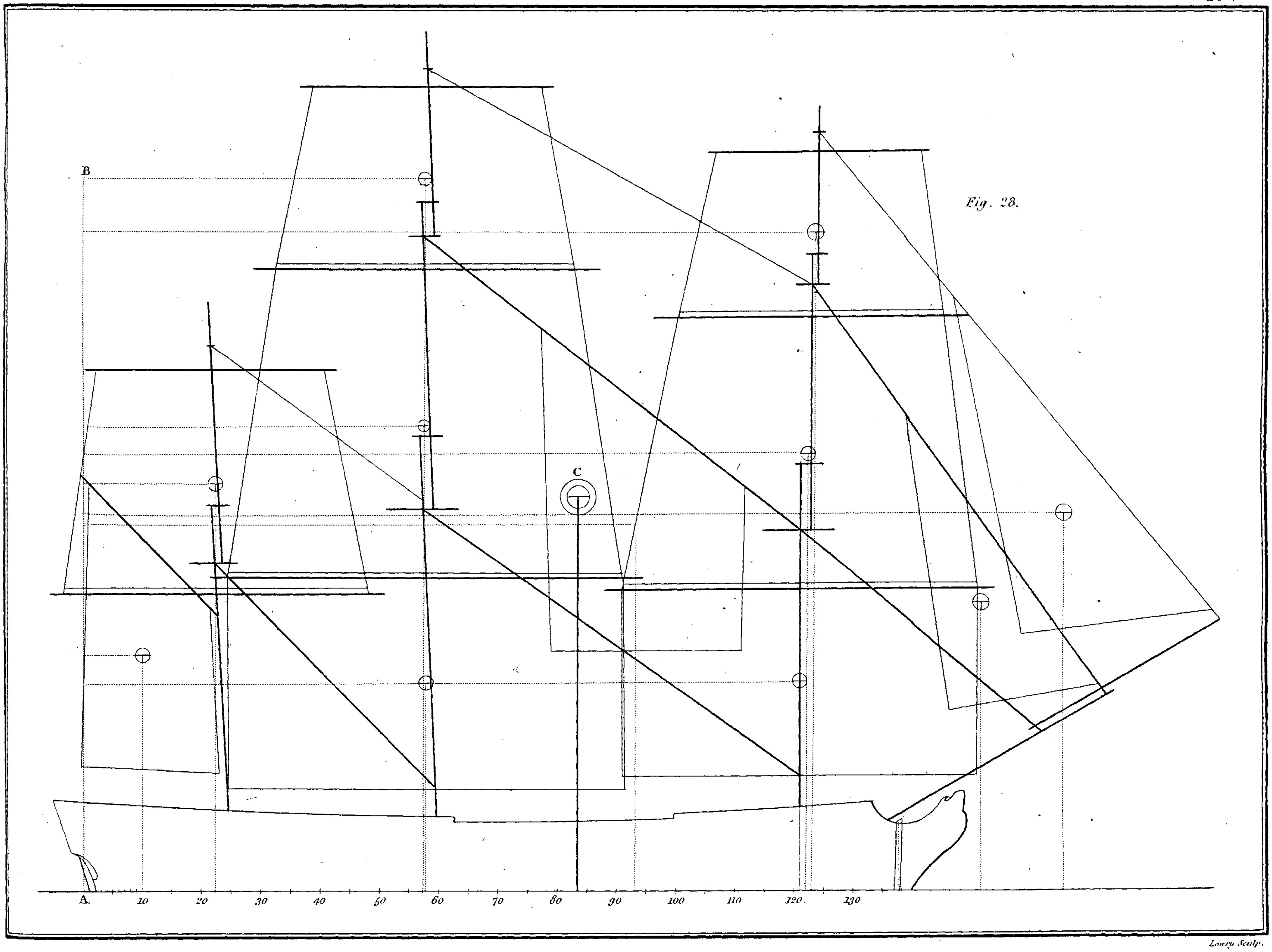
Thus the logarithm of $\frac{35,5 \times 5,93 \times 29000}{(138)^{\frac{1}{3}}} = 6,0725444$, of which the natural number is 1181842 = the moment of the sails, reckoning from the plane of the load water-line.

If we wish to proportion the sails of this frigate, so that their moment may be equal to the above moment, we shall not effect it except by several trials; that is, by drawing different plans of masts and yards, varying the ordinary proportion, so as to get different suits of sails.

The center of gravity of each sail is determined as it stands in Fig. 28. Having calculated the area of each sail, and taken the distance of its center of gravity, as well from the load water-line as from the line *AB*, these quantities are ranged in the following order.

Note. The jib, which is rigged at the top-gallant mast-head, ought to be rigged at the head of the top-mast.

Names of the sails.	Area of the sails.	Center of gravity of the sails from the water-line.	The moment of the sails, from the water-line.	Center of gravity of the sails, from the line *AB*.	Moment of the sails from the line *AB*.
Mizen top-sail	814	41,2	33536,8	10,0	8140
Mizen top-gallant sail	1662	70,0	116340,0	22,0	36564
Main sail	2440	35,7	87108,0	57,5	140300
Main top-sail	3028	80,0	242240,0	57,0	172596
Main top-gallant sail .	1314	122,1	160439,4	57,0	74898
Main top-mast stay-sail	1416	63,5	89916,0	92,7	131263
Fore sail	1890	35,9	67851,0	120,6	227934
Fore top-sail	2428	74,7	181371,6	121,4	294759
Fore top-gallant sail . .	1075	112,4	120830,0	122,8	132010
Jib	644	49,3	31749,2	151,2	97373
Fore top-mast stay-sail	870	58,0	50460,0	164,7	143289
	17581		$\frac{1181842,0}{17581} = 67,22$		$\frac{1459126}{17581} = 83$



Lowry Sculp.

By a little adjusting of the rigging draught, we are able to find the moment just mentioned, so that the common center of gravity of the sails *C* may be 67,22 feet above the load water-line; and 83 feet before the line *AB*, or nearly $\frac{1}{10}$ of the length from the stem to the stern-post before the center of gravity of the ship. But that we may be able to see, whether or not this common center of gravity is well placed in regard to the mean direction of the resistance of the water (Art. 73.), it is necessary to give a method for finding this mean direction.

(88.) To investigate the mean direction of the resistance of the water, the plan is used upon which we have calculated the direct resistance.

We shewed in Art. 72. the method of obtaining all the vertical forces Their values are taken upon a scale, and arranged in the order of the following table.

The distance between the water-lines = 2,25 feet, one-third of which = 0,75, and two-thirds = 1,50. Also the distance between the sections = 4,95, one-third of which = 1,65 and two thirds = 3,3.

The vertical forces before ϕ *for the Privateer* (Fig. 47, 48, 49.).

Between the frames π *and* β (Fig. 20.).

Between the lines of float.	Triangles. No.	Triangles. Base.	Vertical forces.	Force × by the base.	Triangles. No.	Triangles. Base.	Vertical forces.	Force × by the base.
1 & 2	24	3,40	0,88	2,99	23	4,25	1,40	5,95
2 & 3	24	2,64	0,65	1,71	23	3,40	1,15	3,91
3 & 4	24	1,73	0,38	0,65	23	2,64	0,87	2,29
4 & 5	24	0,81			23	1,73	0,58	1,00
5 & 6					23	0,81		
6 & 7								
				5,35				13,15
× by ½ height of trian.				$1+\frac{1}{8}$				$1+\frac{1}{8}$
Sum of the effects =				6,02				=14,79

Between the frames β *and Z.*

Between the lines of float.	Triangles. No.	Triangles. Base.	Vertical forces.	Force × by the base.	Triangles. No.	Triangles. Base.	Vertical forces.	Force × by the base.
1 & 2	22	3,37	1,25	4,21	21	3,74	1,42	5,31
2 & 3	22	2,72	1,02	2,77	21	3,37	1,34	4,51
3 & 4	22	2,07	0,75	1,55	21	2,72	1,09	2,96
4 & 5	22	1,50	0,49	0,73	21	2,07	0,81	1,67
5 & 6	22	1,00	0,26	0,26	21	1,50	0,56	0,84
6 & 7	22	0,30	0,12	0,03	21	1,00	0,31	0,31
				9,55				15,60
				$1+\frac{1}{8}$				$1+\frac{1}{8}$
				=10,74				=17,55

Between the frames Z and X.

Between the lines of float.	Triangles No.	Triangles Base.	Vertical forces.	Force × by the base.	Triangles. No.	Triangles. Base.	Vertical forces.	Force × by the base.
1 & 2	20	2,79	1,18	3,29	19	2,83	1,22	3,45
2 & 3	20	2,47	1,03	2,54	19	2,79	1,21	3,37
3 & 4	20	1,92	0,88	1,68	19	2,47	1,05	2,59
4 & 5	20	1,46	0,64	0,93	19	1,92	0,83	1,59
5 & 6	20	0,97	0,38	0,36	19	1,46	0,63	0,91
6 & 7	20	0,50	0,18	0,09	19	0,97	0,36	0,34
				8,89				12,25
× by ½ height of trian.				$1+\frac{1}{8}$				$1+\frac{1}{8}$
Sum of the effects =				10,00				=13,78

Between the frames X and U.

Between the lines of float.	Triangles. No.	Triangles. Base.	Vertical forces.	Force × by the base.	Triangles. No.	Triangles. Base.	Vertical forces.	Force × by the base.
1 & 2	18	2,39	1,02	2,43	17	2,12	0,95	2,01
2 & 3	18	2,47	1,06	2,61	17	2,39	1,06	2,53
3 & 4	18	2,12	0,98	2,07	17	2,47	1,06	2,61
4 & 5	18	1,50	0,70	1,05	17	2,12	0,93	1,97
5 & 6	18	0,90	0,42	0,37	17	1,50	0,69	1,03
6 & 7	18	0,40	0,20	0,08	17	0,90	0,39	0,35
				8,61				10,50
				$1+\frac{1}{8}$				$1+\frac{1}{8}$
				=9,69				=11,81

Between the frames U and S.

Between the lines of float.	Triangles. No.	Triangles. Base.	Vertical forces.	Force × by the base.	Triangles. No.	Triangles. Base.	Vertical forces.	Force × by the base.
1 & 2	16	1,90	0,81	0,53	15	1,62	0,75	1,21
2 & 3	16	2,12	0,89	1,88	15	1,90	0,90	1,71
3 & 4	16	2,01	0,89	1,78	15	2,12	0,94	1,99
4 & 5	16	1,58	0,73	1,15	15	2,01	0,88	1,76
5 & 6	16	0,93	0,48	0,44	15	1,58	0,70	1,10
6 & 7	16	0,35	0,20	0,07	15	0,90	0,40	0,37
				6,85				8,14
× by ½ height of trian.				$1+\frac{1}{8}$				$1+\frac{1}{8}$
Sum of the effects =				7,71				=9,16

Between the frames S and Q.

Between the lines of float.	Triangles. No.	Triangles. Base.	Vertical forces.	Force × by the base.	Triangles. No.	Triangles. Base.	Vertical forces.	Force × by the base.
1 & 2	14	1,39	0,58	0,80	13	1,07	0,47	0,50
2 & 3	14	1,73	0,78	1,34	13	1,39	0,68	0,94
3 & 4	14	1,84	0,81	1,49	13	1,73	0,83	1,43
4 & 5	14	1,58	0,67	1,05	13	1,84	0,82	1,50
5 & 6	14	0,97	0,46	0,44	13	1,58	0,64	1,01
6 & 7	14	0,40	0,22	0,08	13	1,97	0,44	0,42
				5,20				5,80
				$1+\frac{1}{8}$				$1+\frac{1}{8}$
				=5,85				=6,52

Between the frames Q. and O.

Between the lines of float.	Triangles.		Vertical forces.	Force × by the base.	Triangles.		Vertical forces.	Force × by the base.
	No.	Base.			No.	Base.		
1 & 2	12	1,06	0,41	0,43	11	0,72	0,28	0,20
2 & 3	12	1,34	0,60	0,80	11	1,06	0,51	0,54
3 & 4	12	1,61	0,71	1,14	11	1,34	0,66	0,88
4 & 5	12	1,64	0,70	1,14	11	1,61	0,73	1,17
5 & 6	12	1,10	0,50	0,55	11	1,64	0,71	1,16
6 & 7	12	0,40	0,22	0,08	11	1,10	0,43	0,43
				4,14				4,38
× by ½ height of trian.				$1+\frac{1}{8}$				$1+\frac{1}{8}$
Sum of the effects. =				4,66				=4,93

Between the frames O and M.

Between the lines of float.	Triangles.		Vertical forces.	Force × by the base.	Triangles.		Vertical forces.	Force × by the base.
	No.	Base.			No.	Base.		
1 & 2	10	0,72	0,23	0,16	9	0,53	0,20	0,10
2 & 3	10	1,02	0,45	0,45	9	0,72	0,29	0,20
3 & 4	10	1,29	0,56	0,72	9	1,02	0,50	0,51
4 & 5	10	1,40	0,59	0,82	9	1,29	0,59	0,76
5 & 6	10	1,13	0,44	0,49	9	1,40	0,59	0,82
6 & 7	10	0,40	0,20	0,08	9	1,13	0,41	0,46
				2,72				2,85
				$1+\frac{1}{8}$				$1+\frac{1}{8}$
				=3,06				=3,20

Between the frames M and K.

Between the lines of float.	Triangles.		Vertical forces.	Force × by the base.	Triangles.		Vertical forces.	Force × by the base.
	No.	Base.			No.	Base.		
1 & 2	8	0,48	0,17	0,08	7	0,33	0,13	0,04
2 & 3	8	0,67	0,26	0,17	7	0,48	0,20	0,09
3 & 4	8	0,96	0,42	0,40	7	0,67	0,35	0,23
4 & 5	8	1,13	0,47	0,53	7	0,96	0,47	0,45
5 & 6	8	1,08	0,37	0,39	7	1,13	0,51	0,57
6 & 7	8	0,40	0,18	0,07	7	1,08	0,39	0,42
				1,64				1,80
× by ½ height of trian.				$1+\frac{1}{8}$				$1+\frac{1}{8}$
Sum of the effects. =				1,84				=2,02

Between the frames K and H.

Between the lines of float.	Triangles.		Vertical forces.	Force × by the base.	Triangles.		Vertical forces.	Force × the by base.
	No	Base.			No.	Base.		
1 & 2	6	0,31	0,10	0,03	5	0,25	0,07	0,01
2 & 3	6	0,47	0,19	0,08	5	0,31	0,13	0,04
3 & 4	6	0,72	0,31	0,22	5	0,47	0,47	0,11
4 & 5	6	0,93	0,38	0,35	5	0,72	0,72	0,25
5 & 6	6	0,90	0,32	0,28	5	0,93	0,93	0,39
6 & 7	6	0,39	0,16	0,06	5	0,90	0,90	0,27
				1,02				1,07
				$1+\frac{1}{8}$				$1+\frac{1}{8}$
				=1,14				1,20

Between the frames H and F.

Between the lines of float.	Triangles.		Vertical forces.	Force × by the base.	Triangles.		Vertical forces.	Force × by the base.
	No.	Base.			No.	Base.		
1 & 2	4	0,20	0,08	0,01	3	0,14	0,04	0,00
2 & 3	4	0,30	0,13	0,03	3	0,20	0,08	0,01
3 & 4	4	0,46	0,22	0,10	3	0,30	0,15	0,04
4 & 5	4	0,73	0,31	0,22	3	0,46	0,23	0,10
5 & 6	4	0,82	0,27	0,22	3	0,73	0,35	0,25
6 & 7	4	0,35	0,14	0,04	3	0,82	0,28	0,22
				0,62				0,62
× by ½ height of trian.				$1+\frac{1}{8}$				$1+\frac{1}{8}$
Sum of the effects =				0,70				=0,70

Between the frames F and D.

Between the lines of float.	Triangles.		Vertical forces.	Force × by the base.	Triangles.		Vertical forces.	Force × by the base.
	No.	Base.			No.	Base.		
1 & 2	2	0,15	0,03	0,00	1	0,10	0,02	0,00
2 & 3	2	0,22	0,08	0,01	1	0,15	0,06	0,01
3 & 4	2	0,34	0,17	0,05	1	0,22	0,12	0,02
4 & 5	2	0,55	0,20	0,11	1	0,34	0,16	0,05
5 & 6	2	0,79	0,27	0,21	1	0,55	0,27	0,14
6 & 7	2	0,28	0,10	0,02	1	0,79	0,26	0,20
				0,40				0,42
				$1+\frac{1}{8}$				$1+\frac{1}{8}$
				=0,45				=0,47

RECAPITULATION

of the vertical forces, and of the moments produced by these forces multiplied by their distance from the perpendicular of the stem.

Between the frames.	N°. of the triangles.	Sums of the vertical effect on all the triangles of the same number.	Distance of the center of gravity of the triangles from the perpendicular of the stem.	Moments of forces from the perpendicular of the stem.
π and β	24	6,02	5,65	34,01
	23	14,79	7,30	107,97
β and Z	22	10,74	10,60	113,84
	21	17,55	12,25	214,99
Z and X	20	10,00	15,55	155,50
	19	13,78	17,20	237,02
X and U	18	9,69	20,50	198,64
	17	11,81	22,15	261,59
U and S	16	7,71	25,45	196,22
	15	9,16	27,10	248,24
S and Q	14	5,85	30,40	177,84
	13	6,52	32,05	208,97
Q and O	12	4,66	35,35	164,73
	11	4,93	37,00	182,41
O and M	10	3,06	40,30	123,32
	9	3,20	41,95	134,24
M and K	8	1,84	45,25	83,26
	7	2,02	46,90	94,74
K and H	6	1,14	50,20	57,23
	5	1,20	51,85	62,22
H and F	4	0,70	55,15	38,60
	3	0,70	56,80	39,76
F and D	2	0,45	60,10	27,04
	1	0,47	61,75	29,02
Sum of the effects =		147,99	Sum mom[ts]. =	3191,40

Between the perpendicular of the stem and the frame π.						
Between the water-lines.	N°. of the tri-angles.	Vertical forces.	Base.	Effects.	Center of gravity from perpen-dicular at the stem.	Moments.
1st and 2d	25	0,98	2,02	1,97	3,33	6,56
1st and 2d	26	0,48	1,08	0,51	2,64	1,34
2d and 3d	25	0,78	1,08	0,84	3,62	3,04
Between the perpendicular of the stem and the frame β.						
4th and 5th	23	0,58	1,72	0,99	7,55	7,47
4th and 5th	24	0,28	0,80	0,22	6,07	1,33
5th and 6th	23	0,39	0,80	0,31	8,00	2,48

	4,84		22,22
$\times$ by $\frac{1}{2}$ the height of the triangle......	$1+\frac{1}{8}$		$1+\frac{1}{8}$
Sum of the effects..................	5,44	moments =	25,00
Add the sums above	147,99		3191,40
The vertical effect of the stem.........	8,10	moments =	48,60
The whole vertical effect before ϕ ..	=161,53	moments =	3265,00

Therefore $\frac{3265,00}{161,53} = 20,21$ = the distance of the center of gravity from the perpendicular of the stem.

(89.) It remains, in order to determine the mean direction, to know the quantity of the resultant of the direct resistance, and the distance at which the resultant passes from the plane of the load water-line. This direct resistance is found in the tables of Art. 72. and we may observe once for all, that the resultant of each particular force, as well direct as lateral and vertical, passes always through the center of gravity of the triangle.

These forces and the distance of their center of gravity below the plane of the load water-line, are arranged in the order of the following Table; and multiplying one by the other, they give the moments.

Between the water-lines.	Direct forces.	Center of gravity of the direct forces below the water-lines.	Moments.
1st and 2d	19,47	0,75	14,60
	17,01	1,50	25,51
2d and 3d	14,78	3,00	44,34
	10,56	3,75	39,60
3d and 4th	9,38	5,25	49,24
	6,51	6,00	39,06
4th and 5th	5,91	7,50	44,32
	3,56	8,25	29,37
5th and 6th	2,92	9,75	28,47
	1,01	10,50	10,60
6th and 7th	0,83	12,00	9,96
	0,12	12,75	1,53
Stem	13,16	4,40	57,97
Direct resistance =	105,22	moments =	394,57

Then $\frac{394,57}{105,22} = 3,75$ = the distance of the center of gravity of the direct forces, from the plane of the load water-line.

(90.) We find by the same process, that the vertical effect of the water on the part behind the frame $\phi = 134$, and that its center of gravity is at a perpendicular distance from the sternpost of 24,4 feet; that the direct resistance on the after part = 76,39, and that the distance of its center of gravity from the load water-line = 3,62 feet.

By Art. 66. the effects of the water on the fore-part must be multiplied by 6, and those on the aft-part by 7. It amounts to the same, to let the value of the effects on the fore-part remain, and to increase those on the aft-part by one-sixth; these effects will have among themselves the following proportions.

$$\textit{Afore the frame } \phi \ldots \left\{\begin{array}{l}\text{Direct effect} = 105{,}22.\\ \text{Vertical effect} = 161{,}53.\end{array}\right.$$

$$\textit{Abaft the frame } \phi \ldots \left\{\begin{array}{l}\text{Direct effect} = 89{,}13.\\ \text{Vertical effect} = 156{,}30.\end{array}\right.$$

Take on the plan of the ship (Fig. 48.) the point A at the perpendicular distance of 20,21 feet from the stem perpendicular, and 3,75 feet from the load water-line. From this point draw the lines AC, AD the one parallel, the other perpendicular to the water-line; make the lines AC, AD in the proportion of 105,22 to 161,53. Completing as usual the parallelogram $ADEC$, we shall have the mean direction of the water in the diagonal EA.

We find, by the same method, the mean direction abaft the frame ϕ. Producing these directions, and making the constructions explained in Article 74, we shall find that the center of gravity of the sails for this ship, when the wind is aft, should be at the height of 89,8 feet above the plane of the load water-line. This center is called the *point of sail.*

(91.) If we apply the same operation to the frigate, for which we have investigated the dimensions of the sails (Art. 87.), we shall see if the center of gravity of the sails be too high or too low.

But as this point of sail is only for the case when the wind is aft, it will not be necessary to introduce into the calculations more than the sails which are then set.

And since a great surface of canvass, as we observed in Article 74. does not give to the ship a velocity proportional to the area of canvass, when its center of gravity is situated above or below the point of sail, it follows that it is important to know these points for all ships (at least for ships of war and privateers), for the purpose of finding means, in making use of a certain quantity of sail, to approximate as much as possible their center of gravity to the point of sail.

CHAP. VI.

ON THE DIMENSIONS AND DIFFERENT FORMS OF SHIPS.

(92.) By the dimensions and forms of ships we understand their length, breadth, draught of water; the capacity, more or less, of the bottom, and the distribution of that capacity.

(93.) If it be only required to construct a vessel to go ahead by means of oars, there is no difficulty in determining its form; the plane of resistance must be rendered as small as possible, regard being had to the lading it is to carry. But if we have to construct a vessel, which with a certain lading is to go ahead by means of sails, not only with a favourable wind, but to get to windward when the wind is contrary, we shall find that the form for effecting this, will become much more difficult to determine than one would believe. However, we propose to examine the proportions and form, which would produce the most advantageous rate of sailing by the wind, without attending to any other qualities in the ship.

(94.) In order that a ship may sail well by the wind, it is necessary not only to make the plane of resistance as small as possible, but also to give it a great moment of stability, that it may carry a press of sail without too great an inclination.

Suppose then two bodies of different forms. Let one of these bodies (Fig. 29.) be composed of two triangular prisms AGE, GCE, of which the uppermost surface is taken for the load water-line, being as to its figure a rhomboid; let the other body be formed of two wedges *ABGE, CGED* (Fig. 30.) and have for its upper surface the rectangle *ABCD,* which is taken also for the load water-line; these two bodies being moved in the water, the fluid will necessarily escape by the shortest way (NOTE 39.); thus in the first case (Fig. 29.) the water will direct its course along the side, and in the second (Fig. 30.) it will pass under the body.

Suppose these bodies impelled in the water by means of a quantity of sail proportional to the stability. Let their half-length $= L$, their half-breadth $= B$, and their draught of water $= D$; whence the moment of stability (Fig. 29.) will be $\frac{B^3 \times L}{4}$ (NOTE. 40.) and the plane of resistance $= \frac{B^3 \times D}{L^2 + B^2}$. But as the breadth increases, the plane of resistance (NOTE 41.) will increase in the same proportion as the moment of stability; consequently, a body of such a figure could not acquire a great velocity by means of the sails, and would sail badly close to the wind.

The moment of stability of the body (Fig. 30.) will be $B^3 L$, and the the plane of resistance $= \frac{D^3 B}{L^2 + D^2}$. As the moment of stability increases in a triplicate ratio of the breadth, whilst the plane of resistance increases only in the simple proportion of the said breadth, this form is the most advantageous for sailing close to the wind. Now this body being impelled in the water, the square of its velocity will be in the direct ratio of the area of the sails, and in the inverse ratio of the plane of resistance. But the moment of stability is as that of the sails, and the moment of the sails is as the area of the sails multiplied by the height of a certain point, which height is also proportional to the height of the sails; consequently, the area of the sails is as the moment of stability raised to the power of $\frac{2}{3}$, that is to say, as $(B^3 L)^{\frac{2}{3}}$ (NOTE 42.). The area of the sails therefore divided by the plane of resistance $= \frac{(B^3 L)^{\frac{2}{3}}}{B \times D^3} \times (L^2 + D^2) =$

$B \times \left(\frac{L^{\frac{8}{3}}}{D^3} + \frac{L^{\frac{2}{3}}}{D}\right)$; and hence the velocity will be as $B^{\frac{1}{2}} \times \left(\frac{L^{\frac{4}{3}}}{D^{\frac{3}{2}}} + \frac{L^{\frac{1}{3}}}{D^{\frac{1}{2}}}\right)$.

But $L^{\frac{1}{3}}$ is very small compared with $L^{\frac{4}{3}}$, so that we may neglect the last term of the expression, and the velocity may be considered as proportional to $\frac{B^{\frac{1}{2}} \times L^{\frac{4}{3}}}{D^{\frac{3}{2}}}$.

(95.) From all this we see, that when the area of the load water-line is given, a floating body or a ship, to sail well by the wind, should have great length according to its breadth, and the least draught of water possible.

But if the area of the load water-line be not given, but only its length, in that case it is necessary to give great breadth, because the velocity increases as the square root of the breadth; and if the breadth be given, there should be great length, since this dimension is raised to the power $\frac{4}{3}$, the draught of water being given. But if, from a certain determined length or breadth, we have the choice of augmenting one of these dimensions, it is more advantageous, with respect to the velocity, to augment the length than the breadth.

Thus then we cannot assign any constant proportion between the length, breadth, and draught of water.

(96.) From the above expression for the velocity we see that a large ship should sail better than a small one, which is similar to it, but that nothing farther is required than to diminish the draught of water to render the small one as good a sailer as the great one. For if the velocity of the large one $= \frac{B^{\frac{1}{2}} L^{\frac{4}{3}}}{D^{\frac{3}{2}}} = 12$; if the length, breadth and draught of water of the small one be l, b and d, the depth d must be $=$

$\left(\frac{b^{\frac{1}{2}}l^{\frac{4}{3}}}{12}\right)^{\frac{2}{3}}$ in order that the two ships, built of the same form, may sail equally well.

The depth we speak of is not reckoned from the keel, but is the distance between the load water-line and the flat of the bilge. As the distance AB (Fig. 31.), in pursuance of the object in view, gives a small draught of water, which would occasion leeway, to obviate this inconvenience, we may make the addition DEF below, so that the keel F may still reach a certain depth, and by this means will oppose the leeway in oblique courses; or, for small ships we may make use of pieces called leeboards, which are employed in smacks, &c.

(97.) This form would be advantageous with respect to the direction of the water and the filling of the body, at the water's surface, in sailing close to the wind when the sea is smooth. But since a ship, cannot without wind, go ahead by means of the sails, and since the wind raises the waves, it follows, that by giving to a ship ahead of such a form, it would experience, in sailing close to the wind, too great a shock from the waves, which shock would be directly opposed to the head. Its velocity would thereby be much retarded; on which account, instead of giving to the fore part of the load water-line the figure of a rectangle, it should be rounded off a little to a point. This would diminish, indeed, the moment of stability something, but the effect of the waves on it would be considerably less.

As to the after part, there would be no objection to its having a rectangular figure, in regard to the effect of the waves; but for the reasons, which we have seen in Art. 43., it is proper to make in it some alteration.

(98.) As we cannot conclude any thing from the last Articles concerning the proportions, which ought to take place between the length, breadth, and depth of the ship, and since its qualities depend greatly upon these proportions, it is necessary to enumerate those qualities, which are essential to a merchant ship; in order thence to determine the proportions most advantageous, and most likely to produce such or such qualities, which may be required.

A merchant ship ought:

1. To be able to carry a great lading in proportion to its size.
2. To sail well by the wind, in order to beat easily off a coast where it may be embayed, and also to come about well in a hollow sea.
3. To work with a crew small in number in proportion to its cargo.
4. To be able to sail with a small quantity of ballast.

To procure these advantages to a ship, it appears:

1. That to take a great lading with respect to its size, it ought to have great breadth and depth, in proportion to its length, and to be full in the bottom. Such a ship would also work with a small number of hands in proportion to its cargo. But it would neither sail well nor beat to wind-ward.

2. That to give the property of sailing and beating to windward, to the end that it might beat off a lee shore, as well as come about well in a hollow sea, the ship must necessarily have a considerable moment of stability in proportion to the plane of resistance, that it may be able to carry a press of sail, notwithstanding a strong wind; with this view it is necessary to give to the ship in question, great breadth in proportion to its length; to fill it much towards the load water-line, curtailing it in the bottom. Such a ship would require a numerous crew because of the largeness of the sails, and the weight of its anchors.

3. That if it be required to navigate a ship with few men, in proportion to the lading, it should have a small surface of sails, and anchors of small weight. For this purpose it should have little breadth in proportion to its length.

It would also be enabled to carry a great lading, in proportion to its equipment of men, by giving it great fulness in its bottom; but such a ship would sail badly close to the wind, and would come about with difficulty in a hollow sea.

4. That to enable a ship to sail with a small quantity of ballast, it is necessary to fill the body between wind and water, when it has the ballast in; it should be large and little elevated above the water. A ship of this kind would carry a sufficient lading in proportion to its size, but it would ply badly when laden, especially if it were a large ship; without giving it a considerable quantity of sail, which would render it necessary to have a great number of men.

(99.) By this it is again proved, that we can conclude nothing concerning the length, breadth, and depth of ships, since different qualities require conditions diametrically opposite to each other. We may succeed in uniting two of these advantages by a certain form and by certain proportions given to ships, but it is impossible to combine all four in an eminent degree. It is not possible to gain on one side without losing on another.

Wherefore, for a merchant ship, it is necessary to combine these qualities, so that it may have the most possible of each. That is to say, that the expression representing the velocity and quantity of lading divided by the number of the crew and quantity of ballast, may be a *maximum*.

Again, however, as certain commercial speculations require one quality in preference to another; the nature of this commerce; the latitudes in which it is necessary to navigate; the ports for anchorage; all these must be considered in determining which of these qualities ought to prevail, without altering in any respect the size of the ship.

(100.) We must again observe that the qualities of similar ships vary in a different proportion from what a consideration of their size would give.

If the breadth be represented by the variable quantity B, the burden of the ship will vary in the proportion of B^3; the velocity of sailing $\frac{B^{\frac{1}{2}} \times L^{\frac{4}{3}}}{D^{\frac{3}{2}}}$ will vary as $B^{\frac{1}{3}}$, and the number of the crew, which is proportional to the area of the sails $B^2 L^{\frac{2}{3}}$, will vary in the proportion of $B^{\frac{8}{3}}$. So that, supposing two ships to be similar, the one of 320 lasts, and the other an eighth of this capacity or 40 lasts, whilst the larger will sail ten knots, the small one will only sail eight; and if the great one sail with a crew of twenty-four men, the small one will require four. According to the capacities of the two ships, it ought to be navigable by three men. Hence we see, that *in making small ships similar to large ones, the former will sail worse, and will require a more numerous crew in proportion to their capacities than the large ones.*

(101.) We have seen above, that we may obtain for a small ship a property of sailing equal to that of a large one, by increasing its moment of stability, and diminishing the plane of resistance; but as then it would have a greater quantity of sails, it would be necessary to increase the number of the crew.

(102.) It is possible to render a small ship navigable by a crew proportionate to its capacity, but it cannot be done without diminishing the quantity of canvass, and then the vessel will sail worse. One may remedy this fault to a certain point, by giving it less breadth; but we have seen that this would not be without inconvenience; so that upon the whole, we find that it is necessary to prefer, in small ships, the property of sailing well, to having it in our power to economise in the number of the crew.

(103.) The velocity being in proportion to $\frac{B^{\frac{1}{2}} L^{\frac{4}{3}}}{D^{\frac{3}{2}}}$, it increases as the depth decreases, supposing at the same time the length and breadth to increase. The object is attained more easily by adding to the length, but for the greatest safety of the navigation, in order that the ship overtaken by a squall may come to the wind, and that it may come about easily in a heavy sea, it is more convenient to increase its breadth, whence the metacenter will be more elevated; the sails may then have a greater surface; but once again, the ship would require a more numerous crew.

(104.) We see then, that *great and small ships cannot, with the same form, sail with the same security,* and that we cannot avoid the inconvenience of being obliged to have a more numerous crew in proportion in small ships; as in the place of four men, six, &c.

So that small ships cannot have the same advantages as large ones, when it is required to employ them in the same trade.

(105.) As small ships lose in the quality of sailing, by being of a form similar to that of large ones, also large ones would gain in this respect by being shaped like small ones; we may thence conclude that it is proper to give to large ships the same form which small ones have; since thereby they would gain in the quality of sailing. But for merchant ships, where it is so much the more necessary to give great capacities in the water, as they are the more large, and as they seldom want a superior quality of sailing, provided they are sufficiently stiff upon a wind not to be embayed on a lee shore; considering besides, that these ships would lose the advantage of sailing with a small crew, and moreover, that a large ship costs more in its construction in proportion than a small one: for this kind of ships, I say, it is necessary to try to combine qualities the most advantageous to the interest of the owner.

(106.) All these inquiries do not bring us to the determination of the proportion to be given between the length, breadth, and depth of the ships, and we see that theory alone is not sufficient for this purpose: it becomes necessary therefore to introduce practice, and to see by several trials and various experiments, in what manner different ships answer in different cases. Then we may, by means of the above expressions, give to large or small ships the qualities which we wish, and carry them to a certain degree with relation to those of a known ship.

The table N°. 1. at the end of this book, according to which we may regulate all the proportions of merchant ships from the largest, as those engaged in the India trade, to the smallest, is founded on experience, and may serve as a guide in preparing the draught of a ship of any required tonnage.

But as it is not possible to form a ship, which combines in a certain degree all the qualities which may be wished, for this reason we have given in the table four species of ships.

(107.) In the construction of the first kind, under the denomination of *frigates*, it is to be considered, that they are to navigate in seas where hostilities are to be apprehended; which renders it necessary that they should carry a certain quantity of artillery, and at the same time sail well; and since the service of artillery requires a certain number of men, we may give to the ship a greater quantity of sail. With cannon, a ship has great weight above the water; besides it has to carry a greater quantity of sail; to have sufficient stability, it ought therefore to have its metacenter of a proper height above the load water-line. On which account it should have great length and breadth in proportion to the capacity of the hull.

(108.) The third kind, under the denomination of *barks* or *cats*, have few or no guns; they are built solely for trade; and their object is to carry the greatest possible lading, and sail with the smallest possible number of men. It is necessary that they possess, as far as it is practicable, the qualities which have been the subject of the above Articles.

(109.) The second species, under the denominations of *heck-boats or pinks,* is that of vessels, which in regard to qualities, preserve a mean between the first and the third.

(110.) The fourth species, under the denomination of *flat-floored vessels,* have the same qualities with the third; but not having so great a draught of water when laden they want less ballast.

(111.) It will be more plainly seen by the tables and plans contained in my book of plates, what difference there is between these three species of ships.

If we find it necessary to carry a certain quality to a greater degree than the proportions of the tables give, this alteration may be effected according to the principles laid down; but it must not be forgotten that we cannot improve one quality but at the expence of another. The table is so plain, that for its complete application, it only requires an example. Thus let there be required the proportions and dimensions of a bark of 200 lasts.

By a last is meant 18 skiponds iron weight; the skipond iron weight = 320 pounds; so that a last = 5760 pounds. A cubic foot of sea-water weighs 63 pounds (NOTE 43.); hence a last is nearly equal to 91 cubic feet of sea-water; so that 200 lasts = 18200 cubic feet of sea-water.

Logarithms.

$P = 18200 = 4{,}2600714$ (Note 44.)

$P^{\frac{22}{21}} = D = 4{,}4676938 = 29350$

$52 = 1{,}7160033$

$3)\overline{6{,}1836971}$

$x = 2{,}0612323 = 115{,}14$

4

$5)\overline{8{,}2449292}$

$x^{\frac{4}{5}} = 1{,}6489858$

$1{,}476 = 0{,}1690864$

$z = 1{,}4798994 = 30{,}19$

$x = 2{,}0612323$

$0{,}0687077$

$x^{1-\frac{1}{30}} = 1{,}9925246$

$7{,}032 = 0{,}8470789$

$h = 1{,}1454457 = 13{,}978$

$x = 2{,}0612323$

$0{,}1030616$

$x^{1+\frac{1}{20}} = 2{,}1642939$

$1{,}76 = 0{,}2455127$

$D = 4{,}4676938$

$4{,}7132065$

$x^{1+\frac{1}{20}} = 2{,}1642939$

$\phi = 2{,}5489126 = 353{,}9$

$x = 2{,}0612323$

$x^{\frac{1}{2}} = 1{,}0306161$

$8{,}4 = 0{,}9242793$

$k = 0{,}1063368 = 1{,}277$

Logarithms.

$x = 2{,}0612332$

$2)\overline{4{,}1224646}$

$x^{\frac{2}{3}} = 1{,}3741548$

$18{,}8 = 1{,}2741578$

$d = 0{,}0999960 = 1{,}259$

$x^{1+\frac{1}{20}} = 2{,}1642939$

$z = 1{,}4798994$

$3{,}6441933$

$1{,}5 = 0{,}1760913$

$W = 3{,}4681020 = 2938$

$x^{\frac{23}{20}} = 2{,}3704171$

$43{,}2 = 1{,}6354837$

$V = 0{,}7349334 = 5{,}43$

$x^{\frac{11}{20}} = 1{,}1336777$

$2{,}147 = 0{,}3318320$

$S = 0{,}8018457 = 6{,}337$

$x^{\frac{11}{20}} = 1{,}1336777$

$30 = 1{,}4771213$

$30\, x^{\frac{11}{20}} = 2{,}6107990 = 408{,}1$

$x^{\frac{23}{20}} = 2{,}3704171 = 234{,}6$

$2{,}2392995 = 173{,}5$

$64 = 1{,}8061800$

$L = 0{,}4331195 = 2{,}711$

$x^{3} = 6{,}1836969$

$6{,}6168164$

$52 = 1{,}7160033$

$M = 4{,}9008131 = 79590$

(112.) Thus it appears that a bark of 200 lasts ought to have 29350 cubic feet of displacement to the outside of the timbers; 115,14 feet in length from the stem to the stern-post; 30,19 feet of breadth to the outside of the timbers; 13,98 feet measured at the frame ϕ, from the load water-line to the upper edge of the rabbet of the keel; the surface of the frame ϕ will be 353,9 square feet, the keel will have in depth from the upper edge of the rabbet 1,277 feet; there will be 1,259 difference of draught of water forward and aft; the surface of the load water-line will be 2938 square feet. The center of gravity of the displacement will be below the load water-line 5,43 feet; $\int \frac{\frac{2}{3} y^3 d\dot{x}}{D}$ or the distance of this center of gravity from the metacenter will be 6,337 feet; there will be between the metacenter and the common center of gravity of the ship and the lading, a distance of 2,711 feet; whence the moment of stability = 79590.

It is by the same rules that the proportions of trading ships in Tables N°. 2, 3, 4 and 5 are calculated.

(113.) To find immediately the properties of ships, proportioned according to table N°. 1, Figure 32 is constructed, where the numbers 20, 40, 60, &c. represent the length from the stem to the stern-post.

If *AB* be the load water-line for a bark, *CCB* is the locus of the center of gravity of displacement; *DDB* that of the metacenter; *EEB* that of the center of gravity of the ship and the lading. For a frigate, *FFB* is the locus of the center of gravity of the displacement; *GGB* that of the metacenter, *HHB* that of the ship with its lading. So that for a vessel of the form of a bark 80 feet long, the distance from the load water-line to the center of gravity of displacement = *LC*; the height of the metacenter above the load water-line = *LD*; this load water-line is above the center of gravity of the vessel with its lading by a quantity = *LE*.

(114.) But for a frigate, the distance of the center of gravity of the displacement below the water = LF, the height of the metacenter above the water = LG; the center of gravity of the ship and the lading is below the water by a quantity = LH. The line IIB determines the length the main-mast ought to have, so as to have the proper proportion according to the stability; that is to say, the length of the main-mast is as the distance of IIB from AB.

(115.) If there be given to large and small ships a form similar to that which is 110 feet in length, then the straight line MB will be the locus of the metacenter, and the other line KKB will determine the length of the main-mast, in the proportion required by the stability.

(116.) In determining the center of gravity of the ship and its lading, we have supposed the cargoes of ships to be similar; so that, if the bark of 80 feet in length has its center of gravity in E, the centers of gravity of other barks may be in the line EEB; in like manner, the centers of gravity of all frigates are in the line HHB.

(117.) The place of the midship bend has great influence on the form of the ship. When the draught of the ship is to be made, we are supposed to know its displacement, its length, breadth, and draught of water; with the place of its center of gravity. If the frame ϕ is carried too far forward, the part before will be too lean; if too far aft, it will be too full, and the contrary in the after part. This must be the case, in order that the center of gravity may remain fixed at a given point. Hence the corresponding areas of the transverse sections fore and aft the midship section would differ too much.

(118.) The place of the midship bend depends more or less on the capacity of the extremities of the ship. For if it be required to compose a body of two wedges joined at their bases, having given the place of the common center of gravity; and if, restrained to the same situation for the common center of gravity, we have to compose another body of the same length, but with two hemispheroids, the lengths of these spheroids will not have the same proportion to the whole length as those of the wedges; that is to say, the greatest breadths of these two bodies, will be at different distances from their extremities.

(119.) By calculating the areas of the sections of different kinds of ships, it is found that the areas for sharp frigates, follow as well aft as forward, the same law which the ordinates of a parabola do, that are parallel to the axis; the vertex of which parabola is at the greatest section; or else, that the said areas are in the same proportion as those of the sections of a spheroid.

(120.) Let $ADBI$ be the body of a ship, C the middle point of the length from the stem to the stern-post (FIG. 33.); E the center of gravity; F the place of the greatest section; G the center of gravity of the part before the greatest section; H the center of gravity of the part which is abaft it.

In the parabola $AG = \frac{5}{8}\ AF$ (NOTE 45.) and $FH = \frac{3}{8}\ FB$. Let $AB = a$, $FA = x$, and $CE = m$; then $FB = a - x$; the area of the spaces ADI, BDI, are in the proportion of x to $a - x$; so that $\frac{5}{8} x^2 + \left(x + \frac{3}{8}(a - x)\right) \times (a - x) = a \times \left(\frac{1}{2}\, a - m\right)$, whence $x = \frac{1}{2} a - 4m$; that is to say, the distance between the middle of the length of the ship and its greatest section, ought to be four times the distance between this middle point, and the center of gravity of the ship. In a ship fuller in its extremities, so that AG is equal to $\frac{7}{12}\ AF$, the distance of the greatest section from the middle will be $= 6m$. Should it be still fuller, so that AG is equal to $\frac{9}{16}\ AF$, the distance of the greatest section before the middle point will be $= 8m$.

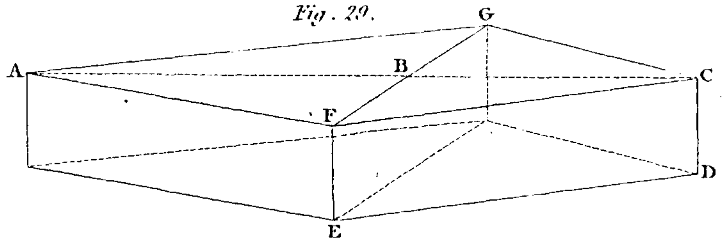


Fig. 29.

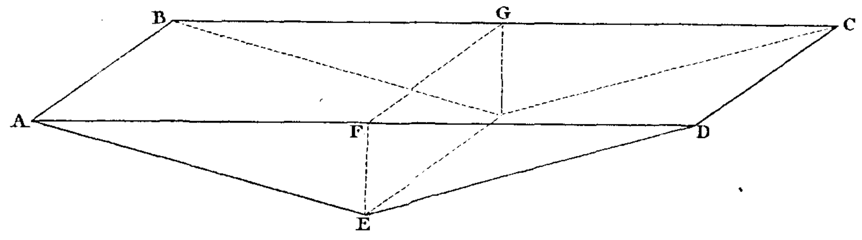


Fig. 30.

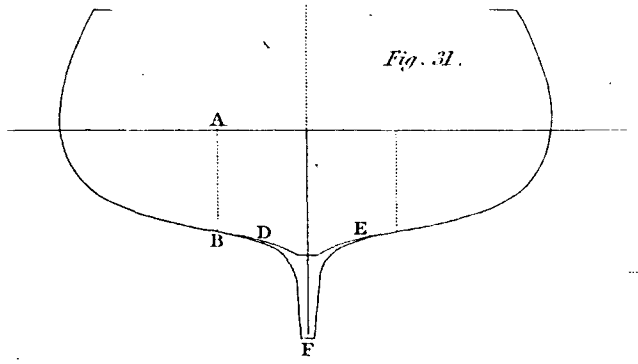


Fig. 31.

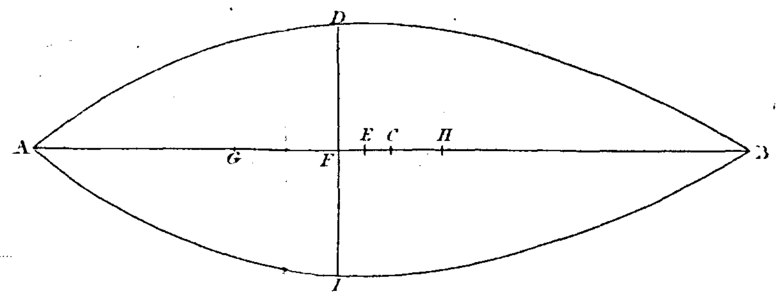


Fig. 33.

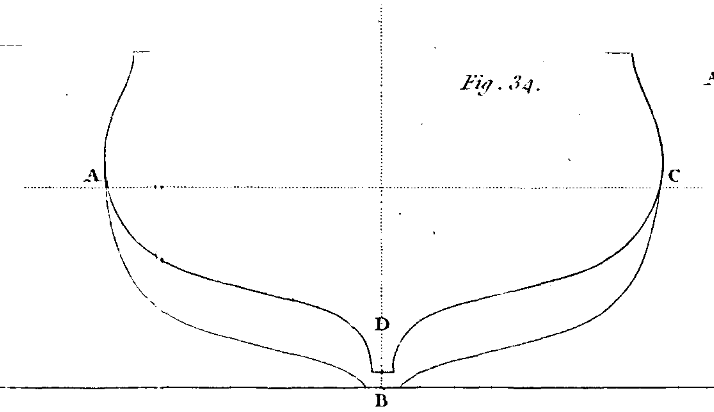


Fig. 34.

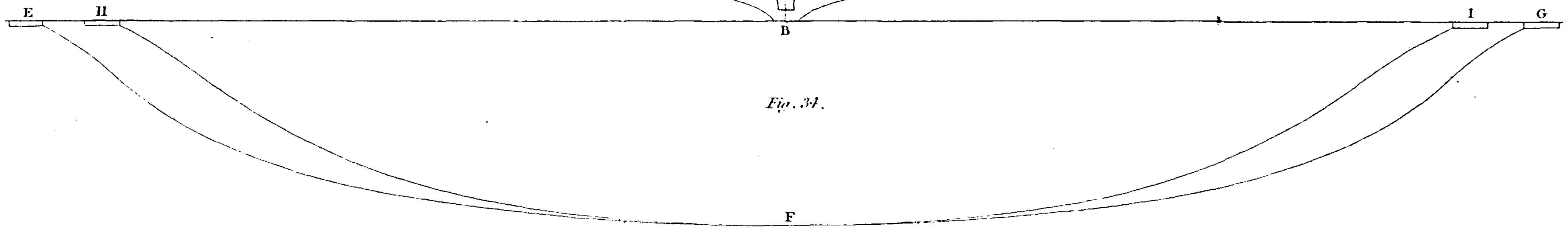


Fig. 34.

Lowry Sculp.

Pl. 9.

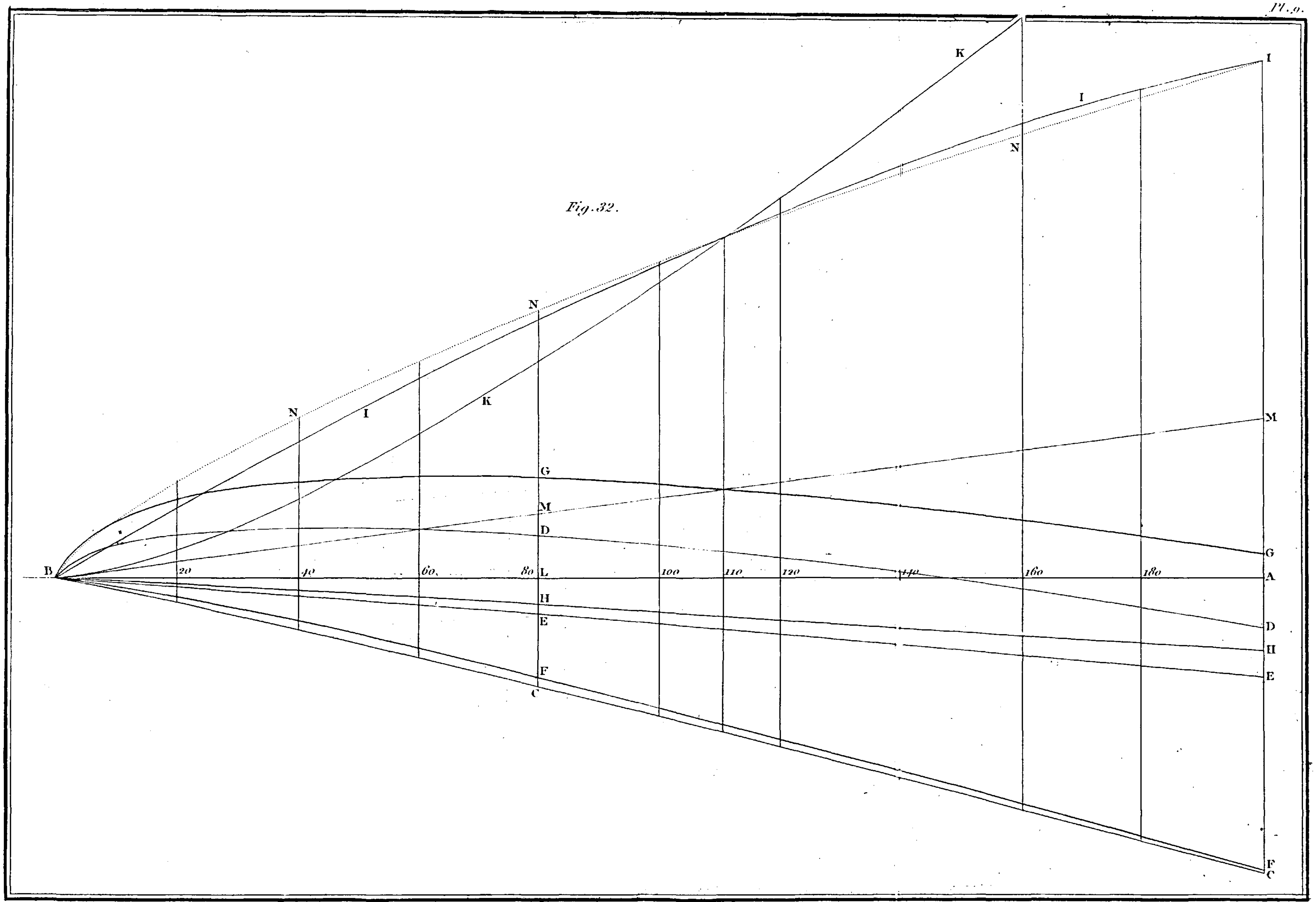


Fig. 32.

W. Lowry. Sculp.

Hence it is seen, that the greatest section should be before the middle of the length at a distance for sharp ships, as frigates, four times, and for merchant ships, which are very full, eight times the distance of the middle point of the length from the center of gravity of the ship.

(121.) This is the place of the midship bend, when the distances are taken on the load water-line; but if they are taken on the upper part of the keel, to which the frames are perpendicular, the midship bend ought to be a little before the greatest section, by a quantity which depends on the difference of draught of water forward and aft, and on the curvature of the ship at the middle.

This distance may be considered, in general, as equal to the difference of the draught of water.

The determination given here of the place of the greatest section, agrees with what we said concerning its situation with reference to the quality of sailing.

CHAP. VII.

ON THE PROPORTIONS OF PRIVATEERS.

(122.) PRIVATEERS are vessels, which an individual arms in time of war, by the authority of government, to take merchant ships and others belonging to the enemy.

In estimating the equipment of privateers, it must be considered, although some merchant ships are unable to make any resistance, that other large vessels may be encountered at sea, which are armed with guns. It is therefore necessary that privateers should be also well armed and have a sufficient crew, as well for action as for taking possession of their prizes.

For the attack of small ships the least privateers will do; but as these can only carry a few guns, the effect of which must be inconsiderable, their object should be to board; their principal force consists in the number of the crew.

If ships of superior force were not to be feared at sea, all sorts of ships might be employed in privateering, provided they were well armed with guns and men. But as a privateer may possibly meet with ships of the line, which are always of greater force, to escape in the chase, it should carry sail well, and sail fast in bad weather.

(123.) Independently of ships of the line, such a vessel is also liable to meet with frigates of war and privateers; with respect to privateers, as on each side they are armed by individuals, who have no other object but their own profit, it is not to be presumed that they will engage in a contest, from which nothing could result but mutual damage, without forwarding the views of their owners.

It is not so with frigates of war; their object is to attack and take, as much as possible, the enemy's privateers. If then a privateer cannot escape by its superiority of sailing (which since frigates are built to sail well is usually the case), it is necessary that it should be able to defend itself. The qualities of the vessel decide most frequently these combats. If the enemy be large and carry heavy guns, the privateer should also have them, and rather of a large caliber than in great number; which is more advantageous, not only on account of their greater effect, but also because there is a greater interval between the guns, so that the men at the oars and guns are not too much in the way of each other. These oars serve during the battle to present the privateer in an advantageous position, and in a calm to retire from a superior enemy. The privateer should sail well in all sorts of weather, and especially come about well; particularly, it should have a strong force in musketry, some small guns or swivels to fire case shot, and a good netting.

With respect to small privateers, as they are constantly forced to run from ships of war, their principal quality should consist in sailing well.

(124.) Besides the necessary qualities for action, the privateer ought to have a sufficient hold to carry stores, both of provisions and ammunition, for a cruise of a determined length, without sinking the vessel beyond a certain fixed depth.

Upon the whole it appears that the most advantageous qualities for a privateer are to sail fast, and to be sufficiently stiff to carry sail in bad weather.

We have seen in Art. 94. that to attain this object, it is necessary to give great length and breadth in proportion to the solidity of the immersed part. But as the construction of a ship of great length and of great breadth is very expensive, and requires a numerous crew to work it, it is not possible to carry these dimensions so far as might be wished;

but one must be content with less than the greatest perfection in the property of sailing well, since the cost of the ship, with the pay and subsistence of the men, which amount to a great sum, would exceed the advantages gained. And as in constructing a privateer, certain views are entertained, which are to be carried into effect by a certain quantity of artillery, it is therefore the artillery, upon which the proportions ought to be founded.

The displacement of a ship, of which the size is known, as well as the weights it is to carry, may be found without difficulty; but it is not possible by theory alone, without the assistance of practical knowledge, to determine the true value, which the moment of stability ought to have.

By the comparison of different species of ships, it has been found, that privateers in general, large as well as small, have the proper stability, when the distance of their metacenter from the center of gravity of the ship is 6 feet; and since according to Art. 38., this center of gravity should be in the load water-line, the metacenter should be 6 feet above the load water-line (Note 23.).

The length, breadth, depth, and displacement, ought therefore to be so proportioned with respect to the guns and their position, that the center of gravity of the ship may be in the load water-line, and the metacenter 6 feet above.

But since these proportions, &c. cannot be found but by the means of approximation, to facilitate the investigation, I shall give hereafter general formulæ, which according to the weight, nature, and situation of the artillery, express the proportions of all kinds of privateers, from the largest frigate to the smallest sloop. For large vessels I have considered particularly the force of the artillery; with respect to the least, I have paid less attention to the artillery, than to the number of the crew, in which its whole force consists.

All vessels constructed from these proportions will be good sailers; and the smallest will sail equally well with the largest.

(125.) As the weight of the artillery and stores, which enter into the calculation and use of these formulæ, is the principal foundation thereof, I have thought proper to give the following table.

Weight of Guns and Stores proper for Privateers.

POUNDERS.	Weight of a shot in provision weight.	Numbers by which the weight of the shot is multiplied to find that of the gun.	WEIGHT of the GUN. Provision weight.	Iron weight.	Numbers by which the weight of the gun is divided to find the weight of the carriage, &c.	Weight of the carriages, breechings and tackles.	Weight of the shot, powder, wadding equal the weight of 126 shot.	Weight of the guns, carriages, breechings, tackles, shot, powder, and wadding.	A	Weight of the guns, carriages, breechings, and tackles.	C
Caliber.	pounds.		pounds.	Skip.		pounds.	pounds.	pounds.	Cubic ft. of water 63lb. each foot.	pounds.	Cubic ft. of water 63lb. each foot.
24	29	215	6235	19,48	4,70	1326	3654	11215	178	7561	120
22	——	216	——	——	4,63	——	——	——	——	——	——
20	——	218	——	——	4,56	——	——	——	——	——	——
18	21,75	221	4807	15	4,49	1070	2740	8617	136,77	5877	93,3
16	——	225	——	——	4,42	——	——	——	——	——	——
14	——	230	——	——	4,35	——	——	——	——	——	——
12	14,5	236	3422	10,69	4,28	799	1827	6048	96	4221	67
10	——	243	——	——	4,21	——	——	——	——	——	——
8	$9\frac{2}{3}$	251	2426	7,58	4,14	586	1218	4230	67,1	3012	47,8
6	7,25	260	1885	5,89	4,07	463	914	3262	51,77	2348	37,3
4	4,833	270	1305	4,07	4,00	326	609	2240	35,55	1631	25,9
3	3,625	276	1000	3,12	3,93	254	457	1711	27,16	1254	20,0
Swiv. 3	3,625	70	254	0,80	——	60	400	714	11,33	314	5,0
Swiv. 2	2,416	70	169	0,53	——	42	266	377	7,57	211	3,35

In the above table, the weight of the gun is proportioned to the weight of the shot; and in order to follow uniformly the law of the increasing proportion between the shot and the guns, as the latter become smaller, we have been induced to put in this table several sorts of guns, which are not in use.

To proportion the weight of the gun by that of the shot, is not certainly the best method; it should be determined by other circumstances; however for the object in view, we may allow this method of proceeding, especially since it gives a result very nearly approaching to the ordinary weight.

There is moreover in the table, in columns A and C, the weight of the guns, which must be multiplied by the number to be carried by the privateer, of which the plan is required. In the calculation, the whole weight of the guns is made equal to A or C.

It may be allowed that a 24 lb. shot weighs 29 pounds provision weight, a cubic foot of iron of this kind weighing 440 pounds: the same proportion is observed for the other shot.

(126.) In the following calculations, it is estimated that the weight of a man is 170 pounds = 2,7 cubic feet of sea-water, supposing one foot to weigh 63 pounds; the weight of a man and his effects = 4 cubic feet; the casks, provisions, wood for cooking during a month = 189 pounds = 3 cubic feet of sea-water; the water including the cask, for 15 days = 112 pounds = 1,78 cubic feet.

D = the displacement of the vessel to the outside of the timbers, B = the weight of the part above the water comprising the masts, yards, sails, rigging; a = the distance of the common center of gravity of these weights from the load water-line; c = the distance of the center of gravity of all the guns, also from load water-line. The center of gravity of the lower tier of guns is supposed to be one-third the height of the middle port from its lower sill. In like manner, the center of gravity of the guns on the quarter-deck and forecastle is taken one-third of the height of the foremost port on the quarter-deck. For the center of gravity of the swivels, we take that of the middle swivel, z = the breadth of the ship to the outside of the timbers, y = the half breadth, and x = the length from the forepart of the stem to the aft part of the stern-post; d = the depth of the ship taken at the frame ϕ, from the load water-line to the rabbet of the keel.

We may also estimate the number of the crew to be $= 3{,}763\ A^{\frac{5}{9}}$, of which the weight is $= 10{,}16\ A^{\frac{5}{9}}$, and with their effects $= 15\ A^{\frac{5}{9}}$. The provisions for k months, and water for half the time, casks, wood, &c. included $= 18 \times k A^{\frac{5}{9}}$.

To be able to observe a certain order between these ships, we have supposed the largest provisioned for a longer time than the small ones, consequently, we may make $k = \frac{A^{\frac{2}{7}}}{2{,}756}$, whence $18 \times k \times A^{\frac{5}{9}} = 6{,}534 \times A^{\frac{53}{63}}$. If all the weights $15\ A^{\frac{5}{9}} + 6{,}534\, A^{\frac{53}{63}} + A = K$, the displacement will be well proportioned, D being $= 6{,}84 \times c^{\frac{1}{4}} \times K^{\frac{13}{15}}$. Then we may make the weight $B = \frac{D^{\frac{21}{20}}}{6{,}281}$, and the distance $a = \frac{D^{\frac{1}{3}}}{3{,}48}$.

Make $C + 10{,}16 \times A^{\frac{5}{9}} = Q$, and let the center of gravity of displacement be below the load water-line by an unknown quantity m; the moment of stability according to Art. 22. will be expressed by $\frac{2}{3}\int y^3 \dot{x} - (m+a) \times B - (m+c) \times Q$ (NOTE 46.); but since $\frac{2}{3}\int y^3 \dot{x} = (m+6) \times D$, according to the preceding Article, $(m+6) \times D - (m+a) \times B - (m+c) \times Q = 6D$; hence $m = \frac{aB + cQ}{D - (B+Q)}$.

It is necessary to take care in making a plan, that the center of gravity of the part immersed does not descend lower than this quantity; it would be better that it should be higher; for by making it lower, the stability will be diminished; the contrary will take place, if it be raised.

We have also found that $(m+6) \times D$, or $\frac{2}{3}\int y^3 \dot{x}$ may be $= \frac{z^3 x^{\frac{21}{20}}}{26}$, and $z = \frac{x^{\frac{9}{10}}}{2{,}36}$; hence $(m+6) \times D = \frac{x^{\frac{15}{4}}}{341{,}8}$, and thus $x = \left(341{,}8 \times (m+6) \times D\right)^{\frac{4}{15}}$

The area of the load water-line should be $=\dfrac{z\,x^{\frac{24}{23}}}{1,626}$, and the area of the frame $\phi=\dfrac{2,366\times D}{x^{\frac{13}{12}}}$; also $d=\dfrac{x}{10,5}$. The center of gravity of the ballast is supposed to be below the plane of the load water-line by a quantity $=\dfrac{x^{\frac{7}{5}}}{95}$, and the weight of the ballast $=$

$$95\times\left\{\frac{1,11\times\big((m+a)\times B+(m+c)\times Q\big)-m\,D}{x^{\frac{7}{5}}-95m}\right\}.$$

We have found that the moment of the sails, in respect to the center of gravity of the ship or to the load water-line, should be $=\dfrac{35,56\times 6D}{x^{\frac{1}{3}}}$; the sails are those mentioned in Art. 83. and 87.

As to the length x, which we have found here, it might be varied according to the distance between the guns, the disposition of the row-ports, and the accommodations; this length, however, must not be much altered, if it be wished that the value of $\frac{2}{3}\int y^3\dot{x}$ should remain constant.

(127.) For a better guide, the following is the least distance, which can be allowed between the guns from center to center; for

24 pounders	$10\frac{1}{3}$ feet;	....8 pounders	$8\frac{5}{6}$ feet;	....4 pounders	$7\frac{1}{12}$ feet;
18 ———	$9\frac{5}{6}$ —	....6 ———	$8\frac{1}{3}$ —	....3 ———	$7\frac{1}{2}$ —
12 ———	$9\frac{1}{3}$				

But if it be wished to make two row-ports between each gun, the distance from gun-port to gun-port cannot be less than 8 feet.

The first port forward may be placed, so that the after side may be abreast of the center of the foremast; or that the foreside may be a little abaft the after side of the foremast.

It is necessary to set off the distance between the after-port and the stern-post, one distance between the ports and one breadth of a port, more or less, according to the disposition of the accommodations.

(128.) It is proper in this place to insert the proportions of the ports, which experience has proved to be the best.

Pounders.	Height of the Sills above the Decks.	Height of the Ports.	Breadth of the Ports.
	Inches.	Inches.	Inches.
24 pounds	28	34	40
18 pounds	26	31	36
12 pounds	24	28	33
8 pounds	22	25	30
6 pounds	20	22	27
4 pounds	18	19	24
3 pounds	16	17	21

For greater clearness, I give below the expressions in the order in which they should be employed in the calculations.

Formulæ for the proportions of Privateers.

$$15\,A^{\frac{5}{9}} + 6{,}534\,A^{\frac{53}{63}} + A = K$$

$$6{,}84 \times c^{\frac{1}{4}} \times K^{\frac{13}{15}} = D$$

$$\frac{D^{\frac{21}{26}}}{6{,}281} = B, \quad \frac{D^{\frac{1}{3}}}{3{,}48} = a, \quad 10{,}16\,A^{\frac{5}{9}} + C = Q$$

$$\frac{aB + cQ}{D - (B + Q)} = m$$

$$\text{weight of ballast} = 95 \times \frac{\left(1{,}11 \times (\overline{m+a} \times B + \overline{m+c} \times Q) - mD\right)}{x^{\frac{7}{5}} - 95\,m}$$

$$341{,}8 \times (m+6) \times D^{\frac{4}{15}} = x$$

$$\frac{x^{\frac{9}{10}}}{2,36} = z, \quad \frac{z x^{\frac{2}{2}\frac{4}{3}}}{1,626} = \text{area of the load water-line.}$$

$$\frac{2,366 \times D}{x^{\frac{1}{1}\frac{3}{2}}} = \text{area of section } \phi, \quad \frac{x}{10,5} = d$$

$3,763 \times A^{\frac{5}{9}} =$ the number of the crew, $\dfrac{A^{\frac{2}{7}}}{2,756} = k$ months provisions.

The distance which the center of gravity of the ballast is below the load water-line $= \dfrac{x^{\frac{7}{5}}}{95}$. The difference of the draught of water fore and aft $= \dfrac{x^{\frac{5}{6}}}{14,46}$.

The moment of the sails from the load water-line $= \dfrac{35,56 \times 6D}{x^{\frac{1}{3}}}$.

(129.) To facilitate the use of the formula according to the number of guns, their caliber, and the height of the battery, the following table has been constructed of the values of A, C, &c. for 16 privateers carrying different numbers of guns.

Number of the Slip.	Guns. First Battery. No.	Guns. First Battery. Caliber.	Guns. Second Battery, or that of quarter deck, and forecastle. No.	Guns. Second Battery, or that of quarter deck, and forecastle. Caliber.	Height of the battery.	Height of the sills.	A third of the height of the sills.	Dist. of center of gravity of guns of 1st battery from load water-line.	Distance between the batteries.	Weight of the first battery with carriages, breachings and tackles, &c.	Weight of the upper battery with carriages, &c.	Quantity C.	Common center of gravity of all the guns above load water-line, or c.	Quantity A.
					Feet.	Feet.	Feet.	Feet.	Feet.	Cubic ft.	Cubic ft.	Cubic ft.	Feet.	Cubic ft.
1	28	18	12	6	8,5	2,58	0,86	9,36	6,4	2612,4	447,6	3060	10,29	4451
2	26	18	10	6	7,	2,58	0,86	7,86	6,3	2425,8	373,	2799	8,69	4074
3	26	12	10	4	6,5	2,33	0,77	7,28	6,2	1742,0	259,	2001	8,08	2851
4	24	12	8	4	6,	2,33	0,77	6,78	6,1	1608,0	207,2	1815	7,47	2588
5	24	8	8	3	5,75	2,08	0,69	6,44	6	1147,2	160,	1307	6,85	1827
6	22	8	—	—	5,5	2,08	0,69	6,19	—	1051,6	—	1052	6,19	1476
7	22	6	—	—	5,25	1,83	0,61	5,86	—	820,6	—	821	5,86	1139
8	20	6	—	—	5,	1,83	0,61	5,61	—	746,	—	746	5,61	1035
9	18	6	—	—	4,75	1,83	0,61	5,36	—	671,4	—	671	5,36	932
10	16	6	—	—	4,5	1,83	0,61	5,11	—	596,8	—	597	5,11	828
11	14	6	—	—	4,25	1,83	0,61	4,86	—	522,2	—	522	4,86	725
12	12	6	—	—	4,	1,83	0,61	4,61	—	447,6	—	448	4,61	621
13	10	6	—	—	3,75	1,83	0,61	4,36	—	373,	—	373	4,36	518
14	8	6	Swiv.	Swiv.	3,5	1,83	0,61	4,11	—	298,4	—	298	4,11	414
15	1	12	16	3	4,	—	—	4,5	—	147,	—	147	4,5	277
16	1	8	16	2	3,75	—	—	4,	—	101,4	—	101,4	4,	188

(130.) Suppose it is required to make a plan for a privateer of 24 twelve pounders on the main deck, 8 four pounders on the quarter deck and fore-castle, with six feet battery, or the lowest sill of the middle gun port 6 feet above the water; this is the privateer number 4 of the table, so that there will be for A, C and c the following values.

$A = 2588$; $C = 1815$; $c = 7{,}47$; log. $7{,}47 = 0{,}8733206$; log. $c^{\frac{1}{4}} = 0{,}2183301$.

Logarithms.		
$A = 2588$ log.	$= 3{,}4129643$	
$A^{\frac{5}{9}}$	$= 1{,}8960913$	
15	$= 1{,}1760913$	N. N^r.
$15A^{\frac{5}{9}}$	$= 3{,}0721826$	$= 1180{,}8$
$A^{\frac{53}{63}}$	$= 2{,}8712239$	
6,534	$= 0{,}8151791$	$A = 2588$
	$= 3{,}6864030$	$= 4858$
K	$= 3{,}9358598$	8627
$K^{\frac{13}{15}}$	$= 3{,}4110785$	
$c^{\frac{1}{4}}$	$= 0{,}2183301$	
684	$= 0{,}8350561$	
D	$= 4{,}4644647$	$= 29140$
$D^{\frac{21}{20}}$	$= 4{,}6876879$	
6,281	$= 0{,}7980288$	
B	$= 3{,}8896591$	$= 7756$
$D^{\frac{1}{3}}$	$= 1{,}4881549$	
3,48	$= 0{,}5415792$	
a	$= 0{,}9465757$	$= 8{,}842$
B	$= 3{,}8896591$	
aB	$= 4{,}8362348$	$= 68590$
$A^{\frac{5}{9}}$	$= 1{,}8960913$	
10,16	$= 1{,}0068937$	$C = 1815$
$10{,}16A^{\frac{5}{9}}$	$= 2{,}9029850$	$= 799{,}8$
Q	$= 3{,}4174717$	$= 2615$
c	$= 0{,}8733206$	
cQ	$= 4{,}2907923$	$= 19534$
$aB + cQ$	$= 4{,}9450750$	$= 88124$
$D - (B + Q)$	$= 4{,}2734411$	$= 18769$
m	$= 0{,}6716339$	$= 4{,}695$
$m + a$	$= 1{,}1315224$	$= 13{,}537$
B	$= 3{,}8896591$	
$(m + a)B$	$= 5{,}0211815$	$= 105000$
$m + c$	$= 1{,}0851121$	$= 12{,}165$
Q	$= 3{,}4174717$	
$(m + c)Q$	$= 4{,}5025838$	$= 31810$
	$= 5{,}1361178$	$= 136810$
1,11	$= 0{,}0453230$	
	$= 5{,}1814408$	$= 151860$
D	$= 4{,}4644647$	
m	$= 0{,}6716339$	
mD	$= 5{,}1360986$	$= 136800$
	$= 4{,}1778250$	$= 15060$
95	$= 1{,}9777236$	
	$6{,}1555486$	

Logarithms.		
$x^{\frac{7}{5}}$	$= 2{,}9969025$	$= 992{,}9$
95	$= 1{,}9777236$	
m	$= 0{,}6716339$	
$95m$	$= 2{,}6493575$	$= 446$
	$2{,}7379079$	$= 5469$
Ballast	$= 3{,}4176407$	$= 2616$
D	$= 4{,}4644647$	
$m + 6$	$= 1{,}0291808$	$= 10{,}695$
$\int \frac{2}{3} y^3 \dot{x}$	$= 5{,}4936455$	$= 311600$
3,41,8	$= 2{,}5337721$	
	$= 8{,}0274176$	
x	$= 2{,}1406447$	$= 138{,}24$
$x^{\frac{9}{10}}$	$= 1{,}9265803$	
2,36	$= 0{,}3729120$	
z	$= 1{,}5536683$	$= 35{,}78$
$x^{\frac{24}{23}}$	$= 2{,}2337162$	
	$= 3{,}7873845$	
1,626	$= 0{,}2111205$	
Area of load water-line.	$= 3{,}5762640$	$= 3769$
$d = \frac{138{,}24}{10{,}5}$		$= 13{,}16$
D	$= 4{,}4644647$	
2,366	$= 0{,}3740147$	
	$= 4{,}8384794$	
$x^{\frac{13}{12}}$	$= 2{,}3190317$	
Area of ϕ	$= 2{,}5194477$	$= 330{,}7$
$A^{\frac{5}{9}}$	$= 1{,}8960913$	
3,763	$= 0{,}5755342$	
Crew	$= 2{,}4716255$	$= 296$
$A^{\frac{2}{7}}$	$= 0{,}9751326$	
2,756	$= 0{,}4402792$	
(k)	$= 0{,}5348534$	$= 3{,}426$
$x^{\frac{7}{5}}$	$= 2{,}9969025$	
95	$= 1{,}9777236$	
Ballast below water.......	$= 1{,}0191789$	$= 10{,}45$
$x^{\frac{5}{8}}$	$= 1{,}3379029$	
14,46	$= 1{,}1601683$	
Diff. of draught of water.....	$= 0{,}1777346$	$= 1{,}506$
$6D$ (NOTE 47.)	$= 5{,}2426408$	$= 174840$
35,56	$= 1{,}5509618$	
	$6{,}7936026$	
$x^{\frac{1}{3}}$	$= 0{,}7135482$	
Moment of the sails.........	$= 6{,}0800544$	$= 1202400$

By this process it will be found, that the privateer of 24 twelve pounders on the main deck, of 8 four pounders on the quarter deck and forecastle, and having the sill of the middle port of the lowest battery 6 feet above the water, should have 29140 cubic feet of displacement outside the timbers, not including the keel, the stem, and the stern-post.

The center of gravity of the said displacement will be below the plane of the load water-line 4,595 feet.

$$\frac{2}{3}\int y^3 d\dot{x} = 311600.$$

The length from the stem to the stern-post = 138,24.

The breadth to the outside of the timbers = 35,78.

Ballast in cubic feet of sea-water ...... = 2616.

Area of the load water-line = 3769, square feet.

Depth of the frame ϕ from load water-line to rabbet of keel 13,16 feet.

Area of frame ϕ	330,7 square feet.
Number of crew	296 men.
Months for which provisioned.............	3,46
Quantity by which the center of gravity of the ballast should be below load water-line..	10,45 feet.
Difference of the draught of water	1,51 feet.
Moment of sails from the center of gravity of the ship, or from the load water-line.....	1202400.

By following the same rules, and in the same manner, are obtained the proportions of 16 privateers in table N°. 6; and by the articles 43 and 120, we are enabled to determine the place of the center of gravity of the ship with respect to the length; together with the quantity, which the frame ϕ ought to be carried before the middle of the length. It is here supposed that all the frames or tranverse sections are perpendicular to the keel.

If the artillery had been planned otherwise, or if it were necessary to place the battery lower or higher, the proportions of the frigate would not be the same: however, it may be observed, that this height of the battery does not differ far from what is in common use.

(131.) To shew more sensibly the difference of form between small and great ships, which are constructed according to the proportions given according to the formulæ, figure 34. is constructed, which is to be understood in the following manner:

ABC (Fig. 34.) is the midship bend of a privateer $138\frac{1}{4}$ feet in length, and $35\frac{3}{4}$ in breadth; *ADC* is the frame ϕ of a small privateer or boat $44\frac{3}{4}$ feet in length, and 13 feet in breadth, and *AC* is the load water-line; and according to the proportion, which there should be between the length and breadth, *EFG* will be the load water-line of the large privateer, and *HFI* that of the small one. These elements being known, it will not be difficult, with some knowledge of construction, and a little practice, to draw plans, which, every thing being well attended to, will differ little from those given in my *Architectura Navalis*, since the formulæ have been calculated after those plans; or to speak more correctly, they have been employed conjointly with others, in finding these different expressions.

I do not pretend to say, however, that one ought always to observe these proportions. Different cases present themselves, which may require different alterations: for instance, to navigate in seas where the waves are short and high, ships, particularly small ones, should have more breadth in proportion to the length.

In like manner, different kinds of rigging require alterations in the proportions: if the vessel be schooner rigged, it is necessary that it should have a greater relative length to allow a proper extent to the sails in proportion to the stability; the rigging of sloops on the contrary requires more breadth in proportion to the length.

There are privateers, which are obliged to go out to sea to meet with prizes; others have no occasion to go far from the coast; these two kinds ought to be provisioned differently; the one requires greater capacity than the other, although they may be of the same force, a circumstance which will necessarily cause differences in the principal dimensions; regarding it as an invariable principle, that the center of gravity of the ship with its lading, should be in the plane of the load water-line, and the metacenter 6 feet above.

As far as regards the accommodations, their distribution may be partly seen in the plans of my *Architectura Navalis;* but the size of the ships, and also the climates where they are meant to navigate, must influence greatly the nature of the accommodations.

Ships sufficiently large and stable should have large gangways, whereon to place the musketry, and they ought to be well netted on the gunwales.

In hot climates, ships should be more open, especially, if they are not liable to be sent on expeditions of long duration; but in cold climates, care should be taken that the crews be well sheltered: so that, in large privateer ships, instead of wide gangways, it would be more convenient to extend the quarter-deck and forecastle, with large gratings in the middle for the passage of the smoke in action. These gratings should be covered with tarpawlings in bad weather.

In some countries, they have their cables in the hold; in others, between decks; both methods have advantages and inconveniences. There are also different customs for the hours of meals, and for their galleys; some cook thrice a day; others cook only once: all this requires in a ship different arrangements, and what is right for one, is not convenient for the other.

Hence we see, how necessary it is to be acquainted with all these, and many other similar circumstances, before a draught is begun; and that it afterwards requires judgment and practice in the business, in order to arrange and adapt rightly, and according to circumstances, every particular thing; so as to include all possible conveniences, to have room to work the ship, and to avoid crowding.

CHAP. VIII.

PROPORTIONS OF MASTS AND YARDS FOR MERCHANT SHIPS.

(132). THE masts and yards being made only to carry sails, it appears that one ought to determine the area and moment of the canvass for merchant ships, in the same manner as for privateers, in order to proportion thereby the said masts and yards. Although in these ships, which take different cargoes, the moment of stability is very variable, yet there may be supposed a fixed point for the center of gravity of the ship and its lading, according to which the moment of the canvass might be calculated, using as a guide in the first instance the rules given for the proportions of merchant ships; as also tables N°. 2, 3, 4 and 5, where the length of the masts is in proportion to the cube root of the moment of stability. But before we attempt to make any alterations in the proportions of the masts and yards, it is right to consider the rules, which are usually followed in this respect, and to examine the true reasons for them, in order to see whether they are to be regarded as good or bad.

(133.) Usually the height of the masts is proportioned to the breadth of the ship, and the length of the yards to the length of the same; whence it follows, that ships of the same length and the same breadth, but of different stability, have the same extent of canvass, which however ought, one would think, to be proportioned to this stability. Nevertheless, true as this rule may be for privateers, that the masts and yards should be proportioned to the stability, there may be reasons why the same rule may not be followed in merchant ships.

(134.) When it is considered that the weight of the anchors of a ship is proportioned to the length and breadth, or to the square of the breadth, and that the act of weighing the anchors requires a certain number of men, as also working sails of a certain size; that large sails require a numerous crew, and that numerous crews are always expensive to maintain; it hence appears, that for a merchant ship it is advantageous to have as small a crew as possible, or that it is most consistent with good management, that the number of the crew should be suited as well to the size of the sails, as to that of the anchors.

It also hence appears, that it is the number of the crew, which confines the area of the sails within certain limits.

It is thus not improper to use the same principle for the masting, as for proportioning the anchors, inasmuch as the number of the crew also depends thereon.

(135.) To see how far the usual proportions of the masts and yards are good; if two ships of the same length and of the same breadth, have according to custom, the same extent of canvass, but one carries sail better than the other, it is not said that this has too much or that too little canvass, but that the former has greater stability than the latter. One would therefore conclude, that it would be better to reform the sails, or make them smaller with relation to the stability (preserving in other respects the ordinary proportions) than to augment the crew, in order to be able to use a larger quantity of canvass.

(136.) However when the canvass according to the usual proportion, is found too great with relation to the stability, one should study rather to place the parts of the lading of the greatest specific gravity lower, than to diminish the area of the sails; especially if the number of the crew cannot be diminished on account of the anchors.

Besides, in different circumstances, the same area of canvass may be as proper for a ship of greater stability, as for one of less; moreover, the surface of the sails may be augmented in the one, by means of studding-sails and stay-sails, and diminished in the other, by taking in reefs according to the state of the weather.

One has thus great reason to use the rule according to which the masting is proportioned for merchant ships, as that gives most nearly those proportions for the masting, which have already been found by experience to be the best.

So that the moment of stability, according to which large ships have masts higher, and small ones lower, than the result of the usual rule, will not serve to found thereon the proportions of masts and yards for merchant ships.

(137.) The proportions then of masts and yards are founded on the length and breadth of ships in the following manner.

As the breadth of ships has the greatest influence on the stability, (Art. 16.) the lower masts and top-masts should be proportioned to the breadth, whence not only the height of the sails, but moreover the height of their common center of gravity, will be in proportion to the said breadth; as to the breadth of the sails, or what is the same thing, the length of the yards, it should be proportioned to the length of the ship: thence it follows, that the moment of the sails will be as the square of the breadth, multiplied by the length. Small ships then will have a greater moment of canvass in proportion to the stability, than large ones; which agrees with what was observed in Art. 83. concerning the area of canvass for small ships: and it is a received custom for small ships, to increase the height of the lower masts still more, but at the same time to diminish that of the top-masts. The height of the main-mast of a trading ship with three masts, its breadth being $= B$, is $= 3{,}23\, B^{\frac{11}{12}}$, and the height of the main top-mast, reckoning from the upper side of the cross-trees, that of the main-mast being $= L$, is $\frac{L^{\frac{11}{10}}}{2,73}$ for frigates, and $\frac{L^{\frac{11}{10}}}{2,84}$ for barks. The relation of the masts, proportioned according to this method, to the masts proportioned according to the stability, may be seen by Fig. 32, where the line BNN determines the height of the masts in the proportion of $B^{\frac{11}{12}}$.

The length of the bowsprit outside of the stem, for frigates, is $1,15 \times$ the breadth of the ship, and for barks $1,1 \times$ the said breadth.

(138.) It is not sufficient to study merely to regulate the height of the masts, and the length of the yards, by the size of the ships; but also to use those which have such a proportion among themselves, that all the rigging may make a handsome appearance.

That the ships may be well rigged, it is necessary in the first place, that the fore-stay and main topmast-stay should be in a straight line, in like manner, the main-stay and the mizen topmast-stay: the fore-stay may end on the bowsprit, between one-third and two-fifths of its length from the small end; secondly, that the top-sails should be of similar figures, or at least, that their sides should be of the same cut; thirdly, that when the ship is seen, at one or the other of the extremities, the shrouds and the breast back-stays should appear parallel: this depends partly on the breadth of the channels, which ought to be regulated in a manner conducive to this end. To effect this, the length of the head of the main-mast, from the under side of the trestle-trees, which is $\frac{5}{36}$ of the length of the said mast, being $= T$, the cap of the fore-mast should be lower than that of the main-mast by a quantity $= 2,22 \times T^{\frac{1}{3}}$ for frigates, and $= 2 \times T^{\frac{1}{4}}$ for barks. The cap of the mizen-mast should be on a level with the main-top.

(139.) If the length of the main top-mast $= S$, the length of the mizen top-mast will be $= 1,3 \times S^{\frac{6}{7}}$ for frigates, and $= 1,316 \times S^{\frac{6}{7}}$ for barks, supposing the length of the pole to be in the same proportion, as for the other top-masts; if it be longer, then that difference is added more.

(140.) The head of the mizen-mast ought to be $\frac{3}{4}$, and that of the fore-mast $\frac{9}{10}$ of that of the main-mast. The length of the fore top-mast should also be $\frac{9}{10}$ of that of the main; the head of these masts $\frac{1}{9}$ or $\frac{2}{17}$ of their length. The length of the top-gallant masts to the stop $= 0{,}54 \times$ the length of the top-mast; the length of the main yard $=$ $0{,}52 \times$ the length of the ship from the stem to the stern-post for frigates, and the main top-sail yard $= 0{,}79 \times$ by the length of the main yard; as for barks, the length from end to end being $= L$, the length of the main yard will be $= 0{,}6 \times L^{\frac{20}{21}}$; and the length of the main top-sail yard will be $= 0{,}81 \times$ by the length of the main yard. The main top-gallant yard $= 0{,}7 \times$ by the length of the main top-sail yard. All the yards of the fore mast are $\frac{9}{10}$ of those of the main-mast.

(141.) The proportion of the mizen top-sail yard to its mast, is equal to the proportion of the main top-sail yard to the main top-mast: the cross-jack yard $= 1{,}22 \times$ the length of the mizen top-sail yard for frigates, and $= 1{,}18 \times$ this length for barks. The sprit-sail yard $=$ the fore top-sail yard; the sprit-sail top-sail yard $=$ the fore-top-gallant yard.

(142.) The girth of the yards is $\frac{1}{11}$ of their length for the lower yards, and those of the top-gallant yards; but $\frac{1}{7}$ for the top-sail yards.

(143.) The distance of the center of gravity of the fore-mast from the perpendicular at the stem is $\frac{4}{31}$ of the length. The center of the main-mast is $\frac{2}{31}$ behind the middle of the ship. The distance of the center of the mizen-mast from the perpendicular at the stern-post is $= 0{,}182 \times$ by the length of the ship.

(144.) The main-mast should rake aft one foot in thirty; the mizen-mast should have double the rake of the main-mast; the fore-mast should be perpendicular; the elevation of the bowsprit, above the horizontal plane, should be in a length of 7 feet, about four feet for frigates, and 3 feet, for barks.

It is according to these proportions that the masts and yards in tables 7 and 8 are calculated; it will be however necessary, when the dimensions of the masts are given for the ship, to make a rigging draught, in order to proportion one according to the other, so that the whole may make a handsome appearance.

(145.) As to the diameter, experience has shewn that if the length of the main-mast, the main-yard, and the maintop-mast, are denoted by L, R, and S feet, the diameter of the main-mast in inches will be $\frac{L \times R^{\frac{1}{3}}}{13}$; that of the main top-mast will be $\frac{S^{\frac{11}{10}}}{4,68}$; the diameter of the fore-mast will be $\frac{1}{20}$ less than that of the main-mast; and the diameter of the fore top-mast will be $\frac{1}{20}$ less than that of the main top-mast. The diameter of the top-gallant mast $= 0,3 \times$ their length reckoning to the stop.

(146.) The diameter of the bowsprit will be a mean between that of the main-mast and that of the fore-mast; the diameter of the jib-boom will be $\frac{3}{4}$ of that of the main top-mast. The diameter of the mizen-mast two-thirds of that of the main-mast, and the diameter of the mizen top-mast $\frac{2}{3}$ of that of the main top-mast.

(147.) The diameter of the main-yard, and that of the fore-yard in inches $= 0,25 \times$ the length of the yard; that of the top-sail yards $=$ $0,23 \times$ also by the length of the yards; that of the top-gallant yard $= \frac{1}{6}$ of their length. The diameters of the sprit-sail yard, and cross-jack yard $= 0,21$ the length. The diameter of the sprit-sail top-sail yard $=$ that of the main top-gallant yard. The diameter of the mizen peak is an inch for four feet in its length. The studding sail booms have two feet greater length than half the yard, and their diameter in inches is $\frac{1}{5}$ or $\frac{1}{6}$ of their length in feet.

(148.) The depth of the main-trestle-trees in inches is the fourth of the height of the top-mast in feet, less half an inch; the thickness of the fore-trestle trees is $\frac{1}{15}$ less than that of the main-trestle-trees, and the mizen $\frac{3}{5}$ of the main; the thickness of the top-mast cross-trees is $\frac{3}{7}$ that of the trestle-trees of the respective tops. The breadth of the said trestle-trees and cross-trees is $\frac{5}{7}$ or $\frac{3}{4}$ of their depth.

The thickness of the caps is $\frac{4}{5}$ of the diameters of the top-masts.

(149.) As the masts and yards taper towards their extremities, it is not sufficient to have their greatest diameters, it is necessary also to know the proportion according to which they are diminished, for the purpose of giving them the form which according to experience affords sufficient strength to sustain the efforts to which they are exposed. The distance between the greatest and least diameters is divided into four parts; the diameter at each of these divisions should be as follows.

(150.) The lower masts are found to be well proportioned when they have their diameter, at the height of the trestle-trees, one-eighth less than at the deck. So that, the diameter at the deck being 128, at the first division it will be 127, at the second 124, at the third 119, and at the fourth 112. The thickness within the trestle-trees will be $\frac{4}{5}$, and above at the head, $\frac{5}{8}$ of the diameter at the deck.

(151.) The top-masts have $\frac{1}{5}$ less diameter under the cross-trees than at the cap of the lower masts. So that, the diameter at the cap being 80, at the first division it will be 79, at the second 76, at the third 71, and at the fourth, below the cross-trees 64. The thickness within the cross-trees and above at the head, will be $\frac{5}{9}$ of the diameter at the cap.

(152.) If the great diameter of the lower and top-sail yards be 27, at the first division it will be 26, at the second 23, at the third 18, and at the outer end 11.

(153.) If the great diameter of the top-gallant yards is 32, at the first division it will be 31, at the second 28, at the third 23, and at the yard-arm 16.

(154.) The bowsprit has commonly at the outer end a diameter only one half of that at the gammoning; if the diameter at the gammoning is 60, at the first division it will be 59, at the second 55, at the third 46, and at the fourth 30.

(155.) Brigs and snows have their fore-masts and its appendages, as well as the bowsprit, of the same proportions as frigates. But the height of the main-mast of brigs ought to be such, that its top may be on a level with the cap of the fore-mast; the head of the main-mast is equal to the head of the fore-mast. The main top-mast is of the same length with the fore top-mast, the main yard and main top-mast yard are the same with the fore yard and fore-top mast yard.

In snows, the main-mast is a mean between the main-masts of a frigate and brig, so also the top-masts; but the main yard and the main top-sail yard, are of the same dimensions with those of frigates.

(156.) The length of the main-mast of schooners and galiasses to the hounds, ought to be thrice the breadth of the vessels; and in howker sloops the whole of the main-mast ought to be thrice their breadth.

The proportions for other masts and yards, as also for all of them, in small vessels, will be found in the draughts of Plate LXII. *Architectura Navalis.* The yards have there their half length.

(157.) East India ships have the length of the main-mast $= 2{,}43 \times$ their breadth; the length of the main top-mast $= 0{,}586 \times$ into that of the main-mast; the length of the main-yard $= 0{,}54 \times$ the length of the ship;

the main top-gallant yard 0,7 × by the top-sail yard; the mizen top-mast $\frac{3}{4}$ of the fore top-mast.

The cap of the fore-mast is $\frac{2}{5}$ of the length of the head of the main-mast lower than the cap of the main-mast; the cap of the mizen-mast is on a level with the main top. The other masts or yards are proportioned like those of merchant vessels frigate built.

(158.) In privateers the masts and yards are first proportioned, as for East India ships, after which a draught of them is made, in which are included the rigging and sails; lastly, their moment is compared with that of the stability Art. 80. and by proceeding as in Art. 87. the masts and yards will be determined, which are suitable to the moment of the sails.

CHAP. IX.

ON DIFFERENT MATTERS RELATING TO THE PRACTICAL PART OF CONSTRUCTION.

Of the scantlings of the pieces for the construction of a ship.

(159.) The art of proportioning the pieces, which enter into the construction of a ship, depends altogether on practice.

A ship that is to be laden with iron, with salt, or other wares of a considerable specific gravity, likely to strain the ship at sea, or the working of which may tend to loosen the parts of the ship, ought to be more solidly put together, than a ship whose cargo is to be light merchandize, as fir, timber, planks, &c. The difference of the quality of the wood also renders necessary a difference in the scantling, in order to obtain the same solidity.

(160.) The solidity of a ship does not depend solely on the strength of the scantling of the wood; great care ought to be taken also to work it properly, as well the timbers for frames as the planking; to unite well all the parts of the edifice, and to establish properly each piece in its respective place.

(161.) As to the scantling of the timber for the construction of privateers, the object of these ships being only to serve in war, it is not necessary to build them of greater strength, than the probable period of their being wanted requires; on which account, the least scantling possible is given them, with a view to economy in expence.

This will be attended with the farther advantage, that the vessel will displace less, and that the bottom will be more elastic, which increases the velocity of sailing (NOTE 48.).

An able practical man must therefore be guided by circumstances.

The scantlings of the pieces, which are given in the following statement, are such as may be used for ships built of oak.

(162.) *Scantling for a Merchant Ship built of Oak.*

Length	160	150	140	130	120	110	100	90	80	70	60	50
Breadth moulded	42	$39\frac{3}{4}$	$37\frac{1}{2}$	$35\frac{1}{4}$	33	$30\frac{3}{4}$	$28\frac{1}{2}$	$26\frac{1}{4}$	24	$21\frac{1}{2}$	19	$16\frac{1}{2}$
	$39\frac{1}{4}$	$37\frac{1}{4}$	$35\frac{1}{4}$	$33\frac{1}{4}$	$31\frac{1}{4}$	$29\frac{1}{4}$	27	$24\frac{3}{4}$	$22\frac{1}{2}$	$20\frac{1}{4}$	18	$15\frac{1}{2}$
Keel sided	18	$17\frac{1}{4}$	$16\frac{1}{2}$	$15\frac{1}{2}$	$14\frac{1}{2}$	$13\frac{1}{2}$	$12\frac{1}{2}$	$11\frac{1}{2}$	$10\frac{1}{2}$	$9\frac{1}{2}$	8	6
Floors in mid-ship sided	14	$13\frac{1}{4}$	$12\frac{1}{2}$	$11\frac{3}{4}$	11	$10\frac{1}{4}$	$9\frac{1}{2}$	$8\frac{3}{4}$	8	$7\frac{1}{4}$	$6\frac{3}{8}$	$5\frac{1}{2}$
First, second, and third futtocks sided	13	$12\frac{1}{2}$	12	$11\frac{1}{4}$	$10\frac{1}{2}$	$9\frac{3}{4}$	9	$8\frac{1}{4}$	$7\frac{1}{2}$	$6\frac{1}{2}$	$5\frac{1}{2}$	5
Top timbers sided	12	$11\frac{3}{4}$	$11\frac{1}{4}$	$10\frac{3}{4}$	10	$9\frac{1}{4}$	$8\frac{1}{2}$	$7\frac{3}{4}$	7	6	$5\frac{1}{4}$	5
Moulded at the floor head	$12\frac{3}{4}$	12	$11\frac{3}{8}$	$10\frac{3}{4}$	10	$9\frac{1}{4}$	$8\frac{1}{2}$	$7\frac{3}{4}$	7	6	5	$4\frac{1}{4}$
Moulded at the main wales	$10\frac{3}{4}$	$10\frac{1}{8}$	$9\frac{1}{2}$	$8\frac{7}{8}$	$8\frac{1}{4}$	$7\frac{1}{2}$	$6\frac{7}{8}$	$6\frac{1}{8}$	$5\frac{1}{2}$	$4\frac{7}{8}$	$4\frac{1}{4}$	$3\frac{1}{2}$
Moulded at the top side	$5\frac{1}{2}$	$5\frac{1}{4}$	5	$4\frac{3}{4}$	$4\frac{1}{2}$	$4\frac{1}{4}$	4	$3\frac{3}{4}$	$3\frac{1}{2}$	$3\frac{1}{4}$	3	$2\frac{1}{2}$
Main wale thick	$7\frac{3}{4}$	$7\frac{3}{8}$	7	$6\frac{1}{2}$	6	$5\frac{1}{2}$	5	$4\frac{1}{2}$	4	$3\frac{5}{8}$	$3\frac{1}{4}$	$2\frac{3}{4}$
Plank of bottom thick	$4\frac{1}{4}$	4	$3\frac{3}{4}$	$3\frac{1}{2}$	$3\frac{1}{4}$	3	$2\frac{7}{8}$	$2\frac{3}{4}$	$2\frac{5}{8}$	$2\frac{1}{2}$	2	$1\frac{1}{2}$
Channel wale thick	$5\frac{3}{4}$	$5\frac{3}{8}$	5	$4\frac{5}{8}$	$4\frac{1}{4}$	$3\frac{7}{8}$	$3\frac{1}{2}$	$3\frac{1}{4}$	3	—	—	—
Plank between main and channel wales thick	$3\frac{3}{4}$	$3\frac{5}{8}$	$3\frac{1}{2}$	$3\frac{3}{8}$	$3\frac{1}{4}$	3	$2\frac{7}{8}$	$2\frac{3}{4}$	$2\frac{5}{8}$	$2\frac{3}{8}$	2	$1\frac{1}{2}$
Plank between channel wale and gun wale thick	3	3	$2\frac{7}{8}$	$2\frac{3}{4}$	$2\frac{5}{8}$	$2\frac{1}{2}$	$2\frac{3}{8}$	$2\frac{1}{4}$	$2\frac{1}{8}$	2	$1\frac{3}{4}$	$1\frac{1}{4}$
Keelson square	17	$16\frac{1}{2}$	$15\frac{3}{4}$	15	14	13	12	$11\frac{1}{4}$	$10\frac{1}{4}$	$9\frac{1}{2}$	8	6
Score of the keelson	6	$5\frac{5}{8}$	$5\frac{3}{8}$	5	$4\frac{5}{8}$	$4\frac{1}{4}$	$3\frac{7}{8}$	$3\frac{1}{2}$	$3\frac{1}{4}$	3	$2\frac{3}{4}$	$2\frac{1}{4}$
Foot waling thick	4	$3\frac{3}{4}$	$3\frac{1}{2}$	$3\frac{1}{4}$	3	$2\frac{3}{4}$	$2\frac{5}{8}$	$2\frac{1}{2}$	$2\frac{3}{8}$	$2\frac{1}{4}$	$1\frac{7}{8}$	$1\frac{1}{2}$
Lower deck clamps thick	7	$6\frac{5}{8}$	$6\frac{1}{4}$	$5\frac{7}{8}$	$5\frac{1}{2}$	$5\frac{1}{8}$	$4\frac{3}{4}$	$4\frac{3}{8}$	4	$3\frac{5}{8}$	$3\frac{1}{4}$	$2\frac{3}{4}$
Lower deck beams moulded	18	17	16	15	14	$12\frac{3}{4}$	$11\frac{1}{4}$	10	9	8	7	$5\frac{1}{2}$
Lower deck beams sided	19	18	17	16	15	$13\frac{3}{4}$	$12\frac{1}{4}$	11	10	9	8	6
Knees sided to	$11\frac{1}{2}$	$10\frac{3}{4}$	10	$9\frac{1}{4}$	$8\frac{1}{2}$	$7\frac{7}{8}$	$7\frac{1}{4}$	$6\frac{5}{8}$	6	$5\frac{3}{8}$	$4\frac{3}{4}$	4
Carlings up and down	$5\frac{3}{4}$	$5\frac{1}{2}$	$5\frac{1}{8}$	$4\frac{3}{4}$	$4\frac{3}{8}$	4	$3\frac{5}{8}$	$3\frac{1}{4}$	3	$2\frac{7}{8}$	$2\frac{3}{4}$	$2\frac{1}{2}$
Ledges ditto	5	$4\frac{3}{4}$	$4\frac{3}{8}$	4	$3\frac{3}{4}$	$3\frac{1}{2}$	$3\frac{1}{4}$	3	$2\frac{3}{4}$	$2\frac{1}{2}$	$2\frac{1}{4}$	2
Binding strakes thick	6	$5\frac{3}{4}$	$5\frac{1}{2}$	$5\frac{1}{4}$	5	$4\frac{3}{4}$	$4\frac{1}{2}$	$4\frac{1}{4}$	4	$3\frac{3}{4}$	$3\frac{1}{2}$	2
Flat of deck thick	4	$3\frac{3}{4}$	$3\frac{1}{2}$	$3\frac{1}{4}$	3	$2\frac{7}{8}$	$2\frac{3}{4}$	$2\frac{5}{8}$	$2\frac{1}{2}$	$2\frac{1}{4}$	2	$1\frac{1}{2}$
Water ways ditto	$5\frac{3}{4}$	$5\frac{3}{8}$	5	$4\frac{5}{8}$	$4\frac{3}{8}$	$4\frac{1}{8}$	$3\frac{7}{8}$	$3\frac{5}{8}$	$3\frac{3}{8}$	$3\frac{1}{8}$	$2\frac{3}{4}$	$1\frac{3}{4}$
Upper deck clamps	$5\frac{3}{4}$	$5\frac{1}{4}$	5	$4\frac{3}{4}$	$4\frac{1}{4}$	$4\frac{1}{8}$	$3\frac{7}{8}$	$3\frac{5}{8}$	$3\frac{1}{4}$	3	$2\frac{3}{4}$	$1\frac{3}{4}$
Upper deck beams moulded	$12\frac{1}{2}$	$11\frac{1}{2}$	$10\frac{3}{4}$	$10\frac{1}{8}$	$9\frac{1}{2}$	$8\frac{7}{8}$	$8\frac{1}{4}$	$7\frac{1}{2}$	$6\frac{3}{4}$	6	5	4
Upper deck beams sided	13	$12\frac{1}{2}$	$11\frac{3}{4}$	11	$10\frac{1}{2}$	10	$9\frac{1}{4}$	$8\frac{1}{2}$	$7\frac{3}{4}$	7	6	5
Knees sided to	8	$7\frac{1}{2}$	7	$6\frac{1}{2}$	6	$5\frac{1}{2}$	5	$4\frac{5}{8}$	$4\frac{1}{4}$	4	$3\frac{3}{4}$	$3\frac{1}{4}$
Carlings up and down	4	4	$3\frac{7}{8}$	$3\frac{3}{4}$	$3\frac{5}{8}$	$3\frac{1}{2}$	$3\frac{1}{4}$	$3\frac{1}{8}$	$2\frac{7}{8}$	$2\frac{3}{4}$	$2\frac{1}{2}$	2
Ledges deep	$3\frac{1}{4}$	$3\frac{1}{4}$	$3\frac{1}{8}$	3	3	$2\frac{7}{8}$	$2\frac{3}{4}$	$2\frac{5}{8}$	$2\frac{1}{2}$	$2\frac{1}{4}$	2	$1\frac{1}{2}$
Flat of deck thick	$3\frac{1}{2}$	$3\frac{1}{4}$	$3\frac{1}{8}$	3	$2\frac{7}{8}$	$2\frac{3}{4}$	$2\frac{5}{8}$	$2\frac{1}{2}$	$2\frac{1}{4}$	2	$1\frac{3}{4}$	$1\frac{1}{2}$
Water ways thick	4	$3\frac{3}{4}$	$3\frac{1}{2}$	$3\frac{1}{4}$	3	$2\frac{7}{8}$	$2\frac{3}{4}$	$2\frac{5}{8}$	$2\frac{1}{2}$	$2\frac{1}{4}$	2	$1\frac{3}{4}$
Quarter deck clamps thick	4	$3\frac{3}{4}$	$3\frac{1}{2}$	$3\frac{1}{4}$	$3\frac{1}{8}$	3	$2\frac{7}{8}$	$2\frac{3}{4}$	$2\frac{5}{8}$	$2\frac{3}{8}$	$2\frac{1}{8}$	$1\frac{7}{8}$
Quarter deck beams moulded	$8\frac{3}{4}$	8	$7\frac{3}{4}$	$6\frac{7}{8}$	$6\frac{1}{2}$	$6\frac{1}{8}$	$5\frac{3}{4}$	$5\frac{1}{4}$	$4\frac{3}{4}$	$4\frac{1}{4}$	$3\frac{5}{8}$	3
Knees sided to	$6\frac{1}{2}$	6	$5\frac{1}{2}$	$5\frac{1}{4}$	$4\frac{3}{4}$	$4\frac{3}{8}$	4	$3\frac{3}{4}$	$3\frac{1}{2}$	$3\frac{1}{4}$	3	$2\frac{1}{4}$
Flat of quarter deck thick	3	$2\frac{7}{8}$	$2\frac{3}{4}$	$2\frac{1}{2}$	$2\frac{1}{4}$	2	2	2	2	$1\frac{3}{4}$	$1\frac{3}{4}$	$1\frac{1}{2}$
Lower deck transom sided to	10	$9\frac{1}{2}$	9	$8\frac{1}{2}$	8	$7\frac{1}{2}$	7	$6\frac{1}{2}$	6	$5\frac{1}{2}$	5	4
Rudder head across	23	$21\frac{7}{8}$	$20\frac{3}{4}$	$19\frac{5}{8}$	$18\frac{1}{2}$	$17\frac{3}{8}$	$15\frac{7}{8}$	$14\frac{7}{8}$	14	12	11	8
Tiller at the after end thick	$10\frac{1}{2}$	10	$9\frac{1}{4}$	$8\frac{1}{2}$	8	$7\frac{1}{2}$	7	$6\frac{1}{2}$	6	$5\frac{1}{2}$	5	4
At the fore end thick	9	$8\frac{5}{8}$	$8\frac{1}{4}$	$7\frac{3}{4}$	$7\frac{1}{4}$	$6\frac{3}{4}$	$6\frac{1}{4}$	$5\frac{3}{4}$	$5\frac{1}{4}$	$4\frac{7}{8}$	$4\frac{1}{2}$	3

The fore end of the keel $\frac{11}{12}$, and the after extremity $\frac{5}{6}$ of the siding at the middle. The thickness of the stern-post, near the transom, and the thickness of the stem at the wale, are equal to that of the middle of the keel, but the upper extremity of the stem is $\frac{1}{6}$ more.

(163.) *Scantling for Privateers.*

Length	160	150	140	130	120	110	100	90	80	70	60	50
Breadth	41	38	36	34	32	29	27	25	22	19	17	15
Keel sided	15½	14¾	14⅛	13¼	12½	11¾	11	10	9	8	7	5½
Sternpost sided at the wing transom	16	15½	15	14¼	13½	12½	11¾	10½	9¼	8	7	5½
Stem sided at the wale	15½	14¾	14⅛	13¼	12½	11¾	11	10	9	8	7	5½
Stem sided at the head	21	20	19	18	16¾	15¾	14¾	13¾	12½	11¼	9½	7
Floor timbers, and first futtocks sided to	11¼	10½	10	9½	9	8½	7⅞	7¼	6⅝	6	5½	5
The other timbers of the frame	10¾	10	9½	9	8½	8	7⅜	6¾	6⅛	5½	5	4½
Moulded at the floor head	11	10¼	9½	8¾	8	7⅜	6¾	6⅛	5½	5	4½	4
Moulded at the height of the deck	9	8	7¼	6½	5¾	5⅛	4⅝	4⅛	3¾	3½	3¼	3
Moulded at the gun wale	5	4¾	4½	4¼	4	3¾	3½	3¼	3	2⅞	2¾	2¼
Wale thick	7	6⅝	6¼	5⅞	5½	5	4½	4¼	3⅞	3½	3¼	2¾
Plank of bottom thick	4	3¾	3½	3¼	3	2¾	2⅝	2½	2⅜	2¼	2	1½
Thickness strake above the wale	3½	3¼	3	2⅞	2¾	2⅝	2½	2⅜	2¼	2⅛	1⅞	1⅜
Thickness top-side	3	2¾	2½	2⅜	2¼	2⅛	2	1⅞	1¾	1½	1 3/3	1¼
Orlop clamps	5	4¾	4⅜	4	3¾	3½	3¼	3	2⅞	2½	2	1¾
Beams of orlop deck square	9½	8¾	8¼	7¾	7¼	6¾	6½	—	—	—	—	—
Flat of orlop deck	3	2⅞	2¾	2⅝	2½	2⅜	2¼	2⅛	2	1⅞	1½	1¼
Upper deck clamps thick	6	5⅜	5¼	4⅞	4½	4⅛	3¾	3⅜	3	2¾	2½	2
Upper deck beams moulded	14	13	12	11	10	9	8¼	7½	6¾	6	5	4
Upper deck beams sided	16	15	14	13	11¾	10½	9¾	9	8¼	7½	6¼	5
Upper deck knees	9¾	8¾	7¾	6¾	6¼	5¾	5¼	4⅞	4½	4	3¼	2¾
Water ways	4¾	4⅜	4	3¾	3½	3¼	3	2¾	2½	2¼	2	1½
Quarter deck clamps	4	3¾	3½	3¼	3	2⅞	2¾	2⅝	2½	2¼	2	1½
Quarter deck beams moulded	8½	7⅞	7¼	6⅝	6	5	5	4¾	4¼	4	3½	3
Quarter deck knees sided	6	5½	5	4⅝	4¼	4	3¾	3½	3¼	3⅛	3	2¾
Roundhouse beams moulded	5	—	—	—	—	—	—	—	—	—	—	—
Roundhouse beams sided	7	—	—	—	—	—	—	—	—	—	—	—
Quarter deck water ways	3	2¾	2½	2¼	2	—	—	—	—	—	—	—
Rudder head sided	20	19½	18¾	17¾	16½	15¾	14¾	13½	12	11	9¼	7
Tiller square	10	9¾	9¾	8½	7⅞	7¼	6½	5⅞	5⅜	4⅜	4¾	3½
Riding bitts	17	16	15	12¾	11½	10¼	9	8	7½	7	6½	5

We have not given here all the pieces, which enter into the construction of a ship, because people, who understand this department, are able to act according to circumstances in proportioning those, which are omitted; considering both the goodness of the execution, and at the same time the weight by which the frame of the ship should be limited. I shall now, with relation to the latter circumstance, give a method of cubing pieces of different forms.

(164.) The common manner of finding the solid content of timber for building, may be sufficiently exact, when it is only with a view to selling or buying; but when the object is to deduce the weight of the pieces from the measurement, it is necessary to obtain the true solid content. In this the two following formulæ will be sufficient. The first is found in Simpson's Fluxions, Tom. I, Art. 154.

For the first, let $AEGB$ (Fig. 35.) be a solid, of which the four sides AH, AF, CH, CF are plane figures, and its bases $ADCB$, $EFGH$ rectangles parallel to each other.

Let the distance between the two bases taken on a perpendicular $= a$; the solid content of the body will be $= \big(AB \times AD + EH \times EF + (AB + EH) \times (AD + EF)\big) \times \frac{1}{6}a$ (NOTE 49.). If $EF = 0$, the body will be like a wedge, having one end smaller than the other, and its solid content will be $= (2AB + EH) \times AD \times \frac{1}{6}a$, but if $EF = EH$, and $AD = AB$, then the body will be the frustrum of a square pyramid; the solid content will be $= (AB^2 + AB \times EH + EH^2) \times \frac{1}{3}a$; and lastly, if EH in this last expression $= 0$, the body will be the whole pyramid, of which the solid content will be $= AB^2 \times \frac{1}{3}a$.

For example, let $AB = 18$ inches, $AD = 12$ inches, $EH = 10$ inches, $EF = 8$ inches, the height $a = 20$ feet; the solidity will be $\big(18 \times 12 + 10 \times 8 + (18 + 10) \times (12 + 8)\big) \times \frac{1}{6} \times 20 = 2853{,}33$; but as the breadth and the thickness are in inches, it is necessary to divide this quantity by 144, and the solidity will be = 19,814 cubic feet.

(165.) For the second formula, let $FACDE$ (Fig. 36.) be a round body generated by the revolution of the curve ABC about GH as an axis; let the generating curve ABC be a parabola, whose vertex is at C; let AI be an ordinate parallel to the axis GH, and CI the abscissa of this ordinate, IK its sub-tangent; let $IK : IC :: m : n$, and the parameter = 1, then the equation of this parabola will be $CI^n = AI^m$; lastly, let the length $GH = a$, the diameter $CE = b$, and the diameter $AF = c$.

The proportion of the square of the diameter of the circle to its area being nearly as 14 to 11, the solidity of this body may be expressed by $\frac{11}{14} a \times \frac{(m+n) \times nc^2 + 2mnbc + 2m^2b^2}{(m+n) \times n + 2mn + 2m^2}$ (Note 50.) If ABC be a conic parabola, then $m = 2$, $n = 1$, and the solidity will be = $\frac{11}{14} a \times \frac{3c^2 + 4bc + 8b^2}{15}$; and if $c = 0$, the solidity will be $\frac{11}{14} a \times \frac{8}{15} b^2$.

If ABC be a cubic parabola of the first species, then $m = 3$, $n = 1$, and the solidity will be $= \frac{11}{14} a \times \frac{4c^2 + 6bc + 18b^2}{28}$; and when $c = 0$, the solidity will be $= \frac{11}{14} a \times \frac{9b^2}{14}$.

If ABC be a cubic parabola of the second species, then $m = 3$, $n = 2$, and the solidity will be $= \frac{11}{14} a \times \frac{10c^2 + 12bc + 18b^2}{40}$; and when $c = 0$, the solidity will be $= \frac{11}{14} a \times \frac{9b^2}{20}$.

If ABC be a right line, then the body is a frustrum of a cone, and $m : n :: 1 : 1$; the solidity will be $= \frac{11}{14} a \times \frac{c^2 + bc + b^2}{3}$; and lastly, if $c = 0$, the body will be an entire cone, of which the solidity will be = $\frac{11}{14} a \times \frac{b^2}{3}$.

For example, there is required the solid content of a yard 68 feet long, 17 inches in diameter at the middle, and 7 inches in diameter at the extremities. Then $a = 68$, $b = 17$, and $c = 7$: if the generating curve by the revolution of which this yard is formed, be a conic parabola, the solidity will be $= \frac{11}{14} a \times \frac{3c^2 + 4bc + 8b^2}{15} = \frac{11}{14} \times 68 \times \frac{3 \times 7^2 + 4 \times 17 \times 7 + 8 \times 17^2}{15} = 10454$; but the diameters 17 and 7 being expressed in inches, it will be necessary to divide this quantity by 144, and we shall have for the solidity of the yard $72\frac{6}{10}$ cubic feet.

Knowing the weight of a cubic foot of wood from which the yard is made, we shall easily obtain its whole weight. For example, if a cubic foot of this wood weigh 40 pounds, multiply this quantity by 72,6, the product will be 2904 pounds = 9 skiponds iron weight, and if 2904 be divided by 63, we shall have the weight equal to that of 46 cubic feet of sea-water.

(166.) This formula for the solidity of round timber might serve to guage a cask, when the curve is any of the parabolic lines. The operation is as follows:

The inside diameter of the cask both at the middle and at the extremities is measured; $CE = b$, $AF = c$; half the difference of these two quantities $= n$.

To know the kind of parabola, which is to be used in the calculation, a rule exactly straight is laid on one extremity, so as to be a tangent to this point, as AK at A.

From the middle point C of the cask, the length CK is taken on a perpendicular to the axis (we suppose the staves equally thick throughout;) CK added to n will give m (NOTE 51.). Take moreover the length of the cask a in the inside.

For example, $a = 4{,}04$ feet, $b = 3{,}4$ feet; $c = 2{,}6$ feet, so that $\frac{b-c}{2} = 0{,}4 = n$. Let the distance CK from the barrel to the rule $AK = 0{,}15$; then $0{,}4 + 0{,}15 = 0{,}55 = m$:

The content then of the cask, according to the formula, will be $=$

$$\frac{11}{14} \times 4{,}04 \times \frac{0{,}95 \times 0{,}4 \times (2{,}6)^2 + 2 \times 0{,}22 \times 8{,}84 + 2 \times 0{,}3025 \times (3{,}4)^2}{0{,}95 \times 0{,}4 + 2 \times 0{,}22 + 2 \times 0{,}3025} =$$

$\frac{11}{14} \times 4{,}04 \times \frac{13{,}452}{1{,}425} = \frac{11}{14} \times 4{,}04 \times 9{,}44 = 30$ cubic feet, or 300 *kans*.

One may also, by means of this formula, find the length and diameter of all kinds of casks for a given content.

For example, suppose it were required to find of what dimensions a cask ought to be to contain 33 cubic feet or 330 kans.

Let the length $= a$, the great diameter $= b$; the diameter at each extremity $= c$; let these interior dimensions be as 6, 5 and 4; then $b = \frac{5}{6}a$, and $c = \frac{4}{6}a$; and if the curvature of the staves form a cubic parabola of the second species, m will be $= 3$, and $n = 2$. So that $\frac{11}{14}a^3 \times \frac{10 \times \frac{16}{36} + 12 \times \frac{20}{36} + 18 \times \frac{25}{36}}{10 + 12 + 18} = 33$; whence $a^3 = \frac{33 \times 14 \times 36 \times (10 + 12 + 18)}{11 \times (10 \times 16 + 12 \times 20 + 18 \times 25)} = \frac{665280}{9350} = 70{,}83$; and lastly, $a = 4{,}123$, whence $b = 3{,}436$, and $c = 2{,}749$ feet.

The method of laying off according to the full size on the mould-loft, for making the moulds.

(167.) Let us take for example the privateer (Fig. 45, and 51.). For the execution in the fore body, between the frames *P, S, W* and the stem are traced other frames *U* and *R* (Fig. 37.); and in the after body, between the frames 21, 24 and the stern-post, those marked 26, 25 and 23 (Fig. 37.); where, for greater clearness, the plan is made on a larger scale.

A ship which has sufficiently little rising in her floors to allow her taking the ground in tide-ways, ought to have such length of floor, that on laying aground, the extremities of the said floors which touch, may be beyond the point of contact at least one foot towards their heads.

But since a ship as clean as the one in question, cannot be laid aground, we are at liberty to make the floors as short as we wish.

Wherefore if the timber for building the ship be on the spot, its form and length should be examined, in order after that to mark on the plan the places where the different timbers are to be shifted, as in *I, II, III.* The floors will be *IBBI*; the first futtocks will be from *B* to *II*; the second futtocks from *I* to *III*; the third futtocks from *II* to *C*; the top timbers from *III* to *C*.

Thus each frame is composed of one floor, six futtocks, and two top-timbers; but if the timber has not the length which we here suppose, it will be necessary to alter the divisions, diminishing the shifts so that there may be one futtock more on each side. However timber should not be used so short as not to give, for ships of this size, six feet shift to the first futtock and floorheads, and four feet and a quarter to the other timbers.

When all the shifts are thus marked, the diagonal lines 1, 2, 3, 4, 5, 6 and 7 are drawn on the body plan, nearly in the direction in which the plank is brought on; according to these diagonal lines the ribbands are nailed, when the frames are got into their places.

(168.) To have the shape of the top timbers, a line is drawn between the main breadth line and top breadth line; it is denoted both on the body plan and on sheer plan, by 8 (Fig. 37.). The line 9 marks the heights of the main breadth, 10 those of the top breadth, and 11 those of the top side.

(169.) All these operations being finished, the different distances are taken, from which a scheme is formed, such as the following one (Fig. 37, 45 and 51.).

Distribution of the frames.

	Ft.	In.	$\frac{1}{8}$
From after perp^r. to 26	2	4	4
From 26 to 25	1	3	2
From 25 to 24	2	6	3
From 24 to 23	3	1	2
From 23 to 21	3	1	2
From 21 to 18	6	2	4
From 18 to 15	6	2	4
From 15 to 12	6	2	4
From 12 to 9	6	2	4
From 9 to 6	6	2	4
From 6 to 3	6	2	4
From 3 to ϕ	6	2	4
From ϕ to *C*	6	2	4
From *C* to *F*	6	2	4
From *F* to *I*	6	2	4
From *I* to *M*	6	2	4
From *M* to *P*	6	2	4
From *P* to *R*	3	1	2
From *R* to *S*	3	1	2
From *S* to *U*	3	1	2
From *U* to *W*	3	1	2
From *W* to fore perp^r.	3	2	3
Whole length between perp^{rs}.	102	6	0

Frame ϕ.

	Height above the rabbet of the keel.			Half breadth.		
	Ft.	In.	$\frac{1}{8}$	Ft.	In.	$\frac{1}{8}$
First diagonal	1	2	1	2	3	7
2d	1	10	5	4	4	3
Between 2d & 3d	2	2	6	5	8	4
3d	2	8	2	7	2	2
Between 3d & 4th	3	3	1	8	6	4
4th	3	11	6	9	9	4
Between 4th & 5th	4	10	6	10	11	7
5th	5	11	6	12	0	1
Between 5th & 6th	7	2	3	12	10	3
6th	8	5	6	13	5	4
7th	10	4	0	13	10	1
Height of Breadth	11	11	2	13	10	5
Between Breadth and Top Breadth	14	6	7	13	1	3
Top Breadth	17	2	1	13	9	5

Height of diagonals at the middle line.

	Afore.			Aft.		
First diagonal ...	3	10	1	5	10	3
Second	5	10	3	7	10	5
Third	8	2	4	10	4	2
Fourth	10	9	2	13	6	5
Fifth	13	3	2	16	4	5
Sixth	15	9	4	18	5	1
Seventh	17	3	1	20	3	4

Main Breadth After Body.

	Height from the upper edge of the rabbet of the keel. Ft.	In.	$\frac{1}{8}$	Half breadth. Ft.	In.	$\frac{1}{8}$
At the frames 3	12	0	0	13	10	1
6	12	1	3	13	8	2
9	12	4	1	13	5	6
12	12	7	7	13	1	7
15	13	1	0	12	8	4
18	13	7	5	12	1	4
21	14	3	6	11	4	3
23	14	8	6	10	11	5
24	15	2	4	10	5	4
25	15	7	2	10	0	4
26	15	9	6	9	10	0
At fashion piece	16	1	0	9	6	3
At side counter timber	16	9	1	8	9	7

Main Breadth Fore Body.

	Height from the upper edge of the rabbet of the keel. Ft.	In.	$\frac{1}{8}$	Half breadth. Ft.	In.	$\frac{1}{8}$
At the frames *C*	11	11	6	13	10	1
F	12	1	4	13	9	
I	12	4	5	13	6	4
M	12	10	3	13		5
P	13	6	5	12	1	
R	13	11	6	11	1	6
S	14	5	7	9	8	
U	15	1	2	7	5	5
W	15	9	7	3	11	6
At the stem	16	4	6			

Between Main and Top Breadth Lines.

After Body

	Height from the upper edge of the rabbet of the keel. Ft.	In.	$\frac{1}{8}$	Half breadth. Ft.	In.	$\frac{1}{8}$
At the frames 3	14	7	4	13	1	
6	14	8	4	13		
9	14	10	6	12	9	6
12	15	1	4	12	6	3
15	15	4	7	12	1	6
18	15	8	7	11	7	6
21	16	2	0	11		2
24	16	8	0	10	3	1
At fashion piece	17	3	0	9	4	5
At side counter timber	17	8	0	8	8	6

Fore Body.

	Height from the upper edge of the rabbet of the keel. Ft.	In.	$\frac{1}{8}$	Half breadth. Ft.	In.	$\frac{1}{8}$
At the frames *C*	14	7	3	13	1	3
F	14	8		13		3
I	14	10		12	10	4
M	15		7	12	5	4
P	15	4	7	11	7	4
R	15	7	3	10	9	7
S	15	10	7	9	6	4
U	16	2	2	7	5	5
W	16	7	0	3	11	6
At the stem	16	10	3			

Top Breadth After Body.

	Height from the upper edge of the rabbet of the keel. Ft.	In.	1/8	Half breadth. Ft.	In.	1/8
At the frames 3	17	2	5	11	9	3
6	17	3	7	11	8	3
9	17	5	7	11	6	3
12	17	8	5	11	3	2
15	17	11	7	10	10	6
18	18	4	0	10	5	2
21	18	8	7	9	10	1
24	19	3	4	9	1	6
At fashion piece	19	10	5	8	3	6
At side counter timber	20	4	2	7	7	6

Top Breadth Fore Body.

	Height from the upper edge of the rabbet of the keel. Ft.	In.	1/8	Half breadth. Ft.	In.	1/8
At the frames *C*	17	2	5	11	9	1
F	17	3	3	11	8	
I	17	5		10	5	5
M	17	7	7	11	1	3
P	17	11	6	10	5	
R	18	2	3	9	10	1
S	18	5	2	8	11	7
U	18	9	4	7	8	4

Top Side After Body.

	Height from the upper edge of the rabbet of the keel. Ft.	In.	1/8	Half breadth. Ft.	In.	1/8
At the frames 15	19	3	1	10	4	2
18	19	7	1	9	11	
21	19	11	7	9	4	4
24	20	6	1	8	8	3
At fashion piece	21	1	7	7	10	1
At side counter timber	21	8		7	2	3

Top Side Fore Body.

	Height from the upper edge of the rabbet of the keel. Ft.	In.	1/8	Half breadth. Ft.	In.	1/8
At the frames *M*	18	8	7	10	9	6
P	19		7	10	2	
R	19	4		9	8	
S	19	7	2	8	11	2
U	19	11	2	7	10	7

Distances on the Diagonals of the After Body.

	First Diagonal.		
	Ft.	In.	$\frac{1}{8}$
From ϕ to 3	–	–	7
6	–	3	3
9	–	6	7
12	–	10	7
15	1	4	3
18	1	10	6
21	2	7	7
23	3	1	6
24	3	8	–
25	4	3	2
26	4	6	4
To mid. line	5	3	–

	Second Diagonal.		
	Ft.	In.	$\frac{1}{8}$
From ϕ to 3	–	1	3
6	–	5	1
9	–	10	4
12	1	5	3
15	2	2	2
18	3	–	7
21	4	1	7
23	4	10	–
24	5	7	3
25	6	4	–
26	6	8	5
To mid. line	7	5	1

	Third Diagonal.		
	Ft.	In.	$\frac{1}{8}$
From ϕ to 3	–	2	–
6	–	7	4
9	1	3	–
12	2	–	5
15	3	–	4
18	4	2	2
21	5	7	2
23	6	5	7
24	7	6	3
25	8	8	–
26	9	4	5
To mid. line	10	6	–

	Fourth Diagonal.		
	Ft.	In.	$\frac{1}{8}$
From ϕ to 3	–	2	4
6	–	7	7
9	1	4	–
12	2	2	3
15	3	3	4
18	4	6	4
21	6	–	5
23	6	11	6
24	8	1	6
25	9	4	4
26	10	3	4
To the margin	11	5	6
To mid. line	13	8	2

	Fifth Diagonal.		
	Ft.	In.	$\frac{1}{8}$
From ϕ to 3	–	2	–
6	–	5	6
9	1	1	–
12	1	10	4
15	2	10	–
18	4	–	3
21	5	6	2
23	6	5	1
24	7	5	6
25	8	6	1
26	9	1	5
To the margin	9	8	6
To mid. line	15	11	–

	Sixth Diagonal.		
	Ft.	In.	$\frac{1}{8}$
From ϕ to 3	–	1	4
6	–	4	1
9	–	9	2
12	1	4	1
15	2	1	3
18	3	1	4
21	4	5	4
23	5	2	4
24	6	1	2
25	6	10	6
26	7	3	7
To the margin	7	9	5
To mid. line	16	8	7

	Seventh Diagonal.		
	Ft.	In.	$\frac{1}{8}$
From ϕ to 3	–	–	6
6	–	3	3
9	–	7	4
12	1	–	7
15	1	8	2
18	2	6	2
21	3	7	4
23	4	3	2
24	5	–	1
25	5	7	7
26	5	11	7
To mid. line	17	–	6

	Upper edge of the Wale.		
	Ft.	In.	$\frac{1}{8}$
Height from the rabbit 3	11	11	6
6	12	–	6
9	12	3	–
12	12	5	6
15	12	9	2
18	13	1	6
21	13	7	2
23	13	10	3
24	14	2	–
25	14	5	1
26	14	6	5
At fashion piece	14	8	3

Distances on the Diagonals of the Fore Body.

	First Diagonal.				Second Diagonal.				Third Diagonal.				Fourth Diagonal.		
	Ft.	In.	$\frac{1}{8}$		Ft.	In.	$\frac{1}{8}$		Ft.	In.	$\frac{1}{8}$		Ft.	In.	$\frac{1}{8}$
From ϕ to *C*	–	–	–	From ϕ to *C*	—	—	4	From ϕ to *C*	–	1	6	From ϕ to *C*	–	1	7
F	–	–	4	*F*	–	2	1	*F*	—	5	2	*F*	—	6	–
I	–	2	1	*I*	–	6	1	*I*	1	–	7	*I*	1	2	3
M	–	5	5	*M*	1	–	7	*M*	1	11	5	*M*	2	3	4
P	1	–	–	*P*	1	11	5	*P*	3	2	3	*P*	3	10	–
R	1	4	3	*R*	2	6	6	*R*	4	–	1	*R*	4	10	1
S	1	9	5	*S*	3	2	7	*S*	4	11	7	*S*	6	1	–
U	2	4	5	*U*	4	—	7	*U*	6	2	3	*U*	7	8	–
W	–	–	–	*W*	5	–	7	*W*	7	7	4	*W*	9	8	–
To mid. line	3	6	5	To mid. line	5	11	1	To mid. line	9	1	–	To mid. line	11	11	4

	Fifth Diagonal.				Sixth Diagonal.				Seventh Diagonal.				Upper edge of the Wale.		
	Ft.	In.	$\frac{1}{8}$		Ft.	In.	$\frac{1}{8}$		Ft.	In.	$\frac{1}{8}$	Height above the rabbit	Ft.	In.	$\frac{1}{8}$
From ϕ to *C*	–	1	–	From ϕ to *C*	—	–	5	From ϕ to *C*	—	—	4	of keel *C*	11	11	5
F	–	4	2	*F*	–	3	–	*F*	–	2	2	*F*	12	–	3
I	–	11	7	*I*	–	8	4	*I*	–	5	7	*I*	12	2	1
M	2	–	2	*M*	1	6	4	*M*	1	2	1	*M*	12	4	7
P	3	8	–	*P*	3	–	4	*P*	2	5	6	*P*	12	9	–
R	4	9	6	*R*	4	2	–	*R*	3	6	6	*R*	12	11	5
S	6	3	1	*S*	5	8	1	*S*	5	1	1	*S*	13	3	–
U	8	2	6	*U*	7	11	5	*U*	7	6	–	*U*	13	7	1
W	10	11	2	*W*	11	3	7	*W*	11	1	5	*W*	13	11	6
To mid. line	14	—	6	To mid. line	15	4	–	To mid. line	15	6	1	At the stem	14	3	3

(170.) From this scheme the ship is laid down in full size, on the mould loft, according to the ordinary foot. The frames and other curve lines in the plans, are drawn on the floor by means of penning battens, which confined to the given spots, take the curvature which is wished.

The half thickness of the keel, stem, and stern-post, is drawn in the body plan on each side of the middle line; a dotted line *aa* also is drawn for the depth of the rabbet, and those *bb* for its breadth on the stem and stern-post.

The upper and lower edges of the wales are also denoted by 12 and 13.

(171.) As well to verify the exactness of the body plan, as to obtain the bevellings of the timbers, all the diagonals from the stem and stern-post to the mid-ship section must be delineated; to do this, on all the diagonals 1, 2, 3, 4 of the body plan, the distances are taken from the middle line to each frame, and they are set off from the middle line *DD* on the corresponding frames in the half-breadth plan; this will give the diagonals 1, 1; 2, 2; 3, 3; &c.

(172.) As it is not possible to place the frames near the extremities, in a plane perpendicular to the middle line *DD*, without having too great a curvature and requiring timber of too large scantling, on account of the great bevelling, the practice is to put them in a vertical plane, but oblique with regard to the plane of elevation or to the middle line *DD*, as *KE*, *FF*, *GG*, *HH*. These three last frames are called *cant frames;* ***KE*** or the aftermost one is the fashion piece, which determines the length of all the lower transoms.

(173.) It is not proper to carry *E* too far from the stern-post, this lengthens the said transoms too much, and as they are much curved, it would be difficult to find pieces proper for making them.

There must be limits also to the canting of the frames, for otherwise the filling frames would necessarily be beat away too much at the heels.

(174.) To determine the moulds and bevellings of these pieces (the filling-frames, transoms, and fashion-pieces) draw on the body plan, some water-lines (NOTE 52.), in the first place at the upper edges of the transoms *L, M, N, O,* and then below, at pleasure, as *c, d, f, g,* and for the fore ones *i, k, l, m;* transfer these water-lines to the half-breadth plan, where they are marked with the same letters.

The lines *M, N, O,* give the moulds of the upper edge of the transoms, and the line *L,* in *IK,* the bevelling of the end of the wing transom.

On the half-breadth plan, is taken the distance from *E* to all the points, where the water-lines cut *KE* or the after edge of the fashion-piece; these distances are set off on the corresponding water-lines on the body plan, from the middle line; and passing a curve through all the spots thus given, we have the line *qq* for the mould of the fashion-piece.

At a distance from *KE,* equal to the siding of the fashion-piece, draw *Pr* parallel thereto; from *E* draw the line *EP* perpendicular to *KE,* take the distance from *P* to all the points where *Pr* meets the water-lines, and set off also these distances from the middle line of the body plan, on the corresponding water-lines. Through all these spots draw *ss,* this curve will give the fore edge of the fashion-piece, and the distance between *qq* and *ss* will shew how much the bevelling of this piece is within or without the after edge.

(175.) To find the point where each diagonal meets the fashion-piece *qq.*

Take all the perpendicular distances from the middle line *DD* to the points where the water-lines meet the line *KE;* set off these distances on the corresponding water-lines of the body plan, also from the middle line; through all the points which this will give, pass the curve *tt,* which will give the projection of the after edge of the fashion-piece.

From the points *u, u,* where the diagonals meet this curve, draw the horizontal lines uw; then w, w, where these small lines meet the curve qq, are the points on the true fashion-piece, where it is cut by the diagonals.

(176.) To find the points where the fashion-piece cuts the diagonals.

Take the perpendicular distance from the middle line to all the points, where the diagonals 1, 1; 2, 2; 3, 3; &c. cut the frames; set off these distances on the corresponding frames in the half-breadth plan from the middle line DD;* through the points, which this operation will give, pass the curves 1, 2, 3, &c. which are dotted; this will give what are called the horizontal diagonal lines.

From the points x, x, where the lines meet KE, draw the small lines xy, xy perpendicular to the middle line DD; the points y, y, where these lines meet the diagonal lines 1, 1; 2, 2; 3, 3; &c. are those where the fashion-piece is cut by the diagonals.

(177.) The fashion-piece gives the bevellings of the extremities of the transoms; but the bevellings of the said transoms between their extremities and the middle are found by the following method.

Draw on the half-breadth plan the lines IV, V and VI, at pleasure, parallel to the middle line DD; take the distances of the points of intersection of these lines with the water-lines, from the perpendicular at the stern-post; set off these distances on the corresponding water-lines on the sheer plan from the said perpendicular at the stern-post, and through the points which this will give, draw the curves IV, V, VI; these lines will give the bevelling of the transoms. The bevelling of the lower transoms may be found by means of the frames 25 and 26.

(178.) The moulds and bevellings of the cant frames in the fore and after bodies, are found by proceeding as has been done for the fashion-piece; which is sufficiently seen by the plan.

(179.) After having drawn the square and cant frames, and the transoms, moulds are made of thin boards, on which all the places for the diagonals are marked, the height of breadth, top breadth, wales, and the decks, if required.

The moulds for the fore and after parts, which have great rounding, are made to the diagonals 1, 1; 2, 2; 3, 3; &c. in the half-breadth plan, of two-inch deals, which are even sheathed to give the greater solidity.

A ribband is carried above the wales, which may either be placed horizontally, or according to a right line, which is most nearly parallel to the wales.

The moulds for the floors are made so broad at the middle, as to have the whole height of the floors.

The bevellings of the pieces are marked, either on the moulds themselves, or on bevelling boards.

(180.) It is essential to use all possible precision in the laying off and in making the moulds; not only the construction thence becomes more conformable to the plan, but also by this means there is a saving in the wages of the workmen, who are thereby enabled to put together the frames and get them into their places, without being obliged to retouch them, in order that they may come well together and graduate well.

On the Construction of the Scale of Solidity.

(181.) Suppose we wish to make the scale of solidity for the privateer (Fig. 43, 44. and 46.), of which we have the displacement calculated in Art. 9.

The calculation for the construction of this scale must commence from the plane of the load water-line, so as to obtain in succession the solidity between this and each of the lower water-lines; the operation is performed in the following manner.

To find the solidity of the part between the first and second water-lines.

Half the area of the load water-line	1293,91
Ditto of the second	1178,03
	2)2471,94
	1235,97
Multiplied by the distance between the water-lines	1,62
Half the solidity between the first and second water-lines	2002,27
Plank	50,73
Stem and stern-post	2,00
	2055,00
	2
Displacement of the part, 1,62 feet below the load water-line ..	4110,00
	= 45,16 lasts.

To find the solidity of the parts between the first and third water-lines.

Half the area of the load water-line = 1293,91 × 1 =	1293,91
Ditto for the second .... = 1178,03 × 4 =	4712,12
Ditto for the third .... = 1030,69 × 1 =	1030,69
	7036,72
Multiplied by one-third the distance between the water-lines ...	0,54
Half the solidity between the first and third water-lines	3799,83
Plank	104,17
Stem and stern-post	4,00
cubic feet	3908,00
	2
Displacement of the part 3,24 feet below the load water-line	7816,00
	= 85,89 lasts.

To find the solidity of the pieces between the first and fourth water-lines.

Half the area of the third water-line........................	1030,69
Ditto of the fourth	856,93
	2)1887,62
	943,81
Multiplied by the distance between the water-lines	1,62
Half the solid between the third and fourth water-lines	1528,97
Half the solid between the first and third water-lines	3799,83
Half the solid between the first and fourth water-lines........	5328,80
Plank	165,20
Stem and stern-post..	6,00
	5500,00
	2
Displacement of the part 4,86 feet below the load water-line	11000,00
	= 120,88 lasts.

To find the solidity of the pieces between the first and fifth water-lines.

Half the area of the load water-line......	= 1293,91	×	1 =	1293,91
Ditto of the second.....................	= 1178,03	×	4 =	4712,12
Ditto of the third	= 1030,69	×	2 =	2061,38
Ditto of the fourth	= 854,93	×	4 =	4327,72
Ditto of the fifth......................	= 662,38	×	1 =	662,38
				12157,51
Multiplied by one-third the distance between the water-lines....				0,54
Half the solidity between the first and fifth water-lines				6565,05
Plank..				239,95
Stem and stern-post...				9,00
				6814,00
				2
Displacement of the part 6,48 feet below the load water-line...				13628,00
				=149,75 lasts.

To find the solidity of the pieces between the first and sixth water-lines.

Half the area of the fifth water-line	662,38
Ditto of the sixth	434,83
	2)1097,21
	548,60
Multiplied by the distance between the water-lines	1,62
	888,73
Half the solidity between the first and fifth water-lines	6565,05
Half the solidity between the first and sixth water-lines	7453,78
Plank	335,22
Stem and stern-post	12,00
	7801,00
	2
Displacement of the part 8,1 feet below the load water-line	15602,00
	=171,45 lasts.

To find the solidity of the pieces between the first and seventh water-lines.

Half the solidity between the first and seventh water-line 7947 (Art. 7.)	
Plank	426
Stem and stern-post	16
	8399 cubic feet
	2
Displacement of the part 9,72 feet below the load water-line	16798 =
	184,6 lasts.

To find the solidity from the load water-line to the keel.

Half the solidity between first water-line and the keel	8105
Plank	500
Stem and stern-post	20
Displacement of the part 11,72 feet below the load water-line	8625 cubic feet
	2
	17250 =
	189,56 lasts.

To construct from hence a scale of burden.

(182.) Draw two lines perpendicular to each other, the one in a horizontal direction, the other in a vertical direction; make on the horizontal line a decimal scale at pleasure to represent lasts, and on the vertical another scale of feet also at pleasure, as is seen in Fig. 50.

Below the horizontal line and at the distance from this superior line of 1.62, 3.24, 4.28, 6.48, 8.1, 9.72 and 11.2 feet, draw parallels thereto.

On the scale of lasts, take the quantities, which have been found, in lasts 45.16, 85.89, 120.88, 149.75, 171.45, 184.6 and 189.58; set off these quantities on the corresponding horizontal lines, from the vertical line.

Through all the points so determined pass a curve, and you will have a scale of solidity.

The horizontal scale is in French tons, English tons, and Swedish lasts.

The method of using the scale is this.

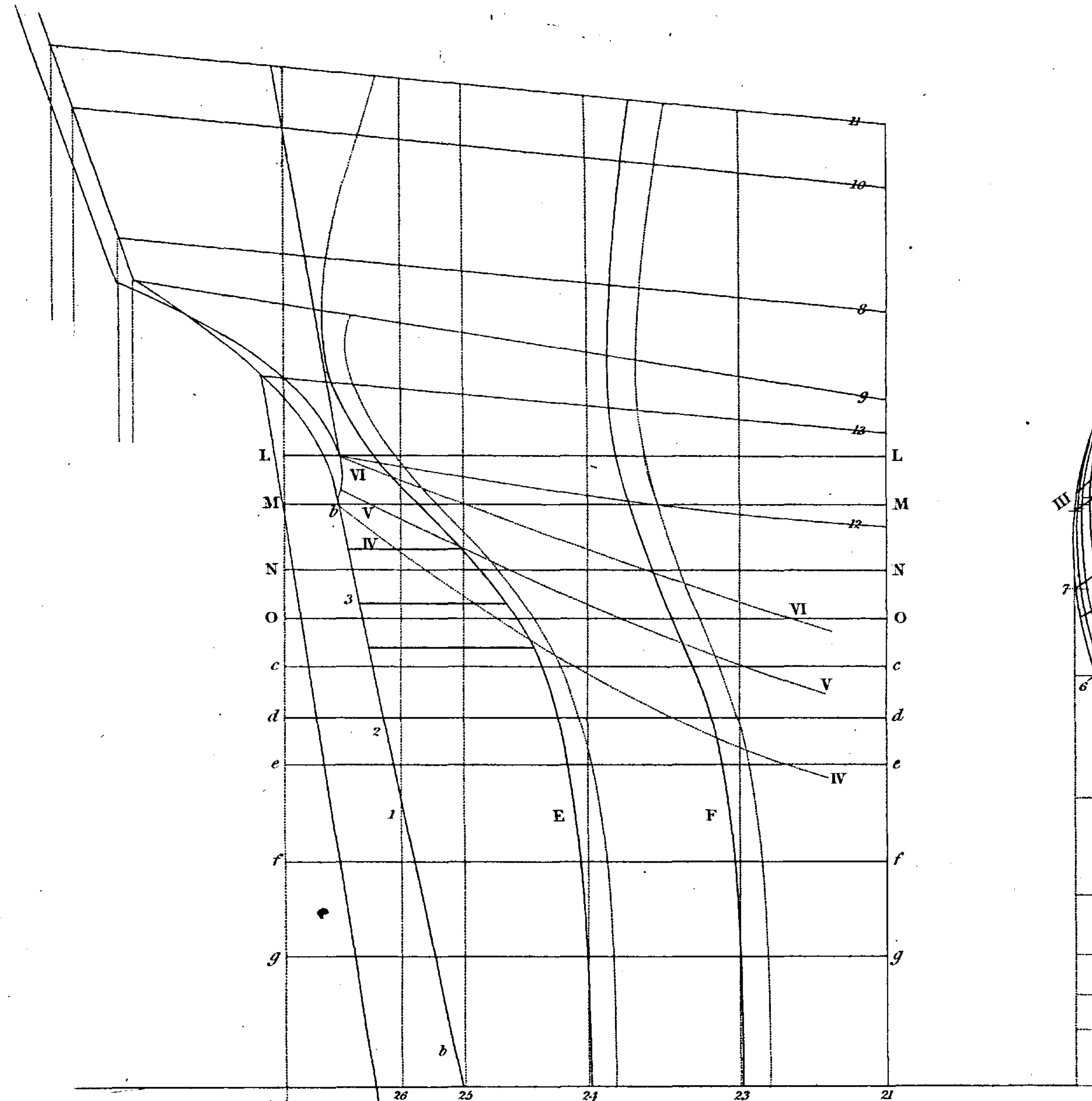
The line *ab* (NOTE 53.) on the sheer plan is the load water-line, the privateer being laden. Suppose that the water-line before it is entirely laden, were *cd*; then the distances *ac*, *bd* are taken, which by the scale of the plan give 4 feet $1\frac{1}{4}$ inches and 5 feet $1\frac{1}{4}$ inches; these two quantities are added, and half the sum is taken, 4 feet $7\frac{1}{4}$ inches.

Take this quantity 4 feet $7\frac{1}{4}$ inches on the scale of solidity, you will have *eg*, which must be transferred perpendicularly to the line *ef*, until it meet the curve in *h*. From *h* draw the line *hi* perpendicularly to *fe*, or what is the same thing, parallel to *eg*; this line marks on the scale of lading the weight, which must be put on board to bring down the ship to the line *ab*, namely, 175 Swedish lasts.

(183.) If the ship be quite light, one may in this manner find the lading, which it can take; or if the water-line of a ship has been once observed, supposing another to be found, one may be able, by means of the said scale, to obtain the weight which the ship has taken on board, or of which it has been discharged, to render it so much more brought down, or more raised.

If similar scales were made by builders for all ships and vessels constructed by them, the owner or commander would have it always in his power to determine the lading he could take on board, and that with such exactness as not to be deceived one last in the largest ship, when the load water-line was determined.

This scale is particularly necessary for ships of war or privateers, to the end that knowing the quantity of provisions and other stores, which they can take, the ballast may be determined, which they can receive without being brought down farther than the load water-line.



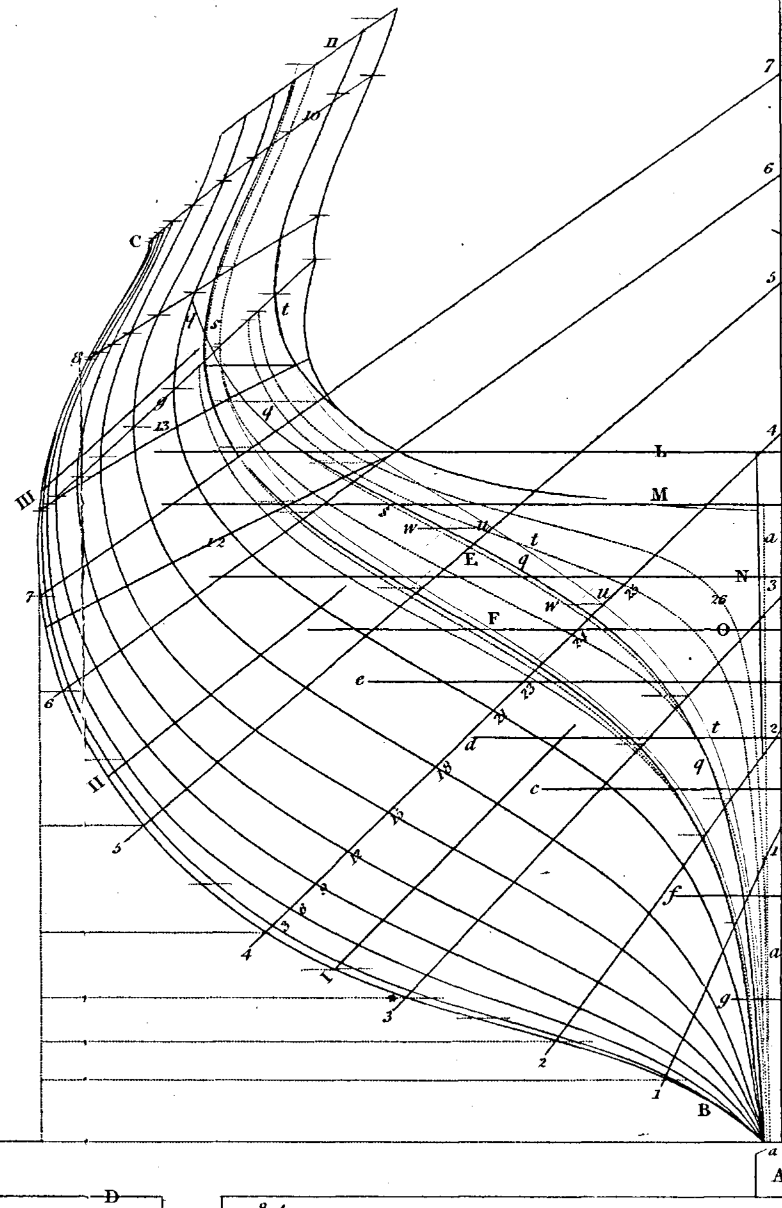
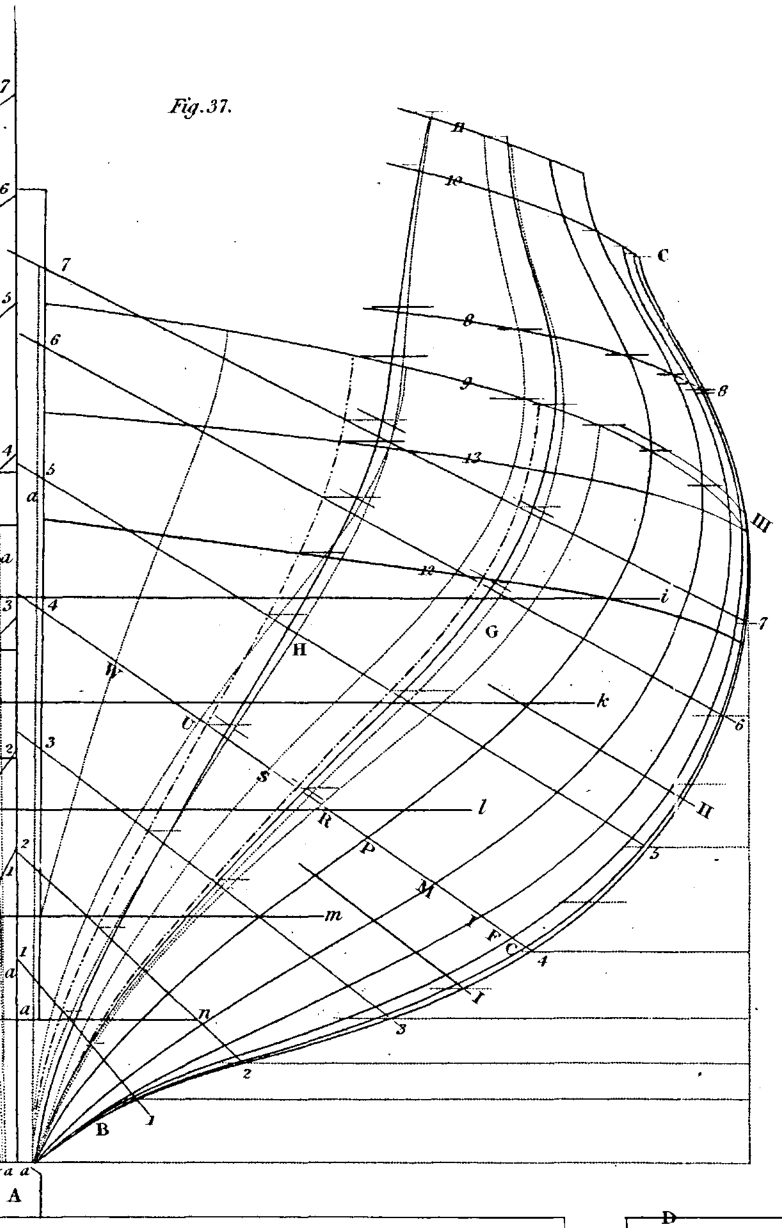
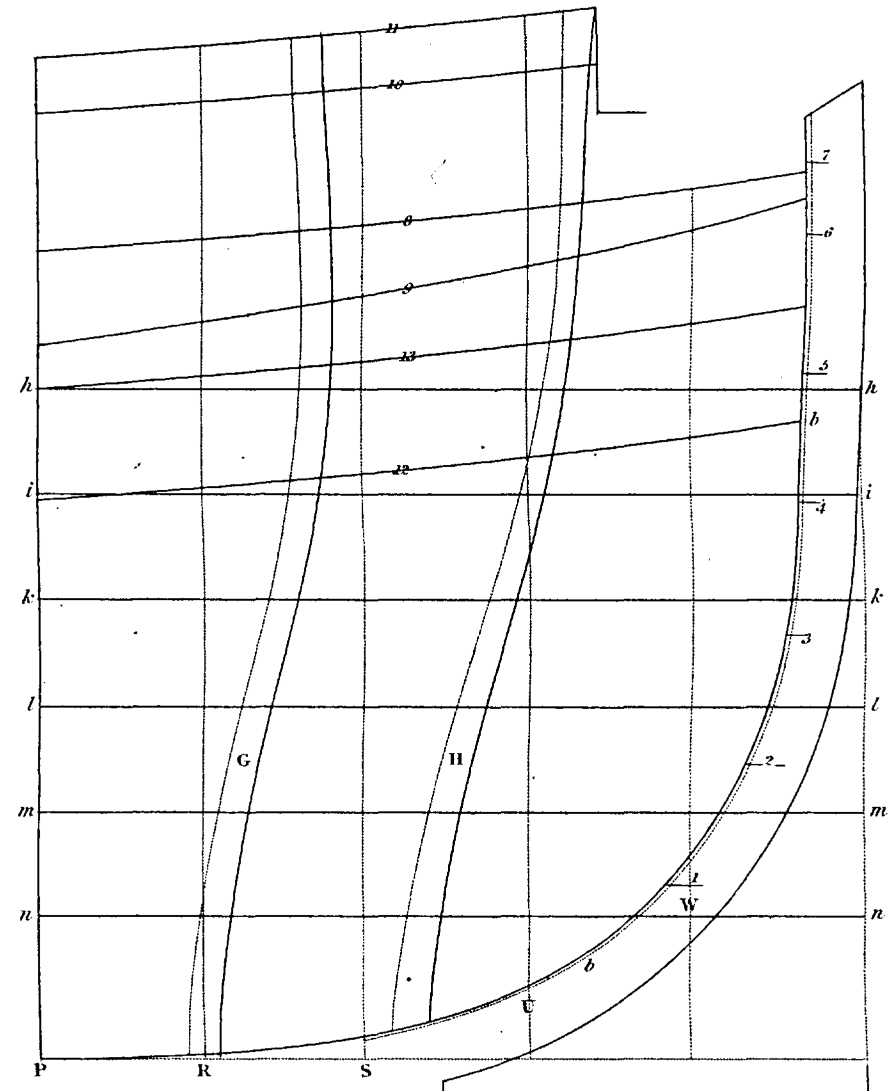
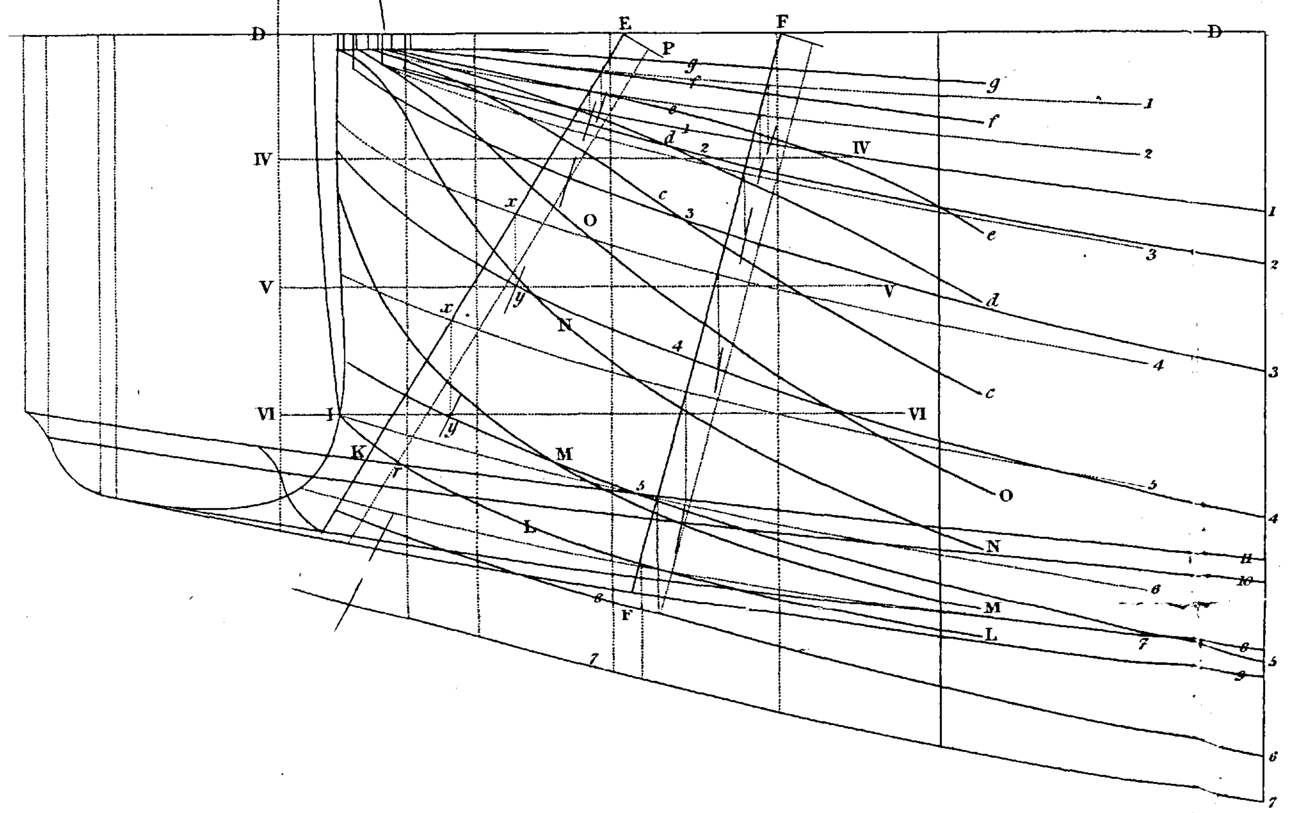
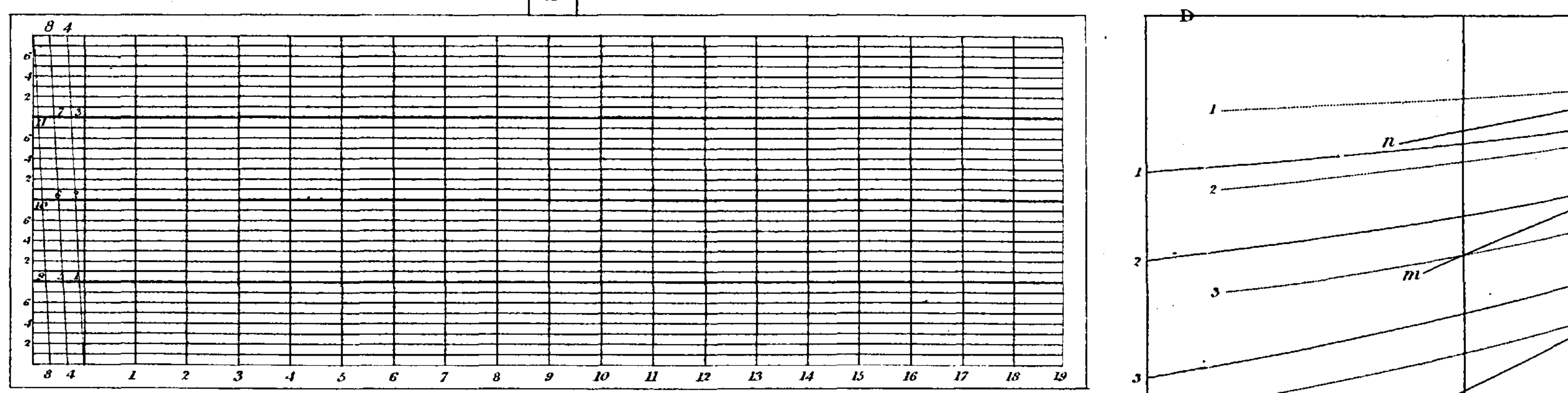


Fig. 37.









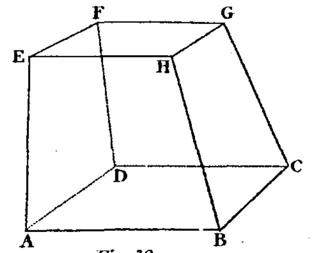


Fig. 30.

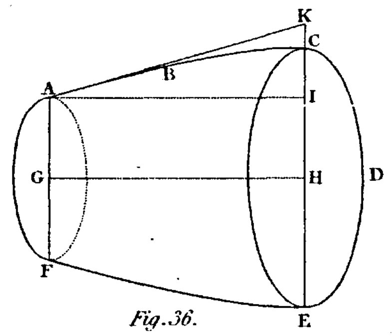
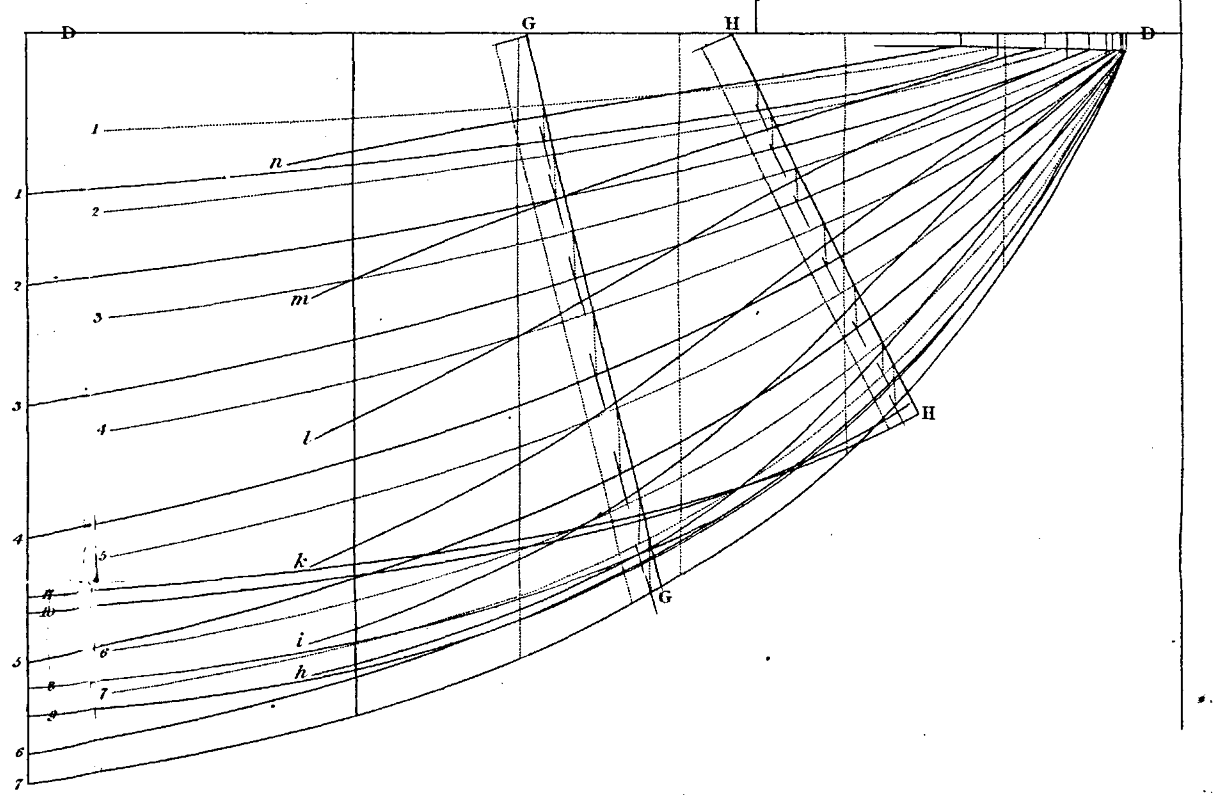


Fig. 36.



Lowry sculp.

CHAP. X.

ON THE PROPERTY IN SHIPS OF BEING ARDENT.

(184.) In sailing by the wind, some ships are more, some less, and some not at all inclined, to turn to the wind; that is, some ships are more and some less ardent; this may proceed from an increase of sail at one, or a diminution of sail at the other end of the ship, which carries the center of gravity of the canvass more towards one or the other extremity.

There are, however, ships of such a form, that they always are ardent, although the center of gravity of the sails be carried farther forward. There are others, which are slack, or with difficulty are brought to the wind, although the said center of the sails be carried farther aft.

No other forces act on the ship, except the air in motion, and the water, that is to say, the wind on the sails, and the water on the bottom of the ship; and since the disposition of the sails alone cannot produce or prevent the tendency to come to the wind, its cause must proceed from the effect of the water against the bottom.

(185.) Let us consider, for a moment, a ship with relation only to its weight, and suppose it to have a body of an indeterminate form, whose weight is collected nearly round the center of gravity. Let the body be moved in the water with a certain velocity. Suppose another force to act in the contrary direction to the motion of the body, not in a line passing through the center of gravity, but a little on one side of it; this body will be forced to turn round its center of gravity, or round a point very near it, and the effect of this force, as to the motion of rotation, will be proportional to the distance of the line, in which this force acts, from the center of gravity. This does not need demonstration, being one of the well known laws of mechanics.

(186.) When a ship sails by the wind, and the resultant of the force of the wind on the sails passes through the vertical line, in which the center of gravity of the ship is, then the water has the same effect on the ship, as the force of which we have just spoken on the supposed body: for if the resultant of the resistance of the water passes on one side or the other of the center of gravity of the ship, it cannot fail to become ardent or slack; ardent, if this resultant pass before the center of gravity; slack, if it pass behind.

This rotatory motion to one side or the other, may be prevented by making the resultant of the force of the wind on the sails pass through the vertical line, through which the resultant of the resistance of the water also passes. The disposition of the sails should always be regulated by this effect; but as transferring the center of gravity of the sails towards either of the extremities is confined within certain limits determined by other considerations, the resultant of the resistance must therefore have likewise its limits, which it cannot go beyond; and as this property of a ship is of very great importance, it is necessary to find the resultant of the resistance, in order to change the form of the bottom, if it does not pass in the proper direction.

This resultant can be found in no other way, than by the effects of the direct, lateral, and vertical efforts of the water's resistance, against all that part of the ship, which is in the water; but it must be observed, that as we consider here the rotation only in a horizontal plane, we need take into account only the direct and lateral forces, which alone are effectual in this respect.

(187.) When the wind is aft, the lateral forces on each side are equal. In this case they need not be taken into consideration. But when the ship sails by the wind, the sails are trimmed obliquely with respect to the middle line of the ship lengthwise, and part of the force of the wind is employed in impelling the ship sideways, at the same time that it impels the ship forward. The ship has such a form, that the resistance to the motion forward is less than the resistance to the motion sideways, and the direction of the course is neither parallel to the middle line, nor perpendicular to it: the ship does not make way as it lies up, it goes on a line, which is called the line of lee-way.

(188.) The lateral effort of the resistance of the water is no longer therefore equal on both sides; it is greater on the lee-side than on the weather-side; so that, if one be subtracted from the other, there will remain the lateral resistance, which, with its whole force, acts on the said lee-side. If knowing the point, through which the resultant of the direct and lateral forces pass, as well with respect to one of the extremities, as with respect to the middle line, we form a rectangle of the said forces, its diagonal will be the mean horizontal direction of the water. Upon this direction, the tendency of the ship to turn one way or the other round its center of gravity, as we have already said, depends.

(189.) Seeing therefore what it is that renders a ship more or less ardent, and since by Art. 67. we can obtain the effort of resistance both direct and lateral, it would seem that there was no farther difficulty in determining the mean direction of the water: but the ship having a side wind, not only is inclined on the opposite side with respect to this force, but also, as we have said in the preceding Article, has lee-way; so that, to determine this mean direction, it becomes necessary, either to vary the construction of the forces (Note 54.), or to construct other lines on the ship, which represent it in its new position.

The method of determining the mean direction by lines projected on the ship, in its new situation being the most easy and clear, I shall give here an example of it, with the calculations which lead to the solution of this question.

(190) To find the mean direction of the resistance of the water on the bottom of the privateer Fig. 47, 48, and 49, sailing with a side wind.

To determine this mean direction, it is necessary to project the ship, as it would appear in its inclined situation to a spectator placed in the direction of its track, or in its line of lee-way (Note 55.).

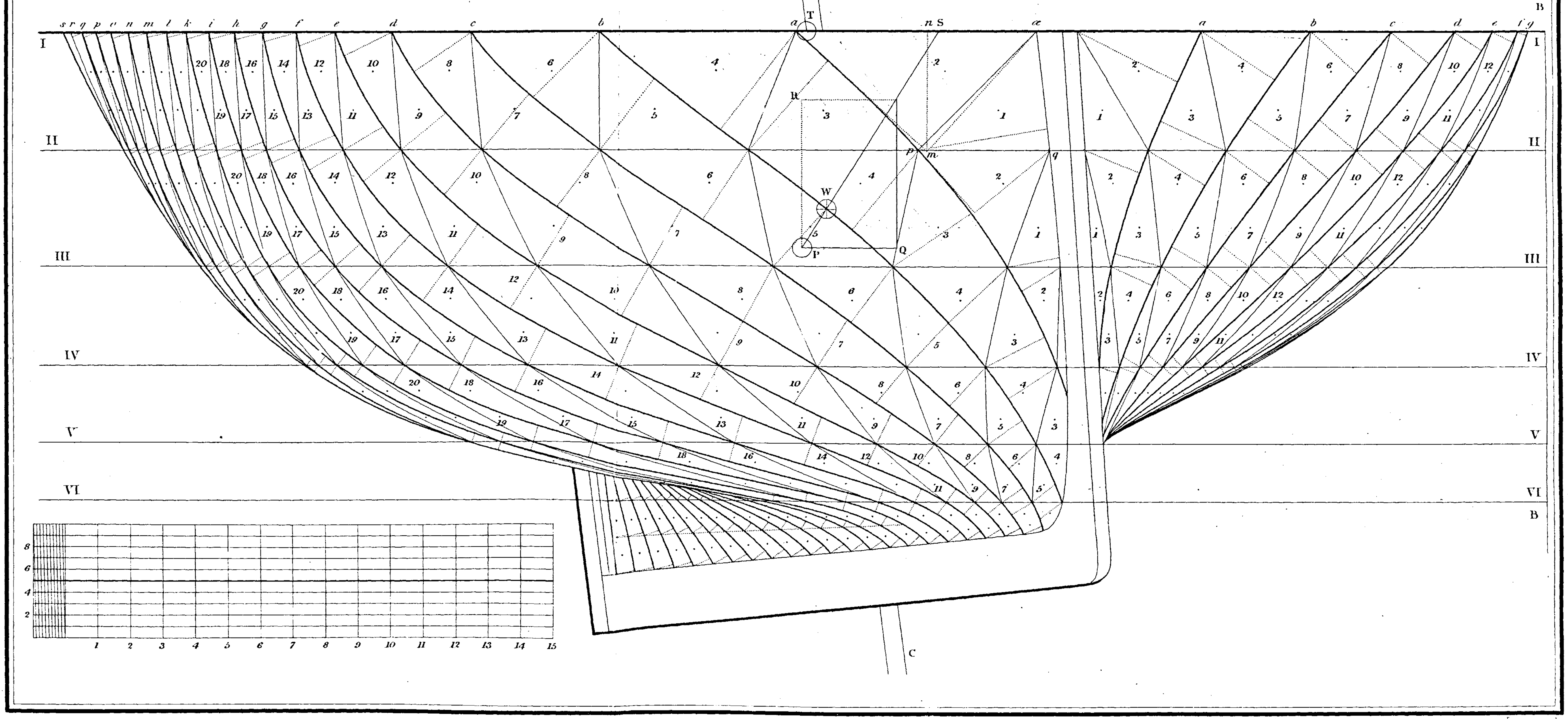
When a ship sails by the wind, it is inclined on the side opposite to the wind, and this inclination is greater or less, according as the force of the wind is greater or less. It is necessary therefore to make some supposition. Let the inclination be 7 degrees, and the lee-way half a point, or $5^\circ.\ 37'\frac{1}{2}$.

That we may be enabled to represent a ship at such an inclination, and with such an oblique course, it is necessary to draw a great number of water-lines on the body plan (Note 56.). In order that the construction of the forces and the measurement on the scale may be made with great exactness, I have made Figures 38 and 39 (in this situation of inclination and obliquity) of a size double that of the plan of the ship for which they are constructed. Figure 38 represents the whole of the bottom forward. T is the center of gravity of the privateer; W that of the displacement, the ship being upright. Fig. 39 represents the whole of the bottom aft. The sections aa, bb, cc, and $\beta\beta$, zz, yy, &c. (Fig. 38 and 39.) are not perpendicular to the middle line or axis of the ship, but to the line of lee-way CC Fig. 40; and the distance between these transverse sections should be divisible without a remainder by the numbers two or three, for the purpose of determining the area and position of the center of gravity of each triangle.

In the Figures 38 and 39 the water-lines II, III, IV, V, and VI, are drawn at pleasure below the load water-line I; but so that the distance between them may be a multiple of 2 or 3, to avoid the accumulation of figures in the calculation of the areas of the triangles, and of the moment of the forces on each of them.

All the spaces $æapq$ are divided (Fig. 38.), into two triangles by the line $æp$, afterwards between all the sections and water-lines are drawn the

Fig. 38.



Lowry sculp.

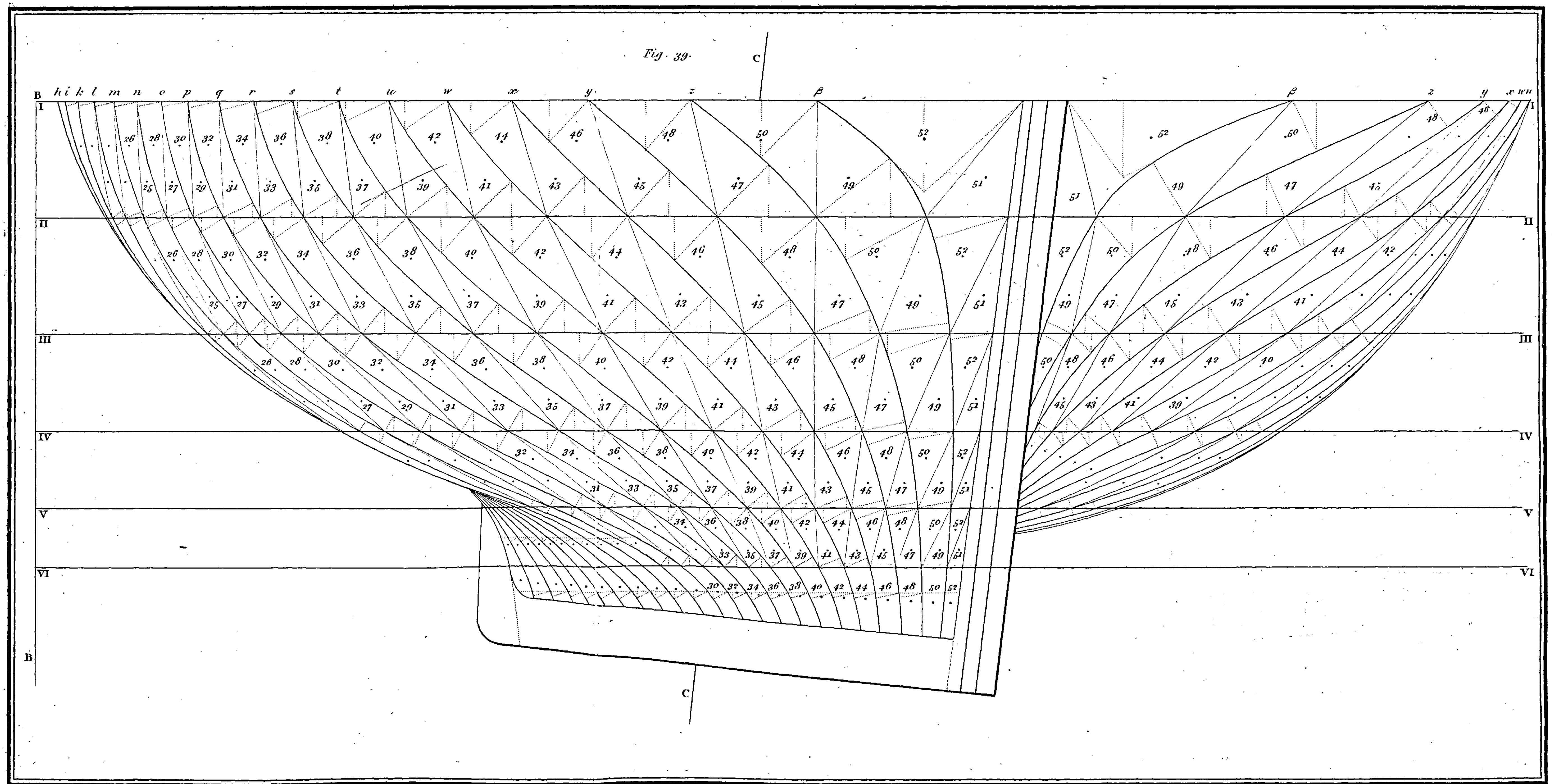


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Fig. 41.

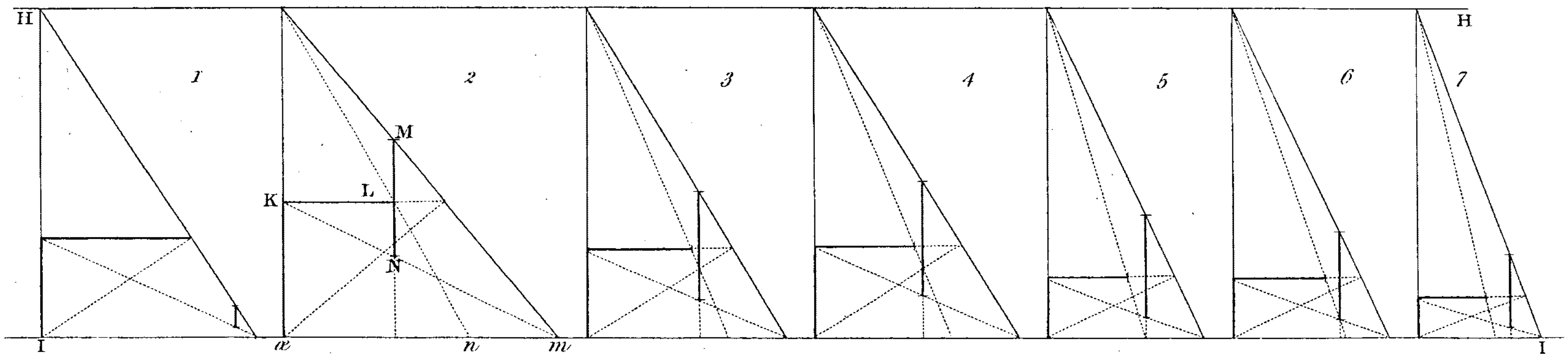
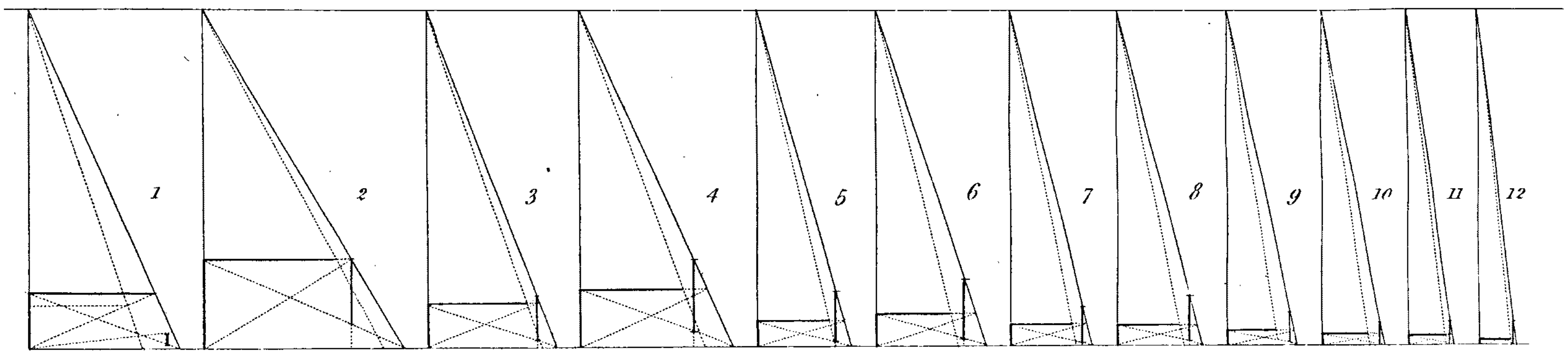


Fig. 42.



Lenty Sc.

perpendiculars $æm$, mn, &c. which are necessary in order to determine the forces, and the centers of gravity of the triangles $æpq$, $æap$, are marked, as in Figure 20, according to Articles 69 and 70.

Somewhere without the plan, a line BB is drawn perpendicular to the water-lines; the distance of the center of gravity of each triangle from this line is measured.

The distances $æm$, mn, and $æn$ are taken, and transferred between the two parallel lines HH, II, Fig. 41; whose distance is equal to the distance between the sections, that is, to twice the distance between the sections aa, bb, &c. Fig. 40. The direct resistances $æK$ (Fig. 41.), the lateral ones KL, and the vertical ones MN, are found by a construction similar to that by which these forces were determined for Fig. 20.

The triangles Nos. 1, 2, 3, 4, &c. answer to Nos. 1, 2, 3, 4, &c. of Figure 38. Figure 41 corresponds to the lee-side: in Figure 42 the forces are constructed for the weather-side.

The areas of the triangles, the quantities of the forces and the effects of these forces, the distances of the centers of gravity of the triangles from a fixed line, and the products of the effects into these distances or the moments, are all collected in the following order.

Calculation for the Fore Part of the Ship (Fig. 38.).

Direct forces on the lee-side, and their distances from the line BB.

Between the water-lines I *and* II.

No.	Areas of the triangles.	Direct forces	Effects.	Distance of the center of gravity from the line *BB*.	Moments.
1	8,87	1,82	16,14	16,75	270,34
2	13,14	2,43	31,93	19,28	615,61
3	9,37	1,68	15,74	22,24	350,05
4	11,12	1,73	19,23	25,58	491,90
5	8,35	1,10	9,18	27,64	253,73
6	7,03	1,15	8,08	30,59	247,16
7	6,42	0,74	4,75	31,79	150,00
8	4,33	0,66	2,85	33,90	96,61
9	4,50	0,51	2,29	34,60	79,23
10	3,21	0,45	1,44	36,09	51,96
11	3,20	0,35	1,12	36,58	40,96
12	2,23	0,26	0,58	37,62	21,81
13	2,35	0,24	0,56	38,02	21,29
14	1,80	0,19	0,34	38,81	13,19
15	1,76	0,17	0,30	39,09	11,72
16	1,58	0,15	0,24	39,75	9,54
17	1,49	0,13	0,19	40,00	7,60
18	1,33	0,11	0,14	40,57	5,67
19	1,33	0,09	0,12	40,72	4,88
20	1,22	0,08	0,09	41,30	3,71
21	1,20	0,07	0,08	41,43	3,31
22	1,09	0,07	0,07	41,94	2,93
23	0,99	0,06	0,06	42,07	2,52
24	1,06	0,06	0,06	42,54	2,55
25	0,88	0,05	0,04	42,62	1,70
26	0,99	0,05	0,05	43,10	2,15
27	0,68	0,04	0,03	43,09	1,29
28	0,93	0,04	0,04	43,57	1,74
29	0,61	0,03	0,02	43,50	0,87
30	0,81	0,03	0,02	44,04	0,88
31	0,43	0,03	0,01	43,88	0,43
32	0,70	0,02	0,01	44,44	0,44
		Effects . . .	115,80	Mom.	2767,77

Between the water-lines II *and* III.

No.	Areas of the triangles.	Direct forces.	Effects.	Distance of the center of gravity from the line *BB*.	Moments.
1	2,80	1,24	3,47	15,65	54,38
2	8,87	1,64	14,54	17,02	247,47
3	6,30	1,19	7,49	18,61	139,38
4	9,37	1,40	13,11	21,29	279,11
5	6,53	0,82	5,35	22,75	121,71
6	8,35	0,93	7,76	25,83	200,44
7	6,91	0,69	4,76	26,80	127,56
8	6,43	0,73	4,69	29,96	140,51
9	6,31	0,52	3,28	30,57	100,26
10	4,50	0,53	2,38	33,19	78,99
11	4,80	0,39	1,87	33,55	62,73
12	3,20	0,38	1,21	35,44	42,88
13	3,58	0,30	1,07	35,65	38,14
14	2,36	0,26	0,61	37,16	22,66
15	2,50	0,20	0,50	37,24	18,62
16	1,76	0,19	0,33	38,39	12,66
17	2,05	0,15	0,30	38,37	11,51
18	1,49	0,12	0,18	39,33	7,07
19	1,67	0,11	0,18	39,30	7,07
20	1,33	0,10	0,13	40,15	5,21
21	1,26	0,08	0,10	40,10	4,01
22	1,21	0,09	0,10	40,85	4,08
23	0,93	0,06	0,05	40,77	2,03
24	0,99	0,06	0,05	41,49	2,07
25	0,70	0,04	0,02	41,29	0,82
26	0,88	0,05	0,04	41,98	1,67
27	0,63	0,04	0,02	41,71	0,83
28	0,68	0,05	0,03	42,39	1,27
		Effects . . .	73,62	Mom.	1735,06

Direct forces on the lee-side, and their distances from the line BB.

Between the water-lines III *and* IV.						*Between the water-lines* IV *and* V.					
No.	Areas of the triangles.	Direct forces.	Effects.	Distance of the center of gravity from the line *BB*.	Moments.	No.	Areas of the triangles.	Direct forces.	Effects.	Distance of the center of gravity from the line *BB*.	Moments.
1	0,43	0,40	0,17	15,01	2,55	3	1,17	0,30	0,35	15,26	5,34
2	2,34	1,03	2,41	15,55	37,47	4	2,71	0,53	1,43	16,10	23,03
3	3,39	0,64	2,17	16,36	35,50	5	1,80	0,30	0,54	16,82	9,08
4	5,25	0,89	4,67	17,95	83,82	6	2,94	0,42	1,23	18,18	22,36
5	3,67	0,56	2,05	19,08	39,11	7	1,92	0,24	0,46	18,67	8,58
6	5,44	0,68	3,70	21,20	78,44	8	3,20	0,31	0,99	20,40	20,19
7	4,00	0,44	1,76	21,98	38,68	9	2,13	0,20	0,42	20,70	8,69
8	5,76	0,56	3,22	24,59	79,17	10	3,63	0,29	1,06	22,89	24,26
9	4,54	0,37	1,68	25,22	42,37	11	2,30	0,16	0,36	22,94	8,25
10	5,26	0,48	2,52	28,19	71,03	12	3,75	0,25	0,94	25,67	24,12
11	4,69	0,32	1,50	28,51	32,76	13	2,55	0,13	0,33	25,48	8,40
12	4,00	0,38	1,52	31,36	47,66	14	3,26	0,19	0,62	28,57	17,71
13	4,08	0,27	1,10	31,46	34,60	15	2,77	0,13	0,36	28,09	10,11
14	2,98	0,27	0,80	33,80	27,04	16	2,52	0,19	0,48	31,11	14,93
15	3,15	0,20	0,63	33,74	21,25	17	2,59	0,09	0,23	30,36	6,98
16	2,08	0,20	0,41	35,59	14,59	18	1,95	0,12	0,23	33,05	7,60
17	2,44	0,14	0,34	35,39	12,03	19	2,25	0,08	0,18	32,29	5,81
18	1,71	0,13	0,22	36,95	8,12	20	1,56	0,10	0,15	34,59	5,18
19	1,95	0,12	0,23	36,69	8,43	21	1,51	0,06	0,09	33,77	3,03
20	1,39	0,11	0,15	38,09	5,71	22	1,00	0,07	0,07	35,67	2,49
21	1,26	0,09	0,11	37,78	4,15	23	0,88	0,04	0,03	34,65	1,03
22	1,05	0,09	0,09	38,97	3,50	24	0,66	0,05	0,03	36,42	1,09
23	0,82	0,04	0,03	38,54	1,15				Effects . . . 10,58		Mom. 238,25
24	0,78	0,05	0,03	39,58	1,18						
25	0,51	0,03	0,01	39,02	0,39						
26	0,58	0,04	0,02	40,04	0,80						
			Effects . . . 31,54		Mom. 731,50						

Direct forces on the lee-side and their distances from the line BB.

Between the water-lines V *and* VI.

No.	Areas of the triangles.	Direct forces.	Effects.	Distance of the center of gravity from the line *BB*.	Moments.
4	0,88	0,29	0,25	15,22	3,80
5	0,82	0,15	0,12	15,58	1,86
6	1,35	0,21	0,28	16,36	4,58
7	0,79	0,09	0,07	16,70	1,16
8	1,44	0,17	0,24	17,76	4,26
9	0,80	0,08	0,06	17,79	1,06
10	1,60	0,13	0,21	19,05	4,00
11	0,90	0,08	0,07	18,98	1,32
12	1,73	0,10	0,17	20,59	3,50
13	0,83	0,05	0,04	20,29	0,81
14	1,92	0,07	0,13	22,21	2,88
15	0,85	0,03	0,02	21,57	0,43
16	2,08	0,06	0,12	24,00	2,88
17	0,99	0,03	0,03	22,96	0,66
18	1,94	0,04	0,07	26,00	1,82
19	0,98	0,02	0,01	24,63	0,24
20	1,69	0,03	0,05	27,94	1,39
21	0,79	0,02	0,01	26,14	0,26
22	1,13	0,02	0,02	29,49	0,58
23	0,65	0,02	0,01	27,42	0,27
24	0,66	0,02	0,01	30,48	0,30
		Effects . . .	1,99	Mom.	38,06

Below the water-line VI.

No.	Areas of the triangles.	Direct forces.	Effects.	Distance of the center of gravity from the line *BB*.	Moments.
6	0,39	0,14	0,05	15,46	0,77
7	0,27	0,09	0,02	15,89	0,31
8	0,40	0,11	0,04	16,33	0,65
9	0,29	0,09	0,02	16,64	0,33
10	0,43	0,09	0,03	17,10	0,51
11	0,31	0,07	0,02	17,24	0,34
12	0,52	0,07	0,03	17,82	0,53
13	0,33	0,05	0,01	17,93	0,17
14	0,51	0,05	0,02	18,75	0,37
15	0,35	0,04	0,01	18,58	0,18
16	0,55	0,04	0,02	19,48	0,38
17	0,37	0,04	0,01	19,20	0,19
18	0,67	0,04	0,02	20,36	0,40
19	0,38	0,04	0,01	19,80	0,19
Carried over effects			0,31	Mom. .	5,32

Below the water-line VI.

No.	Areas of the triangles.	Direct forces.	Effects.	Distance of the center of gravity from the line *BB*.	Moments.
Brought over effects. .			0,31	Mom. .	5,32
20	0,69	0,03	0,02	21,27	0,42
21	0,41	0,04	0,01	20,43	0,20
22	0,45	0,03	0,01	21,72	0,21
23	0,44	0,04	0,01	21,05	0,21
24	0,46	0,03	0,01	22,23	0,22
25	0,46	0,04	0,01	21,64	0,21
26	0,36	0,03	0,01	22,98	0,22
27	0,48	0,04	0,01	22,29	0,22
28	0,38	0,03	0,01	23,59	0,23
29	0,48	0,04	0,01	22,86	0,22
30	0,38	0,03	0,01	24,17	0,24
31	0,47	0,04	0,01	23,47	0,23
32	0,37	0,03	0,01	24,67	0,24
33	0,47	0,04	0,01	24,06	0,24
34	0,37	0,03	0,01	25,13	0,25
35	0,48	0,04	0,02	24,58	0,49
36	0,36	0,03	0,01	25,56	0,25
37	0,48	0,04	0,02	25,17	0,50
38	0,36	0,03	0,01	25,95	0,25
39	0,49	0,05	0,02	25,68	0,51
40	0,40	0,04	0,01	26,39	0,26
41	0,50	0,05	0,02	26,26	0,52
42	0,41	0,04	0,01	26,82	0,26
43	0,53	0,05	0,02	26,79	0,53
44	0,45	0,04	0,01	27,29	0,27
45	0,56	0,05	0,02	27,35	0,54
46	0,43	0,04	0,01	27,72	0,27
47	0,59	0,05	0,02	27,88	0,55
48	0,47	0,04	0,01	28,15	0,28
49	0,62	0,05	0,02	28,45	0,85
50	0,56	0,04	0,01	28,62	0,57
51	0,50	0,01	0,00	28,91	0,00
keel	26,16	0,07	1,83	21,50	39,34
sternp[t].	0,83	0,07	0,05	29,25	1,46
rud.	2,00	0,07	0,14	29,43	4,12
stem	9,80	0,14	1,37	14,75	20,20
gripe	7,50	6,00	45,00	14,26	64,70
		Effects	49,12	Mom.	722,60

Direct forces on the weather-side, and their distances from the line BB.

Between the water-lines I *and* II.

No.	Areas of the triangles.	Direct forces.	Effects.	Distance of the center of gravity from the line *BB*.	Moments.
1	3,78	1,07	4,04	13,64	55,10
2	6,98	1,57	10,95	12,40	135,78
3	4,30	0,72	3,09	10,84	33,49
4	5,92	1,02	6,03	9,23	55,65
5	3,72	0,45	1,67	8,28	13,82
6	4,53	0,59	2,67	6,59	17,59
7	3,29	0,34	1,11	6,14	6,81
8	3,33	0,35	1,16	4,48	5,19
9	2,70	0,25	0,67	4,35	3,01
10	2,28	0,22	0,50	2,89	1,44
11	2,07	0,14	0,08	3,00	0,24
12	1,33	0,10	0,13	1,86	0,24
13	1,26	0,07	0,08	2,06	0,16
14	0,61	0,04	0,02	1,22	0,02
15	0,54	0,03	0,01	1,60	0,01
		Effects	32,21	Mom.	328,55

Between the water-lines II *and* III.

No.	Areas of the triangles.	Direct forces.	Effects.	Distance of the center of gravity from the line *BB*.	Moments.
1	1,26	0,37	0,46	13,88	6,38
2	3,78	0,89	3,35	13,28	44,48
3	2,62	0,34	0,89	12,46	11,08
4	4,30	0,61	2,62	11,30	29,60
5	2,61	0,29	0,75	10,69	8,01
6	3,72	0,41	1,52	9,33	14,18
7	2,43	0,23	0,55	9,08	4,99
8	3,29	0,32	1,05	7,53	7,90
9	2,25	0,19	0,42	7,57	3,17
10	2,70	0,26	0,70	6,00	4,20
11	2,07	0,14	0,29	6,29	1,92
12	2,07	0,16	0,33	4,68	1,54
13	1,49	0,08	0,11	5,16	0,56
14	1,26	0,08	0,10	3,71	0,37
15	1,06	0,05	0,05	4,38	0,21
16	0,54	0,04	0,02	3,17	0,06
17	0,61	0,03	0,01	3,90	0,03
		Effects	13,22	Mom.	138,68

Between the water-lines III *and* IV.

No.	Areas of the triangles.	Direct forces.	Effects.	Distance of the center of gravity from the line *BB*.	Moments.
2	1,05	0,37	0,38	13,75	5,22
3	1,08	0,13	0,14	13,48	1,88
4	2,19	0,30	0,65	12,78	8,30
5	1,06	0,10	0,10	12,48	1,24
6	2,17	0,23	0,50	11,59	5,79
7	1,02	0,07	0,07	11,54	0,80
8	2,02	0,18	0,36	10,40	3,74
9	0,94	0,06	0,05	10,65	0,53
10	1,87	0,14	0,26	09,32	2,42
11	0,85	0,05	0,04	09,82	0,39
12	1,72	0,12	0,20	08,26	1,67
13	0,76	0,04	0,03	09,00	0,27
14	1,34	0,08	0,10	07,42	0,74
15	0,61	0,03	0,01	08,38	0,08
16	0,88	0,05	0,04	06,77	0,27
17	0,39	0,02	0,01	07,91	0,07
18	0,51	0,03	0,01	06,31	0,06
		Effects	2,95	Mom.	33,47

Between the water-lines IV *and* V.

No.	Areas of the triangles.	Direct forces.	Effects.	Distance of the center of gravity from the line *BB*.	Moments.
4	0,86	0,08	0,06	13,60	0,81
6	0,85	0,08	0,06	13,11	0,78
8	0,81	0,07	0,05	12,57	0,62
10	0,75	0,06	0,04	12,15	0,48
12	0,68	0,05	0,03	11,76	0,35
14	0,61	0,04	0,02	11,40	0,22
16	0,49	0,03	0,01	11,14	0,11
18	0,31	0,02			
		Effects	0,27	Mom.	3,37

Sum of the direct forces and of the moments from the line BB.

Effects.	Moments.
115,80	2767,77
73,62	1735,06
31,54	731,50
10,58	238,25
1,99	38,06
49,12	722,60
32,21	328,55
13,22	138,68
2,95	33,47
0,27	3,37
331,30	6737,31

Lateral forces on the lee-side, and their distances from the line AA.

Between what water-lines.	No.	Areas of the triangles.	Lateral forces.	Effects.	No.	Areas of the triangles.	Lateral forces.	Effects.	No.	Areas of the triangles.	Lateral forces.	Effects.
Between I & II	3	9,37	1,84	17,24	4	11,12	1,69	18,78	5	8,35	1 43	11,94
II & III	3	6,30	1,91	12,03	4	9,37	1,54	14,43	5	6,53	1,36	8,88
III & IV	3	3,39	1,68	5,69	4	5,25	1,51	7,92	5	3,67	1,33	4,88
IV & V	3	1,17	1,18		4	2,71	1,37	3,71	5	1,80	1,07	1,92
V & VI	3				4				5	0,82	0,78	0,64
Effects				34,96				44,84				28,26
Dist. of center of gravity from the line *AA*				8				10				14
Moments				279,68				448,40				395,64
Between I & II	6	7,03	1,65	11,59	7	6,42	1,20	7,70	8	4,33	1,55	6,71
II & III	6	8,35	1,20	10,02	7	6,91	1,05	7,25	8	6,43	1,20	7,71
III & IV	6	5,44	1,15	6,25	7	4,00	0,96	3,84	8	5,76	0,90	5,18
IV & V	6	2,94	1,02	3,00	7	1,92	0,76	1,46	8	3,20	0,73	2,33
V & VI	6	1,35	0,84	1,13	7	0,79	0,59	0,46	8	1,44	0,59	0,85
Effects				31,99				20,71				22,78
Dist. of center of gravity from the line *AA*				16				20				22
Moments				511,84				414,20				501,16

Lateral forces on the lee-side, and their distances from the line AA.

Between what water-lines.	No.	Areas of the triangles.	Lateral forces.	Effects.	No.	Areas of the triangles.	Lateral forces.	Effects.	No.	Areas of the triangles.	Lateral forces.	Effects.
Between I & II	9	4,50	1,24	5,58	10	3,21	1,35	4,33	11	3,20	1,17	3,74
II & III	9	6,31	0,90	5,68	10	4,50	1,23	5,53	11	4,80	0,91	4,36
III & IV	9	4,54	0,74	3,36	10	5,26	0,77	4,05	11	4,69	0,59	2,76
IV & V	9	2,13	0,59	1,15	10	3,63	0,58	2,10	11	2,30	0,39	0,89
V & VI	9	0,80	0,43	0,34	10	1,60	0,42	0,67	11	0,90	0,33	0,29
Effects				16,11				16,68				12,04
Dist. of center of gravity from the line *AA*				26				28				32
Moments				418,86				467,04				385,28
Between I & II	12	2,23	1,04	2,32	13	2,35	1,02	2,39	14	1,80	0,89	1,60
II & III	12	3,20	1,10	3,52	13	3,58	0,87	3,11	14	2,36	0,94	2,21
III & IV	12	4,00	0,81	3,24	13	4,08	0,51	2,08	14	2,98	0,75	2,23
IV & V	12	3,75	0,47	1,76	13	2,55	0,31	0,79	14	3,26	0,40	1,30
V & VI	12	1,73	0,29	0,50	13	0,83	0,22	0,18	14	1,92	0,23	0,44
Effects				11,34				8,55				7,78
Dist. of center of gravity from the line *AA*				34				38				40
Moments......				385,56				324,90				311,20
Between I & II	15	1,76	0,83	1,46	16	1,58	0,80	1,26	17	1,49	0,72	1,04
II & III	15	2,50	0,76	1,90	16	1,76	0,78	1,37	17	2,05	0,69	1,41
III & IV	15	3,15	0,55	1,73	16	2,08	0,63	1,31	17	2,44	0,53	1,29
IV & V	15	2,77	0,25	0,69	16	2,52	0,40	1,00	17	2,59	0,22	0,56
V & VI	15	0,85	0,15	0,12	16	2,08	0,17	0,35	17	0,99	0,13	0,12
Effects.........				5,90				5,29				4,42
Dist. of center of gravity from the line *AA*				44				46				50
Moments......				259,60				243,34				221,00
Between I & II	18	1,33	0,71	0,94	19	1,33	0,69	0,91	20	1,22	0,65	0,79
II & III	18	1,49	0,66	0,98	19	1,67	0,64	1,06	20	1,33	0,60	0,79
III & IV	18	1,71	0,59	0,98	19	1,95	0,47	0,91	20	1,39	0,58	0,80
IV & V	18	1,95	0,35	0,68	19	2,25	0,22	0,49	20	1,56	0,36	0,56
V & VI	18	1,94	0,15	0,29	19	0,98	0,09	0,08	20	1,69	0,13	0,22
Effects.........				3,87				3,45				3,16
Dist. of center of gravity from the line *AA*				52				56				58
Moments......				201,24				193,20				183,28

Lateral forces on the lee-side, and their distances from the line AA.

Between what water-lines.	No.	Areas of the triangles.	Lateral forces.	Effects.	No.	Areas of the triangles.	Lateral forces.	Effects.	No.	Areas of the triangles.	Lateral forces.	Effects.
Between I & II	21	1,20	0,65	0,78	22	1,09	0,60	0,65	23	0,99	0,53	0,52
II & III	21	1,26	0,54	0,68	22	1,21	0,57	0,69	23	0,93	0,39	0,36
III & IV	21	1,26	0,35	0,44	22	1,05	0,43	0,45	23	0,82	0,26	0,21
IV & V	21	1,51	0,17	0,25	22	1,00	0,27	0,27	23	0,88	0,11	0,09
V & VI	21	0,79	0,07	0,05	22	1,23	0,10	0,11	23	0,55	0,06	0,03
Effects				2,20				2,17				1,21
Dist. of center of gravity from the line AA				62				64				68
Moments......				136,40				138,88				82,28
Between I & II	24	1,06	0,58	0,61	25	0,88	0,46	0,40	26	0,99	0,53	0,52
II & III	24	0,99	0,46	0,45	25	0,70	0,36	0,25	26	0,88	0,45	0,39
III & IV	24	0,78	0,35	0,27	25	0,51	0,16	0,08	26	0,58	0,25	0,14
IV & V	24	0,66	0,19	0,12	25	0,18	0,02	0,01	26	0,38	0,15	0,05
V & VI	24	0,66	0,07	0,04	25							
Effects				1,49				0,74				1,10
Dist. of center of gravity from the line AA				70				74				76
Moments......				104,30				54,76				83,60
Between I & II	27	0,68	0,37	0,25	28	0,93	0,47	0,43	29	0,61	0,31	0,19
II & III	27	0,63	0,30	0,18	28	0,68	0,39	0,26	29	0,27	0,10	0,02
III & IV	27	0,16	0,03	0,01	28	0,51	0,24	0,12				
Effects				0,44				0,81				0,21
Dist. of center of gravity from the line AA				80				82				86
Moments......				35,20				66,42				18,06
Between I & II	30	0,81	0,40	0,32	31	0,43	0,19	0,08	32	0,70	0,36	0,25
II & III	30	0,61	0,30	0,18	31	0,08	0,01	0,00	32	0,37	0,16	0,05
Effects				0,50				0,08				0,30
Dist. of center of gravity from the line AA				88				92				94
Moments......				44,00				7,36				28,20
Between I & II	33	0,28	0,10	0,02	34	0,61	0,30	0,18				
Effects				0,02				0,18				
Dist. of center of gravity from the line AA				98				100				
Moments.......				1,96				18,00				

Lateral forces on the lee-side, and their distances from the line AA, below the sixth water-line.

No.	Areas of the triangles.	Lateral forces.	Effects.	Distance from the line *AA*.	Moments.
7	0,27	0,49	0,13	20	2,60
9	0,29	0,45	0,13	26	3,38
11	0,31	0,38	0,11	32	3,54
13	0,33	0,31	0,10	38	3,80
15	0,35	0,25	0,08	44	3,52
17	0,37	0,26	0,09	50	4,50
19	0,38	0,22	0,08	56	4,48
21	0,41	0,22	0,09	63	5,67
23	0,44	0,27	0,11	69	7,59
25	0,46	0,25	0,11	75	8,25
27	0,48	0,26	0,12	81	9,72
29	0,48	0,27	0,12	87	10,44
31	0,47	0,28	0,13	93	12,09
33	0,47	0,30	0,14	99	13,86
35	0,48	0,34	0,16	105	16,80
37	0,48	0,36	0,17	111	18,87
39	0,49	0,44	0,21	117	24,57
41	0,50	0,42	0,21	123	25,83
43	0,53	0,52	0,27	129	34,83
45	0,56	0,49	0,27	135	36,45
47	0,59	0,54	0,31	141	43,71
49	0,62	0,59	0,36	147	52,92
51	0,50	0,09	0,04	151,4	6,05
	26,16	0,59	15,43	82	1265,26
	0,83	0,59	0,49	154,4	75,65
	2,00	0,59	1,18	157,8	186,20
	9,80	1,00	9,80	1,76	17,24
		Effects....	30,44	Mom.	1897,82

No.	Areas of the triangles.	Lateral forces.	Effects.	Distance from the line *AA*.	Moments.
6	0,39	0,74	0,28	16	4,48
8	0,40	0,54	0,21	22	4,62
10	0,43	0,41	0,17	28	4,76
12	0,52	0,33	0,17	34	5,78
14	0,51	0,22	0,11	40	4,40
16	0,55	0,20	0,11	46	5,06
18	0,67	0,17	0,11	52	5,72
20	0,69	0,15	0,10	58	5,80
22	0,45	0,14	0,06	63	3,78
24	0,46	0,17	0,07	69	4,83
26	0,36	0,18	0,06	75	4,50
28	0,38	0,17	0,06	81	4,86
30	0,38	0,16	0,06	87	5,22
32	0,37	0,21	0,07	93	6,51
34	0,37	0,23	0,08	99	7,92
36	0,36	0,25	0,09	105	9,45
38	0,36	0,28	0,10	111	11,10
40	0,40	0,32	0,12	117	14,04
42	0,41	0,34	0,13	123	15,99
44	0,45	0,38	0,17	129	21,93
46	0,43	0,41	0,17	135	22,95
48	0,47	0,44	0,20	141	28,20
50	0,56	0,52	0,29	147	42,63
58	0,09	0,09	0,01	93	0,93
60	0,09	0,10	0,01	99	0,99
62	0,10	0,11	0,01	105	1,05
64	0,13	0,12	0,01	111	1,11
66	0,15	0,18	0,02	117	2,34
68	0,17	0,20	0,03	123	3,69
70	0,20	0,27	0,05	129	6,45
72	0,24	0,30	0,07	135	9,45
74	0,25	0,33	0,08	141	11,28
76	0,32	0,43	0,13	147	19,11
		Effects.....	3,41	Mom.	300,93

Between the line AA, and the section (a) of the lee-side.

Between what water-lines.	No.	Areas of the triangles.	Lateral forces.	Effects.	Distance to the line *AA*.	Moments.
1^{st} & 2^{nd}	1	8,87	2,76	24,48	2,00	48,96
	2	13,14	2,00	26,28	4,00	105,12
2^{nd} & 3^{rd}	1	2,80	2,37	6,63	2,75	18,23
	2	8,87	2,03	18,00	4,35	78,30
3^{rd} & 4^{th}	1	0,43	1,46	0,62	3,88	3,40
	2	2,34	2,04	4,77	4,95	22,61
4^{th} & 5^{th}	3	1,17	1,18	1,38	7,35	10,14
5^{th} & 6^{th}	4	0,88	1,16	1,02	9,64	9,83
		Effects		83,18	Mom. ..	296,59

Sum of the lateral forces on the lee-side.

Effects.	Moments.
34,96	279,68
44,84	448,40
28,26	395,64
31,99	511,84
20,71	414,20
22,78	501,16
16,12	419,12
16,68	467,04
12,04	385,28
11,34	385,56
8,55	324,90
7,78	311,20
5,90	259,60
5,29	243,34
4,42	221,00
3,87	201,24
3,45	193,20
3,16	183,28
2,20	136,40
2,17	130,88
1,21	82,28
1,49	104,30
0,74	54,76
1,10	83,60
0,44	35,20
0,81	66,42
0,21	18,06
0,50	44,00
0,08	7,36
0,30	28,20
0,02	1,96
0,18	18,00
30,44	1897,82
3,41	300,93
83,18	296,59
Eff. 410,62	9460,44

Lateral forces on the weather-side, and their distances from the line AA.

Below what water-lines.	No.	Areas of the triangles.	Lateral forces.	Effects.	No.	Areas of the triangles.	Lateral forces.	Effects.	No.	Areas of the triangles.	Lateral forces.	Effetcs.
Between I & II	3	4,30	1,76	7,56	4	5,92	1,86	11,01	5	3,72	1,31	4,87
II & III	3	2,62	1,25	3,27	4	4,30	1,54	6,62	5	2,61	1,06	2,76
III & IV	3	1,08	0,73	0,78	4	2,19	1,14	2,49	5	1,06	0,58	0,61
IV & V	3				4	0,86	0,60	0,51	5			
Effects.........11,61								20,63				8,24
Dist. of center of gravity to the line *AA* 8								10				14
Moments...... 92,88								206,30				115,36
Between I & II	6	4,53	1,37	6,20	7	3,29	1,05	3,45	8	3,33	1,12	3,72
II & III	6	3,72	1,23	4,57	7	2,43	0,80	1,94	8	3,29	0,95	3,12
III & IV	6	2,17	0,91	1,97	7	1,02	0,47	0,48	8	2,02	0,71	1,43
IV & V	6	0,85	0,54	0,46	7				8	0,81	0,42	0,34
Effects.........13,20								5,87				8,61
Dist. of center of gravity to the line *AA* 16								20				22
Moments......211,20								117,40				189,42
Between I & II	9	2,70	0,85	2,29	10	2,28	0,83	1,89	11	2,07	0,66	1,36
II & III	9	2,25	0,66	1,48	10	2,70	0,79	2,13	11	2,07	0,56	1,15
III & IV	9	0,94	0,37	0,34	10	1,87	0,57	1,06	11	0,85	0,27	0,23
IV & V	9				10	0,75	0,28	0,21	11			
Effects......... 4,11								5,29				2,74
Dist. of center of gravity to the line *AA* 26								28				32
Moments......106,86								148,12				87,68
Between I & II	12	1,33	0,58	0,77	13	1,26	0,43	0,54	14	0,61	0,28	0,17
II & III	12	2,07	0,59	1,22	13	1,49	0,39	0,58	14	1,26	0,42	0,14
III & IV	12	1,72	0,45	0,77	13	0,76	0,19	0,14	14	1,34	0,35	0,46
IV & V	12	0,68	0,22	0,14	13				14	0,61	0,20	0,12
Effects 2,90								1,26				0,89
Dist. of center of gravity to the line *AA* 34								38				40
Moments 98,60								47,88				35,60

Lateral forces on the weather-side, and their distances from the line AA.

Between what water-lines.	No.	Areas of the triangles.	Lateral forces.	Effects.	No.	Areas of the triangles.	Lateral forces.	Effects.	No.	Areas of the triangles.	Lateral forces.	Effects.
Between I & II	15	0,54	0,19	0,10	16				17			
II & III	15	1,06	0,30	0,31	16	0,54	0,17	0,09	17	0,61	0,18	0,10
III & IV	15	0,61	0,17	0,10	16	0,88	0,25	0,22	17	0,39	0,10	0,03
IV & V	15				16	0,49	0,14	0,06	17			
Effects..........				0,51				0,37				0,13
Dist. of center of gravity to the line *AA*				44				46				50
Moments.......				22,44				17,02				6,50

Between what water-lines.	No.	Areas of the triangles.	Lateral forces.	Effects.
Between I & II	18			
II & III	18			
III & IV	18	0,51	0,15	0,07
IV & V	18	0,31	0,07	0,02
Effects				0,09
Dist. of center of gravity to the line *AA*				52
Moments........				4,68

Lateral forces on the weather-side, and their distances from the line AA.

Between the line AA and the section a.

Between what water-lines.	No.	Areas of the triangles.	Lateral forces.	Effects.	Dist. from the line *AA*.	Moments.
1st & 2nd	1	3,78	2,28	8,61	2,00	17,22
	2	6,98	3,36	16,47	4,00	65,88
2nd & 3d	1	1,26	1,42	1,78	2,75	4,89
	2	3,78	1,97	7,44	4,35	32,36
3d & 4th	2	1,05	1,21	1,27	4,95	6,28
			Effects....	35,57	Mo.	126,63

Sum of the lateral forces on the weather-side.

Effects.	Moments.
11,61	92,88
20,63	206,30
8,24	115,36
13,20	211,20
5,87	117,40
8,61	189,42
4,11	106,86
5,29	148,12
2,74	87,68
2,90	98,60
1,26	47,88
0,89	35,60
0,51	22,44
0,37	17,02
0,13	6,50
0,09	4,68
35,57	126,63

	Effects	Moments
On the weather-side..........	122,02	1634,57
On the lee-side.............	410,62	9460,44
Remainder of the lateral effects..	288,60 of mom.	7825,87

Calculation for the After Part of the Ship (Fig. 39.).

Direct forces on the weather-side, and their distances from the line BB.

Between the water-lines I *and* II.

No.	Areas of the triangles.	Direct forces	Effects.	Distance of the center of gravity from the line *BB*.	Moments.
20	0,72	0,01	0,01	1,30	0,01
21	0,72	0,02	0,01	2,17	0,02
22	0,90	0,04	0,04	1,65	0,07
23	0,95	0,05	0,05	2,68	0,13
24	1,08	0,06	0,06	2,16	0,13
25	1,30	0,07	0,09	3,36	0,30
26	1,26	0,07	0,09	2,80	0,25
27	1,48	0,10	0,15	4,08	0,61
28	1,35	0,10	0,13	3,51	0,46
29	1,62	0,11	0,18	4,90	0,88
30	1,48	0,12	0,18	4,30	0,77
31	2,16	0,19	0,41	5,90	2,42
32	1,73	0,18	0,31	5,20	1,61
33	2,30	0,22	0,51	7,11	3,63
34	1,98	0,22	0,44	6,25	2,75
35	2,70	0,25	0,67	8,35	5,59
36	2,03	0,21	0,43	7,40	3,18
37	3,06	0,29	0,89	9,90	8,81
38	2,66	0,29	0,77	8,80	6,78
39	3,60	0,36	1,30	11,70	15,21
40	2,81	0,35	0,98	10,35	10,14
41	4,01	0,42	1,68	13,68	22,98
42	3,38	0,42	1,42	12,15	17,25
43	4,57	0,47	2,15	15,93	34,25
44	3,64	0,44	1,60	14,26	22,82
45	5,17	0,56	2,89	18,67	53,96
46	4,32	0,52	2,25	16,53	37,19
47	5,45	0,70	3,81	21,68	82,60
48	5,89	0,69	4,06	19,36	78,60
49	5,94	1,16	6,89	25,20	173,63
50	7,04	0,94	6,62	22,80	150,94
51	4,55	0,95	4,32	29,11	125,75
52	11,11	2,00	22,22	27,30	606,61

Effects . . . 67,61 Mom. 1470,33

Between the water-lines II *and* III.

No.	Areas of the triangles.	Direct forces.	Effects.	Distance of the center of gravity from the line *BB*.	Moments.
22	0,72	0,04	0,03	3,20	0,10
23	0,90	0,07	0,06	4,54	0,27
24	0,95	0,10	0,09	3,60	0,32
25	1,35	0,10	0,13	5,25	0,68
26	1,30	0,12	0,16	4,20	0,67
27	1,87	0,12	0,22	6,15	1,35
28	1,48	0,12	0,18	4,94	0,89
29	2,05	0,13	0,25	7,14	1,78
30	1,62	0,14	0,23	5,80	1,33
31	2,48	0,16	0,40	8,37	3,35
32	2,16	0,20	0,43	6,92	2,98
33	2,88	0,20	0,58	9,80	5,68
34	2,30	0,20	0,46	8,30	3,82
35	3,06	0,20	0,61	11,40	6,95
36	2,70	0,29	0,78	9,80	7,64
37	3,40	0,29	0,99	13,20	13,07
38	3,06	0,30	0,92	11,40	10,49
39	3,67	0,30	1,10	15,16	16,68
40	3,60	0,38	1,37	13,26	18,17
41	2,21	0,38	0,84	17,40	14,62
42	4,01	0,40	1,60	15,35	24,56
43	2,21	0,42	0,93	19,77	18,39
44	4,57	0,50	2,28	17,75	40,47
45	3,78	0,50	1,39	22,18	30,83
46	5,17	0,61	3,15	20,30	63,94
47	3,65	0,59	2,15	24,60	52,89
48	5,45	0,75	4,09	22,90	93,66
49	3,82	0,68	2,60	27,00	70,20
50	5,94	1,10	6,53	25,80	168,47
51	2,34	0,38	0,89	29,00	25,81
52	4,55	1,05	4,78	28,37	135,61

Effects . . . 40,22 Mom. 835,67

Direct forces on the aft part on the weather-side, and their distances from the line BB.

Between the water-lines III *and* IV.

No.	Areas of the triangles.	Direct forces.	Effects.	Distance of the center of gravity from the line *BB*.	Moments.
23	0,55	0,01	0,01	8,00	0,08
24	0,75	0,03	0,02	6,53	0,13
25	1,25	0,03	0,04	8,80	0,35
26	1,12	0,06	0,07	7,15	0,50
27	1,65	0,07	0,11	9,85	1,08
28	1,53	0,08	0,12	8,08	0,97
29	1,78	0,07	0,12	11,00	1,32
30	1,71	0,10	0,17	9,20	1,56
31	2,13	0,12	0,26	12,30	3,20
32	2,07	0,17	0,35	10,30	3,60
33	2,17	0,17	0,37	13,96	5,16
34	2,40	0,20	0,48	11,95	5,74
35	2,29	0,18	0,41	15,45	6,33
36	2,55	0,20	0,51	13,60	6,94
37	2,40	0,20	0,48	17,20	8,26
38	2,83	0,20	0,57	15,30	8,72
39	2,31	0,20	0,46	19,00	8,74
40	3,06	0,29	0,89	17,16	15,27
41	2,31	0,30	0,69	20,80	14,41
42	1,85	0,35	0,65	19,17	12,46
43	2,29	0,34	0,78	22,60	17,63
44	1,85	0,38	0,70	21,20	14,84
45	2,19	0,34	0,74	24,33	18,00
46	3,15	0,44	1,39	23,10	32,11
47	2,07	0,34	0,70	25,90	18,13
48	3,04	0,45	1,37	25,10	34,39
49	2,07	0,34	0,70	27,50	19,25
50	3,18	0,62	1,97	26,85	52,89
51	1,20	0,22	0,26	28,80	7,49
52	1,95	0,50	0,97	28,50	27,64
	Effects. . . .		16,38	Mom.	347,19

Between the water-lines IV *and* V.

No.	Areas of the triangles.	Direct forces.	Effects.	Distance of the center of gravity from the line *BB*.	Moments.
26	1,00	0,02	0,02	11,70	0,23
27	0,96	0,02	0,02	14,52	0,29
28	1,32	0,04	0,05	12,60	0,63
29	1,12	0,04	0,04	15,60	0,62
30	1,43	0,06	0,09	13,70	1,23
31	1,30	0,05	0,06	16,80	1,01
32	1,70	0,08	0,14	14,90	2,09
33	1,28	0,10	0,13	18,00	2,34
34	1,74	0,10	0,17	16,22	2,76
35	1,27	0,10	0,13	19,25	2,50
36	1,84	0,12	0,22	17,62	3,88
37	1,28	0,11	0,14	20,50	2,87
38	1,92	0,18	0,35	19,00	6,65
39	1,20	0,14	0,17	21,70	3,69
40	1,85	0,19	0,35	20,50	7,17
41	1,32	0,15	0,20	22,90	4,58
42	1,85	0,20	0,37	21,90	8,10
43	1,32	0,20	0,26	24,10	6,27
44	1,84	0,28	0,51	23,30	11,88
45	1,26	0,19	0,24	25,35	6,08
46	1,75	0,28	0,49	24,64	12,07
47	1,20	0,19	0,23	26,50	6,09
48	1,66	0,30	0,50	25,95	12,97
49	1,24	0,18	0,22	27,60	6,07
50	1,66	0,29	0,48	27,25	13,08
51	0,67	0,28	0,19	28,43	5,40
52	0,96	0,41	0,39	28,30	11,04
	Effects		6,16	Mom.	141,59

Direct forces on the aft part of the weather-side, and their distances from the line BB.

Between the water-lines V *and* VI.

No.	Areas of the triangles.	Direct forces.	Effects.	Distance of the center of gravity from the line *BB*.	Moments.
28	0,72	0,01	0,01	17,20	0,17
29	0,56	0,02	0,01	19,24	0,19
30	0,84	0,03	0,02	17,90	0,36
31	0,56	0,03	0,02	20,10	0,40
32	0,97	0,05	0,05	28,90	1,44
33	0,56	0,06	0,03	20,80	0,62
34	0,96	0,07	0,07	19,90	1,39
35	0,56	0,06	0,03	21,60	0,65
36	0,95	0,05	0,05	20,75	1,04
37	0,56	0,06	0,03	22,40	0,67
38	0,96	0,10	0,10	21,60	2,16
39	0,67	0,10	0,07	23,20	1,62
40	0,90	0,08	0,07	22,50	1,57
41	0,67	0,07	0,05	24,10	1,20
42	0,99	0,12	0,12	23,50	2,82
43	0,67	0,09	0,06	25,00	1,50
44	0,99	0,17	0,17	24,40	4,15
45	0,67	0,08	0,05	25,80	1,29
46	0,94	0,17	0,16	25,40	4,06
47	0,67	0,10	0,07	26,70	1,87
48	0,90	0,19	0,17	26,40	4,49
49	0,67	0,10	0,07	27,60	1,93
50	0,93	0,18	0,17	27,30	4,64
51	0,45	0,29	0,13	28,25	3,67
52	0,50	0,31	0,15	28,10	4,21
		Effects. . . .	1,93	Mom.	48,11

Below the water-line VI.

No.	Areas of the triangles.	Direct forces.	Effects.	Distance of the center of gravity from the line *BB*.	Moments.
8	0,28	0,06	0,02	14,70	0,29
10	0,48	0,06	0,03	15,10	0,45
11	0,49	0,06	0,03	15,60	0,47
14	0,54	0,03	0,02	16,20	0,32
16	0,63	0,02	0,01	16,70	0,17
18	0,67	0,02	0,01	17,30	0,17
20	0,72	0,02	0,01	17,80	0,18
22	0,76	0,02	0,01	18,40	0,18
24	0,76	0,02	0,01	19,00	0,19
26	0,81	0,02	0,02	19,50	0,39
28	0,95	0,03	0,03	20,10	0,60
30	0,95	0,03	0,03	20,80	0,62
32	0,95	0,03	0,03	21,40	0,64
34	0,95	0,03	0,03	22,00	0,66
36	0,95	0,04	0,04	22,60	0,90
38	0,95	0,04	0,04	23,30	0,93
40	1,29	0,05	0,06	24,00	1,44
42	1,36	0,08	0,11	24,60	2,71
44	1,36	0,10	0,14	25,30	3,54
46	1,43	0,10	0,14	26,00	3,64
48	1,43	0,10	0,14	26,70	3,74
50	1,50	0,10	0,15	27,40	4,11
52	1,03	0,10	0,10	28,00	2,88
	Effects		1,21	Mom.	29,22
keel	20,85	0,07	1,46	21,30	31,10
sternp[t]. & rud.	10,00	0,10	1,00	29,40	29,40
stem	3,85	0,04	0,15	14,00	2,15
	Effects		2,61	Mom.	62,65

Direct forces on the aft part on the lee-side, and their distances from the line BB.

Between the water-lines I *and* II.

No.	Areas of the triangles.	Direct forces.	Effects.	Distance of the center of gravity from the line *BB*.	Moments.
39	1,01	0,02	0,02	44,40	0,89
41	1,84	0,07	0,13	43,70	5,68
42	0,40	0,01	0,00	45,00	
43	2,63	0,10	0,26	42,80	11,13
44	0,65	0,02	0,01	44,44	0,44
45	4,23	0,23	0,97	41,20	39,96
46	1,53	0,08	0,12	43,50	5,22
47	5,47	0,35	1,91	38,70	73,92
48	3,24	0,20	0,65	41,70	27,10
49	5,04	0,59	2,97	35,00	103,95
50	7,65	0,48	3,67	38,70	142,03
51	2,25	0,42	0,94	31,80	29,89
52	11,88	0,34	15,92	33,80	538,10
		Effects	27,57	Mom.	978,31

Between the water-lines II *and* III.

No.	Areas of the triangles.	Direct forces.	Effects.	Distance of the center of gravity from the line *BB*.	Moments.
35	1,03	1,01	0,01	42,00	0,42
37	1,60	0,03	0,05	41,50	2,07
39	2,47	0,08	0,20	40,50	8,10
40	1,01	0,03	0,03	42,20	1,27
41	3,27	0,14	0,46	39,00	17,94
42	1,84	0,08	0,15	41,30	6,19
43	3,27	0,12	0,39	37,20	14,51
44	2,63	0,12	0,32	39,80	12,74
45	2,90	0,22	0,64	35,20	22,53
46	4,23	0,26	1,10	37,80	41,58
47	2,28	0,22	0,50	33,20	16,60
48	5,47	0,40	2,19	35,40	77,53
49	1,89	0,12	0,23	31,60	7,27
50	5,04	0,48	2,42	33,00	79,86
52	2,25	0,50	1,13	31,40	35,48
		Effects	9,82	Mom.	344,09

Between the water-lines III *and* IV.

No.	Areas of the triangles.	Direct forces.	Effects.	Distance of the center of gravity from the line *BB*.	Moments.
31	0,71	0,01	0,01	39,30	0,39
33	1,29	0,02	0,03	38,80	1,16
35	1,86	0,04	0,07	37,80	2,65
36	0,85	0,02	0,02	39,70	0,79
37	1,89	0,05	0,09	36,50	3,28
38	1,33	0,05	0,07	38,70	2,71
39	1,72	0,05	0,09	35,20	3,17
40	2,05	0,10	0,20	37,40	7,48
41	1,39	0,06	0,08	33,80	2,70
42	2,75	0,18	0,49	36,00	17,64
43	1,25	0,07	0,09	32,50	2,92
44	2,72	0,20	0,54	34,40	18,58
45	0,90	0,04	0,04	31,40	1,26
46	2,41	0,18	0,43	32,80	14,10
47	0,57	0,02	0,01	30,70	0,31
48	1,90	0,14	0,27	31,70	8,56
50	1,57	0,12	0,19	30,80	5,85
		Effects	2,72	Mom.	93,55

Between the water-lines IV *and* V.

No.	Areas of the triangles.	Direct forces.	Effects.	Distance of the center of gravity from the line *BB*.	Moments.
31	1,06	0,01	0,01	34,40	0,34
32	0,56	0,01	0,01	36,30	0,36
33	1,06	0,01	0,01	33,10	0,33
34	1,03	0,02	0,02	35,40	0,71
35	0,72	0,01	0,01	31,90	0,32
36	1,49	0,03	0,04	34,30	1,37
38	1,79	0,03	0,05	32,40	1,62
40	1,52	0,02	0,03	31,90	0,96
42	1,14	0,02	0,02	31,30	0,63
44	0,77	0,02	0,01	30,80	0,31
46	0,38	0,02	0,01	30,50	0,30
		Effects	0,22	Mom.	7,25
rud. & stern.	10,00	5,80	58,00	30,15	1748,70

Lateral forces on the weather-side, and their distances from the line AA.

Between what water-lines.	No.	Areas of the triangles.	Lateral forces.	Effects.	No.	Areas of the triangles.	Lateral forces.	Effects.	No.	Areas of the triangles.	Lateral forces.	Effects.
Between I & II	20	0,72	0,37	0,27	21	0,72	0,36	0,26	22	0,90	0,40	0,36
II & III									22	0,72	0,28	0,20
Effects				0,27				0,26				0,56
Dist. of center of gravity from the line *AA*				56				64				62
Moments.				15,12				16,64				34,72
Between I & II	23	0,95	0,40	0,38	24	1,08	0,55	0,59	25	1,30	0,56	0,73
II & III	23	0,90	0,23	0,21	24	0,95	0,38	0,36	25	1,35	0,35	0,47
III & IV	23	0,55	0,11	0,06	24	0,75	0,21	0,16	25	1,25	0,21	0,26
Effects				0,65				1,11				1,46
Dist. of center of gravity from the line *AA*				70				68				76
Moments				45,50				75,48				110,96
Between I & II	26	1,26	0,63	0,79	27	1,48	0,62	0,92	28	1,35	0,70	0,94
II & III	26	1,30	0,51	0,66	27	1,87	0,47	0,89	28	1,48	0,63	0,93
III & IV	26	1,12	0,30	0,34	27	1,65	0,30	0,49	28	1,53	0,44	0,67
IV & V	26	1,00	0,20	0,20	27	0,96	0,18	0,17	28	1,32	0,12	0,16
V & VI					27	0,53	0,16	0,08	28	0,72	0,12	0,09
Effects				1,99				2,55				2,79
Dist. of center of gravity from the line *AA*				74				82				80
Moments.				147,26				209,10				223,20
Between I & II	29	1,62	0,70	1,13	30	1,48	0,76	1,12	31	2,16	0,81	1,75
II & III	29	2,05	0,50	1,02	30	1,62	0,65	1,05	31	2,48	0,60	1,49
III & IV	29	1,78	0,30	0,53	30	1,71	0,42	0,72	31	2,13	0,40	0,85
IV & V	29	1,12	0,19	0,20	30	1,43	0,32	0,46	31	1,30	0,27	0,35
V & VI	29	0,56	0,29	0,16	30	0,84	0,19	0,16	31	0,56	0,29	0,16
Effects				3,04				3,51				4,60
Dist. of center of gravity from the line *AA*				88				86				94
Moments.				267,52				301,86				432,40
Between I & II	32	1,73	0,90	1,56	33	2,30	0,91	2,09	34	1,98	0,94	1,86
II & III	32	2,16	0,73	1,58	33	2,88	0,64	1,84	34	2,30	0,77	1,77
III & IV	32	2,07	0,47	0,91	33	2,17	0,47	1,02	34	2,40	0,55	1,32
IV & V	32	1,70	0,31	0,54	33	1,28	0,31	0,40	34	1,74	0,33	0,57
V & VI	32	0,97	0,28	0,27	33	0,56	0,33	0,18	34	0,96	0,33	0,32
Effects				4,86				5,53				5,84
Dist. of center of gravity from the line *AA*				92				100				98
Moments.				447,12				553,00				572,32

Lateral forces on the weather-side, and their distances from the line AA.

Between what water-lines.	No.	Areas of the triangles.	Lateral forces.	Effects.	No.	Areas of the triangles.	Lateral forces.	Effects.	No.	Areas of the triangles.	Lateral forces.	Effects.
Between I & II	35	2,70	0,93	2,51	36	2,03	0,90	1,83	37	3,06	1,08	3,30
II & III	35	3,06	0,67	2,05	36	2,70	0,83	2,24	37	3,40	0,74	2,52
III & IV	35	2,29	0,50	1,14	36	2,55	0,60	1,53	37	2,40	0,60	1,44
IV & V	35	1,27	0,33	0,42	36	1,87	0,41	0,77	37	1,28	0,49	0,63
V & VI	35	0,56	0,39	0,22	36	0,95	0,34	0,32	37	0,56	0,46	0,26
Effects				6,34				6,69				8,15
Dist. of center of gravity from the line *AA*				106				104				112
Moments				672,04				695,76				912,80
Between I & II	38	2,66	1,16	3,09	39	3,60	1,11	4,00	40	2,81	1,14	3,20
II & III	38	3,06	0,88	2,69	39	3,67	0,83	3,05	40	3,60	0,94	3,38
III & IV	38	2,83	0,66	1,87	39	2,31	0,74	1,71	40	3,06	0,73	2,23
IV & V	38	1,92	0,53	1,02	39	1,20	0,53	0,64	40	1,85	0,52	0,96
V & VI	38	0,96	0,44	0,42	39	0,67	0,56	0,37	40	0,90	0,49	0,44
Effects				9,09				9,77				10,21
Dist. of center of gravity from the line *AA*				110				118				116
Moments				999,90				1152,86				1184,36
Between I & II	41	4,01	1,08	4,33	42	3,38	1,15	4,89	43	4,57	1,14	5,21
II & III	41	4,01	0,94	3,77	42	4,01	1,00	4,01	43	4,01	1,12	4,49
III & IV	41	2,31	0,88	2,03	42	3,33	0,84	2,80	43	2,29	1,09	2,50
IV & V	41	1,32	0,69	0,91	42	1,85	0,68	1,26	43	1,32	0,95	1,15
V & VI	41	0,67	0,58	0,39	42	0,99	0,66	0,65	43	0,67	0,70	0,47
Effects				11,43				13,61				13,82
Dist. of center of gravity from the line *AA*				124				122				130
Moments				1417,32				1660,42				1796,60
Between I & II	44	3,64	1,15	4,19	45	5,17	1,15	5,94	46	4,32	1,14	4,92
II & III	44	4,57	1,12	5,12	45	3,78	1,32	4,99	46	5,17	1,21	6,26
III & IV	44	3,33	1,04	3,46	45	2,19	1,22	2,67	46	3,15	1,21	3,81
IV & V	44	1,84	1,01	1,86	45	1,26	1,01	1,27	46	1,75	1,12	1,96
V & VI	44	0,99	0,79	0,78	45	0,67	0,78	0,52	46	0,94	0,83	0,78
Effects				15,41				15,39				17,73
Dist. of center of gravity from the line *AA*				128				136				134
Moments				1972,48				2093,04				2375,82

Lateral forces on the weather-side, and their distances from the line AA.

Between what water-lines.	No	Areas of the triangles.	Lateral forces.	Effects.	No.	Areas of the triangles.	Lateral forces.	Effects.	No.	Areas of the triangles.	Lateral forces.	Effects.
Between I & II	47	5,45	1,39	7,57	48	5,89	1,24	7,30	49	5,94	1,77	8,57
II & III	47	3,65	1,54	5,62	48	5,45	1,48	8,07	49	3,82	1,85	7,07
III & IV	47	2,07	1,30	2,69	48	3,04	1,44	4,38	49	2,07	1,28	2,45
IV & V	47	1,20	0,96	1,15	48	1,66	1,20	1,99	49	1,24	1,00	1,24
V & VI	47	0,67	0,79	0,53	48	0,90	0,89	0,80	49	0,67	0,75	0,50
Effects				17,56				22,54				19,83
Dist. of center of gravity from the line *AA*				142				140				148
Moments				2493,52				3155,60				2934,84
Between I & II	50	7,04	1,49	10,49	51	4,55	2,16	9,83	52	11,11	2,04	22,66
II & III	50	5,94	1,94	11,52	51	2,34	1,46	3,42	52	4,55	2,11	9,60
III & IV	50	3,18	1,70	5,41	51	1,20	1,18	1,42	52	1,95	1,65	3,22
IV & V	50	1,66	1,30	2,16	51	0,67	1,22	0,82	52	0,96	1,40	1,34
V & VI	50	0,93	0,98	0,91	51	0,45	1,32	0,59	52	0,50	1,37	0,68
Effects				30,49				16,08				37,50
Dist. of center of gravity from the line *AA*				146				153				151
Moments				4451,54				2460,24				5662,50

Lateral forces on the weather-side, and their distances from the line AA.

Between the water-lines V and VI.

No.	Areas of the triangles.	Lateral forces.	Effects.	Distance of the center of gravity from the line AA.	Moments.
7	0,45	0,11	0,05	21,00	1,05
9	0,45	0,11	0,05	37,00	1,35
11	0,45	0,11	0,05	33,00	1,65
13	0,45	0,13	0,06	39,00	2,34
15	0,45	0,10	0,04	45,00	1,80
17	0,45	0,08	0,04	51,00	2,04
19	0,45	0,10	0,04	57,00	2,28
21	0,45	0,10	0,04	63,00	2,52
23	0,81	0,10	0,08	69,00	5,52
25	0,90	0,11	0,10	75,00	7,50
	Effects		0,55	Mom.	28,05

Below the water-line VI.

No.	Areas of the triangles.	Lateral forces.	Effects.	Distance of the center of gravity from the line AA.	Moments.
8	0,28	0,53	0,15	21,00	3,15
10	0,48	0,46	0,22	27,00	5,94
12	0,49	0,40	0,20	33,00	6,60
14	0,54	0,30	0,16	39,00	6,24
16	0,63	0,30	0,19	45,00	8,55
18	0,67	0,30	0,20	51,00	10,20
20	0,72	0,30	0,22	57,00	12,54
22	0,76	0,30	0,23	63,00	14,49
24	0,76	0,30	0,23	69,00	15,87
26	0,81	0,30	0,24	75,00	18,00
28	0,95	0,35	0,33	81,00	26,43
30	0,95	0,37	0,35	87,00	30,45
32	0,95	0,36	0,34	93,00	31,62
34	0,95	0,39	0,37	99,00	36,63
36	0,95	0,38	0,36	105,00	37,80
38	0,95	0,40	0,38	111,00	42,18
40	1,29	0,53	0,68	117,00	79,56
	Effects		4,85	Mom.	386,25

Below the water-line VI.

No.	Areas of the triangles.	Lateral forces.	Effects.	Distance of the center of gravity from the line AA.	Moments.
			4,85		386,25
42	1,36	0,53	0,72	123,00	88,56
44	1,36	0,56	0,76	129,00	98,04
46	1,43	0,60	0,86	135,00	116,10
48	1,43	0,69	0,99	141,00	139,59
50	1,50	0,70	1,05	147,00	154,35
52	1,03	0,70	0,72	151,00	108,72
	Effects.		9,95	Mom.	1091,61
stem	3,85	0,44	1,69	9,00	15,21
keel	20,85	0,58	12,09	80,00	967,20
sternp. & rud.	10,00	0,70	7,00	156,00	1092,00
	Effects.		20,78	Mom.	2074,41

Sum of the direct forces, and their moments from the line BB.

Effects.	Moments.
67,61	1470,33
40,22	835,67
16,38	347,19
6,16	141,59
1,93	48,11
1,21	29,22
2,61	62,65
27,57	978,31
9,82	344,09
2,72	93,55
0,22	7,25
58,00	1748,70
234,45	6106,66

Lateral forces on the aft part on the lee-side, and their distances from the line AA.

Between what water-lines.	No.	Areas of the triangles.	Lateral forces.	Effects.	No.	Areas of the triangles.	Lateral forces.	Effects.	No.	Areas of the triangles.	Lateral forces.	Effects.
Between III & IV	31	0,17	0,23	0,16					33	1,29	0,23	0,30
IV & V	31	1,06	0,10	0,11	32	0,56	0,24	0,13	33	1,06	0,25	0,26
Effects.........				0,27				0,13				0,56
Dist. of center of gravity from the line *AA*				94				92				100
Moments......				25,38				11,96				56,00
Between II & III					35	1,03	0,20	0,20				
III & IV					35	1,86	0,23	0,43	36	0,85	0,23	0,19
IV & V	34	1,03	0,20	0,20	35	0,72	0,10	0,07	36	1,49	0,19	0,28
Effects.........				0,20				0,70				0,47
Dist. of center of gravity from the line *AA*				98				106				104
Moments				19,60				74,00				48,88
Between I & II									39	1,01	0,27	0,34
II & III	37	1,60	0,35	0,56	38	0,45	0,12	0,05	39	2,47	0,37	0,91
III & IV	37	1,89	0,30	0,57	38	1,33	0,32	0,43	39	1,72	0,32	0,55
IV & V					38	1,79	0,19	0,34				
Effects..........				1,13				0,82				1,80
Dist. of center of gravity from the line *AA*				112				110				118
Moments......				126,56				90,00				212,40
Between I & II					41	1,84	0,44	0,81	42	0,40	0,12	0,05
II & III	40	1,01	0,32	0,32	41	3,27	0,49	1,60	42	1,84	0,47	0,86
III & IV	40	2,05	0,39	0,80	41	1,39	0,38	0,53	42	2,75	0,44	1,21
IV & V	40	1,52	0,19	0,29					42	1,14	0,28	0,32
Effects				1,41				2,94				2,44
Dist. of center of gravity from the line *AA*				116				124				122
Moments......				163,56				364,56				297,68

Lateral forces on the aft part on the lee-side, and their distances from the line AA.

Between what water-lines.	No.	Areas of the triangles.	Lateral forces.	Effects.	No.	Areas of the triangles.	Lateral forces.	Effects.	No.	Areas of the triangles.	Lateral forces.	Effects.
Between I & II	43	2,63	0,45	1,18	44	0,65	0,25	0,16	45	4,23	0,49	2,07
II & III	43	3,27	0,56	1,83	44	2,63	0,49	1,29	45	2,90	0,62	1,80
III & IV	43	1,25	0,43	0,54	44	2,72	0,53	1,44	45	0,90	0,44	0,40
IV & V					44	0,77	0,38	0,29				
Effects..........				3,55				3,18				4,27
Dist. of center of gravity from the line *AA*				130				128				136
Moments				461,50				407,04				580,72
Between I & II	46	1,53	0,41	0,63	47	5,47	0,65	2,27	48	3,24	0,53	2,25
II & III	46	4,23	0,57	2,41	47	2,28	0,79	1,80	48	5,47	0,80	4,38
III & IV	46	2,41	0,60	1,45	47	0,57	0,18	0,10	48	1,90	0,70	1,33
IV & V	46	0,38	0,38	0,14								
Effects				4,63				4,17				7,96
Dist. of center of gravity from the line *AA*				134				142				140
Moments......				620,42				592,14				1114,40
Between I & II	49	5,04	0,94	4,74	50	7,65	0,70	5,35	51	2,25	1,20	2,70
II & III	49	1,89	0,80	1,51	50	5,04	1,12	5,64				
III & IV					50	1,57	0,70	1,10				
Effects..........				6,25				12,09				2,70
Dist. of center of gravity from the line *AA*				148				146				153
Moments......				925,00				1765,14				413,10

Lateral forces on the aft part on the lee-side, and their distances from the line AA.

Between what water-lines.	No.	Areas of the triangles.	Lateral forces.	Effects.
Between I & II	52	11,88	1,38	16,39
II & III	52	2,25	1,45	3,26
Effects				19,65
Dist. of center of gravity from the line *AA*				151
Moments				2967,15

Sum of the lateral forces on the lee-side, and their moments with regard to the line AA.

Effects.	Moments.
0,27	25,38
0,13	11,96
0,56	50,00
0,20	19,60
0,70	74,00
0,47	48,88
1,13	126,56
0,82	90,00
1,80	212,40
1,41	163,56
2,94	364,56
2,44	297,68
3,55	461,50
3,18	407,04
4,27	580,72
4,63	620,42
4,17	592,14
7,96	1114,40
6,25	925,00
12,09	1765,14
2,70	413,10
19,65	2967,15
81,32	11330,59 on the lee-side.

Sum of the lateral forces on the weather-side, and of their moments with respect to the line AA.

Effects.	Moments.
0,27	15,12
0,26	16,64
0,56	34,72
0,65	45,50
1,11	75,48
1,46	110,96
1,99	147,26
2,55	209,10
2,79	223,20
3,04	267,52
3,51	301,86
4,60	432,40
4,86	447,12
5,53	553,00
5,84	572,32
6,34	672,04
6,69	695,76
8,15	912,80
9,09	999,90
9,77	1152,86
10,21	1184,36
11,43	1417,32
13,61	1660,42
13,82	1796,60
15,41	1972,48
15,39	2093,04
17,73	2375,82
17,56	2493,52
22,54	3155,60
19,83	2934,84
30,49	4451,54
16,08	2460,24
37,50	5662,50
0,55	28,05
9,95	1091,61
20,78	2074,41
351,94	44737,91 on weather side.
81,32	11330,59 on the lee side.
270,62	33407,32

From these Calculations we have the Effects of the Forces, and their Moments.

On the fore part of the ship (Fig. 38.)

PAGE 146.	Direct effects........................	331,30
	Their moments from *BB*...............	6737,31
153.	Lateral effects........................	288,60
	Their moments from *AA*...............	7825,87

On the aft part of the ship (Fig. 39.)

161.	Direct effects........................	234,45
	Their moments from *BB*...............	6106,66
164.	Lateral effects........................	270,62
	Their moments from *AA* (NOTE 57.)......	33407,32

According to what was said in Article 66. the effects on the fore part of the ship must be multiplied by 6, and those on the after part by 7, and consequently their corresponding moments must be multiplied by the same numbers.

Direct effects forward = $331{,}30 \times 6 = 1987{,}80$
Direct effects aft = $234{,}45 \times 7 = 1641{,}15$
Direct effects . 3628,95

Moments forward = $6737{,}31 \times 6 = 40423{,}86$
Moments aft = $6106{,}66 \times 7 = 42746{,}62$
Moments 83170,48

Whence $\frac{83170{,}48}{3628{,}95} = 22{,}91$ = the distance of the line *BB* from the center of gravity of the direct effects, and $\frac{3628{,}95}{13} = 279{,}15$ = the direct effect or the resistance.

The lateral effects forward = $288{,}60 \times 6 = 1731{,}60$
The lateral effects aft = $270{,}62 \times 7 = 1894{,}34$
Lateral effects . 3625,94

Moments forward = $7825{,}87 \times 6 = 46955{,}22$
Moments aft = $33407{,}32 \times 7 = 233851{,}24$
Moments 280806,46

Whence $\frac{280806,46}{3625,94} = 77,44$ the distance of the line AA from the center of gravity of the lateral effects, and $\frac{3625,94}{13} = 278,92 =$ the lateral effect or resistance, when the absolute force is equal to the distance between the sections aa, bb, cc, &c.

The distance of the line BB from the line CC on the plane of the load water-line $= 22,3$, subtracting this from 22,91, there remains 0,68 for the distance of the direct resistance on the lee-side from the line CC; draw a line FD (Fig. 40.) at a distance of 0,68 from the line CC, parallel thereto. Draw parallel to the tranverse sections the line FE at a distance of 77,44 feet from the line AA. Set off from F to D and from F to E the quantities 279,15 and 278,92, the direct and lateral resistances, taken according to any scale. Complete the rectangle $FDGE$; the diagonal FG will be the mean horizontal direction of the water.

(191.) But if we turn our attention to what has been said heretofore on the multiplication of the forces by 6 and 7, it will be seen by Art. 60. that these expressions originate in the contrary directions of the streams of water. That is to say, that the water which is before the greatest breadth, goes partly in the same direction as the ship, and that the water which is aft, goes in a contrary direction. That this again arises from the elevation of the water forward, and its depression aft; and that this elevation is supposed to be half a foot above, and the depression half a foot below the natural level of the water.

So that if in Fig. 38. which represents the fore part of the ship, you make an addition of half a foot above the load water-line, and if in Figure 39, which represents the after part, you subtract half a foot also from the draught of water, it will be found that the lateral force will be transferred 1,5 feet forward, that the direct force will approach the line CC 0,3 feet.

This alteration is denoted by fe and fd, and, completing the rectangle, fg will represent the mean horizontal direction of the water.

(192.) It must here be observed, that this mean direction is not at the level of the water, or at the same height which the center of gravity of the ship may be supposed to be, but some feet below; so that the mean direction of the water does not pass through the center of gravity, but below, nearly in the vertical line passing through the center. This ship at an inclination of seven degrees, will not in that case become too ardent; but if the inclination be increased, the center of gravity will be carried to lee-ward of the mean direction, whence the ship will become more ardent.

If this ship had been sharper forward and fuller aft, so that the center of gravity of the part immersed had been 2 inches farther aft, the lateral force would have been a little farther forward, and the mean direction would have passed some inches before the center of gravity of the ship, which would have been in consequence more ardent.

Let us see now where the mean direction passes, when the effects are not multiplied by the coefficients 6 and 7.

The direct effects forward and aft $= 331{,}30 + 234{,}45 = 565{,}75$, their moments $= 6737{,}31 + 6106{,}66 = 12843{,}97$; and $\frac{12843{,}97}{565{,}76} = 22{,}70$; from which quantity subtracting 22,3, there will remain 0,4, which is the distance of the direct resistance from the line CC.

The lateral effects forward and aft $= 288{,}6 + 270{,}62 = 559{,}22$; their moments $7825{,}87 + 33407{,}32 = 41233{,}19$; and $\frac{41233{,}19}{559{,}22} = 73{,}73$. Subtract this quantity from 77,44, and there will remain 3,71; we cannot suppose the water to rise or fall as before; the center of gravity of the effects of the lateral forces will therefore be in km 3,71 feet before the place where it was found above. Neglecting this elevation also in the direct effects, their center of gravity will be moved to the line kl; whence the mean direction of the water will be in kn; this mean direction must pass then at a distance fp (nearly $2\frac{3}{4}$ feet) before and to windward of the center of gravity of the ship $\odot$.

In this manner we have two mean directions of the water, namely, fg and kn; the question to be determined is, which is right.

(193.) According to the ordinary method of rigging ships, the common center of gravity of the sails, with regard to the length should be in P, 13 feet before the center of gravity; its height 78 feet above the surface of the water. When a ship heels 7 degrees, this center of gravity of the sails will be $9\frac{1}{2}$ feet to lee-ward of the middle line of the load water-line, and by reason of the thickness of the masts and yards, and of the curvature which the masts take, there will be an addition certainly of $2\frac{1}{2}$ feet; whence the center of gravity of the sails will fall 2,12 feet to lee-ward of the middle line.

As the ship keeps always the course CC, the sails QR should be trimmed, so as to be perpendicular to the mean direction of the water; if then through Q, QT be drawn perpendicular to QR, the line QT must be parallel to kn; and as in this case QT passes precisely in the line kn, the ship will keep its course CC without the necessity of putting the helm to either side; this is on the supposition that the sails have their surface plane.

But as the wind, in filling the sails, first produces in them a curvature, which does not allow of their being considered as planes; and secondly, on account of its direction coming from the weather-side to pass out at the opposite, forms a kind of bag more on the lee-side than on the weather-side: the center of its effect on the sails cannot be in the middle line, but must be carried through a distance QR towards the lee-side; and this distance must be greater or less, according as they are more or less large. I will, as a mean, suppose that in this ship this distance does not exceed 6 feet: then the resultant of the effort of the wind on the sails will be in the line SR, and the ship will tend to the wind, turning round its center of gravity $\odot$ with a moment $= Sp \times$ the resistance of the ship in the direction kn: but as the ship should go a-head in the line CC, it becomes necessary to make such use of the rudder, that the above moment may be equal to the lateral effect of the water on it multiplied by its distance from the center of gravity of the ship; and that these moments will be equal, the rudder must make an angle of about 15° with the middle line of the ship.

A ship of this form, whose center of gravity is about $2\frac{1}{4}$ feet before the middle of the length, and the diagonal lines of which in the fore body have a similar curvature with this, from experience does not appear to be very ardent; so that it is not possible that the ship can be so ardent or lie so hard on the rudder, as to render it necessary, when the heeling is not more than 7°, to keep the tiller always 15° to windward of the middle line. We may justly conclude therefore *that the mean direction of the water cannot be in the line* kn, *but that it must pass nearer the center of gravity* ⊙, *as in* fg, and that it may be situated to leeward of the same center.

(194.) Farther, suppose that the water, which is abaft the greatest breadth of the ship in its actual position, not to have the least influence upon the disposition to come to the wind: that its effort on the fore part alone produces this disposition: the direct effect forward $= 331{,}3$; its moment $= 6737{,}31$ and $\frac{6737{,}31}{331{,}3} = 20{,}33$; subtracting this quantity from $22{,}3$, the distance of the direct resistance from the line CC to windward $=$ $1{,}97$ feet; this gives the line qr. The lateral effect forward $= 288{,}6$; its moment $= 7825{,}87$; and $\frac{7825{,}87}{288{,}6} = 27{,}11$, the distance of the center of gravity of the lateral forces from the line AA: this gives qs. Completing the rectangle of these effects, the diagonal qt will be the mean direction of the water. Through the center of gravity ⊙ let fall the perpendicular ⊙u on the line qt produced; from the point R let fall on ⊙u the perpendicular RS, which will be parallel to qu. The ship will have an ardency, whose moment round the center of gravity $= Su \times$ the resistance on the ship in the direction qt.

This ardency cannot be counterbalanced by the rudder, while the center of effort of the sails remains in R. It is necessary to carry it forward, so that the resultant of the effort of the wind on the sails, may be situated in the line qt or some feet aft: and farther, supposing it possible to carry so far forward the center of gravity of the sails, still the ship would not be kept from the wind; for upon any inclination the fore part would principally be immersed by the force of the wind on the sails; whereby the mean direction of the water would be carried still farther forward; so that it would not be possible to prevent the ship's coming to the wind.

It is absurd then to lay down a principle, that the water abaft the greatest section of the ship has no influence on its disposition to come to the wind.

(195.) We obtain from this Chapter an unexpected advantage, in the strong confirmation *that there is no mistake in adopting as a principle for calculating the resistance of the water against the ship; that not only the after part ought to be considered in the calculation as well as the fore part, but also that the expression for the effect of the water on the after part, should have a certain coefficient greater than the one given to its expression for the fore part.*

We may also find the area of the plane of resistance for a ship sailing by the wind, with the heeling and with lee-way which have been supposed.

It has been already found that the sum of the direct effects forward and aft multiplied by 6 and 7 = 3698,95; and as the distance between the sections aa, bb, &c. which has been considered as the absolute force, = 6 feet, according to Article 68 the area of the plane of resistance will be $= \frac{3628{,}95}{6 \times 13} = 46{,}52$ square feet. It appears from Article 71, that the plane of resistance for the same ship going with the wind aft = 36,24 square feet; consequently, in order that the ship in both cases may sail

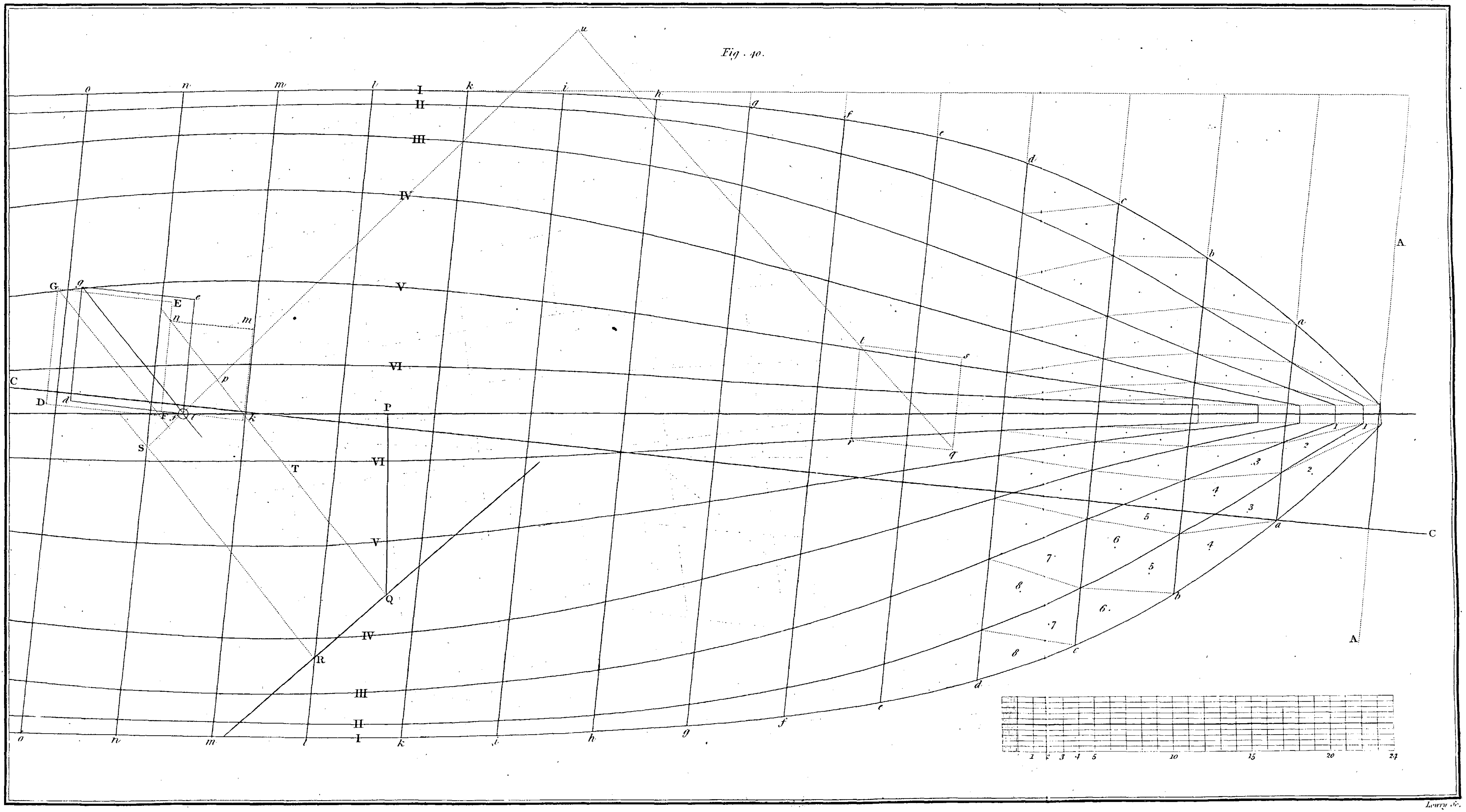


Fig. 40.

Lowry Sc.

with the same velocity, it must necessarily present to the wind a much greater extent of sails, with a side wind, than with the wind aft (NOTE 58.), and not only on account of the greater surface of the load water-line, but also from a consideration of the obliquity of the wind on the sails.

The line PQ (Fig. 38.) is the lateral resistance, the line PR the vertical resistance, and the line PS their mean direction, calculated only for this part of the ship.

CHAP. XI.

ON THE MEASUREMENT FOR TONNAGE AND STOWAGE, WITH INSTRUCTIONS ON THESE POINTS, AND ALSO DIFFERENT IMPORTANT DETAILS CONCERNING THE PROVISIONING, WITH A VIEW TO THE MAKING OF THE ACCOMMODATIONS AND STORE-ROOMS.

On the Measurement for Tonnage.

(196.) BY measurement for tonnage is meant the taking of the dimensions of a ship, in order, from the consideration of its form, to find the lading it can carry, and with which it can navigate without danger.

(197.) To measure for tonnage in the Swedish manner, is to determine the number of lasts, which the ship can carry, as follows.

The length of the ship is taken on the upper deck from the stem to the sternpost, the breadth within the cieling, and the draught of water from the plank of the said upper deck to the plank of the bottom, these three dimensions are multiplied together, and the product is divided by 200; the five-sixths of the quotient will be the weight, which the ship can take in lasts of 18 skiponds iron weight *per* last; as much *per cent.* however is subtracted from this quantity as the measurer judges the ship more or less full in the floors, or as it carries a greater or less number of guns. The remainder is the burthen in lasts (NOTE 59.).

It follows from hence that if two ships were constructed from the same plan, but the upper deck of the one placed one foot higher than that of the other, the former would be found of a greater quantity of lasts than the latter; which ought however to be the contrary, for the former ship ought to carry less, as its sides being raised a foot weigh more (the two ships being laden to the same draught of water). The result of this calculation may moreover be erroneous on this account, that the degrees of the ship's rising, more or less, will not be always estimated correctly by a person in the hold; whence it happens that the addition or subtraction on this account must be in a great measure arbitrary; without mentioning other reasons, which render the measurement for tonnage, by this method, very uncertain.

If a last were a certain space, this manner of measuring would be more tolerable, but as it is a weight, it is altogether without reason.

(198.) The method of measuring for tonnage in England, is not used for the direct purpose of finding the quantity of lasts which the ship can carry, but to obtain the content, according to which the ship pays the duties.

The capacity is found thus: the product of the length of the keel multiplied by the breadth of the ship to the outside of the plank, and again by the half breadth; this product, I say, divided by 94, gives the capacity of the ship in tons. If the ship carries more than this quantity, it is said to carry more than its measurement for tonnage, and *vice versâ*.

Little need be said in regard to this method, because the immediate object of it is not to find the burthen; however the manner of determining the length of the keel, upon which length the calculation is founded, is faulty; $\frac{3}{5}$ and $\frac{1}{8}$ of the breadth of the ship are taken, for the rake of the stem and stern-post; these two quantities are subtracted from the length taken from the aft side of the wing transom at the middle line; the remainder is considered as the length of the keel. That this method is erroneous appears as follows.

Let the length of the ship from the stem to the stern-post equal m, and its breadth $= n$; then the length of the keel $= m - \left(\frac{3}{5} + \frac{1}{8}\right) \times n$. And as $\frac{3}{5} + \frac{1}{8}$ make nearly $\frac{3}{4}$, one may say that the measurement of the ship in tons, by the preceding rule, will be $= \frac{(m - \frac{3}{4}n) \times \frac{1}{4}n^2}{94}$. If this expression be made $= 0$, then the tonnage of the ship is equal to 0; it could therefore carry nothing. It is true, that to make this the case, the breadth of the ship must be $\frac{4}{3}$ of the length, which is never the case.

Since when a ship is built by contract, it is usual to give so much *per* ton, it would follow from this method of measuring, that it is advantageous to the owner to give great breadth in proportion to length (NOTE 60.).

(199.) These two methods of admeasurement being entirely defective, I give here the view which ought to be taken of this operation, from which will be seen the method of measuring a ship exactly, in order to determine the weight it can carry.

It is known that the weight a ship can carry, is always equal to the displacement of water which that weight occasions; the question then is only to measure the part of the ship, which is to be immersed in the water by the weight of the cargo. This measurement may be made with greater or less exactness. I shall give here the process necessary to attain the object in view, which is the most simple, but at the same time the least exact.

The ship, when its admeasurement is taken, is supposed to be light; its draught of water is taken in this state forward and aft; afterwards the draught of water is determined forward and aft, which it is to have when the lading is in: hence the number of feet is known, to which each extremity must be brought down; these are added together, and half their sum taken. There are known; first, the quantity which the ship would be brought down by the effect of the lading; secondly, its length, which is measured from the wing transom; thirdly, its breadth which is taken to the outside of the plank: these three dimensions are multiplied together, and the product is divided, if the ship be full at its extremities, by 110; if on the contrary it be lean, by 115; and the quotient is the burthen of the ship in lasts. But if the vessel be a store-ship or have the form of one, keeping its greatest breadth almost the whole length, and also full at the extremities, 105 is taken for the divisor.

For example, a ship has length in a straight line before the wing transom 134 feet, and breadth to the outside of the plank 34 feet.

Suppose that it has a draught of water, when light, abaft 12 feet, forward 8 feet 7 inches; suppose also that the draught of water when laden is abaft 19 feet, and forward 18; subtracting twelve feet from 19, 7 will remain; and subtracting 8 feet 7 inches from 18 feet, 9 feet 5 inches will remain, which added to 7 feet, will make 16 feet 5 inches, half of which is 8 feet $2\frac{1}{2}$ inches, which the laden should bring the ship down. Multiplying 134 feet, 34 feet, and 8 feet $2\frac{1}{2}$ inches together, the product will be 37400.

If the ship be a bark, or supposing it to be full in its extremities, this number must be divided by 110, and the burthen of the ship will be 340 lasts; if it be a frigate, or a ship very sharp fore and aft, the divisor will be 115, and the ship will carry $325\frac{1}{5}$ lasts; if this ship be fuller above and below, as well as at the extremities 112 might be used as the divisor, and it would carry $333\frac{13}{14}$ lasts.

This method also depends partly on the correctness of the eye, in estimating the degree, more or less, of the rising of the ship, and choosing in consequence the divisor; it is to be attained by a little attention and practice. The measurer will not be deceived thus 5 lasts; and according to the common method of measuring, he may make an error of 40 lasts for ships of this size.

One might perform the operation with more exactness, by taking more breadths independently of the middle one, and then there ought not to be an error of one last; but as this would require more time, to take the measures and make the calculations, I shall not enter upon it.

(200.) In loading a ship, it is necessary to take care to put no more on board than the lading which is consistent with its sailing.

For example: If the ship has ballast in, when measured, it is necessary to add its weight to the burden, which has been found for the vessel: but if the water, the provisions, the guns and ammunition, &c. are not on board, if there be wanting only a cable, a sail, or any thing of this kind, their weight when known must be subtracted from the burden given by the measurer.

To estimate these things, it may be supposed that provisions with the casks and wood for one man, for one month, weighs 186 provision pounds. The water also for one man for the same time 217 pounds: the man himself with his effects 260 pounds.

When the number of the ship's crew is known, the time for which it is to be provisioned and watered, it is not difficult to find the total weight of these things.

(201.) The weight of a 12 pounder with its carriage, breaching and tackle, is very nearly 13 skiponds; that of an 8 pounder with the same, is 10 skiponds; of 6, 8 skiponds; of 4, 6 skiponds; of 3, 4½ skiponds; of 2, 3½ skiponds; all iron weight. The powder, shot, wads, &c. should be an eighth of the weight of the gun and its carriage, in time of war; in time of peace, less.

The galley and cooking utensils (if these be not on board) may be estimated at 30lbs. for each man of the crew.

(202.) It is necessary to see in like manner if it want cables, hawsers, or other parts of the rigging. The square of the circumference of the cordage divided by 4, gives the weight of a fathom of the said cordage.

Thus it is required to find the weight of a 15 inch cable; the square of 15 is 225; dividing 225 by 4, you will have $56\frac{1}{4}$lbs. for the weight of a fathom of this cable. A hundred fathoms of it will, therefore, weigh 5625lbs. which makes nearly 14 skiponds, provision weight, or 17 skiponds, 10 lisponds, iron weight.

(203.) If the rigging be wanting altogether, it may be supposed that the weight of the whole (NOTE 61.) for a ship, frigate-built, with the masts, is equal to its burden in lasts, divided by 1,88; but for a bark, which has less rigging in proportion to the lading it can carry, the divisor will be 1,98. For ketches, galeasses, howker-sloops, the divisor should be 2,5; this is sufficiently exact for the object in view.

(204.) To obtain the weight of the sails, it is necessary first to know of what kind of canvass they are made for great and small ships.

Capacity of the Ship in Lasts.	400	200	100	50	25
Main-sail and fore-sail	*AA*	*AA*	*A*	*B*	*B*
The two top-sails	*A*	*A*	*B*	*C*	*T. D.*
Top-gallant sails............	*T. D.*	*T. D.*	*T. D.*		
Mizen	*AA*	*AA*	*A*	*B*	
Mizen top-sail..............	*C*	*C*	*T. D.*	*T. D.*	
Studding-sails	*T. D.*	*T. D.*	*H. D.*	*H. D.*	
Fore-top-mast stay-sail.......	*AA*	*AA*	*A*	*B*	*B*
Mizen stay-sail, & main stay-sail	*A*	*A*	*B*	*C*	
Main top-mast stay-sail.......	*C*	*C*	*T. D.*	*T. D.*	
Thickness of bolt ropes	inches	inches	inches	inches	
Main-sail and fore-sail	$4\frac{1}{2}-4\frac{1}{4}$	$4-3\frac{3}{4}$	$3\frac{1}{2}-3\frac{1}{4}$	$3-2\frac{3}{4}$	
Main top-sail & fore-top-sail ..	$4\frac{1}{4}-4$	$3\frac{3}{4}-3\frac{1}{2}$	$3\frac{1}{4}-3$	$2\frac{3}{4}-2\frac{1}{2}$	

T. D. denotes Tent Canvass, and *H. D.* Halsing Duck.

Species of canvass.		Length of the piece.	Breadth.	Weight of the whole piece.	Weight of a square ell.
Stockholm Canvass.	*AA*	56 ells	5 qrs.	57 lbs.	0,814 lbs.
	A	56	5	52	0,743
	B	56	5	47	0,672
	C	56	5	42	0,597
	T. D	72	4	40	0,555

When the height and breadth of a sail are known, its area may be found in square ells by Art. 86; this area is multiplied by the weight of the square ell, adding to this product the weight of the bolt-ropes, and we have that of the sail.

(205.) When in this manner the weight of all which is wanting on board the ship has been found, it will be necessary to subtract it from the quantity of lasts, which the measurement has given; the remainder will be the true burden of the ship.

But to shorten the operation of the measurement, the measurer ought to be provided with a table containing these calculations ready made, arranged so that by inspection only he may see the weight of what is wanting.

On the lading of the ship, or on the manner of finding how much a ship can take in of a certain kind of merchandise; or, if it be laden, how much thereof it has taken.

(206.) When a ship is to take in such or such merchandise, it is necessary to know the quantity thereof which it can take, and with that view to be in possession of different articles of information on this subject; for example, that 15 tons of Finland tar, 17 tons of pitch, 15 tons of

Cagliari salt, 16 $\frac{1}{2}$ tons of salt of Saint Hub, weigh nearly one last: that three tons $\frac{1}{3}$ to $\frac{2}{5}$ of salt make a salm, and 4$\frac{1}{2}$ tons a moj; a little more or less; for this varies. A last of pitch or tar fills a space of 144 cubic feet.

By the following table it is seen how many dozen of fir-planks of different dimensions make a last, when they are not too green.

Breadth in inches.	Length in ells.	Thickness of the planks in inches.				
		1 inch	1$\frac{1}{4}$ inch	1$\frac{1}{2}$ inch	1$\frac{3}{4}$ inch	2 inches
8	6	18$\frac{1}{2}$	14$\frac{3}{4}$	12$\frac{1}{4}$	10$\frac{1}{2}$	9$\frac{1}{4}$
	7	15$\frac{3}{4}$	12$\frac{2}{3}$	10$\frac{1}{2}$	9	8
9	6	16$\frac{1}{3}$	13$\frac{1}{6}$	11	9$\frac{1}{3}$	8$\frac{1}{6}$
	7	14	11$\frac{1}{4}$	9$\frac{1}{3}$	8	7
10	6	14$\frac{5}{6}$	11$\frac{3}{4}$	9$\frac{5}{6}$	8$\frac{1}{2}$	7$\frac{1}{3}$
	7	12$\frac{2}{3}$	10$\frac{1}{6}$	8$\frac{1}{2}$	7$\frac{3}{4}$	6$\frac{1}{3}$
11	6	13$\frac{1}{3}$	10$\frac{3}{4}$	9	7$\frac{1}{4}$	6$\frac{2}{3}$
	7	11$\frac{1}{2}$	9$\frac{1}{6}$	7$\frac{3}{4}$	6$\frac{7}{12}$	5$\frac{3}{4}$
12	6	12$\frac{1}{4}$	9$\frac{5}{6}$	8$\frac{1}{6}$	7	6$\frac{1}{6}$
	7	10$\frac{1}{2}$	8$\frac{1}{2}$	7	6	5$\frac{1}{4}$

The method of using the table is this:

It is required to find how many dozen of planks, 1$\frac{1}{2}$ inch thick, 10 inches broad, and 7 ells long, will make a last: in the column of 1$\frac{1}{2}$ inch, in the line 7 ells, to 10 inches in breadth is found 8$\frac{1}{2}$, the number of dozen of planks, which will make a last. This number of planks fills a space of 148 cubic feet.

When the planks are green, they may go as far as eight *per cent.* more in weight, but never more. A last of this sort of planks very green, takes up a space of 137 cubic feet.

To see the use of information of this kind: suppose a ship homeward bound with a lading of salt; her draught of water thus laden is set off. It is found, after it has been unladen, that it has carried 5157 tons of Cagliari salt: dividing this quantity by $15\frac{1}{6}$, the quotient will be 340, which is the burden of the ship in lasts. Consequently, reloading this ship at the same draught of water, it will carry a weight of 340 lasts.

But if the ship is to be laden with merchandise so bulky in proportion to its weight, that the ship is full, before it is brought down to its draught of water fixed upon, in that case it is necessary to know the capacity of the inside of the ship.

It is necessary then to have the space of the hold in cubic feet, which is found by the following method:

(207.) When the ship is to be laden with merchandise specifically light, it is necessary in order to give stability, to put on board some ballast of iron, gravel, sand, or something of this sort: the ballast being levelled horizontally or parallel to the deck, the hold is measured thrice, in three different places (Note 62.), that is to say, three breadths or ordinates are taken through the center of the mizen mast; three others, some feet abaft the foremast; lastly, three others at half-way between these two sections.

These three breadths, in each section, are taken immediately under the deck, upon the ballast, and half-way between the ballast and the deck.

We have, therefore, three breadths in each of three sections of the hold. The area of each of these sections is found by adding the half of the breadths taken under the deck and upon the ballast, to the intermediate breadth, and multiplying this sum by half the distance of the deck from the ballast.

The capacity in cubic feet, is got by adding half the areas of the sections forward and aft, to the area of the intermediate section, and multiplying this sum by half the distance between the extreme sections.

It is necessary to add the parts contained between the extreme sections, and the stem and stern-post.

Considering these spaces as paraboloids the area of each extreme section is multiplied, respectively, by half its distance from the stem and stern-post, which will give its capacity.

From the sum of these three quantities, is subtracted the pump well, and the capacity of the hold will be had in cubic feet.

It is necessary also to add the spaces between decks, where merchandise is put.

The sum of these different spaces is divided by the quantity of cubic feet of merchandise, which makes up a last.

For example: it is required to load a ship, the ballast is levelled so that there remains 12 feet of hold below the orlop-deck-beams, to the ballast. The measures ought to be taken in three places; abaft at the mizen mast; forward three or four feet abaft the foremast; and exactly at the middle point between these two sections.

Suppose then that at the after section the breadth under the deck is $= 27\frac{1}{2}$ feet, that upon the ballast $= 3$ feet; the intermediate one (6 feet below the beam) $= 19\frac{1}{2}$, the half of $27\frac{1}{2} = 13\frac{3}{4}$; the half $3 = 1\frac{1}{2}$, and $13\frac{3}{4} + 19\frac{1}{2} + 1\frac{1}{2} = 34\frac{3}{4}$, which multiplied by 6 (half of the height of the hold) will give for the product $208\frac{1}{2}$ square feet, which is the area of this section.

As to the middle section, let the breadth under the deck be $= 30\frac{1}{2}$, that upon the ballast $= 18\frac{1}{2}$; the intermediate one 29 feet; the half of $30\frac{1}{2} = 15\frac{1}{4}$; the half of $18\frac{1}{2} = 9\frac{1}{4}$; and $15\frac{1}{4} + 29 + 9\frac{1}{4} = 53\frac{1}{2}$, which multiplied by $6 = 321$ square feet, the area of the middle section.

Lastly, at the foremost section, let the breadth under the deck be $= 29\frac{1}{2}$, that on the ballast $= 5$ feet; the intermediate one $= 25\frac{1}{2}$; the half of $29\frac{1}{2} = 14\frac{3}{4}$, the half of $5 = 2\frac{1}{2}$; and $14\frac{3}{4} + 25\frac{1}{2} + 2\frac{1}{2} = 42\frac{3}{4}$, which multiplied by $6 = 256\frac{1}{2}$ square feet, the area of the foremost section.

To get from hence the capacity in cubic feet, take the half of $208\frac{1}{2} = 104\frac{1}{4}$, the half of $256\frac{1}{2} = 128\frac{1}{4}$; and we shall have $104\frac{1}{4} + 321 + 128\frac{1}{4} = 553\frac{1}{2}$.

Supposing the distance between the sections forward and aft to be $= 87$ feet, half of which $= 43\frac{1}{2}$; multiplying $43\frac{1}{2}$ by $553\frac{1}{2}$, the product will be $24077\frac{1}{4}$ cubic feet, for the part of the hold, between the two extreme sections.

Suppose the distance from the after section, quite aft (to the sternson), $= 18$ feet; half of which $= 9$; multiplying 9 by the area of this section $= 208\frac{1}{2}$ the product will be $1876\frac{1}{2}$ cubic feet, the space abaft the mizen-mast.

Suppose the distance of the fore section quite forward $= 16$ feet, half of which $= 8$ feet; multiplying 8 by the area of this section $= 256\frac{1}{2}$, the product will be 2052 cubic feet, the space forward towards the fore-mast.

Adding $24077\frac{1}{4}$, $1876\frac{1}{2}$ and 2052, the sum is $28005\frac{3}{4}$ cubic feet.

Let the pump well be 5 feet in one direction, 4 in the other, with 12 feet in height; its content will be $5 \times 4 \times 12 = 240$ cubic feet, which being subtracted from $28005\frac{3}{4}$, the remainder will be $27765\frac{3}{4}$ for the capacity of the hold.

It is not necessary to subtract any thing on account of the curvature of the deck, since a part of the lading may be placed between the beams, if it consist of certain articles, as planks, &c.

If the part of the lading, which is to be placed between decks, occupy there a length of 60 feet; suppose the space between decks of $5\frac{3}{4}$ in height; and its breadth from one side to the other taken within the knees $= 28$ feet; then $60 \times 5\frac{3}{4} \times 28 = 9660$ cubic feet, which added to $27765\frac{3}{4}$ cubic feet will make $37425\frac{3}{4}$ cubic feet, for the whole space that the lading is to occupy in the ship.

If the ship is to be laden with planks, this quantity must be divided by 148 or 137, according as the planks are dry or green; in the first case, the quotient is $= 252\frac{129}{148}$, and in the second $= 273\frac{25}{137}$ lasts. So that the ship considering its capacity, is able to take in a weight of plank $= 252$ or 273 lasts, according to the state in whieh they are. But it remains to see whether the ship is able to carry this lading, without being brought down farther than to the determined load water-line.

(208.) Suppose that the ship having its ballast, but before the cargo is on board, has to be brought down when the lading is completed, $5\frac{3}{4}$ feet aft, and $8\frac{1}{4}$ feet forward, so that the mean depth of the space, which the ship is to be brought down in the water by the lading $= 7$ feet.

Let the length of the ship be $= 134$ feet, its breadth $= 34$, then according to Article 199. the number of lasts, which it is able to carry $=$ $\frac{134 \times 34 \times 7}{110} = 290$.

However, if the planks which are to be taken on board be of green wood, they will weigh 273 lasts; the ship would not be brought down then but in proportion to this weight, for which the depression in the water should be $= \frac{273 \times 110}{134 \times 34} = 6\frac{3}{4}$ feet, so that it would draw one quarter of a foot less water, than the determined load water-line.

If the cargo consisted of planks of dry wood, it might be found in the same manner, that it would not make the ship sink more than $6\frac{1}{9}$ feet, that is to say, $\frac{8}{9}$ of a foot less than its load water-line.

(209.) When it is wished to know the number of dozen of planks that the ship is able to take in, it is necessary in the first place to be acquainted with their quality.

Suppose that the cargo which the ship is to take, consists of four sorts of planks, an equal number of each, all 2 inches thick; one sort 6 ells long, and 10 inches broad, of which $7\frac{1}{3}$ dozen go to the last; the second sort 7 ells long, 10 inches broad, and $6\frac{1}{3}$ dozen to the last; the third 7 ells long, 11 inches broad, and $5\frac{3}{4}$ dozen to the last; the fourth 7 ells long, 12 inches broad, and $5\frac{1}{4}$ dozen to the last.

We shall have the number of dozen of planks of each sort by dividing

253 lasts by $\frac{1}{7\frac{1}{3}}+\frac{1}{6\frac{1}{3}}+\frac{1}{5\frac{3}{4}}+\frac{1}{5\frac{1}{4}}$, which reduced to a more simple expression $=\frac{3}{22}+\frac{3}{19}+\frac{4}{23}+\frac{4}{21}$, and in one single fraction $=\frac{132977}{201894}$.

The quotient of 253 divided by this last fraction = 384, which is the number of dozens of planks of each kind; and consequently, all the lading will be = 1536 dozens of planks, both dry wood and green wood.

If the ship be to be laden with pitch, $37425\frac{3}{4}$ must be divided by 144; and multiplying by 15, there will result 3898 for the quantity of this merchandise in tons, which the ship will be able to contain.

But for a lading in casks, one cannot always reckon on this mode of calculating; because for the little, which the depth of the hold is too small to place there one cask, a whole tier is lost; and if the same happens between decks, the error might amount to 16 *per cent.*

If the ship be laden with several kinds of merchandise; in order to know the quantity of merchandise, which has been really put on board, having taken the draught of water before the laden was begun, it is noted how much it has brought the ship down: having then this depth, as also the length and breadth of the ship, the mode of proceeding is as above, whence is got the number of lasts equal to the weight of the merchandise. If it were all pitch or tar, multiplying this quantity of lasts by 17 or 15, the result would be the number of tons.

One may in the same manner, by means of the draughts of water, see from time to time, of how much the ship is discharged.

(210.) We have just given the weight of several kinds of merchandise for a cargo; we shall now give in addition that of several others, as well as some instructions, which are necessary, when the plans of certain species of ships are to be drawn, and which may serve for a guide in the distribution of the accommodations.

Weight of a Cubic Foot (provision pounds) of the following Articles.

Lead	672	Biscuit	26
Wrought iron	475	Wheat	44,5
Cast iron	440	Finland rie	42,6
Pitch	83	Bread rie	40,25
Tile	116	Barley	39,5
Lime	42	Barley-meal	36,18
Sea water	63	Oats	31
Fresh water	61	Oatmeal	30
Oak	53	Malt	28,9
Fir	38	Peas	52,25

Weight of a Ton (in lisponds provision weight) of the following Articles.

Cagliari salt	19	Stuff for paying	coarse	16,9
Salt of St. Hub	17½		clean	15,4
Salt Beef	15	Finland tar	coarse	19,2
Herrings	from 15 to 18		clean	14,8
Ground rie	12			

Dimension of Casks in feet and inches.

	Outside. Whole length.	Outside. Diameter at middle.
Casks of 300 kans	4 . 7	3 . 6
Casks of 72 kans	2 . 9	2 . 2
Barrel of a quintal of powder	2 . 1	1 . 6
Barrel of tar	2 . 8	1 . 11
Cask of beef, herrings, flour, and stuff for paying	2 . 6	1 . 10
Hogshead of Bourdeaux wine	3 . 1½	2 . 4

Dimensions of Casks, in feet and inches.

	Outside. Whole length.	Outside. Diam'. at mid.
Bourdeaux Wine in a double cask	3 . 5	2 . 8
A Cask of Brandy containing 3 hogsheads of Bourdeaux	4 . 1	3 . 0
A Cask of Virginia tobacco, containing nearly 1200 lbs.	4 . 0	3 . 0
A Cask of Sugar, containing nearly 1700 lbs.	4 . 6	3 . 4

Spaces filled by the following goods in feet and inches.

	Length.	Breadth.	Height.
A bale of Petersburgh hemp of 5½ skip	8 . 0	4 . 6	4 . 0
A bale of Smyrna cotton from 300 to 320 lbs.	7 . 0	2 . 10	2 . 0
A whole chest of tea	2 . 11	2 . 5	2 . 0
A quarter chest of 60 cattgies	1 . 11	1 . 5	1 . 6
Ditto of 25 ditto	1 . 5	1 . 1	1 . 3
Ditto of 10 ditto	1 . 1	0 . 10	0 . 11
A chest of porcelain	3 . 4	2 . 6	1 . 8

A last of hemp, fills nearly a space of 340 cubic feet, and one of cotton, 640 cubic feet.

Finland birch, which is reckoned by the cord, is cut to 6 quarters of an ell in length, and this cord is four ells long and three ells deep; it weighs nearly three skiponds, provision weight.

A Stockholm brick of 12 inches by 6 inches and 3 inches, weighs between 14 and 15 pounds, and 8 of them make a cubic foot.

(211.) These articles of merchandise have not always precisely the same weight; they vary according to their quality, so as to weigh, sometimes more, sometimes less.

A ton of dry provisions = 5,6 cubic feet; 56 kans to the ton, and 32 kappars also to the ton.

A ton of liquid provisions contains 48 kans; 8 quarts to a kan.

A last = 18 skiponds, iron weight; 5 skiponds iron weight = 4 skiponds provision weight; 20 lisponds make one skipond; 20 pounds make a lispond; 16 ounces make a pound, 32 lods also make a pound.

A thousand pounds, Swedish = 863,8 pounds French (poids de Marc) = 932,4 pounds, English.

A hundred Swedish lasts = $248\frac{4}{5}$ French tons = $239\frac{3}{4}$ English tons.

An English foot = $12\frac{5}{16}$ Swedish inches.
A French foot = $13\frac{1}{8}$ ditto.
A Dutch foot = $11\frac{9}{20}$ ditto.
A Hamburgh foot = $11\frac{11}{20}$ ditto.

The pik which is used at Constantinople = $34\frac{1}{4}$ Swedish inches.

Diameter or Caliber of Guns in inches, nearly.			
Pounders.	Pounders.	Pounders.	Pounders.
24 = $6\frac{1}{4}$ inches	18 = $5\frac{11}{16}$ inches	12 = 5 inches	8 = $4\frac{3}{8}$ inches
6 = $3\frac{15}{16}$	4 = $3\frac{7}{16}$	3 = $3\frac{1}{8}$	2 = $2\frac{1}{4}$

Length of short pieces $\begin{cases} \text{for bullet} = 3\frac{1}{2} \text{ diameters of the bullet.} \\ \text{for lead ball} = 4 \text{ diameters of the ball.} \end{cases}$

Weight of a Foot of Iron Bar of the following kinds, in provision weight.

Thickness of the iron.	Square.	Octagonal.	Round.	Thickness of the iron.	Square.	Octagonal.	Round.
3 inches	29,45 lbs.	24,27 lbs.	23,14 lbs.	1¼ inch	5,11 lbs.	4,14 lbs.	4,02 lbs.
2½	20,45	16,85	16,07	1⅛	4,14	3,41	3,25
2¼	16,56	13,65	13,02	1	3,27	2,70	2,57
2	13,09	10,79	10,29	⅞	2,51	2,06	1,97
1⅞	11,50	9,48	9,04	¾	1,84	1,52	1,45
1¾	10,02	8,26	7,87	⅝	1,28	1,05	1,00
1⅝	8,64	7,12	6,79	½	0,81	0,67	0,64
1½	7,36	6,07	5,78	⅜	0,46	0,38	0,36
1⅜	6,19	5,10	4,86	¼	0,20	0,17	0,16

According to this table, a foot of a square bar of iron 1⅛ inches thick, weighs 4,14 pounds; if this bar be octagonal, it will weigh 3,41 pounds, and if it be round, 3¼ pounds, provision weight.

By the regulation of 1759, respecting the allowance of seamen, on board Merchant ships, each man has *per* month, or for 30 days:

Oatmeal	23½	quarts
Peas	45	ditto
Salt fish	8⅗	pounds
Salt beef	13	ditto
Salt pork	8⅗	ditto
Biscuit	21½	ditto
Beer	4⅓	quarts
When there is no beer, oil	4½	ditto
Vinegar	2½	ditto

Of common beer 15 kans, as long as it lasts; or 6 of wine, when it can be had; herring, at the Captain's pleasure.

They reckon usually on $1\frac{1}{3}$ kan of water a day, for one man; but water is never taken for so long a time as the other provisions.

(212.) The knowledge of these details is very necessary. For example, a plan of a ship is to be made, for which, we cannot make use of the proportions given in Chaps. 6 and 7, because this ship has a different object from either commerce or sailing. It is necessary to know the weight of the wood, iron, &c. which must be used in the construction of the ship, as also that of the other articles which may belong to it; these weights added to that which it is to carry, give the displacement, which is to regulate the drawing of the plan.

If it be the space in the hold, on which we are to reckon, in loading with any particular kind of loose grain, the draught of water of the ship being determined, by knowing the quantity and specific gravity of the grain, we may determine the necessary capacity of the hold. For this measurement is commonly used the kappar, a part of a ton.

If the lading be in casks, as of salt beef, herrings, wine, or other similar articles, it will not be difficult from the number, size, and weight of the casks, to determine the size of the ship, and to settle the depth of hold, as well as the height between decks, so as not to lose too much space in the stowage.

(213.) When it is necessary to make accommodations for the provisions, as bread, peas, grain, &c., supposing the number of the crew, and the time for which the ship is to be provisioned, to be known, it is easy to determine the capacity which the store-rooms should have; and it is the more necessary to make an exact calculation in this respect, because there is always in ships very little space for things which are essential, particularly in ships of war. If too much be taken for one thing, there will be space wanting for another.

For example, if we wish to know the size it is necessary to give to the bread-room of a ship with a crew of 24 men, to be provisioned for six months:

The amount of bread for one month, weighs 21½ pounds; that for six months 129 pounds, and consequently 3096 pounds for the whole crew for six months. The cubic foot of biscuit weighs 26 pounds; divide this number 3096 by 26, the quotient will be 119 cubic feet, which is the space which the biscuit should take up, being well stowed.

Thus may be found the room proper for putting the peas: one man being allowed 45 quarts *per* month, that is, 270 quarts for 6 months, and consequently 6480 quarts for the whole crew, for the same time, which makes 810 kans, or 14½ tons; and as the ton contains 5,6 cubic feet, multiply this quantity 5,6 by 14½, the products will be 81; wherefore there will be wanted for the peas a space of 81 cubic feet.

It is necessary, however, to give a little more space than the result of the calculation, which depends on the place where the passages into the store-rooms can be worked.

In a similar manner, if the ship take three months or 91 days' water, 1⅓ kan to a man *per* day, which will make for one man for three months 121⅓ kans, and consequently 2912 kans for the whole crew. The space which the proper casks will take up, is found by means of their dimensions.

Thus also by the dimensions of barrels of powder, the length and diameter of cartridges filled up, the size is found which must be given to the powder room and ammunition chest, and also their distribution.

Fig. 44.

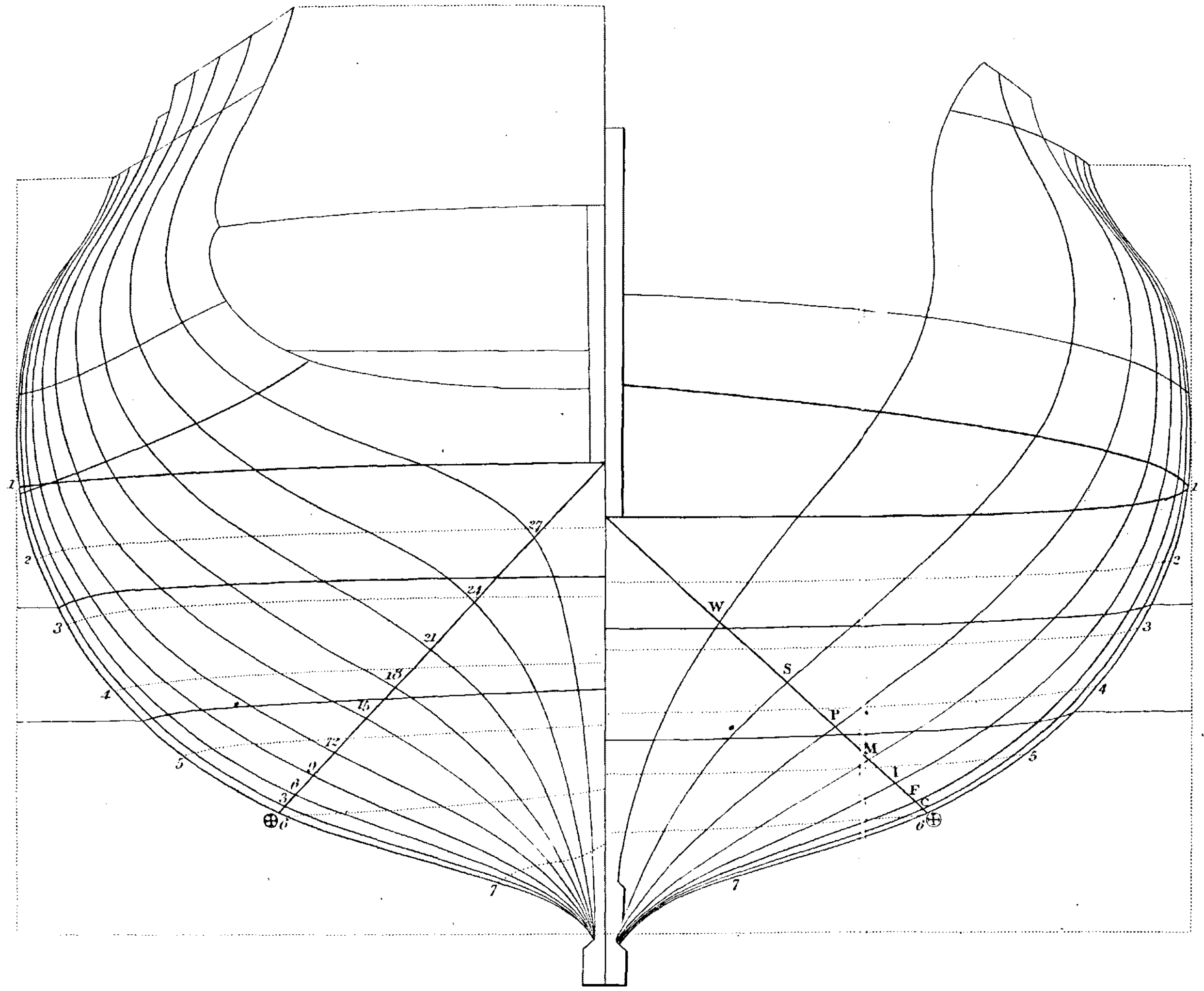
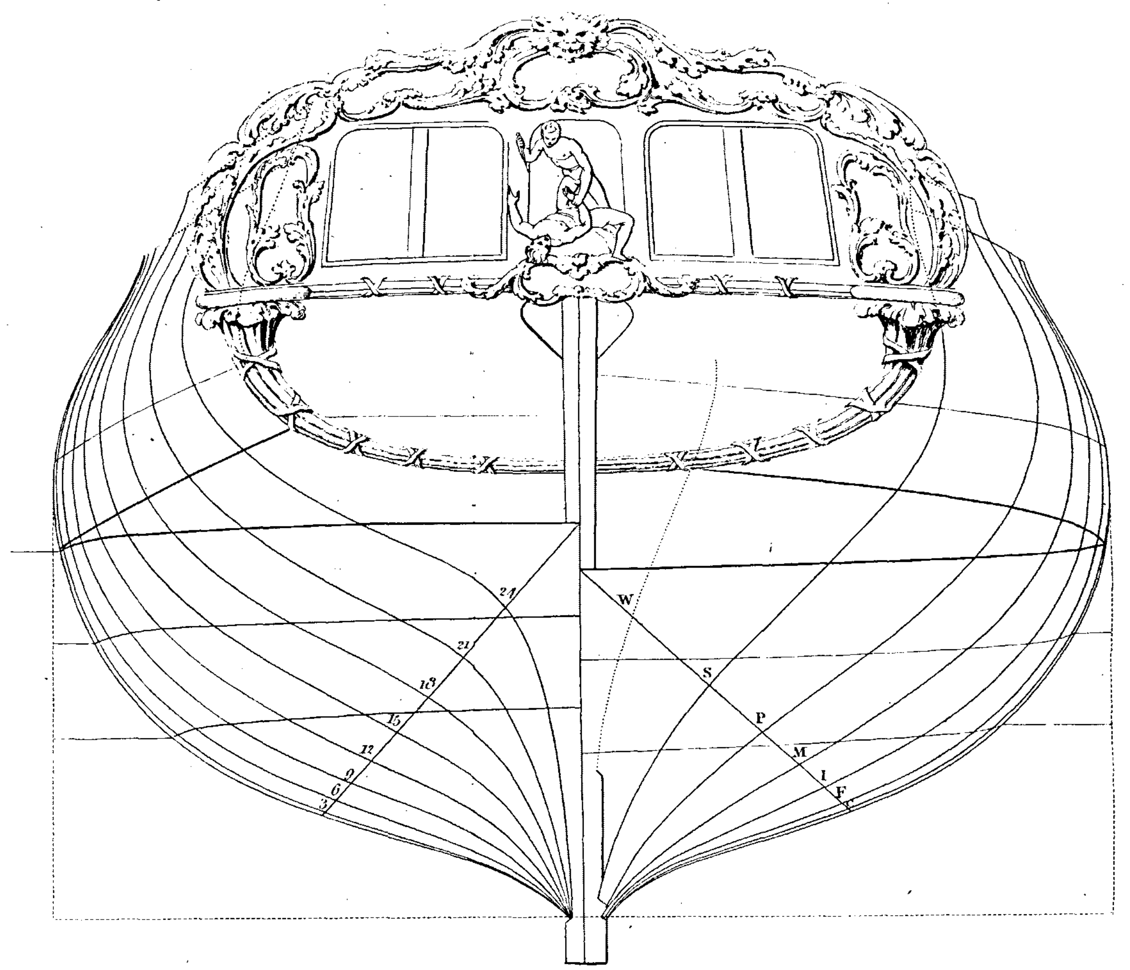


Fig. 45.



Lowry sculp.

Fig. 49.

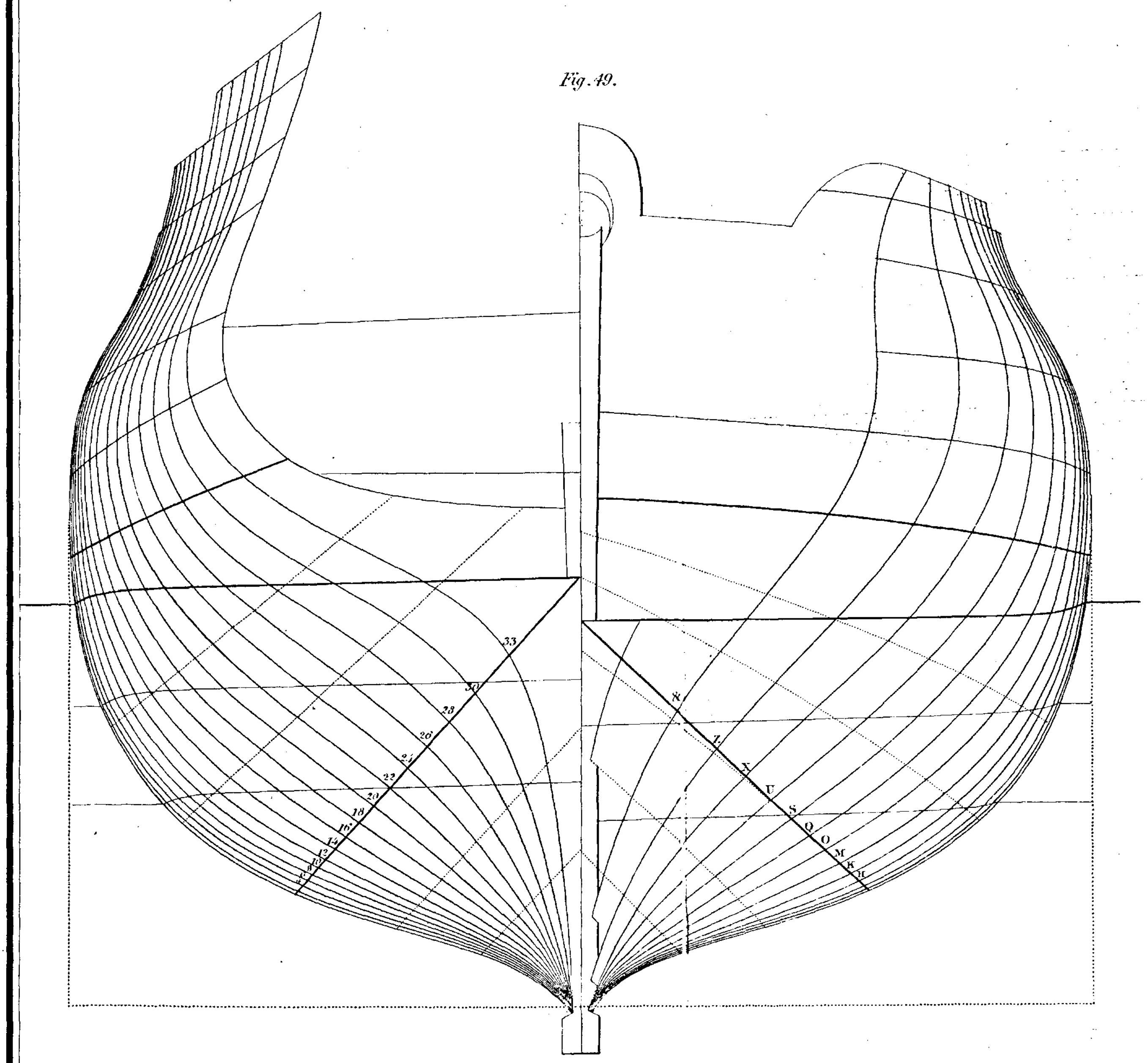
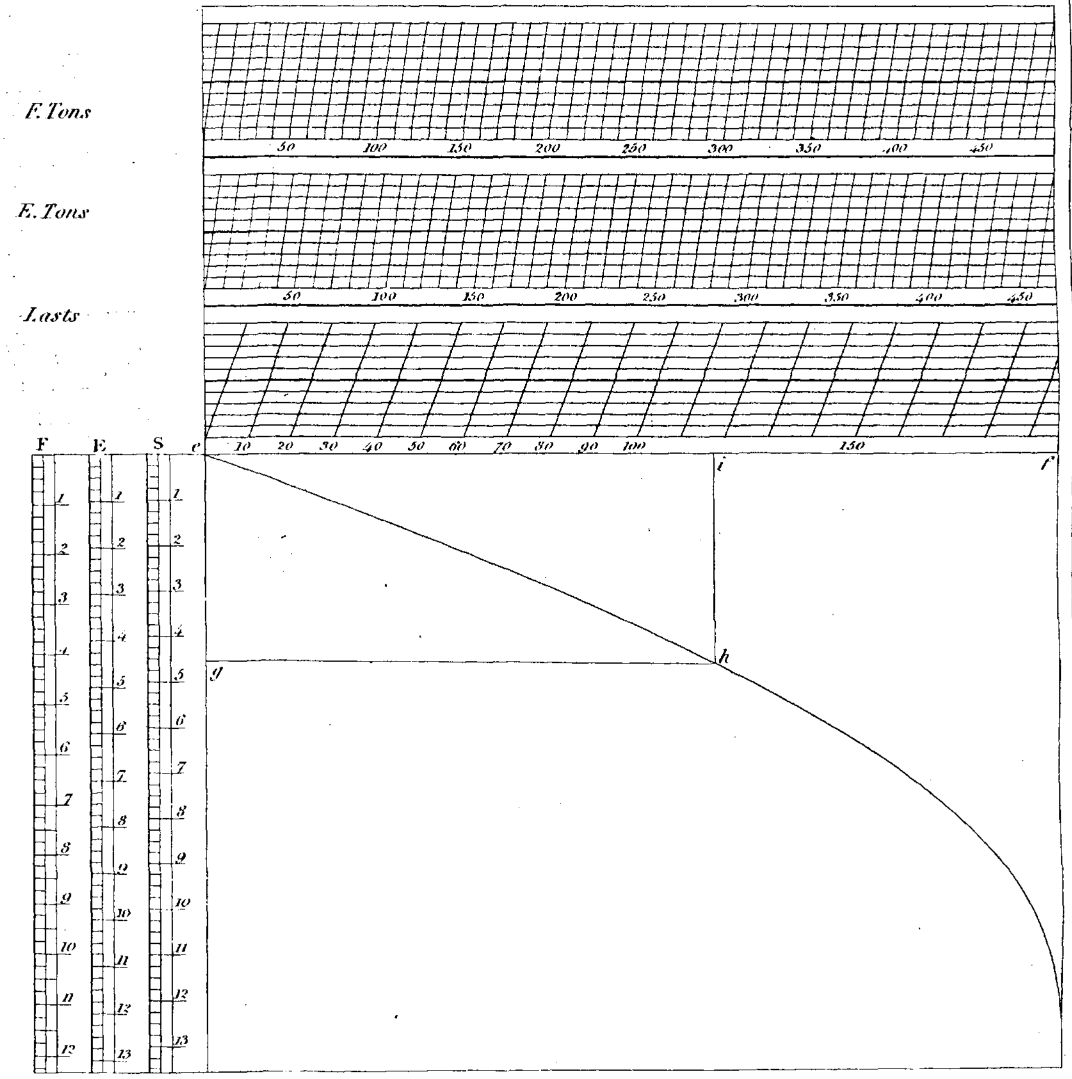


Fig. 50.



Lowry sculp.

Table of Cubes for the calculation of stability, or to get the value of the expression $\frac{2}{3}.\int y^3 \dot{x}$, (p. 18.)

Roots.	Cubes.	Roots.	Cubes.	Roots.	Cubes.	Roots.	Cubes.
0,01	0,000001	0,37	0,050653	0,73	0,389017	1,09	1,29
0,02	0,000008	0,38	0,054872	0,74	0,405224	1,10	1,33
0,03	0,000027	0,39	0,059319	0,75	0,421875	1,11	1,37
0,04	0,000064	0,40	0,064000	0,76	0,438976	1,12	1,40
0,05	0,000125	0,41	0,068921	0,77	0,456533	1,13	1,44
0,06	0,000216	0,42	0,074088	0,78	0,474552	1,14	1,48
0,07	0,000343	0,43	0,079507	0,79	0,493039	1,15	1,52
0,08	0,000512	0,44	0,085184	0,80	0,512000	1,16	1,56
0,09	0,000729	0,45	0,091125	0,81	0,531000	1,17	1,60
0,10	0,001000	0,46	0,097336	0,82	0,551000	1,18	1,64
0,11	0,001331	0.47	0,103823	0,83	0,572000	1,19	1,68
0,12	0,001728	0,48	0,110592	0,84	0,593000	1,20	1,72
0,13	0,002197	0,49	0,117649	0,85	0,614000	1,21	1,77
0,14	0,002744	0,50	0,125000	0,86	0,636000	1,22	1,82
0,15	0,003375	0,51	0,132651	0,87	0,658000	1,23	1,86
0,16	0,004096	0,52	0,140608	0,88	0,681000	1,24	1,91
0,17	0,004913	0,53	0,148877	0,89	0,705000	1,25	1,95
0,18	0,005832	0,54	0,157464	0,90	0,729000	1,26	2,00
0,19	0,006859	0,55	0,166375	0,91	0,754000	1,27	2,05
0,20	0,008000	0,56	0,175616	0,92	0,779000	1,28	2,09
0,21	0,009261	0,57	0,185193	0,93	0,804000	1,29	2,15
0,22	0,010648	0,58	0,195112	0,94	0,831000	1,30	2,20
0,23	0,012167	0,59	0,205379	0,95	0,857000	1,31	2,25
0,24	0,013824	0,60	0,216000	0,96	0,885000	1,32	2,30
0,25	0,015625	0,61	0,226981	0,97	0,913000	1,33	2,35
0,26	0,017576	0,62	0,238328	0,98	0,941000	1,34	2,41
0,27	0,019683	0,63	0,250047	0,99	0,970000	1,35	2,46
0,28	0,021952	0,64	0,262144	1,00	1,000000	1,36	2,51
0,29	0,024389	0,65	0,274625	1,01	1,030000	1,37	2,57
0,30	0,027000	0,66	0,287496	1,02	1,060000	1,38	2,63
0,31	0,029791	0,67	0,300763	1,03	1,090000	1,39	2,69
0,32	0,032768	0,68	0,314432	1,04	1,120000	1,40	2,74
0,33	0,035937	0,69	0,328509	1,05	1,160000	1,41	2,80
0,34	0,039304	0,70	0,343000	1,06	1,190000	1,42	2,86
0,35	0,042875	0,71	0,357911	1,07	1,220000	1,43	2,92
0,36	0,046656	0,72	0,373248	1,08	1,260000	1,44	2,99

Roots.	Cubes.	Roots.	Cubes.	Roots.	Cubes.	Roots.	Cubes.
1,45	3,05	1,85	6,33	2,25	11,39	2,65	18,61
1,46	3,11	1,86	6,43	2,26	11,54	2,66	18,82
1,47	3,18	1,87	6,54	2,27	11,70	2,67	19,03
1,48	3,24	1,88	6,64	2,28	11,85	2,68	19,25
1,49	3,31	1,89	6,75	2,29	12,01	2,69	19,46
1,50	3,37	1,90	6,86	2,30	12,17	2,70	19,68
1,51	3,44	1,91	6,97	2,31	12,33	2,71	19,90
1,52	3,51	1,92	7,08	2,32	12,49	2,72	20,12
1,53	3,58	1,93	7,19	2,33	12,65	2,73	20,35
1,54	3,65	1,94	7,30	2,34	12,81	2,74	20,57
1,55	3,72	1,95	7,41	2,35	12,98	2,75	20,80
1,56	3,80	1,96	7,53	2,36	13,14	2,76	21,02
1,57	3,87	1,97	7,64	2,37	13,31	2,77	21,25
1,58	3,94	1,98	7,76	2,38	13,48	2,78	21,48
1,59	4,02	1,99	7,88	2,39	13,65	2,79	21,72
1,60	4,10	2,00	8,00	2,40	13,82	2,80	21,95
1,61	4,17	2,01	8,12	2,41	14,00	2,81	22,19
1,62	4,25	2,02	8,24	2,42	14,17	2,82	22,43
1,63	4,33	2,03	8,36	2,43	14,35	2,83	22,66
1,64	4,41	2,04	8,49	2,44	14,53	2,84	22,91
1,65	4,49	2,05	8,61	2,45	14,71	2,85	23,15
1,66	4,57	2,06	8,74	2,46	14,89	2,86	23,39
1,67	4,66	2,07	8,87	2,47	15,07	2,87	23,64
1,68	4,74	2,08	9,00	2,48	15,25	2,88	23,89
1,69	4,83	2,09	9,13	2,49	15,44	2,89	24,14
1,70	4,91	2,10	9,26	2,50	15,62	2,90	24,39
1,71	5,00	2,11	9,39	2,51	15,81	2,91	24,64
1,72	5,09	2,12	9,53	2,52	16,00	2,92	24,90
1,73	5,18	2,13	9,66	2,53	16,19	2,93	25,15
1,74	5,27	2,14	9,80	2,54	16,39	2,94	25,41
1,75	5,36	2,15	9,94	2,55	16,58	2,95	25,67
1,76	5,45	2,16	10,08	2,56	16,78	2,96	25,93
1,77	5,54	2,17	10,22	2,57	16,97	2,97	26,20
1,78	5,64	2,18	10,36	2,58	17,17	2,98	26,46
1,79	5,73	2,19	10,50	2,59	17,37	2,99	26,73
1,80	5,83	2,20	10,65	2,60	17,58	3,00	27,00
1,81	5,93	2,21	10,79	2,61	17,78	3,01	27,27
1,82	6,03	2,22	10,94	2,62	17,98	3,02	27,54
1,83	6,13	2,23	11,09	2,63	18,19	3,03	27,82
1,84	6,23	2,24	11,24	2,64	18,40	3,04	28,09

Roots.	Cubes.	Roots.	Cubes.	Roots.	Cubes.	Roots.	Cubes.
3,05	28,37	3,45	41,06	3,85	57,07	4,25	76,77
3,06	28,65	3,46	41,42	3,86	57,51	4,26	77,31
3,07	28,93	3,47	41,78	3,87	57,96	4,27	77,85
3,08	29,22	3,48	42,14	3,88	58,41	4,28	78,40
3,09	29,50	3,49	42,51	3,89	58,86	4,29	78,95
3,10	29,79	3,50	42,87	3,90	59,32	4,30	79,51
3,11	30,08	3,51	43,24	3,91	59,78	4,31	80,06
3,12	30,37	3,52	43,61	3,92	60,24	4,32	80,62
3,13	30,66	3,53	43,99	3,93	60,70	4,33	81,18
3,14	30,96	3,54	44,36	3,94	61,16	4,34	81,75
3,15	31,26	3,55	44,74	3,95	61,63	4,35	82,31
3,16	31,55	3,56	45,12	3,96	62,10	4,36	82,88
3,17	31,85	3,57	45,50	3,97	62,57	4,37	83,45
3,18	32,16	3,58	45,88	3,98	63,04	4,38	84,03
3,19	32,46	3,59	46,27	3,99	63,52	4,39	84,60
3,20	32,77	3,60	46,66	4,00	64,00	4,40	85,18
3,21	33,08	3,61	47,05	4,01	64,48	4,41	85,77
3,22	33,39	3,62	47,44	4,02	64,96	4,42	86,35
3,23	33,70	3,63	47,83	4,03	65,45	4,43	86,94
3,24	34,01	3,64	48,23	4,04	65,94	4,44	87,53
3,25	34,33	3,65	48,63	4,05	66,43	4,45	88,12
3,26	34,65	3,66	49,03	4,06	66,92	4,46	88,72
3,27	34,97	3,67	49,43	4,07	67,42	4,47	89,31
3,28	35,29	3,68	49,84	4,08	67,92	4,48	89,91
3,29	35,61	3,69	50,24	4,09	68,42	4,49	90,52
3,30	35,94	3,70	50,65	4,10	68,92	4,50	91,12
3,31	36,26	3,71	51,06	4,11	69,43	4,51	91,73
3,32	36,59	3,72	51,48	4,12	69,93	4,52	92,34
3,33	36,93	3,73	51,89	4,13	70,44	4,53	92,96
3,34	37,26	3,74	52,31	4,14	70,96	4,54	93,58
3,35	37,59	3,75	52,73	4,15	71,47	4,55	94,20
3,36	37,93	3,76	53,16	4,16	71,99	4,56	94,82
3,37	38,27	3,77	53,58	4,17	72,51	4,57	95,44
3,38	38,61	3,78	54,01	4,18	73,03	4,58	96,07
3,39	38,96	3,79	54,44	4,19	73,56	4,59	96,70
3,40	39,30	3,80	54,87	4,20	74,09	4,60	97,34
3,41	39,65	3,81	55,31	4,21	74,62	4,61	97,97
3,42	40,00	3,82	55,74	4,22	75,15	4,62	98,61
3,43	40,35	3,83	56,18	4,23	75,69	4,63	99,25
3,44	40,71	3,84	56,62	4,24	76,22	4,64	99,90

Roots.	Cubes.	Roots.	Cubes.	Roots.	Cubes.	Roots.	Cubes.
4,65	100,54	5,05	128,79	5,45	161,88	5,85	200,20
4,66	101,19	5,06	129,55	5,46	162,77	5,86	201,23
4,67	101,85	5,07	130,32	5,47	163,67	5,87	202,26
4,68	102,50	5,08	131,10	5,48	164,57	5,88	203,30
4,69	103,16	5,09	131,87	5,49	165,47	5,89	204,34
4,70	103,82	5,10	132,65	5,50	166,37	5,90	205,38
4,71	104,49	5,11	133,43	5,51	167,28	5,91	206,42
4,72	105,15	5,12	134,22	5,52	168,20	5,92	207,47
4,73	105,82	5,13	135,01	5,53	169,11	5,93	208,53
4,74	106,50	5,14	135,80	5,54	170,03	5,94	209,58
4,75	107,17	5,15	136,59	5,55	170,95	5,95	210,64
4,76	107,85	5,16	137,39	5,56	171,88	5,96	211,71
4,77	108,53	5,17	138,19	5,57	172,81	5,97	212,78
4,78	109,21	5,18	138,99	5,58	173,74	5,98	213,85
4,79	109,90	5,19	139,80	5,59	174,68	5,99	214,92
4,80	110,59	5,20	140,61	5,60	175,62	6,00	216,00
4,81	111,28	5,21	141,42	5,61	176,56	6,01	217,08
7,82	111,98	5,22	142,24	5,62	177,50	6,02	218,17
4,83	112,68	5,23	143,06	5,63	178,45	6,03	219,26
4,84	113,38	5,24	143,88	5,64	179,41	6,04	220,35
4,85	114,08	5,25	144,70	5,65	180,36	6,05	221,44
4,86	114,79	5,26	145,53	5,66	181,32	6,06	222,54
4,87	115,50	5,27	146,36	5,67	182,28	6,07	223,65
4,88	116,21	5,28	147,20	5,68	183,25	6,08	224,76
4,89	116,93	5,29	148,04	5,69	184,22	6,09	225,87
4,90	117,65	5,30	148,88	5,70	185,19	6,10	226,98
4,91	118,37	5,31	149,72	5,71	186,17	6,11	228,10
4,92	119,09	5,32	150,57	5,72	187,15	6,12	229,22
4,93	119,82	5,33	151,42	5,73	188,13	6,13	230,35
4,94	120,55	5,34	152,27	5,74	189,12	6,14	231,47
4,95	121,29	5,35	153,13	5,75	190,11	6,15	232,61
4,96	122,02	5,36	153,99	5,76	191,10	6,16	233,74
4,97	122,76	5,37	154,85	5,77	192,10	6,17	234,88
4,98	123,51	5,38	155,72	5,78	193,10	6,18	236,03
4,99	124,25	5,39	156,59	5,79	194,10	6,19	237,18
5,00	125,00	5,40	157,46	5,80	195,11	6,20	238,33
5,01	125,75	5,41	158,34	5,81	196,12	6,21	239,48
5,02	126,51	5,42	159,23	5,82	197,14	6,22	240,64
5,03	127,26	5,43	160,10	5,83	198,15	6,23	241,80
5,04	128,02	5,44	160,99	5,84	199,18	6,24	242,97

Roots.	Cubes.	Roots.	Cubes.	Roots.	Cubes.	Roots.	Cubes.
6,25	244,14	6,65	294,08	7,05	350,40	7,45	413,49
6,26	245,31	6,66	295,41	7,06	351,90	7,46	415,16
6,27	246,49	6,67	296,74	7,07	353,39	7,47	416,83
6,28	247,67	6,68	298,08	7,08	354,89	7,48	418,51
6,29	248,86	6,69	299,42	7,09	356,40	7,49	420,19
6,30	250,05	6,70	300,76	7,10	357,91	7,50	421,87
6,31	251,24	6,71	302,11	7,11	359,42	7,51	423,56
6,32	252,44	6,72	303,46	7,12	360,94	7,52	425,26
6,33	253,64	6,73	304,82	7,13	362,47	7,53	426,96
6,34	254,84	6,74	306,18	7,14	363,99	7,54	428,66
6,35	256,05	6,75	307,55	7,15	365,53	7,55	430,37
6,36	257,26	6,76	308,92	7,16	367,06	7,56	432,08
6,37	258,47	6,77	310,29	7,17	368,60	7,57	433,80
6,38	259,69	6,78	311,67	7,18	370,15	7,58	435,52
6,39	260,92	6,79	313,05	7,19	371,69	7,59	437,24
6,40	262,14	6,80	314,43	7,20	373,25	7,60	438,98
6,41	263,37	6,81	315,82	7,21	374,80	7,61	440,71
6,42	264,61	6,82	317,21	7,22	376,37	7,62	442,45
6,43	265,85	6,83	318,61	7,23	377,93	7,63	444,19
6,44	267,09	6,84	320,01	7,24	379,50	7,64	445,94
6,45	268,34	6,85	321,42	7,25	381,08	7,65	447,70
6,46	269,59	6,86	322,83	7,26	382,66	7,66	449,45
6,47	270,84	6,87	324,24	7,27	384,24	7,67	451,22
6,48	272,10	6,88	325,66	7,28	385,83	7,68	452,98
6,49	273,36	6,89	327,08	7,29	387,42	7,69	454,76
6,50	274,62	6,90	328,51	7,30	389,02	7,70	456,53
6,51	275,89	6,91	329,94	7,31	390,62	7,71	458,31
6,52	277,17	6,92	331,37	7,32	392,22	7,72	460,10
6,53	278,44	6,93	332,81	7,33	393,83	7,73	461,89
6,54	279,73	6,94	334,25	7,34	395,45	7,74	463,68
6,55	281,01	6,95	335,70	7,35	397,06	7,75	465,48
6,56	282,30	6,96	337,15	7,36	398,69	7,76	567,29
6,57	283,59	6,97	338,61	7,37	400,31	7,77	469,10
6,58	284,89	6,98	340,07	7,38	401,95	7,78	470,91
6,59	286,19	6,99	341,53	7,39	403,58	7,79	472,73
6,60	287,50	7,00	343,00	7,40	405,22	7,80	474,55
6,61	288,80	7,01	344,47	7,41	406,87	7,81	476,38
6,62	290,11	7,02	345,95	7,42	408,52	7,82	478,21
6,63	291,43	7,03	347,43	7,43	410,17	7,83	480,05
6,64	292,75	7,04	348,91	7,44	411,83	7,84	481,89

Roots.	Cubes.	Roots.	Cubes.	Roots.	Cubes.	Roots.	Cubes.
7,85	483,74	8,25	561,51	8,65	647,21	9,05	741,22
7,86	485,59	2,26	563,56	8,66	649,46	9,06	743,68
7,87	487,44	8,27	565,61	8,67	651,71	9,07	746,14
7,88	489,30	8,28	567,66	8,68	653,97	9,08	748,61
7,89	491,17	8,29	569,72	8,69	656,23	9,09	751,09
7,90	493,04	8,30	571,79	8,70	658,50	9,10	753,57
7,91	494,91	8,31	573,86	8,71	660,78	9,11	756,06
7,92	496,79	8,32	575,93	8,72	663,05	9,12	758,55
7,93	498,68	8,33	578,01	8,73	665,34	9,13	761,05
7,94	500,57	8,34	580,09	8,74	667,63	9,14	763,55
7,95	502,46	8,35	582,18	8,75	669,92	9,15	766,07
7,96	504,36	8,36	584,28	8,76	672,22	9,16	768,57
7,97	506,26	8,37	586,38	8,77	674,53	9,17	771,09
7,98	508,17	8,38	588,48	8,78	676,84	9,18	773,62
7,99	510,08	8,39	590,59	8,79	679,15	9,19	776,15
8,00	512,00	8,40	592,70	8,80	681,47	9,20	778,69
8,01	513,92	8,41	594,82	8,81	683,80	9,21	781,23
8,02	515,85	8,42	596,95	8,82	686,13	9,22	783,78
8,03	517,78	8,43	599,08	8,83	688,46	9,23	786,33
8,04	519,72	8,44	601,21	8,84	690,81	9,24	788,89
8,05	521,66	8,45	603,35	8,85	693,15	9,25	791,45
8,06	523,61	8,46	605,50	8,86	695,51	9,26	794,02
8,07	525,56	8,47	607,64	8,87	697,86	9,27	796,60
8,08	527,51	8,48	609,80	8,88	700,23	9,28	799,18
8,09	529,47	8,49	611,96	8,89	702,59	9,29	801,76
8,10	531,44	8,50	614,12	8,90	704,97	9,30	804,36
8,11	533,41	8,51	616,29	8,91	707,35	9,31	806,95
8,12	535,39	8,52	618,47	8,92	709,73	9,32	809,56
8,13	537,37	8,53	620,65	8,93	712,12	9,33	812,17
8,14	539,35	8,54	622,83	8,94	714,52	9,34	814,78
8,15	541,34	8,55	625,03	8,95	716,92	9,35	817,40
8,16	543,34	8,56	627,22	8,96	719,32	9,36	820,03
8,17	545,34	8,57	629,42	8,97	721,73	9,37	822,66
8,18	547,34	8,58	631,63	8,98	724,15	9,38	825,29
8,19	549,35	8,59	633,83	8,99	726,57	9,39	827,94
8,20	551,37	8,60	636,06	9,00	729,00	9,40	830,58
8,21	553,39	8,61	638,28	9,01	731,43	9,41	833,24
8,22	555,41	8,62	640,50	9,02	733,87	9,42	835,90
8,23	557,44	8,63	642,74	9,03	736,31	9,43	838,56
8,24	559,48	8,64	644,97	9,04	738,76	9,44	841,23

Roots.	Cubes.	Roots.	Cubes.	Roots.	Cubes.	Roots.	Cubes.
9,45	843,91	9,85	955,67	10,25	1076,89	10,65	1207,95
9,46	846,59	9,86	958,58	10,26	1080,05	10,66	1211,35
9,47	849,28	9,87	961,50	10,27	1083,21	10,67	1214,77
9,48	851,97	9,88	964,43	10,28	1086,37	10,68	1218,18
9,49	854,67	9,89	967,36	10,29	1089,55	10,69	1221,61
9,50	857,37	9,90	970,30	10,30	1092,73	10,70	1225,04
9,51	860,08	9,91	973,24	10,31	1095,91	10,71	1228,48
2,52	862,80	9,92	976,19	10,32	1099,10	10,72	1231,92
9,53	865,52	9,93	979,15	10,33	1102,30	10,73	1235,38
9,54	868,25	9,94	982,11	10,34	1105,51	10,74	1238,83
9,55	870,98	9,95	985,07	10,35	1108,72	10,75	1242,30
9,56	873,72	9,96	988,05	10,36	1111,93	10,76	1245,77
9,57	876,47	9,97	991,03	10,37	1115,16	10,77	1249,24
9,58	879,22	9,98	994,01	10,38	1118,39	10,78	1252,73
9,59	881,97	9,99	997,00	10,39	1121,62	10,79	1256,22
9,60	884,74	10,00	1000,00	10,40	1124,86	10,80	1259,71
9,61	887,50	10,01	1003,00	10,41	1128,11	10,81	1263,21
9,62	890,28	10,02	1006,01	10,42	1131,37	10,82	1266,72
9,63	893,06	10,03	1009,03	10,43	1134,63	10,83	1270,24
9,64	895,84	10,04	1012,05	10,44	1137,89	10,84	1273,76
9,65	898,63	10,05	1015,07	10,45	1141,17	10,85	1277,29
9,66	901,43	10,06	1018,11	10,46	1144,44	10,86	1280,82
9,67	904,23	10,07	1021,15	10,47	1147,73	10,87	1284,36
9,68	907,04	10,08	1024,19	10,48	1151,02	10,88	1287,91
9,69	909,85	10,09	1027,24	10,49	1154,32	10,89	1291,47
9,70	912,67	10,10	1030,30	10,50	1157,62	10,90	1295,03
9,71	915,50	10,11	1033,36	10,51	1160,94	10,91	1298,60
9,72	918,33	10,12	1036,43	10,52	1164,25	10,92	1302,17
9,73	921,17	10,13	1039,51	10,53	1167,58	10,93	1305,75
9,74	924,01	10,14	1042,59	10,54	1170,90	10,94	1309,34
9,75	926,86	10,15	1045,68	10,55	1174,24	10,95	1312,93
9,76	929,71	10,16	1048,77	10,56	1177,58	10,96	1316,53
9,77	932,57	10,17	1051,87	10,57	1180,93	10,97	1320,14
9,78	935,44	10,18	1054,98	10,58	1184,29	10,98	1323,75
9,79	938,31	10,19	1058,09	10,59	1187,65	10,99	1327,37
9,80	941,19	10,20	1061,21	10,60	1191,02	11,00	1331,00
9,81	944,08	10,21	1064,33	10,61	1194,39	11,01	1334,63
9,82	946,97	10,22	1067,46	10,62	1197,77	11,02	1338,27
9,83	949,86	10,23	1070,60	10,63	1201,16	11,03	1341,92
9,84	952,76	10,24	1073,74	10,64	1204,55	11,04	1345,57

Roots.	Cubes.	Roots.	Cubes.	Roots.	Cubes.	Roots.	Cubes.
11,05	1349,23	11,45	1501,12	11,85	1664,01	12,25	1838,27
11,06	1352,90	11,46	1505,06	11,86	1668,22	12,26	1842,77
11,07	1356,57	11,47	1509,00	11,87	1672,45	12,27	1847,28
11,08	1360,25	11,48	1512,95	11,88	1676,68	12,28	1851,80
11,09	1363,94	11,49	1516,91	11,89	1680,91	12,29	1856,33
11,10	1367,63	11,50	1520,87	11,90	1685,16	12,30	1860,87
11,11	1371,33	11,51	1524,85	11,91	1689,41	12,31	1865,41
11,12	1375,04	11,52	1528,82	11,92	1693,67	12,32	1869,96
11,13	1378,75	11,53	1532,81	11,93	1697,94	12,33	1874,52
11,14	1382,47	11,54	1536,80	11,94	1702,21	12,34	1879,08
11,15	1386,20	11,55	1540,80	11,95	1706,49	12,35	1883,65
11,16	1389,92	11,56	1544,80	11,96	1710,78	12,36	1888,23
11,17	1393,67	11,57	1548,82	11,97	1715,07	12,37	1892,82
11,18	1397,42	11,58	1552,84	11,98	1719,37	12,38	1897,41
11,19	1401,17	11,59	1556,86	11,99	1723,68	12,39	1902,01
11,20	1404,93	11,60	1560,90	12,00	1728,00	12,40	1906,62
11,21	1408,69	11,61	1564,94	12,01	1732,32	12,41	1911,24
11,22	1412,47	11,62	1568,98	12,02	1736,65	12,42	1915,86
11,23	1416,25	11,63	1573,04	12,03	1740,99	12,43	1920,50
11,24	1420,03	11,64	1577,10	12,04	1745,34	11,44	1925,13
11,25	1423,83	11,65	1581,17	12,05	1749,69	12,45	1929,78
11,26	1427,63	11,66	1585,24	12,06	1754,05	12,46	1934,43
11,27	1431,43	11,67	1589,32	12,07	1758,42	12,47	1939,10
11,28	1435,25	11,68	1593,41	12,08	1762,79	12,48	1943,76
11,29	1439,07	11,69	1597,51	12,09	1767,17	12,49	1948,44
11,30	1442,90	11,70	1601,61	12,10	1771,56	12,50	1953,12
11,31	1446,73	11,71	1605,72	12,11	1775,96	12,51	1957,82
11,32	1450,57	11,72	1609,84	12,12	1780,36	12,52	1962,51
11,33	1454,42	11,73	1613,96	12,13	1784,77	12,53	1967,22
11,34	1458,27	11,74	1618,10	12,14	1789,19	12,54	1971,93
11,35	1462,13	11,75	1622,23	12,15	1793,61	12,55	1976,66
11,36	1466,00	11,76	1626,38	12,16	1798,05	12,56	1981,38
11,37	1469,88	11,77	1630,53	12,17	1802,48	12,57	1986,12
11,38	1473,76	11,78	1634,70	12,18	1806,93	12,58	1990,86
11,39	1477,65	11,79	1638,86	12,19	1811,39	12,59	1995,62
11,40	1481,54	11,80	1643,03	12,20	1815,85	12,60	2000,38
11,41	1485,45	11,81	1647,21	12,21	1820,32	12,61	2005,14
11,42	1489,35	11,82	1651,40	12,22	1824,79	12,62	2009,92
11,43	1493,27	11,83	1655,59	12,23	1829,28	12,63	2014,70
11,44	1497,19	11,84	1659,80	12,24	1833,77	12,64	2019,49

Roots.	Cubes.	Roots.	Cubes.	Roots.	Cubes.	Roots.	Cubes.
12,65	2024,28	13,05	2222,45	13,45	2433,14	13,85	2656,74
12,66	2029,09	13,06	2227,56	13,46	2438,57	13,86	2662,50
12,67	2033,90	13,07	2232,68	13,47	2444,01	13,87	2668,27
12,68	2038,72	13,08	2237,81	13,48	2449,46	13,88	2674,04
12,69	2043,55	13,09	2242,94	13,49	2454,91	13,89	2679,83
12,70	2048,38	13,10	2248,09	13,50	2460,37	13,90	2685,62
12,71	2053,22	13,11	2253,24	13,51	2465,85	13,91	2691,42
12,72	2058,08	13,12	2258,40	13,52	2471,33	13,92	2697,23
12,73	2062,93	13,13	2263,57	13,53	2476,81	13,93	2703,04
12,74	2067,80	13,14	2268,75	13,54	2482,31	13,94	2708,87
12,75	2072,67	13,15	2273,93	13,55	2487,81	13,95	2714,70
12,76	2077,55	13,16	2279,12	13,56	2493,33	13,96	2720,55
12,77	2082,44	13,17	2284,32	13,57	2498,85	13,97	2726,40
12,78	2087,34	13,18	2289,53	13,58	2504,37	13,98	2732,26
12,79	2092,24	13,19	2294,74	13,59	2509,91	13,99	2738,12
12,80	2097,15	13,20	2299,97	13,60	2515,46	14,00	2744,00
12,81	2102,07	13,21	2305,20	13,61	2521,01	14,01	2749,88
12,82	2107,00	13,22	2310,44	13,62	2526,57	14,02	2755,78
12,83	2111,93	13,23	2315,68	13,63	2532,14	14,03	2761,68
12,84	2116,87	13,24	2320,94	13,64	2537,72	14,04	2767,59
12,85	2121,82	13,25	2326,20	13,65	2543,30	14,05	2773,50
12,86	2126,78	13,26	2331,47	13,66	2548,90	14,06	2779,43
12,87	2131,75	13,27	2336,75	13,67	2554,50	14,07	2785,37
12,88	2136,72	13,28	2342,04	13,68	2560,11	14,08	2791,31
12,89	2141,70	13,29	2347,33	13,69	2565,73	14,09	2797,26
12,90	2146,69	13,30	2352,64	13,70	2571,35	14,10	2803,22
12,91	2151,68	13,31	2357,95	13,71	2576,99	14,11	2809,19
12,92	2156,69	13,32	2363,27	13,72	2582,63	14,12	2815,17
12,93	2161,70	13,33	2368,59	13,73	2588,28	14,13	2821,15
12,94	2166,72	13,34	2373,93	13,74	2593,94	14,14	2827,15
12,95	2171,75	13,35	2379,27	13,75	2599,61	14,15	2833,15
12,96	2176,78	13,36	2384,62	13,76	2605,28	14,16	2839,16
12,97	2181,82	13,37	2389,98	13,77	2610,97	14,17	2845,18
12,98	2186,88	13,38	2395,35	13,78	2616,66	14,18	2851,21
12,99	2191,93	13,39	2400,72	13,79	2622,36	14,19	2857,24
13,00	2197,00	13,40	2406,10	13,80	2628,07	14,20	2863,29
13,01	2202,07	13,41	2411,49	13,81	2633,79	14,21	2869,34
13,02	2207,16	13,42	2416,89	13,82	2639,51	14,22	2875,40
13,03	2212,24	13,43	2422,30	13,83	2645,25	14,23	2881,47
13,04	2217,34	13,44	2427,72	13,84	2650,99	14,24	2887,55

Roots.	Cubes.	Roots.	Cubes.	Roots.	Cubes.	Roots.	Cubes.
14,25	2893,64	14,65	3144,22	15,05	3408,86	15,45	3687,95
14,26	2899,74	14,66	3150,66	15,06	3415,66	15,46	3695,12
14,27	2905,84	14,67	3157,11	15,07	3422,47	15,47	3702,29
14,28	2911,95	14,68	3163,57	15,08	3429,29	15,48	3709,48
14,29	2918,08	14,69	3170,04	15,09	3436,11	15,49	3716,67
14,30	2924,21	14,70	3176,52	15,10	3442,95	15,50	3723,87
14,31	2930,35	14,71	3183,01	15,11	3449,80	15,51	3731,09
14,32	2936,49	14,72	3189,51	15,12	3456,65	15,52	3738,31
14,33	2942,65	14,73	3196,01	15,13	3463,51	15,53	3745,54
14,34	2948,81	14,74	3202,52	15,14	3470,38	15,54	3752,78
14,35	2954,99	14,75	3209,05	15,15	3477,26	15,55	3760,03
14,36	2961,17	14,76	3215,58	15,16	3484,16	15,56	3767,29
14,37	2967,36	14,77	3222,12	15,17	3491,05	15,57	3774,56
14,38	2973,56	14,78	3228,67	15,18	3497,96	15,58	3781,83
14,39	2979,77	14,79	3235,22	15,19	3504,88	15,59	3789,12
14,40	2985,98	14,80	3241,79	15,20	3511,81	15,60	3796,42
14,41	2992,21	14,81	3248,37	15,21	3518,74	15,61	3803,72
14,42	2998,44	14,82	3254,95	15,22	3525,69	15,62	3811,04
14,43	3004,68	14,83	3261,55	15,23	3532,64	15,63	3818,36
14,44	3010,94	14,84	3268,15	15,24	3539,61	15,64	3825,69
14,45	3017,20	14,85	3274,76	15,25	3546,58	15,65	3833,04
14,46	3023,46	14,86	3281,38	15,26	3553,56	15,66	3840,39
14,47	3029,74	14,87	3288,01	15,27	3560,55	15,67	3847,75
14,48	3036,03	14,88	3294,65	15,28	3567,55	15,68	3855,12
14,49	3042,32	14,89	3301,29	15,29	3574,56	15,69	3862,50
14,50	3048,62	14,90	3307,95	15,30	3581,58	15,70	3869,89
14,51	3054,94	14,91	3314,61	15,31	3588,60	15,71	3877,29
14,52	3061,26	14,92	3321,29	15,32	3595,64	15,72	3884,70
14,53	3067,59	14,93	3327,97	15,33	3602,69	15,73	3892,12
14,54	3073,92	14,94	3334,66	15,34	3609,74	15,74	3899,55
14,55	3080,27	14,95	3341,36	15,35	3616,80	15,75	3906,98
14,56	3086,63	14,96	3348,07	15,36	3623,88	15,76	3914,43
14,57	3092,99	14,97	3354,79	15,37	3630,96	15,77	3921,89
14,58	3099,36	14,98	3361,52	15,38	3638,05	15,78	3929,35
14,59	3105,75	14,99	3368,25	15,39	3645,15	15,79	3936,83
14,60	3112,14	15,00	3375,00	15,40	3652,26	15,80	3944,31
14,61	3118,53	15,01	3381,75	15,41	3659,38	15,81	3951,80
14,62	3124,94	15,02	3388,52	15,42	3666,51	15,82	3959,31
14,63	3131,36	15,03	3395,29	15,43	3673,65	15,83	3966,82
14,64	3137,78	15,04	3402,07	15,44	3680,80	15,84	3974,34

Roots.	Cubes.	Roots.	Cubes.	Roots.	Cubes.	Roots.	Cubes.
15,85	3981,88	16,25	4291,02	16,65	4615,75	17,05	4956,48
15,86	3989,42	16,26	4298,94	16,66	4624,08	17,06	4965,20
15,87	3996,97	16,27	4306,88	16,67	4632,41	17,07	4973,94
15,88	4004,53	16,28	4314,82	16,68	4640,75	17,08	4982,69
15,89	4012,10	16,29	4322,78	16,69	4649,10	17,09	4991,44
15,90	4019,68	16,30	4330,75	16,70	4657,46	17,10	5000,21
15,91	4027,27	16,31	4338,72	16,71	4665,83	17,11	5008,99
15,92	4034,87	16,32	4346,71	16,72	4674,22	17,12	5017,78
15,93	4042,47	16,33	4354,70	16,73	4682,61	17,13	5026,57
15,94	4050,09	16,34	4362,71	16,74	4691,01	17,14	5035,38
15,95	4057,72	16,35	4370,72	16,75	4699,42	17,15	5044,20
15,96	4065,36	16,36	4378,75	16,76	4707,84	17,16	5053,03
15,97	4073,00	16,37	4386,78	16,77	4716,28	17,17	5061,87
15,98	4080,66	16,38	4394,83	16,78	4724,72	17,18	5070,72
15,99	4088,32	16,39	4402,88	16,79	4733,17	17,19	5079,58
16,00	4096,00	16,40	4410,94	16,80	4741,63	17,20	5088,45
16,01	4103,68	16,41	4419,02	16,81	4750,10	17,21	5097,33
16,02	4111,38	16,42	4427,10	16,82	4758,59	17,22	5106,22
16,03	4119,08	16,43	4435,19	16,83	4767,08	17,23	5115,12
16,04	4126,80	16,44	4443,30	16,84	4775,58	17,24	5124,03
16,05	4134,52	16,45	4451,41	16,85	4784,09	17,25	5132,95
16,06	4142,25	16,46	4459,53	16,86	4792,61	17,26	5141,88
16,07	4149,99	16,47	4467,67	16,87	4801,15	17,27	5150,83
16,08	4157,75	16,48	4475,81	16,88	4809,69	17,28	5159,78
16,09	4165,51	16,49	4483,96	16,89	4818,25	17,29	5168,74
16,10	4173,28	16,50	4492,12	16,90	4826,81	17,30	5177,72
16,11	4181,06	16,51	4500,30	16,91	4835,38	17,31	5186,70
16,12	4188,85	16,52	4508,48	16,92	4843,97	17,32	5195,69
16,13	4196,65	16,53	4516,67	16,93	4852,56	17,33	5204,70
16,14	4204,46	16,54	4524,87	16,94	4861,16	17,34	5213,71
16,15	4212,28	16,55	4533,09	16,95	4869,78	17,35	5222,74
16,16	4220,11	16,56	4541,31	16,96	4878,40	17,36	5231,77
16,17	4227,95	16,57	4549,54	16,97	4887,04	17,37	5240,82
16,18	4235,80	16,58	4557,78	16,98	4895,68	17,38	5249,88
16,19	4243,66	16,59	4566,03	16,99	4904,33	17,39	5258,95
16,20	4251,53	16,60	4574,30	17,00	4913,00	17,40	5268,02
16,21	4259,41	16,61	4582,57	17,01	4921,67	17,41	5277,11
16,22	4267,29	16,62	4590,85	17,02	4930,36	17,42	5286,21
16,23	4275,19	16,63	4599,14	17,03	4939,06	17,43	5295,32
16,24	4283,10	16,64	4607,44	17,04	4947,76	17,44	5304,44

Roots.	Cubes.	Roots.	Cubes.	Roots.	Cubes.	Roots.	Cubes.
17,45	5313,57	17,85	5687,41	18,25	6078,39	18,65	6486,89
17,46	5322,71	17,86	5696,98	18,26	6088,39	18,66	6497,33
17,47	5331,86	17,87	5706,55	18,27	6098,40	18,67	6507,78
17,48	5341,02	17,88	5716,14	18,28	6108,41	18,68	6518,24
17,49	5350,19	17,89	5725,73	18,29	6118,45	18,69	6528,72
17,50	5359,37	17,90	5735,34	18,30	6128,49	18,70	6539,20
17,51	5368,57	17,91	5744,96	18,31	6138,54	18,71	6549,70
17,52	5377,77	17,92	5754,58	18,32	6148,60	18,72	6560,21
17,53	5386,98	17,93	5764,22	18,33	6158,68	18,73	6570,73
17,54	5396,21	17,94	5773,87	18,34	6168,76	18,74	6581,26
17,55	5405,44	17,95	5783,53	18,35	6178,86	18,75	6591,80
17,56	5414,69	17,96	5793,20	18,36	6188,96	18,76	6602,35
17,57	5423,94	17,97	5802,89	18,37	6199,08	18,77	6612,91
17,58	5433,21	17,98	5812,58	18,38	6209,21	18,78	6623,49
17,59	5442,49	17,99	5822,28	18,39	6219,35	18,79	6634,07
17,60	5451,77	18,00	5832,00	18,40	6229,50	18,80	6644,67
17,61	5461,07	18,01	5841,72	18,41	6239,67	18,81	6655,28
17,62	5470,38	18,02	5851,46	18,42	6249,84	18,82	6665,90
17,63	5479,70	18,03	5861,21	18,43	6260,02	18,83	6676,53
17,64	5489,03	18,04	5870,97	18,44	6270,22	18,84	6687,17
17,65	5498,37	18,05	5880,73	18,45	6280,43	18,85	6697,83
17,66	5507,72	18,06	5890,51	18,46	6290,64	18,86	6708,49
17,67	5517,08	18,07	5900,30	18,47	6300,87	18,87	6719,17
17,68	5526,46	18,08	5910,11	18,48	6311,11	18,88	6729,86
17,69	5535,84	18,09	5919,92	18,49	6321,36	18,89	6740,56
17,70	5545,23	18,10	5929,74	18,50	6331,62	18,90	6751,27
17,71	5554,64	18,11	5939,57	18,51	6341,90	18,91	6761,99
17,72	5564,05	18,12	5949,42	18,52	6352,18	18,92	6772,72
17,73	5573,48	18,13	5959,27	18,53	6362,48	18,93	6783,47
17,74	5582,91	18,14	5969,14	18,54	6372,78	18,94	6794,22
17,75	5592,36	18,15	5979,02	18,55	6383,10	18,95	6804,99
17,76	5601,82	18,16	5988,91	18,56	6393,43	18,96	6815,77
17,77	5611,28	18,17	5998,80	18,57	6403,77	18,97	6826,56
17,78	5620,76	18,18	6008,71	18,58	6414,12	18,98	6837,36
17,79	5630,25	18,19	6018,64	18,59	6424,48	18,99	6848,18
17,80	5639,75	18,20	6028,57	18,60	6434,86	19,00	6859,00
17,81	5649,26	18,21	6038,51	18,61	6445,24	19,01	6869,84
17,82	5658,78	18,22	6048,46	18,62	6455,64	19,02	6880,68
17,83	5668,32	18,23	6058,43	18,63	6466,04	19,03	6891,54
17,84	5677,86	18,24	6068,40	18,64	6476,46	19,04	6902,41

Roots.	Cubes.	Roots.	Cubes.	Roots.	Cubes.	Roots.	Cubes.
19,05	6913,29	19,45	7357,98	19,85	7821,35	20,25	8303,77
19,06	6924,18	19,46	7369,34	19,86	7833,17	20,26	8316,07
19,07	6935,09	19,47	7380,70	19,87	7845,01	20,27	8328,39
19,08	6946,00	19,48	7392,08	19,88	7856,86	20,28	8340,73
19,09	6956,93	19,49	7403,47	19,89	7868,72	20,29	8353,07
19,10	6967,87	19,50	7414,87	19,90	7880,60	20,30	8365,43
19,11	6978,82	19,51	7426,29	19,91	7892,48	20,31	8377,80
19,12	6989,78	19,52	7437,71	19,92	7904,38	20,32	8390,18
19,13	7000,75	19,53	7449,15	19,93	7916,29	20,33	8402,57
19,14	7011,74	19,54	7460,60	19,94	7928,21	20,34	8414,97
19,15	7022,74	19,55	7472,06	19,95	7940,15	20,35	8427,39
19,16	7033,74	19,56	7483,53	19,96	7952,09	20,36	8439,82
19,17	7044,76	19,57	7495,01	19,97	7964,05	20,37	8452,26
19,18	7055,79	19,58	7506,51	19,98	7976,02	20,38	8464,72
19,19	7066,83	19,59	7518,02	19,99	7988,01	20,39	8477,18
19,20	7077,89	19,60	7529,54	20,00	8000,00	20,40	8489,66
19,21	7088,95	19,61	7541,07	20,01	8012,01	20,41	8502,15
19,22	7100,03	19,62	7552,61	20,02	8024,02	20,42	8514,66
19,23	7111,12	19,63	7564,16	20,03	8036,05	20,43	8527,17
19,24	7122,22	19,64	7575,73	20,04	8048,09	20,44	8539,70
19,25	7133,33	19,65	7587,31	20,05	8060,15	20,45	8552,24
19,26	7144,45	19,66	7598,90	20,06	8072,22	20,46	8564,79
19,27	7155,58	19,67	7610,50	20,07	8084,29	20,47	8577,36
19,28	7166,73	19,68	7622,11	20,08	8096,38	20,48	8589,93
19,29	7177,89	19,69	7633,74	20,09	8108,49	20,49	8602,52
19,30	7189,06	19,70	7645,37	20,10	8120,60	20,50	8615,12
19,31	7200,24	19,71	7657,02	20,11	8132,73	20,51	8627,74
19,32	7211,43	19,72	7668,68	20,12	8144,87	20,52	8640,36
19,33	7222,63	19,73	7680,35	20,13	8157,02	20,53	8653,00
19,34	7233,85	19,74	7692,04	20,14	8169,18	20,54	8665,65
19,35	7245,07	19,75	7703,73	20,15	8181,35	20,55	8678,32
19,36	7256,31	19,76	7715,44	20,16	8193,54	20,56	8690,99
19,37	7267,56	19,77	7727,16	20,17	8205,74	20,57	8703,68
19,38	7278,83	19,78	7738,89	20,18	8217,95	20,58	8716,38
19,39	7290,10	19,79	7750,64	20,19	8230,17	20,59	8729,09
19,40	7301,38	19,80	7762,39	20,20	8242,41	20,60	8741,82
19,41	7312,68	19,81	7774,16	20,21	8254,65	20,61	8754,55
19,42	7323,99	19,82	7785,94	20,22	8266,91	20,62	8767,30
19,43	7335,31	19,83	7797,73	20,23	8279,19	20,63	8780,06
19,44	7346,64	19,84	7809,53	20,24	8291,47	20,64	8792,84

Roots.	Cubes.	Roots.	Cubes.	Roots.	Cubes.	Roots.	Cubes.
20,65	8805,62	21,05	9327,31	21,45	9869,20	21,85	10431,68
20,66	8818,42	21,06	9340,61	21,46	9883,01	21,86	10446,01
20,67	8831,23	21,07	9353,92	21,47	9896,83	21,87	10460,35
20,68	8844,06	21,08	9367,24	21,48	9910,67	21,88	10474,71
20,69	8856,89	21,09	9380,58	21,49	9924,51	21,89	10489,08
20,70	8869,74	21,10	9393,93	21,50	9938,37	21,90	10503,46
20,71	8882,60	21,11	9407,29	21,51	9952,25	21,91	10517,85
20,72	8895,48	21,12	9420,67	21,52	9966,14	21,92	10532,26
20,73	8908,36	21,13	9434,06	21,53	9980,04	21,93	10546,68
20,74	8921,26	21,14	9447,46	21,54	9993,95	21,94	10561,12
20,75	8934,17	21,15	9460,87	21,55	10007,87	21,95	10575,56
20,76	8947,09	21,16	9474,30	21,56	10021,81	21,96	10590,02
20,77	8960,03	21,17	9487,74	21,57	10035,76	21,97	10604,50
20,78	8972,98	21,18	9501,19	21,58	10049,73	21,98	10618,99
20,79	8985,94	21,19	9514,65	21,59	10063,71	21,99	10633,49
20,80	8998,91	21,20	9528,13	21,60	10077,70	22,00	10648,00
20,81	9011,89	21,21	9541,62	21,61	10091,70	22,01	10662,53
20,82	9024,89	21,22	9555,12	21,62	10105,71	22,02	10677,07
20,83	9037,91	21,23	9568,63	21,63	10119,74	22,03	10691,62
20,84	9050,93	21,24	9582,16	21,64	10133,79	22,04	10706,19
20,85	9063,96	21,25	9595,70	21,65	10147,84	22,05	10720,76
20,86	9077,01	21,26	9609,26	21,66	10161,91	22,06	10735,36
20,87	9090,07	21,27	9622,82	21,67	10175,99	22,07	10749,96
20,88	9103,14	21,28	9636,40	21,68	10190,09	22,08	10764,58
20,89	9116,23	21,29	9649,99	21,69	10204,19	22,09	10779,21
20,90	9129,33	21,30	9663,60	21,70	10218,31	22,10	10793,86
20,91	9142,44	21,31	9677,21	21,71	10232,45	22,11	10808,52
20,92	9155,56	21,32	9690,84	21,72	10246,59	22,12	10823,19
20,93	9168,69	21,33	9704,49	21,73	10260,75	22,13	10837,88
20,94	9181,85	21,34	9718,14	21,74	10274,92	22,14	10852,58
20,95	9195,01	21,35	9731,81	21,75	10289,11	22,15	10867,29
20,96	9208,18	21,36	9745,49	21,76	10303,31	22,16	10882,01
20,97	9221,37	21,37	9759,18	21,77	10317,52	22,17	10896,75
20,98	9234,56	21,38	9772,89	21,78	10331,74	22,18	10911,50
20,99	9247,78	21,39	9786,61	21,79	10345,98	22,19	10926,27
21,00	9261,00	21,40	9800,34	21,80	10360,23	22,20	10941,05
21,01	9274,24	21,41	9814,09	21,81	10374,50	22,21	10955,84
21,02	9287,48	21,42	9827,85	21,82	10388,77	22,22	10970,64
21,03	9300,75	21,43	9841,62	21,83	10403,06	22,23	10985,46
21,04	9314,02	21,44	9855,40	21,84	10417,36	22,24	11000,29

Roots.	Cubes.	Roots.	Cubes.	Roots.	Cubes.	Roots.	Cubes.
22,25	11015,14	22,65	11619,96	23,05	12246,52	23,45	12995,21
22,26	11030,00	22,66	11635,36	23,06	12262,47	23,46	12911,72
22,27	11044,87	22,67	11650,77	23,07	12278,43	23,47	12928,24
22,28	11059,76	22,68	11666,19	23,08	12294,40	23,48	12944,77
22,29	11074,65	22,69	11681,63	23,09	12310,39	23,49	12961,31
22,30	11089,57	22,70	11697,08	23,10	12326,39	23,50	12977,87
22,31	11104,49	22,71	11712,55	23,11	12342,41	23,51	12994,45
22,32	11119,43	22,72	11728,03	23,12	12358,43	23,52	13011,04
22,33	11134,38	22,73	11743,52	23,13	12374,48	23,53	13027,64
22,34	11149,35	22,74	11759,03	23,14	12390,53	23,54	13044,26
22,35	11164,33	22,75	11774,55	23,15	12406,60	23,55	13060,89
22,36	11179,32	22,76	11790,08	23,16	12422,69	23,56	13077,53
22,37	11194,33	22,77	11805,63	23,17	12438,79	23,57	13094,19
22,38	11209,34	22,78	11821,19	23,18	12454,90	23,58	13110,87
22,39	11224,38	22,79	11836,76	23,19	12471,03	23,59	13127,55
22,40	11239,42	22,80	11852,35	23,20	12487,17	23,60	13144,26
22,41	11254,48	22,81	11867,95	23,21	12503,32	23,61	13160,97
22,42	11269,56	22,82	11883,57	23,22	12519,49	23,62	13177,70
22,43	11284,64	22,83	11899,20	23,23	12535,67	23,63	13194,45
22,44	11299,74	22,84	11914,84	23,24	12551,87	23,64	13211,20
22,45	11314,86	22,85	11930,50	23,25	12568,08	23,65	13227,98
22,46	11329,98	22,86	11946,17	23,26	12584,30	23,66	13244,76
22,47	11345,12	22,87	11961,85	23,27	12600,54	23,67	13261,56
22,48	11360,28	22,88	11977,55	23,28	12616,79	23,68	13278,38
22,49	11375,44	22,89	11993,26	23,29	12633,06	23,69	13295,21
22,50	11390,62	22,90	12008,99	23,30	12649,34	23,70	13312,05
22,51	11405,82	22,91	12024,73	23,31	12665,63	23,71	13328,91
22,52	11421,03	22,92	12040,48	23,32	12681,94	23,72	13345,78
22,53	11436,25	22,93	12056,25	23,33	12698,26	23,73	13362,67
22,54	11451,48	22,94	12072,03	23,34	12714,60	23,74	13379,57
22,55	11466,73	22,95	12087,82	23,35	12730,94	23,75	13396,48
22,56	11481,99	22,96	12103,63	23,36	12747,31	23,76	13413,41
22,57	11497,27	22,97	12119,45	23,37	12763,69	23,77	13430,36
22,58	11512,56	22,98	12135,29	23,38	12780,08	23,78	13447,31
22,59	11527,86	22,99	12151,14	23,39	12796,48	23,79	13464,29
22,60	11543,18	23,00	12167,00	23,40	12812,90	23,80	13481,27
22,61	11558,51	23,01	12182,88	23,41	12829,34	23,81	13498,27
22,62	11573,85	23,02	12198,77	23,42	12845,79	23,82	13515,29
22,63	11589,21	23,03	12214,67	23,43	12862,25	23,83	13532,32
22,64	11604,58	23,04	12230,59	23,44	12878,72	23,84	13549,36

Roots.	Cubes.	Roots.	Cubes.	Roots.	Cubes.	Roots.	Cubes.
23,85	13566,42	24,25	14260,52	24,65	14977,89	25,05	15718,94
23,86	13583,49	24,26	14278,16	24,66	14996,13	25,06	15737,77
23,87	13600,57	24,27	14295,83	24,67	15014,38	25,07	15756,62
23,88	13617,67	24,28	14313,51	24,68	15032,65	25,08	15775,48
23,89	13634,79	24,29	14331,19	24,69	15050,93	25,09	15794,36
23,90	13651,92	24,30	14348,91	24,70	15069,22	25,10	15813,25
23,91	13669,06	24,31	14366,63	24,71	15087,53	25,11	15832,16
23,92	13686,22	24,32	14384,37	24,72	15105,86	25,12	15851,08
23,93	13703,39	24,33	14402,12	24,73	15124,20	25,13	15870,02
23,94	13720,58	24,34	14419,88	24,74	15142,55	25,14	15888,97
23,95	13737,78	24,35	14437,66	24,75	15160,92	25,15	15907,94
23,96	13754,99	24,36	14455,46	24,76	15179,31	25,16	15926,92
23,97	13772,22	24,37	14473,27	24,77	15197,70	25,17	15945,92
23,98	13789,47	24,38	14491,09	24,78	15216,12	25,18	15964,94
23,99	13806,73	24,39	14508,93	24,79	15234,55	25,19	15983,96
24,00	13824,00	24,40	14526,78	24,80	15252,99	25,20	16003,01
24,01	13841,29	24,41	14544,65	24,81	15271,45	25,21	16022,07
24,02	13858,59	24,42	14562,53	24,82	15289,92	25,22	16041,14
24,03	13875,90	24,43	14580,43	24,83	15308,41	25,23	16060,23
24,04	13893,23	24,44	14598,34	24,84	15326,92	25,24	16079,34
24,05	13910,58	24,45	14616,27	24,85	15345,43	25,25	16098,45
24,06	13927,94	24,46	14634,21	24,86	15363,97	25,26	16117,59
24,07	13945,31	24,47	14652,17	24,87	15382,51	25,27	16136,74
24,08	13962,70	24,48	14670,14	24,88	15401,08	25,28	16155,90
24,09	13980,10	24,49	14688,12	24,89	15419,66	25,29	16175,08
24,10	13997,52	24,50	14706,12	24,90	15438,25	25,30	16194,28
24,11	14014,95	24,51	14724,14	24,91	15456,86	25,31	16213,49
24,12	14032,40	24,52	14742,17	24,92	15475,48	25,32	16232,71
24,13	14049,86	24,53	14760,21	24,93	15494,12	25,33	16251,95
24,14	14067,33	24,54	14778,27	24,94	15512,77	25,34	16271,21
24,15	14084,82	24,55	14796,35	24,95	15531,44	25,35	16290,48
24,16	14102,33	24,56	14814,43	24,96	15550,12	25,36	16309,77
24,17	14119,85	24,57	14832,54	24,97	15568,82	25,37	16329,07
24,18	14137,38	24,58	14850,66	24,98	15587,53	25,38	16348,38
24,19	14154,93	24,59	14868,79	24,99	15606,26	25,39	16367,72
24,20	14172,49	24,60	14886,94	25,00	15625,00	25,40	16387,06
24,21	14190,06	24,61	14905,10	25,01	15643,76	25,41	16406,43
24,22	14207,65	24,62	14923,27	25,02	15662,53	25,42	16425,80
24,23	14225,26	24,63	14941,47	25,03	15681,32	25,43	16445,20
24,24	14242,88	24,64	14959,67	25,04	15700,12	25,44	16464,60

Roots.	Cubes.	Roots.	Cubes.	Roots.	Cubes.	Roots.	Cubes.
25,45	16484,03	25,59	16757,56	25,73	17034,11	25,87	17313,68
25,46	16503,47	25,60	16777,22	25,74	17053,97	25,88	17333,77
25,47	16522,92	25,61	16796,88	25,75	17073,86	25,89	17353,86
25,48	16542,39	25,62	16816,57	25,76	17093,76	25,90	17373,98
25,49	16561,87	25,63	16836,27	25,77	17113,67	25,91	17394,11
25,50	16581,37	25,64	16855,98	25,78	17133,60	25,92	17414,26
25,51	16600,89	25,65	16875,71	25,79	17153,55	25,93	17434,42
25,52	16620,42	25,66	16895,46	25,80	17173,51	25,94	17454,60
25,53	16639,97	25,67	16915,22	25,81	17193,49	25,95	17474,79
25,54	16659,53	25,68	16934,99	25,82	17213,48	25,96	17495,00
25,55	16679,10	25,69	16954,79	25,83	17233,49	25,97	17515,23
25,56	16698,70	25,70	16974,59	25,84	17253,51	25,98	17535,47
25,57	16718,30	25,71	16994,41	25,85	17273,55	25,99	17555,73
25,58	16737,92	25,72	17014,25	25,86	17293,61	26,00	17576,00

(N°. 1.) *Rules for Proportions of Merchant Ships.*

SPECIES OF SHIP.	Burthen in lasts reduced into cubic feet, reckoning 91 cubic feet for each last.	Displacement in cubic feet to the outside of the timbers.	Length from the perpendicular at the stem to that at the sternpost.	Greatest breadth to the outside of the timbers.	Distances of the load water-line from the upper edge of the rabbet of the keel, at the frame ϕ.	Area of the midship section.	Depth of the keel measured from the upper edge of the rabbet.	Difference of draught of water.	Area of the load water-line.
	$\underbrace{P}$	$\underbrace{D}$	$\underbrace{x}$	$\underbrace{z}$	$\underbrace{h}$	$\underbrace{\phi}$	$\underbrace{k}$	$\underbrace{d}$	$\underbrace{W}$
Frigates.	$D^{\frac{17}{18}}$	$P^{\frac{18}{17}}$	$(56D)^{\frac{1}{3}}$	$\frac{x^{\frac{4}{5}}}{1,383}$	$\frac{x}{8,1}$	$\frac{1,705D}{x^{1+\frac{1}{40}}}$	$\frac{x^{\frac{2}{5}}}{4,64}$	$\frac{x^{\frac{3}{4}}}{23,3}$	$\frac{z\,x^{1+\frac{1}{30}}}{1,49}$
Heckboats or Pinks.	$D^{\frac{19}{20}}$	$P^{\frac{20}{19}}$	$(54D)^{\frac{1}{3}}$	$\frac{x^{\frac{4}{5}}}{1,429}$	$\frac{x^{1-\frac{1}{60}}}{7,547}$	$\frac{1,729D}{x^{1+\frac{1}{27}}}$	$\frac{x^{\frac{3}{7}}}{5,66}$	$\frac{x^{\frac{2}{3}}}{17,5}$	$\frac{z\,x^{1+\frac{1}{24}}}{1,5}$
Cats or Barks.	$D^{\frac{21}{22}}$	$P^{\frac{22}{21}}$	$(52D)^{\frac{1}{3}}$	$\frac{x^{\frac{4}{5}}}{1,476}$	$\frac{x^{1-\frac{1}{30}}}{7,032}$	$\frac{1,76D}{x^{1+\frac{1}{20}}}$	$\frac{x^{\frac{1}{2}}}{8,4}$	$\frac{x^{\frac{2}{3}}}{18,8}$	$\frac{z\,x^{1+\frac{1}{20}}}{1,5}$
Flat-bottomed Vessels, or Vessels with a small draught of water.	$1,07D^{\frac{21}{22}}$	$\frac{P^{\frac{22}{21}}}{1,07}$	$(63D)^{\frac{1}{3}}$	$\frac{x^{\frac{4}{5}}}{1,6}$	$\frac{x^{1-\frac{1}{10}}}{6,436}$	$\frac{2,1D}{x^{1+\frac{1}{10}}}$	$\frac{x^{\frac{1}{2}}}{9,8}$	$\frac{x^{\frac{2}{3}}}{24}$	$\frac{z\,x^{1+\frac{1}{30}}}{1,4}$

Sequel of rules for proportions of Merchant Ships (N°. I.)

SPECIES OF SHIP.	Quantity by which the center of gravity of the displacement is below the load water-line. V	$\int \frac{2}{3} \times \frac{y^3 \dot{x}}{D}$. S	Fraction of the distance between the center of gravity of displacement and the load water-line, which the center of gravity of the ship and lading is below the water.	Distance of the metacenter from the center of gravity of the ship and lading. L	Moment of stability. M
Frigates.	$\frac{x^{\frac{7}{6}}}{48}$	$\frac{x^{\frac{1}{2}}}{1{,}289}$	$\frac{1}{4}$	$\frac{49{,}65\,x^{\frac{1}{2}} - x^{\frac{7}{6}}}{64}$	$\frac{x^3}{56}\left(\frac{49{,}65\,x^{\frac{1}{2}} - x^{\frac{7}{6}}}{64}\right)$
Heckboats or Pinks.	$\frac{x^{\frac{139}{120}}}{45{,}54}$	$\frac{x^{\frac{21}{40}}}{1{,}651}$	$\frac{2}{7}$	$\frac{38{,}8\,x^{\frac{21}{40}} - x^{\frac{139}{120}}}{64}$	$\frac{x^3}{54}\left(\frac{38{,}8\,x^{\frac{21}{40}} - x^{\frac{139}{120}}}{64}\right)$
Cats or Barks.	$\frac{x^{\frac{23}{20}}}{43{,}2}$	$\frac{x^{\frac{11}{20}}}{2{,}147}$	$\frac{1}{3}$	$\frac{30x^{\frac{11}{20}} - x^{\frac{23}{20}}}{64}$	$\frac{x^3}{52}\left(\frac{30\,x^{\frac{11}{20}} - x^{\frac{23}{20}}}{64}\right)$
Flat-bottomed Vessels, or Vessels with a small draught of water.	$\frac{x}{26}$	$\frac{x^{\frac{1}{2}}}{1{,}341}$	$\frac{1}{5}$	$\frac{24{,}23\,x^{\frac{1}{2}} - x}{32{,}5}$	$\frac{x^3}{63}\left(\frac{24{,}23\,x^{\frac{1}{2}} - x}{32{,}5}\right)$

(N°. 2.) *Proportions of Merchant Ships, calculated by the rules in the preceding Table* N°. 1. *Frigates.*

No.	Weight in lasts.	Displacement.	Length from stem to stern.	Breadth.	Area of midship section.	Draught of water at ϕ on the keel.	Draught of water. Aft.	Draught of water. Forward.	Depth of keel.	Area of plane of load water-line.	Quantity by which the center of gravity is before the middle.	Quantity by which ϕ is before the middle of the length from stem to stern.
		cub. ft.	feet.	feet.	sq. ft.	feet.	feet.	feet.	feet.	sq. ft.	feet.	feet.
1	500	85510	168,6	43,71	760,9	20,81	23,62	21,61	1,66	5853	2,37	12,04
2	480	81890	166,1	43,21	739,5	20,51	23,30	21,31	1,65	5700	2,33	11,86
3	460	78280	163,6	42,69	717,9	20,20	22,97	21,00	1,64	5545	2,30	11,69
4	440	74680	161,1	42,16	694,4	19,89	22,63	20,71	1,63	5388	2,26	11,51
5	420	71090	158,5	41,61	673,8	19,57	22,29	20,37	1,62	5229	2,23	11,32
6	400	67520	155,8	41,04	651,3	19,23	21,92	20,03	1,61	5066	2,18	11,13
7	380	63950	153,0	40,45	628,4	18,89	21,56	19,69	1,60	4900	2,15	10,93
8	360	60390	150,1	39,84	605,2	18,53	21,17	19,33	1,59	4732	2,10	10,72
9	340	56840	147,1	39,20	581,5	18,16	20,77	18,96	1,58	4560	2,07	10,51
10	320	53310	144,0	38,53	557,5	17,78	20,36	18,57	1,56	4384	2,03	10,29
11	300	49790	140,7	37,84	533,0	17,38	19,93	18,17	1,55	4205	1,98	10,05
12	280	46280	137,4	37,11	508,0	16,96	19,47	17,75	1,53	4022	1,93	9,81
13	260	42790	133,8	36,34	482,3	16,52	19,00	17,31	1,52	3833	1,88	9,56
14	240	39310	130,1	35,53	456,2	16,06	18,50	16,86	1,50	3640	1,82	9,29
15	220	35850	126,1	34,66	429,6	15,57	17,98	16,36	1,48	3442	1,77	9,01
16	200	32410	122,0	33,75	401,7	15,06	17,42	15,85	1,46	3234	1,72	8,71
17	180	28990	117,5	32,75	373,3	14,51	16,82	15,29	1,44	3022	1,65	8,39
18	160	25590	112,7	31,68	343,9	13,92	16,18	14,70	1,42	2799	1,58	8,05
19	140	22220	107,5	30,50	315,5	13,28	15,49	14,05	1,39	2568	1,51	7,68
20	120	18870	101,8	29,21	281,4	12,57	14,72	13,35	1,36	2324	1,43	7,27
21	100	15557	95,5	27,75	247,8	11,79	13,87	12,56	1,33	2066	1,34	6,82
22	90	13915	92,0	26,93	230,3	11,36	13,40	12,12	1,31	1929	1,30	6,57
23	80	12283	88,3	26,05	212,1	10,90	12,90	11,66	1,28	1790	1,24	6,31
24	70	10664	84,2	25,08	193,2	10,40	12,34	11,15	1,26	1640	1,17	6,01
25	60	9058	79,7	24,02	173,6	9,85	11,73	10,59	1,23	1484	1,11	5,69
26	50	7468	74,8	22,81	152,8	9,23	11,06	9,97	1,20	1318	1,05	5,34
27	40	5896	69,1	21,42	130,8	8,53	10,29	9,26	1,16	1141	0,97	4,94
28	30	4348	62,4	19,79	107,1	7,71	9,37	8,41	1,12	947	0,88	4,46
29	20	2830	54,1	17,61	80,7	6,68	8,23	7,37	1,06	729	0,70	3,86
30	10	1359	42,4	14,48	49,8	5,23	6,60	5,88	0,96	465	0,60	3,03

Proportions of Merchant Ships, &c. Sequel of the Table on the other side (N°. 2.)

No.	Quantity by which the center of gravity of displacement is below the water.	Distance of the metacenter from center of gravity of displacement.	Distance of the metacenter from center of gravity of the ship with lading.	Moment of stability.	Height of the main-mast in proportion to the stability.			Weight of the sheet-anchor.		Number of crew.	No. which multiplied by displacement, and divided by length from end to end = area of the frame ϕ.
					Above center of gravity of the ship.	Below the center of gravity.	Whole length.				
	feet.	feet.	feet.		feet.	feet.	feet.	skip.	lisp.		
1	8,253	10,072	3,883	332000	94,78	15,28	110,06	16	—	57	1,500
2	8,115	10,000	3,914	320500	93,68	15,06	108,74	15	14	55	
3	7,975	9,925	3,942	308600	92,52	14,85	107,37	15	8	52	
4	7,830	9,847	3,975	296850	91,31	14,62	105,93	15	1	50	
5	7,681	9,767	4,006	284820	90,04	14,36	104,40	14	13	47	
6	7,529	9,684	4,036	272520	88,74	14,15	102,89	14	5	45	1,504
7	7,371	9,596	4,067	260100	87,37	13,90	101,27	13	17	42	
8	7,209	9,505	4,099	247500	85,95	13,64	99,59	13	8	39	
9	7,041	9,409	4,128	234650	84,43	13,37	97,80	12	16	37	
10	6,868	9,309	4,157	221550	82,84	13,10	95,94	12	4	35	
11	6,688	9,204	4,187	208500	81,16	12,82	93,98	11	12	34	
12	6,500	9,092	4,217	195200	79,40	12,52	91,92	11	—	32	1,508
13	6,305	8,975	4,245	181640	77,51	12,19	89,70	10	8	30	
14	6,101	8,848	4,273	167990	75,53	11,87	87,40	9	16	28	
15	5,886	8,713	4,299	154100	73,38	11,51	84,89	9	3	27	
16	5,659	8,568	4,324	140120	71,10	11,14	82,24	8	10	25	
17	5,419	8,410	4,346	125960	68,62	10,74	79,36	7	17	23	
18	5,162	8,237	4,365	111710	65,92	10,31	76,23	7	4	21	1,510
19	4,886	8,045	4,381	97330	62,96	9,85	72,81	6	10	19	
20	4,586	7,830	4,391	82850	59,67	9,34	69,01	5	16	17	
21	4,254	7,582	4,391	68202	55,95	8,77	64,72	5	1	15	
22	4,075	7,425	4,388	61052	53,89	8,45	62,34	4	13	13	
23	3,881	7,289	4,380	53795	51,67	8,12	59,79	4	5	12	
24	3,673	7,119	4,366	46555	49,24	7,75	56,99	3	17	11	1,525
25	3,447	6,928	4,344	39340	46,55	7,35	53,90	3	9	10	
26	3,198	6,709	4,311	32190	43,55	6,90	50,45	3	—	9	
27	2,917	6,450	4,263	25140	40,09	6,38	46,47	2	11	7	
28	2,591	6,130	4,186	18200	36,00	5,79	41,79	2	1	6	
29	2,193	5,707	4,061	11494	30,89	5,03	35,92	1	10	4	
30	1,648	5,050	3,814	5182	23,69	3,95	27,64	-	18	3	1,553

(N°. 3.) *Proportions of Merchant Ships: Heckboats or Pinks.*

No.	Burthen in large lasts.	Displacement.	Length from stem to stern.	Breadth.	Area of the frame ϕ.	Draught of water at ϕ on the keel.	Draught of water. Aft.	Draught of water. Forward.	Depth of keel.
		cubic feet.	feet.	feet.	sq. feet.	feet.	feet.	feet.	feet.
4	440	69940	155,7	39,71	644,1	18,97	21,46	19,81	1,54
5	420	66600	153,2	39,20	623,8	18,67	21,14	19,60	1,53
6	400	63260	150,6	38,69	603,2	18,36	20,80	19,19	1,51
7	380	59940	147,9	38,10	580,9	18,03	20,46	18,86	1,50
8	360	56620	145,1	37,54	561,0	17,70	20,10	18,52	1,49
9	340	53310	142,3	36,94	539,3	17,35	19,73	18,17	1,48
10	320	50020	139,3	36,32	517,2	17,00	19,35	17,81	1,46
11	300	46740	136,1	35,66	494,7	16,62	18,94	17,43	1,45
12	280	43460	132,9	34,97	471,8	16,23	18,52	17,04	1,44
13	260	40200	129,5	34,26	448,3	15,82	18,08	16,62	1,42
14	240	36950	125,9	33,49	424,3	15,39	17,62	16,19	1,40
15	220	33720	122,1	32,69	399,6	14,93	17,13	15,72	1,38
16	200	30500	118,1	31,82	374,2	14,45	16,61	15,24	1,36
17	180	27300	113,8	30,90	348,0	13,94	16,05	14,71	1,34
18	160	24120	109,2	29,89	320,9	13,38	15,45	14,15	1,32
19	140	20950	104,2	28,79	292,7	12,78	14,80	13,54	1,29
20	120	17810	98,7	27,57	263,2	12,12	14,08	12,86	1,26
21	100	14703	92,6	26,20	232,1	11,38	13,28	12,11	1,23
22	90	13159	89,2	25,44	215,9	10,97	12,84	11,70	1,21
23	80	11625	85,6	24,60	199,1	10,53	12,36	11,25	1,19
24	70	10101	81,7	23,70	181,5	10,03	11,81	10,74	1,17
25	60	8588	77,4	22,69	163,3	9,54	11,28	10,24	1,14
26	50	7088	72,6	21,57	144,0	8,56	10,64	9,64	1,11
27	40	5605	67,1	20,25	123,5	8,29	9,91	8,96	1,07
28	30	4141	60,6	18,68	101,3	7,51	9,05	8,16	1,03
29	20	2702	52,6	16,67	76,6	6,53	7,96	7,15	0,97
30	10	1302	41,3	13,72	47,5	5,14	6,40	5,72	0,87

Proportions for Merchant Ships: Heckboats or Pinks.
Sequel of the Table on the other side, (N°. 3.)

No.	Area of the plane of load water-line.	Quantity by which the center of gravity is before the middle.	Quantity by which ϕ is before the middle of the length from stem to stern.	Quantity by which the center of gravity of displacement is below the water.	Distance of the metacenter from the center of gravity of displacement.	Distance of the metacenter from the center of gravity of the ship with its lading.	Absolute moment of stability.	Number which multiplied by the displacement and divided by length from end to end equal the area of the frame ϕ.
	sq. ft.	feet.	feet.	feet.	feet.	feet.		
4	5093	2,20	11,97	7,605	8,576	3,171	221720	1,434
5	4943	2,15	11,78	7,463	8,502	3,202	213220	
6	4790	2,11	11,58	7,316	8,426	3,228	204230	
7	4634	2,07	11,37	7,165	8,347	3,257	195200	
8	4474	2,03	11,16	7,009	8,264	3,284	185940	
9	4312	2,00	10,94	6,848	8,178	3,312	176610	
10	4146	1,95	10,71	6,682	8,087	3,339	167020	1,440
11	3976	1,91	10,47	6,509	7,991	3,367	157370	
12	3804	1,87	10,22	6,329	7,890	3,394	147500	
13	3625	1,82	9,96	6,132	7,783	3,428	137810	
14	3442	1,76	9,68	5,944	7,669	3,447	126780	
15	3255	1,71	9,39	5,738	7,547	3,472	117070	1,447
16	3059	1,66	9,08	5,552	7,416	3,495	106610	
17	2859	1,60	8,75	5,289	7,273	3,519	96050	
18	2649	1,53	8,40	5,041	7,118	3,536	85262	
19	2430	1,46	8,01	4,775	6,986	3,555	74480	
20	2199	1,39	7,59	4,485	6,750	3,564	79930	1,458
21	1955	1,30	7,12	4,168	6,527	3,567	52450	
22	1827	1,25	6,86	3,990	6,401	3,569	46960	
23	1692	1,20	6,58	3,804	6,264	3,564	41430	
24	1551	1,15	6,28	3,603	6,112	3,553	35890	
25	1405	1,08	5,95	3,384	5,941	3,539	28070	1,471
26	1249	1,02	5,58	3,135	5,745	3,514	24910	
27	1081	0,95	5,16	2,870	5,514	3,475	19475	
28	898	0,87	4,66	2,553	5,228	3,415	14141	
29	690	0,77	4,04	2,166	4,852	3,316	8958	
30	441	0,70	3,17	1,634	4,271	3,113	4054	1,506

(N°. 4.) *Proportions of Merchant Ships: Cats and Barks.*

No.	Burthen in lasts.	Displacement.	Length from stem to stern.	Breadth.	Area of frame ϕ.	Draught of water at the frame ϕ to the upper side of keel.	Draught of water. Aft.	Draught of water. Forward.	Depth of the keel.	Area of the load water-line.	Quantity by which the center of gravity is before the middle.
		cub. feet.	feet.	feet.	sq. feet.	feet.	feet.	feet.	feet.	sq. ft.	feet.
7	380	56880	143,5	36,02	544,1	17,30	19,58	18,12	1,43	4432	2,15
8	360	53750	140,9	35,48	524,4	16,99	19,24	17,80	1,41	4280	2,10
9	340	50620	138,1	34,91	504,4	16,66	18,89	17,47	1,40	4126	2,07
10	320	47510	135,2	34,33	484,0	16,32	18,52	17,12	1,38	3968	2,03
11	300	44400	132,2	33,70	463,2	15,97	18,15	16,77	1,37	3802	1,98
12	280	41300	129,0	33,37	441,9	15,60	17,75	16,39	1,35	3636	1,92
13	260	38230	125,7	320,9	420,2	15,22	17,33	16,00	1,33	3468	1,88
14	240	35140	122,3	31,68	397,2	14,71	16,89	15,58	1,32	3293	1,83
15	220	32080	118,6	30,92	375,0	14,38	16,42	15,14	1,30	3113	1,78
16	200	29350	115,1	30,19	353,9	13,98	16,00	14,73	1,28	2938	1,73
17	180	26000	110,6	29,23	327,1	13,44	15,41	14,18	1,25	2737	1,66
18	160	22980	106,1	28,28	301,9	12,92	14,84	13,65	1,23	2540	1,59
19	140	19983	101,3	27,25	275,6	12,35	14,22	13,07	1,20	2321	1,51
20	120	17002	96,0	26,10	248,1	11,72	13,54	12,42	1,17	2105	1,44
21	100	14046	90,1	24,81	219,2	11,02	12,78	11,71	1,13	1870	1,35
22	90	12579	86,8	24,09	204,0	10,64	12,35	11,31	1,11	1747	1,30
23	80	11155	83,4	23,33	188,7	10,23	11,91	10,90	1,09	1623	1,25
24	70	9667	79,5	22,45	171,9	9,77	11,49	10,42	1,06	1486	1,20
25	60	8225	75,3	21,51	154,8	9,28	10,86	9,91	1,03	1345	1,13
26	50	6795	70,7	20,44	136,7	8,72	10,25	9,35	1,00	1195	1,06
27	40	5378	65,4	19,20	117,4	8,09	9,56	8,69	0,96	1034	1,00
28	30	3979	59,1	17,72	96,5	7,34	8,73	7,92	0,92	859	0,90
29	20	2602	51,3	15,82	73,3	6,40	7,68	6,95	0,85	661	0,80
30	10	1258	40,3	13,04	45,7	5,07	6,19	5,56	0,76	424	0,70

Proportions of Merchant Ships: Cats and Barks. Sequel of the Table on the opposite side. (N°. 4.)

No.	Quantity by which the frame ϕ is before the middle of the length from the stem to stern.	Quantity by which the center of gravity of displacement is below the water.	Distance of the metacenter from the center of gravity of displacement.	Distance of the metacenter from the center of gravity of the ship with its lading.	Moment of stability.	Height of the main-mast in proportion to the stability. Above the center of gravity.	Below the center of gravity.	Whole length.	Weight of the sheet-anchor.		Number of crew.	No. which multiplied by displacement, and divided by length from end to end = area of the frame ϕ.
	feet.	feet.	feet.	feet.		feet.	feet.	feet.	sk.	lisp.		
7	11,96	6,999	7,153	2,474	140700	74,54	12,07	86,61	10	15	27	1,390
8	11,73	6,849	7,080	2,502	134400	73,41	11,88	85,29	10	6	26	
9	11,50	6,693	7,002	2,528	127980	72,21	11,65	83,86	9	17	25	
10	11,26	6,517	6,921	2,556	121440	70,95	11,43	82,38	9	8	24	
11	11,01	6,366	6,836	2,583	114690	69,61	11,19	80,80	8	19	23	
12	10,75	6,191	6,746	2,609	107780	68,20	10,94	79,14	8	10	22	
13	10,47	6,010	6,650	2,637	100810	66,69	10,69	77,38	8	1	20	
14	10,19	5,820	6,549	2,662	93570	65,05	10,41	75,46	7	12	19	
15	9,88	5,620	6,441	2,688	86230	63,30	10,12	73,42	7	3	18	
16	9,59	5,432	6,336	2,711	79590	61,63	9,87	71,50	6	14	17	
17	9,21	5,185	6,197	2,738	71180	59,38	9,48	68,86	6	5	16	
18	8,84	4,946	6,058	2,761	63460	57,15	9,12	66,27	5	14	14	1,400
19	8,44	4,687	5,905	2,778	55520	54,66	8,73	63,39	5	3	13	
20	7,99	4,406	5,733	2,797	47550	51,91	8,31	60,22	4	11	12	
21	7,50	4,095	5,535	2,808	39440	48,77	7,83	56,60	3	19	11	
22	7,23	3,925	5,412	2,809	35340	47,02	7,56	54,58	3	13	9	
23	6,95	3,748	5,307	2,811	31360	45,18	7,28	52,46	3	7	8	
24	6,62	3,549	5,169	2,806	27130	43,05	6,96	50,01	3	1	8	1,413
25	6,28	3,335	5,018	2,799	23020	40,76	6,63	47,39	2	14	7	
26	5,89	3,100	4,846	2,784	18920	38,22	6,24	44,46	2	7	6	
27	5,45	2,834	4,642	2,759	14842	35,21	5,80	41,01	2	—	6	
28	4,93	2,525	4,393	2,715	10806	31,68	5,28	36,96	1	12	4	
29	4,28	2,145	4,064	2,641	6871	27,24	4,62	31,86	1	4	3	
30	3,35	1,624	3,557	2,483	3125	20,95	3,69	24,64	–	14	3	1,464

(N°. 5.) *Proportions of Merchant Ships of a small draught of water, in form like Barks.*

No.	Burthen in lasts.	Displacement.	Length from stem to stern.	Breadth.	Area of the frame ϕ.	Draught of water at the frame ϕ to the upper side of the keel.	Draught of water. Aft.	Draught of water. Forward.	Depth of the keel.	Area of the plane of the load water-line.
		cub. feet.	feet.	feet.	sq. feet.	feet.	feet.	feet.	feet.	sq. feet.
10	320	44400	140,9	32,74	403,4	13,35	15,21	14,08	1,21	3908
11	300	41500	137,8	32,15	386,6	13,08	14,92	13,81	1,20	3749
12	280	38080	134,5	31,54	369,3	12,80	14,61	13,52	1,18	3588
13	260	35720	131,0	30,89	351,5	12,50	14,29	13,22	1,17	3421
14	240	32840	127,4	30,21	333,4	12,19	13,96	12,99	1,15	3250
15	220	29990	123,6	29,48	314,7	11,86	13,60	12,57	1,13	3074
16	200	27140	119,6	28,70	295,4	11,51	13,22	12,21	1,12	2891
17	180	24300	115,2	27,88	275,4	11,14	12,81	11,82	1,09	2703
18	160	21480	110,6	26,97	254,7	10,73	12,36	11,40	1,07	2506
19	140	18670	105,6	25,99	233,1	10,29	11,88	10,95	1,05	2302
20	120	15900	100,1	24,90	210,6	9,81	11,35	10,45	1,02	2086
21	100	13130	93,9	23,65	186,5	9,26	10,75	9,89	0,99	1855
22	90	11756	90,5	22,97	173,9	8,96	10,41	9,57	0,97	1734
23	80	10391	86,8	22,23	160,8	8,63	10,05	9,23	0,95	1609
24	70	9034	82,9	21,41	147,1	8,28	9,66	8,88	0,93	1476
25	60	7687	78,5	20,51	132,8	7,89	9,23	8,46	0,90	1338
26	50	6350	73,7	19,48	117,7	7,45	8,75	8,01	0,87	1190
27	40	5027	68,2	18,31	101,5	6,94	8,18	7,49	0,84	1038
28	30	3719	61,6	16,90	83,9	6,34	7,52	6,88	0,80	850
29	20	2432	53,5	15,02	64,1	5,58	6,67	6,08	0,75	650
30	10	1176	42,0	12,43	40,4	4,49	5,44	4,94	0,66	424

Proportions for Merchant Ships, &c. Sequel of the Table on the other side, (N°. 5.)

No.	Quantity by which the center of gravity is before the middle.	Quantity by which the frame φ is before the middle of the length.	Quantity by which the center of gravity of displacement is below the water.	Distance of the metacenter from the center of gravity of the displacement.	Distance of the metacenter from the center of gravity of the ship and its lading.	Moment of stability.	Height of the main-mast in proportion to the stability. Above the center of gravity.	Below the center of gravity.	Whole length.	No. which multiplied by displacement, and divided by length from end to end = area of the frame φ.
	feet.	feet.	feet.	feet.	feet.		feet.	feet.	feet.	
10	2,12	10,84	5,419	8,852	4,514	200400	83,64	9,55	93,19	1,280
11	2,07	10,59	5,298	8,752	4,511	187200	81,76	9,36	91,12	
12	2,05	10,34	5,172	8,648	4,505	173900	79,79	9,17	88,96	
13	1,96	10,08	5,040	8,537	4,501	160790	77,73	8,96	86,69	
14	1,91	9,80	4,901	8,418	4,495	147660	75,56	8,75	84,31	
15	1,85	9,51	4,755	8,291	4,486	134520	73,24	8,52	81,76	1,300
16	1,80	9,19	4,599	8,154	4,474	121400	70,76	8,36	79,12	
17	1,74	8,86	4,443	8,005	4,458	108340	68,13	8,01	76,14	
18	1,67	8,51	4,255	7,843	4,437	95300	65,29	7,73	73,02	
19	1,59	8,12	4,060	7,662	4,412	82400	62,20	7,42	69,62	
20	1,50	7,69	3,849	7,460	4,360	69360	58,81	7,09	65,90	1,325
21	1,41	7,22	3,610	7,225	4,336	56910	54,98	6,71	61,69	
22	1,36	6,97	3,480	7,093	4,308	50640	52,89	6,50	59,39	
23	1,31	6,68	3,339	6,949	4,277	44440	50,62	6,27	56,89	
24	1,24	6,37	3,187	6,788	4,237	38280	48,17	6,02	54,19	
25	1,18	6,04	3,020	6,608	4,190	32220	45,48	5,79	51,27	1,356
26	1,11	5,66	2,834	6,401	4,132	26240	42,49	5,44	47,93	
27	1,02	5,24	2,622	6,157	4,062	20420	39,05	5,07	44,12	
28	0,93	4,74	2,371	5,855	3,960	14727	35,02	4,65	39,67	
29	0,80	4,11	2,058	5,455	3,806	9256	30,01	4,11	34,12	
30	0,63	3,23	1,616	4,833	3,544	4170	23,00	3,33	26,33	1,442

(No. 6.) *Proportions for Privateers, according to the formulæ in p. 97.*

No.	ARTILLERY. Guns. In battery. Number.	In battery. Caliber.	On the quarter deck, &c. Number.	On the quarter deck, &c. Caliber.	Bow chases. Number.	Bow chases. Caliber.	Swivels. Number.	Swivels. Caliber.	Length from stem to stern, from outside to outside.	Breadth to the outside of the frames at the load water-line.	Displacement.	$\int \frac{2}{3} y^3 \dot{x}$.	Area of the load water-line.	Area of the frame ϕ.
		lb.		lb.		lb.		lb.	feet.	feet.	cub. ft.		sq. ft.	sq. ft.
1	28	18	12	6	—	—	—	—	161,52	41,16	47170	558500	5086	452,3
2	26	18	10	6	—	—	—	—	155,65	39,82	42330	486200	4747	422,0
3	26	12	10	4	—	—	—	—	142,38	36,74	31910	348100	3995	350,8
4	24	12	8	4	—	—	—	—	138,24	35,78	29140	311600	3769	330,7
5	24	8	8	3	—	—	—	—	126,75	33,10	22080	225400	3184	275,3
6	22	8	—	—	—	—	—	—	119,78	31,45	18430	182060	2853	244,3
7	22	6	—	—	—	—	—	—	112,60	29,75	15064	143350	2530	213,5
8	20	6	—	—	—	—	—	—	109,84	29,09	13907	131545	2411	202,5
9	18	6	—	—	—	—	—	—	106,94	28,40	12749	118970	2288	191,1
10	16	6	—	—	—	—	—	—	103,82	27,65	11577	106470	2160	179,2
11	14	6	—	—	—	—	—	—	100,46	26,84	10395	94130	2027	166,7
12	12	6	—	—	—	—	—	—	96,76	25,96	9185	81780	1884	153,4
13	10	6	—	—	—	—	—	—	92,70	24,97	7967	69620	1734	139,4
14	8	6	—	—	—	—	—	—	88,01	23,83	6698	57300	1567	124,0
15	—	—	—	—	1	12	16	3	81,31	22,19	5175	42590	1343	104,38
16	—	—	—	—	1	8	16	2	74,60	20,54	3845	30825	1136	85,13

Proportions for Privateers, &c. Sequel of the Table on the other side, (N°. 6.)

No.	Height of the water-line above the rabbet taken at the frame ϕ.	Quantity by which the center of gravity of the displacement is below the water.	Height of the metacenter above the water.	Quantity by which the center of gravity is before the middle.	Quantity by which ϕ is before the middle of the length from stem to stern.	Differences of the draught of water.	Quantity of ballast in cubic feet of sea water.	Center of gravity of the ballast below the water.	Number of crew.	Months for which provisioned.	Moment of the sails with regard to the center of gravity, or to the water-line.	Height of the battery above the water.	No. which multiplied by the displacement and divided by length from end to end = the area of the frame ϕ.
	feet.	feet.	feet.	feet.	feet.	feet.	cub. ft.	feet.	No.			feet.	
1	15,40	5,84	6	1,61	8,10	1,66	4224	1,300	400	4,00	1935000	8,50	1,548
2	14,80	5,485	6	1,56	7,86	1,62	3705	12,34	381	4,00	1679100	7,00	1,552
3	13,50	4,907	6	1,42	7,21	1,53	2861	10,89	312	3,52	1303800	6,50	1,565
4	13,16	4,695	6	1,38	7,03	1,51	2616	10,45	296	3,43	1202400	6,00	1,568
5	12,10	4,205	6	1,27	6,50	1,42	2020	9,26	244	3,10	938000	5,75	1,580
6	11,40	3,878	6	1,20	6,17	1,37	1676	8,55	217	2,92	797700	5,50	1,588
7	10,70	3,582	6	1,13	5,86	1,34	1393	7,84	188	2,71	665600	5,25	1,595
8	10,40	3,459	6	1,10	5,70	1,30	1286	7,57	178	2,64	619525	5,00	1,600
9	10,10	3,331	6	1,07	5,56	1,28	1183	7,29	168	2,56	573100	4,75	1,603
10	9,80	3,197	6	1,04	5,41	1,25	1070	7,00	157	2,47	525600	4,50	1,607
11	9,50	3,055	6	1,00	5,23	1,23	959	6,68	146	2,38	477100	4,25	1,612
12	9,20	2,903	6	0,97	5,08	1,20	856	6,34	134	2,28	426855	4,00	1,616
13	8,80	2,738	6	0,93	4,89	1,17	742	5,97	121	2,16	375600	3,75	1,622
14	8,40	2,555	6	0,88	4,65	1,13	626	5,55	107	2,03	321268	3,50	1,629
15	7,70	2,230	6	0,81	4,32	1,08	503½	4,97	86	1,81	254900	4,00	1,640
16	7,10	2,018	6	0,75	4,02	1,02	367	4,41	69	1,62	194850	3,75	1,651

(N°. 7.) *Proportions of Masts and Yards for Merchant Ships with three Masts: Frigate-built.*

Numbers.	Length from stem to stern.	Breadth.	Main-mast.		Main top-mast.		Main-top gallant-mast.		Diameter of the fore-mast.	Fore top-mast.		Fore-top gallant-mast.		Diameter of the mizen-mast.	Mizen top-mast.	
			Length.	Diameter.	Length.	Diameter.	Length.	Diameter.		Length.	Diameter.	Length.	Diameter.		Length.	Diameter.
	feet.	feet.	feet.	in^s.	feet.	in^s.	feet.	in^s.	in^s.	feet.	in^s.	feet.	in^s.	in^s.	feet.	in^s.
1	168,6	43,71	103,0	35,2	60,0	19,2	32,5	9,7	34,0	54,0	18,2	29,0	8,7	23,5	43,5	12,9
2	166,1	43,21	102,0	34,6	59,2	19,0	32,2	9,6	33,4	53,5	18,0	28,7	8,7	23,1	43,0	12,7
3	163,6	42,69	101,0	34,1	58,5	18,7	32,0	9,5	32,7	52,7	17,7	28,5	8,6	22,7	42,5	12,6
4	161,1	42,16	99,7	33,5	57,7	18,5	31,5	9,4	32,1	52,0	17,5	28,2	8,5	22,4	42,0	12,5
5	158,5	41,61	98,5	33,0	57,0	18,2	31,0	9,2	31,5	51,2	17,2	28,0	8,4	22,0	41,5	12,4
6	155,8	41,04	97,2	32,4	56,2	18,0	30,5	9,1	30,9	50,5	17,0	27,7	8,2	21,6	41,0	12,2
7	153,0	40,45	96,0	31,7	55,5	17,7	30,0	9,0	30,2	49,7	16,7	27,2	8,1	21,2	40,5	12,0
8	150,1	39,84	94,7	31,1	54,7	17,5	29,5	8,9	29,5	49,0	16,5	26,7	8,0	20,9	40,0	11,7
9	147,1	39,20	93,5	30,5	53,7	17,0	29,0	8,7	29,0	48,2	16,1	26,2	7,9	20,2	39,5	11,5
10	144,0	38,53	92,2	29,7	52,7	16,7	28,5	8,5	28,2	47,5	15,7	25,7	7,7	19,9	39,0	11,2
11	140,7	37,84	90,5	29,0	51,7	16,5	28,0	8,4	27,5	46,7	15,4	25,2	7,6	19,4	38,5	11,0
12	137,4	37,11	88,7	28,2	50,7	16,0	27,5	8,2	26,9	45,7	15,0	24,7	7,5	19,0	37,7	10,7
13	133,8	36,34	87,0	27,5	49,7	15,7	27,0	8,0	26,1	44,7	14,6	24,2	7,4	18,4	37,0	10,5
14	130,1	35,53	85,2	26,7	48,7	15,4	26,5	7,9	25,4	43,7	14,2	23,7	7,2	18,0	36,2	10,2
15	126,1	34,66	83,2	25,9	47,5	15,0	25,7	7,6	24,5	42,7	13,9	23,2	7,1	17,2	35,5	10,0
16	122,0	33,75	81,2	25,0	46,2	14,5	25,0	7,5	23,7	41,7	13,5	22,5	6,9	16,6	34,7	9,6
17	117,5	32,75	79,0	24,0	44,7	14,0	24,2	7,2	22,7	40,5	13,1	21,7	6,6	16,0	34,0	9,5
18	112,7	31,68	76,7	23,0	43,2	13,5	23,1	7,0	21,9	39,0	12,7	21,0	6,4	15,4	33,0	8,9
19	107,5	30,50	74,0	21,7	41,7	13,0	22,5	6,7	20,6	37,5	12,4	20,2	6,1	14,6	32,0	8,5
20	101,8	29,21	71,2	20,5	40,0	12,4	21,5	6,5	19,5	36,0	12,0	19,5	5,9	13,7	30,7	8,1
21	95,5	27,75	68,0	19,2	38,0	11,6	20,5	6,1	18,2	34,0	11,2	18,5	5,5	13,0	29,2	7,7
22	92,0	26,93	66,0	18,5	37,0	11,2	20,0	6,0	17,5	33,0	10,9	18,0	5,4	12,5	28,5	7,5
23	88,3	26,05	64,0	17,6	35,7	10,9	19,2	5,7	16,7	32,0	10,5	17,5	5,1	12,0	27,7	7,2
24	84,2	25,08	62,0	16,9	34,2	10,5	18,5	5,5	16,0	30,7	10,0	16,7	5,0	11,4	27,0	7,0
25	79,7	24,02	59,5	15,9	32,7	10,0	17,7	5,2	15,0	29,5	9,5	16,0	4,7	10,6	26,0	6,7
26	74,8	22,81	56,7	14,7	31,0	9,4	16,7	5,0	14,0	28,0	9,0	15,2	4,5	9,7	24,7	6,4
27	69,1	21,42	53,5	13,6	29,2	8,7	15,7	4,7	13,0	26,2	8,2	14,2	4,2	9,0	23,5	6,0
28	62,4	18,79	49,7	12,2	27,0	8,0	14,5	4,4	11,6	24,2	7,5	13,0	4,0	8,1	21,7	5,7

Proportions of Masts and Yards for Merchant Ships, &c.
Continuation of the Table on the other side, (N°. 7.)

No.	Bow sprit.		Jib-boom.	Length of the head of the main-mast.		Length of the head of the fore-mast.		Length of the head of the mizen-mast.		Quantity by which the fore-mast is lower than the main-mast.		Main-yard.		Main-top sail-yard.		Main-top gallant-yard.		Fore-yard.	
	Length.	Diameter.										Length.	Diameter.	Length.	Diameter.	Length.	Diameter.	Length.	Diameter.
	feet.	ins.	ins.	ft.	ins.	ft.	ins.	ft.	ins.	ft.	ins.	feet.	ins.	feet.	ins.	feet.	ins.	feet.	ins.
1	48,5	34,6	14,4	14	4	12	10	10	9	5	5	87,5	21,9	69,2	16,0	48,5	8,0	79,0	19,7
2	48,0	34,1	14,2	14	2	12	9	10	8	5	5	86,2	21,6	68,2	15,7	47,7	8,0	77,7	19,5
3	47,5	33,5	14,1	14	—	12	7	10	6	5	4	85,0	21,4	67,2	15,4	47,0	7,9	76,5	19,2
4	47,0	32,9	14,0	13	10	12	6	10	5	5	4	83,7	21,1	66,2	15,1	46,2	7,7	75,2	19,0
5	46,5	32,2	13,9	13	8	12	4	10	3	5	4	82,5	20,7	65,2	14,9	45,5	7,6	74,0	18,7
6	46,0	31,6	13,6	13	6	12	2	10	2	5	3	81,0	20,4	64,2	14,6	44,7	7,5	72,7	18,4
7	45,2	31,0	13,4	13	4	12	–	10	–	5	3	79,5	20,0	63,0	14,4	44,0	7,4	71,5	18,0
8	44,5	30,4	13,1	13	2	11	10	9	11	5	3	78,0	19,6	61,7	14,1	43,2	7,2	70,2	17,6
9	43,7	29,7	12,9	13	–	11	8	9	9	5	3	76,5	19,2	60,5	13,9	42,5	7,1	68,7	17,2
10	43,0	29,0	12,6	12	9	11	6	9	7	5	2	74,7	18,7	59,2	13,6	41,5	7,0	67,2	16,9
11	42,2	28,2	12,4	12	7	11	3	9	5	5	2	73,0	18,4	58,0	13,4	40,5	6,7	65,7	16,5
12	41,5	27,5	12,1	12	4	11	1	9	3	5	2	71,2	17,9	56,5	13,0	39,5	6,6	64,2	16,1
13	40,7	26,7	11,9	12	1	10	10	9	–	5	1	69,5	17,4	55,0	12,6	38,5	6,5	62,5	15,6
14	39,7	26,0	11,6	11	10	10	8	8	10	5	1	67,5	16,9	53,5	12,2	37,5	6,2	60,7	15,1
15	38,7	25,1	11,2	11	7	10	5	8	8	5	–	65,5	16,4	51,7	11,9	36,2	6,0	59,0	14,6
16	37,7	24,2	10,9	11	4	10	2	8	6	5	–	63,5	15,9	50,0	11,5	35,0	5,9	57,0	14,1
17	36,5	23,4	10,5	11	–	9	11	8	3	4	11	61,0	15,4	48,2	11,1	33,7	5,6	55,0	13,6
18	35,2	22,5	10,1	10	8	9	7	8	–	4	11	58,5	14,9	46,2	10,6	32,5	5,4	52,7	13,1
19	34,0	21,2	9,7	10	4	9	3	7	9	4	10	56,0	14,1	44,0	10,1	31,0	5,1	50,2	12,5
20	32,5	20,0	9,4	9	11	8	11	7	5	4	9	53,0	13,2	41,7	9,6	29,2	4,9	47,7	11,9
21	31,0	18,7	8,9	9	5	8	5	7	1	4	8	49,7	12,4	39,2	9,0	27,5	4,6	44,7	11,1
22	30,0	18,0	8,4	9	2	8	3	6	8	4	8	48,0	12,0	37,7	8,6	26,5	4,5	43,0	10,7
23	29,0	17,2	8,1	8	11	8	–	6	7	4	7	46,0	11,5	36,2	8,2	25,5	4,4	41,2	10,4
24	28,0	16,5	7,9	8	7	7	9	6	5	4	7	43,7	11,0	34,5	7,9	24,2	4,1	39,5	9,9
25	26,7	15,5	7,5	8	3	7	5	6	2	4	6	41,5	10,4	32,7	7,5	23,0	4,0	37,2	9,4
26	25,5	14,5	7,0	7	11	7	1	5	11	4	5	39,0	9,7	30,7	7,1	21,5	3,7	35,0	8,7
27	23,7	13,4	6,5	7	5	6	8	5	7	4	4	36,0	9,0	28,2	6,5	19,7	3,5	32,2	8,0
28	22,0	12,0	6,0	6	11	6	3	5	2	4	3	32,5	8,1	25,7	5,9	18,0	3,1	29,2	7,2

Proportions for Masts and Yards of Merchant Ships, &c.
Continuation of the preceding Table, (N°. 7.)

No.	Fore-top-sail yard.		Fore-top-gallant yard.		Cross-jack yard.		Mizen-top-sail yard.		Sprit-sail yard.		Sprit-sail top-sail yard.		Depth of the trestle trees. Of the tops.			Depth of the trestle trees. Of the Cross trees.	
	Length.	Diameter.	Length.	Diameter.	Length.	Diameter.	Length.	Diameter.	Length.	Diameter.	Length.	Diameter.	Main-mast.	Fore.	Mizen.	Main-top-gallant.	Fore-top-gallant.
	feet.	ins.	feet.	ins.	feet.	ins.	feet.	ins.	feet.	ins.	feet.	ins.	ins.	ins.	ins.	ins.	ins.
1	62,2	14,2	43,7	7,2	61,0	12,7	50,0	11,5	62	13,0	43,5	8,0	14,5	13,7	8,7	6,2	5,9
2	61,5	14,1	43,2	7,1	60,2	12,6	49,5	11,4	61	12,9	43,0	8,0	14,2	13,6	8,5	6,1	5,7
3	60,5	13,9	42,5	7,0	59,5	12,5	49,0	11,1	60	12,6	42,2	7,9	14,1	13,5	8,4	6,0	5,6
4	59,5	13,6	41,7	6,9	58,7	12,4	48,5	11,0	59	12,4	41,5	7,7	14,0	13,2	8,2	6,0	5,6
5	58,5	13,4	41,0	6,9	58,0	12,1	47,5	10,9	58	12,1	40,7	7,6	13,7	13,1	8,2	5,9	5,5
6	57,5	13,1	40,2	6,7	57,2	12,0	46,7	10,7	57	12,0	40,0	7,5	13,5	13,0	8,1	5,7	5,5
7	56,5	12,9	39,5	6,6	56,2	11,7	46,0	10,5	56	11,7	39,2	7,4	13,5	12,7	8,0	5,7	5,4
8	55,5	12,6	38,7	6,5	55,2	11,6	45,2	10,4	55	11,5	38,5	7,2	13,2	12,5	8,0	5,7	5,2
9	54,5	12,4	38,0	6,4	54,2	11,4	44,5	10,1	54	11,2	37,7	7,1	13,0	12,2	7,9	5,5	5,1
10	53,2	12,1	37,2	6,1	53,2	11,1	43,7	10,0	53	11,1	37,0	7,0	12,7	12,1	7,7	5,5	5,0
11	52,0	11,9	36,5	6,0	52,2	11,0	42,7	9,7	52	11,0	36,2	6,7	12,5	11,9	7,5	5,2	5,0
12	50,7	11,6	35,7	5,9	51,2	10,7	41,7	9,5	51	10,7	35,5	6,6	12,2	11,6	7,4	5,2	4,9
13	49,5	11,4	34,7	5,7	50,0	10,5	40,7	9,4	50	10,5	34,7	6,5	12,0	11,4	7,2	5,0	4,9
14	48,0	11,1	33,7	5,6	48,7	10,2	39,7	9,1	49	10,2	34,0	6,2	11,7	11,1	7,0	5,0	4,7
15	46,5	10,7	32,7	5,4	47,5	10,0	38,7	8,9	47	9,9	33,0	6,0	11,5	10,9	6,7	4,7	4,5
16	45,0	10,4	31,7	5,2	46,0	9,7	37,7	8,5	45	9,5	31,7	5,9	11,2	10,5	6,7	4,6	4,4
17	43,5	10,0	30,5	5,0	44,5	9,4	36,5	8,2	43	9,0	30,5	5,6	11,0	10,2	6,5	4,5	4,2
18	42,0	9,6	29,2	4,9	42,7	9,0	35,2	8,0	41	8,6	28,7	5,4	10,7	9,9	6,2	4,5	4,1
19	40,0	9,2	27,7	4,6	41,0	8,6	33,7	7,6	39	8,1	27,5	5,1	10,2	9,5	6,0	4,2	3,9
20	37,7	8,7	26,2	4,4	39,0	8,1	32,0	7,2	37	7,7	26,0	4,9	9,5	9,0	5,7	4,0	3,7
21	35,2	8,1	24,7	4,1	37,0	7,7	30,2	7,0	35	7,4	24,5	4,6	9,0	8,5	5,5	3,7	3,6
22	34,0	7,9	23,7	4,0	35,7	7,5	29,2	6,7	33	7,0	23,5	4,5	8,7	8,2	5,2	3,6	3,5
23	32,7	7,5	22,7	3,9	34,5	7,2	28,2	6,5	32	6,7	22,5	4,4	8,5	8,0	5,0	3,5	3,4
24	31,2	7,1	21,7	3,6	33,0	7,0	27,0	6,1	31	6,5	21,5	4,1	8,2	7,7	4,7	3,5	3,1
25	29,5	6,7	20,7	3,4	31,5	6,6	25,7	5,9	29	6,0	20,2	4,0	7,7	7,2	4,5	3,2	3,0
26	27,7	6,2	19,2	3,2	29,7	6,2	24,5	5,5	27	5,6	19,0	3,7	7,2	6,9	4,2	3,2	2,9
27	25,5	5,7	17,7	3,0	27,7	5,7	22,7	5,1	25	5,2	17,5	3,5	6,7	6,4	4,0	3,0	2,6
28	23,0	5,2	16,0	3,0	25,2	5,2	20,7	4,6	23	4,9	16,0	3,1	6,2	6,1	3,7	2,7	2,5

(N°. 8.) *Proportions of Masts and Yards for Merchant Ships with three Masts: Bark-built.*

No.	Length from stem to stern.	Breadth.	Main mast. Length.	Main mast. Diameter.	Main-top mast. Length.	Main-top mast. Diameter.	Main-top-gallant mast. Length.	Main-top-gallant mast. Diameter.	Diameter of the fore-mast.	Fore-top mast. Length.	Fore-top mast. Diameter.	Fore-top-gallant mast. Length.	Fore-top-gallant mast. Diameter.	Diameter of the mizen-mast.	Mizen-top mast. Length.	Mizen-top mast. Diameter.
	feet.	feet.	feet.	ins.	feet.	ins.	feet.	ins.	ins.	feet.	ins.	feet.	ins.	ins.	feet.	ins.
7	143,5	36,02	86,2	25,2	47,5	15,0	25,5	7,6	24,0	42,7	14,2	23,0	7,1	16,9	36,0	10,0
8	140,9	35,48	85,0	24,7	46,7	14,7	25,2	7,5	23,5	42,0	14,0	22,7	7,0	16,5	35,5	9,9
9	138,1	34,91	83,7	24,2	46,0	14,5	25,0	7,4	23,0	41,2	13,7	22,5	6,9	16,1	35,0	9,7
10	135,2	34,33	82,5	23,7	45,2	14,2	24,5	7,2	22,5	40,5	13,5	22,2	6,7	15,9	34,5	9,5
11	132,2	33,70	81,2	23,2	44,5	14,0	24,0	7,1	22,0	39,7	13,2	21,7	6,6	15,5	34,0	9,4
12	129,0	33,07	79,7	22,6	43,7	13,4	23,5	7,0	21,5	39,0	12,9	21,2	6,5	15,1	33,5	9,1
13	125,7	32,39	78,2	22,0	42,7	13,4	23,0	6,9	21,0	38,2	12,6	20,7	6,4	14,7	33,0	8,9
14	122,3	31,68	76,7	21,4	41,7	13,0	22,5	6,7	20,6	37,5	12,2	20,2	6,2	14,2	32,2	8,6
15	118,6	30,92	75,2	20,7	40,7	12,6	22,0	6,6	19,6	36,7	12,0	19,7	6,1	13,9	31,5	8,5
16	115,1	30,19	73,5	20,0	39,7	12,4	21,5	6,5	19,0	35,7	11,7	19,2	6,0	13,4	30,7	8,2
17	110,6	29,23	71,2	19,2	38,5	11,9	20,7	6,2	18,2	34,7	11,4	18,7	5,9	12,9	30,0	7,9
18	106,1	28,28	69,0	18,7	37,2	11,4	20,0	6,0	17,4	33,5	10,9	18,0	5,6	12,2	29,2	7,6
19	101,3	27,25	66,7	17,5	35,7	10,9	19,2	5,7	16,6	32,5	10,4	17,2	5,4	11,7	28,2	7,2
20	96,0	26,10	64,2	16,5	34,2	10,4	18,5	5,5	15,4	30,7	9,9	16,5	5,1	11,0	27,2	6,9
21	90,1	24,81	61,2	15,5	32,5	9,7	17,5	5,2	14,7	29,2	9,4	15,7	4,9	10,4	26,0	6,6
22	86,8	24,09	59,7	14,9	31,5	9,5	17,0	5,1	14,1	28,5	9,1	15,2	4,7	10,0	25,5	6,4
23	83,4	23,33	58,0	14,2	30,5	9,2	16,5	5,0	13,5	27,5	8,9	14,7	4,6	9,5	24,7	6,2
24	79,5	22,45	56,0	13,6	29,5	8,9	16,0	4,7	13,0	26,5	8,5	14,2	4,5	9,1	24,0	6,0
25	75,3	21,51	53,7	12,9	28,2	8,4	15,2	4,5	12,2	25,2	8,0	13,7	4,2	8,6	23,0	5,6
26	70,7	20,44	51,2	12,1	26,7	7,9	14,5	4,2	11,6	24,0	7,4	13,0	4,0	8,1	22,0	5,2
27	65,4	19,20	48,5	11,1	25,0	7,4	13,5	4,0	10,6	22,7	7,1	12,5	3,7	7,5	21,0	5,0
28	59,1	17,72	45,0	10,0	23,2	6,7	12,5	3,7	9,4	20,7	6,5	11,2	3,5	6,7	19,5	4,5

Proportions of Masts and Yards for Merchant Ships, &c.
Continuation of the preceding Table, (N°. 8.)

No.	Bow-sprit.		Jib-boom thick.	Length of the head of the main mast.		Length of the head of the fore mast.		Length of the head of the mizen mast.		Quantity by which the fore-mast is lower than the main mast.		Main yard.		Main-top-sail yard.		Main-top-gallant yard.		Fore yard.	
	Length.	Diameter.										Length.	Diameter.	Length.	Diameter.	Length.	Diameter.	Length.	Diameter.
	feet.	ins.	ins.	ft.	ins.	ft.	ins.	ft.	ins.	ft.	ins.	feet.	ins.	feet.	ins.	feet.	ins.	feet.	ins.
7	39,5	24,5	11,2	12	—	10	9	9	—	3	9	68,0	17,0	55,0	12,6	38,5	6,4	61,2	15,4
8	39,0	24,0	11,0	11	10	10	8	8	10	3	9	66,7	16,6	54,0	12,4	37,7	6,2	60,0	15,0
9	38,5	23,5	10,9	11	8	10	5	8	9	3	9	65,5	16,4	53,0	12,1	37,0	6,1	59,0	14,7
10	37,7	23,0	10,7	11	5	10	4	8	7	3	8	64,2	16,0	52,0	12,0	36,3	6,0	57,7	14,5
11	37,0	22,5	10,5	11	3	10	2	8	5	3	8	62,7	15,6	51,0	11,7	35,7	5,9	56,5	14,1
12	36,2	22,0	10,2	11	1	10	—	8	4	3	8	61,5	15,2	49,7	11,5	34,7	5,7	55,3	13,9
13	35,5	21,5	10,0	10	10	9	9	8	2	3	7	60,0	15,0	48,5	11,1	34,0	5,6	54,0	13,5
14	34,7	21,0	9,7	10	8	9	7	8	—	3	7	58,3	14,6	47,2	10,9	33,0	5,5	52,5	13,1
15	34,0	20,0	9,5	10	5	9	5	7	10	3	7	56,5	14,1	46,0	10,5	32,2	5,4	50,7	12,6
16	33,2	19,4	9,2	10	2	9	2	7	8	3	6	55,0	13,7	44,7	10,2	31,2	5,2	49,5	12,4
17	32,0	18,9	8,9	9	11	8	11	7	5	3	6	53,0	13,2	43,0	9,9	30,0	5,0	47,7	12,0
18	31,0	17,7	8,5	9	6	8	8	7	2	3	6	51,0	12,7	41,3	9,5	29,0	4,9	46,0	11,5
19	30,0	17,0	8,2	9	3	8	4	7	—	3	5	48,7	12,2	39,5	9,0	27,7	4,6	43,7	11,0
20	28,7	16,0	7,9	8	11	8	—	6	8	3	5	46,3	11,5	37,5	8,6	26,2	4,4	41,7	10,5
21	27,2	15,0	7,4	8	6	7	8	6	4	3	5	43,5	10,9	35,3	8,1	24,7	4,1	39,2	9,7
22	26,5	14,4	7,1	8	3	7	5	6	3	3	4	42,0	10,5	34,0	7,7	23,7	3,9	37,7	9,4
23	25,7	13,7	6,9	8	—	7	3	6	—	3	4	40,5	10,1	32,7	7,5	23,0	3,7	36,5	9,1
24	24,7	13,2	6,6	7	9	7	—	5	10	3	4	38,7	9,6	31,3	7,1	22,0	3,6	35,0	8,7
25	23,7	12,5	6,2	7	6	6	9	5	7	3	3	36,7	9,1	29,7	6,7	20,7	3,4	33,0	8,2
26	22,5	11,9	5,9	7	2	6	5	5	4	3	3	34,7	8,6	28,0	6,4	19,7	3,1	31,2	7,7
27	21,0	10,9	5,5	6	9	6	1	5	—	3	2	32,2	8,0	26,0	6,0	18,2	3,0	29,0	7,2
28	19,0	9,9	5,1	6	3	5	8	4	8	3	2	29,2	7,2	23,7	5,4	16,5	2,7	26,3	6,4

Proportions of Masts and Yards for Merchant Ships, &c.
Continuation of the Table on the other side, (N°. 8.)

No.	Fore-top-sail yard.		Fore-top-gallant yard.		Cross-jack yard.		Mizen-top-sail yard.		Sprit-sail yard.		Sprit-sail-top-sail yard.		Depth of the trestle trees.				
													Of the tops.			Of the cross trees.	
	Length.	Diameter.	Length.	Diameter.	Length.	Diameter.	Length.	Diameter.	Length.	Diameter.	Length.	Diameter.	Main-mast.	Fore.	Mizen.	Main-top-gallant.	Fore-top-gallant.
	feet.	ins.	feet.	ins.	feet.	ins.	feet.	ins.	feet.	ins.	feet.	ins.	ins.	ins.	ins.	ins.	ins.
7	49,5	13,4	34,5	5,7	49,7	10,4	41,7	9,6	49,5	10,2	34,5	6,4	11,2	10,7	7,0	5,0	4,6
8	48,5	11,1	34,0	5,6	48,7	10,2	41,0	9,4	48,5	10,1	34,0	6,2	11,0	10,6	6,9	4,9	4,5
9	47,7	11,0	33,3	5,5	48,0	10,0	40,3	9,2	47,7	10,0	33,3	6,1	11,0	10,4	6,7	4,7	4,4
10	46,7	10,7	32,7	5,4	47,3	9,9	39,7	9,1	46,7	9,7	32,7	6,0	10,7	10,2	6,6	4,6	4,2
11	45,7	10,5	32,2	5,2	46,3	9,7	39,0	9,0	45,7	9,6	32,2	5,9	10,7	10,0	6,5	4,5	4,1
12	44,7	10,2	31,2	5,1	45,3	9,5	38,2	8,7	44,7	9,2	31,2	5,7	10,5	9,7	6,4	4,4	4,0
13	43,7	10,0	30,7	5,0	44,3	9,2	37,3	8,5	43,7	9,1	30,7	5,6	10,2	9,6	6,2	4,4	4,0
14	42,5	9,7	29,7	4,9	43,5	9,1	36,5	8,4	42,5	8,9	29,7	5,5	10,0	9,4	6,0	4,2	4,0
15	41,5	9,5	29,0	4,7	42,5	8,9	35,7	8,2	41,5	8,7	29,0	5,4	9,7	9,1	5,9	4,1	3,9
16	40,2	9,2	28,0	4,6	41,2	8,6	34,7	8,1	40,2	8,4	28,0	5,2	9,5	8,9	5,7	4,0	3,9
17	38,7	9,0	27,0	4,5	39,7	8,4	33,5	7,7	38,7	8,1	27,0	5,0	9,2	8,6	5,5	4,0	3,7
18	37,0	8,5	26,0	4,4	38,7	8,1	32,5	7,4	37,0	7,7	26,0	4,9	9,0	8,4	5,2	3,9	3,6
19	35,5	8,2	24,7	4,2	37,2	7,7	31,2	7,1	35,5	7,4	24,7	4,6	8,5	8,0	5,0	3,7	3,4
20	33,7	7,9	23,2	4,0	35,3	7,4	29,7	6,9	33,7	7,0	23,7	4,4	8,0	7,6	4,7	3,5	3,1
21	31,7	7,4	22,2	3,7	33,7	7,0	28,2	6,6	31,7	6,6	22,2	4,1	7,7	7,2	4,6	3,4	3,0
22	30,7	7,0	21,3	3,5	32,5	6,7	27,2	6,2	30,7	6,4	21,3	3,9	7,5	7,0	4,5	3,1	2,9
23	29,5	6,7	20,7	3,2	31,2	6,5	26,2	6,0	29,5	6,1	20,7	3,7	7,2	6,7	4,4	3,0	2,9
24	28,2	6,4	19,7	3,1	30,2	6,2	25,3	5,7	28,2	5,9	19,7	3,6	7,0	6,5	4,2	3,9	2,7
25	26,7	6,1	18,7	3,0	28,7	6,0	24,2	5,5	26,7	5,6	18,7	3,4	6,5	6,1	4,0	2,9	2,6
26	25,2	5,9	17,7	2,9	27,3	5,7	23,0	5,2	25,2	5,4	17,7	3,1	6,2	5,9	3,7	2,7	2,1
27	23,5	5,4	16,3	2,7	25,5	5,4	21,5	5,0	23,5	5,0	16,3	3,0	5,7	5,5	3,5	2,5	2,4
28	21,2	4,9	15,0	2,5	23,5	4,9	19,7	4,5	21,2	4,5	15,0	2,7	5,5	5,0	3,2	2,2	2,1

NOTES

ON THE

ARCHITECTURA NAVALIS MERCATORIA

OF

F. H. De CHAPMAN,

&c. &c. &c.

NOTES

ON

Chap. I.

Note 1. The line AG must be supposed to be perpendicular to the axis of the parabola. *Clairbois.*

Note 2. Let the area HIK (Pl. A. Fig. 1.) be supposed to be generated by the motion of a straight line DE, drawn parallel to HK, from I towards R. Then the fluxion of the area DIE is equal to DE multiplied into the velocity of DE in a direction perpendicular to itself; that is, if FG represent or measure this velocity, $\dot{\overline{DIE}} = DE \times FG$.

Let $DE = y$, $IF = x$, then $FG = \dot{x} \times$ sin. $\angle F$, and $\dot{\overline{DIE}} = y\dot{x} \times$ sin. $\angle F$. But by the property of the curve, $ax = y^2$, and $\dot{x} = \frac{2y\dot{y}}{a}$; consequently $\dot{\overline{DIE}} = \frac{2y^2\dot{y}}{a} \times$ sin. $\angle F$; taking the fluents, $DIE = \frac{2y^3}{3a} \times$ sin. $F = \frac{2xy}{3a} \times$ sin. F, which quantities vanish at the same time; hence the whole area $HIK = \frac{2}{3} . IR \times HK \times$ sin. $\angle F = \frac{2}{3} . IR \times Hx$ or $\frac{2}{3} . IR \times AC = \frac{2}{3}\left(b - \frac{a+c}{2}\right) \times 2m$.

Note 3. The application of this rule for measuring curvilinear areas will be in general easier, when put in the following form.

Rule for finding the Area of a Curve; applicable when the number of equidistant ordinates is odd.

Write down in one column the 2d, 4th, 6th, and all the even ordinates; and in another column the 3d, 5th, 7th, and all the odd ordinates, except the first and last. Having added the numbers in each column together, multiply the sum of the even ordinates by 4, and the sum of the odd ordinates by 2. Add the two products and the first and last ordinates together. The result multiplied by one-third of the common interval between the ordinates, will be the approximate area required. (See Example of Construction at the end of these Notes.)

This rule, as Chapman shews, gives the area with geometrical exactness, on the supposition that each portion of the curve passes through the extremities of three successive ordinates, as *HIK, KLM,* &c. (Fig. 1.), is part of a conic parabola. The error arising from its general application will only be the spaces intercepted between such parabolic segments and the given curve. If therefore a sufficient number of ordinates be drawn, and there be no sudden and great alterations in their length, the area thus found will be quite correct enough for the purposes required.

Hence, in the application of the rule, the abscissa or straight line on which the ordinates are erected must be assumed, so that these ordinates may not be subject to any sudden and great increase or decrease. For in that case the space between the given curve and the parabolic segment might be too great to be neglected in the measurement. Sometimes it will be found necessary to measure the area in separate parts, assuming a different abscissa, whenever it appears that by continuing the same, any considerable part of the area would be thus neglected.

The following rule for approximating to a curvilinear area may also be found useful. It is investigated by supposing a parabolic arc of the third dimension to pass through the extremities of every four successive ordinates. The error resulting from its application will be the curvilinear segments intercepted between the proposed curve and the parabolas.

The number of ordinates on the whole must be one greater than a multiple of 3, as 4, 7, 10, &c.

Rule for approximating to a Curvilinear Area; applicable when the number of equidistant ordinates is greater by one than some multiple of 3.

Write down in one column the 4th, 7th, 10th, and every ordinate except the last, of which the number is a multiple of 3 and one more; in another column write down all the remaining ordinates except the first and last. Multiply the sum of the former column by 2, and the sum of the latter by 3; to the products add the first and last ordinates, and multiply the sum by $\frac{3}{8}$ of the common interval between the ordinates. This will be nearly the area contained between the extreme ordinates. (See example of Construction at the end of these Notes.

Similar remarks to those made respecting the mode of application of the former rule, apply also to this.

NOTE 4. According to the common method of calculating, the area $AFKE = 30{,}562$. Now $30{,}611 - 30{,}562 = 0{,}049$. This method then is more exact than the common one by nearly $\frac{1}{20}$ of a square foot, or $\frac{1}{600}$ of the surface. *Clairbois.*

NOTE 5. Taking the proportion of the diameter to the circumference $1 : 3{,}1415926$, $AFKL = 50{,}26548$. *Ibid.*

NOTE 6. Contained by a parabolic line, or by a curve composed of parts considered as parabolic. *Ibid.*

NOTE 7. Suppose a straight line parallel to AC (Pl. A. Fig 1.) to be drawn from H, and to meet KC in a point x; dividing the trapezium into a rectangle $HACx$ and a right-angled triangle KxH. Then the distance of the center of gravity of the rectangle from $AH = m$; that of the triangle from $AH = \frac{2}{3} \times 2m$; consequently the distance of the center of gravity of the trapezium from the same line $= \dfrac{m \times 2\,ma + \frac{2}{3} \times 2\,m \times (c - a) \times m}{2\,m \times \frac{a + c}{2}}$

$= \text{(by reduction)}\ \frac{2}{3}\,m \times \dfrac{a + 2\,c}{a + c}.$

NOTE 8. The following rule will in general be more easily applied than Chapman's.

Rule for finding the center of gravity of a Curvilinear Area.

Multiply each ordinate by its distance from the first ordinate (the first itself being supposed to be multiplied by 0). Put down the 2d, 4th, 6th, and all the even products in one column, and in another column the 3d, 5th 7th, and all the odd products excepting the first and last. Multiply the sum of the number in the first column by 4, and the sum of the numbers in the second column by 2. To the results add the first and last products. The sum multiplied by $\frac{1}{3}$ of the common interval between the ordinates will give a number, which divide by the area of the curve found by the rule in Note 3, and the quotient will be the distance of the center of gravity of the curvilinear area between the first and last ordinates from the first ordinate. (See the example of Construction at the end of these Notes.)

The second rule given in Note 3. may be applied in a similar manner; the products, as above, being used instead of the simple ordinates.

NOTE 9. See the rules in Notes 3 and 8, which are applied by substituting sections for ordinates. (For application, see the example of Construction at the end of these Notes.)

NOTE 10. In the cylinder, the proper expression is

$$\frac{0 \times CD^2 + 1 \times 4\,CD^2 + 2 \times CD^2}{CD^2 + 4\,CD^2 + CD^2} \times AH = \frac{6\,CD^2}{6\,CD^2} \times AH = AH = \frac{AB}{2};$$

for the first ordinate is not evanescent, but equal to CD^2.

NOTES ON CHAP. II.

NOTE 11. WHEN we say only the *center of gravity*, we are to be understood as speaking of the center of gravity of the ship, considered as a heterogeneous body, or of the system of all its component parts. When we speak of the center of gravity of the part under the water considered as homogeneous, we always call it the center of gravity of the displacement. *Clairbois.*

NOTE 12. Chapman here supposes two forces to act on the ship, one of which is the ship's weight pressing downwards at its center of gravity; the other is the pressure upwards of the fluid through the center of gravity of the displacement. The concurrence of these forces in righting the ship, after it has inclined, he calls the stability.

It must be observed, however, that the weight of the ship acting at the center of gravity can produce no effect in making the ship turn round that point. The whole revolving power arises from the vertical pressure of the fluid, which is equal to the weight of the ship, and takes place upwards on the side of the vessel that is immersed farther in the fluid by the heeling. The ship is thus turned round an axis passing through its center of gravity, and also is supported by the same buoyancy.

NOTE 13. The inclination being very small, the prism immersed $ACa \times \dot{x}$ may be considered as equal to the corresponding small prism $BCb \times \dot{x}$ raised out of the fluid. The latter prism may therefore be supposed to be transferred from its center of gravity to that of the former, and its moment in such transfer, in a horizontal direction, will be $BCb \times \frac{4}{3}y = \frac{by\dot{x}}{2} \times \frac{4}{3}y = \frac{2}{3}by^2\dot{x}$. But the moment of the displacement

D, in consequence of this transfer, in the same direction, will be $D \times EF$. Consequently $D \times EF = \int \frac{2}{3}\, by^2\dot{x}$.

NOTE 14. $b : y :: EF : EG$, consequently $b = \frac{EF}{EG} \times y$, where $\frac{EF}{EG}$ is a constant quantity, the angle of heeling being supposed given. Now $EF = \int \frac{2}{3} \times \frac{by^2\dot{x}}{D}$, or substituting for b its values, $EF = \frac{EF}{EG} \times \int \frac{2}{3} \times \frac{y^3\dot{x}}{D}$. Multiplying both sides by $\frac{EG}{EF}$, we have $EG = \int \frac{\frac{2}{3} y^3 \dot{x}}{D}$

NOTE 15. As we shall have occasion, in the course of these Notes, to make a few remarks on this method of measuring the stability of ships, which is given not only by Chapman, but also by most other writers on Naval Architecture, it may be proper in this place to investigate a general expression for the stability of a ship at any inclination.

When a ship is inclined in the sea from an upright position, a prismatic solid is emerged on one side, which call E; and another prismatic solid is immersed on the other, which call I. These two solids must be equal to one another, since the capacity of the displacement remains upon the whole unaltered. The line which separates I from E must be a straight line, since it is the intersection of two planes; namely, that of the load water-line when the ship is upright, and that of the load water-line when the ship is in an inclined position. This line is also parallel to the axis of rotation, which is a straight line passing through the center of gravity of the ship from head to stern; for this axis of rotation is supposed to be parallel to each of the two above-mentioned water-lines. Let the line in question, namely, that which separates the immersion from the emersion, be denoted by x.

Since by the heeling of the ship, E is taken from the displacement, and I (which is equal to it) is added to the displacement, E may be considered as transferred to I (the bulk of each being supposed to be collected in its center of gravity). Let the horizontal distance of the centers of gravity of E and I be b; then the moment produced by this removal in the direction of b is bE or bI.

Let G (Pl. A. Fig. 2.) be the center of gravity of the ship, F the center of gravity of the displacement, when the ship floats upright, Q its center of gravity when the ship heels, or is laterally inclined. Let $QTVM$ be a vertical straight line; through F and G draw FT and GV perpendicular to QM, and through G draw GO parallel to QM cutting FT in O.

Then when the ship heels through the angle ASa or FGO, the buoyancy of the fluid is supposed to act upwards in the line QM with a force equal to the weight of the ship, or measured in bulk, equal to the displacement D. The effort therefore made to right the ship, that is, to turn it round a longitudinal axis passing through G, is equal to $D \times GV = D \times FT - D \times FO$. But $D \times FT$ is the horizontal moment of the displacement in consequence of the transposition of E to I, and is therefore equal to the horizontal moment of E, that is, to bI. Hence the effort of the buoyancy to right the ship $= bI - D \times FO = bI - D \times FG \times \sin. FGO$ $=$ (if $FG = d$ and $\sin. FGO$ or $\sin.$ inclination $= s$) $bI - Dds$.

Let now a longitudinal plane be supposed to pass through the line denoted by x, perpendicular to the water's surface. Let Z be any section ASa of the solid I, perpendicular to x, and let z be the corresponding section BSb of the solid E. Let W and w be the horizontal distances of the centers of gravity of Z and z from the above-mentioned longitudinal vertical plane. Then $\frac{\int ZW\dot{x}}{I}$ is equal to the horizontal distance of the center of gravity of the solid I from that plane, and $\frac{\int zw\dot{x}}{E}$ is the horizontal distance of the center of gravity of the solid E

from the same plane. Consequently $\frac{\int ZW\dot{x}}{I} + \frac{\int zw\dot{x}}{E}$, or since $E = I$, $\frac{\int ZW\dot{x} + \int zw\dot{x}}{I} = b$, and $\int ZW\dot{x} + \int zw\dot{x} = bI$. Hence the stability of a ship is properly measured by $\int ZW\dot{x} + \int zw\dot{x} - Dds$.

The mode of approximating to the value of this expression will be seen in the example of a Construction given at the end of these Notes.

When the angle of heeling of a ship is evanescent, or in a practical sense very small, $Z = z = \frac{y \times sy}{2} = \frac{sy^2}{2}$, and $W = w = \frac{2}{3}y$, y denoting the half breadth of the ship at the surface of the water. Consequently the stability in this case is $\int \frac{sy^2}{2} \times \frac{2}{3}y\dot{x} + \int \frac{sy^2}{2} \times \frac{2}{3}y\dot{x} - Dds = \int \frac{2}{3}sy^3\dot{x} - Dds$; and at a given indefinitely small angle it is measured by $\int \frac{2}{3}y^3\dot{x} - Dd$.

If the displacement be given, the stability will be measured by $\frac{\int \frac{2}{3}y^3\dot{x}}{D} - d$, which is the case when two ships of equal displacement are inclined to a very small given angle of heeling. But $\frac{\int \frac{2}{3}y^3\dot{x}}{D}$ = the height of the metacenter above the center of gravity of the displacement. Hence in the supposed case the stability is measured by the height of the metacenter above the center of gravity of the ship.

If the center of gravity of the displacement coincide with the center of gravity of the ship, then $d = 0$, and the stability at a very small angle of heeling is generally $\int \frac{2}{3}sy^3\dot{x}$, and at a given small angle of heeling it will be $\int \frac{2}{3}y^3\dot{x}$.

No dependence, however, can be placed on any of the latter expressions, as a measure of stability, except at the instant the ship begins to heel. After an inclination through a finite angle 5°, 10°, &c. the proportion of the stabilities in two distinct cases might be very different from what the expression $\int \frac{2}{3} sy^3 \dot{x}$ would give, when $d = 0$, and from what $\int \frac{2}{3} sy^3 \dot{x} - Dds$ would give, when the center of gravity of the ship was above that of the displacement. For the values of W and w might in that case neither be equal to each other, nor to $\frac{sy^2}{2}$, and at the same time the values of Z and z might differ very much from $\frac{2}{3}y$.

For instance, suppose two ships A and B (Pl. A. Fig. 3.) to have exactly the same load water-line; suppose, also, the center of gravity of the ship to coincide in each, with the center of gravity of the displacement. Then the value of $\int \frac{2}{3} sy^3 \dot{x}$ would be the same in each, and consequently the stability of each, if measured by this expression, would be the same.

But if the sides of the one fell out above and below the surface of the water as in A, and the sides of the other fell in as in B, it scarcely needs the aid of calculation to see that the stability of A, notwithstanding the above coincidences, must be greater than that of B; and that the difference of stability, on account of the different shape of the sides, might be so considerable, that whilst A carried the proper quantity of sail, with perfect security and convenience, B might heel under the same pressure much too far.

Note 16. The Rules given in Notes 3 and 8 will be more convenient, using the cubes of the ordinates instead of the simple ordinates.

Note 17. The metacenter before the augmentation of the displacement. *Clairbois.*

Note. 18. One term is wanting in this formula. The moment of

P is included, being supposed to be placed in its center of gravity L; that of Q is also included, which is supposed to be placed in K. But these two weights do not constitute the whole of the vessel. Q is the weight above the surface of the water, P is that which corresponds to the augmentation of the displacement. There is another weight $D-Q$ supposed to be situated in the center of gravity of the displacement, before it has received any augmentation. I think Mr. Chapman has not mentioned it in the calculation, because he has supposed it to be situated in E the center of gravity of the displacement, and consequently multiplied by 0. But it is not in the new center of gravity, to which the moments of the weights are referred. The expression ought to be $\int \frac{2}{3} y^3 \dot{x} + zP - \frac{aD + bP}{D + P} \times Q - cQ - (D - Q) \times EK$, which may be reduced to a more convenient formula.

Upon this Mr. Chapman founds a system of construction, which he appears to have actually carried into execution, in all his ships built for sailing. As we cannot agree with him in his conclusion, we will state the proposition again.

In two ships of the same rate, of equal principal dimensions, of the same displacement, having the same load water-line; if a greater rising of floor be given to one of those ships, making up the dimensions by an increase of breadth, or an enlargement beginning at the surface of the ballast and going to the surface of the water, will the stability be thence increased or not? In a Note to my *Essay on Naval Architecture*, p. 23, there is an answer to this question, which we owe to Chevalier de Borda. In a ship which has more floor, the centers of gravity of the ballast and lading will be lower than in a ship, which has greater rising. Combining the quantity of depression of these centers of gravity with the weights of the two elements (the lading and the ballast), it appears that the ship, which has the most floor, has a stability greater or less than that of the ship with more rising, or is equal to it, according as *the ratio of the* *specific gravity of the lading to that of sea water, multiplied into the quantity by which the center of gravity of part of the lading is depressed, plus the ratio of the specific gravity of the ballast to that of sea water, multiplied also into the quantity by which the center of gravity of part of the ballast is depressed; according, I say, as the sum of these two terms is greater or less than the quantity by which the center of gravity of part of the bottom, considered as homogeneous, is depressed; or is equal to this quantity.*

This leads to a formula of very easy application. Suppose $m =$ ratio of specific gravity of lading to that of sea water, and $n =$ the ratio of the specific gravity of ballast to that of sea water, $p'i' =$ the depression of the center of gravity of the variable part of the lading, and $i'o' =$ that of the center of gravity of the ballast.

Then we have $(m-1).p'i' + (n-1).i'o'$, which is positive, equal to nothing, or negative; if it be positive, the stability of the ship, which has the most floor, is the greater; if it be equal to nothing, the stability is the same; if negative, it is less.

In a ship of 74 guns, $p'i'$ may be supposed to be 5 feet, $i'o' = 1$ foot; $m = \frac{1}{2}$; $n = 5$: then substituting these values in the formula $(m-1)$. $p'i' + (n-1).i'o'$, we have $(\frac{1}{2} - 1) \times 5 + (5 - 1) \times 1 = +1\frac{1}{2}$. We should find in like manner that this formula would give a positive quantity for all our ships of war and frigates. The floor therefore gives stability. This is not the case with ships, which have little or no ballast; those made to carry little artillery, such as packet-boats or pleasure vessels, gain stability by having considerable rising. As to ships of burden, they are constructed throughout as full as possible; but they would also gain stability, if there were means of increasing the rising of the floors. *Clairbois.*

The proof of the above Rule given by Clairbois for determining the diminution or increase of the stability by transferring part of the displacement near to the load water-line to the seat of ballast, is as follows:

Let a (Pl. A. Fig. 4.) be the part of the displacement transferred to c.

In consequence of this let the ballast in b be put in the space c, and the lading before in a, in b. Let z = the vertical distance of the centers of gravity of a and b, y = that of the centers of gravity of b and c. Let the weight of a, supposed to be filled with water, be w.

Let specific gravity of ballast : specific gravity of water :: n : 1, and specific gravity of lading : specific gravity of water :: m : 1. Then nw = weight of a in ballast, that is, weight of displaced ballast; in like manner mw = weight of displaced lading.

Hence $w(z+y)$ = moment of transferred displacement;
$mw \times z$ = ditto of displaced lading;
$nw \times y$ = ditto of displaced ballast;
consequently $nw \times z + mw \times y$ = ditto of lading and ballast jointly.

The center of gravity of the ship will therefore be carried down by the transfer, more or less than the center of gravity of displacement, or equally with it, according as $mw \times z + nw \times y$ is greater or less than $w \times (z+y)$, or equal to it; that is, according as $(m-1) \cdot z + (n-1) \cdot y$ is positive, negative, or equal to 0. But as the height of the metacenter above the center of gravity of the displacement is supposed to remain the same, its height above the center of gravity of the ship will be increased in the first case, diminished in the second, and it will remain unaltered in the third. Hence, considering the latter height as a proper measure of the stability, it follows that the stability will be increased, diminished, or will remain the same, according as the expression $(m-1) \times z + (n-1) \times y$ is positive, negative, or equal to 0.

It is evident, from the above proof of the Rule given by Clairbois for estimating the effect of transferring part of the displacement on the stability, that he considers solely the separation or approach thereby produced of the center of gravity of the ship, and the center of gravity of the displacement. Chapman's method also amounts to the same thing.

The reasoning of Clairbois would be conclusive, provided $\int \frac{2}{3} s y^3 \dot{x} - Dds$ (Note 15.) were a general measure of the stability. For if the two centers be farther separated than before, in consequence of the transfer of the part near the load water-line to the seat of the ballast, the value of Dds must be increased, and therefore the $\int \frac{2}{3} sy^3\dot{x} - Dds$ diminished; if these centers be thereby made to approach each other, $\int \frac{2}{3} sy^3\dot{x} - Dds$ must be for a similar reason increased.

But the proper measure of the stability at any finite angle of inclination is $bI - Dds$ or $\int ZW\dot{x} + \int zw\dot{x} - Dds$ (Note 15.) in which the variation which takes place in the value of $\int ZW\dot{x} + \int zw\dot{x}$ must be considered, as well as the variation in the value of Dds. And hence, it appears that Chapman's conclusion may be right, although it is obtained from an expression in which he has beyond doubt omitted an essential term; and although the whole of his reasoning, as also that of Clairbois, seems to be founded on principles, which cannot be depended on for determining the stability of a ship.

The following are the results of calculations made on two 74 gun ships A and B, of very nearly the same displacement and principal dimensions; the floors of B having greater rising than those of A; and the part between wind and water in B being more filled than in A. For the notation see Notes 15 and 18.

In A .... $bI = 424749$;
In B .... $bI = 452755$;
The difference is....... 28006.

The displacement in each was nearly 100000 cubic feet; the variable part of the displacement was about 3000 cubic feet, $z = 5$ feet, $y = 1$ foot, $m = ,5 =$ specific gravity of lading, $n = 5 =$ specific gravity of ballast. Then,

$3000 \times ,5 \times 5 =$ moment of shifting part of the lading;

$3000 \times 5 \times 1 =$ moment of shifting part of the ballast;

The center of gravity of B is therefore higher than that of A by

$$\frac{3000 \times 5 \times ,5 + 3000 \times 5 \times 1}{100000} = ,22 \text{ feet.}$$

$3000 \times 6 =$ moment of shifting part of the displacement. Consequently the center of gravity of the displacement in B is higher than it is in A by $\frac{3000 \times 6}{100000} = ,18$ feet.

Hence, it appears that the value of d in B is greater than in A by $,22 - ,18 = ,04$ feet, and the stability of A is greater than that of B at the supposed angle of inclination 20°, from the consideration of the negative part of the expression for the stability, namely Dds, by $100000 \times ,04 \times ,342 = 1368$.

Hence it appears, that upon the whole the stability of the ship, with the greater rising of floor, at an inclination of 20°, is greater than the stability of the other by 28006 – 1368 or 26638.

From the above example, we see how greatly the stability of a ship is increased by filling it between wind and water, and how little in proportion it is altered by a partial displacement of the lading and ballast. This is what Chapman observes, and hence it is that he recommends the construction of ships of the line with rising floors.

But in fact it does not appear, that the question between those, who would build ships of the line with great rising in their floors, and those who would build them with flat floors, can be altogether decided by the mere consideration of superior stability. It is necessary to take into the account many other properties, which are materially affected by such difference of shape; one of the principal of which is the easiness of a ship's movements at sea, particularly with respect to rolling. Let it be supposed that a ship of the line, with flat floors, has sufficient stability, and is perfectly easy in rolling; then another ship of the same principal dimensions and displacement with rising floors, may have greater stability at an inclination of 5°, 10°, 20°, &c. But it does not hence follow, that the latter ship is on this account alone to be preferred to the former. For its greater stability may possibly render it laboursome and uneasy in rolling, and subject to those sudden shocks, the effects of which are perhaps more to be feared than a small deficiency in stability.

Besides in construction, the question is under a given displacement to form a ship, which shall have the best possible properties, not only in stability (which should be neither too great, nor too little, at different angles of heeling), but also in several other respects; as in rate of sailing, in easiness of pitching, in coming well about, in convenience of stowage, &c. So that in forming a draught for building, it is necessary to combine and reconcile all these different considerations, before a preference can be properly given either to rising or flat floors.

We have said, that a construction must be made from a given displacement, as a basis. This is indeed generally supposed to be a fixed quantity, which does not admit of variation; although in fact it may be something diminished in particular cases, with the best possible effect, provided a sufficient stability can be maintained with a smaller quantity of ballast, which is the only weight that can be lessened in ships of war. And herein perhaps consists one great advantage of filling a ship towards the load water-line, as much as other considerations admit of; by which means the stability is brought to a proper value with a less displacement. A ship thus constructed has a less body in the water, whereby its rate of sailing must be increased, and its evolutions, if it be skilfully formed in other respects, must become more rapid and easy. This also perhaps entered into the view of Chapman, whose experience and skill as a ship-builder entitle every direction he gives to the utmost attention; although the mathematical reasoning by which he endeavours to elucidate or prove, what probably he knew to be true in practice, is certainly inconclusive.

NOTES ON CHAP. III.

NOTE 19. If by heeling round the longitudinal axis passing through the center of gravity of a ship (this axis being supposed quiescent), there is a tendency to carry a greater solid content under the water on one side than is raised out on the other, the axis of rotation must rise during the inclination. For if not, since the displacement on the whole would be increased, there would be a greater buoyancy than before, and consequently a greater buoyancy than the weight of the ship would balance. In such a case therefore, whenever the ship rolls, it must rise in heeling and fall in righting again.

Supposing that an inclination round the same axis (considered quiescent) would carry less capacity under the water than it would raise out, the same alternate rising and falling would take place; with this difference, that the ship would fall in heeling and rise in righting again.

The existence and extent of this motion, which must render the rolling of a ship very uneasy, depend on the position of the center of gravity of the ship, and also on the shape of the sides between wind and water. In Fig. 5, 6, and 7. Pl. A. each of which figures represents the body of a ship whose sides are parallel to the plane of the masts, ab is the surface of the water, AB is the load water-line in its upright position, G is the center of gravity of the ship supposed equally distant from AB and ab. In Fig. 5. G is supposed to be on the surface of the water; in Fig. 6. G is supposed to be below the surface of the water, and in Fig. 7. above the surface of the water. At an inclination of 10° ASa is the immersion and BSb the emersion, supposing the axis of rotation passing through G to be quiescent.

By inspecting the figures it is evident that in Fig. 5. the immersion and emersion are equal; the ship therefore in heeling will neither rise nor fall. In Fig. 6. the immersion is greater than the emersion; consequently the ship will rise in heeling. In Fig. 7. the immersion is less than the emersion, and the ship will fall in heeling.

If in Fig. 5. the sides were made to fall out above the load water-line, it is manifest, supposing the axis of rotation quiescent, that the immersion would exceed the emersion. In this case, therefore, the ship would rise. In Fig. 6. supposing the sides above the load water-line to fall out, the immersion would exceed the emersion more than before, which would produce a still greater rising in the ship than when the sides are upright.

If this were the case with the ship represented in Fig. 7, the immersion would be greater than before, supposing the axis quiescent; hence the falling of such a vessel would be diminished.

If the sides of a ship fell out below the water, preserving above it their parallelism to the plane of the masts, the ship represented by Fig. 5. would fall in heeling, the rising of that represented by Fig. 6. would be corrected, and the falling of that represented by Fig. 7. would be increased.

From the above remarks, it appears that the observation of Chapman respecting the situation of the center of gravity of the ship is not correct, except for the case in which the sides of the ship between wind and water are parallel to the plane of the masts. When they are not so, to prevent the sudden shocks which a ship is liable to, from the causes assigned by Chapman, the center of gravity should be something above or below the load water-line, according to the particular shape of this part of the ship.

Chapman says, that the rise and fall of the ship is equal to the versed sine of the angle Geg to the radius EG. By inspecting Fig. 6. Pl. A., it will be seen that supposing G to be fixed, the immersion must exceed the emersion. Through Y the middle point between A and B draw RYV parallel to ab; then if RV were the water's surface, the immersion RYA would be equal to the emersion VYB. If therefore the surface of the water descend through XZ the versed sine of the angle at G to the radius GX, or which is the same thing, if the point G rise through the same line ZX, the displacement will remain unaltered. This must be true at any inclination whatever, if the sides between wind and water be shaped as is represented in this figure.

Supposing the sides not to be parallel to the plane of the masts, the above reasoning will be true when the inclination is evanescent or in a practical sense very small.

Hence, it appears that instead of *to the radius* EG must be read *to the radius* EX, supposing X to be the point, where EG cuts the surface of the water; and then the article is true only in very small (strictly evanescent) inclinations.

NOTE 20. It appears by the last note that Chapman's reasoning respecting the value of Ee cannot be correct. It is true, however, that in large angles of rolling, where there is a great disproportion between the immersion and emersion (the axis of rotation being supposed quiescent) the shocks arising from the ship's rising and falling must be great. To obviate this fault in construction, it would be necessary to find by computation the exact position of the ship's center of gravity, and then to alter the body till the immersion and emersion caused by heeling round a quiescent longitudinal axis passing through that point were equal.

Thus, let G (Fig. 8. Pl. A.) be the center of gravity of the proposed plan represented by AOB. Draw GX perpendicular to the load water-line, and GY making an angle XGY with XG equal to any proposed inclination. Take GY equal to GX, and through Y draw aYb perpendicular to GY. Then ab will be the load water-line, when the ship is inclined; and BSb, ASa will represent respectively the prismatic solids, which have been called the immersion and emersion. If upon computing the content of each, they are found to be unequal, the body must be altered till they are made equal.

It is important also to pay attention to a similar adjustment in regard to pitching. For a great inequality between the immersion and emersion round a quiescent axis would be attended in this case with similar bad effects as in rolling, by the sudden rising and falling of the ship.

NOTE 21. The reasoning of Chapman on this subject is exceedingly obscure. The point G cannot be considered as the center of percussion, because when a body revolves round an axis passing through the center of gravity, the center of percussion is at an infinite distance. The length of a pendulum vibrating in the same time as the ship may be found as follows.

The metacenter is supposed to be acted on by the mean buoyancy of the fluid in a direction perpendicular to the horizon. And this force is a constant one, accelerating the rotatory motion of the ship to its upright position, and retarding this motion as it heels on the other side. The vibrations of a ship may therefore be considered as analogous to the oscillations of a heavy body by its own weight, where the constant force of gravity (supposed to act on its center of gravity) accelerates it to the lowest point, and afterwards retards it in ascending; and the length of the isochronal pendulum may be found in the former case in the same manner as in the latter.

Now the distance of the center of oscillation from the center of suspension in a body vibrating by its own weight, is found by dividing the angular inertia of all the particles, that is, the sum of the products of each particle into the square of its distance from the axis of rotation, by the whole body multiplied into the distance between the said axis and the center of gravity, on which the whole weight acts downwards.

If therefore P, p, &c. denote the particles of a ship, and D, d, &c. their distances from the axis of rotation passing through the center of gravity, the length of the isochronal pendulum will be $\frac{P \times D^2 + p \times d^2 + \&c.}{\text{whole ship} \times EG}$ where E is the center of gravity (in this case the center of suspension), and G is the metacenter, on which the whole buoyancy of the fluid, which is equal to the weight of the ship, acts upwards.

Supposing the products $P \times D^2$, $p \times d^2$, &c. to be given as well as the weight of the ship, the length of the isochronal pendulum will vary inversely as the line EG; that is, the greater the distance of the metacenter above the center of gravity of the ship, the shorter will be the pendulum, and therefore the quicker the vibrations of the ship; and the less that distance is, the slower will the rolling become. Supposing the line EG and the weight of the ship to be given, the duration of the vibrations will vary with the values of D, d, &c.; the less they are, the shorter will be the pendulum, and the quicker the rolling; the greater they are, the slower it will be.

The above reasoning is strictly true, only when the vibrations are evanescent; it may be considered as nearly true, when they are in a practical sense very small. When a ship rolls through finite angles, the vibrations are very different from those of a pendulum of an invariable length. For the point G, where the vertical axis passing through the center of gravity may be supposed to be acted on by the mean buoyancy of the fluid in righting the vessel, is not then a fixed point. No precise or general conclusions can be drawn from the expression for the length of the isochronal pendulum, respecting the degree of quickness or slowness of the vibrations, as depending on the length of EG. What is thence concluded respecting the position of the weights, is however true for any angles of rolling; the farther they are from the longitudinal axis passing through the ship, the greater will be their inertia, and the greater will be the resistance the ship opposes to an inclining power. It may be proper, therefore, in cases where the stability is too little to have recourse to such an arrangement of the weights, care being taken, however, to keep them at the same distance below the surface of the water.

Note 22. If the stability be diminished, a greater inclination will be produced by a given acting force; but the inclination and also the righting of the ship will be more slow and easy. For the acting force will be overcome more gradually and slowly; there will therefore be less straining of the parts of the ship. At the same time it is manifest that the stability cannot be diminished too much without compromising the service of the ship, and even endangering its safety.

Again, an increase of stability has the effect of rendering the angle of inclination less; and so far it is useful; but carried to excess, the inclining force would be destroyed so suddenly, that the shock might be dangerous. The effect also of the stroke of a wave on the side, the breadth being supposed to be increased, for the purpose of giving additional stability, would become greater; so that a ship thus constructed, would in the least sea, be subject to continual and quick vibrations. Chapman in his reasoning on this subject, seems to consider the height of the metacenter alone as a sufficient criterion of the properties of a ship with respect to the easiness or vivacity of its rolling. But it was shewn in Note 15, that this is not the case, unless the angles of rolling be considered as evanescent. It is possible that the height of the metacenter may be something diminished, and yet by an attention to the shape of the sides, the stability may be made sufficiently powerful. It is possible, on the other hand, that the height of the metacenter may be increased beyond what is usually given to it, and yet by injudicious alterations in the shape of the sides the stability may be found too little.

In order to form a proper estimate of a ship's properties in this respect, in the process of drawing the plan, it is necessary to make accurate calculations of the stability at different angles of inclination, and to compare the result in each case with the stability of tried and approved ships of the same kind and size. So that to enable the constructor to plan ships, which might be expected to answer fully in point of stability, he must be furnished not only with various calculations on all kinds of ships, which have been previously built, but also with a minute detail of their performance at sea.

Note 23. Chapman seems here to be of opinion that the larger the ship the higher ought to be the metacenter; this however does not appear generally to be the case. Bouguer in his *Traité du Navire*, B. 3. Sect. 4. Chap. iii. says that the metacenter above the center of gravity in the frigate *La Gazelle* was 4 or 5 feet; in ships of 60 guns it was from 6 to 7 feet; in ships of 80 or 90 guns, from 4 to 5 feet; in ships of 110 or 120 guns, sometimes as little as 2 feet. In the British Navy the height of the metacenter above the surface of the water, using in the calculation the main breadths, is generally less than 6 feet, and it is the least, instead of being the greatest, in the largest ships. In the 18 gun brigs it is 5,5 feet, and these vessels are by no means deficient in stability. In the frigates of 36 guns it is nearly 6 feet. In the *Leopard*, a fourth rate, it is 4,2 feet. In the third rates it is from 4 to 5,5 feet nearly. In the *Howe*, a first rate of 120 guns, it is 3,7 feet.

Note 24. The usual shape given to the bottom of a ship is such that the center of gravity of the displacement is before the middle; and as the center of gravity of the ship must be in the same perpendicular with that of the displacement, it must also be before the middle. *Clairbois.*

Note 25. The length in Swedish construction is taken between two perpendiculars to the keel. The one at the stern is drawn from a point on the after side of the sternpost at the height of the wing transom at the middle line; that forward is drawn from a point on the fore side of the stem at the same height above the water-line with the wing transom.

Note 26. Chapman here touches upon a point of great importance in the construction of ships, which may be developed a little farther as follows. When a ship floats upright, the centers of gravity of the ship and the displacement are at the same distance from the stern. When the ship is inclined, the latter point is carried to leeward, and in consequence the buoyancy of the water, supposed to act upwards through it, tends to turn the ship back. The axis round which the ship will then revolve, depends on the position of the center of gravity of the displacement after the inclination. If it be in the transverse section passing through the center of gravity of the ship (which is supposed in all disquisitions on this subject), the vessel will be made to roll round an axis parallel to its length; since in that case there cannot be any tendency to roll round a transverse axis passing through the center of gravity.

But if the center of gravity of the inclined displacement be behind or before the said transverse section, in that case the buoyancy will cause the ship to revolve round a transverse axis as well as round a longitudinal one; in other words, it will cause the ship to revolve round a diagonal axis; a motion that must tend to disunite the parts of the ship, to derange its different adjustments, and operate considerably in retarding its progress.

It seems desirable therefore to keep the center of gravity of the displacement, as the ship inclines, in the transverse section in which it is placed, when the ship floats upright. This is effected by taking care in the construction, that the line joining the centers of gravity of the immersion and emersion, at least at common angles of heeling, is parallel to that section. For the motion of the center of gravity of the displacement takes place in consequence of the removal of the emersion and the addition of the immersion, which is equal in bulk to the emersion; it may be considered therefore as produced by transferring the emersion collected in its center of gravity to the center of gravity of the immersion. And by a well-known principle of Mechanics, if this transfer be along a line parallel to the transverse section, the center of gravity of the whole system or of the whole displacement, being once in the plane of that section, must always be so. (For the mode of calculation see Construction at the end of these Notes.)

Note 27. A body that receives an impulse as here stated by Chapman, is made to revolve round an axis passing through its center of gravity, and not round an axis passing before or behind that point. However the conclusion is not affected by this mistake.

NOTES on CHAP. IV.

Note 28. In the scholium to Prop. 34. Lib. ii. of Newton's Principia, the following construction is given for the frustum of a cone of a given base and height, which is less resisted than any other, when it is moved through a resisting medium in the direction of its axis. Bisect the altitude OD (Pl. A. Fig. 9.) in Q, and produce OQ to S, so that QS may be equal to QC; then S will be the vertex of the required frustum.

From this construction of the frustum of a cone of least resistance, Newton concluded that the angle, which the curve of a given length and breadth generating the solid of least resistance made with its least ordinate, was 135°. For as the height of the frustum of the cone is continually diminished, the angle SCO approaches continually to an angle of 45° as its limit. Hence an evanescent frustum of this kind is less resisted than any other evanescent solid whatever of the same base and height. Considering therefore the termination of the solid of least resistance as an evanescent frustum of a cone, the angle which the generating curve makes with the least ordinate must be the supplement of 45° or 135°.

Note 29. The equation to the curve generating the solid of least resistance is $\frac{y\dot{y}^3\dot{x}}{(\dot{x}^2+\dot{y}^2)^2}=a$. At the point G the angle $AGF = 135°$; consequently $\dot{x}^2=\dot{y}^2$, and $(\dot{x}^2+\dot{y}^2)^2 = 4\dot{y}^4$; whence $\frac{y\dot{y}^3\dot{x}}{(\dot{x}^2+\dot{y}^2)^2}=\frac{y}{4}$. It appears therefore that the constant quantity a is $\frac{1}{4}$ of the least ordinate.

Note 30. This elevation of the water before the ship, forms a kind of prow of water, whose figure is not so well adapted for dividing the fluid as that of the ship; and the ship being preceded by this prow of water, cannot overcome so easily the resistance of the fluid, as if it divided it immediately; which it does very nearly when the velocity is small. *Clairbois.*

Note 31. Perhaps the theory given by Chapman of the resistance to ships will be more clearly understood, by attending to the following general observations.

By the motion of a ship a-head, part of the pressure of each particle of the fluid against the stern is taken off; this diminution of pressure forward is equivalent to a positive resistance on the fore-part; and the proportion it bears to the whole pressure forward, when the ship is at rest, depends on the shape of the after-part of the ship. The more finely tapered it is, the less retardation will the relative impulse of the particles aft produce. The more flat it is, the greater will be the retardation. And the reason is this. When a ship is perfectly at rest, the pressure of the fluid forward is the same, whether its after body is finely tapered or flat, but by its shooting a-head, the particles acquire a relative motion aft; and in the former case this motion is in a direction very oblique to the body, whilst in the latter it is in a direction almost perpendicular thereto. Still however the same number of particles is left behind in a given time by a ship, which is lean aft, as by one which is full; so long as the midship section remains the same. Hence it appears, that the relative diminution of pressure forward must depend on the degree of obliquity with which the after surface quits these particles. This diminution of pressure forward, or as it is generally called, the negative resistance, being added to the positive resistance on the fore body, which depends on the shape of the fore body in the same manner as the negative resistance depends on that of the after body, we have an expression for the whole resistance to the ship. This Chapman makes $C \times \frac{DC^2}{AC^2} \times n^2 + C \times \frac{DC^2}{BC^2} \times n^2$.

Again, by the motion of the ship the water is accumulated at the fore body, or is there driven up above the level of the sea, the particles not having sufficient time to escape laterally. The consequence of this accumulation of the fluid before the ship, must be a proportional depression behind it. Independently therefore of the velocity with which the water rushes towards the stern to fill up the void place caused by the motion of the ship a-head, it has also a certain additional motion in descending from this elevation forward. And as the ship shoots a-head, the fluid from forward moves faster to fill up the void space left behind, than from any other quarter; provided the form of the body is such as to admit of its easy transmission, that is, provided the form of the after body be sufficiently tapering and fine. By this motion of the fluid the after body of the ship may be considered as pressed by a fluid gliding along its surface, with a velocity equal to the velocity of the ship added to that acquired by falling down a certain inclined plane. On this account, therefore, the diminution of pressure forward, or the negative resistance, is something increased.

But if the after body be full and flat, in that case the fluid is transmitted towards the stern-post more slowly, having continually to change the direction of its course in flowing from the fore-part of the ship. It arrives there only in sufficient time to meet near the stern-post and round the quarters of the vessel, the fluid which rushes after the ship to fill up the void space left behind; or rather the water rushes from all sides of the stern, and there is that collision of the particles, which is called the eddy water, close to the surface of the after body. By this collision the fluid acquires a motion in various directions, and the diminution of pressure forward, or the negative resistance, becomes more considerable.

When the velocity is small, this concussion of the particles close to the stern ceases, and the fluid in this case may be considered as moving behind the vessel in the same direction with it; by which the vessel is in some degree forced a-head, and the resistance diminished. From such considerations Chapman assumes the general expression for the negative resistance to be $C \times \frac{DC^2}{BC^2} \times (n \pm w)^2$.

Chapman also remarks that the fluid, which is raised on the fore body of the ship by its moving forward, acquires and communicates to the column a-head part of the velocity of the ship, by which the positive resistance is something diminished. At the same time the transverse section C, by the rising of the fluid, is something increased. Whence Chapman makes the expression for the positive resistance $C' \times \frac{DC^2}{AC^2} \times (n-v)^2$.

Hence, the general expression for the sum of the positive and negative resistances, or for the whole resistance, is $C' \times \frac{DC^2}{AC^2} \times (n-v)^2 + C \times \frac{DC^2}{BC^2} \times (n \pm w)^2$.

NOTE 32. It is necessary, however, to suppose that they floated sufficiently above the water, to admit of the elevation of the water without being totally immersed. *Clairbois.*

NOTE 33. Chapman has here multiplied the expression for the minimum by a variable quantity, by which the whole fluxional process is vitiated. Let $AD = x$, $BD = y$, and $CD = 1$, then the mininum is $\frac{6}{x^2+1} + \frac{7}{y^2+1}$, hence $-\frac{12x\dot{x}}{(x^2+1)^2} - \frac{14y\dot{y}}{(y^2+1)^2} = 0$, and by reduction $6x(y^2+1)^2 - 7y(x^2+1)^2 = 0$. Supposing the length to be to the breadth as 4 to 1, or, as CD is made equal 1, supposing AB to be 8, we get an equation of 5 dimensions, the root of which (x) that gives the place of the greatest breadth, is 3,889 very nearly. Assuming $AB = 6$, or the length to the breadth as 3 to 1, the root of the resulting equation that gives the place of the greatest breadth is 2,911. Hence, it appears, that as far as can be collected from these principles, the greatest transverse section of a ship ought to be in the former case about $\frac{1}{72}$th of the length, and in the latter case about $\frac{1}{67}$th of the length, before the middle.

NOTE 34. In Fig. 17. EFG a plane perpendicular to the side, is supposed to turn round F till it passes through a fore and aft line EF.

It is then perpendicular to the side and also to the transverse sections; and consequently to the moulded edge of the frame passing through G. In this position GE is supposed to be drawn perpendicular to the side, and therefore to every line on the side; GH is drawn at right angles to EF. Then since EF, a fore and aft line, is perpendicular to the transverse sections, GH must be in the foremost transverse section. Consequently HF is the distance between the sections. Draw a horizontal line HK perpendicular to EF, and GK perpendicular of HK. Then GK is perpendicular to the horizon, by Euclid, B. xi. P. 11.

From this construction it is manifest, if EF represent the absolute force of a particle of the fluid, that EH will be its relative direct force, HK its relative lateral force, and KG its relative vertical force. Let now the triangle GHK be projected on the body-plan, (Fig. 18.) Then H will be projected in the line EF to a point as D; G will be projected to F; and consequently GH into DF, to which it must be equal. It follows, that HK and KG must be projected into their parallels and equals DG and GF.

In Fig. 19. $PR = HF$ (Fig. 17.) = interval between the sections; PT (Fig. 19.) = GH (Fig. 17.) or DF (Fig. 18.); consequently $RU = EF$ = absolute force of a particle. The remaining part of the construction is manifest.

Note 35. Let x be the plane of resistance; then according to the preceding notation mx = resistance on the fore part, m being the absolute force of a particle. Also mx will be the negative resistance, or diminution of pressure forward in consequence of the motion. Consequently $6mx + 7mx$ or $13mx$ = whole resistance on x; that is $13mx = 6M + 7N$, and $x = \dfrac{6M + 7N}{13m}$.

Chapman's theory of resistances to ships cannot be much depended on as leading to true results, inasmuch as he admits into it two suppositions, which have been repeatedly proved by experiment to be false;

first, that the resistance to a plane surface (the projection and velocity being given) varies as the square of the sine of the angle, which the surface makes with the line of motion; and secondly, when this angle is given, that it varies as the square of the velocity. Chapman himself discovered by experiments, made in 1794, the erroneous nature of the former of these principles, and in his account of these interesting experiments, which he printed at Stockholm in 1795, he endeavours to substitute another theory in the place of the one given here in his Architectura Mercatoria Navalis.

Without entering into this subject, in which it is difficult to draw any particular conclusions applicable to ship-building, it may be observed generally that the resistance to ships moving with the same velocity, seems to depend on the following circumstances,

First, on the area of the midship section, as causing a greater or less displacement of fluid by the motion of the ship.

Secondly, on the form of the fore body, as causing more or less additional resistance from the motion of the ship, considering only the inertia of the particles displaced; that is, supposing the void space left astern in consequence of this displacement to be instantly filled again by the fluid.

Thirdly, on the form of the after body, as causing a greater or less diminution of pressure forward, on account of the motion of the ship alone.

Fourthly, on the shape of the whole body, as affording a more or less easy and rapid transit of the displaced fluid to the stern, that is, to the void space, which otherwise would be left behind the ship for an instant.

Fifthly, on the form of the whole body, with respect to direction and the quantity of superficies, as causing more or less friction, and more or less adhesion of the fluid.

In the construction of a ship the displacement is supposed to be a given quantity. The area of the midship section may be varied to a certain degree, and still the same displacement may be retained. The less this is, the less will be the resistance, since the quantity of fluid displaced in a given time will thereby be diminished; and this section will be the least possible (supposing the length given) when the fore and after bodies are full, and every transverse section equal. But such a form on many accounts, and even from the considerations of the resistance alone, could not be adopted. The impact of the fore body against the fluid would be too direct, the motion of the after body from the fluid would also be too direct, and the fluid displaced could not flow easily to the after parts of the ship.

Supposing the length of the ship to be undetermined, in that case by increasing the length the midship section might be diminished without limit. The body might at the same time be properly formed for cleaving the fluid and also transmitting it to the stern. But then (without entering into any other considerations except the resistance) the friction would be so far increased by the extension of the body, as to retard the ship more than if it were shorter, and the midship section greater. It appears therefore that the midship section cannot be too far diminished either by filling the fore and after bodies, or by extending the whole or either of these bodies, without an increase of the resistance.

Let now the proper area of the midship section be supposed to be determined, it next becomes a question in a general point of view, how the fore and after bodies must be formed so that the ship may meet with the least resistance.

The fore body must be formed not only so as to cleave the fluid with the greatest facility, but also so as to disperse it to the right and left, and thereby facilitate its transit to the stern; at the same time it must diminish the resistance in one point of view to form the after body so that the two streams, which may be conceived to flow on the sides of the ship, may at the stern take as much as possible the same direction, namely, the one opposite to the direction in which the ship is moving. With these two views therefore the half of the ship before the middle must be filled a little more than the after part. Now this may be done two ways; either by carrying the greater transverse section before the middle, or by filling the whole fore body of the ship and keeping the greatest section in the middle. But the superiority of the former method appears from the consideration that by this means the proper effect is produced on the fore body, whilst at the same time a finer run may be given to the after body. Whence is seen the propriety of placing the greatest transverse section of a ship before the middle.

Upon the whole therefore in constructing a ship from a given displacement for fast sailing we must give a proper area to the midship section; we must carry that section something before the middle. Care must be taken to shape the fore and after bodies, the former, so that the fluid may be cloven with facility, and at the same time the displaced fluid dispersed, and transmitted toward the stern; and the latter so that the fluid so displaced may flow with as great facility and rapidity as possible to the stern. At the same time the after body must not be elongated so as to increase too much the friction.

The above general remarks are made without reference to the amount of the acting power, that is, the quantity of sail, which however it is very important to attend to in construction. Supposing a ship to be formed with a given displacement so as with a certain motive power (not producing inclination) to sail the fastest, still it does not follow that its form is the best for moving through the water by means of sails, the power of which is exerted in inclining the ship as well as in forcing it a-head. If this form were modified a little, so that a greater quantity of sail could be carried without inclining the ship too far upon a wind, the increase of which sail would more than counterbalance the addition thereby caused in the resistance, the ship would be improved by this alteration in its quality of sailing. This consideration therefore must be added to those before slightly touched on, in constructing a ship for fast sailing.

NOTES ON CHAP. V.

NOTE 36. A PART of the effort of the wind on the sails, and of that of the water on the bottom, would be employed in keeping the ship in its inclined position. *Clairbois.*

NOTE 37. Chapman here gives a true measure of the stability, but in any application of these principles to practice, where he takes DF for the height of the metacenter, there must be an error.

NOTE 38. This expression is valuable from the circumstance of its being the result of Chapman's own experience and observation on the performance of a great number of vessels. It is to be observed however that F is not, as he supposes, the metacenter, when the inclination of the ship is finite. Besides if it were the metacenter, its height above the center of gravity of the ship would not be a true measure of the stability. And therefore on account of the admission of the erroneous principle respecting the metacenter, this expression (although coming from such high authority) should be used with caution; especially in determining the proper quantity of sails for vessels differing materially as to their form from those examined or built by Chapman.

NOTES ON CHAP. VI.

NOTE 39. THIS is by no means proved; the elementary particles of the fluid would certainly take the longest way in escaping, provided they experienced in that direction the greatest facility in disengaging themselves. This appears to be the case in Figure 30, where the fluid must escape, at least a considerable part of it, along the side of the body;

having in passing below, to stem a column of fluid, whose resistance is the greater on account of its superior depth. *Clairbois.*

NOTE 40. Chapman takes in this and the following case $\int y^3\dot{x}$ for a measure of the stability; considering the displacement as the same in each case, and neglecting the constant multiplier $\frac{2}{3}$. For the whole fluent he makes, in each case, $y = B$ and $x = L$ (see Art. 16.)

NOTE 41. The plane of resistance does not increase in the same proportion as the moment of stability, as may be seen from the expressions. The divisor of the moment of stability is constant, and the variable breadth or B, is in the divisor of the expression for the plane of resistance. *Clairbois.*

NOTE 42. Let $F =$ force of the wind on the sails, $S =$ surface of the sails, $A =$ area of the plane of resistance, $R =$ resistance, $V =$ velocity. Then $R \propto V^2 \times A$, but $R = F$, and $F \propto S$; consequently $S \propto V^2 \times A$, and $V^2 \propto \frac{S}{A}$.

Let $H =$ the height of the point of the sail; then the area of the sails $\times\ H \propto$ stability, or since $H \propto S^{\frac{1}{2}}$, $S \times S^{\frac{1}{2}} \propto$ stability; consequently $S \propto (\text{stability})^{\frac{2}{3}}$.

NOTE 43. 1000 lbs. Swedish = 863,8 lbs. French; $13\frac{1}{8}$ inches Swedish = 12 inches French (pied de Roi). So that if the cubic foot of sea water weigh 63 lbs., the cubic foot French of sea water will weigh 71,17 lbs. (poids de Marc). *Clairbois.*

Chapman in his treatise on finding the area of sails for ships of the line, gives the following proportions between the Swedish and English weights and measures, 1000 lbs. Swedish = 937 lbs. English; 1000 feet Swedish = 975 feet English; 1000 square feet Swedish = 950,62 square feet English; 1000 cubic feet Swedish = 926,86 cubic feet English.

Whence $\frac{937 \times 63}{926,86} = 63,69 =$ weight of an English foot of sea water in pounds Avoirdupois.

We may add to the above that taking a mean of the specific gravities of sea water found by different persons, the weight of a cubic foot English is very nearly 64lbs., so that 35 cubic feet weigh almost exactly one ton. This number will be found very convenient in calculation.

NOTE 44. $18200 = 4,2600714$; by this we are to understand that 18200 is the number, whose logarithm is 4,2600714; and so of the rest. $P^{\frac{2}{2}\frac{2}{1}} = 29035$, and not 29350. *Clairbois.*

NOTE 45. $DF = b$; then the distance of the center of gravity of DAF from $DF = \frac{\int x \,.\, (b-y) \,.\, \dot{x}}{\text{area}} = \frac{\int x \,.\, \left(b - \frac{x^2}{p}\right) . \,\dot{x}}{\text{area}} = \frac{\frac{b x^2}{2} - \frac{x^2}{p} \times \frac{x^2}{4}}{\text{area}} =$ (when $x = FA$) $\frac{\frac{DF \times AF^2}{2} - \frac{DF \times AF^2}{4}}{\frac{2}{3} DF \times AF} = \frac{3}{8} AF$. Consequently the distance of the center of gravity of ADI from $A = \frac{5}{8} AF$.

NOTES ON CHAP. VII.

NOTE 46. IN order that $\frac{2}{3}\int y^3 \dot{x} - (m+a) \,.\, B - (m+c) \,.\, Q$ may be a proper expression for the moment of stability, it is necessary that all the weights below the load water-line, namely, the wood work of the bottom and the contents of the hold, as far as the level of the water, should have their center of gravity in the same place with that of the displacement; now it is lower for those weights, which altogether may be expressed by $D - (B + Q)$. Let the center of gravity of these weights be lower than that of the displacement by a quantity $= \delta$; then the expression for the moment of stability should be $\frac{2}{3}\int y^3 \dot{x} + \delta \times (D - B + Q) - (m + a) . B - (m + c) . Q$; where m varies with δ. In causing the center of gravity of the displacement to descend, that is, in making m greater, there is an advantage, because δ will increase in a greater proportion. *Clairbois.*

The expression given by Chapman as corrected by Clairbois, is not a proper measure of the stability except in very small inclinations of the ship. In finite inclinations it is necessary to take into the account the alterations, which are made in the sides of the ship between wind and water; whence it will appear that Chapman's conclusion, in one point of view is right, although his expression is erroneous (See Note 1.).

NOTE 47. There is here a small error in the calculation: log. $6D =$ 5,2426159 = log. 174830, and not 5,2426408; hence, the moment of the sails is only 1202346. *Clairbois.*

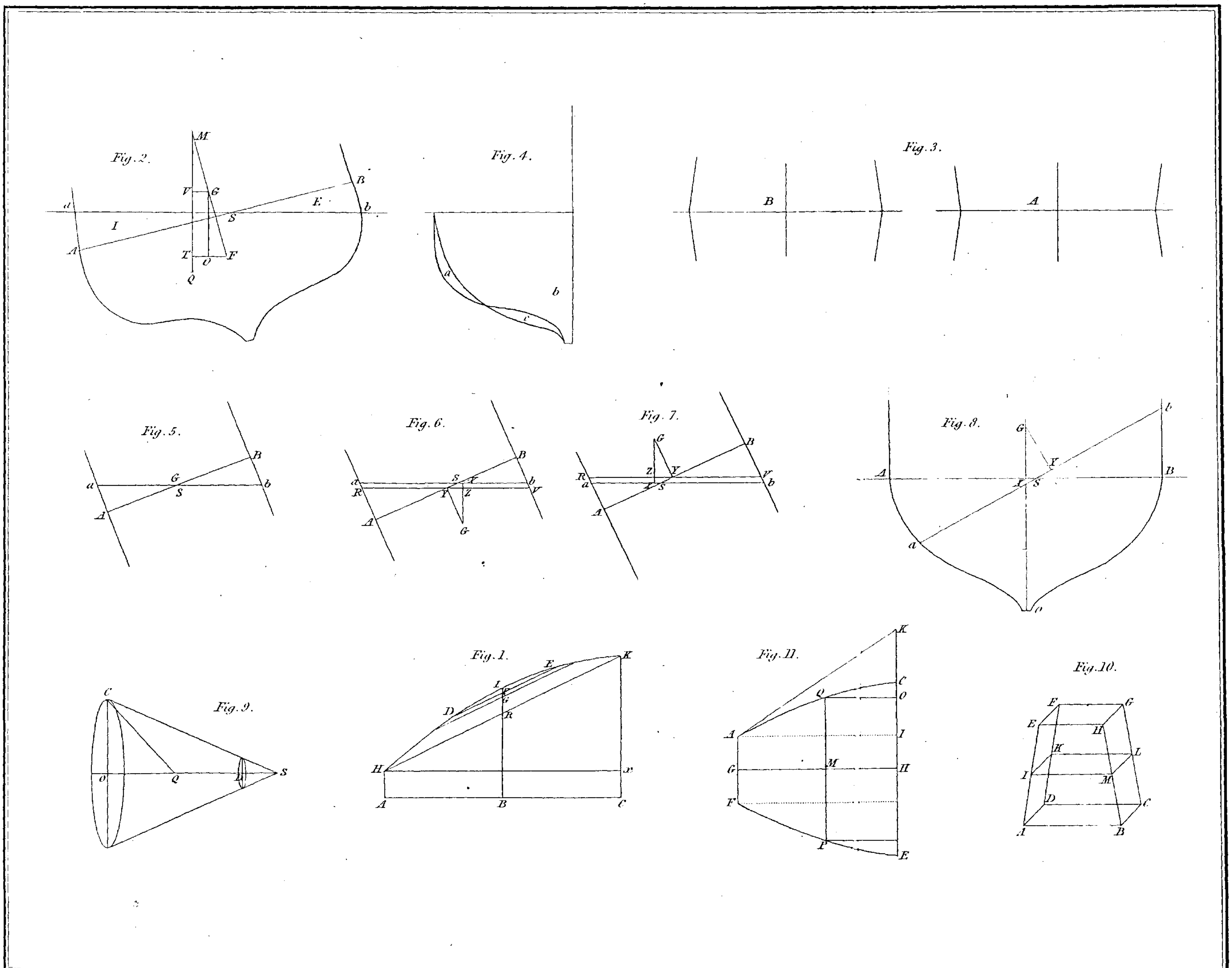
NOTES ON CHAP. IX.

NOTE 48. THE greater scantling a ship has, the more strongly it is bound together, and the more it feels as a solid body, the whole effect of a shock in an instant; the more powerfully does the sea, which strikes it incessantly on the prow (particularly when close to the wind) impede its way. Seamen who cut the gunwale and adopt other ways of loosening the ship, when they are chased and on the point of being taken, do not therefore, in my opinion, act so absurdly as a certain celebrated geometer imagines. Shrouds and stays which are too taught, produce the same effect in lessening the elasticity of the whole vessel, and it is perhaps to this cause we may attribute the difference of sailing which is sometimes noticed in the same ship; this effect may be felt, although the rigging has not been touched, when it has been set up in dry weather. In damp and rainy weather it soon becomes inflexible as a bar of iron; no bad consequences would be produced, on an urgent occasion, by giving the rigging a little slack." *Clairbois.*

NOTE 49. $AB = a$ (Pl. A. Fig. 10.), $AD = b$, $EH = c$, $EF = d$, h = perpendicular height of the solid, let x = distance of IL, any section thereof parallel to the base, from the plane EG. It is evident from the nature of the figure, that the section IL is a rectangle, and that $h : x :: AB - EH : IM - EH :: AD - EF : IK - EF$; from these proportions we have $IM - EH = \frac{a-c}{h} \times x$ and $IK - EF = \frac{b-d}{h} . x$; hence $IM = \frac{a-c}{h} \times x + c$, $IK = \frac{b-d}{h} \times x + d$; and consequently the area of the rectangle $IL = \frac{(a-c).(b-d)}{h^2} \times x^2 + \frac{ad - 2cd + cb}{h} \times x + cd$, which being multiplied by $\dot{x}$, and the fluent taken, there results $\frac{(a-c).(b-d)}{3h^2} \times x^3 + \frac{ad - 2cd + cb}{2h} \times x^2 + cdx$ for the content $IFGL$; which, when $x = h$, becomes $\frac{(a-c).(b-d) \times h}{3} + \frac{ad - 2cd + cb}{2} \times h + cdh = (2ab + ad + bc + 2cd) \times \frac{1}{6}h = \big(AB \times AD + EH \times EF + (AB + EH) \times (AD + EF)\big) \times \frac{1}{6}h$ (Simpson's Fluxions, Art. 154.).

NOTE 50. $GH = a$ (Pl. A. Fig. 11.) $CE = b$, $AF = c$, $OQ = HM = x$, $CO = x^{\frac{m}{n}}$, $PQ = 2MQ = 2HO = 2HC - 2CO = EC - 2CO = b - 2x^{\frac{m}{n}}$, $p = ,7854$ &c. $= \frac{11}{14}$. Then $p . PQ^2 . \dot{x}$ = fluxion of solid ($\dot{s}$) $= p\dot{x} . (b^2 + 4x^{\frac{2m}{n}} - 4bx^{\frac{m}{n}}) = p . (b^2\dot{x} + 4x^{\frac{2m}{n}}\dot{x} - 4bx^{\frac{m}{n}}\dot{x})$, & $s = p . \left(b^2x + \frac{4x^{\frac{2m}{n}} . x}{\frac{2m}{n} + 1} - \frac{4bx^{\frac{m}{n}} . x}{\frac{m}{n} + 1}\right)$ $= p . \left(b^2 . OQ + \frac{4n . CO^2 . OQ}{2m + n} - \frac{4nb . CO . OQ}{m + n}\right)$. For the whole solid $CO = CI = \frac{CE - AF}{2} = \frac{b - c}{2}$, and $OQ = HG = a$; consequently

Pl. A.



Lowry Sc.

$$s = p \cdot \left(b^2 a + \frac{4n \cdot \left(\frac{b-c}{2}\right)^2 \cdot a}{2m+n} - \frac{2n \cdot (b^2 - bc) \cdot a}{m+n}\right) = \text{by reduction}$$

$$pa \cdot \frac{(m+n) \cdot nc^2 + 2mnbc + 2m^2 b^2}{(m+n) \cdot n + 2mn + 2m^2}.$$

Note 51. Let $IC = x$, $IA = y$. Then the subtangent $IK = \frac{y\dot{x}}{\dot{y}}$. But since $IK : IC :: m : n$, $\frac{y\dot{x}}{\dot{y}} : x :: m : n$, and $\frac{n\dot{x}}{x} = \frac{m\dot{y}}{y}$; consequently n hyp. log. $x = m$ hyp. log. y, or $x^n = y^m$; that is, $CI^n = AI^m$ as in Art. 165.

Here Chapman supposes IC or x to be equal to n; and by adding CK thereto he gets IK or $\frac{y\dot{x}}{\dot{y}}$, which in that case must be equal to m.

Note 52. These water-lines, having no farther object than to give the moulds of the transoms, and the bevellings of the cant frames, are drawn in a plane parallel to the keel. *Clairbois.*

Note 53. See the work *Architectura Navalis*, Plate IV. No. 4. The use of this scale is so simple, that we have not thought it necessary to add a draught of a ship to our work, in order to render it more intelligible. *Clairbois.*

NOTES on CHAP. X.

Note 54. There is in this place a very elegant theory upon the alteration of the forces, with respect to the variable quantities of the leeway and inclination. But since, although very long, it requires considerable additions, and besides only leads to principles more abstruse and operations more tedious, than the construction of lines on the ship in its inclined position and oblique course. I have omitted this theory, and given only the second method. *Clairbois.*

NOTE 55. That part of the body is projected from forward, which can be seen by an eye placed in the line of lee-way, supposed at the same time to be at an infinite distance. A line is drawn across the body plan to represent the load water-line when the ship is inclined, making the angle of heeling with the upright load water-line. Parallel to this several other inclined water-lines are drawn.

Secondly, these lines are delineated according to their true form, on a horizontal plane, by taking the distance of the different sections on them from the middle line in the body plan, and setting these distances off from a line drawn to represent the middle longitudinal line.

Thirdly, any line is drawn lengthways through the last mentioned figure in the direction of the lee-way, and then lines are drawn at equal intervals perpendicular to this, which will represent on the horizontal plan new vertical sections of the body perpendicular to the plane of lee-way.

Lastly, a line *Cc* (Fig. 46.) representing this plane of lee-way is drawn and the distances on the horizontal plan transferred and set off from *Cc* to *a*, &c. on a line drawn to the inclination of the new water-lines on the body plan to the middle line; and thus the sections *a, b*, &c. are run off.

NOTE 56. It is convenient in making the body-plan at first to observe the difference of draught of water at each section, in order that the water-lines on the plan may be straight lines. *Clairbois.*

NOTE 57. The line *AA*, which is the axis of the moments of the lateral effects, neither is nor can be represented except in Fig. 40. *Clairbois.*

NOTE 58. When the wind is aft, since the ship goes in the same direction as the wind, the velocity of the current of air is diminished on board by the whole velocity of the ship: when the wind is a-beam, the velocity of the current suffers no other diminution on board than that of the ship sideways, which may be represented by the sine of the angle of lee-way.

Hence it is manifest that the wind has greater force, when its direction is perpendicular to the great axis of the ship, than when it is in the same line with it. *Clairbois.*

NOTES ON CHAP. XI.

NOTE 59. ONE is often obliged to use methods similar to this, when the hold is too much lumbered to admit of those dimensions being taken, which are necessary in order to obtain a more exact tonnage.

Our practice, in this case, is to take the length from the outside of the stem to that of the stern-post, the main breadth to the outside of the wales, the depth in hold from the midship beam to the keel, which may be always taken at the pump; to multiply these three dimensions together, and divide the product by 100; the quotient is the burthen in tons of 2000 lbs., or of 42 cubic feet of articles, which would bring down the ship to its load water-line, if the space designed for the cargo was filled with them.

Let us see how far this method agrees with Mr. Chapman's. Let ax = the length in the inside in Swedish feet, of which $13\frac{1}{8}$ inches make 12 inches (pieds de Roi); bx = the breadth within the ceiling; x = the depth in hold from the upper deck to the ceiling; z = the quantity to be subtracted; $\left(\frac{5}{6} \times \frac{abx^3}{200} - z\right) \times 5760$ = the burthen in Swedish pounds $= \left(\frac{5}{6} \times \frac{abx^3}{200} - z\right) \times 4975$ in pounds (poids de Marc).

We take the same dimensions, but to the outside of the ship. Supposing the difference of the principal dimensions inside and those outside to be $= \frac{1}{10}$ of the inside dimensions $= \frac{1}{10}x$, we shall have the excess of the exterior parallelopiped above the interior one abx^3 by this proportion, $x : abx^3 :: \frac{3}{10}x : \frac{3}{10}abx^3$ (Essay on *Naval Architecture*, p. 153. l. 15.).

The product of our three dimensions therefore would be $abx^3 + \frac{3}{10}abx^3 = \frac{13}{10}abx^3$ in Swedish feet, and in pieds de Roi, $\frac{13}{10}ab \times \frac{12}{13\frac{1}{8}}x \times \frac{12}{13\frac{1}{8}}x \times \frac{12}{13\frac{1}{8}}x = \frac{13}{10}ab \times \frac{1728}{2261}x^3$. This quantity must be divided by 100 and multiplied by 2000, to reduce it to pounds (poids de Marc), or it must be multiplied at once by 20; $\frac{13}{10}ab \times \frac{1728}{2261}x^3 \times 20 = \frac{44928}{2261}abx^3$; whence we have the equation $\frac{44928}{2261} \times abx^3 = \left(\frac{5}{6} \times \frac{abx^3}{200} - z\right) \times 4975$; hence $z = \left(\frac{24875}{1200} - \frac{44928}{2261}\right) \times \frac{abx^3}{4975} = (20.7 - 19.9) \times \frac{abx^3}{4975} = 0{,}8 \times \frac{abx^3}{4975} = \frac{4}{5} \times \frac{abx^3}{4975} = \frac{4}{24875} \times abx^3 = \frac{1}{6219}abx^3$.

The quantity therefore to subtract from the result of the Swedish method of measuring for tonnage, to make it agree with ours, would be exceedingly small. But we must consider that the parallelopiped, which we deduce from that given by the Swedish method, is greater than it would be found by taking the dimensions in the ship; because the shape of the inside of the ship is not exactly similar to that of the outside, as we have observed (Essay on *Naval Architecture*, p. 166. l. 7.). Also in the measurement of our ships for tonnage, which have a poop and forecastle, it is only in a particular construction, that we add or subtract any thing; with respect to those without a poop and forecastle, we subtract between a sixth and a twelfth, for cabins, and store-rooms, &c.

The circumstance of our method's agreeing so perfectly with the Swedish method is a reason for placing a greater confidence in it, when we cannot do better. *Clairbois.*

A ship which has a foot more depth in hold, may be brought down in the water a foot more, and sail with equal safety. *Clairbois.*

Note 60. One cannot exceed certain limits in this respect. What advantage would there be in having at a low price a ship, which would be worth nothing at all. *Clairbois.*

NOTE 61. *The weight of the whole.* It is apparently the weight of the ship with its furniture, equipment, provisions, and crew; for a bark of 200 lasts, the said lading weighing as much as 18200 cubic feet of sea-water, displaces 29035 feet (111) to the outside of the timbers, and about 30435 feet to the outside of the plank. If nothing farther were here meant than the weight of the furniture, equipment, provisions, and crew, these things would weigh $\frac{18200}{1,98} = 9191$; whence the lading and furniture $= 18200 + 9191 = 27391$; this quantity being subtracted from the displacement 30433, there would only remain for the weight of the shell 3042, or less than a tenth of the displacement. But if it is the weight of the ship equipped, the lading only being excepted, that Mr. Chapman means by the *weight of the whole,* still the divisor 1,98 will not answer; it would be necessary to divide the lading by 1,5; that is, supposing the weight of the ship $= \frac{18200}{1,5} = \frac{2}{3} . 18200 = 12133\frac{1}{3}$, then $12133 + 18200 = 30333$, the quantity of displacement; where it is proper to observe that the weight of the ship equipped is $\frac{2}{3}$ of the lading or $\frac{2}{5}$ of the displacement; which may be the case with ships, that have none or few guns, and are not of a very large scantling. *Clairbois.*

NOTE 62. This, I believe, is the best method for measuring a ship's tonnage, whose hold is clear, in tons of 42 cubic feet; considering that if the parts therein neglected are against the freighter, as I have already observed, the divisor is greatly to its advantage. But since it is proper that all the space should be paid for, even when from the nature of the cargo it is necessary to put on board ballast, the breadths must therefore be taken, on the level of the upper side of the kelson.

To shorten the calculation, having the nine breadths at equal intervals both with regard to length and depth, take one-fourth of the extreme breadths, and half the middle one in the after and fore planes; take half the extreme breadths, and the whole breadth at the middle in the intermediate plane. Add the quantities together and multiply the sum by the product of the distances between the measurements with regard to length and height. Let a, b, c, be the three breadths at the mizen mast, A, B, C, those taken at the middle; and α, β, γ, those near the foremast, p half the depth in the hold from the beams to the kelson, or the distance between the ordinates in depth; L half the distance between the extreme measurements, or the distance of the extreme measurements from the middle one; the solid content of the part of the bottom will be $\left(\frac{1}{4}a + \frac{1}{2}b + \frac{1}{4}c + \frac{1}{2}A + B + \frac{1}{2}C + \frac{1}{4}\alpha + \frac{1}{2}\beta + \frac{1}{4}\gamma\right) p \times L$. *Clairbois.*

EXAMPLE OF CONSTRUCTION

REFERRED TO IN THE NOTES.

In the course of the preceding Notes, several references have been made to an example of construction at the end. The following brief remarks on construction of ships of war, may serve for an introductory explanation to it.

DISPLACEMENT.

(1.) Before a construction can be made, it is necessary to determine very exactly the displacement; that is, the number of cubic feet of sea-water, which the body of the vessel, when equipped, will displace, or the weight of these in tons. The constructor knows the number of guns and men the vessel is to carry; hence he forms a rough design of the principal dimensions, and then computes the weight of some known ship, whose dimensions are nearly the same, and built of the same kind of wood; adding or subtracting what he judges the vessel in preparation may weigh more or less. The weight of a vessel of nearly equal principal dimensions is known from the draught of water noted at the launching.

To this he adds the weight of every thing to be put on board, in guns, rigging, provisioning, &c. The result is the displacement required in tons.

It may be observed, generally, that it is advantageous to give the projected ship the requisite stability with as little ballast as possible, by which means a constructor is enabled to reduce the displacement or magnitude of the body under water, a circumstance very favourable to a ship in sailing and working. With a similar view every weight put on board, and reckoned in getting the displacement, should be kept as low as possible. No useless baggage or weights of any kind should be put on board on any account whatever.

LENGTH.

(2.) The displacement of a ship being known, the constructor finds it convenient in the next place to determine more precisely the length, breadth, and draught of water. In doing this, he must be guided by similar ships of the same force that have been found to answer well at sea, and by his own information derived from observation, enquiry, and scientific principles. If he increases the length, supposing a given number of guns to be placed in one battery, he must increase something the spaces between the ports, which however if possible should be avoided as giving useless space. In some instances a port may be added on a side, care being taken at the same time to make a judicious formation of the body in other respects, so as to preserve the displacement, the stability, and a sufficient draught of water.

It may be remarked in speaking on this subject, that the ship which in the least space carries the greatest force (supposed in every respect effective), and has at least equal properties with others in sailing and working, is always to be preferred. Indeed this is to be considered as an object on which the attention of a naval architect, who has to propose constructions, must be especially fixed.

(3.) Some caution is necessary in determining the length on the following accounts. Every alteration in the length renders an alteration also necessary in the other principal dimensions, namely, the breadth and draught of water. We have therefore not only to consider what effects the change in the length produces of itself, but also what consequences will follow from the variation in the breadth and draught of water that are thereby rendered necessary. Again, too long a ship is greatly impeded by the increased friction of the fluid, and on that account sails badly, especially before the wind. It tacks and wears ill, from the resistance on its extremities, thus placed at too considerable a distance from the axis of rotation. On the other hand, in too short a ship the resistance to its sailing would be increased by the suddenness of its curvature at the extremities. It would work badly and steer loosely, from the facility with which it would yield to the impulse of waves striking its head and stern, in preventing or producing rotatory motion.

Such considerations will be borne in mind in determining the length.

BREADTH.

(4.) The breadth of a ship of a given force is contained within much smaller limits than the length. The smallest variation in this dimension, should not be made without the greatest caution and study.

The object of the constructor will of course be to give sufficient stability, and no more. If the breadth be too little, the vessel will incline too far from the lateral force of the wind, and from the stroke of a wave; if too great, it will not incline far enough, that is, it will be stopt so suddenly, that the shocks will be dangerous to its safety.

Nothing can enable a constructor to give the most advantageous breadth, but a careful observation of the performance of other ships, and a thorough knowledge of the principles on which stability depends. But the stability though greatly governed by the breadth, does not entirely depend thereon. The form of the vessel throughout between wind and water, is to be taken into the account, before the breadth can be finally determined. A straight of breadth extending as far as possible fore and aft, and above and below the load water-line, is no doubt the most advantageous to the stability at any finite angle of heeling. And if this form should be fixed upon, the breadth might in consequence be something reduced. But again, another consideration intervenes, which is the regulation of the stability as to its gradual increase in heeling to different angles. The vessel should be sufficiently stiff at a small angle, and afterwards its resistance to farther inclination should neither increase too slowly nor too rapidly. Whether this adjustment, so necessary to the good performance of a ship at sea, may be effected by a slight reduction of the breadth, and an extensive straight fore and aft, and above and below the load water-line, or by a breadth something greater, and a curved side throughout, or by a combination of both, the constructor has to weigh well before he fixes the dimension in question.

In varying the breadth from these or any other considerations, it is necessary in the last place to attend to the changes thereby caused in the other dimensions.

DRAUGHT OF WATER AT HEAD AND STERN.

(5.) A ship with too great a draught of water will sail badly, on account of the great pressure of the fluid on the lower parts of the bottom; one with too little will sail badly, especially on a wind, on account of the great impeding effect of the waves, which move on the surface of the sea, and reach probably as far down as the vessel has depth; besides for a similar reason it will tack and wear with difficulty and uncertainty, since in going about, the waves, in which such a vessel may be supposed to be totally immersed, must strike the extremities with full effect.

The constructor in this, must be guided by what has been done and experienced before, and by his own ideas on the subject. He must recollect also that any great alteration in this dimension may involve others in the length and breadth.

(6.) It is usual to give a ship greater depth in the water at the stern than the head. By this means a finer run is got aft, and the rudder is plunged more deeply into the fluid. The former quality is favourable to sailing, and both are advantageous in giving the rudder effect in tacking and wearing. By this means also the body of the vessel, in sailing, presents a surface inclined upwards to the waves, that constantly meet it when upon a wind; it is thus something lifted over the waves, and passes on more easily and securely. Besides in ships of the common form this lowering of the body at the stern is found necessary to bring the mean resistance of the fluid far enough aft to balance the effort of the wind on the sails, when the ship is by the wind. And the more the body, independently of this deeper part aft, is formed to carry the mean resistance forward, the greater ought to be the difference of the draught of water fore and aft. Lastly, a particular mode of rigging, renders an alteration to this point of construction the more necessary.

In some kinds of rigging, the point of sail is farther aft than in others; in such a case the draught of water ought to be increased at the stern, in order that the force of the wind on the sails, and the resistance on the bottom, may be directly opposed to each other. In some, the point of sail is farther forward than usual; in such cases a less draught of water aft may be given.

STEM AND STERN-POST.

(7.) The constructor may possibly next consider the form of the stem and stern-post. The former should neither be too raking nor too vertical in its position. If it rakes too much, the ship will probably want length of keel for holding a wind, the weights in the fore extremity will overhang greatly, and the waves in striking so considerable a part forward not deeply enough immersed, will constantly drive the ship from its course, and also render tacking difficult. On the other hand if the stem be too upright, the waves will not have sufficient effect in lifting up the fore part of the vessel, supposing the fore body not to vary much from the usual shape, and the part towards the keel forward by its depth and distance from the axis of rotation, will cause too great a resistance to the ship in going about.

It may be advisable, in general, to give as full a sweep as possible to the stem, where it is joined to the keel, and as much rake as possible above; thus endeavouring, as far as other circumstances allow, to secure the advantages of both forms, and to avoid the disadvantages of either alone.

It may be remarked, lastly, that a round stem tends to diminish the positive resistance.

(8.) It is usual also to give the stern-post a rake or inclination aft to the load water-line, by which the after surface of the ship is presented somewhat obliquely to the fluid, and the negative resistance is diminished. A rake in the stern-post also enables the constructor to sink the keel deeper at the stern, by which the ship has more hold of the water, a more direct and easy run is got to the rudder, while at the same time the resistance to rotation is diminished. If carried vertically down to the same depth, the rudder might be made to act with equal effect, but in that case the resistance to rotation would be increased.

PLACE OF THE MID-SHIP BEND, OR GREATEST TRANSVERSE SECTION.

(9.) The situation and form of the greatest transverse section must next be determined on. It is usually placed between a twentieth and a fifteenth before the middle of the length between the perpendiculars. The exact distance depends on the ideas of the constructor, derived from observation and theory. The advantage of so placing it, arises in a general point of view, from the following considerations.

When the body of a ship is impelled through a fluid, the fore part should be so shaped as not only to cleave the fluid, but also to disperse it, as much as possible, to the right and left. The after body should at the same time be so shaped as to transmit the displaced fluid with the greatest facility and dispatch to the stern. It is on these two accounts that bodies moving with considerable velocity, the propelling force being given, have greater velocity with the obtuse end than with the acute end foremost. Now by carrying the greatest transverse section something before the middle, the fore body becomes naturally fuller than the after body, while at the same time a finer run may by that means be given towards the stern; which is favourable both to sailing and also to the effect of the rudder.

Care must be taken, however, not to carry this to excess, as several bad effects would arise from so doing; the principal of which would be these. By having too full a fore body, the ship would require great weights forward to bring it to its proper seat in the water; it would thus become laboursome. Secondly, the center of gravity and consequently the axis of rotation, would be too far from the middle. Thirdly, the mean resistance of the fluid would be carried too far aft, on account of the roundness of the body forward and its leanness and flatness behind. And fourthly, the positive resistance forward would be too much increased.

PREPARATION OF SOME OF THE PRINCIPAL LINES IN THE DRAUGHT.

(10.) Before the constructor proceeds farther, it may be proper to draw the few lines he has fixed on in pencil, and to prepare the paper for the insertion of the other parts of the draught.

Draw a straight line for the length of the load water-line from the after edge of the stern-post rabbet to the fore side of the stem rabbet. At the extremities square up and down perpendiculars to this line; upon which take the draught of water head and stern, and draw a line for the bottom of the false keel. Set up square to this line the thickness of the false keel, and next of the keel itself as far as the lower edge of the rabbet; and draw another line parallel to the former. Upon this line the exterior surface of the planking ends, and therefore all the transverse sections.

Continue the lower edge of the rabbet of the keel into the fore edge of the rabbet of the stem, which last carry to the top. Draw a line for the after edge of the rabbet of the stern-post, and another before this for the fore edge. At the main section in the load water-line set up the height of the port sill, and below this again the depression of the deck. A little above this at the distance of the round up, draw with a sweep the deck at the middle, and then the deck at the side. Set up, and draw in a similar manner the upper decks, the top timber line, and the top side line. From the after extremity of the load water-line, set up the height of the upper and after edge of the wing transom at the middle. In line of battle ships this height is governed by, and usually the same as, the height of the port sills above the deck; in other ships, in setting it up, care must be taken to have at least sufficient room between the transom and the upper deck, for the tiller to work over the head of the stern-post, clear of the lower side of the beams. Having thus taken the height of the wing transom, its touch on the fore side of the rabbet of the stern-post will be on the same level. Knowing the round down and round forward of the wing transom, draw the projection of its upper and after edge from the said touch to the side, and below the under edge of the tuck rail, or margin, on which the diagonal lines and buttock lines end. Draw the middle and side lines of the counter timbers for the upper and lower counters; taking care to keep the upper counter of such a height, that the space above it to the lower side of the deck transom may give a well proportioned light. End the decks, &c. on the proper lines at the stern. Draw the outline of the stern-post, and rudder; and lastly, draw the foreside of the stem, knee of the head, and gripe, the last of which is brought into the lower side of the false keel. These lines will be sufficient at present for the sheer draught.

(11.) At a convenient distance below the lowest line in the sheer draught, draw a straight line parallel to the load water-line, between the extreme perpendiculars, to represent the middle line of the half-breadth plan. At the distance determined on before the middle point of the load water-line on the sheer draught, square down a perpendicular to this middle line, and set off upon it from the middle line the half-breadth at the water's surface.

(12.) Produce the load water-line in the sheer plan to the left, and upon it so produced assume a point at a convenient distance, on each side of which take the half-breadth at the load water-line to the outside of the planking. Square up and down perpendiculars to the main breadth so taken, one at each extremity; and one at the middle point, for the middle line of the half body plan.

Take the half siding of the stem at different heights, and to the right of the middle line draw in a line representing this. In a similar manner to the left draw the half siding of the stern-post.

(13.) From the body plan take the half siding of the stem and stern-post at different heights, and squaring down lines from the corresponding points in the sheer plan, set these sidings above the middle line of the half-breadth plan, and draw in lightly lines through the points so found, one of which will represent the side of the stem at the fore edge of the rabbet, and the other the side of the stern-post, at the after edge of the rabbet.

FORM OF THE MID-SHIP BEND, OR MAIN TRANSVERSE SECTION.

(14.) Having drawn the lines described above, the next thing is to sketch in the main transverse section on the body plan, of which we have given the ending on the lower edge of the rabbet of the keel, and the breadth at the load water-line. The following may be considered as the general considerations, which determine its figure.

It should be formed so as under the least area to give the proper displacement, due regard being had at the same time to the sailing and working of the vessel, and also to the regulation of the stability at different angles of heeling. It is of consequence too, as this section has great influence on the whole, to give it that shape, which will produce a body best calculated for making lateral resistance, a vessel being thereby enabled to hold a better wind.

Undoubtedly a large straight of breadth, that is, a considerable vertical space near the load water-line, seems to combine two of these advantages, in giving stability and causing lateral resistance. Some constructors carry this straight below and above the load water-line, some carry it only upwards from the load water-line. But there are few vessels entirely without it. It has been before remarked that this straight gives stability by preserving the breadth between wind and water, and by affording a long flat side near the water, it prevents the ship from making too much lee-way, when by the wind*. It is likewise consistent with beauty and convenience both in the upper works, and in the bottom.

(15.) There is a farther reason for continuing the straight of breadth below the load water-line. A greater portion of the section is thereby given near the surface of the water, and this being extended round the broadest part of the ship, a greater solidity is produced, than if the same area was placed lower down. The conclusion is, that the same displacement is thereby given under a less main transverse section.

When the straight of breadth is drawn, it is farther necessary to describe that part of the section which lies below it towards the keel, and the part which lies above towards the top-side. The line below, if the straight be continued much downwards, in many cases, will be little more than a straight line united to it by a circular arc. If the straight be

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* Perhaps this straight might with advantage be inclined inward 5° or 6°, beginning something below the water. A ship so formed, when upon a wind, would in heeling bring this flat part into a vertical position, and it would then oppose the greatest resistance to lateral motion.

continued but a short way downwards from the load water-line, the remainder of the main transverse section to the keel will be more curved outward.

Above the straight of breadth the object of the constructor will be to throw the side gradually in. The more the sides of a large ship fall in, preserving at the same time a handsome curvature upwards and lengthways, the more safe will be its vibrations in a rough sea. Care however must be taken not to carry this to excess, as injurious to the accommodations, and giving too little room on the upper decks.

But there is an infinite number of ways in which the main transverse section is drawn, according to the taste and skill of the constructor, and also according to the class of the ship. To enter into so extensive a subject would not be consistent with the object of this brief outline.

In books on Naval Architecture several geometrical methods are given of delineating the main transverse section, but it is impossible to notice them here. Indeed it may be questioned how far such methods are consistent with that freedom, with which a constructor should be enabled to draw, and if necessary to alter and retouch the different curves in a draught.

(16.) The constructor having sketched the main transverse section according to his own ideas, next measures the number of feet in it. This is done by drawing an odd number of ordinates at the distance of 1, 2, 3, &c. feet*, parallel to the load water-line, and proceeding according to one of the rules in Note 3; taking care to assume a different abscissa when the curvature changes fast. *An example of this calculation is given* in the construction at the end.

* In these measurements it is convenient, if possible, to assume the distance of the ordinates such, that if the former rule be applied, $\frac{1}{3}$ of that distance in feet may be a whole number, and if the second rule be used, $\frac{3}{8}$ of it may be so. The number of ordinates in the first case must be odd, in the second they must amount to a number one greater than some multiple of 3.

Alterations are made if necessary in the main transverse section, and the same form of calculation repeated, till the area appears to be the number of feet fixed on, which is known by the reference to similar ships, being taken something more or less, according to the ideas of the constructor.

LOAD WATER-LINE.

(17.) When the half main transverse section is drawn to the satisfaction of the constructor, the other half exactly similar to the first, is drawn on the other side of the middle line*.

The next thing is to draw the load water-line. The half extreme breadth is set off in the half breadth plan at the place of the main transverse section; through its extremity a curve is sketched and then drawn more exactly by means of a batten, to the points where the extreme perpendiculars from the sheer plan cuts the sides of the stem and stern-post on the half-breadth plan. This curve running horizontally along the middle of the ship must, as is evident, have a great influence on the shape and properties of the vessel. It is usual therefore to take great pains in drawing it.

The center of gravity of the load water-line is carried before the middle something less in general than the distance, it is intended to carry the center of gravity of the displacement, and that of the ship. And its greatest breadth is placed, as we have before said, four or five times the distance of the center of gravity of displacement before the middle. From this greatest breadth it is advantageous, in two or three points of view, to carry the curve as nearly parallel to the middle line as circumstances allow of. By this means a longer flat side, lengthways, is given

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* In speaking of the different curves used in the construction of ships, we are to understand half of the whole curve for both sides of the ship, that is, the curve for one side only.

to the ship, and an equal stability is produced under a less breadth and less main section. A straight load water-line therefore tends to make the ship resist more powerfully lateral motion; and also to reduce the resistance, provided the extremities are not rendered too obtuse.

There is another advantage arising from such a form. From the great area thus given to it, it follows that any increase or diminution of weights put into the ship affects in a less degree the draught of water, and therefore the sailing properties of the vessel.

(18.) The load water-line being drawn, its area is measured by either of the rules given in Note 3. For this purpose equal distances of a few feet as 3 or 6 (see Note, p. 284.) are taken both ways from the main section, to within a short distance of the extremities. Ordinates are then drawn perpendicular to the middle line, which ordinates may be continued upwards in the sheer plan to the load water-line. These ordinates are then measured by a quarter inch decimal scale, and being arranged according to the rule made use of, we thus get the area of what may be called the middle space. To get the areas of the extreme spaces, where the curvature is more irregular, ordinates are drawn at a less interval as 1, 2, 3, &c. feet, the extreme ordinate being in one case the siding of the stem, and in the other that of the stern-post. The measurement in other respects is made in the same manner as before. The two extreme spaces, and the horizontal sections of the stern-post and rudder aft, and of the stem and knee of the head forward, being added to the middle space, we have the area of the whole water-line.

(19.) Afterwards the center of gravity of the same curve is computed as follows. Multiply each ordinate in the middle space by its distance* from its aftermost ordinate. Arrange the products according

* The interval between two ordinates may be considered as an unit, the resulting moment being multiplied by the true interval.

to the rule made use of, and proceed as in the rule Note 8; the result will be the moment of the middle space. The moments of the small extreme spaces reckoned from the same line are found in a similar manner, those of the sections of the stern-post, &c. are estimated nearly. The moments before the line being added, and those behind it subtracted, we have the moment of the whole load water-line. The quotient of this divided by the area of the curve is the distance of its center of gravity from the after perpendicular.

If the area, or the situation of the center of gravity with respect to length, be not such as the constructor wishes, he makes alterations in the load water-line till it is.

The main transverse section and the load water-line are now supposed to be drawn with great exactness, the former on the body plan, the latter on the half breadth plan. We proceed to explain briefly the other parts of the construction.

BOW AND QUARTER SECTIONS.

(20.) The constructor will find it convenient in the next place to fix on a transverse section on the bow and another on the quarter of the ship, at the points where the body is curved in rapidly to its extremities. These sections together with the main one already drawn in, will determine in a great measure the shape of the whole body. The sketching of these, so as to produce such a form as is wished, requires considerable experience in construction. A point in each is known on the load water-line; their curvature downward and upward may be varied greatly according to the idea of the constructor with regard to leanness or fulness fore and aft; still however depending in some measure on the form of the main transverse section.

One principal object must be kept in view in drawing them, namely, to give such a form to the ship, that in heeling it may revolve round a line parallel to the axis of the load water-line. That is, care must be taken, as far as it can be done in giving the first delineation of these sections, that the centers of gravity of the immersion and emersion * (see Note 26.) may be at the same distance from the stern, in other words, that these points may be in the same transverse section. If the quarter section be full above the water, the bow section must be so too, and the curvature under the water must be regulated in a similar manner.

(21.) Having drawn these two extreme sections, in addition to the main one, it will be found advantageous to run off, on the sheer plan, the height of breadth line, both the lower and the upper, if there are both. Then run off on the half-breadth plan, one or two inferior water-lines, the top side, and top timber lines; and as many level lines, or superior water-lines, as may be necessary for finding the half-breadth of the wing transom; for drawing the margin both on the half-breadth and body plan, with the side counter timber on the latter.

After this two other transverse sections may be drawn on the body plan, one half way (as taken on the sheer plan) between the main section and each extreme section. These must be delineated from the spots determined by the water-lines, main breadth, &c.

From the body as far as it is constructed run off a few diagonals, and longitudinal vertical sections, from which and the curves already drawn, the constructor will be able to form a tolerably distinct idea of the vessel's form. If the diagonals and longitudinal sections do not appear to be such as he wishes, it will be necessary to alter some, or all the curves hitherto described till they are so; or rather, till all the curves hitherto described are suitable to his ideas.

From what has been done, it will be easy to draw the transverse sections corresponding to all the ordinates in the half-breadth plan, and as many equidistant water-lines as may be necessary.

* By the *immersion* is meant the prismatic space or solid carried under the water on the lee side by the inclination of the ship; by the *emersion*, the prismatic space or solid raised out on the weather side.

CALCULATIONS ON THE BODY.

(22.) The transverse sections on the body plan corresponding to the ordinates on the half-breadth plan, being thus drawn, as correctly as can be done at this period of the construction, the following calculations should be made to ascertain the capacity, proper distribution, and adjustment of the body. First, the displacement must be computed by means of the equi-distant sections on the body plan, and others at the extremities drawn by means of the water-lines at small intervals (Note 9.); secondly, the place of the center of gravity of the displacement with respect to length, must be found by means of the same sections (Note 9.); thirdly, the position of the centers of gravity of the immersion and emersion with respect to length must be computed, by which the adjustment of the vessel in heeling and rolling is ascertained (Note 26.).

At the same time also the displacement may be computed by the water-lines, and also its center of gravity with respect to depth.

A table of ordinates in the middle body is made such as Plate *C* (see following Construction), which contains the ordinates of the transverse sections, drawn on the body plan at equal intervals, as 2, 3, &c. feet below and parallel to the load water-line. They are measured by a quarter inch decimal scale. In the top spaces are put the ordinates of the load water-line, beginning with that in the aftermost section included, and proceeding forward. In the spaces immediately under those are put the ordinates of the second water-line, arranging them in a similar manner; and so on, to the lowest water-line drawn at the interval fixed on.

To find the Displacement from the Vertical Sections.

(23.) Put the ordinates of the table in the spaces taken from top to bottom, which are the ordinates of the transverse sections, into one of the rules, and thus compute the area of each section from the load water-line to the lowest ordinate of each middle section. Afterwards draw ordinates at smaller intervals under the lowest of the middle section, as far as the ending of the exterior planking, or the lower edge of the rabbet of the keel. Put these into a second table and compute the extreme area in each section, adding thereto the corresponding section of the keel and false keel.

(24.) Beyond the sections nearest to the extremities of the body, draw sections at smaller equal intervals, as far as the perpendiculars; put the ordinates of these into separate tables, and by the application of one or other of the rules, or if necessary both, find the areas of these extreme sections, to which respectively add the parts below them and the bottom of the false keel. Estimate as near as possible the solid content of that part of the stern-post, rudder, &c. that lie without the extreme sections last used.

(25.) The areas of the sections of the middle body insert in spaces in the table under the lowest ordinate of the middle section. In the spaces immediately below these put the corresponding extreme areas of each section to the bottom of the false keel. The sums, which will be the whole areas, insert in spaces below these again. We have thus the areas of the transverse sections in the middle body in the lowest horizontal range of spaces in the table.

(26.) Apply one of the rules to these areas, and the result will be the solid content of the middle body. In like manner the solidity of each extreme part is found, which together with the estimated content of the rudder, stern-post, stem and gripe, or such parts of them as have been left out, being added to the middle body, we have half the whole displacement in cubic feet.

To find the Place of the Center of Gravity of the Displacement with respect to Length.

(27.) Multiply each transverse section by its distance (see Note p. 283.) from the aftermost section of the middle body. Apply one of the rules to the products, and the result will be the moment of the middle body. Find in a similar manner the moments of the extreme parts of the body from the same section; and estimate as nearly as possible those of the stem, gripe, &c. Add together the moments before the said aftermost section of the middle body, and subtract those aft. The result will be half the moment of the displacement; which being divided by half the displacement, we have the required position of the center of gravity with respect to length, which should be between one fiftieth and a hundredth of the length before the middle point between the perpendiculars.

(28.) By proceeding in a similar manner we may determine the areas of the water-lines, the displacement from those areas, and its center of gravity with respect to depth, that is, the distance of this center of gravity below the load water-line.

To find the Distance from the aftermost transverse Section in the middle Body, of the Centers of Gravity of the Immersion and Emersion.

(29.) Supposing the center of gravity of the ship to be on the load water-line, the common form of ships is such that the immersion would generally be greater than the emersion. The load water-line, when the ship heels, which we will call the inclined load water-line, may therefore, except in particular constructions, be supposed to cut the upright load water-line, in a straight line that lies on the lee side of the middle of the latter (see Note 19.). Assume, therefore, a point a little on one side of the middle point of the load water-line on the body plan, as $\frac{2}{10}$ or $\frac{3}{10}$ of a foot, and then take a second point at the same distance on the other side of it. From these points as centers with a considerable length of radius, describe two quadrantal arcs, cutting the load water-line produced, and also the middle line of the body plan produced upward. Divide each of these quadrants into two equal parts; and these parts by trial into five equal subdivisions, each of which will be 9°. Join the points of division nearest to the load water-line and the centers on each side, and produce these straight lines under the load water-line, so as to cut all the transverse sections there.

(30.) The sectorial areas intercepted between the load water-line and the straight lines thus drawn under it, will be so many sections of the emersion at 9°; those intercepted between the load water-line and the straight lines drawn above it, will be the corresponding sections of the immersion. By means of a decimal scale measure the area of each section, considering it as made up of a plane triangle, and a curvilinear part; the latter of which may be measured as a parabolic area, by multiplying the base into the height and taking $\frac{2}{3}$ of the product. Having applied one of the rules to the sectorial areas of the immersion in the middle body, the solidity of this part is found. And in a similar manner is found the solidity of the immersion at the extremities, as far as the fore and aft perpendiculars, which will be sufficient for the object in view. By adding these results together, we have the solidity of the whole immersion.

(31.) Thus also the solid content of the emersion is determined.

If the immersion and emersion are not equal or nearly so, other equidistant points are assumed on each side of the middle line of the body plan, within or without the other, according as the immersion or emersion is the less*, and other straight lines are drawn cutting off new

* Let e be the difference between the immersion and emersion in cubic feet, and let a be the area of the inclined load water-line as first assumed, which may be found in the same

sectors, parallel to the former straight lines. The calculation is gone through again, and a similar process, if necessary, is repeated, till the two solids are equal.

(32.) Then the moments of the solids are found in the same manner as that of the displacement was found, the sectors being merely substituted for the tranverse sections. And the moment of each being divided by the solid itself, we have the distance of its center of gravity from the aftermost section.

(33.) We now know the displacement; the position of its center of gravity with respect to length, and also the position, in the same respect, of the centers of gravity of the immersion and emersion. If the two first elements come out what has been determined on, and the two latter centers of gravity be in the same transverse section, that is, at the same distance before the aftermost section, the construction of the body is so far correct. But if not, such alterations must be made in the body as the results seem to render necessary, in order, upon a second trial, to give all of them right; taking care at the same time to keep in view every other essential point in the construction, and drawing the curves with great accuracy.

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same manner as the area of the upright load water-line. Let x be the perpendicular distance of the true inclined load water-line from the assumed. Then it is manifest that $ax = e$ very nearly, and consequently $x = \frac{e}{a}$. The value therefore of the expression $\frac{e}{a}$ being set off on a perpendicular to the inclined load water-line as first assumed, we shall have the position of the true one correctly.

STABILITY.

(34.) Having ascertained the proper adjustment of the body in the particulars above stated, which perhaps demand the first attention of the constructor, it is necessary, before the last touches are given to the body, to compute the stability. A person who is well acquainted with the principles on which this depends, will be able, from the principal dimensions and the form of the sides between wind and water, to form a tolerably accurate estimate of the vessel's qualities in this respect, without the aid of computation. It is in consideration of this, that the more exact determination of the stability may be deferred, till the other parts of the calculations are finished.

The stability should be computed at two or three angles of heeling, as at 2°, 5°, 7°, 9°, &c.; by which it will be seen whether the vessel may be expected to have sufficient stiffness at each angle, and at the same time be easy in rolling. A known and approved vessel of the same size is taken for comparison, such deviations however being allowed as the constructor, from his knowledge of the subject, may judge advantageous.

(35.) The general expression for the stability is given in Note 15. namely, $\int WZ\dot{x}+\int wz\dot{x}-dDs$. The fluent of $WZ\dot{x}$ is approximated to by means of the sectors already measured for an inclination of 9°. The different values of Z and z are already known, the values of W and w are found as follows. Let SBD (Fig. 4. Pl. B.) be one of these sectors, SD the upright load water-line, SB the inclined load water-line. Join BD dividing the figure into a triangle SBD; and a curvilinear area BCD. Bisect BD in E, draw EC perpendicular to BD, and take EF two-fifths of it with a decimal scale. By means of a small and accurate square, let fall from E and F two perpendiculars EG and FH to SB. Then two-thirds of SG is the distance of the center of gravity of the triangle from S, measured on the surface of the water; and SH is the distance from the same point of the center of gravity of the curvilinear part, considered as a parabolic area. And $\frac{2}{3}SG \times SBED + SH \times BCDE =$ value of WZ for this sector. Thus the value of WZ is found for every section of the immersion in the middle body. Then by the application of one of the rules $\int WZ\dot{x}$ is determined.

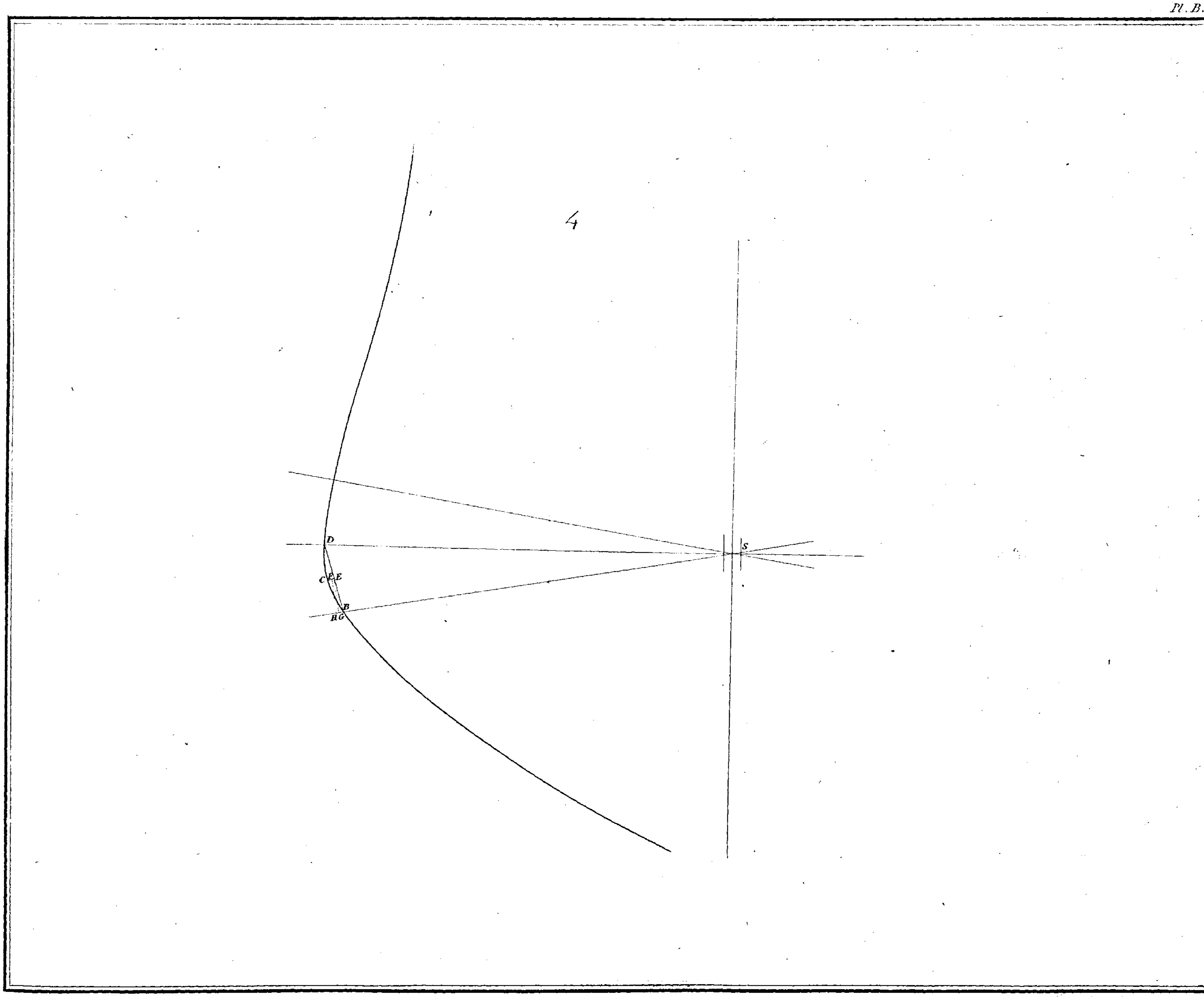
(36.) A similar method is followed in finding the moment of the extreme solids of the immersion, that is, the fluent of $WZ\dot{x}$ for those more curved parts of the immersion that lie near the stem and stern-post.

(37.) In a similar manner the fluent of $wz\dot{x}$ is found for the emersion.

(38.) In the expression dDs, the value of D is already known; s may be taken from a table of natural sines. To find the value of d, it is necessary to know the distance of the center of gravity of the ship from the load water-line. This cannot be determined accurately without very long calculations, in which the distance of the center of gravity of every weight in the ship from the load water-line must be measured, and its moment got. The difference of the moments above and below the water divided by the whole weight of the ship, or the displacement D in tons, will be the distance required. There are methods of shortening this tedious calculation, but this is not the place for explaining them*. The

* This calculation, if made rigorously, is very tedious. If the position of the center of gravity with respect to height were found exactly for one ship of each class, it would perhaps be easy to deduce therefrom the position of the same point for any construction not differing greatly in its principal dimensions and form from these, by taking into account only the difference of the moments, &c. of the parts of the new construction from the corresponding ones of the other. It is thus that the height of the center of gravity of the construction B has been deduced.

4



sum or difference of this distance and the depth of the center of gravity of the displacement, will be the value of d. Hence we know dDs.

In this manner is determined the stability at any angle of inclination, or $\int ZW\dot{x}+zw\dot{x}-dDs$, at as many angles of heeling as the constructor may judge necessary. By comparing the results with those for some known and approved ship, the constructor will be able to form a very accurate estimate of the performance of the ship proposed in point of stability.

If the stability appear to be too small or too great at all, or any, of the angles of inclination, in that case, tedious as the repetition of all the operations may appear to be, it will be necessary to reform the body, and go through every calculation again.

FAIRING THE BODY.

(39.) When the results of all the calculations are such as the constructor wishes, it is proper to run off a great number of different lines or curves, in order to ascertain the fairness in point of curvature of every part, and the beauty of the whole. With this view water lines are drawn at smaller intervals, both above and below the load water-line; several diagonals and buttock-lines are also delineated. If in doing this any want of fairness should be discovered, or if any line should not have that curvature, which the constructor knows to be essential to the beauty of a ship, or to any particular effect not developed by calculation, he is under the necessity of again retouching the body, and of again going through every part of the calculations.

(40.) After the body of the ship has been carefully adjusted and faired, as explained above, and every requisite correction made, it is necessary to compute the direct, lateral, and vertical resistances; in order to determine therefrom the position of the point of sail with respect to height and length, that is, with a view to the masting of the ship. The methods of doing this are fully explained by Chapman in Chapters IV, V, and X; the only question may be, whether or not the theory he gives is sufficiently correct to be depended on.

This is a subject upon which, in this place, little can be added, likely to be useful to the constructor. The results of experiments on resistances certainly differ from the theory given by Chapman; yet it must be considered, that very few, if any, experiments have been hitherto made, so as to include every circumstance, which operates in the resistance to ships. In some, the body has been entirely immersed; in others, the displacement has not been a fixed quantity; and in all that I am acquainted with, the models used appear to have been much too small to allow of conclusions being drawn from them, applicable with perfect safety to ships. This seems to have been the case with the models used in the experiments described in Chapter IV, and was also the case with those used in the interesting experiments he published an account of in 1795.

The theory Chapman has given in this treatise, may perhaps be found sufficiently near the truth, for the comparison of the direct resistance on different ships; for finding the mean horizontal direction, when the ship is before the wind, in order to determine the position of the point of sail with respect to length; and also for finding its mean direction upwards, by which the height of the point of sail is regulated. The constructor in making those computations for the body he has completed, will compare the results with those of known and approved ships; and if the calculated directions differ but little from the limits assumed and known from other ships, which it may be presumed will be the case, the corresponding adjustments may be made in masting the vessel, by carrying the point of sail something farther forward or aft, higher or lower, than common. A slight error in the direction of the mean horizontal resistance might also be corrected by increasing or diminishing the gripe, or by giving a greater or less depth to the false keel aft.

Should a considerable error be found in the direction of the mean resistance, in that case it will be necessary again to alter the body, till these adjustments, as well as the rest, are correct.

After all the pains the constructor may take, from the imperfection of the theory of resistances, or from some other unknown causes, it is possible that a ship, on going to sea, will not be found to have the point of sail exactly adjusted to the mean resistance. In this case nothing can be done except by altering the masting, for effecting which, if possible, every practical facility should in the first place be left in the building; or by bringing the ship more by the head or stern, thus adjusting the seat of the ship in the water to the masting, as it is.

Such are the principal steps in the construction of a ship rigorously made, and certainly no construction of great consequence should be made without some attention to them.

(41.) Lastly, it may be of considerable importance to form from the draught, now considered as complete, a block model of the vessel it is proposed to build; from which a still more accurate judgment may be formed of the fitness and beauty of the body. And should any defect be thus discovered, farther alterations must still be made, till the draught and the model are perfectly approved of. These different alterations and repeated calculations in some cases may appear very tedious, but they will not appear unnecessary to any person at all skilled in the business of construction. The many obvious reasons for using every means to ascertain the correctness and even nicety of every part of a ship, previous to its being built, need not be mentioned.

The different transverse sections in the construction which follows, in conformity to the method described above, are projected on a transverse plane perpendicular to the load water-line; also the curves are supposed to be drawn on the outside of the planking. Whereas in draughts for building, the sections are perpendicular to the keel, and the curves go no farther than the exterior surface of the timbers. To form one draught from the other, to space the timbers, place the ports, &c. is a mechanical operation, which it would be improper to describe here; this is within the reach of every practical person tolerably acquainted with the use of the drawing pen.

EXAMPLE OF CONSTRUCTION.

See Plate (R) and Table of Ordinates.

AREA OF HALF MAIN SECTION.

UPPER SPACE.

Ord. Ft.	Ord. Ft.	Ord. Ft.
1...24.9	2...25.00	3...24.65
5...20.39	4...23.08	× 2
45.29	48.08	49.30
	× 4	
	192.32	
	49.80	
	45.29	

Area of upper space	286.91	($\frac{1}{3}$ interval = 1.)
Ditto of lower space	96.79	
Hence to keel.....	0.79	
Section of keel....	1.44	
Area of half M. S..	385.93	

LOWER SPACE.

Ord. Ft.	Ord. Ft.	Ord. Ft.
1...20.39	2...19.50	3...18.54
11... 1.62	4...17.64	5...16.42
	6...14.95	7...13.24
22.01	8... 9.90	9... 4.70
	10... 2.85	
		52.90
	64.84	× 2
	× 4	105.80
	259.36	
	105.80	
	22.01	
($\frac{1}{3}$ Interval = $\frac{1}{4}$)	4)387.17	
	96.79	

AREA OF HALF LOAD WATER LINE.

AFTER SPACE.

Ord. Ft.	Ord. Ft.	Ord. Ft.
1...16.05	2...14.69	3...12.87
7... .8	4...10.60	5... 7.51
	6... 3.80	
16.85		20.38
	29.09	× 2
	× 4	
		40.76
	116.36	
	40.76	
	16.85	
	173.97	
	× .61 = $\frac{1}{3}$ interval.	
	106.1217	
	3.6 Sect. of post & rudder.	
	109.721	

MIDDLE SPACE.

Ord. Ft.	Ord. Ft.	Ord. Ft.
1..16.05	4...22.70	2... 19.31
28...18.55	7...24.48	3... 21.33
	10...24.90	5... 23.60
34.60	13...24.90	6... 24.13
	16...24.90	8... 24.72
	19...24.84	9... 24.85
	22...24.70	11... 24.90
	25...23.72	12... 24.90
		14... 24.90
	195.14	15... 24.90
	× 2	17... 24.90
		18... 24.85
	390.28	20... 24.83
	1289.07	21... 24.76
	34.60	23... 24.53
		24... 24.23
	1713.95	26... 22.87
$\frac{3}{8}$ interval...	2.25	27... 21.18
Middle area	3856.3875	429.69
Fore ditto	149.060	× 3
After ditto	109.721	
		1289.07
Area of half L. W. L.	4115.168	

FORE SPACE.

Ord. Ft.	Ord. Ft.	Ord. Ft.
1...18.55	2...16.40	3...13.3
5... .8	4... 8.72	× 2
19.35	25.12	26.6
	× 4	
	100.48	
	26.60	
	19.35	
Area of section of stem and knee of head.	146.43 ($\frac{1}{3}$ int^{l} = 1.)	
	..2.63	
	149.06	

To find the distance forward of Center of Gravity of L. Water-line.

MOMENTS IN MIDDLE SPACE.

1...0000.00
28...2988.90

2988.90

Note. Each ordinate in middle space is multiplied by its distance from ordinate 1.

4... 408.60
7... 881.28
10...1344.60
13...1792.80
16...2241.00
19...2682.72
22...3112.20
25...3415.68

15878.88
× 2

31757.76
105655.38
2988.90

140402.04
($\frac{2}{3}$ interval) × 2.25

Whole moment of middle space=315904.5900

2... 115.86
3... 225.96
5... 676.40
6... 724.80
8...1038.24
9...1192.80
11...1494.00
12...1643.40
14...1942.20
15...2091.60
17...2390.40
18...2534.70
20...2830.62
21...2971.20
23...3237.96
24...3343.74
26...3430.50
27...3304.08

35218.46
× 3

105655.38

MOMENTS IN AFTER SPACE.

1...000000
7... 8.78

8.78

2...26.88
4...58.19
6...34.77

119.84
× 4

479.36
204.22
8.78

692.36
($\frac{1}{3}$ interval) × .61

69236
415416

3...47.14
5...54.97

102.11
× 2

204.22

Mom. of after sp..=422.3396
Post and rudder.... 47.70

Negative moments..470.04

MOMENTS IN FORE SPACE.

1...2988.90
5... 139.20

3128.10

2...2706.00
4...1491.12

4197.12
× 4

16788.48
4468.80
3128.10

3...2234.4
× 2

4468.8

Moment of fore space= 24385.38 ($\frac{1}{3}$ interval = 1.)
Ditto of middle ditto ..315904.59
Ditto of stem section .. 462.93

Sum of positive mom^ts^.340752.90
D° of negative mom^ts^. . 470.04

Difference..........340282.86
Divided by 4115.17

Equal 82.68

Hence the distance of the center of gravity from ord. 1 of middle space is........82.68 feet.
And the distance of the middle point from ord. 1..........................81.50

Therefore the distance of the center of gravity of the L. W. L. before the middle = 1.18

To find the Displacement by the Vertical Sections.

HALF VERTICAL SECTIONS IN MIDDLE BODY.

1...101.72	4...224.11	2...145.51
28...151.52	7...312.49	3...186.03
———	10...359.87	5...258.25
253.24	13...380.89	6...288.09
	16...385.93	8...332.15
	19...375.69	9...347.48
	22...346.17	11...368.57
	25...284.25	12...375.77
	———	14...383.83
	2669.30	15...385.49
	× 2	17...384.04
	———	18...380.16
	5338.60	20...368.18
	16980.69	21...358.42
	253.24	23...330.17
	———	24...309.67
	22572.53	26...251.31
	$\frac{3}{8}$ interval= × 2.25	27...207.11
		———
		5660.23
		× 3
		———
		16980.69

Note. Each half vertical section is found as the half main section is in p. 297.

Displacement of half middle body=50788.1925 cubic feet.

IN AFTER BODY.

1...101.72	2...87.81	3...72.63
7... 15.71	4...57.88	5...41.94
———	6...25.50	———
117.43	———	114.57
	171.19	× 2
	× 4	———
	———	229.14
	684.76	
	229.14	
	117.43	
	———	
	1031.33	
	× .61 = $\frac{1}{3}$ interval	
	———	

629.1113=$\frac{1}{2}$ displacement of after body.

IN FORE BODY.

1...151.52	2...118.41	3...79.76
5... 4.96	4... 37.97	× 2
———	———	———
156.48	156.38	159.52
	× 4	
	———	
	625.32	
	159.52	
	156.48	
	———	

Displacement of half fore body=941.52 ($\frac{1}{3}$ interval=1.)

Displacement of half middle body................	50788.19
Ditto of half fore body.....	941.52
Ditto of half after body	629.11
Ditto of half stern-post and rudder	87.46
Ditto of half knee of head before the rabbet........	14.14
Whole half displacement.......................	52460.42

Hence the whole displacement is 104920.84 cubic feet, or, allowing 35 cubic feet of sea water to a ton, 2997.73 tons.

To find the Distance forward of the Center of Gravity of Displacement.

MOMENTS IN MIDDLE BODY.

1...00000.00
28...24546.24

Note. Each half section is multiplied by its distance from Sect. 1.

4... 4033.98
7...11249.64
10...19432.98
13...27424.08
16...34733.70
19...40574.52
22...43604.82
25...40932.00

221985.72
× 2

443971.44
1424286.18
24546.24

1892803.86
($\frac{3}{8}$ interval) × 2.25

Whole moment of half middle body = 4258808.6850

2... 873.06
3... 2232.36
5... 6198.00
6... 8642.70
8...13950.30
9...16679.04
11...22114.20
12...24800.82
14...29938.74
15...32381.16
17...36867.84
18...38778.36
20...41972.52
21...43010.40
23...43582.44
24...42734.46
26...37696.50
27...32309.16

474762.06
× 3

1424286.18

MOMENTS IN AFTER BODY.

1...000.00
7...172.49

2...160.69
4...317.76
6...143.32

621.77
× 4

2487.08
1145.64
172.49

3805.21
× .61 = $\frac{1}{3}$ interval.

3...265.82
5...307.00

572.82
× 2

1145.64

Moment of after body. = 2321.1781
Post and rudder.. 1141.35

Negative moments. = 3462.52

MOMENTS IN FORE BODY.

1...24546.24
5... 863.04

25409.28

2...19537.68
4... 6492.87

26030.55
× 4

104122.20
26799.36
25409.28

3...13399.68
× 2

26799.36

Moment of half fore body 156330.84 ($\frac{1}{3}$ interval = 1.)
Ditto of middle body.... 4258808.68
Ditto of knee of head.... 2474.64

Positive moments....... 4417614.16
Negative moments...... 3462.53

Difference............ 4414151.63
Divided by........... 52460.42

Equal................ 84.14

Hence the center of gravity of the displacement is before ord. 1.......... 84.14 feet.
And the distance from ord. 1. to the middle point is.................... 81.50 feet.

Therefore the center of gravity of displacement is before the middle ...... 2.64 feet.

To find the Content of the Immersion when heeled to 9° (ART. 29.)

AREAS OF SECTIONS IN THE MIDDLE BODY.

1...24.47	4...42.16	2...33.23
28...31.19	7...46.75	3...38.46
55.66	10...49.61	5...44.40
	13...50.31	6...45.79
	16...50.31	8...47.87
	19...49.87	9...49.37
	22...49.67	11...50.66
	25...46.67	12...50.31
	385.35	14...50.31
	× 2	15...50.31
	770.70	17...50.18
	2521.08	18...49.94
	55.66	20...49.75
	3347.44	21...49.72
	⅓ interval = × 2.25	23...49.36
		24...48.56
		26...43.62
		27...39.12
		840.36
		× 3
		2521.08

Content in middle body 7531.7400 cub. ft.

IN FORE BODY.

1...31.19	2...27.57	3...22.37
7... .03	4...17.09	5...10.83
31.22	6... 3.79	33.20
	48.45	× 2
	× 4	66.40
Interval is 2 feet.	193.80	
	66.40	
	31.22	
	291.42 × ⅔	

Content in fore body = 194.28 cub. ft.

IN AFTER BODY.

1...24.47	2...22.93	3...18.32
7... 0.04	4...12.71	5... 5.66
24.51	6... 1.55	23.98
	37.19	× 2
	× 4	47.96
Interval is 1.83 feet.	148.76	
	47.96	
	24.51	
	221.23 × 0.61	

In after body = 134.9503 cub. ft.

Sum of contents or whole immersion......= 7860.97 cub. ft.

To find the Content of the Emersion, when heeled to 9° (ART. 29.)

AREAS OF SECTIONS IN THE MIDDLE BODY.

1...17.19	4...39.79	2...25.99
28...24.37	7...49.40	3...34.34
41.56	10...51.71	5...45.73
	15...52.42	6...48.40
	16...52.42	8...50.67
	19...52.42	9...51.33
Interval is 6 feet.	22...51.42	11...52.42
	25...44.49	12...52.42
		14...52.42
	394.07	15...52.42
	× 2	17...52.42
		18...52.42
	788.14	20...52.29
	2543.04	21...52.22
	41.56	23...49.65
		24...48.43
	3372.74	26...40.39
	$\frac{3}{8}$ of interval × 2.25	27...33.72
	Content in middle body = 7588.6650 cub.ft.	847.68
		× 3
		2543.04

IN FORE BODY.

1...24.37	2...20.45	3...16.74
7... 0.12	4...12.07	5... 7.33
24.49	6... 2.68	24.07
Interval is 2 feet.	35.20	× 2
	× 4	48.14
	140.8	
	48.14	
	24.49	
	213.43 × $\frac{2}{3}$	
Content in fore body = 142.28		

IN AFTER BODY.

1...17.19	2...14.05	3...10.16
7... 1.98	4... 7.63	5... 5.58
19.17	6... 1.23	13.74
Interval is 1.83 feet.	22.91	× 2
	× 4	27.48
	91.64	
	27.48	
	19.17	
	138.29 × 0.61	
In after body = 84.3569		

Sum of contents or whole emersion...... = 7815.30 cub. ft.

To find the Distance forward of the Immersion's Center of Gravity.

MOMENTS IN THE MIDDLE BODY (Art. 32.)

1...0000.00
28...5052.78

4... 841.50
7...1683.00
10...2678.94
13...3622.32
16...4527.90
19...5385.42
22...6258.42
25...6720.48
31718.52
× 2
63437.04
208099.08
5052.78
276588.90 × 2.25

Moment in middle body = 622325.0250

2... 199.38
3... 461.52
5...1065.60
6...1373.70
8...2010.54
9...2369.76
11...3003.60
12...3320.46
14...3924.18
15...4226.04
17...4817.28
18...5093.88
20...5671.50
21...5966.40
23...6515.52
24...6701.28
26...6543.00
27...6102.72
69366.36
× 3
208099.08

IN FORE BODY.

1...5052.78
7... 5.22
5058.00

2...4521.48
4...2871.12
6... 651.88
8044.48
× 4
32177.91
11109.04
5058.00
48344.96 × ⅔

3...3713.42
5...1841.10
5554.52
× 2
11109.04

Moment in fore body = 32229.97

IN AFTER BODY.

1...0.00
7...0.44
0.44

2...39.93
4...69.77
6...14.18
123.88
× 4
495.52
216.96
0.44
712.92 × 0.61

3...67.05
5...41.43
108.48
× 2
216.96

Negat. mom. in aft body = 434.8512

Hence the whole moment of the immersion is 654120.11, which divided by the content 7860.97 gives 83.21 the distance of the center of gravity before Sect. 1. of the middle body.

To find the Distance forward of the Emersion's Center of Gravity.

MOMENTS IN THE MIDDLE BODY (Art. 32.)

1...0000.00	4...0716.22	2... 155.94
28...3947.94	7...1778.40	3... 412.80
3947.94	10...2792.34	5...1097.52
	13...3774.24	6...1452.00
	16...4717.80	8...2128.14
	19...5661.36	9...2463.84
	22...6478.92	11...3145,29
	25...6406.56	12...3459.72
	32325.84	14...4088.76
	× 2	15...4403.28
	64651.68	17...5032.32
	209909.34	18...5346.84
	3947.94	20...5962.06
	278508.96 × 2.25	21...6266.40
		23...6553.80
		24...6683.34
		26...6058.50
		27...5260.32
		69969.78
		× 3
		209909.34

Moment in middle body = 626645.16

IN FORE BODY.

1...3947.90	2...3353.80	3...2778.84
7... 21.05	4...2027.56	5...1246.10
3968.97	6... 460.96	4024.94
	5842.52	× 2
	× 4	8048.00
	23370.08	
	8049.88	
	3968.95	
	35389.01 × $\frac{2}{3}$	

Moment in fore body=23592.94

IN AFTER BODY.

1...0.00	2...25.71	3...32.27
7...2.18	4...39.88	5...26.20
	6...11.25	58.47
	76.84	× 2
	× 4	116.94
	307.36	
	116.94	
	2.18	
	426.48 × 0.61	

Negat. mom. in aft body=260.1528

Hence the whole moment of the emersion is 649977.95, which being divided by the content 7815.3, the quotient is 83.16 feet, the distance of the center of gravity before Sect. 1. of the middle body.

To find the Displacement by the Water-lines.

AREAS OF HALF-WATER LINES IN THE UPPER BODY.

1...4115.17	2...3884.75	3...3510.34
5...2450.67	4...3028.73	× 2
6565.84	6913.48	7020.68
	× 4	
Interval is 3 feet.	27653.92	
	7020.68	
	6565.84	

Displacement of half upper body = 41240.44 cub. ft.

AREAS IN LOWER BODY.

1...2450.67	2...2290.92	3...2128.97
11... 235.65	4...1977.61	5...1783.66
	6...1591.72	7...1356.64
2686.32	8...1033.54	9... 615.79
	10... 392.78	
		5885.36
Interval is .75 feet.	7286.78	× 2
	× 4	
		11770.72
	29147.12	
	11770.72	
	2686.32	
	43604.16	
	× .25 = ⅓ interval.	

Displacement of half lower body = 10901.0400 cub. ft.

Solid content of half upper body	41240.44
Ditto of half lower body	10901.04
Ditto of half solid below lower body	107.13
Ditto of half keel and rudder, &c	217.18
Whole half displacement by water-lines	52465.79
Whole half displacement by vertical sections (p. 299.)	52460.42
	2)104926.21
Mean half displacement	52463.10

Hence the whole displacement is 104926.20, or (dividing by 35) 2998.89 tons.

To find the Depth of the Center of Gravity of the Displacement.

MOMENTS IN HALF THE UPPER BODY.

1...00000.00	2...11654.25	3...21062.04
5...29408.04	4...27258.57	× 2
	38912.82	42124.08
	× 4	
	155651.28	
	42124.08	
	29408.04	

Moment of half upper body = 227183.40 × 1.

IN HALF LOWER BODY.

1...29408.04	2...29209.23	3...28741.09
11... 4595.17	4...28180.94	5...26759.40
34003.21	6...25069.59	7...22384.56
	8...17828.56	9...11084.22
	10... 7368.56	88969.27
	107656.88	× 2
	× 4	177938.54
	430627.52	
	177938.54	
	34003.21	
	642569.27 × 0.25	

Moment of half lower body = 160642.3175

Moment of half upper body	227183.40
Ditto of half lower body	160642.31
Ditto of half solid below the lower body	2121.17
Ditto of half keel, rudder, &c.	6767.90
Sum	396714.78

Hence the center of gravity of the displacement below the load water-line is 396714.78 divided by 52465.79 or 7.56 feet.

To find the Stability, when heeled to 9° (Art. 35.).

Values of WZ in the Immersion of the Middle Body.

1...282.69	4...641.25	2...447.46
28...400.56	7...750.05	3...558.52
683.25	10...803.92	5...691.93
	13...815.02	6...726.73
	16...815.02	8...773.11
	19...807.98	9...799.13
	22...801.99	11...811.13
	25...738.91	12...815.02
	6174.14	14...815.02
	× 2	15...815.02
	12348.28	17...812.92
	39881.55	18...809.03
	683.25	20...805.99
	52913.08 × 2.25	21...803.04
		23...799.23
		24...783.74
		26...663.97
		27...562.86
		13293.85
		× 3
		39881.55

Value of $\int WZ\dot{x}$ in middle body = 119054.4300

Values of WZ in Fore Body.

1...400.56	2...297.42	3...173.18
5... 0.01	4... 55.19	× 2
400.57	352.61	346.36
	× 4	
	1410.44	
	346.36	
	400.57	

$\int WZ\dot{x}$ in fore body = 2157.37 ($\frac{1}{3}$ interval = 1.)

Values of WZ in After Body.

1...282.69	2...254.53	3...181.65
7... .01	4...106.70	5... 37.29
282.70	6... 4.60	218.94
	365.83	× 2
	× 4	437.88
	1463.32	
	437.88	
	282.70	
	2183.90 × 0.61	

$\int WZ\dot{x}$ in after body = 1332.179

Whole fluent of $WZ\dot{x}$ is therefore nearly 122543.98.

To find the Stability, when heeled to 9° (Art. 35.).

Values of wz in the Emersion of the Middle Body.

1...164.16	4...580.42	2...305.97
28...280.47	7...804.99	3...461.88
444.63	10...869.36	5...708.63
	13...889.99	6...771.27
	16...890.09	8...835.98
	19...885.08	9...857.22
	22...858.23	11...881.91
	25...690.65	12...888.67
	6468.81	14...890.09
	× 2	15...890.09
	12937.62	17...889.72
	41038.14	18...887.48
	444.63	20...883.61
	54420.39 × 2.25	21...880.69
		23...819.02
		24...778.57
		26...591.53
		27...457.05
		13679.38
		× 3
		41038.14

$\int wz\dot{x}$ in middle body = 122445.8775

Values of wz in Fore Body.

1...280.47	2...186.03	3...99.04
5... 0.12	4... 30.47	× 2
280.59	216.50	198.08
	× 4	
	866.00	
	198.08	
	280.59	

$\int wz\dot{x}$ in fore body = 1344.67 ($\frac{1}{3}$ interval = 1.)

Values of wz in After Body.

1...164.16	2...121.42	3...77.42
7... 0.12	4... 48.83	5...22.55
164.28	6... 3.15	99.97
	173.40	× 2
	× 4	199.94
	693.60	
	199.94	
	164.28	
	1057.82 × 0.61	

$\int wz\dot{x}$ in after body = 645.2702

Whole fluent of $wz\dot{x}$ is therefore nearly 124435.82.

The height of the center of gravity of the construction, by comparison with another ship of the same kind, has been found to be 0.93 ft. above the load water-line. Consequently the value of d in the expression $\int WZ\dot{x} + \int wz\dot{x} - dsD$ is $7.56+0.93=8.49$ feet, and $s = \sin. 9° = 0.15643$. Hence by substitution the required stability is 107637.81 (See Art. 35.).

TABLE OF ORDINATES.

UPPER BODY. *Horizontal Section 3 feet apart.*

Of AFTER BODY — *Common Interval* 1.83 *feet.*

Pieces aft including Post and Rudder.	7	6	5	4	3	2	1	
109.72	8	3.8	7.51	10.6	12.87	14.69	16.05	1
67.95		2.13	4.0	5.81	7.53	9.25	10.73	2
41.36		1.43	2.34	3.32	4.42	5.44	6.5	3
26.93		.9	1.43	2.00	2.55	3.24	3.88	4
19.00		.74	1.02	1.32	1.62	2.0	2.35	5
Areas from ord. 1 to ord. 5.		19.52	34.85	49.80	63.65	77.53	89.84	

Vertical Sections *of* MIDDLE BODY — *Common Interval* 6 *feet.*

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	16.05	19.31	21.33	22.7	23.6	24.13	24.48	24.72	24.85	24.9	24.9	24.9	24.9	24.9
2	10.73	14.88	17.91	20.24	22.00	23.21	23.96	24.44	24.73	24.93	24.95	25.00	25.00	25.00
3	6.5	10.12	13.33	16.10	18.46	20.26	21.6	22.55	23.24	23.72	24.04	24.25	24.44	24.65
4	3.88	6.34	9.06	11.82	14.32	16.44	18.17	19.5	20.5	21.35	22.00	22.38	22.77	22.9
5	2.35	3.83	5.71	7.86	10.17	12.28	14.14	15.64	16.92	17.95	18.8	19.43	19.9	20.21
Areas	89.84	128.26	161.58	191.00	215.97	235.53	250.34	261.22	269.17	275.41	279.58	282.35	284.76	286.01

	15	16 φ	17	18	19	20	21	22	23	24	25	26	27	28
1	24.9	24.9	24.9	24.85	24.84	24.83	24.76	24.7	24.53	24.23	23.72	22.87	21.18	18.45
2	25.00	25.00	25.00	25.00	25.00	24.9	24.86	24.53	24.05	23.36	22.42	21.01	18.83	15.00
3	24.65	24.65	24.65	24.51	24.34	24.06	23.52	23.08	22.32	21.34	20.03	18.14	15.29	11.14
4	23.04	23.08	23.00	22.78	22.53	22.1	21.44	20.62	19.58	18.32	16.63	14.36	11.34	7.65
5	20.38	20.39	20.25	19.96	19.56	18.8	18.17	17.2	15.96	14.41	12.55	10.25	7.56	4.54
Areas	286.74	286.91	286.45	284.95	283.20	279.75	275.17	268.66	259.65	248.04	232.53	210.88	180.00	135.87

Of FORE BODY — *Common Interval* 3 *feet.*

	Middle areas.	1	2	3	4	5	Pieces forward including the knee of head.	Whole half horizontal areas.
1	3856.38	18.45	16.4	13.38	8.72	.8	149.06	4115.17
2	3713.13	15.00	12.54	9.2	4.84		103.67	3884.75
3	3401.77	11.14	8.7	5.72	2.22		67.21	3510.34
4	2962.51	7.65	5.42	3.12			39.30	3028.73
5	2412.40	4.54	2.9	1.36			19.27	2450.67
Areas		135.87	108.54	75.43	30.30			

LOWER BODY. *Horizontal Sections .75 feet apart.*

Of AFTER BODY

	7	6	5	4	3	2	1	
19.00		.74	1.02	1.32	1.62	2.0	2.35	1
17.77		.73	.97	1.23	1.45	1.76	2.13	2
15.91		.68	.92	1.13	1.3	1.55	1.95	3
15.46		.67	.87	1.04	1.18	1.43	1.72	4
13.55		.62	.8	.97	1.08	1.28	1.51	5
13.17		.62	.75	.87	.97	1.13	1.33	6
13.53		.6	.72	.82	.89	1.00	1.18	7
12.08		.58	.67	.74	.82	.92	1.04	8
10.91		.57	.63	.65	.75	.8	.9	9
10.7		.55	.58	.64	.68	.75	.8	10
10.31		.55	.58	.6	.62	.65	.72	11
Areas from ord. 5 or 1 to ord. 11.		4.7	5.77	6.78	7.67	8.96	10.55	
Pieces below including the keel and false keel.	15.71	1.28	1.29	1.3	1.31	1.32	1.33	
Whole half areas of the Vertical Sections.	15.71	25.5	41.94	57.88	72.63	87.81	101.72	

Vertical Sections *of* MIDDLE BODY

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	2.35	3.83	5.71	7.86	10.17	12.28	14.14	15.64	16.92	17.95	18.8	19.43	19.9	20.21
2	2.13	3.38	5.06	7.00	9.12	11.23	13.04	14.54	15.85	16.98	17.84	18.55	19.0	19.23
3	1.95	2.96	4.45	6.19	8.12	10.15	11.89	13.44	14.8	15.9	16.74	17.5	17.94	18.27
4	1.72	2.64	3.96	5.5	7.24	9.16	10.83	12.4	13.68	14.32	15.68	16.52	16.95	17.3
5	1.51	2.26	3.38	4.72	6.24	7.92	9.54	11.07	12.38	13.5	14.42	15.24	15.71	16.1
6	1.33	1.95	2.91	4.03	5.31	6.8	8.26	9.78	11.0	12.2	13.2	13.85	14.35	14.8
7	1.18	1.72	2.47	3.41	4.43	5.67	6.96	8.21	9.44	10.55	11.35	12.05	12.6	13.04
8	1.04	1.48	2.08	2.81	3.52	4.54	5.57	6.47	7.45	8.2	8.75	9.43	9.9	9.9
9	.9	1.26	1.68	2.22	2.68	3.32	4.01	4.4	4.7	4.7	4.7	4.7	4.7	4.7
10	.8	1.15	1.32	1.67	1.92	2.24	2.60	2.72	2.85	2.85	2.85	2.85	2.85	2.85
11	.72	.84	1.00	1.2	1.28	1.42	1.58	1.62	1.62	1.62	1.62	1.62	1.62	1.62
Areas	10.55	15.86	22.99	31.56	40.7	50.92	60.43	68.78	76.12	82.26	86.78	91.2	93.9	95.59
Pieces below	1.33	1.39	1.46	1.55	1.58	1.64	1.72	2.15	2.19	2.20	2.21	2.22	2.23	2.23
Whole half areas	101.72	145.51	186.03	224.11	258.25	288.09	312.49	332.15	347.48	359.87	368.57	375.77	380.89	383.83

	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1	20.38	20.39	20.25	19.96	19.56	18.8	18.17	17.2	15.96	14.41	12.55	10.25	7.56	4.54
2	19.48	19.5	19.28	19.02	18.58	18.0	17.13	16.13	14.9	13.25	11.35	9.1	6.37	3.78
3	18.51	18.54	18.38	18.08	17.62	17.0	16.12	15.04	13.81	12.15	10.23	7.95	5.53	3.16
4	17.60	17.64	17.45	17.15	16.65	15.98	15.08	13.96	12.72	11.1	9.15	7.0	4.77	2.63
5	16.38	16.42	16.23	15.38	15.35	14.64	13.74	12.6	11.35	9.72	7.88	5.94	3.95	2.08
6	14.88	14.95	14.75	14.32	13.8	13.08	12.16	11.07	9.86	8.24	6.52	4.91	3.2	1.56
7	13.04	13.24	12.9	12.28	11.77	11.14	10.2	9.3	8.14	6.74	5.4	4.04	2.56	1.15
8	9.9	9.9	9.7	9.3	8.68	7.9	7.17	6.63	5.95	5.1	4.25	3.16	2.0	.78
9	4.7	4.7	4.7	4.7	4.7	4.63	4.5	4.24	3.93	3.58	3.16	2.35	1.48	
10	2.85	2.85	2.85	2.85	2.85	2.8	2.7	2.6	2.44	2.27	2.08	1.58	1.00	
11	1.62	1.62	1.62	1.62	1.62	1.5	1.46	1.4	1.3	1.23	1.14	.93		
Areas	96.52	96.79	95.6	93.25	90.57	86.56	81.42	75.63	68.8	59.96	50.1	38.93	25.5	12.73
Pieces below	2.23	2.23	1.99	1.96	1.92	1.87	1.83	1.78	1.72	1.67	1.62	1.5	1.61	2.92
Whole half areas	385.49	385.92	384.04	380.16	375.69	368.18	358.42	346.07	330.17	309.67	284.25	251.31	207.11	151.52

Of FORE BODY

	Middle areas.	1	2	3	4	5	Pieces forward including the knee of head.	Whole half horizontal areas.
1	2412.40	4.54	2.9	1.36			19.27	2450.67
2	2256.88	3.78	2.38	.87			16.27	2290.92
3	2100.80	3.16	1.89				12.26	2128.97
4	1952.41	2.63	1.5				9.74	1977.61
5	1763.44	2.08	1.1				6.98	1783.96
6	1571.87	1.56	.74				6.68	1591.72
7	1337.98	1.15					5.13	1356.64
8	1016.86	.78					4.6	1033.54
9	593.80						11.08	615.79
10	374.48						7.81	392.99
11	213.74						11.60	235.65
Areas		12.73	6.51	.83				
Pieces below		2.92	3.36	3.5	7.07	4.96		
Whole half areas		151.52	118.41	79.76	37.37	4.96		


Scale of Plans Fig. 43. 44. & 46.
S 5 10 15 20 25 30
E 1 2 3 4 5 6 7 8 9 10 15 20 25 30
F 5 10 15 20 25
Fig. 43.
27 24 21 18 15 12 9 6 3 ⊕ C F I M P S
W

Lowry sculp.

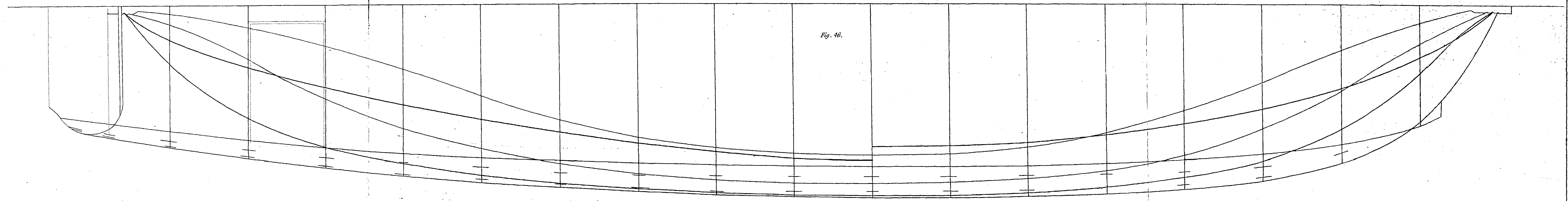


Fig. 46.

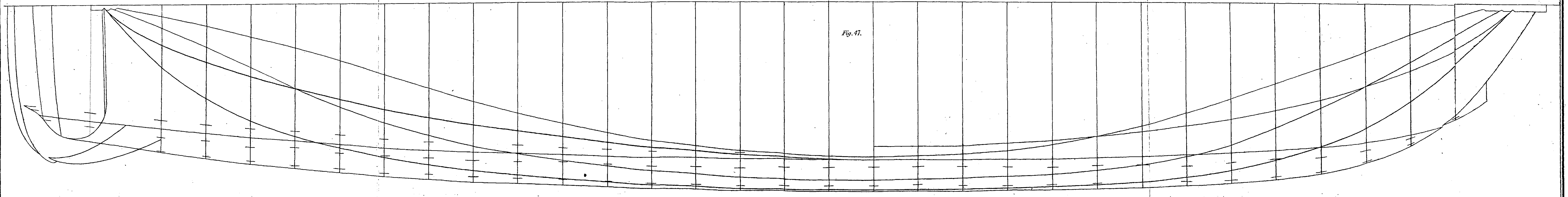
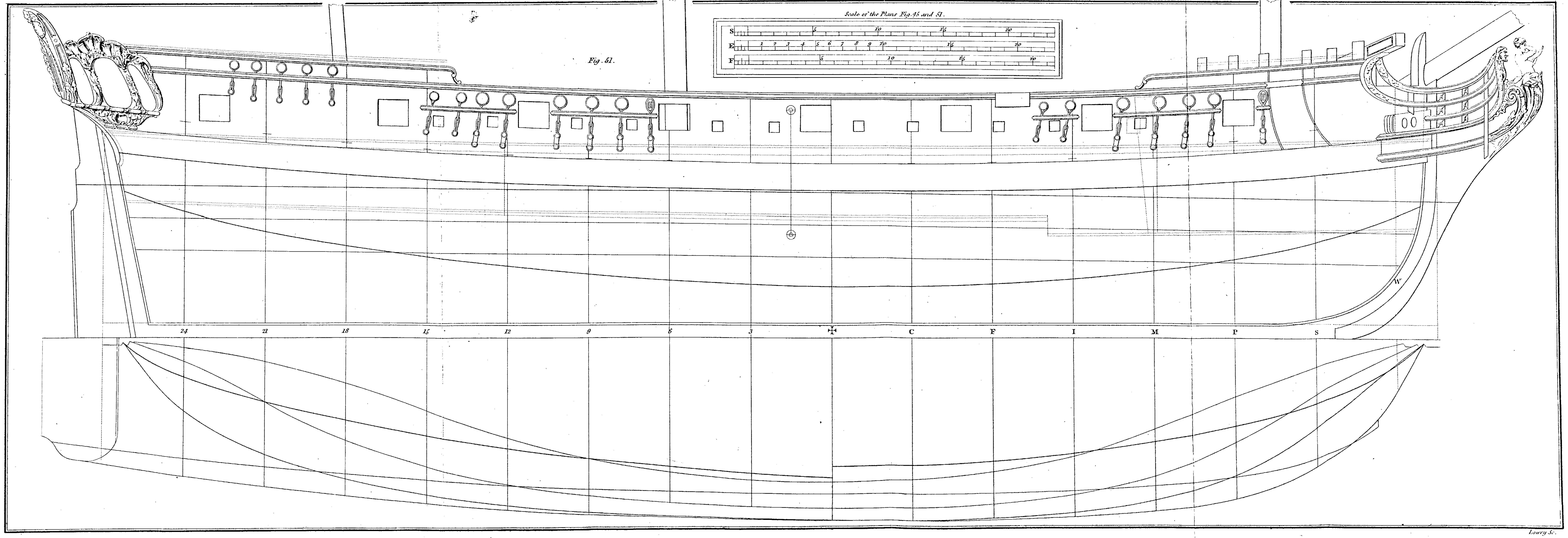


Fig. 47.

Lowry sculp.

Pl. 18.

Lowry sculp.


Scale of the Plans Fig. 45 and 51.
S 5 10 15 20
E 1 2 3 4 5 6 7 8 9 10 15 20
F 5 10 15 20
Fig. 51.
24 21 18 15 12 9 6 3 C F I M P S
W

Lowry Sc.

Engraved by W. Lowry