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IX. *On the Principles of Equilibrium, and the Stability of floating Bodies applied to River and Canal Boats of different Forms.* By Mr. JOHN GEORGE ENGLISH, *Teacher of Mathematics and Mechanical Philosophy.* Communicated by the Author.

THE principles of dynamics in general, and of statics in particular, have already been so fully explained by some of the ablest mathematicians in Europe, that little or nothing of consequence is further to be expected on those subjects, unless our mode of calculus be either greatly improved or totally changed. And as neither of these events is likely soon to take place, we ought certainly, in the mean time, to apply to the common concerns of life the principles of which we are already in possession. But since war and merchandize seem at present to be the chief business of all European nations, and since neither the one nor the other can be carried on to any great extent without navigation, nor can any vessel with safety be navigated without a proper degree of stability; it is therefore a matter of the greatest importance to determine with accuracy the stability of nautical vessels of all kinds.

However operose and difficult the necessary calculations may in some cases become before the degree of this essential quality can be obtained, yet they all depend upon the four following simple and obvious theorems, accompanied with other well known stereometrical and statical principles.

THEOREM I. Every floating body displaces a quantity of the fluid in which it floats, equal to its own weight: and consequently, the specific gravity of the fluid will be to that of the floating body, as the magnitude of the whole is to that of the part immersed.

THEOREM II. Every floating body is impelled downward by its own essential power, acting in the direction of a vertical line passing through the centre of gravity of the whole;

whole; and is impelled upward by the reaction of the fluid which supports it, acting in the direction of a vertical line passing through the centre of gravity of the part immersed: therefore, unless these two lines are coincident, the floating body thus impelled must revolve round an axis, either in motion or at rest, until the equilibrium is restored.

THEOREM III. If by any power whatever a vessel be deflected from an upright position, the perpendicular distance between two vertical lines passing through the centres of gravity of the whole, and of the part immersed respectively, will be as the stability of the vessel, and which will be positive, nothing, or negative, according as the metacentre is above, coincident with or below, the centre of gravity of the vessel.

THEOREM IV. The common centre of gravity of any system of bodies being given in position, if any one of these bodies be moved from one part of the system to another, the corresponding motion of the common centre of gravity, estimated in any given direction, will be to that of the aforesaid body, estimated in the same direction, as the weight of the body moved is to that of the whole system.

From whence it is evident, that in order to ascertain the stability of any vessel, the position of the centres of gravity of the whole, and of the part immersed must be determined; with which, and the dimensions of the vessel, the line of floatation, and angle of deflection, the stability or power either to right itself or overturn may be found.

In ships of war and merchandise, the calculations necessary for this purpose become unavoidably very operose and troublesome; but they may be much facilitated by the experimental method pointed out in the New Transactions of the Swedish Academy of Sciences, first quarter of the year 1787 page 48.

In river and canal boats, the regularity and simplicity of the form of the vessel itself, together with the compact disposition and homogeneous quality of the burden, render that method for them unnecessary, and make the requisite calculation

lations become very easy. Vessels of this kind are generally of the same transverse section throughout their whole length, except a small part in prow and stern, formed by segments of circles or other simple curves; therefore a length may easily be assigned such, that any of the transverse sections being multiplied thereby, the product will be equal to the whole solidity of the vessel. The form of the section *ABCD* is for the most part either rectangular as in *fig. 1.* (*Plate XIII.*), trapezoidal as in *fig. 2.* or mixtilineal as in *fig. 3.* in all which *MM* represents the line of floatation when upright, and *EF* that when inclined at any angle *MXE*; also *G* represents the centre of gravity of the whole vessel, and *R* that of the part immersed.

If the vessel be loaded quite up to the line *AB*, and the specific gravity of the boat and burden be the same, then the point *G* is simply the centre of gravity of the section *ABCD*; but if not, the centres of gravity of the boat and burden must be found separately, and reduced to one by the common method, namely, by dividing the sum of the momenta by the sum of weights, or areas, which in this case are as the weights. The point *R* is always the centre of gravity of the section *MMCD*, which, if consisting of different figures, must also be found by dividing the sum of the momenta by the sum of the weights as common. These two points being found, the next thing necessary is to determine the area of the two equal triangles *MXE*, *MXF*, their centres of gravity *o*, *o*, and the perpendicular projected distance *nn* of these points on the water line *EF*. This being done, through *R* and parallel to *EF* draw *RT* = a fourth proportional to the whole area *MMCD*, either triangle *MXE* or *MXF*, and the distance *nn*; through *T*, and at right angles to *RT* or *EF*, draw *TS* meeting the vertical axis of the vessel in *S* the metacentre; also through the points *G*, *B*, and parallel to *ST*, draw *NGW* and *BV*; moreover through *S*, and parallel to *EF*, draw *WSV* meeting the two former in *V* and *W*; then *SW* is

Engraved by Lowry.

as the stability of the vessel, which will be positive, nothing, or negative, according as the point S is above, coincident with, or below, the point G. If now we suppose W to represent the weight of the whole vessel and burden (which will be equal to the section M M C D multiplied by the length of the vessel), and P to represent the required weight applied at the gunwale B to sustain the vessel at the given angle of inclination; we shall always have this proportion: as VS : SW :: W : P; which proportion is general, whether SW be positive or negative; it must only in the latter case be supposed to act upward to prevent and overturn.

In the rectangular vessel, of given weight and dimensions, the whole process is so evident, that any further explanation would be unnecessary. In the trapezoidal vessel, after having found the points G and R, let AD, BC be produced until they meet in K. Then since the two sections M M C D, E F D C are equal, the two triangles M M K, E F K are also equal; and therefore the rectangle EK $\times$ BF = KM $\times$ KM = KM²; and since the angle of inclination is supposed to be known, the angles at E and F are given. Consequently, if a mean proportional be found between the sines of the angles at E and F, we shall have the following proportions:

As the mean proportional thus found : sine $\angle E$:: KM : KF,
And as the said mean proportional : sine $\angle F$:: KM : KE;
therefore ME, MF become known; from whence the area of either triangle M X E or M X F, the distance $n n$, and all the other requisites may be found.

In the mixtilineal section, let AB = 9 feet = 108 inches, the whole depth = 6 feet = 72 inches, and the altitude of M M the line of floatation 4 feet or 48 inches; also let the two curvilinear parts be circular quadrants of 2 feet, or 24 inches radius each. Then the area of the two quadrants = 904.7808 square inches, and the distance of their centres of gravity from the bottom = 13.8177 inches very nearly; also the

the area of the included rectangle $abie = 1440$ square inches, and the altitude of its centre of gravity 12 inches; in like manner the area of the rectangle $ABcd$ will be found $= 5184$ square inches, and the altitude of its centre of gravity 48 inches; therefore we shall have

Momentum of the 2 quadrants $= 904.7808 \times 13.8177 = 12501.98966016$	
Momentum of the rectan. $abie = 1440 \times 12 = 17280$	
Momentum of the rectan. $ABcd = 5184 \times 48 = 248832$	
7528.7808	278613.98966016

Now the sum of the momenta divided by the sum of the areas will give $\frac{278613.98966016}{7528.7808} = 37.006$ inches, the altitude of G the centre of gravity of the section $ABCD$ above the bottom. In like manner the altitude of R the centre of gravity of the section $MMCD$ will be found to be equal $\frac{123093.98966061}{4936.7808} = 24.934$ inches; and consequently their difference, or the value of $GR = 12.072$ inches, will be found.

Suppose the vessel to heel 15° , and we shall have the following proportion, namely, As radius : tangent of $15^\circ :: MX = 54$ inches : 14.469 inches $= ME$ or MF ; and consequently the area of either triangle MXE or $MXF = 390.663$ square inches. Therefore, by theorem 4th, As $4936.7808 : 390.663 :: 72 = mn = \frac{2}{3} AB : 5.6975$ inches $= RT$; and again, As radius : sine of $15^\circ :: 12.072 = GR : 3.1245$ inches $= RN$; consequently $RT - RN = 5.6795 - 3.1245 = 2.553$ inches $= SW$ the stability required.

Moreover, As the sine of 15° : radius $:: 5.6975 = RT : 22.013 = RS$, to which if we add 24.934 , the altitude of the point R , we shall have 46.947 for the height of the metacentre, which taken from 72 , the whole altitude, there remains 25.053 ; from which and the half width $= 54$ inches, the distance BS is found $= 59.529$ inches very nearly,

nearly, and the angle $SBV = 80^{\circ} - 06' - 42''$; from whence $SV = 58.645$ inches.

Again : Let us suppose the mean length of the vessel to be 40 feet, or 480 inches, and we shall have the weight of the whole vessel equal to the area of the section $MMCD = 4936.7808$ multiplied by 480 = 2369654.784 cubic inches of water, which weighs exactly 85708 pounds avoirdupoise, allowing the cubic foot to weigh 62.5 pounds.

And, finally, as $SV : SW$ (*i. e.*) as $58.645 : 2.573 :: 85708 : 3760+$, the weight on the gunwale which will sustain the vessel at the given inclination. Therefore a vessel of the above dimensions, and weighing 38 tons, 5 cwts. 28 lbs. will require a weight of 1 ton, 13 cwts. 64 lbs. to make her incline 15° .

In this example the deflecting power has been supposed to act perpendicularly on the gunwale at B; but if the vessel is navigated by sails, the centre velique must be found; with which, and the angle of deflection, the projected distance thereof on the line SV may be obtained; and then the power, calculated as above, necessary to be applied at the projected point, will be that part of the wind's force which causes the vessel to heel. And conversely, if the weight and dimensions of the vessel, the area and altitude of the sails, the direction and velocity of the wind be given, the angle of deflection may be found.

X. *New Method of freeing Molasses from their sharp Taste, and rendering them fit to be used instead of Sugar.* From Crell's Chemical Annals, 1798, Vol. I. Part 2.

CADET DEVAUX, according to the experiments made by Lowitz, gives the following method : Take twenty-four pounds of molasses, twenty-four pounds of water, and six pounds of charcoal coarsely pulverised; and having mixed them in a kettle, boil the whole over a slow wood fire.

When