dissipated. The exact equality between the + and - pressures no longer exists, and the body experiences a definite resistance which it would not do if the fluid were infinite in all directions.

“It is clear, moreover, that the nearer the moving body approaches the surface the greater are the differences of pressure to be satisfied, the greater will be the waves formed, and the greater the dissipation of energy. Thus, for example, a fish will experi­ence an increase of resistance as its path lies nearer to the surface, the train of waves it creates becoming then a visible accompani­ment of its progress. *A fortiori,* when the body moves along the surface as a ship does on water, those differences of pressure which would exist during the motion if the fluid were infinite in all directions satisfy themselves in still larger waves, which, in fact, are the waves which accompany the body in its motion. The waves which thus visibly accompany a vessel *in transitu* form a marked phenomenon in river steaming. Thus we see how, although in a perfect fluid extended infinitely in all directions, a body, when once put in motion, would move absolutely without resistance, yet, when the fluid is bounded by a gravitating surface at or near the line of motion, the body will experience resistance by the formation of waves, notwithstanding that the fluid is a perfect one.

“If the fluid is again supposed to be infinite in all directions, but imperfect, the phenomena previously described undergo appropriate modifications, and the moving body will also suffer a specific resistance,—in the first place by its having to overcome the friction and viscosity of those particles of the fluid with which it is in contact, and next because the friction of the surrounding particles *inter se* destroys that orderly arrangement of the stream-line con­figuration which allows of the energy imparted to the particles being returned without loss. If the supposed imperfect fluid is bounded by a free surface, as already described, and the body moves at or near this surface, it will experience resistances depend­ing on fluid friction, almost exactly in the same manner as if the fluid were infinite in all directions. It will also experience very nearly the same resistance in virtue of the wave-making action as in the perfect fluid ; and we here see the two sources of resistance existing independently of each other, and due to totally different causes.

Important as the question is as to the effect of form upon resist­ance, that of its effect upon stability or steadiness at sea is even more so. Before the use of steam for the propulsion of ships the speed which could be attained in seagoing ships by sail power was largely a question of stability or power to carry a large spread of canvas without inclining or “ heeling ” too greatly. Small differences in the form of the transverse sections of the ship in the region of the load water-line and under water were influential in this respect, and naval constructors occupied themselves greatly with such ques­tions. The form of the problem completely changes when the pro­pelling power is no longer an upsetting force. The important questions in steam ships are the proportions of length, breadth, and depth ; the form of “entrance’’ and “run” ; the construction of propelling machinery within the ship ; and the proportions, form, and number of revolutions of the propeller. But, while this is so, the effect of the stability of the steamship upon her behaviour at sea, as a question of rolling or “labouring,” remains very great. There are, moreover, a very large number of seagoing ships still dependent upon sails for their propulsion, and the question of sailing power is very important in vessels employed on our coasts for commerce and for pleasure. The latest and most complete in­vestigation of questions of stability is to be found in Sir Edward J. Reed’s recently published work, *The Stability of Ships.* There is a more popular exposition of the subject by Mr W. H. White, director of naval construction, in his *Manual of Naval Architecture* (1877, 2d ed. 1882), of which use has been made in the following pages.

A ship floating freely and at rest in still water displaces a volume of water exactly equal in weight to her own weight. The circum­stances of the water in which she floats are in fact the same whether the cavity made in the water by the ship is filled by the ship as in fig. 2, or by a volume of water having the same weight as the ship (fig. 3).

When the ship oc­

cupies the cavity

the whole of her

weight may be sup­

posed to be con­

centrated at her

centre of gravity,

G, fig. 2, and to act vertically downwards. When the cavity is filled with water its weight, called in relation to the ship the “displacement,” may be supposed to be concentrated at B, fig. 3, which is the centre of gravity of the “displacement” or of the displaced water. This centre of gravity is usually known in relation to the ship as the “centre of buoyancy.” The weight of this water may be supposed to be concentrated at B, and to act vertically downwards. As this water would remain in the cavity at rest, its downward' pressure must be balanced by equal upward

pressures, that is by the buoyancy of the surrounding water. These upward pressures must act in the same way as if there were a single pressure equal and opposite to the weight of the water, and acting through the “centre of buoyancy." In fig. 2 a ship is represented floating freely and at rest in still water. Her total weight may be supposed to act vertically downwards through the centre of gravity G, and the buoyancy vertically upwards through the centre of buoyancy. The second condition which the ship floating freely and at rest in still water will always satisfy is there­fore said to be that her centre of gravity will lie in the same vertical line with the centre of gravity of the volume of water which she displaces. So long as the ship rests under the action of these opposing and balanced forces the line joining the centres B and G is vertical and represents the common line of action of the weight and buoyancy. There are of course horizontal fluid pres­sures acting upon her, but these are balanced among themselves.

The ship may be floating at rest, but under constraint, and not freely. There may be the pressure of wind on the sails, or the strain of a rope holding her in a position of rest although the centres B and G are no longer in the same vertical line. Fig. 4 represents such a case.

The vessel is at rest,

but there is some ex-

ternal force operating

other than that of

buoyancy ; and the

equal and opposite

forces of the weight

and buoyancy act in

different vertical lines,

and no longer balance

each other. They

form a mechanical

“couple,” tending to

move the ship from

the position of con­

strained rest in which

she is shown. If W

represents the total

weight of the ship (in

tons), and *d* the per­

pendicular distance between the parallel lines of action of the weight and buoyancy (in feet), then the operative moment of the “couple” is represented by the product of the two quantities W and *d,* mea­sured in foot-tons. If the constraint is removed, and the vessel is freed from all external forces save those of the fluid in which she floats, she will move under the operation of the “couple” towards the upright position until the consequent alteration in the form of the cavity of the displacement brings the centre of buoyancy into the same vertical with the centre of gravity of the ship. What has been illustrated by reference to transverse inclination of the ship is equally true of oblique or longitudinal inclinations. If the position of the weights in the ship remains unaltered under such changes of inclination the centre of gravity remains unaltered. In all calcula­tions it has to be assumed that the centre of gravity is a fixed point in the ship, and that movable weights will be secured in the ship. With this assumption the position of the centre of gravity of a ship can be correctly assigned by calculation, small disturbances caused by movements of men, &c., not being large enough to be appreciable.

The statical stability of a ship may be defined as the effort which she makes when inclined steadily by external forces to overcome the constraint and return to the position in which she floats freely, at or near the upright. This effort, as already explained, depends upon the position of the centre of buoyancy B, or the distance from the vertical line through G which the altered form of the cavity of the displacement has caused it to assume. It may always be measured by the product of the two quantities W (in tons) and *d* (in feet) (see fig. 4). This product in foot-tons is known as the “moment of statical stability ” for the particular angle of inclina­tion and corresponding position of B which are assumed. A little reflexion will show that when large angles of inclination are reached the centre B ceases to recede from the vertical through the centre of gravity of the ship, but will, as the inclination increases, approach this vertical line, and eventually pass to the other side of it.

The moment of statical stability is at its maximum when the distance *d* is greatest. The angle which the ship has reached when the centre B has reached this point is called the “ angle of maximum stability.” As the centre B travels backwards from this position with the increasing inclination of the ship the dis­tance *d* decreases and the righting power of the ship decreases pro­portionately. When B passes the vertical line through G the moment of stability changes its character and becomes an upset­ting force, which will continue to act until the ship reaches a new position of rest, usually bottom upwards. The angle which the ship reaches before this change takes place, *i.e.,* when B passes to the other side of the vertical line through G, is called the “ angle of vanishing stability” and it indicates the ship’s “range of