the taking away of the mizen-topſail. But we choſe to give the whole mechanical inveſtigation; becauſe it gave us an opportunity of pointing out to the reader, in a case of very eaſy comprcheiiſion, the preciſe man­ner in which the ſhip is acted on by the different sails and by the water, and what ſhare each of them has in the motion ultimately produced. We ſhall not repeat this manner of procedure in other cases, becauſe a little reflection on the part of the reader will now enable him to trace the *modus operandi* through all its ſteps.

We now see that, in reſpect both of progreſſive mo­tion and of converſion, the ſhip is affected by shivering the sail D, in the same manner as if a force equal and oppoſite to D *d* were applied at D, or at any point in the line D*d.* We must now have recourse to the prin­ciples established under the article Rotation.

Let p repreſent a particle of matter, r its radius vec­tor, or its diſtance p G from an axis paſſing through the centre of gravity G, and let M repreſent the whole quantity of matter of the ſhip. Then its momentum of inertia is = Sp*×* r2 *(See* Rotation, n⁰ 18.) The ſhip, impelled in the point D by a force in the direc­tion *dD,* will begin to turn round a ſpontaneous verti­cal axis, paſſing through a point S of the line *q*G, which is drawn through the centre of gravity G, per­pendicular to the direction *d*D of the external force, and the diſtance GS of this axis from the centre of gravity is = *L —*— (ſee Rotation, n⁰ 96.), and it is M ∙ Gq and it is taken on the oppoſite side of G from y, that is, S and *q* are on oppoſite ſides of G.

Let us expreſs the external force by the ſymbol F. It is equivalent to a certain number of pounds, being the preſſure of the wind moving with the velocity V and inclination a on the surface of the ſail D; and may therefore be computed either by the theoretical or ex­perimental law of oblique impulſes. Having obtained this, we can aſcertain the angular velocity of the rota­tion and the abſolute velocity of any given point of the ſhip by means of the theorems eſtabliſhed in the article Rotation.

But before we proceed to this inveſtigation, we ſhall conſider the action of the rudder, which operates preciſely in the ſame manner. Let the ſhip AB (fig. 11.) have her rudder in the poſition AD, the helm being hard a-ſtarboard, while the ſhip sailing on the ſtarboard tack, and making leeway, keeps on the courſe *ab.* The lee ſurface of the rudder meets the water obliquely. The very foot of the rudder meets it in the direction DE parallel to *ab.* The parts farther up meet it with various obliquities, and with various velo­cities, as it glides round the bottom of the ſhip and falls into the wake. It is abſolutely impoſſible to cal­culate the accumulated impulſe. We ſhall not be far miſtaken in the deflection of each contiguous filament, as it quits the bottom and glides along the rudder; but we neither know the velocity of theſe filaments, nor the deflection and velocity of the filaments gliding without them. We therefore imagine that all compu­tations on this ſubject are in vain. But it is enough for our purpoſe that we know the direction of the abſolute preſſure which they exert on its ſurface. It is in the direction D*d,* perpendicular to that ſurface. We alſo may be confident that this preſſure is very considerable, in proportion to the action of the water on the ſhip’s bows, or of the wind on the ſails; and we may ſuppoſe it to be nearly in the proportion of the ſquare of the velocity of the ſhip in her courſe; but we can­not affirm it to be accurately in that proportion, for reaſons that will readilv occur to one who conſiders the way in which the water falls in behind the ſhip.

It is obſerved, however, that a fine ſailer always ſteers well, and that all movements by means of the rudder are performed with great rapidity when the velocity of the ſhip is great. We ſhall ſee by and bv, that the ſpeed with which the ſhip performs the angu­lar movements is in the proportion of her progreſſive velocity: For we ſhall ſee that the ſquares of the times of performing the evolution are as the impulſes inverſely, which are as the ſquares of the velocities. There is perhaps no force which acts on a ſhip that can be more accurately determined by experiment than this. Let the ſhip ride in a ſtream or tideway whoſe velocity is accurately meaſured; and let her ride from two moor­ings, ſo that her bow may be a fixed point. Let a ſmall tow-line be laid out from her item or quarter at right angles to the keel, and connected with ſome ap­paratus fitted up on ſhore or on board another ſhip, by which the ſtrain on it may be accurately meaſured; a person conversant with mechanics will ſee many ways in which this can be done. Perhaps the following may be as good as any: Let the end of the tow-line be fixed to ſome point as high out of the water as the point of the ſhip from which it is given out, and let this be very high. Let a block with a hook be on the rope, and a conſiderable weight hung on this hook. Things be­ing thus prepared, put down the helm to a certain angle, ſo as to cauſe the ſhip to ſheer off from the point to which the far end of the tow-line is attached. This will ſtretch the rope, and raiſe the weight out of the water. Now heave upon the rope, to bring the ſhip back again to her former poſition, with her keel in the direction of the ſtream. When this poſition is attained, note care­fully the form of the rope, that is, the angle which its two parts make with the horizon. Call this angle *a.* Every perſon acquainted with theſe ſubjects knows that the horizontal ſtrain is equal to half the weight multi­plied by the cotangent of a*,* or that 2 is to the co­tangent of *a* as the weight to the horizontal ſtrain. Now it is this ſtrain which balances and therefore meaſures the action of the rudder, or D*e* in fig. 11. There­fore, to have the abſolute impulſe D*d,* we muſt increaſe D*e* in the proportion of radius to the ſecant of the angle *b* which the rudder makes with the keel. In a great ſhip ſailing six miles in an hour, the impulſe on the rudder inclined 30⁰ to the keel is not leſs than 3000 pounds. The ſurface of the rudder of ſuch a ſhip contains near 80 ſquare feet. It is not, however, very neceſſary to know this abſolute impulſe D*d,* be­cauſe it is its part D*e* alone which meaſures the energy of the rudder in producing a conversion. Such expe­riments, made with various poſitions of the rudder, will give its energies correſponding to theſe poſitions, and will ſettle that long diſputed point which is the belt poſition for turning a ſhip. On the hypotheſis that the impulſions of fluids are in the duplicate ratio of the sines of incidence, there can be no doubt that it ſhould make an angle of 54⁰ 44' with the keel. But the form of a large ſhip will not admit of this, becauſe a tiller of a length ſufficient for managing the rudder in sailing