contrary rotation. If the ship under these three sails keeps steadily in her course, without the aid of the rudder, we must have D i × iC + Ee × k C = Ff × mC. This is very possible, and is often seen in a ship under her mizentopsail, main-topsail, and fore-topsail, all parallel to one another, and their surfaces duly proportioned by reefing. If more sails are set, we must always have a similar equili­brium. A certain number of them will have their efforts di­rected from the larboard arm of the lever *im* lying to leeward of CI, and a certain number will have their efforts directed from the starboard arm lying to windward of CI. The sum of the products of each of the first set, by their distances from C, must be equal to the sum of the similar products of the other set. As this equilibrium is all that is necessary for preserving the ship’s position, and the cessation of it is immediately follow­ed by a conversion ; and as these states of the ship may be had by means of the three square sails only, when their sur­faces are properly proportioned, it is plain that every move­ment may be executed and explained by their means. This will greatly simplify our future discussions. We shall there­fore suppose in future that there are only the three topsails set, and that their surfaces are so adjusted by reefing, that their actions exactly balance each other round that point C of the middle line AB, where the actions of the water on the different parts of her bottom in like manner balance each other. This point C may be differently situated in the ship according to the leeway she makes, depending on the trim of the sails ; and therefore although a certain proportion of the three surfaces may balance each other in one state of leeway, they may happen not to do so in another state. But the equilibrium is evidently attainable in every case, and we therefore shall always suppose it.

Il must now be observed, that when this equilibrium is destroyed, as, for example, by turning the edge of the mizen-topsail to the wind, which the seamen call *shivering* the mizen-topsail, and which may be considered as equiva­lent to the removing the mizen-topsail entirely, it does not follow that the ship will turn round the point C, this point remaining fixed. The ship must be considered as a free body, still acted on by a number of forces, which no longer balance each other ; and she must therefore *begin* to turn round a spontaneous axis of conversion, which must be de­termined in the way set forth in the article Rotation. It is of importance to point out in general where this axis is situated. Therefore let G

(fig. 10.) be the centre of

gravity of the ship. Draw

the line *q* G *v* parallel to the

yards, cutting Dd in *q, Ee*

in r, CI in *t,* and *Ef* in *v*.

While the three sails are set,

the line *q v* may be consider­

ed as a lever acted on by

four forces, *viz.* D*d* impell­

ing the lever forward per­

pendicularly in the point *q ;*

Ee, impellingit forward in the point *r; Ef,* impelling it for­ward in the point *v;* and CI, impelling it backward in the point *r.* These forces balance each other both in respect of progressive motion and of rotatory energy : for CI was taken equal to the sum of Dd, Ee, and *Ef;* so that no ac­celeration or retardation of the ship’s progress in her course is supposed.

But by taking away the mizen-topsail, both the equili­briums are destroyed. A part D*d* of the accelerating force is taken away ; and yet the ship, by her inertia or inherent force, tends, for a moment, to proceed in the direction *Cp* with her former velocity ; and by this tendency exerts for a moment the same pressure CI on the water, and sustains the same resistance IC. She must therefore be retarded in her motion by the excess of the resistance IC over the re­

maining impelling forces Ee and *Ef,* that is, by a force equal and opposite to Drf. She will therefore be retarded in the same manner as if the mizen-topsail were still set, and a force equal and opposite to its action were applied to G, the centre of gravity, and she would soon acquire a smaller ve­locity, which would again bring all things into equilibrium ; and she would stand on in the same course, without chang­ing either her leeway or the position of her head.

But the equilibrium of the lever is also destroyed. It is now acted on by three forces only, viz. Ee and I·’/,' impelling it forward in the points *r* and *v,* and IC impelling it back­ward in the point *t.* Make *rv: r* o=Ee + *Ff: Ff,* and make *op* parallel to CI and equal to Ee+Ff Then we know, from the common principles of mechanics, that the force *op* acting at *o* will have the same momentum or energy to turn the lever round *any* point whatever as the two forces Ee and *Ef* applied at *r* and *v ;* and now the lever is acted on by two forces, viz. IC, urging it backwards in the point *t,* and *o p* urging it forwards in the point *o.* It must therefore turn round like a floating log, which gets two blows in op­posite directions. If we now make IC—*op: opz=to: tx,* or IC—*op: IC=to: ox,* and apply to the point *x* a force equal to IC—o *p* in the direction IC ; we know by the com­mon principles of mechanics, that this force IC—*op* will produce the same rotation round any point as the two forces IC and o *p* applied in their proper directions at *t* and *o.* Let us examine the situation of the point *x.*

The force IC—*op* is evidently =Dd, and *op* is=Ee+ *Ef.* Therefore *ot : t* ∙x=D *d: ο p.* But because, when all the sails were filled, there was an equilibrium round C, and therefore round *r,* and because the force *op* acting at *o* is equivalent to E e and F *f* acting at *r* and *v,* we must still have the equilibrium ; and therefore we have the momentum Dd × *qt* = op × ot. Therefore *or: r q—Dd: op,* and *tq —tx.* Therefore the point *x* is the same with the point *q.*

Therefore, when we shiver the mizen-topsail, the rotation of the ship is the same as if the ship were at rest, and a force equal and opposite to the action of the mizen-topsail were applied at *q* or at D, or any point in the line Dy.

This might have been shown in another and shorter way. Suppose all sails filled, the ship is in equilibrio. This will be disturbed by applying to D a force opposite to D *d;* and if the force be also equal to Dd, it is evident that these two forces destroy each other, and that this application of the force *dD* is equivalent to 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 comprehension, 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 *Dd* were applied at D, or at any point in the line Dd. We must now have recourse to the principles established under the article RotatioN.

Let ∕> represent a particle of matter, r its radius vec­tor, or its distance pG 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 = *∫p∙r2,* (see RotatioN, No. 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 ex-