with great velocity has not room to deviate above 30⁰ from the direction of the keel; and in this poſition of the rudder the mean obliquity of the filaments of wa­ter to its ſurface cannot exceed 40⁰ or 45⁰. A greater angle would not be of much ſervice, for it is never for want of a proper obliquity that the rudder sails of producing a conversion.

A ſhip miſſes stays in rough weather for want of a Sufficient progreſſive velocity, and becauſe her bows are beat off by the waves: and there is ſeldom any diffi­culty in wearing the ſhip, if ſhe has any progreſſive motion. It is, however, always deſirable to give the rudder as much influence as poſſible. Its ſurface ſhould be enlarged (eſpecially below) as much as can be done consiſtently with its ſtrength and with the power of the steerſmen to manage it; and it ſhould be put in the moſt favourable ſituation for the water to get at it with great velocity; and it ſhould be placed as far from the axis of the ſhip’s motion as poſſible. Theſe points are obtained by making the ſtern-poſt very upright, as has always been done in the French dockyards. The Britiſh ſhips have a much greater rake; but our builders are gradually adopting the French forms, experience ha­ving taught us that their ſhips, when in our posseſſion, are much more obedient to the helm than our own.— In order to afcertain the motion produced by the ac­tion of the rudder, draw from the centre of gravity a line *Gq* perpendicular to *Dd*  (Dd being drawn thro’ the centre of effort of the rudder). Then, as in the conſideration of the action of the sails, we may conceive the line *q*G as a lever connected with the ſhip, and im­pelled by a force D*A* acting perpendicularly at *q.* The consequence of this will be, an incipient converſion of the ſhip about a vertical axis paſſing through ſome point S in the line *q*G, lying on the other side of G from *q;* and we have, as in the former caſe, GS = M ∙ Gy

Thus the action and effects of the ſails and of the rudder are perfectly ſimilar, and are to be conſidered in the same manner. We fee that the action of the rud­der, though of a ſmall ſurface in compariſon of the ſails, must be very great: For the impulſe of water is many hundred times greater than that of the wind; and the arm qG of the lever, by which it acts, is incomparably greater than that by which any of the impulsions on the ſails produces its effect; accordingly the ſhip yields much more rapidly to its action than ſhe does to the la­teral impulſe of a ſail.

Obſerve here, that if G were a fixed or ſupported axis, it would be the ſame thing whether the abſolute force D*d* of the rudder acts in the direction D*d,* or its tranſverſe part D*e* acts in the direction De, both would produce the ſame rotation; but it is not ſo in a free body. The force D*d* both tends to retard the ſhip’s motion and to produce a rotation: It retards it as much as if the ſame force D*d* had been immediately applied to the centre. And thus the real motion of the ſhip is compounded of a motion of the centre in a di­rection parallel to *Dd,* and of a motion round the centre. Theſe two constitute the motion round 8.

As the effects of the action of the rudder are both more remarkable and somewhat more simple than thoſe of the ſails, we ſhall employ them as an example of the mechaniſm of the motions of converſion in general; and as we muſt content ourſelves in a work like this with what is very general, we ſhall simplify the inveſtigation by attending only to the motion of converſion. We can get an accurate notion of the whole motion, if want­ed for any purpoſe, by combining the progreſſive or retrograde motion parallel to Dd with the motion of rotation which we are about to determine.

In this caſe, then, we obſerve, in the firſt place, that the Db ∙ qG; angular velocity (ſee Rotation, no 22.) is

and, as was ſhown in that article, this velocity of rota­tion increaſes in the proportion of the time of the forces uniform action, and the rotation would be uniformly ac­celerated if the forces did really act uniformly. This, however, cannot be the caſe, becauſe, by the ſhip’s change of poſition and change of progreſſive velocity, the direction and intenſity of the impelling force is con­tinually changing. But if two ſhips are performing ſimilar evolutions, it is obvious that the changes of force are ſimilar in ſimilar parts of the evolution. Therefore the conſideration of the momentary evolution is ſufficient for enabling us to compare the motions of ſhips actuated by ſimilar forces, which is all we have in view at preſent.

The velocity *v,* generated in any time *t* by the con­tinuance of an invariable momentary acceleration (which is all that we mean by ſaying that it is produced by the action of a constant accelerating force), is as the acce­leration and the time jointly. Now what we call the *angular velocity* is nothing but this momentary accele­ration. Therefore the velocity *v* generated in the time

F ∙ qG

"sv777''

The expreſſioivof the angular velocity is alſo the expreſſion of the velocity *v* of a point ſituated at the distance 1 from the axis G.

Let z be the ſpace or arch of revolution deſcribed in the time *t* by this point, whoſe diſtance from G is

f∙qg

= 1. Then z = *ν t = jyf^ tti* and taking the F ∙ qG

fluent z = — t2*.* This arch meaſures the whole

A\*

angle of rotation accompliſhed in the time *t.* Theſe are therefore as the ſquares of the times from the begin­ning of the rotation.

Thoſe evolutions are equal which are meaſured by equal arches. Thus two motions of 45 degrees each are equal. Therefore becauſe *z* is the ſame in both,

F∙q G

the quantity *~Γ t* 2 is a constant quantity, and t2 is F ∙ *q* G

reciprocally proportional tθyy r\* ’ or is proportional

to *ſMy y* and *t* is proportional to ∖ That

F∙qG √F∙qG

is to ſay, the times of the ſimilar evolutions of two ſhips are as the ſquare root of the momentum of iner­tia directly, and as the ſquare root of the momentum of the rudder or ſail inverſely. This will enable us to make the compariſon eaſily. Let us ſuppoſe the ships perfectly ſimilar in form and rigging, and to differ only in length L and l : SP ∙ R2 is to Spr2 as L5 to l5.