We see, in the first place, that the velocity of the ship is, *cœteris paribus,* proportional to the velocity of the wind, and to the sine of its incidence on the sail jointly ; for while the surface of the sail S and the equivalent surface for the bow remains the same, *v* increases or diminishes at the same rate with V∙ sin. *a.* When the wind is right astern, the sine

V

of *a* is unity, and then the ship’s velocity is ——=

*∕ m* A

\*z^s^+1∙

Note, that the denominator of this fraction is a common number ; for *m* and *n* are numbers and A and S being

a

quantities of one kind, — is also a number.

o

Γt must also be carefully attended to, that S expresses a quantity of sail actually receiving wind with the inclination *a.* It will not always be true, therefore, that the velocity will increase as the wind is more abaft, because some sails will then becalm others. This observation is not, however, of great importance ; for it is very unusual to put a ship in the situation considered hitherto ; that is, with the yards square, unless she be right before the wind.

If we should discover the relation between the velocity and the quantity of sail in this simple case of the wind right

V

aft, observe that the equation *v— — -* gives us

//nA

+b

//nA 1 ∕znA ,r ,mA , √v »

√ —=■ o-l-c=V, and √ —— *v—\ —v,* and —-r ci=V—*v ,*

*nS* nS «S

and —- — — ; and because *n* and *m* and A are con-

ιzιA (V—o)2

β\*

stant quantities, S is proportional to —-p, or the sur­face of sail is proportional to the square of the ship’s velo­city directly, and to the square of the relative velocity in­versely. Thus, if a ship be sailing with one-eighth of the velocity of the wind, and we would have her sail with one- fourth of it, we must quadruple the sail. This is more easi­ly seen in another way. The velocity of the ship is propor­tional to the velocity of the wind ; and therefore the rela­tive velocity is also proportional to that of the wind, and the impulse of the wind is ns the square of the relative ve­locity. Therefore, in order to increase the relative velocity by an increase of sail only, we must make this increase of sail in the duplicate proportion of the increase of velocity.

Let us, in the next place, consider the motion of a ship whose sails stand oblique to the keel.

The construction for this purpose differs a little from the former, because, when the sails are trimmed to any oblique position DCB, (figs. 5 and C), there must be a deviation from the direction of the keel, or a leeway BC*b*. Call this *x.* Let CF be the velocity of the ship. Draw, as before, E*g* per­pendicular to the yard, and FG perpendicular to Ε*g* also, draw FH perpendicular to the yard: then, as before, EG, which is in the subduplicate ratio of the impulse

on the sail, is equal to E*g*

*—Gg.* Now E*g* is, as be­fore, = V ×sin.a, and G*g* is equal to FH, which is = CF ×sin.FCH,or=v× sin.(b+x). Therefore we have the impulse =nS(V∙ sin. a*—v ∙* sin. (b + x))2.

This expression of the impulse is perfectly simi­lar to that in the former case, its only difference consisting in the subduc- tive part, which is here

*v* × sin. *∣>+ x* instead of

*v.* But it expresses

the same thing as be­

fore, viz. the diminu­

tion of the impulse. The

impulse being reckon­

ed solely in the direc­

tion perpendicular to

tlιe sail, it is diminished

solely by the sail with­

drawing itself *in that di­*

*rection* from the wind ;

and as *g*E may be con­

sidered as the real impulsive motion of the wind, GE must be considered as the relative and effective impulsive mo­tion. The impulse would have been the same had the ship been at rest, and had the wind met it perpendicularly with the velocity GE.

We must now show the connexion between this impulse and the motion of the ship. The sail, and consequently the ship, is pressed by the wind in the direction CI perpendi­cular to the sail or yard with the force which we have just now determined. This (in the state of uniform motion) must be equal and opposite to the action of the water. Draw IL at right angles to the keel. The impulse in the direction CI (which we may measure by CI) is equivalent to the im­pulses CL and LI. By the first the ship is impelled right forward, and by the second she is driven sideways. There­fore we must have a leeway, and a lateral as well as a direct resistance. We suppose the form of the ship to be known, and therefore the proportion is known, or discoverable, be­tween the direct and lateral resistances corresponding to every angle *x* of leeway. Let A be the surface whose per­pendicular resistance is equal to the direct resistance of the ship corresponding to the leeway *x,* that is, whose resistance is equal to the resistance really felt by the ship’s bows in the direction of the keel when she is sailing with this lee­way ; and let B in like manner be the surface whose per­pendicular resistance is equal to the actual resistance to the ship’s motion in the direction LI, perpendicular to the keel. (This is not equivalent to A' and B' adapted to the rec­tangular box, but to A'· cos. *2x* and B'∙ sin. *ix).* We

CL· ∙ B

have therefore A : B=CL : LI, and LI= —-—. Also, *A*

because CIz=χ∕CL2 + LI2, we have A : ⅛∕A2 + B2=CL :

CI, and CI= -*~~b~~ ~~\*l⅛ +~~* The resistance in the di- A

rection LC is properly measured by m A v2 as has been al­ready observed. Therefore the resistance in the direction 1C must be expressed by *m.J*A\* + B2∣o2 ; or (making C the

surface which is equal tox∕A2-∣-B2, and which will there­fore have the same perpendicular resistance to the water having the velocity *v*) it may be expressed by *m*Cv2.

Therefore, because there is an equilibrium between the impulse and resistance, we have mCv2=nS(V ∙ sin. *a—v∙*

sin.0+ar)2,and - Co2, or yCc2=S(V∙ sin. *a—ν ∙ sin.6-⅜-x)2, n*

and √y√Co=√S(V∙ sin. *a*—o∙ sin. *b+x)∙*

Therefore o = VS-V·\*»·« r,

*J q .J C +* √ S ■ sin. *b -(- x*

V ■ sin. *α xτ* Sin. *a*

*IQ* ΞΣΞΣΞ ∕Q ———~

^i√s + 8in'\*+x + sin∙6+x∙

Observe that the quantity which is the coefficient of V in this equation is a common number ; for sin. *a* is a num­ber, being a decimal fraction of the radius i, sin. *b* -p *x* is also a number, for the same reason. And since *m* and w