

II. *Animadversions upon some Experiments relating to the Force of moving Bodies ; with two new Experiments on the same Subject. By the Reverend Dr. Desaguliers, F. R. S.*

IN a former Paper \* I demonstrated, by Reason and Experiments, that the *Momentum*, or Force of moving Bodies, is always proportionable to their Mass multiplied into their Velocity ; as it is the Opinion of the greatest Part of the Mathematicians and Philosophers. Now I come to consider the Experiments, that have led some ingenious Men into an Error, in relation to this Proposition. *Polenus* in his Book † gives an Account of his Experiments relating to this Matter, in these Words : “ I took a Vessel, that had in it congeal’d Tallow six Inches deep, and fix’d it to a level Floor, in such manner, that the Surface of the Tallow, which was flat, should every where be equally distant from the Floor. I had caused to be made two Balls of equal Bigness, the one of Lead, the other of Brass, the last of which was a little hollow in the middle, that it might weigh but one Pound, whilst the other weigh’d two. Suspending these Balls from the Ceiling by Threads, in such manner, that the lighter Ball hung over the Surface of the Tallow, from twice the Height that the heavier Ball did ; I cut the Threads, and the Balls falling perpendicularly upon the Tallow, by their

\* *Philosoph. Transf.* No. 375.

† De Castellis, pag. 56. No. 118.

“ Fall made Pits in the Tallow, that were precisely  
 “ equal: the Ball of one Pound, from the Beginning  
 “ of its Fall, till it came to rest, going through a Space  
 “ express’d by the Number two, produc’d an Effect  
 “ equal to that, which the two Pound Ball did pro-  
 “ duce, in falling thro’ a Space express’d by the Num-  
 “ ber one. It follows therefore, that we may look  
 “ upon it as a settled Truth, That the active Forces  
 “ (*vires vivas*) of falling Bodies are then equal, when  
 “ their proper Weights are in a reciprocal *Ratio* of  
 “ the Spaces, which the said Bodies describe by their  
 “ Fall. And because these Spaces are in the same *Ra-*  
 “ *tio*, as the Squares of the Numbers expressing the Ve-  
 “ locities; it appears by the Experiment, that the  
 “ active Force (*vim vivam*) of the falling Body, is  
 “ that which is made up of the Body itself, multiplied  
 “ into the Space described in the Fall, or into the  
 “ Square of the Number, that expresses the Velocity of  
 “ the Body, at the end of the Motion. This Experi-  
 “ ment I did not only make once, but several times,  
 “ changing the Balls, the Distances, and the Body on  
 “ which they fell; as for example, making use of Clay,  
 “ or of soft Wax: and notwithstanding these various  
 “ ways of trying the Experiments, the Effects were  
 “ constantly the same; which made me easily con-  
 “ clude, that there was always the same Reason in Na-  
 “ ture for this Phenomenon.

Thus far *Polenus*, whose Mistake lies in this; that  
 he estimates the Force of the Stroke of the falling Balls,  
 by the Depth of the Impression made in the Tallow,  
 Clay, Wax, or any yielding Substance. But we must  
 consider, that when two Bodies move with equal Forces,  
 but different Velocities, that, which moves the swiftest,  
 must make the deepest Impression, whilst the slowest  
 Body

Body communicates its Motion to the Clay round about, and therefore does not strike in so deep as the swifter Body, which puts in Motion few Parts of the Clay, besides those that are before it, and which Parts have so much less Time to oppose this Body's Motion, as its Velocity is greater than the other's. To make this plainer, Let us suppose a Door half open, and moving very freely on its Hinges; if a Pistol be fir'd against it, the Ball will go thro' the Door without moving it out of its Place; but if we take a large Weight of Lead, and throw it against the same Door, with the same Force as the Pistol Bullet mov'd, the Door will be remov'd from its Position, and carried out of the Place on its Hinges by the Stroke; because in the first Case, the Motion of the Ball is communicated but to a few Parts of the Door, and in the last it is diffus'd all over it. Nay, the Door will be mov'd by the Stroke, even tho' there should be a prominent Part in the Lead, that should be no bigger than a Pistol-Bullet, in order to strike the Door upon no more of its Surface, than the Bullet had done.

*For illustrating this farther I contriv'd the following Experiment.*

I caus'd a Machine to be made, as represented in *Pl. I. Fig. 1.* consisting of a Base of Wood *AB*, which could be set horizontal by means of three Screws, such as *SS*: Upon this Board, or Base, there stood upright two parallel Boards, about four Inches wide, and four Inches asunder, with the Elbow-piece *EF* sliding behind one of them, so as to raise its upper End *F* to any Height desired. Between these Boards, square Frames of Wood *GG* &c. with Paper extended upon them, could slide in, to the Number of Six, in an horizontal  
Z z 2
Position.

Position. These Paper Diaphragms being thus plac'd, I suspended an Ivory Ball of about one Inch and an half Diameter, weighing something more than an Ounce and an half, by a short Thread, under F, so that its Center of Gravity hung four foot over the first Diaphragm; then cutting the Thread, the Ball fell upon the Paper, and by its perpendicular Stroke broke thro' that Diaphragm, and the three next under it. Then putting so much Lead into the Ball abovemention'd, (which was made hollow for that Purpose) as to make it weigh twice as much as it did before; and bringing down F, to let it fall but from one foot, it broke thro' only two Diaphragms by its Fall. Making the Experiment several times with different Heights, but still keeping the Proportion in Height of four to one, when the Balls were as one and two, the heavy and slowest Ball broke thro' but half the Number of Papers. It happen'd indeed sometimes, that there was some little difference, when the Papers were not equally strong, or equally stretch'd, but the swiftest Ball always broke through more Papers than the slow one.

Now tho' this Experiment does at first seem to confirm *Polenus's* Theory; yet, when duly weigh'd, it proves no such thing. For the lighter Ball does not break thro' more Papers, because it has more Force, or a greater Quantity of Motion, but because each Diaphragm has but half the time to resist the Ball, that falls with a double Velocity, and therefore their Resistance being as the time, as many more of them must be broken by the swift Ball, as by the slow one.

*P. S.* To all the Objectors, that allow the Force of moving Bodies, and their Quantity of Motion to be the same, what has been said in this and my former Paper, seems to be a full Answer; but as there are now some Philosophers, who distinguish that Force from the  
Quantity

Quantity of Motion, I am oblig'd to say something more for the clearing up of that Point.

If I understand them right, they call *vis viva* a Force, whose Effect is sensible, as the Force of Gravity, when it accelerates Bodies in their Fall; and *vis mortua* a Force, which being destroy'd, produces no sensible Effect, as the Force of Gravity acting upon a Weight in one Scale of a Balance, when the Weight cannot descend by reason of a Counterpoise in the other Scale. But certainly no Man, that considers the thing attentively, would make that Distinction. However, since *Polenus* allows, that the Quantity of Motion in Bodies is as the Mass multiplied into the Velocity (or  $MV$ ); but says, that the Force, with which they act, which he distinguishes by the Name of *vis viva*, is as the Mass multiplied into the Square of the Velocity, or  $MVV$ : I have made the following Experiment to shew his Notion to be inconsistent; tho' all the *Phænomena* of unequal Weights applied to a *Statéra*, so as to make an *Æquilibrium*, might serve for that Purpose, if it had not been objected, that the particular Construction of the Machine hinder'd it from agreeing with the suppos'd Theorem, that the Force is as the Matter multiply'd into the Square of the Velocity.

### EXPERIMENT.

Let two Balls, A and B, (*Pl. I. Fig. 2.*) be joyn'd by a String, which going thro' the smooth Hole C of an even Table, and under the Pulley P, suspends a Weight W. It is plain, that upon letting go the Balls A and B, from the Places A and B, they will move towards C with the same Force, because each of them will be drawn towards C by half the Force of the Weight W, whether the Balls be equal, or unequal.

1. The

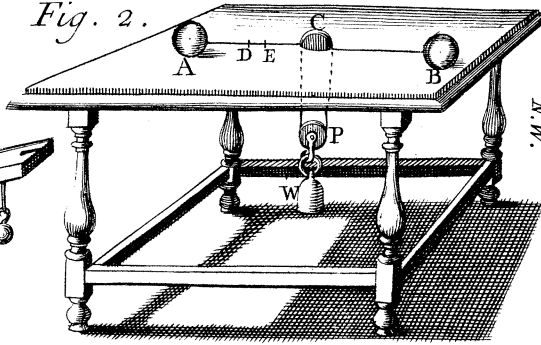
1. The Balls being of two Ounces each (of Ivory), were, at the same instant of Time, let loose from A and B, each distant twelve Inches from C, and both came to C at the same Time. Here the equal Forces will agree with the Product of the Masses into the Velocities, or into the Squares of the Velocities; because  $A \times 12 = B \times 12$ , as well as  $A \times 144$  is equal to  $B \times 144$ .

2. If A be taken of four Ounces Weight, and let go from D, or six Inches, whilst B, still equal to two, moves from 12 Inches; both Bodies will again meet at C: therefore here the equal Forces must be express'd by the Masses into the Velocities, and not into their Squares; for tho'  $A \times 6$  be equal to  $B \times 12$  ( $4 \times 6 = 2 \times 12$ ),  $A \times 6 \times 6$ , or 144 is but half of  $B \times 12 \times 12$ , or 288. Whereas if the Forces had been as *Polenus* affirms, B should have been let loose only from 8.4 Inches.

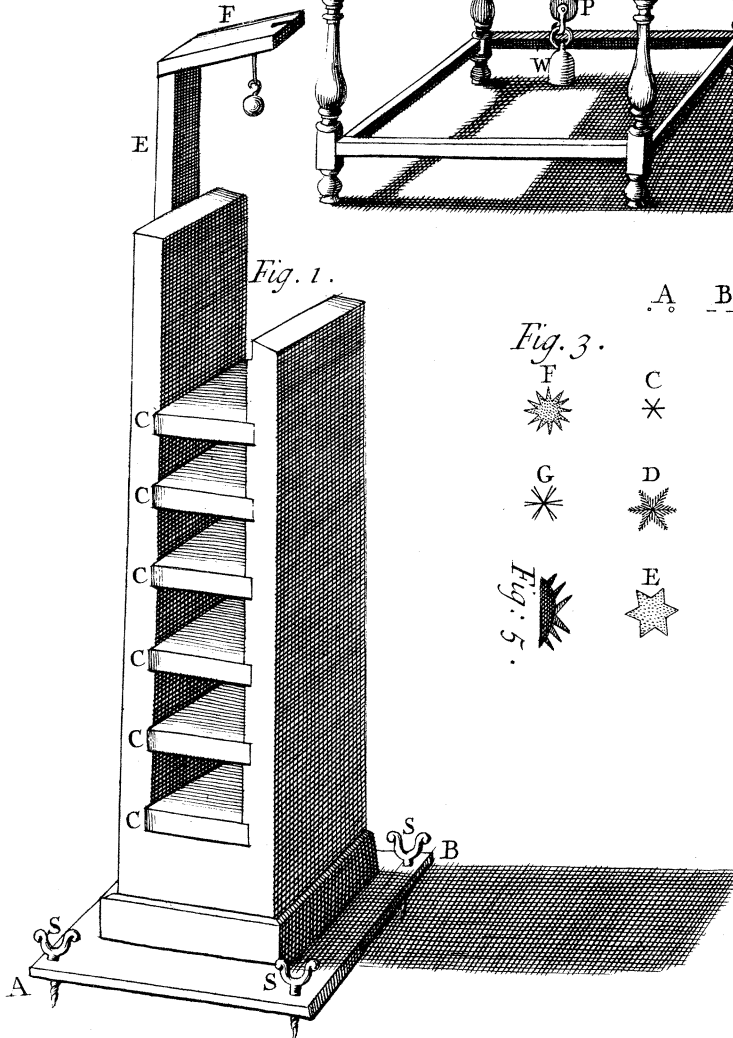
3. When A is six Ounces, it is let loose only from E, or 4 Inches, to meet at C with B let loose from 12; for then  $A \times 4 = B \times 12$ , whilst  $A \times 4 \times 4$ , or 96, is three times less than  $B \times 12 \times 12$ , or 288. So that according to *Polenus*, B must have been let loose from 7; but in that Case it comes sooner to C than A.

*N. B.* The Weight W must be greater than the Weight of both Balls, lest the Friction of the Table should spoil the Experiment.

*Fig. 2.*



*Fig. 1.*



*Fig. 3.*



A B



*Fig. 4.*

