

tively affirm, that he bought the Small Pox when at School, and of such a Lady, now living, and gave her three Pence for the Matter contained in 12 Pustules. That hundreds in this Country have had the Small Pox this way is certain; and it cannot produce one single Instance of their ever having them a second time.

Haverford West,
Feb. 15. 172 $\frac{2}{3}$.

Richard Wright.

IX. *An Account of some Experiments made to prove, that the Force of Moving Bodies is proportionable to their Velocities: (or rather that the Momentum of Moving Bodies is to be found by multiplying the Masses into the Velocities) In Answer to such who have sometime ago affirm'd, that that Force is proportionable to the Square of the Velocity, and to those who still defend the same Opinion. By the Reverend John Theophilus Desaguliers, LL. D. F. R. S.*

AS far as I can learn, Monsieur *Leibnitz* was the first that oppos'd the receiv'd Opinion, concerning the Quantity of the Force of moving Bodies; by saying, that it was to be estimat'd by multiplying the Mass of the Bodies, not by their Velocity, but by the Square of it. But, instead of shewing any Paralogism, in the mathematical Demonstrations, which

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are made use of to prove the Proposition, or any Mistakes in the Reasonings from the Experiments made to confirm it, he uses other *Mediums* to prove his Assertions ^a; and without any Regard to what others had said on that Subject, brings new Arguments, which the Reverend and Learned Dr. *Clark* has fully answered in his fifth Letter to him. Messieurs *John Bernoulli, Wolfius, Hermannus*, and others, have follow'd and defended Monsieur *Leibnitz's* Opinion, and in the same manner, so that what is an Answer to him, is so to them.

Polenus (Professor at *Padua*) has acted after the same manner in the experimental Way, making some Experiments to defend Monsieur *Leibnitz's* Opinion, without having shewn those to be false. which are made use of to prove the contrary ^b; and now lately, an ingenious Professor abroad (who was of the Opinion commonly receiv'd, and in his Writings had demonstrated it in the usual way ^c, confirming it with the common Experiments made in that Case) happening to make some Experiments like those of *Polenus*, has drawn Conclusions from them to shew the Force of moving Bodies to be proportionable to the Square of their Velocity; and being wholly come over to that Opinion, endeavours to deduce it from Physical Principles.

As there can hardly be said any thing new, or better than has been said, to shew the Force abovemention'd to be proportionable to the Mass multiplied into the Velocity; I only repeat here the Substance of what others have said, and make some old Experiments over again; but then I consider some Circum-

^a Acta Erudit. ad ann. 1686. p. 162.
57, &c.

^b Polenus de Castellis, p. 56,
^c Gravesande Introductio, Vol. I. No. 132.

stances, that perhaps have been overlook'd, and at last, by a new Experiment, endeavour to shew, what has led into an Error some of those, who defend the new Opinion.

If a Man with a certain Force can move a Weight of fifty Pounds, through a Space of four Feet, in a determinate time ; it is certain he must employ twice that Force to move one hundred Pounds Weight, through the same Space in the same time. But if he uses but the same Force, he will move the one hundred Pounds Weight but two Feet in the same time. For as the one hundred Pounds Weight contains two fifty Pound Weights, if each of them has two Degrees of Velocity given to it, it will exactly require the same Force that would give one of them four Degrees of Velocity ; hence it appears, that the Force is proportionable to the Mass multiply'd into the Velocity.

E X P E R I M E N T I.

Fig. 1. Let the Balance A B, whose *Fulcrum*, or Center of Motion, is at C, be so divided, that the *Brachium* A C be but the fourth Part of the *Brachium* C B ; it is known to all Mechanicians, that a Weight of one hundred Pounds at A, will keep in *Æquilibrium* a Weight of twenty five Pounds hanging at B, where it will have a Velocity four times greater than that of the Weight at A. For, not only when the Balance is horizontal, there will be an *Æquilibrium*, but when the Balance is put in Motion, it will return to an *Æquilibrium* in an horizontal Position ; the equal and contrary Forces applied at each, destroying one another. Whereas, if the Forces were as the Mass multiply'd into the Square of the Velocity, the twenty five Pound Weight should have been suspended at D, only

twice as far from C, as the Weight at A; and in general, let the make of the Engine be what it will, let the mechanical Powers be combined in any manner, when two heavy Bodies, by means of a Machine, act upon one another in different directions, if their Velocities are reciprocally as their Masses, they will destroy each others Forces and come to rest.

As this is true in respect of mechanical Powers, so it is in respect to the Shock or Blow given by falling Bodies. An heavy Body, falling with an accelerated Motion, goes through a space of one Foot in a quarter of a Second, and acquires a Velocity, which would carry it two Foot in the same Time with an uniform Motion; the same Body falls through a space of four Foot in half a Second, and acquires a Velocity, that would with an uniform Motion carry it eight Foot in half a Second. Therefore, as the Time of the fall through a space of four Foot is twice the Time of a fall through one Foot, the Velocity in the latter Case is double that of the first, and consequently the Blow, that the Body will give, will be double.

E X P E R I M E N T II.

Fig. II. Let the Weight P of one Pound, be placed in the Scale suspended at the end A, of the Ballance AB, which bears upon the *Gnomon*, or Iron Supporter, *k b i*. Then if the Weight C be let fall from D, or one Foot, it will by its Stroke on the end of the Beam B, raise up the opposite end A with the Weight P, so high, that the Spring *g b* will fly from the Button *i*, which kept it streight and upright before the Shock. If the Weight P be of two Pounds, it cannot be raised by the fall of C from any height less than F or four Foot; whereas, if the force of the Shock was proportionable to the Space,

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without any regard to the time, as Monsieur *Leibnitz* and his followers have affirmed, P ought to be raised, when C falls only from E, or two Foot, which never happens ; or, if the Stroke was proportionable to the *Mais* multiplied into the square of the Velocity, when C falls from F, then P might weigh four Pound, whereas the Experiment will never succeed under those Circumstances.

I know it is objected, that the Blow cannot be always direct, and that the String that goes through the hole in the falling Weight, to guide it in its Fall, causes a sensible Friction, and therefore that something of the Force is thereby lost. But we are to observe, that if that was all, there would be no need of raising up C in the second Case quite up to F, instead of E, whereas in Fact, it must always be raised beyond F, to allow for the Friction, that hinders it from producing a double Effect in falling from F. For if the Experiment be repeated an hundred times, the Weight, P when of two Pounds, will never be raised by letting C fall from any place between E and F.

EXPERIMENT III.

If (in order to avoid Friction) instead of a Blow struck upon the end B, by the falling Body, the said Body C be fastned to a pretty long String tied to the button *m*, as at *c*, and first lifted up one Foot, and then let fall ; so that in falling one Foot, it may pull down B, and lift up A with the Weight P of one Pound ; whenever P is two Pounds, C must fall from a height greater than *f* or four Foot, otherwise it will not raise the *Brachium* A, especially if it be let fall between *e* and *f*.

EXPE.

E X P E R I M E N T I V.

I took the Weight C of seventeen Ounces Troy, which was a round ball of Lead with a hole through the middle of it, and having passed the String N-X through it, before it was fastened to the Hook X, I placed the whole Machine in such manner, that the String being stretched by the Weight N, went through the hole of the Weight C, and likewise through the hole of the *Brachium* B, upon which C lay, without touching the sides of the hole either in the Weight or Ballance; then having put such a Weight P in the opposite Scale, as C falling from the height of one Inch, was able to raise high enough, to let loose the Spring *g b* from the Button *i*: I added to P another Weight equal to it, and then letting fall C along the String that guided it, from an height of two Inches, then of three, and then exactly of four, it would not raise the double Weight P to the former height, but falling from five Inches, or a little higher, it raised it up.

E X P E R I M E N T V.

Leaving every thing as it was before, I changed the Weight C for another leaden Ball of twice the Weight, which falling from one Inch, raised the double Weight P to the usual height; then changing the Weight P in any Proportion, whatever height was requir'd for the heaviest Ball C (or C 2) to fall from, in order to raise the Weight at P; more than four times the height was required for the first Ball C, to raise the same Weight so high. as to let loose the Spring.

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E X P E R I M E N T VI.

I tried the Experiment with the Weight C hanging at the String *mc* (as in Experiment III.) and a Fall from an height of five, or near five Inches, was required to raise double the Weight in the opposite Scale, that a fall from one Inch would raise; only here the height above four Inches was not so great as in the former Experiment, the Friction being something less. Then I suspended the great Ball C (or C 2) by the String *mc*, and when by falling one Inch it raised the Weight P, the little Weight C could not produce the same Effect, without falling from a greater height than four Inches.

It is here to be observed, that which way soever these Experiments are tried, the Objections rising from the Friction do no way serve to confirm the new Opinion, because they shew that (upon account of the Friction) the Heights must be something more than in a duplicate Proportion of the Velocities, but never less, to give a Blow with the same Body in Proportion to the Velocity.

That the *Momentum* of Bodies is in Proportion to the Mass multiplied into the Velocity, is also most evidently shewn from the Congress of elastic Bodies, as has been demonstrated by Sir *Isaac Newton* in his *Principia*, in the Corollaries to his Laws of Motion. I had often tried the Experiments there mentioned with Balls of Ivory and Balls of Glass, and some of them with two Balls of Steel, of two Ounces each, and found every thing answer, allowing for the want of perfect Elasticity in the Bodies. But now upon this Occasion, as the Objections to the receiv'd Opinion were renewed, I was willing to repeat the Experiments with the utmost Accuracy; and therefore, as Ivory Balls
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are not equally dense in all their Parts, and Glass Balls break after two or three strokes; I caused Balls to be nicely turned of Steel, and made as hard (as the Workmen call it) that is, as elastick as possible, and the Weights of them were precisely as follows: Two Balls of twelve Ounces Troy each, one of six Ounces, one of three, one of two, and one of Eight-penny-weight. Then making Pendulums of these Balls, and hanging them upon the Machine contrived by *Mariotte* for the Congress of Bodies, and lately improved by *Dr. Gravesande*², I measured $57\frac{1}{2}$ Inches between the Center of Suspension and the Center of Gravity of the Balls, and then every Degree of the Circle they described in their Oscillation was one Inch, and the Degrees being marked upon a line of Chords on a Brass Ruler above the Balls, by their Strings successively covering the cross Lines of Division, the Degrees that the Balls fell from, and those to which they rose, were very discernable to an Eye placed at a convenient Distance.

E X P E R I M E N T VII.

I took the two Balls 12, and removing each from the lowest Point of their equal and respective Circles, up to 4 Inches, or 4 Degrees, I let them fall so that they met at bottom, and were both reflected again to 4, the Place from whence they fell.

E X P E R I M E N T VIII.

Every thing else being as before, instead of one of the Balls 12, I took the Ball 6, then letting 6 go from

² Introd. No. 170. Vol. 1.

8 Degrees, and 12 from 4, after Reflection 12 was driven up again to 4, as before.

EXPERIMENT IX.

The Ball 3 falling from sixteen Degrees met the Ball 12 that fell still from 4, and after Reflection 12 went up again to 4.

EXPERIMENT X.

The Ball 2 falling from 6° and 12 from 1°, 12 was reflected to 1, and when 2 fell from 12 Degrees, and the Ball 12 from 2, the 12 was reflected to 2.

EXPERIMENT XI.

The Ball of eight Penny Weight (which weigh'd but $\frac{1}{3}$ of the Ball 12) falling from fifteen Inches or Degrees, rais'd up 12 (that fell from half a Degree) to the same Place again.

In all these Experiments the Error, or want of perfect Reflection, was greater in the little Balls than in the great ones, on account of their going thro' a greater *Arc* of a Circle, whereby they deviated more from a Cycloid than the great ones; as likewise on Account of the Resistance of the Air, which must be greater because of the little Balls going through a greater *Arc*, moving with more Velocity, being suspended by a String as thick as that of the great ones, and having more Surface in Proportion to their Weight. But all the Errors do not bring the *Phænomena* any thing near what they ought to be, if the Force of the Bodies was as the Square of their Velocities multiply'd into their Masses, for then the Ball 12 would have been driven to Heights very different from what it rose up to.

In the eighth Experiment, the Ball 12 should have risen to near five Inches and three quarters, for the Ball 6 falling with the Velocity, 8 must have had its Force $= 8 \times 8 \times 6 = 384$; and then, that the Ball 12 might have the same Force or Quantity of Motion, it must rise near to 5, 7 because $5,7 \times 5,7 \times 12 = 389,88$.

In the ninth, 12 should have risen to 8; for the Ball 3 must have had its Force $= 16 \times 16 \times 3 = 768$, and if 12 receiv'd its whole Force it must have risen to 8 because $8 \times 8 \times 12 = 768$.

In the second Part of the tenth Experiment, 12 should have risen to near 5, because $12 \times 12 \times 2 = 288$, and $5 \times 5 \times 12$ is but 300.

In the eleventh, the Ball 12 (thirty times heavier than the little one) must have gone to $2 \frac{1}{4}$ Inches, because the *Momentum* of the little Ball being $= 15 \times 15 \times 1 = 225$, that of the Ball 12 must be $= 2,75 \times 2,75 \times 12 = 226 \&c$.

It may be here alledg'd, that one ought to subtract the *Momentum*, with which the great Ball comes upon the little one; but that won't mend the Matter much, tho' indeed the Difference will be less. For,

In the eighth Experiment, if we subtract $4 \times 4 \times 12 = 192$ from 389,88 there will remain 197,88, and the Ball 12 will go but to 4; but then in Experiment 9, if we subtract the same N^o 192 from 768, we shall have 576, which would carry 12 to near seven Degrees, because $7 \times 7 \times 12 = 588$.

In the tenth Experiment, there is only 48 to be subtracted; and in the eleventh only 15; and therefore the Velocity of 12 will very much fall short of what is agreeable to the new Opinion.

After the Experiments made, and what has been said, till these Consequences are overthrown, no notice ought to be taken of any Objections, or new Experiments.

ments. But to give the Objectors all possible Satisfaction, I shall, in another Paper, endeavour to shew the Fallacies of the Arguments, and solve the *Phænomena* of the Experiments made; shewing, both by Reason and Experiment, that the Facts ought to be as they are, in consequence of the receiv'd Opinion and Laws of Resistance.

F I N I S.

E R R A T U M.

PAG. 250. in the Note for, de la Hire, &c. read Milnes, *ibid.*

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