CHAPTER V.

REMARKS ON PERPETUAL MOTION, DERIVED FROM TREATISES ON NATURAL PHILOSOPHY.

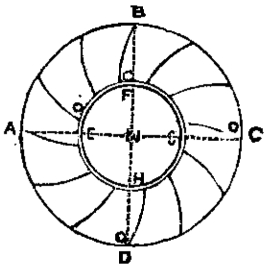
We here offer the opinions of Martin, 1747; Maclaurin, 1748; Rutherford, 1748; Hooper, 1783; Emerson, 1794; Nicholson, 1800; Young, 1807; Gregory, 1815; Partington, 1828; Arnott, 1828;—all authors easily accessible, and some or all of whom should be consulted before expending time or money on schemes which it is abundantly evident are constantly and shamefully terminating in disappointed hopes.

In his Lectures on Mechanics, Martin takes occasion to illustrate the impossibility of effecting Perpetual Motion, observing that—

A lever is any inflexible line, rod, or beam, moveable about or upon a fix'd point (called the prop or fulcrum), upon one end of which is the weight to be raised; at the other end is the power applied to raise it, as the hand, &c. Since (as we have before proved) the momentums of the weight and power are as the quantities of matter in each multiplied by their respective celerities, and the celerities are as the distances from the centre of motion, and also as the spaces pass'd through in a perpendicular direction in the same time, it must follow that there will be an equilibrium between the weight and power when they are to each other reciprocally as the distances from the centre, or as the celerities of the motions, or as the perpendicular ascent or descent in the same time; and this universally in all mechanical powers whatsoever, which is therefore the fundamental principle of all mechanics.

(XXXVII.) 1. The nature of this proposition being not understood by smatterers in mechanics, gave occasion to imagine the possibility of a perpetual motion from one part of it, which they did not see was utterly impossible from another part of it.

2. That part which seem'd to promise the possibility thereof was this, viz., that the momenta of equal bodies were as their distances from the centre of motion. Hence, say the Perpetual Motion men, if a wheel were constructed of the form of that in the figure A B C D, with circular cells going from the inner part E F G H to the outer, containing equal balls C D E F; then upon turning the wheel they must move towards the centre N on one part, as the ball E; and from it on the opposite part, as the ball C; and by this means the ball C will have a greater momentum than the ball F, and so will determine the wheel to move round;



and since this must be the case of all the balls E and C that come into the situation E C, the wheel must necessarily move continually, because it will bring two balls into that situation.

3. 'Tis true, where there are but two balls E and C, the ball C would by this contrivance move the wheel one quarter round, viz., while it descended from C to D, and by this means would raise the ball E to F, and there they will abide in the situation D F. But, say the men of this persuasion, two other balls succeeding to the places E and C will keep the wheel moving. Yes, so they would, if the balls at D and E could be taken away the moment they come into that position,—not else; for the balls C and E, in order to move the wheel, must move the balls D and F, which have equal momenta (as being the same distance each from the centre as are the other two respectively), which is absurd by the general proposition.

4. The absurdity of a perpetual motion will still farther appear, if we consider that the momenta of bodies are always proportional to the perpendicular descent or ascent to or from the centre of the earth. Since, therefore. in the wheel the bodies are all equal by supposition, and the perpendicul spaces through which they descend and ascend, above and below the horizontal line or diameter A C, are equal, it

follows that an equilibrium must ensue. Thus, so far is this wheel from producing a perpetual motion, that it admits of none at all.*

Maclaurin, to the same purpose, treating of the Laws of Motion, and their general Corollaries, says:—

1. The first law of motion is, "That a body always perseveres in its state of rest, or of uniform motion in a right line, till by some external influence it be made to change its state." That a body of itself perseveres in its state of rest, is matter of most common and general observation, and is what suggests to us the passive nature of body; but that it likewise, of itself, perseveres in its state of motion as well as of rest, is not altogether so obvious, and was not understood for some time by philosophers themselves, when they demanded the cause of the continuation of motion. It is easy, however, to see that this last is as general and constant a law of nature as the first. Any motions we produce here on the earth soon languish, and at length vanish; whence it is a vulgar notion that, in general, motion diminishes and tends always toward rest. But this is owing to the various resistances which bodies here meet with in their motion, especially from friction, or their rubbing upon other bodies in their progress, by which their motion is chiefly consumed. For when, by any contrivance, this friction is much diminished, we always find that the motion continues for a long time. Thus, when the friction of the axis is lessened by friction wheels applied to it and turning round with it, the great wheel will sometimes continue to revolve for half an hour; and when a brass topp moves on a very small pivot on a glass plane, it will continue in motion very smoothly for a great number of minutes. A pendulum, suspended in an advantageous manner, will vibrate for a great while, notwithstanding the resistance of the air. Upon the whole, it appears that if the friction and other resistances could be taken quite away, the motions would be

* Philosophia Britannica; or, a New and Comprehensive System of the Newtonian Philosophy. By B. Martin. 2 vols. 1747. 8vo. (Vol. 1. Third Lecture on Mechanics. Pp. 106-8.) N.B.—Under "Perpetual Movement," the above is copied literally into "A New and Complete Dictionary of Arts and Sciences. By a Society of Gentlemen." 4 vols. 1754. 4to.

perpetual. But what sets this in the clearest light is, that a body placed on the deck or in the cabin of a ship continues there at rest while the motion of the ship remains uniform and steady; and the same holds of a body that is carried along in any space that has itself an uniform motion in a right line. For if a body in motion tended to rest, that which is in the cabin of a ship ought to fall back towards the stern; which would appear as surprising, when the motion of a ship is uniform and steady, as if the body should of itself move towards the stern when the ship is at rest. It is for this reason that the uniform motion of the earth upon its axis has no effect on the motion of bodies at the surface; that the motion of a ship carried away with a current is insensible to those in the ship, unless they have an opportunity to discover it by objects which they know to be fixed, as the shores and the bottom of the sea, or by astronomical observations; and that the motions of the planets and comets, in the free celestial spaces, require no new impulses to perpetuate them.*

[He then proceeds to consider the other laws of motion.]

And of the Mechanical Powers, he says:—

30. The mechanical powers, according to their different structure, serve for different purposes; and it is the business of the skilful mechanic to chuse them, or combine them, in the manner that may be best adapted to produce the effect required, by the power which he is possessed of, and at the least expence. The lever can be employed to raise weights a little way only, unless the engine itself be moved, as, for example, to raise stones out of their beds in quarries. But the axis and wheel may serve for raising weights from the greatest depths. The pullies being easily portable aboard ships, are therefore much employed in them. The wedge is excellent for separating the parts of bodies, and the screw for compressing or squeezing them together; and its great friction is even sometimes of use to preserve the effect already produced by it. The strength of the engine, and of its parts, must be proportioned to the effects which are to be produced by it. As we find that, when the centre of motion is placed between the power

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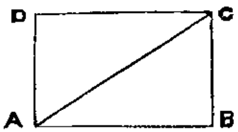
and the weight, it must sustain the sum of their efforts, a small balance ought not to be employed for weighing great weights, for these disorder its structure, and render it unfit for serving that purpose with accuracy; neither are great engines proper for producing small effects: the detail of which things must be left to the skilful and experienced mechanic.

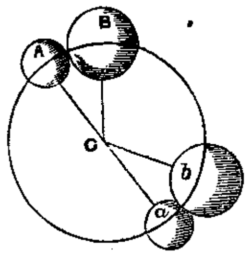
31. But besides the raising of weights and overcoming resistances, in mechanics we have often other objects in view. To make a regular movement, that may serve to measure the time as exactly as possible, is one of the most valuable problems in this science, and has been most successfully effected hitherto by adapting pendulums to clocks, tho' many ingenious contrivances have been invented to correct the irregularities of those movements that go by springs. Some have endeavoured to find a perpetual movement, but without success; and there is ground to think, from the principles of mechanics, that such a movement is impossible. In many cases, when bodies act upon each other, there is a gain of absolute motion; but this gain is always equal in opposite directions, and the quantity of direct motion is never increased. To make a perpetual movement, it appears necessary that a certain system of bodies, of a determined number and quantity, should move in a certain space for ever, and in a certain way and manner; and for this there must be a series of actions returning in a circle, to make the movement continual, so that any action by which the absolute quantity of force is increased, of which there are several sorts, must have its corresponding counter-action, by which that gain of force is destroyed, and the quantity of force restored to its first state. Thus, by these actions, there will never be any gain of direct force, to overcome the friction and the resistance of the medium. But every motion will be abated, by these resistances, of its just quantity; and the motions of all must at length languish and cease.

32. To illustrate this, it is allowed that by the resolution of force there is a gain or increase of the absolute quantity of force; as the two forces A B and A D (Fig. 2) taken together, exceed the force A C which is resolved into them. But you cannot proceed resolving motion



(*Fig.* 2 ,*tab.* 1.)

in infinitum, by any machine whatsoever; but those you have resolved must be again compounded, in order to make a continual movement, and the gain obtained by the resolution will be lost again by the composition. In like manner, if you suppose A and B (Fig. 42) to be perfectly elastic, and that the lesser body A strikes B quiescent, there will be an increase of the absolute quantity of force, because A will be reflected; but if you suppose them both to turn round any centre C, after the stroke, so as to meet again in *a* and *b*, this increase of force will be lost, and their motion will be reduced to its first quantity. Such a gain, therefore, of force as must be afterwards lost in the action of the bodies can never produce a perpetual movement. There are various ways, besides these, by which absolute force may be gained; but since there is always an equal gain in opposite directions, and no increase obtained in the same direction, in the circle of actions necessary to make a perpetual movement, this gain must be presently lost, and will not serve for the necessary expence of force employed in overcoming friction and the resistance of the medium.

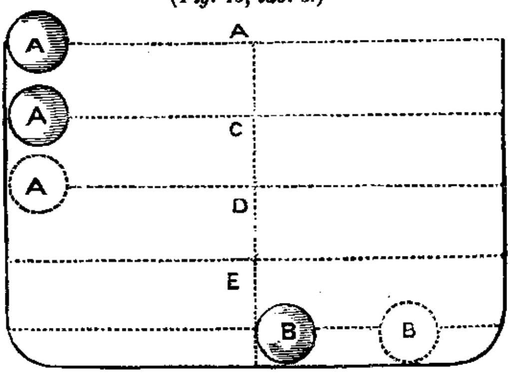


(*Fig.* 42, *tab.* 3.)

33. We are to observe, therefore, that tho' it could be shewn that in an infinite number of bodies, or in an infinite machine, there could be a gain of force for ever, and a motion continued to infinity, it does not therefore follow that a perpetual movement can be made. That which was proposed by Mr. Leibnitz, in August, 1690, in the Leipsic acts, as a consequence of the common estimation of the forces of bodies in motion, is of this kind, and, for this and other reasons, ought to be rejected. It is, however, necessary to add that, though on many accounts it appears preferable to measure the forces as well as motions of bodies by their velocities, and not by the squares of their velocities; yet, in order to produce a greater velocity in a body, the power or cause that is to generate it must be greater in a higher proportion than that velocity, because the action of the power upon the body depends upon their relative motion only; so that the whole action of the power is not employed

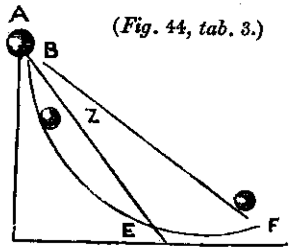
in producing motion in the body, but a considerable part of it in sustaining the power, so as to enable it to act upon the body and keep up with it. Thus the whole action of the wind is not employed in accelerating the motion of the ship, but only the excess of its velocity above that of the sail on which it acts, both being reduced to the same direction. When motion is produced in a body by springs, it is the last spring only which acts upon the body by contact, and the rest serve only to sustain it in its action; and hence a greater number of springs is requisite to produce a greater velocity in a given body than in proportion to that velocity. A double power, like that of gravity, will produce a double motion in the same time; and a double motion in an elastic body may produce a double motion in another of the same kind. But two equal successive impulses, acting on the same body, will not produce a motion in it double of what would be generated by the first impulse, because the second impulse has necessarily a less effect upon the body, which is already in motion, than the first impulse which acted upon it while at rest. In like manner, if there is a third and fourth impulse, the third will have less effect than the second, and the fourth less than the third. From this it appears what answer we are to make to a specious argument that is adduced

(*Fig.* 43, *tab.* 3.)



to show the possibility of a perpetual motion. Let the height A B (Fig. 43) be divided into four equal parts A B, C D, E B—suppose the body A to acquire by the descent a velocity as 1, and this motion by any contrivance to ransmitted to an equal body B; then let the body A, by qual descent C D, acquire another motion as 1, to be smitted likewise to the same body B, which in this manner supposed to acquire a motion as 2, that is sufficient to carry upwards from B to A; and because there yet remain the otions which A acquires by the descents D E and E B, that may be sufficient to keep an engine in motion, while B and A ascend and descend by turns, it is hence concluded that a sufficient gain of force may be obtained in this manner, so as to produce a perpetual movement. But it appears, from what has been shewn, that a motion as 2 cannot be produced in B by the two successive impulses transmitted from A, each of which is as 1.

Some authors have proposed projects for producing a perpetual movement, with a design to refute them; but, by mistaking the proper answer, have rather confirmed the unskilful in their groundless expectations. An instance of this we have in Dr. Wilkins's "Mathematical Magick," book 2, chap. 13. A loadstone at A (Fig. 44) is supposed to have a sufficient force to bring up a heavy body along the plane F A, from F to B; whence the body is supposed to descend by its gravity, along the curve B E F, continually. But supposing B Z E to be the surface upon which, if a body was placed, the attraction of the loadstone and the gravity of the body would balance each other, this surface shall meet B E F at some point E between A and F, and the body must stop in descending along A E F at the point E.*



(*Fig.* 44, *tab.* 3.)

* An Account of Sir Isaac Newton's Philosophical Discoveries, in four books. By Colin Maclaurin, M.A. Published from the author's MS. papers, by Patrick Murdoch, M.A. and F.R.S. Third edition, 8vo. 1775. Book 2, chap. 3, p. 187. N.B.—First edition, 4to., printed 1748.

The foregoing article may be found copied into "A New and Complete Dictionary of Arts and Sciences. By a Society of Gentlemen." 4 vols. 4to. 1754.

Dr. Rutherford, in allusion to Perpetual Motion, says:—

98. The friction of the parts of a machine against each other will in time destroy any motion that has been communicated to it.

Amongst the other mutual actions of bodies upon each other, we reckon friction. No machine can have the surface of its parts made exactly smooth by polishing, though their roughness may be made too small for our eyes to discover it. And as a body by striking directly upon another, that is either at rest or in motion, will lose velocity, so, as the parts of a machine rub against each other, when the prominence of one part, though ever so small, strikes upon the prominence of another part, the motion of the parts will by this means be diminished, and by frequent strokes of the same sort will in time be entirely destroyed.

From hence it follows that no machine can be so contrived as to have a perpetual motion, or always to preserve the motion once impressed upon it; for the motion communicated will by the friction of the machine be constantly decreasing, and must end at last.

To prevent this, in all the contrivances for a perpetual motion the usual attempt has been to find out a way of repairing the motion which is lost by friction; and as bodies move themselves by the force of gravity, and as motion is likewise generated by the spring of such bodies as are elastic, the way of repairing the motion as it decays by friction must be by the application of one or other of these two properties of matter. The motion of some clocks is kept up by the force of gravity; but then this motion is not a perpetual one, for the clock stops as soon as the weights are down. Other clocks are kept in motion by elastic springs; but this motion ceases likewise, when the spring, by having expanded itself, is grown too weak to repair it any longer. And indeed, neither of these properties can be so applied as to make a perpetual motion. This I will endeavour to shew, from one or two of the principal contrivances in the two following propositions:—

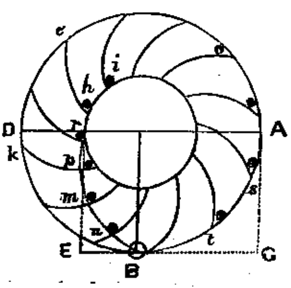
99. The force of gravity cannot produce a perpetual motion.

The general reason for this has been already given; for, since gravity produces motion in bodies only whilst they can descend, the motion of a machine, which is lost by the friction of its parts, can be repaired by a weight no longer than till the weight is down, or is come to the ground, and is prevented by it from descending any longer.

In order to remove this difficulty, machines have been contrived with more weights than one, of which some are to be constantly ascending whilst the others are descending. Where we may observe that the descending weights are applyed to two purposes; they are to repair the motion in the machine, and likewise to raise the other weights which were down as low as they could go; and these weights, when they are raised, are to descend again, and in their turn to answer the same purpose. For this end, some one or more of the mechanical powers is made use of, by the assistance of which the descending weights may be made to move always with a greater velocity than the ascending ones; and then, if the quantities of matter in the weights be equal, their moments will be as their velocities, and consequently the descending weights may by this means have a moment given them so much greater than the ascending ones have as to be sufficient to answer the two purposes already mentioned.

It would be endless to examine all the inventions of this sort. The principle upon which they depend is applyed in the neatest manner in the wheel described by Desaguliers; and by examining the principle in this one instance, we shall see the fallacy of it, and how little hopes of success there is in any other application of it. The wheel (Fig. 1, plate 4) has two rims or circumferences, D *e* A B and *r h i f*. The space between the two rims is divided into cells by the spokes *q* A, *f t*, *p* D, *h e*, &c., which are bent in such a manner as to cause weights placed loose in the cells to descend on the side A *s t* B from A to B, which is the lowest point, on the outer rim of the wheel, and to ascend again from B on the other side of the wheel B D, in the line B *n m p r*, which comes nearer the centre C and touches the inner rim. Thus the weights

(*Fig.* 1, *pl.* 4.)



on the descending side of the wheel being farther from the centre of motion than those on the ascending side, it is imagined that the moment of the former will always be greater than the moment of the latter. The weight A, in particular, descends to B in the arc A *s t* B, which is a quarter of a circle; but it rises from B to D in the curve B *n m p r*, which is less than a quarter of a circle. And, since the velocity is as the space described in a given time, the velocity and consequently the moment of A when it descends is greater than its moment when it ascends. This will be the case of every weight in its turn; therefore, the descending weights will always have a greater moment than the ascending ones.

The fallacy is this:—The velocity with which the weight A descends to B is estimated by the line A *s t* B, whereas the velocity of all bodies in motion is to be estimated in the line of their direction, by the second law of motion. For it is only in the line of direction that any force acts so as to communicate motion to a body; and it is in the same line only that the body in motion acts, when it communicates motion and is itself considered as a moving force. From hence it follows, that the velocity with which a weight descends, if the weight is considered as a moving force, must be estimated in the line of its direction, that is, in a line drawn from its centre of gravity to the centre of the earth; or, the velocity of a weight is proportional to the approach of it in any given time to the earth's centre. In like manner, the velocity with which the weight ascends is to be estimated in the line of its direction, and in any given time it is as the distance to which it is raised from the earth's centre in that time. From hence it appears that, though the weight A descends to B in the curve A *s t* B, yet the velocity with which it descends being as its approach to the earth's centre, is as A G = C B; and though the same weight ascends in the lesser curve B *n m p r*, yet the velocity with which it ascends being as the distance to which it is raised from the earth's centre in that time, is as E *r* = C B = A G. Therefore, the descending and ascending velocities are equal, and consequently the moment of the descending weights will be no greater than the ascending ones.

I do not know whether this will be made more intelligible by distinguishing between the weight's velocity whilst it descends and the velocity with which it descends. This may appear to the reader too nice a distinction; but I hope he will understand my meaning, if he observes that whilst A descends it does not move directly downwards in the line A G, but moves partly downwards and partly in a horizontal direction, and by both these motions together is carried to B. Since, therefore, whilst it descends it is likewise carryed horizontally, I think it is evident that it does not descend with its whole velocity; therefore, its velocity whilst it descends is different from the velocity with which it descends, as different as the whole is from its part. Or otherwise, whilst A descends to B in the line A *s t* B, we may consider its motion as resolved into the two sides of a parallelogram, A G and A C = G B; where the velocity with which it descends is A G, and the other part of its velocity A C or G B carries it horizontally. In like manner we may distinguish between the velocity which the weight has whilst it ascends and the velocity with which it ascends; for if, as before, the weight ascends in the curve B *n m p r*, we may consider its motion as resolved into the two sides of a parallelogram, B C = E *r* and B E; where the velocity with which it ascends is E *r*, and the other part of its velocity B E carries it horizontally. Now, the descending velocity A G is equal to the ascending velocity E *r;* and, therefore, the moment with which the weight descends will be equal to the moment with which it ascends. The horizontal velocity G B of the descending weight is greater, indeed, than the horizontal velocity B E of the ascending one. But I suppose it is unnecessary to prove that this cannot possibly contribute anything towards turning the wheel, or towards making the moment on the descending side greater than the moment on the ascending side; for I imagine the reader will easily see that a motion in the direction G B E or A C *r* will not contribute in the least towards making the point A descend, or towards turning the line A C D round upon the centre of motion.

100. The force of elasticity cannot produce a perpetual motion.

Elastic springs, as has been observed already, by expanding themselves grow weak; and, when they are quite expanded, become entirely unable to produce any motion at [illegible]. But in proposition 83 it was shown that if an elastic [illegible] A strikes upon another B, which is greater than itself, the moment of B after the stroke will be greater than that of A was before it. In like manner, if B was to strike upon C, another elastic body greater than itself, the motion might still be increased. And thus, by placing more elastic bodies in the row, of which each should be greater than the last before it, the motion might be increased in what proportion we pleased. Now, why might not motion produced in this manner be applied to repair what is lost in a machine by the friction of its parts, and to make the motion of the machine a perpetual one? I intended to supply the reader with an answer to this question when I desired him to remember in the instance of two bodies, in proposition 83, that though there is motion produced if we consider the greater body alone, yet if both bodies are taken together there is no motion produced in the same direction; but the moment in the same direction is exactly the same after the stroke that it was before it. This would be the case were there ever so many bodies. But a machine can only be moved by moving forces in the same direction; for equal moving forces in contrary directions would destroy each other and produce no effect on the machine, and the effect produced by unequal ones in contrary directions will be as their difference. Since, therefore, the moving force, by which the motion of the machine should be repaired, is the moment of these elastic bodies, and since their moment in the same direction is the same after the stroke that it was before; it follows, that no such moment is produced by the stroke as can keep the motion of the machine and make it perpetual. For instance, suppose the machine consists of four wheels; call them *c*, *d*, *e*, and *f*. Let *c* be the first mover, and let *f* be the last. Now, if *c* begins to move with 8 degrees of moment, and by the friction 2 degrees are lost when the motion comes to the wheel *f*, then *f* can return only 6 degrees of motion on *c*, the first mover. And thus the motion, as it decays in every round, will at last be entirely lost, unless some method could be found for repairing it. Suppose, therefore, that there were two elastic balls A and B, and that A is to B as 2 to 4; then, by proposition 83, if A strikes B with a moment 6, B will gain by the stroke a moment 8. Now, if *f*, the last wheel which has only the moment 6, was to strike upon A, and A to strike upon B, and B to strike upon the first wheel *c*, then this first mover would have the same motion 8 communicated to it, with which it began to move. And as the two elastic bodies would always repair the 2 degrees of motion that are lost by friction in conveying the motion from *c* to *f*, why might not this contrivance be so applyed as to make the machine a perpetual motion? I answer, because, though B strikes *c* with 8 degrees of motion, yet A will at the same time be reflected with 2 degrees against *f*, and striking *f*, the last mover, by reflection, will stop the machine with a force 2, whilst B is moving it with a force 8. Therefore, by the action of both bodies together, of B impelling *c* with the moment 8, and of A reflected back upon *f* with the moment 2, the machine will be moved only with the difference, or $8-2=6$. So that if *c* began to move at first with the moment 8, and this moment by being carried round through *d* and *e* to *f* was reduced to 6, the two elastic balls A and B will not repair the moment lost; but the machine will have only 6 degrees of moment, notwithstanding the seeming increase of motion by A's striking upon B.*

Dr. Hooper describes "A Clock to go perpetually by the influence of the Celestial Bodies," and very properly discriminates the difference between such action and a self-motive power. He says:—

The construction of the movements in this clock is the same with those in common use; it differs from those only in its situation and the manner in which it is wound up.

This clock is to be placed near a wall, by or against which the tide constantly flows. To each of the barrels round which the string that carries the weight is wound, there must hang a bucket, and into that, when the tide rises to a certain height, the water runs, by means of a pipe fixed in the wall. The bucket then overbalancing the weight, descends, and winds up the clock; but when it comes to a certain depth, it is taken by a catch fixed in the wall, which by turning it over discharges the water; the weights of the clock then descend in the usual manner, and the buckets are drawn up.

Now, as this clock is kept in motion by the tide, and as

* A System of Natural Philosophy. By T. Rutherford, D.D., F.R.S. 2 vols. 4to., 1748. Vol. 1, pp. 88-92.

the tide proceeds from the influence of the sun and moon, it necessarily follows that the motion of the clock proceeds from the same cause, and that as long as the parts of the machine remain, motion will be perpetual.

This, according to the common acceptation of the term, is certainly a perpetual motion, and so is every mill that is driven by a constant stream; but that is not the sense in which the term was used by the advocates for a perpetual motion in the last century. They meant a machine which, being once put in motion, should, by its peculiar construction, move perpetually without any fresh force impressed. This they attempted by various means: as the attraction of a loadstone, the descent of heavy bodies, the difference of the momentum in revolving weights, &c., all of which, though ingenious enough, discover a want of due attention to the principles of mechanics. Besides, if a perpetual movement could be effected by either of those means, it would be of very little or no use: for the unavoidable wear of the several parts of the machine, arising from the incessant friction, must necessarily destroy that equality of motion which alone could render its perpetuity of any consequence.*

Emerson, in Prop. CXVIII., treating how "To determine the friction and other irregularities in mechanical engines," says:—

6. As to the mechanic powers. The single leaver makes no resistance by friction. But if, by the motion of the leaver in lifting, the fulcrum or support be changed further from the weight, the power will be decreased thereby.

7. If any wheel of a machine running upon an axis, the friction on the axis is as the weight upon it, the diameter of the axis, and the angular velocity. This sort of friction is but small.

8. In the pulley, if p q be two weights, and q the greater, and if $W=\frac{4pq}{p\times q}$, then W is the weight upon the axis of the single pulley. And it is not increased by the acceleration of the weight q, but remains always the same.

* Rational Recreations. By W. Hooper, M.D. 4 vols. 8vo. 1783. Vol. 1, p. 187, recreation 55.

The friction of the pulley is very considerable when the sheaves rub against the blocks, and by the wearing of the holes and axles.

The friction on the axis of the pulley is as the weight W, its angular velocity the diameter of the axis directly and the diameter of the pulley inversely. A power of 100lbs. with the addition of 50lbs. will but draw up 500lbs. with a tackle of 5.

And 15lbs. over a single pulley will draw up only 14lbs.

9. In the screw there is a great deal of friction. Those with sharp threads have more friction than those with square threads, and endless screws have more than either. Screws with a square thread raise a weight with more ease than those with a sharp thread.

In the common screw the friction is so great, that it will sustain the weight in a position given when the power is taken off. And, therefore, the friction is at least equal to the power. From whence it will follow, that in the screw the power must be to the weight or resistance, at least as twice the perpendicular height of a thread to the circumference described by one revolution of the power, if it be able to raise the weight, or only sustain it. This friction of the screw is of great use, as it serves to keep the weight in any given position.

10. In the wedge the friction is at least equal to the power, as it retains any position it is driven into. Therefore, in the wedge the power must be to the weight at least as twice the base to the height, to overcome any resistance.

11. To find the friction of any engine, begin at the power, and consider the velocity and the weight at the first rubbing part, and estimate its quantity of friction by some of the foregoing articles; then proceed to the next rubbing part, and do the same for it; and so on through the whole.

And note, something more is to be allowed for increase of friction by every new addition to the power.

Cor.—Hence will appear the difficulty, or, rather, impossibility of a perpetual motion, or such a motion as is to continue the same for ever, or at least as long as the materials will last, that compose moving machines.

For such a motion as this ought continually to return undiminished, notwithstanding any resistance it meets with, which is impossible. For, although any body once put into motion, and moving freely without any resistance, or any external retarding force acting upon it, would for ever retain that motion, yet, in fact, we are certain that no body or machine can move at all without some degree of friction and resistance; and, therefore, it must follow that, from the resistance of the medium, and the friction of the parts of the machine upon one another, its motion will gradually decay, till, at last, all the motion is destroyed, and the machine is at rest. Nor can this be otherwise, except some new active force, equal to all its resistance, adds a new motion to it. But that cannot be from the body or machine itself; for then the body would move itself, or be the cause of its own motion, which is absurd.*

Among the numerous communications made by William Nicholson to the journal he conducted, and which bears his name, he contributed the following carefully-written paper—"Concerning those Perpetual Motions which are producible in Machines by the Rise and Fall of the Barometer or the Thermometrical Variations in the Dimensions of Bodies:"—

In a former communication, I have given an account of some of the delusive projects for obtaining a perpetual motion from an invariable power.† In that paper, I remarked that the flow of rivers, the vicissitudes of tides, the variations of winds, the thermometrical expansions of solids and fluids, the rise and fall of the mercury in the barometer, the hygrometric changes in organised remains, and every other of those mutations which never fail to take place around us, may be applied as first movers to mills, clocks, and other engines, and keep them going till worn out. Many instances of this kind of perpetual motion are seen in water-mills and other common engines, which are necessarily confined to certain local situations. The windmill, though less confined with respect to place, is the subject of a much more variable power; other instruments, still less confined with regard to situation and exposure, have been made, which are capable of

* The Principles of Mechanics. By W. Emerson. 4to. 1794. Fourth edition, p. 173.

† Philosophical Journal, vol. 1, p. 375.

continuing their motion without ceasing. Such was the clock, or perpetual motion, in Cox's Museum, which was shewn about twenty years ago in London. My former paper was written to shew the value of the perpetual motion, strictly so called, which has for the most part been pursued by men of little information. In the present memoir, I shall endeavour to ascertain that of this second kind of motion, which, because more promising, and of nearly the same practical value, has been followed at some expense by men of higher claims. For this purpose, I shall first describe a few schemes, and then investigate the quantity of power they are likely to afford.

Fig. 1, plate 6, is a sketch of the first mover in a clock which formed part of Cox's Museum, which was sold by public lottery, about the year 1776, if my recollection be accurate. A represents the surface of the mercury in a barometer, the glass vessel of which had the form of a bottle or chemical mattrass. The diameter of the upper surface of the mercury was, I think, about twelve inches. C D represents the bason, or receptacle, into which the aperture of A B was plunged. I suppose, of course, that the lower surface of mercury, which was exposed to the pressure of the atmosphere, was nearly the same as the upper, A B, as, in fact, it appeared to be. From the intervention of the case, and other parts of the apparatus, I could only conjecture the manner in which the effect was produced; but this was afterwards explained to me by Mr. Rehe,* who contrived and made it. The bason B D is suspended by two chains K L, which pass over the pullies or wheels H I, and are attached to the frame E F, which last is fixed to the barometer A B. Let us now suppose the apparatus to be at liberty, and it will be clearly seen, that if the two masses attached to the opposite ends of the chains K L be not precisely equal, the heaviest will descend, and cause the lightest to rise. The masses must, therefore, be brought nearly to this state of equality, by the adjustment of weight added to one or both of them. In this state, suppose the pressure of the atmosphere to increase, and the consequence will be, that a portion of the mercury, being forced from the vessel C D into A B, will

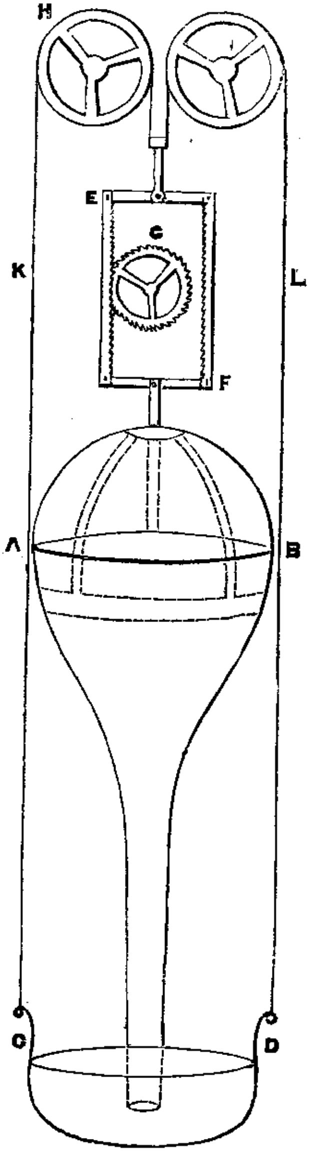
* This gentleman is at present one of the Board of Inspection of Naval Works at the Admiralty. June, 1799.

render this last heavier, and cause it to descend, while C D at the same time rises. And, on the other hand, when, by a diminished pressure of the external air, the mercury subsides in A B, the vessel C D will preponderate, and A B will rise. Now, the frame E F, which is interposed between the barometer and the pullies I K, is jointed at the corners, and also at the places where it is attached to the chain and the barometer; and the inner edges of the upright pieces E F are formed into teeth, like those of a saw, the slopes of which lie in opposite directions, as is shewn in the figure. The wheel G, which is placed between these bars, is also toothed in the same manner; and its diameter is such, that when the teeth on each side, as, for example, E, are engaged, those on the other side, F, may be free; but it is too large to admit of both sides being disengaged at once. The wheel G is prevented, by a click, from moving in the direction opposite to that which may be produced by the action of the bars E and F. Hence, the play of the machine is evident. When the pressure of the atmosphere diminishes, and the barometer rises from its cistern, the side E of the frame will move the wheel G through a greater or less space, according to the variation; and when, on the contrary, it falls, the teeth E will be drawn out of their bearing, and those of F will be thrown into the wheel, and still produce a motion of the same kind; the joints of the frame E F allowing it to change its figure enough for this purpose. It is hardly necessary to remark that this wheel G, being connected with the clock, serves to wind it up, and that the clock is constructed to go for a much greater number of days than the barometer has ever been known to remain stationary.

The ingenious mechanic will readily form a notion of many other methods of applying the variations of the barometer to similar objects. The wheel-barometer of Robert Hook, as well as another contrivance, in which the barometer and its cistern are placed at the different extremities of an inclined lever, may likewise be used for this purpose.

Several artists have exerted their industry in attempts to apply the variations produced by change of temperature in bodies as a first mover. If a thermometer be suspended by its centre of gravity in such a manner that the tube may lie nearly horizontal, the daily variations in the bulk of the mercury will cause a preponderance on the one side or the other,

(*Fig. 1, pl. 6.*)



accordingly as the temperature is higher or lower than it was at the original fixing of the centre of suspension. The thermometer may contain mercury or any other fluid, or it may consist of air confined by mercury, as in the manometer. In this contrivance, the great and frequent ranges of variation afford much promise of utility. The limits of convenient or practicable power from change of equilibrium in a fluid thermometer will hereafter be examined. A much greater force seems to offer itself in the power by which the expansion is produced; but the difficulty of forming a piston or other apparatus for confining fluids, will probably constitute an insurmountable impediment to this method.

The solid thermometer does not present the same difficulty. Fig. 2 represents a series of expansion-bars, each consisting of a plate of brass, soldered to another of steel, and possessing the property of bending by change of temperature, according to the laws already explained in this work.* If the steel face of C A be uppermost, and the end C be fixed to C B, the extremity A will rise from B when the temperature is elevated; and if the succeeding bars be similarly fixed above each other, as in the figure, the whole system will occupy a greater length, or elevation, above C B, when heated, than when cold. Another more convenient method of disposing the bars is shewn in Fig. 3. In this, the bars are fixed together at the middle, with the brass faces turned towards each other. Each bar has a slight curvature (much less than is here shewn), which will be increased by heat, and by that means cause the distance between the middle of two extreme bars to be greater than it would be at a lower temperature.

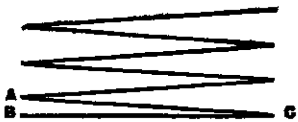
These causes of action may be applied to machinery by various contrivances, some of which serve to increase the length of range, but add nothing to the power. This last, no doubt, is an object of convenience, according to the effect intended to be produced. The only method of adding to the power will consist in increasing the number of the bars. Fig. 4 represents a system for this purpose, which is the simplest and most convenient that has occurred to me. A C represents the circumference of a barrel, resembling those in which the mainsprings of clocks are put, the length and diameter of which may be varied, according to the power

* Philosophical Journal, vol. 1, pp. 62, 576.

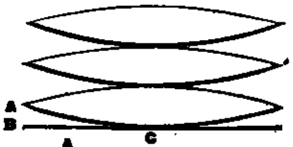
intended to be gained. To this external part is fixed a ratchet-wheel, to receive the click C, which confines its motion to one direction. At A is fixed a plate, to receive the action of the expansion-pieces. B D is an internal cylinder of the same kind, which is also confined, by a ratchet-wheel and click, to move only in the same direction as the outer part A C. It is not necessary to describe the operative arrangements by which these two cylinders are disposed so as to move on the same axis, and the ends duly applied, so as to form one box, while the interior and exterior parts are allowed to move independent of each other. At B is fixed a plate, by which the action of the expansion-pieces is communicated to the inner cylinder. A series of bars, similar to those delineated in Fig. 3, are disposed in the space between the two cylinders, the greatest part of which they occupy, leaving only such an interval between A and B as may be sufficient to allow for the motion of the bars. In this interval is placed a spring, tending to cause A and B to recede from each other; and, lastly, there are side-pins proceeding from the places of friction of every pair of bars, which respectively pass through circular grooves in the caps, and prevent the motion of the bars from being interrupted or impeded by their touching either the inner or the outer cylinders. E represents a wheel, which is supposed to be connected, by tooth-work or otherwise, with the face of the external cylinder, and may be considered as the machinery intended to be moved. Or otherwise, if the clicks C and D, with the teeth they act upon, be reversed, and the interior cylinder be fixed to the axis itself, that axis may be used as the first mover.

Suppose this apparatus to be put together at a certain temperature in the day-time, and that in the night the temperature becomes colder, in this case, the curvature of all the bars will diminish, and the distance between A and B will be increased by the action of the intermediate spring; but as the plate A is prevented by the click C from receding, the plate B will be pushed forward, and the interior cylinder will gather a certain number of its teeth upon the click D. The next day, when the temperature again rises, all the expansion-bars will bend, and the space between A and B will be diminished; this, however, cannot happen by the motion of B, which is held fast by the click D. The external part will, consequently, be now carried forward, and will act upon the

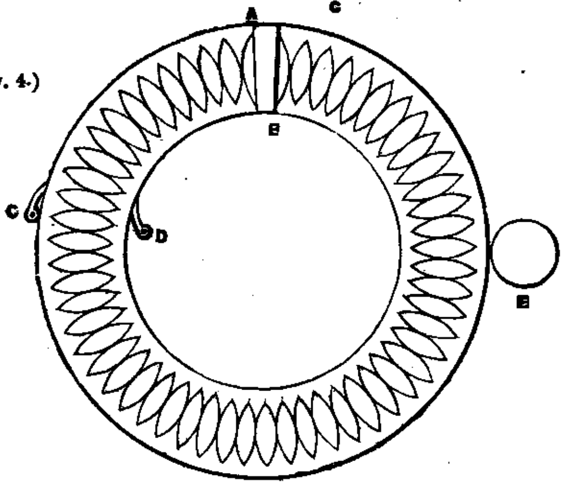
(*Fig.* 2.)



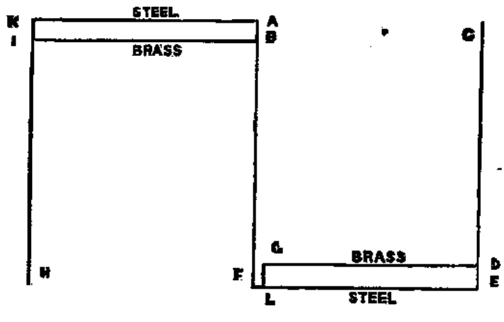
(*Fig.* 3.)



(*Fig.* 4.)



(*Fig.* 5.)



apparatus E. A second lowering of the temperature, by whatever cause, will occasion the interior part again to advance, and, in this manner, the accumulations of force may be incessantly reiterated.

Experience must determine how far the properties of these compound bars may be changed in the course of time.* It seems probable that the mere changes communicated by the atmosphere could scarcely produce any sensible effect; and whether this effect would be detrimental to the general result, may also be questioned. Considerations of this nature lead to the enquiry, whether our object may not, with equal facility, be obtained by the direct push or pull of bars of metal, as in the gridiron pendulum, or that of Ellicott.†

If a succession of bars of brass were disposed round a cylindrical face of less expansible metal, so as to form an helical line from the one end to the other; or, otherwise, if we suppose a brass clock chain, with a right-lined edge, to be wrapped round such a cylinder; or, again, if, instead of the cylinder, we suppose the chain to pass over a succession of rollers, whether disposed in a cylindrical system or according to the form of a pulley, the result will be the same; that is to say, the chain will contract and expand about the ten-thousandth part of its length, for every ten degrees of Fahrenheit's thermometer. In the way of rough estimate, let us, therefore, assume a cylinder of cast-iron, one foot in diameter and one foot in length, having a groove turned in its surface, like a screw, with twelve turns in the inch, for the purpose of lodging a system of friction rollers to receive the brass chain, wrapped round it. Such a chain,‡ consisting of 144 turns, would measure 450 feet,§ and would contract nearly 0.54 inches for every 10 degrees, or one-twentieth of an inch for each degree of change of temperature; but as the cylinder itself contracts, the whole effect will be somewhat less than half that quantity; that is to say, each degree of the thermometer will be one-fortieth of an inch.

The philosophical world is aware that hygrometers have

* Philosophical Journal, vol. 1, p. 62.

† *Ibid.*, pp. 59, 60.

‡ And would cost about £25.

§ For pyrometrical data, see Philosophical Journal, vol. 1, p. 58.

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been made, on this principle, with catgut, hair, whalebone, and other materials. It seems probable that the first of these would exert considerable force as a first-mover, but it would scarcely prove durable; and, what is still worse, the variations of moisture in the atmosphere are little suited to operate upon machinery preserved in a case in an apartment.

If the increase of the space moved through by the expansion of metals, upon the principle of Ellicott's pendulum, should be adopted instead of the compound bars in Fig. 4, the project of Fig. 5 may be followed. A bar of steel A K is fixed beside a bar of brass B I, the joinings I K being inflexible; but those at A B, in the lever A F, being jointed, the difference of expansion between the two metals will be magnified at F, in the proportion of A F to A B. The lines L C G D E represent a second combination of the same kind, in which the point G will have a similar and equal motion to that of F; but the bar E L being prolonged to F, so as to bear upon the lever E F, the whole of the second combination will be pushed forward by the expansion of the first, on account of which, the motion of G will, in fact, be double that of F; by the addition of a third combination, the motion will be tripled, &c. A sufficient number of these, properly placed in the cavity between the two cylinders, Fig. 4, would afford the same consequences; but it may be doubted whether any contrivance of this last kind could afford the same power in as small a space as that occupied by the compound bars.

I shall now proceed to form an estimate of the quantities of force communicated by these several contrivances.

The apparatus (Fig. 1, plate 6), or barometrical clock, is driven by a force which may be estimated in its annual quantity from the sum of the deviations of the barometer taken from a meteorological journal, such as that in the Philosophical Transactions; together with the quantity of mercury so moved, which may be derived from the dimensions of the surfaces in the tube and basin. From these variations, severally, must be taken the quantity of what mechanics call lost time, or the ineffectual movement between the direct and retrograde actions on the machinery. The whole power will be measured by the entire column of variation, supposed to descend through half its height; for this will be the case when a perpendicular tube empties itself by the descent of any fluid contained in it. I have not taken the trouble to collect these elements; but it may easily be imagined that the sum of all the variations during the year would amount to no great quantity. I understand, from the ingenious constructor of this apparatus, that the accumulated power was not sufficient to allow the clock to be maintained by a force equal to that which drives a common watch, namely, six ounces, with the daily fall of twelve inches.

In the investigation of the power of expansion, in Fig. 4, a variety of curious objects of physical and mathematical research offer themselves to our consideration. In a former part of this journal,* it has been shewn that the curvature assumed by a straight compound bar, having each of its parts uniformly thick, will be circular; whence it follows, from the nature of versed sines of small arcs, that the distance A B, Fig. 2, will, *cæteris paribus*, be as the square of C A; and it should seem as if a considerable advantage might be derived from using the whole length of the bar, as in that figure (2), instead of the two half-lengths in Fig. 3. But it must be considered that the effect of hammer-hardening the lower part, and wire-drawing the upper, of the compound bar C A, is twice as great at C, Fig. 2, as it is at C in Fig. 3, and is shewn in the greater spring or yielding of the parts, and that the action at A, in this figure, is doubled at the opposite extremity of the bar; so that, upon the whole, the action at A, on account of the short lever A C, Fig. 3, being twice as powerful as that at A in Fig. 2, and being exerted through the space A B, Fig. 3, of one-fourth part of the space A B in Fig. 2, will be half the action at the end of Fig. 2. But as both extremities of the bar are made to act in Fig. 3, the whole of its action will be precisely equal to that in Fig. 2. The combination, Fig. 3, appears, therefore, to be preferable on account of its convenient figure only.

It may also be questioned whether these bars should be made extremely thin or the contrary. If they be very thin, the effect of the reaction being equivalent to a pull or push endways upon the bar, which is greater than the reaction itself, in the proportion of the length of the bar to its half thickness, it may easily be imagined that the texture and cohesion will be most strongly affected; but, on the contrary, if the bar be very thick, the effect from change of tempera-

* Vol. 1, p. 62.

ture may resolve itself entirely into an action upon the parts near the contiguous surfaces, without producing any flexure at all. It appears, therefore, that there is a thickness which is practically better than any other; but what this thickness may be, remains to be determined by trials. As the quantity of motion is inversely as the thickness (Philos. Journal, i., 576), and the force directly as that thickness, it must follow that the quantity of mechanic effect in all similar bars, neither extremely thick nor extremely thin, will be the same upon equal changes of temperature. I should give the preference to thin bars, not so much reduced as to have any perceptible spring.

If the Fig. 4 be supposed of such dimensions as that the circular arc struck through the middle parts of all the bars might be three feet in length, and the bars were each six inches long in the radial direction, with a thickness nearly equal to that of the second experiment related at the last-quoted article of our journal, the space moved through by each bar, upon an alteration of 146 degrees, would be about 0.05 inch, or half a tenth; but 300 of these bars might with ease be contained in the circular space of three feet; and these would produce a motion of fifteen inches by the same change of temperature, or one-tenth of an inch for every degree of Fahrenheit. In order to determine the force with which this change of position would be effected, we are in want of some experiments on the expansions of metals. It is generally supposed that a rod or wire will contract or dilate by change of temperature in the same manner, whether it be at perfect liberty to move horizontally, or be made to support a weight hung from its extremity, or placed on its upper end. This is, in fact, supposed to be the case in the estimates for constructing gridiron pendulums; and if it were strictly true, the power of this wheel would be constantly equal to the reaction against which it should be exerted. But it would be to little purpose to institute a calculation upon data assumed at random. I shall therefore only remark that the power of this wheel is very considerable, and may be increased almost at pleasure, by enlarging the dimensions of the bars in the direction parallel to the axis of the cylinder.

Whatever question there may be with regard to the force and durability of this system of bars—neither of which I am disposed to doubt—there can be scarcely any with regard to the spiral chain round the cylinder. The direct expansion and contraction of metals is certainly very powerful, and was shewn in a striking manner by the Rev. Mr. Jones, in an experiment related, if my memory be correct, in George Adam's Philosophical Lectures. He hung a very heavy weight to the longer end of a lever, the shorter arm of which pressed upwards against the longer arm of another lever, and the shorter arm of this last was supported by a rod of metal. By this mechanical arrangement, it will be understood, without difficulty, that a very slight motion of the arm which bore upon the metal might be attended with a very considerable motion of that extremity which supported the weight; and the dimensions were such, that this was in fact the case.

The flame of a candle applied to the bar of metal caused it to expand, and carried up the load without difficulty.

Hygrometric contractions and dilations are known to be performed with immense force; but want of durability in the materials, and the difficulty with regard to exposure, which has been already mentioned, seem to forbid the practical use of this power for the purpose to which our attention is now directed.

The contrivance, Fig. 5, may be considered as effectual; but the objections which have been made to Ellicott's pendulum are still more strongly applicable to this, namely, that the friction, the wear, and the irregular action of the joints, must be hurtful to the general effect.*

In Nicholson's Journal, vol. 1, for 1802, page 27, is given the "Construction of an hydraulic apparatus, which by means of the syphon raises water above its level, and performs its alterations without attendance." It is the invention of "William Close." It has pipes and valves which require nice adjustment, it is stated, "to prevent the sudden pressure of the atmosphere from forcing the air out of the empty pipes with such rapidity as would [and no doubt did] destroy the operation of the syphon." The article is not of sufficient interest to extract *in extenso*.

* A Journal of Natural Philosophy, Chemistry, and the Arts. By William Nicholson. Vol. 3, pp. 126 and 172. 1800. 4to.

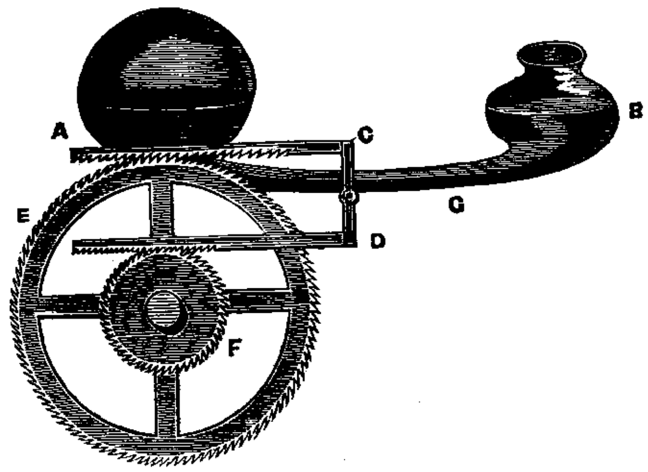
A New Project for Perpetual Motion. In a Letter from R. B. to Mr. Nicholson.

SIR,—I was much gratified, several years ago, by some essays with which you obliged your readers upon the perpetual motion. In the first volume, p. 375, of your quarto series, I find an account of several schemes (necessarily abortive) for producing perpetual motions by the action of gravity; and in your third volume I find an account of various methods of keeping up the motion of a machine by means of the changes which take place in the barometer and thermometer. I have ventured to send you the sketch of a project for a perpetual motion of the latter kind, which has long remained among my memorandums. You will see it is not of the class of perpetual motions, properly speaking, but merely the application of some existing intermittent motions in nature to the purpose of maintaining the rotation of machinery.

* * * * * *

Fig. 1, plate 12.—A represents the marine barometer of Halley, but varied by the addition of a vessel B at the open

(*Fig.* 1, *pl.* 12, *vol.* 9.)



end, in which the water, or other fluid, exposes a surface nearly equal to that in the closed vessel A. These two vessels are connected by a long horizontal tube G. It is evident that any change, either in the pressure of the external air or the elasticity of the internal air, will cause the fluid to run along the tube, and add to the weight of A or of B, according to circumstances. The heavier vessel will preponderate, but it will be prevented from descending too far by a stop or bearing to which it will arrive. Any change in the inclination of G will move the attached lever C D; by means of which, one of the two horizontal racks will be made to push round that ratchet-wheel into which its teeth fall, at the same time that the other rack will be drawn backwards upon its wheel. The opposite action will drive forward the other wheel; and, as both these wheels are fixed on the same axis, the system will be driven the same way by every change of density or weight in the air that takes place.*

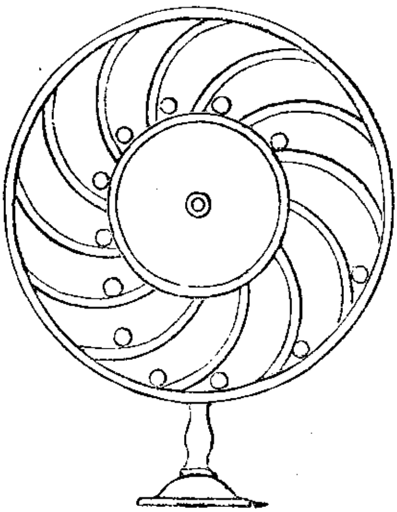
Dr. Young, in his ninth lecture "On the Motions of Connected Bodies," remarks:—

To seek for a source of motion in the construction of a machine betrays a gross ignorance of the principles on which all machines operate. The only interest that we can take in the projects which have been tried for procuring a perpetual motion must arise from the opportunity that they afford us to observe the weakness of human reason, to see a man spending whole years in the pursuit of an object which a week's application to sober philosophy might have convinced him was unattainable. The most satisfactory confutation of the notion of the possibility of a perpetual motion is derived from the consideration of the properties of the centre of gravity. We have only to examine whether it will begin to descend or to ascend when the machine moves, or whether it will remain at rest. If it be so placed that it must either remain at rest or ascend, it is clear, from the laws of equilibrium, that no motion from gravitation can take place; if it may descend, it must either continue to descend for ever, with a finite velocity, which is impossible, or it must first descend and then ascend with a vibratory motion, and then the case will be reducible to that of a pendulum, where it is obvious that no new motion is generated, and that the friction and resistance of the air

* A Journal of Natural Philosophy, Chemistry, and the Arts. By Wm. Nicholson. Vol. 9, p. 212. 1804. 8vo.

must soon destroy the original motion. One of the most common fallacies, by which the superficial projectors of machines for obtaining a perpetual motion have been deluded, has arisen from imagining that any number of weights ascending by a certain path on one side of the centre of motion and descending on the other at a greater distance, must cause a constant preponderance on the side of the descent: for this purpose, the weights have either been fixed on hinges which allow them to fall over at a certain point, so as to become more distant from the centre, or made to slide or roll along grooves or planes which lead them to a more remote part of the wheel, from whence they return as they ascend; but it will appear, on the inspection of such a machine, that although some of the weights are more distant from the centre than others, yet there is always a proportionally smaller number of them on that side on which they have the greatest power, so that these circumstances precisely counterbalance each other. (Fig. 78, pl. 6, page 91.)

(*Fig.* 78, *pl.* 6.)



Note on plate 6, page 763, vol. 1:—

Fig. 78.—A wheel supposed to be capable of producing a

perpetual motion; the descending balls acting at a greater distance from the centre, but being fewer in number than the ascending. In the model, the balls may be kept in their places by a plate of glass covering the wheel. (Page 92.)*

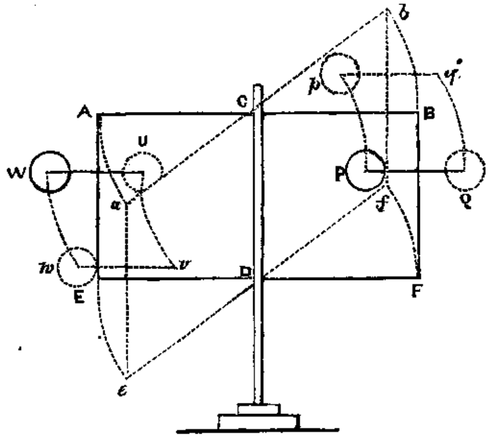
The following occurs in a Scholium at page 82 of Dr. Gregory's "Treatise of Mechanics:"—

Before we close our discussion respecting the lever, it may not be amiss just to remark, that in every attempt to determine the advantage gained by this machine peculiar attention must be paid, not only to the directions in which the forces are exerted, but to the points on the lever to which their action is to be referred. Without a due regard to these particulars, the mechanist will often be involved in error, even in simple cases where there might be supposed but little probability of mistake. In fact, even the simple property of the straight lever, that equal weights acting at equal distances from the fulcrum on opposite sides will be in equilibrio, while at unequal distances the one which acts most remotely from the fulcrum will preponderate, has more than once been a source of error in unskilful hands; and in particular, it has lain at the foundation of most of those ill-fated and useless contrivances which have been struck out by such as were in pursuit of the perpetual motion. In these contrivances the object of the projector has generally been to apply different weights to a rotatory machine in such manner that, at successive moments of time, first one and then another should be brought to greater distances from the centre, and so, by being placed at the extremity of a longer lever, should produce a constant motion. To prevent, therefore, such waste of time and ingenuity, we shall here describe an apparatus invented by Dr. Desaguliers (see Phil. Trans., No. 419, or New Abridg., vol. 6, p. 542), in which two equal weights may be placed at any unequal distance whatever from the centre of motion, and still remain in equilibrio. In Fig. 3, pl. 5, A B represents a balance with equal arms, and E F another of equal dimensions: they turn freely upon the centres C D, and their extremities are connected by equal

* A Course of Lectures on Natural Philosophy. By Thomas Young, M.D. 2 vols. 4to. 1807.

inflexible bars A E, B F; the whole being permitted to move freely at the points A B C D, so as to assume the forms of varying parallelograms, in consequence of any motion upon

(*Fig. 3, pl. 5.*)



the points C and D. Across the bars A E, B F, are fixed others, as W U, P Q, from any points of which equal weights, P W, may be suspended. Now, on whatsoever part of the bar P Q the weight P is fixed, it is manifest that it will, on account of that bar being firmly connected with the vertical rod B F, act as though it were placed at F; and, in like manner, in whatever part of the bar W U the weight W be suspended, it will act as though it were placed at E: so that, however great may be the difference of the distances of the bodies P and W from C D, they will still, if equal in weight, balance each other in any position of the system. Nor is this in any respect incompatible with the principle of the equal products of weight and velocity, which we have mentioned (130) as a useful indication of an equilibrium; for, suppose this compound balance to be brought by motion on its centres into the position *a b c d*, the weights being then at *w* and *p*, those weights will have moved through the arcs W *w*, P *p*, while the extremities of the levers will have passed through the equal and respectively parallel arcs A *a*, E *e*, B *b*, F *f;* of consequence, the velocities of the two weights will have been equal, as they ought to be, in conformity with that principle. Thus, then, it appears, from this simple contrivance, that weights do not preponderate in machines merely on account of their different distances from the centre of motion; and, consequently, a mere increase of distance does not universally give a mechanical advantage.

[The paragraph 130, before alluded to, occurs at page 71, as follows:—]

130. Writers on the subject of mechanics have often attempted to demonstrate the properties of the several simple machines by means of a celebrated theorem, which is this: When two heavy bodies counterpoise each other by means of any machine, and are then made to move together, the products of each mass into its velocity, or, as it is technically expressed, the quantities of motion with which one body descends and the other ascends perpendicularly, will be equal. Since an equilibrium always accompanies this equality of motions, it bears such a resemblance to the case wherein two moving bodies stop each other when they meet together with equal quantities of motion, that many have thought that the cause of an equilibrium in the several machines might be immediately assigned by saying that, because one body always loses as much motion as it communicates to another, two heavy bodies counteracting each other must continue at rest when they are so circumstanced that one cannot descend without causing the other to ascend at the same time, and with velocities inversely proportional to their masses; for then, should one of them begin to descend, it must instantly lose its whole motion by communicating it to the other. But this argument, however plausible it may seem, is (as Dr. Hamilton remarked) by no means satisfactory; for when we say that one body communicates its motion to another, we must necessarily suppose the motion to exist first in the one and then in the other; but in the present case, where the two bodies are so connected that one cannot possibly begin to move before the other, the descending body cannot be said to communicate its motion to the other, and thereby make it ascend; but whatever we should suppose causes one body to descend, must also be the immediate cause of the other's ascending, since, from the connection of the bodies, it must

act upon them both together, as if they were really but one. And therefore, without contradicting the laws of motion, we might suppose the superior weight of the heavy body, which is in itself more than able to sustain the lighter, would overcome the lighter, and cause it to ascend with the same quantity of motion with which the heavier descends; especially as both their motions, taken together, may be less than what the difference of the weights, which is here supposed to be the moving force, would be able to produce in a body falling freely. For these reasons, and various others which might easily be assigned, we are of opinion that all proofs founded upon this theorem as a basis are necessarily unsatisfactory: we have, nevertheless, thought it right to notice it; and, as it may serve as a good index of an equilibrium in many machines, and admits in some instances of a useful application, we may again refer to it in the practical part of this treatise.*

In treating "Of Friction," Millington says:—

From a number of experiments that have been made to investigate the power of friction, it appears to increase in a less ratio than that of the weight of the moving body, although this conclusion is contrary to the generally-received opinion, and has a limit; for if the moving surface be too small or too thin to support its own weight, it will not bear evenly, and will wear into a groove or notch which may occasion much additional friction.

However perfectly a piece of machinery may be made, still friction, to a certain degree, must ever exist, and cannot be prevented. It follows, therefore, that the power that is given to one extreme of a machine can never be conveyed without abatement to the other; and hence it will immediately appear that a perpetual motion is impossible, because this presumes that a certain power is to be communicated to a machine, and is to be transferred through all its different movements from the beginning to the end of the machine, when it must be given back again without diminution, in order that it may be communicated back again to the beginning of the machine to

* A Treatise of Mechanics. By Olinthus Gregory, LL.D., &c. vols. 8vo. Third edition, 1815. (Vol. 1, pp. 71 and 82.)

produce a repetition of the same impulse it had produced in the first instance, otherwise the motion of the machine could not be maintained. But since no effect can be produced that is greater than its cause, and as the cause must be diminished by friction, *vis inertiæ*, &c., in its transfer through a machine, so it cannot be renewed with a power equal to that with which it began; consequently, a perpetual motion must be considered as an unattainable thing, inasmuch as it implies a renewal of power which no machine can give to itself.*

In his "Manual," Partington describes, as follows, a well-known galvanic apparatus maintaining long-continued motion :—

Mr. Singer contrived an arrangement (of M. De Luc's electrical column or dry pile) which is well calculated to form a perpetual motion, by excluding, to a very considerable extent, the operation of extraneous causes of interruption; and it at the same time renders the disposition of the apparatus rather elegant. A series of from 1,200 to 1,600 groups are arranged in two columns of equal length, which are separately insulated in a vertical position by glass pillars constructed on his principle of insulation; the positive end of one column is placed lowest, and the negative end of the other; and their upper extremities being connected by a wire, they may be considered as one continuous column. A small bell is situated between each extremity of the column and its insulating support, and a brass ball is suspended by a thin thread of raw silk, so as to hang midway between the bells, and at a very little distance from each of them. For this purpose, the bells are connected, during the adjustment of the pendulum, by a wire, that their attraction may not interfere with it; and, when the wire is removed, the motion of the pendulum commences. The apparatus is placed upon a circular mahogany base, in which a groove is turned to receive the lower edge of a glass shade, with which the whole is covered.†

* An Epitome of the Elementary Principles of Natural and Experimental Philosophy. 1 vol. 8vo. 1823. Page 85.

† A Manual of Natural and Experimental Philosophy. By Charles F. Partington. 8vo. 1828. Vol. 2, p. 206.

Dr. Arnott, in his "Elements of Physics," section 2 of the first part, on "Motions and Forces," says:—

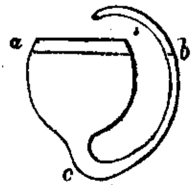
Further illustrative of the truths that action and reaction are equal and contrary, and that in every case of hard bodies striking each other, they may be regarded as compressing a very small strong spring between them, we may mention that when any elastic body, as a billiard ball, strikes another larger than itself, and rebounds, it gives to that other, not only all the motion which it originally possessed, but an additional quantity, equal to that with which it recoils, owing to the equal action in both directions of the repulsion or spring which causes the recoil. When the difference of size between the bodies is very great, the returning velocity of the smaller is nearly as great as its advancing motion was, and it gives a momentum to the body struck, nearly double of what it originally itself possessed. This phenomenon constitutes the paradoxical case of an effect being greater than its cause, and has led persons imperfectly acquainted with the subject to seek from the principle a *perpetuum mobile*. (Page 109.)

The following reflections occur at page 141, part 2, "Mechanics:"—

What an infinity of vain schemes—some of them displaying great ingenuity—for perpetual motions, and new mechanical engines of power, &c., would have been checked at once, had the great truth been generally understood, that no form or combination of machinery ever did or ever can increase, in the slightest degree, the quantity of power applied. Ignorance of this is the hinge on which most of the dreams of mechanical projectors have turned. No year passes, even now, in which many patents are not taken out for such supposed discoveries; and the deluded individuals, after selling perhaps even their household goods to obtain the means of securing the supposed advantages, often sink in despair, when their attempts, instead of bringing riches and happiness to their families, end in disappointment and utter ruin. The frequency and eagerness and obstinacy with which even talented individuals, owing to their imperfect knowledge of this part of natural philosophy, have engaged in such undertakings, is a remarkable phenomenon in human nature.

In section 1 of the third part, treating on "Hydrostatics," he says :—

A projector thought that the vessel of his contrivance, represented here, was to solve the renowned problem of the perpetual motion.* It was goblet-shaped, lessening gradually towards the bottom until it became a tube, bent upwards at *c*, and pointing with an open extremity into the goblet again. He reasoned thus: A pint of water in the goblet *a* must more than counterbalance an ounce which the tube *b* will contain, and must therefore be constantly pushing the ounce forward into the vessel again at *a*, and keeping up a stream or circulation, which will cease only when the water dries up. He was confounded when a trial shewed him the same level in *a* and in *b*.†



In Montucla's admirable "Histoire des Mathematiques," completed by J. de la Lande, and published in 4 vols., 4to., 1802, no less than eight pages are devoted to a dissertation (here briefly translated) as follows :—

On perpetual motion—a chimera old and celebrated enough in mechanics for us to treat of it in this work. It is understood to be a movement which continually preserves and renews itself without exterior help. Many real discoveries have been the result of this enquiry. Montucla's "Mathematical Recreations" and the "Journal des Savans," 1678 to 1745, treat on this subject. Several machines have been made, intended to solve this knotty problem, and made much noise in the scientific world, but have all proved failures; and it is now more an insult than praise to say any one is

* A contrivance on precisely the same principle here enunciated, was proposed by the Abbe de la Roque, in "Le Journal des Sçavans, Paris, 1686. The instrument was a U tube, one leg longer than the other and bent over, so that any liquid might drop into the top end of the short leg, which he proposed to be made of wax, and the long one of iron. Presuming the liquid to be more condensed in the metal than the wax tube, it would flow from the end into the wax tube, and so continue. Page 29.

† Elements of Physics, or Natural Philosophy. By Neil Arnott, M.D. Third edition, 1828. Page 270.

searching after perpetual motion. Among all the known properties of matter and motion, there does not appear among them one single principle that would give the intended effect. It is allowed that action and reaction must be equal. Friction and the air also retard motion. Neither can any machine receive greater motive power than that which is first communicated to it. And perpetual motion cannot take place unless the power communicated be much greater than the generating power, and unless it compensates for the diminution of power caused by friction, which is impossible. Thus the question is reduced to finding a weight heavier than itself, or an elastic power greater than itself. Thus it is requisite to find some method by which a combination of mechanical power will gain a strength equivalent to that which is lost; it is principally this last point that is sought, to resolve the problem. It is certain that the multiplication of powers serves no purpose, as whatever is gained in power is lost in time, so that the quantity of motion remains the same. One small power can never be mechanically made really equal to a greater one.

Maupertius, in his letters on different scientific subjects, remarks that atmospheric changes, &c., are excluded, and that inertia, &c., are alone made subservient to obtaining perpetual motion, which he considers unattainable. Inertia and elasticity are also inapplicable.

In 1700, a report was current that perpetual motion had been found. Sauveur explained it to the Academy of Sciences, and Parent proved its impossibility.

In the philosophical works of 's Gravesande, published at Amsterdam, 1774, is an account of a machine constructed by Orffyreus in 1715. It was called the Wheel of Cassel, and is described in a letter to Newton. Gravesande is persuaded that it can be shown that perpetual motion is not a contradiction; and it appears to him that Leibnitz was wrong in regarding as an axiom the impossibility of this movement. It caused general surprise that this great man should try to prove its possibility, and expressing a hope that the prejudices of mathematicians regarding this movement would not prevent their giving serious attention to the subject. Jean Bernoulli also believes in the success of Orffyreus's discovery. (See Opera, tome i., page 41.)

Wolf, in 1716, in his "Dictionary of Mathematics," gives the arguments of Sturm, Lorini, Stévin, and Leibnitz, against perpetual motion. He considers there is a doubt whether the movement in Orffyreus's machine was not the effect of some invisible fluid.

The examination that 's Gravesande made of Orffyreus's wheel so aggravated him that he broke the machine the same day, as may be seen in the "Annal. Physico-Med. de Breslaw," Leipzig, 1723, page 427. Also, in his life, 's Gravesande states that Orffyreus wrote on the wall that it was the impertinent curiosity of the professor which caused him to break it. This seems to indicate that he feared an ulterior examination; but 's Gravesande has never confessed that he himself was deceived. At the same period appeared D. G. Diez's dissertation against perpetual motion, and he names De Lanis, Drebbel, Becher, and Mitz, all as chimeras.

Peresc and Kepler were incredulous on this subject, the first wrote 1691 and the latter 1607 (published 1718).

Baron de Zach has made some very curious researches in respect to different inventions for perpetual motion, in "Reichs-Anzeiger," 1796. In conclusion, there is a lecture on perpetual motion, by Henrich., 1770.

In 1775, the Royal Academy of Sciences in Paris passed the resolution not to examine any machines announced as intended for perpetual motion, and gave their motives for so doing in the History of the Academy, 1775, page 65.

[See Appendix E.]