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THE CONSTANCY OF MOTION.

BY GEORGE ILES.

THE conservation of energy, as treated in the most recent work of authority on the subject, Prof. Balfour Stewart's, published in the "International Scientific Series," regards energy as divisible into two classes, actual and potential: actual energy, as in the case of a rushing stream of water, or a radiant and contracting mass of molten iron; and potential energy, where, for instance, a stone is at a height and may fall, or where a spring is tightly coiled and may unwind.

Prof. Stewart speaks the general opinion of modern physicists, Profs. Rankine, Tyndall, and others, when he states that, in cases of potential energy, the bodies endowed with it are absolutely at rest, and that the motion exhausted in storing up such energy is represented by a mere advantage of position, which, when utilized, yields in actual, palpable motion the energy which has lain completely quiescent, as when the stone falls to the earth, or the freed spring uncoils.

This division of energy into actual and potential seems to me to be defective. It prevents the direct comprehension in the mind of energy as being motion and nothing else; it leaves unexplained how a body perfectly at rest can come to move; and further implies the dissipation of energy (which I have treated in a previous number of this journal) in a new phase, for, if all the actual energy in the universe were to become potential, all the real and positive motions which constitute life might indefinitely cease.

Let us examine, then, some cases of "potential" energy, and see if they be not actual, although under a disguise; so that the present definition of the conservation of energy may be replaced by the more intelligible statement that motion is constant; that it is never abolished for a time, nor absolutely suspended, all appearances to the contrary notwithstanding; and that so, all cases of energy are dynamic, and no part of them static, as now currently held.

For matter seemingly at rest may contain within itself motions as real as those to which at another time it openly gives rise, when it radiates heat or attracts by magnetism.

First of all, then, let us consider the case of a stone at a height, say on the brow of a cliff, capable of falling at any time when slightly pushed.

Gravity is the one force, of all the forms of energy, whose relations with others it is most difficult to imagine.

Other forces affect each other most palpably: magnetism forsakes a magnet when it is made white hot; chemical affinity is most sensitive to variations of temperature, and even in some cases to mechanical tremor; the transmission of electricity is favored by the cooling of a conductor, and so on.

Otherwise is it with gravity: a given mass of matter, however mechanically moved, electrified, magnetized, heated, or subjected to chemical changes, at the same point on the earth's surface, always weighs the same.

The only force with which gravity has any analogy is magnetism; and were magnetism always attractive, instead of polar, with equal opposite manifestations of attraction and repulsion, the analogy would be a strong one.

Let us, however, work out what analogy there is, and we may find that as the subtile movements of light were made plain by the study of the grosser movements of sound in air, so may the long-hidden laws of gravity be revealed in part, by tracing the similitude existing between their effects and those of common magnetism.

Both forces obey the law of squares: according to that law, they diminish as we recede from their centres of attraction. And what is very suggestive is, that, as their appetites are satisfied, they decrease in exactly the same ratio.

Two small magnets at a great distance from each other (so as to be practically out of the range of each other's influence), having each a force equal to 1, when permitted to unite, have together a force less than 2; and this because work can be done by their attraction mechanically, or may appear as heat; and of course this must diminish their original stock of energy.

Precisely so with gravity. Suppose, for simplicity's sake, the radius of the earth to be 4,000 miles. Let us then imagine a stone of four tons lifted from the earth's surface to a distance of 4,001 miles; it would there weigh one ton—very nearly. Were such a mass to fall it would pass through 4,001 miles of space, and yield corresponding work.

Now let us further imagine a world, concentric with our present one, to be made up by the union of the earth with seven other such planets, and let us leave out of the question any possible condensation in the matter of this new world. Then supposing the stone to have resumed its former position in space, if gravity were allowed to act again, it could only do so through one mile, instead of 4,001 miles as before.

And mark how the geometrical necessities of enlargement lessen the working power of a mass attracting by gravity; for a stone weighing four tons on our present globe would only weigh twice as much on a sphere containing eight times the matter.

In the latter case, the surface would be twice as distant from the centre as in the former; for the attraction diminishes as the square of the distance of surface from the centre. Therefore the 8 times increased bulk has to be divided by 4, the square of the doubled radius.

Thus the weight of a definite mass on any celestial body varies as the density of the body and as the radius of it.

One of our pound-weights taken to the sun would there weigh 27 pounds, the sun's radius being about 110 times that of the earth, but its density only about one-fourth as great; while its bulk exceeds that of our planet by as much as 1,252,000 times.

If we now attentively observe the energy of a magnet in its usual genesis, we may learn somewhat, not only of gravity, but of attraction in general. The most convenient way to make magnets is by the use of an electric coil. A piece of properly-tempered steel is inserted in a helix of copper wire, through which a current circulates proceeding from the mechanical motion of a steam-engine, converted into electricity by suitable apparatus.

Other methods of magnetization there are, but none so directly instructive as this; here we have the visible, palpable motion of heavy wheels disappearing, and the chief result is the attractive force developed in the steel. The conviction dawns upon us that the motion of the wheels has been taken up by the molecules of the bar, that the steel has now internal movements which before it had not; and that these movements of its particles exist in full actuality, capable of doing tangible work when fitly permitted. Let us bring a piece of iron or steel near to the magnet, and instantly it leaps toward it, confirming our conviction.

That a medium exists for the conveyance of such molecular motion, we are obliged to think; but what it is, or how it is affected, we cannot yet imagine. Thus much, however, is plain, that, as a medium purely, it can be no source of motion, so that the mere fact of distance between bodies can be no satisfactory explanation of attraction.

Attraction, then, wherever it appears, I believe to be due to contained motion in the particles of the bodies presenting it; which molecular motion is the equivalent of, and convertible into, the movement of masses as wholes.

Gravity, I venture to hold, is a force due to a distinct motion of the ultimate parts of matter, which has not yet been formulated. And, as the energy expended in sundering two united magnets reappears in the increase of their attractive powers, or the acceleration of such motion of their particles as constitutes magnetism, so the lifting of a stone from the earth would imply that the force consumed in so doing must take the form of a quickening in that motion of its particles which constitutes gravity. And we have seen how every successive act of obedience to both these forces of aggregation makes them weaker and weaker, as it reasonably should.

Therefore, I conclude that the energy of a stone at a height is not potential, but actual; that its value as a source of work, at any time, is represented, by the swifter motion of its molecules as compared with those of a stone on the earth's surface; and that, as a stone falls, its internal motion takes the phase of mass motion.

This theory would lead us to suppose that the onward momentum of the planets, as they turn before the sun, is the expression of an equal internal gravitive motion of their ultimate parts, which exactly balances these mighty celestial revolutions.

The next case of "potential" energy to be inquired into is that of a coiled spring, which, in unwinding, may yield the force it took to coil it.

This case may be intelligibly explained on the same principle of the constancy of motion. The particles of a spring may be assumed to have a definite plane of molecular motion, which motion we shall presume is that due to temperature. In coiling, these planes are changed, and energy is required to do it; just as when a gyroscope-top is rapidly revolving in a certain fixed plane, it may, by a measurable effort, be made to revolve in a conical curve, with one end of its axis stationary, and the other describing a circle in space. And, as the gyroscope strongly tends to move in a uniform plane, and can do work in resuming such a plane, so I assume that the particles in a coiled spring have two similar motions, one of which is at any time available for tangible work when the spring is freed.

Yet another example. Let us take the case of a cylinder of compressed air which for years, tightly sealed, may serve as a store of force.

Prof. Clerk Maxwell explains how an ounce of air, in a closed and fragile jar, sustains the outside pressure of the atmosphere amounting to several tons; this he does by the theory that the ounce of air is made up of molecules which have so rapid a motion among themselves that they collide on the inside of the jar with as great a force as that of the atmospheric pressure externally.

This theory, now widely accepted, rests on the solid grounds of the measured velocity of air rushing into a vacuum, which is the same as that assumed for its internal motion; and further, on some observations of the diffusion of various gases into each other, which it would be out of place to detail here.

On the basis, then, of Prof. Maxwell's theory, we can believe that, in a cylinder of compressed air, the energy stored up exists in no merely "potential" form, but in the full actuality of the rapid motion of gaseous particles, which may take the shape of mass-motion when the piston is allowed to move outward.

An extension of the hypothesis that motion is continuous would lead to the inference that the so-called latent heat of water at 32° Fahr., as compared with ice at the same temperature, is due to the swifter movement of the molecules in the former case; and no facts are better known than that mechanical motion can become heat, and that heat turns ice into water.

Another implication of this theory is that atoms, as free hydrogen, oxygen, or carbon, are in exceedingly greater commotion than molecules, such as those of water or carbonic-acid gas. For the decomposition of such molecules may be effected by the exhaustion of mechanical motion, and I take it that the dynamic state of the products must balance this expenditure. What else can become of it?

The measure of the contained motion in two different atoms can be noted on their combining chemically, by the increase of temperature, which has its well-known mechanical equivalent.

The analogy between chemical units and small magnets is very close: as a magnet decreases in size, so, relatively thereto, does its attractive power increase; and, were we able to go on dividing until we came to a single atom of iron, we should doubtless have the magnetism merge into the equivalent phase of intense chemical affinity.

Without further illustration, then, of the principle set forth, I will say that, as in recent years we have had to familiarize ourselves with the idea that many forms of actual energy are impalpable, as the rays of light and the waves of sound, so now I think there are good grounds for extending our ideas so as to believe that all phases of "potential" energy are really actual; that, as we cannot but think that only motion can breed motion, energy means motion; and that as such its amount is constant, and its presence, behind whatever veil, continuous; so that it is only properly divisible into two kinds, perceptible and imperceptible.