THE

YOUNG MILL-WRIGHT'S

AND

MILLER'S GUIDE.

PART THE FIRST.

CHAPTER I.

MECHANICS.

Of the general Properties of Bodies, and the first Principles of Mechanics.

ARTICLE 1.

PRELIMINARY REMARKS.

ALTHOUGH there are many good, practical workmen who are entirely ignorant of the theory of mechanics as a science, it will be universally acknowledged that an acquaintance with the general properties of matter, and the laws of motion would not only be gratifying to every intelligent mind, but would introduce a certainty into many mechanical operations which would ensure their success: and this is a truth, with the importance of which the author of this work was so fully impressed, that he devoted a whole chapter to its consideration. The present editor has thought it best to alter and modify the original work, but he has been careful not only to relate all that appeared to him important in it, but to make such additions, and give such an arrangement to the whole, as have appeared to him calculated to place the subjects of which it treats in a more familiar light.

It is only, however, those properties of bodies, and those laws of motion, which most intimately concern the practical mechanician, that it is thought proper, here, to treat at any length, as any thing farther would be entirely foreign to the object of this work.

ARTICLE 2.

ON THE ESSENTIAL PROPERTIES OF BODIES.

There are certain properties of bodies which belong to matter in all its forms; these are called its essential properties, as they are those without which it cannot exist: these are *Extension*, *Figure*, *Impenetrability*, *Divisibility*, *Mobility*, *Inertia*, and *Attraction*.

Extension. We become acquainted with the existence of matter only by the space which it occupies. We cannot conceive of a body without length, breadth, and thickness, which are the three dimensions of extension. These vary greatly from each other in different bodies; and in some they are all equal to each other, as in the sphere and the cube.

Figure, or shape, is the necessary result of extension, and constitutes its limits. The business of the machinist is to give to various substances those figures, or shapes, which shall adapt them to his purpose.

Impenetrability is that property, by which a body occupies a certain space, which cannot, at the same time, be occupied by another body. If a nail be driven into a piece of wood, it removes a portion of the latter out of its way. Water and other fluids may be made to enter the pores of wood, but it is manifest that two distinct particles of matter cannot exist in the same space with each other.

Divisibility is the susceptibility of matter to be divided into any number of parts. If, in conceiving of the minuteness of the particles of matter, we carry the imagination to its utmost limits, we must confess that a single particle must contain as many halves, quarters, and eighths, as the largest masses. We are not to conclude from this, however, that matter is actually infinitely divisible, although it is mathematically so. It is probable that the Creator has formed masses of matter of certain minute particles, which are infinitely hard, and incapable, from their nature, of mechanical division.

Mobility is one of those essential properties of matter, which form the very foundation of operative mechanics, as it is the capability of matter to be moved from the place, or space, which it now occupies. No mechanical operation, indeed, or any other change, can be effected in matter without motion.

Inertia, or inactivity, is that negative property of matter by which it resists every change of state, whether of rest or of motion. By this term we mean to express the fact that matter is powerless; that if at rest, it has nothing within itself tending to put it into motion; and if in motion, its own tendency is to continue to move, which it would consequently do perpetually, but for those extraneous resistances to which every thing upon the surface of the earth is subjected. The term *vis inertia*, or the power of inertia, is altogether objectionable, although it is very frequently employed. If inertia were a power existing in a body, it must be in some definite quantity, capable of being expressed in numbers, and of resisting a force less than itself; but it is a fact, that any force impressed, however small, will move any body, however great.

Attraction is that power which exists in particles or in masses, of matter, by which they tend to approach each other. It has been divided into five kinds: the attraction of *Gravitation*, of *Cohesion* or aggregation, of *Magnetism*, of *Electricity*, and *Chemical attraction*. It is the two former only of these attractions which claim particular attention in their relationship to mechanics.

The attraction of *cohesion* is that power by which particles of matter become united together and form masses. We could conceive of the existence of matter without attraction, but it must be in its original constituent particles only, unformed into masses; all matter, however, is manifestly endowed with this property, and its particles are, therefore, capable of being united together. In order that the attraction of cohesion may be exerted, it is necessary that the particles of matter be in contact with each other, as it does not take place at sensible distances. By sawing, filing, grinding, and many other mechanical operations, we destroy the attraction of cohesion; and this, indeed, is the great object of these processes. In those bodies which are capable of undergoing fusion, as the metals, we can readily restore this attraction, by subjecting the disentegrated particles to this process.

The attraction of *Gravitation* is manifested in masses as well as in particles of matter; by it all the bodies in nature tend to approach each other. The sun, the earth, the moon, and all the planets, notwithstanding their immense distances, are subjected to this universal law. A stone, or other substance, if unsupported, falls to the earth, in consequence of the attraction existing between it and the earth. What we call weight, results from this attraction, and is the measure of its force or power, in different bodies. The weight of a body is the sum of the attractive force exerted upon its individual particles. A piece of lead, weighing two pounds, contains twice as many particles as another weighing but one pound, and it is therefore drawn to the earth with double the force. It might be supposed that, in consequence of this double quantity of attraction, the piece of two pounds would fall with double the velocity of that of one pound; but, upon making the experiment, the time of their fall will be precisely the same in each. This arises from the inertia of matter, by which, when at rest, it tends to remain so; and, therefore, to move a double quantity with the same velocity, must require a double force. Gravitation must be considered as acting equally on each particle, and consequently, there exists no reason why a piece weighing two pounds should fall with any greater rapidity than would its two halves, were it divided. Light bodies, which expose a large surface to the air, are retarded in their fall by the resistance which it presents; were that removed, a feather would fall with the same velocity as a piece of lead.

This fact is of high importance in practical mechanics, as, in the greater number of instances, gravitation is the active agent in moving machines; and in the construction of all, it is an element which must enter into the calculation of their power.

ARTICLE 3.

AXIOMS, OR LAWS, OF MOTION AND REST.

1. Every body in a state of rest, will remain so; and every body in motion, will continue to move in a right line, until a change is effected by the agency of some mechanical force.

2. The change from rest to motion, and from motion to rest, is always proportional to the force producing these changes.

3. Action and reaction are always equal, and in directions contrary to each other; or, when two bodies act upon each other, the forces are always equal, and directed towards contrary parts.

The first of these laws results, necessarily, from the inertia of matter. The assertion, however, that a body in motion would continue to move in a right line, may require some illustration. That motion when once communicated would never cease, is fairly inferred from the fact, that the motion is continued in the exact proportion in which the obstruction is diminished. A pendulum will vibrate longer in air than in water, and longer still in an exhausted receiver, and stops at last in consequence of the friction on its points of suspension, and the imperfection of the vacuum.

When a stone is thrown in a horizontal direction, as motion is constantly retarded, it also moves in a curve, and eventually falls to the ground. The retardation, in this case, is exactly proportioned to the density of the air, and the curve in which it moves is the consequence of the force of gravity, which is always drawing it towards the earth: the curve in which it moves is determined by this known force, and is precisely proportionate to it. It necessarily follows, that, if the cause of retardation, and of deflexion were both removed, that the body would continue its course in a right line. The preceding remarks may serve to illustrate the second, as well as the first law.

The third law is confirmed by all our observations on the motions of the heavenly bodies, and by all our experiments. If a glass bottle be struck by a hammer, or a hammer by a glass bottle, the bottle will in either case be broken by the same degree of moving power: were the hammer equally fragile with the bottle, both would be broken. If a stone be thrown against a pane of glass, the glass will be broken, and the stone be retarded, in exact proportion to the resistance offered by the glass.

To assert the contrary of this law, would be to maintain an absurdity; for if action and reaction be not equal, one must be greater than the other, which would be to say that the effect was greater than, or not equal to, the cause.

ARTICLE 4.

ON ABSOLUTE AND RELATIVE MOTION.

The idea intended to be conveyed by the term *motion* is too familiar to require a definition.

Motion is either absolute, or relative.

Absolute motion is the removal of a body from one part of space to another, as the motion of the earth in its orbit.

Relative motion is the change of place which one body undergoes in relationship to another: such, for example, as the difference of motion in the flight of two birds, or the sailing of two ships.

Were all the articles upon the surface of the earth to retain their respective situations, they would still be in absolute motion with the earth in space, but they would experience no relative motion, and would appear to us to be at rest.

In the theory of mechanics, much information is derived from our knowledge of the laws observed by the heavenly bodies in their absolute motions; but, in practical mechanics, we have to do with relative motion, only.

On equable, accelerated, and retarded Motion.

Time must, of necessity, enter into the idea of motion, as it is the measure of its *velocity*. Thus, a body which passes the distance of two miles in an hour, moves with twice the velocity of another, which, in the same time, travels but one mile.

A body in motion may continue to move with the same velocity throughout its whole course; its motion is then said to be *equable:* or,

Its motion may be perpetually increasing, as is the case with falling bodies. This is denominated *accelerated motion.*

Retarded motion, is that which is continually decreasing; such is the motion of a stone, or of a cannon ball, projected perpendicularly upwards.

The cause of the equable acceleration of falling bodies, and the retardation of such as are projected upwards from the earth, will be rendered clear, by attending to the article on falling bodies.

ARTICLE 5.

OF MOMENTUM.

It is known to every one that if the velocity of a moving body be increased, the force with which it will strike against another body will be increased also: the fact is equally familiar, that if the weight of a body in motion be increased, the result will be similar. It is evident, therefore, that the force with which a body in motion strikes against another body, must be in the compound ratio of its velocity, and its mass, or quantity of matter. This force is called its *momentum,* which is the product of its *quantity of matter* multiplied by its *quantity of motion;* or, in other words, its *weight* multiplied by its *velocity.*

The effects produced by the collision of bodies against each other differ greatly in those which are elastic, from those that are nonelastic, which will be more particularly noticed presently.

ARTICLE 6.

ON POWER, OR FORCE, AND ON THE MOTIVE POWER.

Force, or *Power*, in a mechanical sense, is that which causes a change in the state of a body, from motion to rest, or from rest, to motion.

When two or more forces act upon a body, in such a way as to destroy the operation of each other, there is then said to be an *equilibrium of forces*.

The Motive Powers, are those which we employ to produce motion in machines: these are, the strength of men, and of other animals; the descent of weights; the force of water in motion; wind, or the motion of the air; the elasticity of springs, and the elastic force of steam. The whole of these are included in the two principles of *Gravitation* and *Elasticity*.

Attempts have been made to employ other agents as motive powers, but these have either failed altogether, or have not been attended with that success which justifies the giving to them a place in a practical work. Among these may be mentioned magnetism; electricity; condensed air; air rendered more elastic by heating it; explosive gases and fulminating compounds.

ARTICLE 7.

ON THE EFFECT OF COLLISION, OR IMPACT.

The striking of bodies against each other is denominated collision, or impact.

Bodies are divided into *elastic*, and *nonelastic*. By elastic bodies are intended those which resume their dimensions and form, when the force which changed them is removed. Nonelastic bodies are those which not only change their forms, when struck, but remain permanently altered in this particular. Although there are no solid bodies which possess either of these properties in perfection, yet the difference between those which are most, and those which are least elastic, is sufficiently great to justify the division.

Ivory, and hardened steel are eminently elastic. Such bodies, when struck together, become flattened at the point of contact; but immediately resuming their form, they react upon each other, and rebound. Lead and soft clay are nonelastic: if two balls of either of these substances be struck together, a permanent flattening is produced at their points of contact, and they do not rebound.

If two nonelastic bodies, A and B, fig. 1, each having the same quantity of matter, move towards each other with equal velocities, they will come into contact, as at A B, in the centre, where they will remain at rest after the stroke, because their momentums were equal, and in opposite directions. That is, if each have two pounds of matter, and a velocity which we may call ten, the momentum of each is twenty; and just sufficient, therefore, to destroy each other.

If, on the contrary, the bodies be perfectly elastic, they will recede from each other with the same velocity with which they met. In the former case, a permanent indentation was produced on the bodies; in the present, the flattening is instantaneous only, and the particles resuming their former position and arrangement, react upon each other with a force equal to their action, and, after the stroke, recede with undiminished velocity.

If two nonelastic bodies, A and B fig. 2 moving in the same direction with different velocities, impinge upon each other, they will move on together after the stroke with such velocity, as, being multiplied into the sum of their weights, will produce the sum of the momentums which they had before the stroke: that is, if each weigh one pound, and A has 3, and B 4 degrees of velocity, the sum of their momentums is 12; $1 \times 8 + 1 \times 4 = 12$: then after the stroke their velocity will be 6; which multiplied into their quantity of matter 2, produces 12. The quantity of motion before and after the stroke, or, which is the same thing, their momentums, will be unchanged.

If, on the contrary, they had both been elastic, and movingas before, then, after the stroke, A would have moved with four, and B with eight degrees of velocity: they would consequently have interchanged velocities, but the quantity of motion would remain unchanged.

If A and B be nonelastic bodies, equal in quantity of matter, and A moving with a velocity 10, come into contact with B at rest, they will move on together with the velocity 5. The quantity of motion will therefore remain unchanged, a double mass moving with one half the velocity. If the bodies A and B be both elastic, B, after the stroke, will fly off with the velocity 10, and A will remain at rest. The quantity of motion will, as before, remain unchanged. To understand this difference between elastic and nonelastic bodies, we may suppose that when the two elastic bodies come into contact with each other, they tend to move on together, like the nonelastic, with one half the velocity of the body A; that is, A gives half its motion to B; but, being elastic, the impinging parts, which give way, instantaneously resume their form, and react upon each other with a force equal to their first action, which drives A back with a velocity 5, and B forward with an equal velocity: the effect of which must be to leave A at rest, and to accumulate the whole motion in B.

ARTICLE 8.

ON COMPOUND MOTION.

If a body be struck by two equal forces, in contrary directions, it will remain unmoved; but if the forces, instead of acting on the body in directions exactly opposite, strike it in two directions inclined to each other, motion will be communicated to the body so struck; but its direction will not be that of either of the striking bo-