7. If a body free to move be acted on by an incessant force by article 3, motion will ensue which will be accelerated so long long as the force acts, or the body has space to move in, unless arrested by some other force. During the first instant of time the body will pass over a certain space, and will have acquired a certain velocity, which would carry it over double the space in the next instant of time, but the force being incessant, will cause the body to move the same distance in the next instant of time, independent of the previously acquired velocity, which jointly will carry it over three times the distance the second instant of time that it moved in the first, and its velocity will be doubled. Hence the spaces passed over in equal successive portions of time, will be as the odd numbers, 1, 3, 5, 7, &c., and the velocity acquired at the end of each portion of time, simply as the times 1, 2, 3, 4, &c. The velocity will be as the time the force is acting, and the space passed over as the square of time.

Heavy bodies subjected to the action of gravity near the surface of the earth will describe, in the first second of time, a distance equal to 16·0799 feet. But for all practical purposes 16 feet is near enough the truth. A heavy body will fall from rest one foot in the first fourth of a second, and acquire a velocity of one foot per eighth of a second, therefore the square root of the distance fallen in feet, will equal the velocity in feet per eighth of a second, which if multiplied by eight will give the velocity in feet per second.

8. The want of uniformity in terms as used by writers, has caused considerable confusion, and many misunderstandings. The terms below will be used as indicated.

Power is the term used to express the power of a certain force, or a force of certain intensity operating through a certain space, whose unit is one pound descending by, or raised against gravity one foot. When the force is constant it is usual to estimate the power at so much per second or minute, as for instance 33,000 pounds raised one foot per minute, or 550 pounds raised one foot per second, is termed a horse power. The effect produced by a power is estimated similarly.

Momentum is a term used to denote the product of a certain force, acting during a certain time. Its unit is a force equal to one pound, acting during the time of one fourth of a second. The velocity in feet per eighth of a second, multiplied by the mass will equal the momentum of a body in motion.

The momentum of a body in motion is by article 2 and 6, the intensity with which it will act, or the pressure it will exert against an obstacle which arrests its motion in one fourth of a second of time, or is equal to a force that would give the body its motion by acting on it one fourth of a second.

Intensity of a force is its capacity to generate motion. Its unit is equal to the force of gravity on one pound of matter near the surface of the earth.

Impetus is the force of motion, or the power of a body in motion, to produce effect, and is equal to the square of the velocity multiplied by the mass.

The units of space and time being arbitrary, that of velocity is arranged to correspond with that of power. The square of the velocity in feet per eighth of a second multiplied by the mass, will equal the power necessary to generate the velocity.

Mechanics of Unelastic Fluids.—9. Fluids are bodies so constituted, that their parts are all ready to yield to the action of the smallest force or pressure, in whatever direction it may be exerted. Every particle of fluid presses, and is pressed equally in all directions, whether it be upwards or downwards, laterally or obliquely; and when in a state of rest, the pressure exerted against the surface of the vessel which contains it, is perpendicular to that surface.

10. The particles of a fluid, situated at the same perpendicular depth below the surface, are equally pressed; and the pressure upon any of its constituent elements, wheresoever situated, is equal to the weight of a column of fluid particles, whose length is equal to the perpendicular depth of the particle or element pressed.

Fluids in Motion.—11. Fluids acquire the same velocity by issuing out at an aperture, that heavy bodies do by falling a distance equal to their height of head from under which they issue; consequently, by art. 7, the velocity from under any height of head, will be as the square root of that highth.

12. When fluids in motion impinge perpendicularly on a plain fixed surface, the constant pressure against the obstacle, will equal the weight of water that impinges in the fourth of a second, multiplied by the velocity per eighth of a second. For, by art, 8, the force necessary to give the water velocity, is equal to the momentum; and as the water that strikes in the fourth of a second, must necessarily be the fourth of a second in having its motion arrested, the constant pressure will equal this quantity multiplied by the velocity in feet per eighth of a second

The pressure, will equal the weight of water that impinges during the time necessary for a heavy body to acquire an equal velocity by falling from rest. For the quantity that impinges in that time, must necessarily have its motion arrested, during the same time, and, by art, 3, and 7, the constant force necessary to arrest the motion of a body in the time that it would acquire its motion by falling, is equal to the weight of that body.

Or, the velocity with which the water impinges in feet per second, divided by the velocity acquired by falling one second multiplied into the weight of the quantity that impinges in one second, will equal the constant pressure.

Example.—Let a sluice of water one foot sectional area impinge perpendicularly on a plain fixed surface, at the rate of sixteen feet per second; required the constant pressure in pounds.

By 1st. Here, the velocity per eighth of second is 2, and the quantity dsscharged in the fourth of a second is 4 cubic feet, and $2 \times 4 \times 62{\cdot}5 = 500$ lbs. the constant pressure.

By 2nd. The time necessary to acquire a velocity of 16 feet per second is 0·5 seconds; and $\cdot5 \times 16 \times 62{\cdot}5 = 500$ lbs. as above.

By 3rd. $1 \div 632 \times 16 \times 62{\cdot}5 = 500$ lbs. the constant pressure.

13. When water is compelled to move in a curve it will resist having its direction changed, and if it be whirled round in a cylindrical vessel of any size, it will rise as high in the vessel as the heighth of head necessary to give it an equal velocity.

14. The tendency of fluid particles towards the orifice occasioned by their sustaining less pressure in that direction gives rise to a contraction in the jet of fluid, which, in issuing from the orifice, assumes the form of a truncated cone, whose greater base corresponds to the orifice. This diminution in the size of the jet is called the contraction of the vein.—When the orifice is pierced through a thin plate, the diameter of the vein is such that only ·62 of the theoretical quantity will be discharged. If a tube equal in length to twice the diameter of the orifice be inserted, the quantity discharged will equal ·80; but if the tube be cone shaped, in form similar to the contraction of the vein, then the theoretical quantity will be discharged very nearly.

15. By art, 2, the re-action against a vessel aving an outlet of water, will equal a force necessary to give the issuing water its motion. Sir Isaac Newton supposed it was equal to the weight of a column of water the size of the orifice and twice the highth of the head; which conclusion would have been correct, had the water issued with a velocity equal to that assigned by theory, and in a vein equal to the size of the orifice. But the contraction of the vein (art, 14) causes a diminution in the quantity discharged; unless, however, the smallest part of the vein be taken for the orifice; when Sir Isaac's conclusions will be found very nearly correct

By art, 2, and 12, the re-action will equal the weight of water that issues during the time required for a heavy body to acquire a velocity equal to that of the effluent water by falling from rest.

As fluids press equally in all directions, when a part of the pressure in one direction is taken off by the opening of an orifice, the containing vessel will tend to move, in a contrary direction with a preponderant force equal to that required to give the water motion;—not that the issuing water reacts,—but by art, 2, when a body is found moving in any one direction, it is known that a force equal to that which gave it motion has acted in a contrary direction.

The Re-action Water Wheel.—16. There are but three modes by which water actuates machines; or, more correctly speaking, there are three ways by which the force of gravity, through the medium of water, will propel machinery, viz., 1st. by inertia, generally termed percussion; 2. By gravity, directly; and 3. By pressure, generally termed re-action.

All water motors, whatever may be their construction, are propelled by the force of gravity, through the medium of water, in one or the other of these modes; or by two or more of them combined.

The class of motors actuated by percussion, termed undershot wheels, have, very properly, gone out of use, and will be passed over without notice.

The class actuated by gravity direct are used to some extent, yet it is deemed unnecessary to treat of them here.

17. The most interesting motor, is that class of water wheels propelled by pressure, usually termed re-action water wheels. It is comparatively speaking, of modern origin, and was not until quite recently very highly esteemed, but will, no doubt, when its principles of action are properly understood, and its advantages duly appreciated, supersede all other motors.

The common re-action wheel, as formerly constructed, can only give an effect, approximately, equal to one half the power. For by art, 15, the pressure, or re-action, can only equal the weight of water that issues at the jets during the time that a heavy body would acquire an equal velocity by falling from rest. And, as the water comes into the wheel without velocity in the direction of the motion of the wheel, when the wheel is moving, the water as it enters the wheel is given a motion similar to that of the wheel by the wheel; which requires such a portion of the force, or pressure, as the velocity of the wheel bears to that of the effluent water. If the wheel move as fast as the water issues, the retarding force will equal the impellant force,—or, the force necessary to give the water a motion as it enters the wheel, equal to that of the wheel, will equal the force of pressure or re-action; (see art. 3 and 15). In which case the machine will produce no effect. But if the wheel move half as fast as the water issues, then the retarding force will equal only half the pressure, and the effect will equal half the power.

18. To establish a rule for estimating the effect produced by re-action wheels: put V=the velocity of the effluent water: v=the velocity of the influent water, and w=the velocity of the wheel,—all in feet per second. Put m= the weight of water that issues per second, and g=the velocity acquired by falling one second. Then, by arts. 12 and 15 $(V \div g)m$=re-action or impellant force; and $(w-v \div g)m$=retarding force, or force necessary to give the water a velocity equal to that of the wheel; which, taken from the impellant force, leaves $(V-w \times v \div g)m$=the preponderant force, which being multiplied by the velocity of the water, is reduced to $m \div g(V-w \times v)w=E$, the effect. 21-1

But in the purely re-action wheel the water enters the wheel without velocity, and $v=o$, whence $w-v=w$. Therefore the expression takes the form $E=m \div g(V-w)w$. 21-2

This formula indicates that when $w=\frac{1}{2}V$ the effect is a maximum, and $E=\frac{1}{2}P$; but when $w=v$, or $w=o$, the whole expression vanishes, and $E=o$.

The practical rule deduced from this equation may be expressed in words as follows, viz.,

RULE—To the velocity with which the water enters the wheel, add that of the effluent water, less that of the wheel; multiply this sum by the velocity of the wheel, and by the weight of water that issues in one second; and divide the product by the velocity acquired in falling one second (32) and the quotient will be the effect per second.

It may not be improper to state here that the expression $E=m \div g(V-w \times v)w$, must be affected with the experimental co-efficient n, which varies according to circumstances that will be discussed hereafter.

EARLY HISTORY OF TURBINE WATER WHEELS.—19. By the term "turbine," is understood, that class of re-action wheels which receive the water with a whirling motion. 21-3

Some short time previous to 1830, it was discovered that, by giving the water a motion with that of the wheel previous to its acting on a re-action wheel, the effect would be greater than when the water came into it without motion in that direction.

Z. and A. Parker obtained a patent, October the 19th, 1829, embracing this principle in the specification. Mr. Parker says he discovered the principle, accidentally, in 1827.

In 1823, M. Fourneron of France, commenced an investigation of the action of water on wheels, which terminated in the discovery of the celebrated wheel which bears his name.—He wrote an essay, which was published in a Journal in France, in 1834, giving a full description of the invention, and several machines which he had erected; and was awarded a prize of six thousand francs for the successful introduction of his wheels into use.

It is somewhat singular, that the discovery should have been made on both continents at the same time. Fourneron says he established his first turbine at Pont sur l'Ognon, in France, in the year 1827: the same date of Mr. Parkers discovery in the United States.

The original discoverers, not understanding the principles of action, did not make their claims, when applying for a patent, broad enough to cover the whole grounds; and in consequence, since 1830, a number of patents have been issued to persons of the United States, embracing their principle to a greater or less extent. While all who observe the operation of these wheels see their superior action, few, or none appear to understand their principles of action. And most writers on the subject, appear to mistify, rather than elucidate the action of water on this class of wheels.—Some seem to think the water acts by impulse, some by re-action and re action and percussion combined; while many bring in centrifugal and other unknown forces as auxiliary. Experimenters differ so widely in their reports,—some who are interested giving such extravagant results—that the studying of the elements of mechanics, and becoming familiar with the few principles of nature which originate, carry on and terminate all mechanical movements, are the only means by which millwrights can gain a correct knowledge of the action of the machine. They will then perceive that there is no great mystery about the action of water. 21-4

PRINCIPLE OF ACTION.—20. The principle by which the turbine water wheel is made to be more efficient than the common re-action wheel, is very simple, and well known to all mechanicians. It is that principle (see art, 5) which causes a bullet dropped from the ceiling of a steam boat to strike the same point on the floor, as if the vessel were still; that which enables passengers or a car moving 40 miles per hour, to walk forward with as much ease as aft; and the satelites to respect their secondaries as their center of motion, as they would do if the primary was removed and they at rest.

That principle which causes two bodies moving in the same direction, with equal velocity, to act on each other as if at rest.

21. Notwithstanding the earth and moon act on each other while moving around the sun precisely as they would do if the sun were removed and they moving in a right line or were not progressing at all; yet, as some suppose that centrifugal force varies the action of bodies on each other on the earth, it may be necessary, before proceeding to discuss the above principle, to illustrate that principle of inertia by which a body in motion opposes being compelled to describe a curve, called centrifugal force. On investigation it will appear, that, notwithstanding the high authoritiy to the contrary, that there is no such force as centrifugal, and that the very term (centreflying) is erroneous. For bodies moving in a circle have no tendancy, whatever, to fly from their circle of motion; but merely oppose being compelled to move in a curve; (art 3) and are continually making an effort to move in a direct line, not from the centre, but perpendicularly to a line drawn from the centre through the body. If "centrifugal force," be a correct term, then is "vis inertia," equally so; for they are both the same; viz: That principle impressed on on all ponderable matter by which it tends to remain in that state in which it is placed.

FIG. 1. 21-5

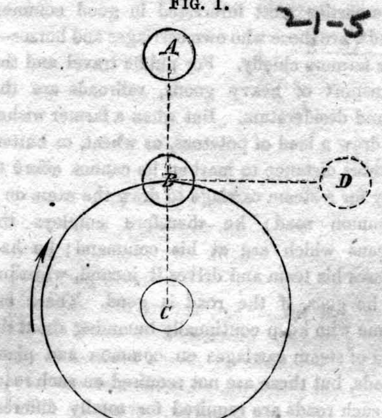

FIGURE 1.—if, while the body B, fig. 1, is moving around C, as its center, on arriving at the point B, in the circle, it should have its connection with C, destroyed, it would not approach A, on the opposite side from the centre C, but would move towards D, perpendicular to a line drawn from C, through B to A; and would have just as great a tendancy to fly from A, as from C. And moreover, its velocity will be no greater after its connection with C, is broken, than when moving in the circle; which would be the case if it tended to fly from C.—See "Scientific American," vol. 7, page 363, for a further illustration of this principle.

22. It was demonstrated, art, 18, that the simple re-action wheel could only approximate to an effect equal to half the power.—On an inspection of its principle of action, it will readily be perceived that the machine is defective; for the water has an actual velocity after leaving the wheel equal to one half that with which it issues; Therefore, one half the power is, necessarily lost. Now if the actual velocity which the water has after acting on the machine, can be consumed in, or prevented by giving the water a motion previous to acting on the wheel; if a machine can be so constructed that it will move as fast as the water issues, and the pressure, or re-action independent of a retarding force will equal that due half the head, we should have a machine realizing the power. If one half the head can be used to give to the water a motion in unison with that of the wheel before acting, and the other half used to impell the wheel by pressure, by art, 20, this may be effected.

FIG. 2. 21-6

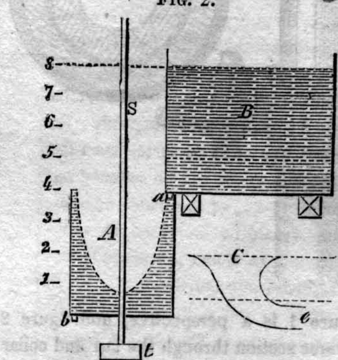

FIG. 2.—Let A, represent a cylindrical vessel on a shaft, or spindle stopped at t; whose depth is four feet. Let B, be a cistern placed over the brim of A, and filled with water to the highth of four feet above the surface of the water in A. a is a bent tube, (see it enlarged at C) inserted at the bottom of B, conducting the water into A, at a tangent to its inner surface; b is a similar tube to a, at which the water issues from A, horizontally, at a tangent to its inner surface, in a direction contrary to the movement of A. c represents a section of the tubes a, and b, on a larger scale, and in another position; e, being the orifice at which the water escapes, and is directed towards the front at a, and b, in the figure. The scale at the right of the figure shows the highth in feet.

When a, and b, are both open, and B, kept full of water; the vessel A, will revolve in a direction contrary to that with which the water issues at b, and in the direction of that at a; and the water in A, will revolve with the vessel. If by any means the velocity of the periphery of the vessel A, should be so retarded that it revolves just as fast as the water issues at the jets; by art 20, the water will re-act at b, and tend to impell the vessel A, as it would do if A was at rest and the water came in at a, perpendicularly. Here we have $v=w=V$, hence, $E=m \div g(V-w \times v)w=P$, the power. 21-7

If a friction brake be applied to the shaft s, so adjusted that the periphery of the vessel revolves with a velocity of 16 feet per second, and twenty pounds of water escape per second at b, then the pressure at b, (and consequently its equivalent on the brake) will equal the weight of water that escapes during the time that a body would acquire an equal velocity by falling from rest, and by art 7, as heavy bodies will by falling from rest acquire a velocity of 16 feet per second in half a second of time, the constant pressure at b, and on the brake, will equal one half the weight of the water that issues at b, per second; or, 10lbs. Which being multiplied by the velocity of the wheel per second, 16 feet, will give the effect; equal to 160 And the weight of water issuing, per second 20lbs. multiplied by the whole highth, 8 feet, will equal the power, 160. Hence the effect is equal to the power. $E=20 \div 32(16-16+16)16=160$. And, $P=20 \times 8=160$.

To demonstrate that the effect is doubled by apylying one half the head to giving the water a motion before acting, and using the other half to propell the vessel A. Suppose the wa-