

and by this means a circular movement may be converted into alternate rectilinear movement, with any required modification of velocity or direction.

This piece of mechanism is extremely simple of construction, is practicable on a scale of reduced dimensions, and is capable of numerous useful applications, of which we shall give selected examples.

SECTION IX.

To convert direct circular motion, of uniform velocity, or which varies by a given law, into alternate circular motion, of velocity either equable, or variable by a given law, and in the same, or in different directions.

THE arrangements, shewn in the articles E 7, U 7, B 7', E 7', G 7', H 7', I 7', K 7', L 7', M 7', may also be considered as examples of the required conversion.

A 9.

A is a wheel with waved teeth, and which communicates an alternate circular movement to the bent lever P S R. The method of constructing these curved teeth may be seen in the memoir of M. Deparcieux, to the Academy of Sciences, which we have already mentioned. There is no reciprocal action in this piece of mechanism.

B 9.

This is a remarkable instance of the preceding example, in which there is but one wave or curve. An application of it may be found in the Repertory of Arts and Manufactures, vol. iii, page 220; in the specification of a patent granted to William Fulton, &c. for a method of working pumps; and in Les Annales des Arts et Manufactures, vol. xxii, page 325.

A groove of this figure may be described on the surface of a cylinder, and if the extremities of two levers be introduced to it, an alternate motion may then be transmitted to four pumps at once, under an arrangement by which two of them shall be elevated while the other two shall be depressed.

In Leupold's work—*Theatrum Machinarum Hydraulicarum*, vol. i, we find an application of this contrivance to the raising water by means of two buckets. He places the mechanism shewn in B 9, near the upper extremity of a vertical axis, which turns constantly in the same direction, by the action of a fall of water upon the float-boards of an horizontal water wheel. A piece of wood placed vertically in the prolongation of the axis, supports a long horizontal beam, which presents the precise appearance of a balance, of which the supporting vertical piece will represent the suspension, and the horizontal beam the arms. The beam carries a bucket at each extremity, and is supported upon the mechanism exhibited in the article B 9, by friction rollers. The rotation of the shaft of the water wheel will communicate an oscillatory movement to the horizontal arm, and the two buckets will, by their alternate action, raise the water from a reservoir to an higher level.

C 9.

In this figure we have an elevation of the subject in the upper figure, and a plan in the lower figure, with corresponding letters of reference.

The memoir of M. Deparcieux (see A 7) furnishes the methods of describing a curve $a m n p$, which is grooved, and fixed to a lever $A B$ which is at liberty to turn freely upon an axis which passes through its extremity A ; if we suppose 1. That the wheel M has an equable rotatory motion on its centre, 2.—That the pin p fixed to a point on the surface of the wheel M , shall work in the groove which forms the curve $a m n p$, this curve may be of such a figure that the lever $A B$ shall make oscillations which will fulfil one of the following conditions:—1. That the arcs described by any point of the bar $A B$, shall be described with an equable velocity; 2.—That the velocity shall vary by a given law; 3.—That it shall not be the arc itself, but rather the chord of that arc which shall traverse with an equable velocity, or varying by a given law.

The curve described in the present figure, is of a nature to satisfy the first of these three conditions.

D 9.

We have in this figure also a plan and elevation of the subject, with their corresponding letters of reference.

The curve $a m n p$ may also be fixed on the surface of the wheel M , and in such a manner that the equable circular motion of the wheel M shall communicate to the lever $A B$ an oscillatory movement which may fulfil one of the three conditions stated in the foregoing example, by means of a pin p fixed in the lever, and which acts in the groove of the curve $a m n p$. The subject of that, and the preceding article, are capable of various useful applications in the solution of a great number of curious problems.

If the alternate circular motion of the lever be considered, all such motions will be arranged in this place; but if a grooved bar be fixed on the chord of the described arc, the intersection of that groove, with a longitudinal groove made in the lever, will present an open space in which a point may be inserted which shall have an alternate rectilinear movement; and in this case, the two motions $C 9$ and $D 9$ will be classed in Section 7. The same will be the case if the movement be that of a weight suspended from the extremity of a bar, by means of a rope which passes over a fixed pulley. Lastly, if an alternate circular movement be communicated to the wheel M , the same motions will then be arranged in the 17th and 19th Sections.

The movement $D 9$ has been applied to the construction of a watch escapement by M. Volet. (*Machines approuvées par l'Académie Royale*, Vol. vii. No. 450.)

E 9.

A cylinder A furnished with cams or curved projecting pieces, has a movement of rotation on its axis, and operates to raise the hammer B , which is suspended on an axis at C . This motion is too well known to need many illustrative examples.

F 9.

The upper of these figures is an elevation of the subject, the lower a plan, with the same letters of reference to each figure.

This gives an inverse solution of the problem in Section IX. A is the lower extremity of the shaft of a large wheel or fly, on which is fixed the ratchet wheel

B. *CC* is a wheel fitted on the shaft of the fly, by its friction, and carries a click-piece *q*, which acts upon the ratchet wheel by means of a spring.

The alternate circular motion of the wheel *C* transmits to the fly and the shaft *A* a direct circular motion in the same direction; but the wheel *C* will only act during the half of its oscillation. An application of this motion by White, may be seen in the report of Messrs. Prony and Molard, adverted to at H 7.

G 9.

This is another application of the movement described in the preceding article, *PQ* is a lever having an alternate circular motion, which it communicates to the wheel *C*, by means of the rope *a b c d e*, the proper tension of the rope is produced by the weight *P*, or by a spring. The wheel *C* is fitted on the axis *A* of the fly-wheel *N*, by its friction only; on the end of the axis of the fly-wheel is fixed a ratchet wheel shewn in the figure, and in which the click-piece α acts, the click being fixed on the wheel *C*. Under this arrangement, the alternate circular motion of *C* will cause the fly-wheel *N* to revolve constantly in the same direction.

An application of this movement is described in the "Bibliothèque Britanique," vol. vi, article "Arts," in an account of a patent granted to T. Bingen, for a method of producing a rotatory motion, by the action of an alternate movement in any direction, and which may be afforded by the power of steam or any other principle. The editor subjoins some observations on fly-wheels.

H 9. Plate 7.

AB is a lever which is capable of an alternate circular motion about the axis *C*: *cd* is an arm which has a free motion on its extremity *c*; its other extremity *d* is fixed to the toothed wheel *E*, which works with a similar wheel *F* set on the axis of the fly-wheel *N*; on the reverse side of the wheels *E* and *F*, is an arm *ef* which preserves the constant distance of the wheel *E* from the centre of the fly-wheel; the alternate circular movement of the lever *AB* elevates and depresses the wheel *F*, but this could not take place unless the

wheel **F** revolved on its centre. According to the arrangement of the machine the actual movement may be either direct or alternate; but the inertia of the fly-wheel operates to render it direct and nearly equable: a reciprocal action takes place, when the machine has commenced its movement. This mechanism is adopted in steam engine work—a description of it occurs in Prony's *Architecture Hydraulique*, part ii, page 118.

It will be observed, that notwithstanding the two wheels **E** and **F** are of the same diameter, the fly-wheel **N** makes two revolutions for each oscillation of the lever, which prevents the necessity of using fly-wheels of the large dimensions required to produce the same effect in the usual construction.

I 9.

The following is a description of a rotatory motion, for which a patent was obtained in England by Edmund Cartwright. This rotatory motion is communicated by steam, and its velocity may be increased at pleasure, without the assistance of wheel-work.

A B represents the side elevation of the upper part of the framing which incloses the boiler, the cylinder, the fly-wheel, and all the acting parts of the engine; an axis crosses this framing, on which the pulley or wheel **C** revolves; a chain passes over this wheel and is attached to the upper end **T** of the piston rod; (the wheel **C** receives an alternate circular motion by the action of the piston and its counterpoising weight **P**;) the wheel **C** carries a lever handle **D**, which by means of the arm **K** communicates with the lever **F**, placed horizontally on the top, or at the side of the boiler. Another axis, which may be placed either above, below or at the side of the first, passes through the fly-wheel **G**, and carries at its other extremity a lever handle **H**, which communicates with the horizontal lever **F** by means of the arm **I**, as before described of the wheel **C** by means of the arm **K**.

It is evident that when the wheel **C** is made to revolve by the action of the piston **T**, the arm **D** which is fixed on its axis, will cause the fly-wheel **G** to revolve also, the wheels **G** and **C** being connected with the same lever **F**. If **C** therefore be moved alternately in the direction **a b** and **b a** by the action of the

piston, and its counterpoise P ; and if the lever D of the wheel C moves in the same direction, the lever H of the fly-wheel will perform the same alternate movement, unless it should be (as it ought) of such length as that at the termination of its arc of rotation, it is at liberty to pass beyond it; which in fact, produces the complete rotation of the fly-wheel.

If the lever D of the wheel C be so disposed, as that when it revolves in any quantity not exceeding one entire revolution, it shall pass from e to a, by f, or in the direction traversed by a given point of the wheel C, then D will cause two vibrations of the lever for one stroke of the piston, and the fly-wheel G will in the same time make two revolutions. Further, if the diameter of C be so determined that it shall complete one revolution and a half for each stroke of the piston, and retrograde the same quantity, the lever F will receive three vibrations for each stroke of the piston rod. Lastly, if the wheel C be of such a diameter that it shall make two direct, and two retrograde revolutions for each stroke of the piston rod, the lever F will then make four vibrations, and the fly-wheel four revolutions.

It thus appears that the fly-wheel may revolve with any given velocity, without the aid of any combination of wheel work.

K 9.

This figure represents the common treadle. If we suppose the lever arm of the fly-wheel to be connected with the end of the lower lever or treadle, by an inflexible arm, the relation between the component parts of the treadle, and the effect or action become determinate, which, in a certain degree, is not the case when the arm is flexible; we will suppose the following data:—1. The length of the lower lever.—2. Its centre of rotation.—3. The value of the arc which it will describe at each oscillation.—4. The position of the centre of the fly-wheel with respect to the centre of rotation of the lower lever, the length of the upper or shorter lever, and that of the longer and inflexible arm, are known quantities. To determine their value, place the treadle or lower lever in its two extreme positions, the higher and the lower points of its vibrations, and draw right lines from the centre of the fly-wheel to the extremity of the treadle in

those two positions. The first of these distances is known, and should be equal to the difference of the length of the inflexible or longer arm, and the upper or shorter lever; the second, which is also a known quantity, should be equal to the sum of those lengths; consequently, the length of the longer arm, which must be more than that of the upper lever, is equal to half the sum of the two distances between the centre of rotation of the fly-wheel and the extremity of the treadle, in its two extreme positions; and the short lever must be equal to half the difference of those distances. If we suppose the angular velocity of the treadle to be equable, the velocity of the fly-wheel will be variable through its whole course; but the inequalities of its motion will become less sensible as the angular measure of the motion of the lower lever or treadle is smaller, and as the distance between the centre of the fly-wheel, and the centre of rotation of the treadle is greater.

L 9.

The conversion of an equable circular motion into an alternate circular motion whose velocity shall be variable according to a given law, is a problem which has engaged much attention in the fabrication of time keepers. The following example is selected from the *Machines approuvées par l'Academie*, Vol. iv. No. 267.

“ A clock motion which shows true time, invented by the curate of St. Cyr.”

“ The annual wheel A carries a curve of equation B C D; upon the face of this curve is cut a groove parallel to its edges; in the groove, moves a stud E fixed on the piece E F, and moveable on the point F; the stud is also fixed to a second piece E G, this is attached to the cylinder H, which carries the minute hand I, so that it follows the variations of the curve more than half the circumference of the minute dial, which is sufficient to mark the inequalities indicating the equation.”

Descriptions of other pieces of mechanism for the resolution of the same problem, may be seen in the following memoirs, contained in the *Recueil des Machines approuvées par l'Academie des Sciences*.

Clock which shows the true time, invented by Le Bon, Vol. iii. No. 146.

A clock motion, which shews the true time, by the same author, Vol. iv. No. 235.

Clock, which shews the true time, invented by M. Kriegleissen, Vol. iv. No. 269.

A clock motion, which shews the true and mean time, by Thiout, Vol. iv. No. 278.

An equatorial watch, invented by Dutertre, Vol. vii. No. 453.

An equatorial clock, invented by Ferdinand Berthoud, Vol. vii. No. 488.

Another clock is described in the seventh volume, No. 495.

M 9.

The following is the mechanism adopted by M. Breguet in an equatorial clock.

It may be considered as composed of two parts—one of them fixed, the other moveable.

The fixed portion of the arrangement is the square plate A A A A, held by four screws; it is cut through or grooved in the form of the curve of equation.

The moveable portion is composed of a plate g g, having its centre of motion in a; it carries a moveable tail-piece which has its centre of motion in b; one of its two extremities c, acts against the edge of the curve; the other extremity d, applies to the continuation e of an index or needle f, which has the same centre of rotation as the plate g g. The continuation of the index f is pressed into its action on the tail d by means of a spring h, the fixed extremity of which is screwed to one extremity of the plate g g as in the figure; the index J is fixed on the same axis as the index f and is concentric with it, or moves on the same centre of rotation.

The plate g g performs a complete rotation on its centre of motion a in one year; and, as we have described, carries with it in its course all the moveable parts of the machine. It will be conceived that the index J, which is fixed to the plate g g, might point out the days of the year by being set on a dial divided into 365 equal parts, and the index might be expected to traverse equal spaces upon these divisions in equal times, which however will not be the case. When the lever c acts on that part of the curve which is farthest from the centre, as I, the index J will be several divisions in advance of the index f; but on the con-

trary, when the lever acts on the part *M* of the curve which is nearest to the centre, the index *f* will then precede the index *J* by a certain number of divisions.

This difference of motion between the two indices is produced by the action of the lever *cbd* upon the plate *AAAA*, and the construction of the curve is calculated to advance or retard the index *f* relatively to the index *J*, by a quantity of the arc, or a number of divisions equal to the difference between the true and mean time in minutes, on the day indicated by the index *J*.

N 9.

The subject of this figure is a ratchet lever: it is the invention of *M. de la Garousse*; the description of it is extracted from the account of “*Machines approuvées par l’Academie des Sciences*,” Vol. ii, No. 74. In this machine an alternate circular motion is converted into direct circular motion, without reciprocal action.

The hooked arms *IL*, *MN*, are moveable on the points *IM*, and are so disposed that the lever by its alternate and direct motion, causes one of them to draw the ratchet wheel constantly towards it, while the other quits the tooth which it had acted on, and applies itself to another.

The inventor has applied his lever to a machine for communicating a simultaneous action to four corn mills. Vol. ii, No. 121.

See also figure 1, plate 26 of the first volume of—*Theatrum Machinarum de Leupold*.

O 9.

This mechanism is a wheel lever, invented by *M. de la Garousse*; see *Machines approuvées par l’Academie*, Vol. ii, No. 72. It is a modification of the preceding contrivance.

The large lever *AB* has its fulcrum in *C*; above and below are two short arms *D* and *E*, each moveable on its centre pin; and each of them also applies to one of the spindles of the lantern wheel *F*.

The alternate circular motion of the great lever produces the direct circular

motion of the wheel **F**, on the spindles of which the arms **D** and **E** act in rotation. If a rope were coiled on the axis of the wheel **F**, a direct rectilinear motion would be produced, and the arrangement would consequently belong to Sec. 4.

P 9.

In this machine, **a b** is a kind of pendulum or long lever handle attached to an horizontal cylinder **R**, which operates to give it an alternate circular movement; the two click-pieces **o n**, **p k** are fixed upon its convex surface and near its extremities by hinges, and they act upon the opposite teeth of the horizontal ratchet wheel **ST**, communicating to it a direct circular movement while the action of the moving power is uninterrupted.

In Vol. v. No. 209 of *Machines approuvées par l'Academie des Sciences*, we find an application of this movement to the construction of a machine for drawing loads, by M. Alix.

Q 9.

This machine is a modification of the lever of M. de la Garousse, (**O 9.**) but is not of equal merit—the power not being constant in its action.

This contrivance has been proposed for raising weights, by M. Henry. See *Machines approuvées par l'Academie*, Vol. iv, No. 264.

Several different arrangements of levers upon this plan may be seen in the first volume of—*L'Architecture Hydraulique de M. Bélidor*,; and in the—*Theatrum Machinarum de Leupold*.

R 9.

A is a horizontal wheel toothed on its upper face through a little less than one half of its periphery; **B** and **C** are two toothed wheels fixed to the axis **d e**; their distance should be equal to the diameter of the wheel **A**. It is evident that the toothed portion of the wheel **A**, which must always be less than its semi-periphery, will fall into action with the wheels **B** and **C** alternately, and communicate an alternate circular motion to the axis **d e**.

In Bockler's work (see **E 3** and **K 3**) fig. 109, we find this arrangement applied to the working of pumps. He first communicates the direct circular motion of

the horizontal shaft of a vertical water wheel to a vertical axis, and then converts the motion of the vertical axis, into an alternate circular motion upon another horizontal axis by the contrivance we have described in the present article and lastly, the alternate circular motion of that horizontal axis communicates a vertical and alternate rectilinear motion to the piston rods of four pumps: two of which are made to rise, while the other two descend, and this by the mechanism described in our article M I7; the pump rods have racks upon them, and the horizontal axis has pinions or toothed wheels.

In Ramelli's work (referred to in our article A 7') may be seen an application of this contrivance to the action of two pumps.

If the wheels B and C were indented on a portion of their inner faces, and the wheel A were toothed over its entire periphery, and were placed between the edges of the wheels B and C, it will be evident that the direct circular motion of the axis dc will produce an alternate circular motion on the axis of the wheel A.

Bevel wheels may be introduced in the arrangements of this piece of mechanism although we have given no representation of such an application in our figure.

Ramelli, in the work above mentioned, shews several applications of this last method, which is, in fact, but a modification of the arrangement first described in this article.

O B S E R V A T I O N S.

In all mechanical combinations for the measurement of time, the moving power, or sustaining force communicates a direct rotatory motion to each wheel of the train. To render this movement uniform, notwithstanding the irregularities which must necessarily affect all mechanical arrangements of great delicacy, whether arising from the moving power—the imperfection of workmanship—the influence of temperature—or from other accidental sources, the last wheel of the train, or scape-wheel, has been placed in contact with the regulator; that is to say—with the pendulum or balance, of the clock or watch. This regulator makes an alternate circular motion, which in the present state of perfection of the art, possesses the property of performing its oscillations in equal times, of

whatever extent those oscillations may be, or under whatever temperature they may be performed. These valuable properties are afforded by various methods of construction, of great ingenuity and intelligence; but the particular consideration of which does not come within our present purpose.

The communication between the direct circular motion of the scape-wheel, and the alternate circular motion of the regulator, is effected by a piece of mechanism technically termed the escapement; its functions are to maintain the action of the sustaining force on the regulator against the loss which it suffers at each vibration from friction and the resistance of the air, and to communicate the equable action of the regulator to the train-of wheels*.

All the known escapements may be arranged in four distinct classes, viz.

1. The escapements of recoil.
2. The dead-beat escapements.
3. The free vibration escapements.
4. The free vibration, and remontoire escapements.

The recoil escapements are those in which the scape-wheel acts constantly on the regulator, by its alternate action on two pallets; these are impelled in turn by the teeth of the wheel, and the regulator continuing its vibration produces the retrograde motion of the wheel.

The recoil escapements may also be arranged under three distinct heads, viz.

1. The crown-wheel escapement †.
2. The anchor or crutch escapement ‡.
3. The double lever escapement §.

The dead-beat escapements are those in which the teeth of the wheel, after escaping from the pallet or impelling lever, fall on a circular plane, or on a portion of a cylinder carried by the regulator, the motion of which continuing, the tooth remains at rest. There are two descriptions of these escapements, one

* Histoire de la mesure du temps par les Horloges, par Berthoud, vol. ii, page 303.

† Essai sur l'horlogerie, par Berthoud, 1786, vol. i, page 136.

‡ Idem, vol. i, page 139.

§ Idem, vol. i, page 138.

which is properly the dead-beat escapement, and is adopted in clock-making; another which is termed the cylinder escapement, and is applied in the construction of watches.

The free vibration escapement is also a dead-beat escapement, the wheel being at rest after the impulsion; but the repose of the wheel, in this instance, differs from that of the escapements above mentioned, in as much as the wheel after its impulsion, neither comes into contact with, nor rests upon the cylinder carried by the regulator; but is checked by a piece which is separate from that portion, so that the regulator completes its vibration freely, without experiencing any resistance from the escapement.

The free remontoire escapement* differs essentially from all others, either of those adopted in clock-making, or those used in the construction of watches: in all these escapements, the action of the scape wheel is directed immediately on the regulator, communicating to it the sustaining force which it has itself received from the train and the mover, without modification; so that this force cannot be considered as perfectly equable, from the irregularities of the wheel-work, the friction of the pivot, and of the sustaining force itself. In the free remontoire escapement the scape-wheel does not act directly on the regulator, but at each vibration coils a spring into a given position, or to a determined point of tension; and which at its return, restores to the balance the necessary sustaining force whence it results that the power exerted being equable, and communicated to the balance, the latter will describe equal arcs in equal times. This invention takes its date from the commencement of the 17th century.

We shall not attempt to detail or describe all the escapements which have been invented; and still less to constitute ourselves judges of their merit. We shall confine ourselves to the giving a few examples in each of the four classes above mentioned: those who may wish for more extensive information on the subject, may beneficially consult the elaborate work of M. Berthoud from which valuable source we extract the following accounts.—

* Histoire de la mesure du temps, vol. ii, page 44.

S 9.

The crown-wheel escapement.

The scape-wheel $I I'$ receives from the moving power a direct circular motion in the direction $I S I' S'$, (so that the perpendicular sides of the ratchet teeth precede in the progress of the wheel) and it transmits this motion to the levers or pallets $h i$, which are carried by the verge or vertical axis KK , which is also the axis of the balance.

The alternate motion, or vibration of the balance is here produced by the action of the wheel $I I'$ upon the pallets of the axis of the balance; they are set at an angle of about 90 degrees with each other, so that when the pallet h is impelled by one tooth of the wheel, and has escaped, the other pallet i is presented to a tooth of the wheel diametrically opposite, and is impelled in its turn; the wheel turning constantly in the same direction, the balance vibrates on itself, and by its alternate vibrations regulates the velocity of the wheel I , and consequently the action of the whole train.

This balance differs materially from those we term regulators, which possess the property of making isochronous vibrations.

An improvement of this escapement was made by M. Huygens in 1675, by the application of the spring to the balance (a discovery which Leibnitz awards to M. Huygens.) The intention of this alteration was to produce several revolutions of the balance for each vibration; for which purpose he converted the balance into a toothed wheel, working with a pinion set on the axis of the balance.

In the works of Rosbery and Bockler, already mentioned in our article $K 3$, we find the description of several mills, in which a weight is the moving power; and whose action is regulated by a contrivance similar to that here described.

T 9.

The dead-beat escapement for seconds pendulums in clocks, constructed by Graham.

This escapement does not materially differ from the recoil anchor escapement invented by Clement, a clock-maker of London, in 1680.

The piece which forms the escapement has also the anchor form; but with this difference—that the pallets are so constructed as to produce no recoil: this becomes what is termed a dead-beat escapement, by means of circular or cylindrical faces which are formed on the pallets, and correspond with the inclined surfaces which produce the maintaining power of the pendulum. The *Traité de Thiout*, page 93—and *l'Essai sur l'Horlogerie de Berthoud*, No. 1324, may be consulted as to the curvature required for the anchor pallets, to produce the isochronous vibrations of the pendulum.

This dead-beat escapement of Graham's, when executed with the necessary care and precision, is still the most perfect which can be used for the purpose; and especially if made with ruby pallets, as is sometimes the case.

The action of this escapement is thus:—The pallet *a* we may suppose has escaped, and the other pallet *b* receives a tooth of the swing-wheel upon its cylindrical portion; the vibration is completed, and the pallet enters the tooth completely without touching it; the returning vibration is made, and the wheel remains stationary until the inclined surface of the pallet presents itself to the point of the tooth—the tooth then acts upon it, the pallet is driven off, and at its escape the tooth *c* strikes the cylindrical portion of the pallet *a*, and is retained until the inclined surface presents itself; the wheel is then in action, follows the inclined surface of the pallet, and passing it, gives motion to the pendulum.

U 9.

The dead-beat cylinder escapement for watches, invented by Graham.

F is the scape-wheel of twelve teeth, upon each of which is fixed a small wedge or inclined plane *i*; on the verge or axis of the balance, there is fixed a portion of a hollow cylinder of steel or other hard material, as is shewn at *B* in the figure; the interior diameter of this hollow cylindrical portion is equal to the length of one tooth of the wheel, and is at liberty to revolve about the tooth nearly one turn. It will be seen by this description, that when the balance ad-

vances from a, towards b and c, the wheel F is in a quiescent state; and when the point a arrives at the extremity of the inclined plane i, the action of the wheel will be thereby transmitted to the balance, and the inclined plane rests upon the interior C of the cylinder; the wheel has another interval of repose, the balance returns in the opposite direction, again receives the action of the same inclined plane at its exit at C, and the following tooth applies itself to its exterior curve in the same manner as the preceding one, and so on of the rest. See the description of this escapement, in the *Traité d'horlogerie de Lepaute*, printed in 1755, page 171; in *l'Essai sur l'horlogerie par Ferdinand Berthoud*, Paris, 1786, vol. i, page 131; and in the *Traité des échappemens par Jodin*, Paris, 1754, page 132.

A 9'.

Dead-beat pin escapement, by M. Amant, clockmaker of Paris.

It is composed of a plane wheel, on which is arranged a circular line of pins. The pin I quits the pallet A, and the pallet B receives the impulse of the escapement; the vibration continuing, the pallet B falls, and the wheel rests, the seconds hand of this escapement has therefore no recoil. The vibration is repeated, the pin acts upon the inclined plane, restores the movement, and so on.

We here see that in dead-beat escapements as soon as a tooth of the scape-wheel has effected its impulsion of the balance, the same tooth rests on a portion of a cylinder which is carried by the balance, so that this tooth acts upon the cylindric portion of that axis during the whole time occupied by the balance in completing its vibration. Now, as this cylindrical portion of the axis is of course contiguous to it, it necessarily follows that while the balance completes its vibration, and the action of the scape-wheel is thus suspended by the cylindric portion of that axis, the scape-wheel itself will be perfectly quiescent; that is to say—it will never advance nor recede, whence the appellation of this escapement is that of repose, or dead-beat escapement; but notwithstanding the apparent advantages of this escapement, its principle of construction renders it naturally liable to much detrimental influence from oil, friction, and other consequent irregularities, however perfect may be its mechanical execution. M. Berthoud states—that these difficulties or defects in the common dead-beat es-

capements, induced him to seek the practical means of remedying them: for this purpose he arranges the escapement in such a manner that when the wheel has produced its impulsion, the balance may complete its vibration freely, and that during that time, the action of the wheel shall not be interrupted by the balance itself, as in the common dead-beat escapement, but by a detent which is disengaged by an instantaneous movement, so that the balance may not thereby encounter any other resistance or friction than what arises from the disengagement of the detent; and further, that the impulsion of the wheel shall be transferred to the balance with the least possible quantity of friction, and under circumstances which shall obviate the necessity of applying oil to the works. Such were the original ideas of M. Berthoud of the requisite construction for an escapement, which he denominated a free vibration or detached escapement.

In this escapement the balance makes two vibrations while but one tooth of the wheel escapes at a time, that is to say—that the balance shall vibrate on itself, and that the wheel in its escape at the return of the second vibration, shall restore to the regulator in one vibration, the loss of maintaining power which it has sustained in two. Thus, during the whole time of one vibration, and the greater portion of the second, the action of the wheel will remain suspended by the detent, allowing the balance to vibrate freely.

The invention of the free or detached escapement seems to belong equally to different artists, who without any inter-communication among themselves, had, as it should seem, nearly the same ideas of the subject. The persons who thus seem equally entitled to claim priority of invention are Le Roy, Mudge, and Ferdinand Berthoud. It appears however, that many years antecedent to this, J. Dutertre had organized a similar contrivance, but which was not published, and we are consequently unacquainted with the particulars of its construction.

B 9'.

Free escapement, as invented by Arnold.

C is the scape-wheel of this escapement; **D** a circular piece set on the axis of the balance; **t** a small projecting point from the axis; **n m** a spring having

its centre of motion in *n*; the action of this spring is to press constantly towards the wheel *C*, and its progress in that course is checked by the projecting piece *q*; a point *p* also projects upwards from its extremity *m*. The spring *n m* carries a second spring *r s* of extremely delicate form and action, and which has its point of support in *r*.

This understood, we will imagine the balance to vibrate in the direction indicated by the dart in the figure; the projecting pin *t*, will then fall into contact with the extremity *s* of the finer spring *r s*, which opposing little resistance, will allow it to pass; but at the returning vibration in the contrary direction, the spring *r s* will meet the obstacle *p*, and instead of bending in the point of support *r*, it will cause the first spring *n m* to bend on the point *n*, and will consequently allow the escape of a tooth of the wheel *C*; at this moment another tooth of *C* will strike into the indentation of the piece *D*, and restores the loss of power to the balance. Thus at each double vibration of the balance, the point *q* of the spring *n m* releases a tooth of the wheel *C*, and the balance receives a new impulsion.

C 9'.

Free Escapement, by Ferdinand Berthoud.

The description of this escapement is extracted from the inventor's work—*Histoire de la mesure du temps par les horloges*, vol. ii, page 35.

In the figure, *A* represents the escapement wheel, *a b c* the detent; the arm *a* of the detent suspends the action of the wheel, while the balance makes a free vibration; the spring *d* brings back this detent as soon as the pallet *c* has thrown off the arm *b*; at the same instant a tooth of the wheel *A* acts upon the cylinder *h* which is carried by the regulator, and transmits the maintaining power to the balance; the balance having completed another vibration—returns, and in its retrograde motion the pallet *c* meets the end *b* of the detent; but this recedes, flying off from the arm *b* and towards the centre of the more distant circle from *b*, and the spring *l* brings it back to its action when the balance has completed its vibration; so that at its return, the pallet *c* is again presented to the arm of the detent to disengage the wheel and repeat the impulsion of the balance.

Haley's free Remontoire Escapement.

In the year 1796 Mr. Charles Haley, an English watchmaker, obtained a patent for a free remontoire escapement: a description of which is inserted in the *Repertory of Arts and Manufactures*, No. xxxiii, page 145. Vol. VI.; and in the *Annales des Arts et Manufactures*, Vol. VIII. page 38; and M. Berthoud has extracted an account of it in the second volume of his work—“*Histoire de la mesure du temps par les horloges.*”

A description of the escapement of Delafons may also be seen in—“*Les Annales des Arts et Manufactures*, Vol. ix, page 69.”

D 9'.

Description of Breguet's Remontoire Escapement for Watches.

This account is extracted from Berthoud's “*Histoire de la mesure du temps par les horloges*, Vol. ii, page 55.”

A A is a plate of metal upon which is fixed the entire movement of the escapement.

In order clearly to describe the mechanism of this escapement, it will be more satisfactory to the reader to consider it under three distinct portions or divisions, the respective action of which will be stated separately, and their relation to each other afterwards explained.

Part 1. This portion of the arrangement is composed 1st of the wheels B B' and D which are fixed to each other. The wheel B B' is placed in action with the moving power by a train of wheels, which produce its rotation in the direction B C B'.

2nd—Of a pinion g which drives the wheel B B'; its teeth are equal in number to so many of those of the wheel B B' which are contained in the space between two following teeth of the wheel D D'. This pinion will therefore at each of its revolutions be opposite to a tooth of the wheel D D'. On the axis of the pinion is a fly i g h; the branch g i of which, is shorter than the other g h, at the extremity of which is a small piece of steel.

3rd.—It contains a check spring rrF , fixed at the end rr and placed at right angles to the direction of the flye at about two thirds of its length from its fixed end, there projects a piece V which carries a ruby or other precious stone, or a piece of tempered steel. In that state of the mechanism which is represented in the figure, the ruby presses against the extremity h of the flye and so performs the office of a stop, which prevents the fly from moving in the direction in which the pinion g would carry it by the action of the wheel BB' ; it thus suspends the motion of the wheel BB' , and consequently the action of the moving power. But if from any cause the spring rrF is inflected on the side of the pinion g , at the moment that the stud V , comes opposite to the notch near the extremity h , the fly escapes, and performs one revolution, and if at the completion of that revolution the spring rrF has taken its first position, it will be stopped by the stud V and will pass no further.

PART II.—The second portion of the arrangement is composed——

1st. Of an impelling spring G , curved at its extremity. This spring, as will be more fully explained hereafter, serves to restore the maintaining power to the regulator at each oscillation; it carries a projecting piece or catch m , within which is a small notch, having a ruby projecting from its interior surface. When the impelling spring is inflected by the action of the wheel DD' which communicates to it the action of the first mover, it is checked by this catch and its stud together with a piece we shall presently describe.

2nd.—Of a check spring aH , fixed at its extremity a , and upon which is fastened a very delicate spring N . The spring H carries a ruby p , which enters into the notch of the catch m , and fixes the spring at its inflection. Another jewelled stud placed at its extremity s holds the spring N , so that the end of the spring, pressed from right to left, offers but little resistance; and pressed from left to right, it throws all its effort upon the stud s , and inflecting the spring H disengages the jewel p from the cavity of the catch m .

3rd.—The pieces K and b are carried by the upper extremity of the axis of the balance, and are so placed as to form an angle of 90 degrees between them. When the balance vibrates from right to left, or in the direction bK , the piece K inflects the spring, and passes beyond it; and the piece b being situated

above the plane of the wheel $B B'$ and below that of the spring H , the vibration from right to left is performed freely, and without any other obstacle than the flexion of the spring N . But when the balance afterwards vibrates in the contrary direction from left to right, the piece K presses the spring N against the stud s , the spring H is inflected, the stud p is disengaged from the catch m , and the spring G , left to its own action, operates as we shall presently describe.

On preserving and communicating the sustaining Power.

The action of the arrangements for preserving and communicating the sustaining power, will be clearly understood from the preceding description. At the instant the stud p of the spring H is disengaged from the catch m of the spring G , and G is released, the straight side of the piece b is at right angles to the direction of the extremity q of the spring, which strikes it, and imparts to the balance the power necessary to enable it to complete its vibration: immediately after this first percussion, the same extremity q strikes the end F of the spring $F r r$, inflects it and drives the stud V opposite to a notch in the fly $i h$, which is thus released; and the moving power which acts on the wheel $B B'$ and thus on the pinion will cause it to perform one revolution, at the completion of which, the spring $F r r$ being again in its first position, it is checked by the stud V ; but during this revolution, a tooth of the wheel $D D'$ has pressed against the projection n (which is shewn near the end q of the spring G) and has forced it back, and this action continuing according to the relation of the wheels B and D , until the stud p of the spring H is again engaged in the catch m ; every part of the machine will then be in the situation represented in the figure, and the action be repeated as before.

E 9'.

This piece of mechanism is a remontoire escapement for clocks, and is invented by M. Breguet.

A is the last mover, and moves from right to left in the direction of the dart shown in the figure.

B, a wheel of six curved teeth, set on the axis of the wheel **A** ; but at its opposite extremity.

C, a pinion acting with the wheel **A**, and performing six revolutions for one revolution of the wheel **A**.

D, A fly-wheel set on the arbor of the pinion and fixed there by its friction only; by the operation of a small spring, it is allowed to continue its motion, when the pinion is suddenly checked.

E, a small vane, or cross-piece of steel fixed on the arbor of the pinion **C**, and resting against the stop or check-piece **F**.

F, the above-mentioned check-piece, turning on the pivot **V**.

G, an arbor which carries three pieces of considerable importance in the arrangement:—1. The piece **c**, which has on one side the curved tail-piece or tooth **d**, and on the opposite side two ratchet teeth **e f**: the first of these operates to stop the motion of the arbor by means of the check-piece **H**, and the second, to impel the pendulum when the arbor is entirely free;—2. A pin, or small roller **g**, fixed in the piece **c** for the purpose of raising the check-piece **F**;—3. A small weight **h**, whose distance from the axis may be varied by means of a screw adjustment, in order to regulate the impelling force which acts on the pendulum, according to the arc of oscillation required to be described.

H, a check-piece which turns freely on its centre, which is fixed to the case of the wheel-work.

II, the bob of the pendulum, suspended to the upper extremity.

LL, a plate of copper fixed to the bob of the pendulum.

M, a small and very light lever, which at one end turns on the pivot **i**, and at the other presses on the pin **l**; the extremity furthest from the pivot carries a projecting edge-piece **m**, which disengages the piece **H**, and the arbor **G**.

N, an edge-piece, on which the pendulum receives its impulsion. Its projection or elevation above the plane of the plate **LL** should be such as will allow it to pass freely behind the piece **H**, and having a portion of its thickness to engage with the piece **C**; its lower part should glance upon the tooth **f** at its movement, but without any actual contact.

The moving power turns the wheel **A**, the cross-piece **E** will be stopped by

the piece **F**: if we suppose the bob of the pendulum to oscillate from right to left, the projecting piece **m** of the lever **M** will be in contact with the check-piece **H**, and will disengage the tooth **e**, while the piece **N** is presented to the impelling tooth **f**. The arbor **G** is then completely free, and the action of the weight **h**, as well as the weight of the tooth **d**, gives it a tendency to turn from right to left; and its motion being quicker than that of the pendulum, it arrives at the piece **N**, and impels it, the tooth **f** rising in its progress. The arbor **G** continuing its motion, the pin **g** comes in contact with the tail of the check **F**, and leaves the fly **D** free: the tooth **d** being at the same time opposite to the tooth **f**. Therefore, while the fly performs one revolution, the tooth **p** acting upon the tooth **d** brings the arbor **G** to its first position; the piece **f** presents itself to check the fly, and the piece **H** acts upon the notch **e** to check the arbor **G**. The pendulum in its motion from left to right experiences no opposition but from the head of the piece **H** to which the edge **m** applies; but the termination of these pieces being similarly sloped or inclined, the lever **M** raises itself, and afterwards falls to its first position.

This method of preserving the sustaining power of a pendulum in its oscillations, we consider to be the most perfect of any at present known.

F 9'. Plate II.

In our article I 7' we have observed that in weaving machinery, the shuttle frame is required to traverse the arc **a b** (F 9') with an alternate circular motion, the axis of rotation being in **C**; that its velocity should not be equable, but decreasing as it approaches the extremity **a** of the arc **a b** nearest to the large roller, and accelerated as it approaches the other extremity; and that this alternate circular motion subjected to these conditions, is communicated to the shuttle frame by the direct and equable circular motion of an axle **d**, which is driven by any moving power.

This problem may be resolved with all desirable precision and facility, by the methods already explained; the following method by approximation has been used in England, and we have also seen its application in Paris, in the manufactory of M. Cala, an eminent constructor of spinning machinery.

Let $d e$ represent the crank arm of the axis of rotation d , its length equal to half the chord of the arc $a b$; $c f g$ a metal rod suspended in the point f to a second rod $h f$, which turns upon the point h . While the point e of the crank proceeds from e to e , from l to m , and from m to n , the point f of the rod $h f$ passes from i to f , from f to s , and from s to k ; and consequently the distance $k i$ will be equal to the distance $n l$. The shuttle frame being required to traverse the arc $a b$ in the same interval, the distance $a i$ is divided into two parts $i r$ and $r a$, the portion $f g$ of the rod $e f g$ is taken equal to $r i$, and a third rod $g p$ equal in length to $a r$, is placed as in the figure, so that its extremities may turn freely on the points g and p of the rod $e f g$ and the line $c p$ of the shuttle frame; and the shuttle frame will traverse the arc $a b$ with a velocity the variations of which will depend on the relative proportions of $f g$ and $g p$; these distances will be easily arranged by a few trials.

G 9'.

Let $A B$ represent a horizontal shaft, which receives an alternate circular motion from the moving power, n and m two ratchet wheels fixed upon the shaft so that their teeth are reversed with respect to each other; C , D and E three toothed bevel wheels, of which C and D are of equal diameter; they are held on the shaft $A B$ by friction only; they carry the two click pieces p and q , and they work with the third wheel E , the axis of which is properly supported. The shaft $A B$, by its alternate circular motion, acts on the wheels C and D alternately, and soon acquire a direct circular motion; and, as this must take place in opposite directions, the wheel E will turn constantly in the same direction; and thus, the alternate circular motion of an axis or wheel, may be converted into the direct circular motion of another wheel, the direction of the second axis being at right angles to that of the first, or the plane of the second wheel being at right angles to that of the first.

H 9'.

The conversion of a direct circular motion, into an alternate circular motion, by a method sufficiently simple for practical purposes, and which will allow the

alternations to be regulated at pleasure, is a problem of universal interest with mechanics and artists of every description.

In our articles L 7', (Plate 4), and M 7', (Plate 5), we have given two examples of the conversion of direct circular motion into alternate rectilinear motion, by the action of a counterpoising weight, which acts alternately on the opposite sides of a vertical line passing through the axis of rotation of the arm; the alternate changes of position, taken by the weight alternates the action of an arrangement of wheel-work, which converts the rotatory motion of a spindle into an alternate motion, as in the case of the axis E F in the figure L 7', and the two cylinders F and G in the figure M 7'; the alternate circular motion so produced is afterwards converted into alternate rectilinear motion. In these two examples we see the methods by which the change of position of the counterpoise is effected; and which are calculated for the particular purposes of these machines; but in general whenever a counterpoising weight is adopted for the conversion of direct circular motion into alternate circular, the periods of the alternation may be regulated either by some simple combination of wheel-work, or by the arrangements D 3 Plate I, and S 8 Plate II, which will be found of universal application.

Let MN, figure H 9', Plate II, represent an axis corresponding with E F in the figure L 7', Plate 4, or to one of the cylinders F or G in the figure M 7', Plate 5; P, the counterpoising weight; n o, the axis of rotation of the vertical arm on which the counterpoise is supported; q o an arm placed at right angles to the vertical arm and the axis n o; e s r, the axis of the machine S 8 Plate II, placed as in the figure; it will now be perfectly easy, as has been already explained, to cause the arm r s to perform only one revolution about the axis D E, while the axis MN shall make n revolutions at pleasure. We will now suppose that the axis r s be raised from the lower towards the upper part of the figure, and on its arriving there, the counterpoising weight P will be situated in the vertical line which passes through n o; it will now fall towards the point p'; the rotation of the axis MN will be changed; the axis s r will also return in the opposite direction, will meet the arm o q at the upper part of the figure, will

return it from the upper to the lower part, and cause the weight **P** to move toward p'' ; and so on.

I 9'.

In this figure we have a plan, and an elevation of the subject:—the figure on the right being the elevation, that on the left, the plan. The same parts of the machine has in each figure the same letters of reference respectively.

The mechanism shewn at **D 3**, Plate 1, may be employed here for the same purposes, as follows:—

That arrangement may be placed as in the present figure, the axis **AB** is terminated by a square arm **gh** which is fitted by its friction into an aperture cut in the centre of the pulley **G**; this pulley is supported by a collar, or in any sufficiently substantial way, which will not impede the rotatory motion; the moveable nut **M'** carries a forked piece or double-armed lever **iklm**; an endless rope passes round the axis **MN** and the pulley **G**, by means of the fixed pulley **H**.

The circular motion of the axis **MN** is communicated to the pulley **G**, and consequently to the axis **AB**; and this axis in its rotation is at liberty to rise or fall freely; if we suppose the nut **M'** to rise, the lower branch **ml** of the forked piece **iklm** will come into contact with the lever **oq** of the counterpoise **P**, and cause the weight to fall towards the right hand; (see the plan) the arbor **MN** at the same time will move in the opposite direction; the nut **M** will descend, and the upper branch **ik** of the forked piece comes into contact with the lever **oq**, and by its action carry the weight **P** over and allow it to fall on the other side, in the period proposed; and so on. An arrangement of pulleys of different diameters may be substituted for the pulley **G**, as is done in the toothed wheel **B** of the mechanism **S 8**, Plate 11; the periods of intermission of the alternate circular motion, may by this means be varied at pleasure.

The mechanism shewn in our subject **P 3**, Plate 10, may be also used as an auxiliary method of resolving this problem.

K 9'.

This figure comprehends a plan and two elevations for the illustration of the