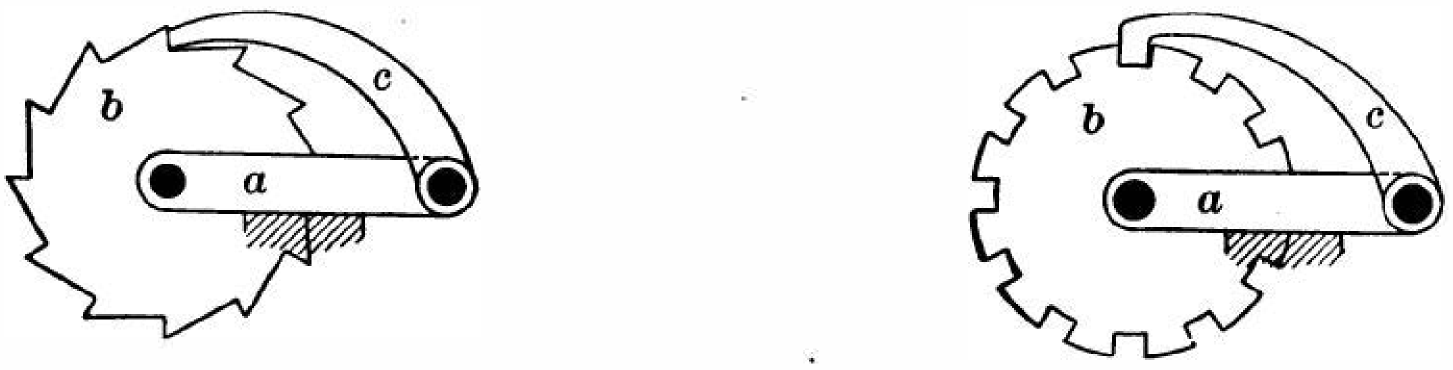
CHAPTER IX.

RATCHET MECHANISMS AND ESCAPEMENTS.

75. Ratchet-gearing.—We have so far considered mechanisms in which relative motion of the various links is possible at any instant, so that no link is definitely held or checked by another. We have now to study the action of *Ratchet-gearing*, which may be said to be gearing so arranged that certain links are temporarily or periodically locked together or connected during the action of the mechanism. This locking or checking of relative motion may be so effected that relative motion of the two links is only possible in one sense or direction (when the gear is called by Reuleaux a *Running-ratchet Train*), or movement in both directions may be rendered impossible when the ratchet acts, in which case the gear is known as a *Stationary-ratchet Train*. Fig. 150 shows the two kinds of ratchet-train in their typical forms. Each consists of a frame or arm a, a ratchet-wheel b, and a ratchet or click c. In the first figure b is evidently capable of left-handed rotation only, so long as the ratchet c (sometimes called a *pawl*) is resting against its teeth. In the second figure motion is only possible when the pawl is



Running. FIG. 150. **Stationary.**

lifted clear. Examples of simple ratchet-trains will readily occur to the reader; in Fig. 151, for instance, is shown the

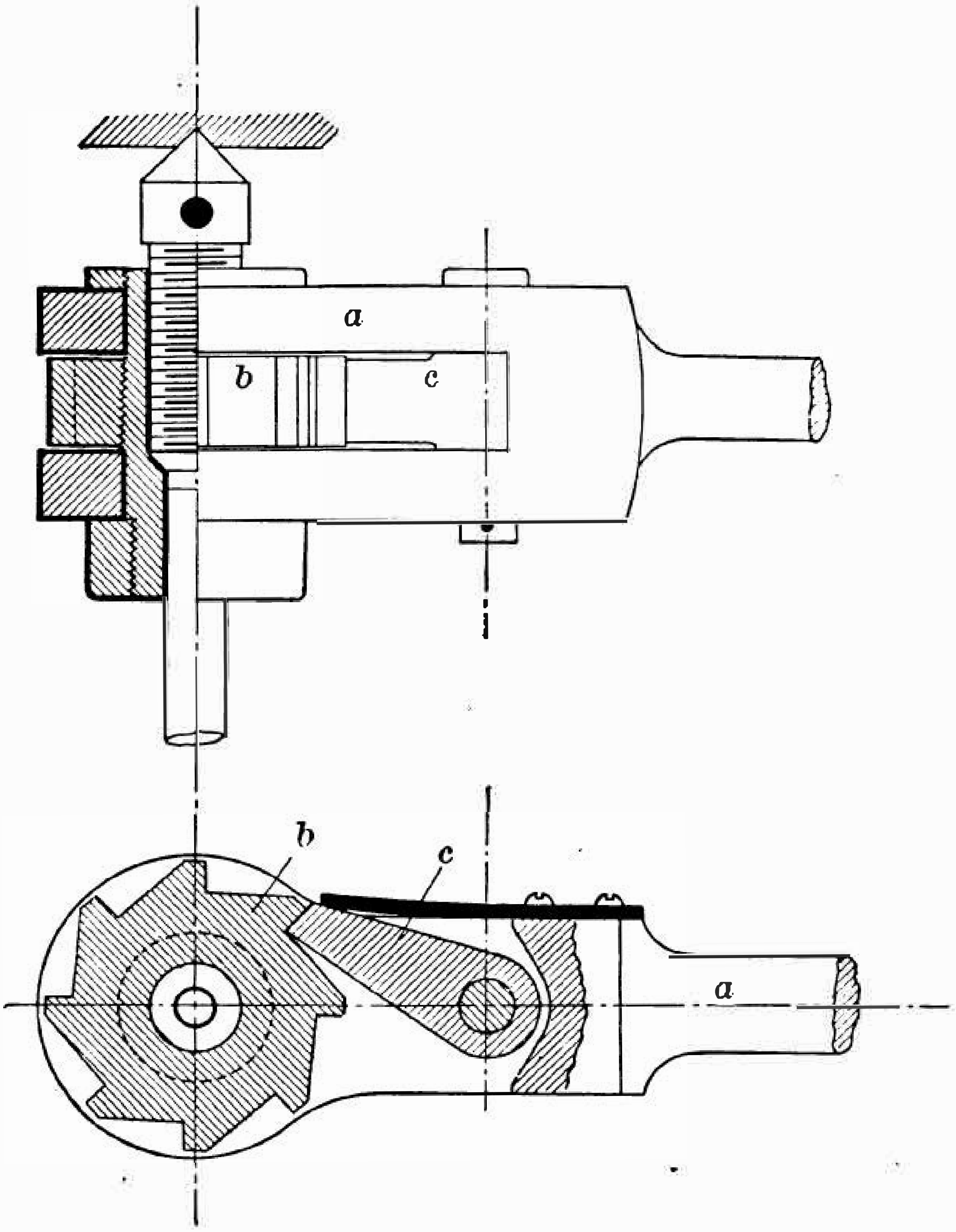


FIG. 151.

mechanism of a ratchet-drill, in which the different links are lettered in the same way as in the preceding figure.

76. Running Ratchets.—It is not necessary that the connection between the pawl and ratchet-wheel in a running ratchet should be of the positive kind shown above. Fig. 152 shows a form of frictional ratchet gear commonly used to transmit motion in one sense only from the crank-axle to the sprocket-wheel of a "free-wheel" bicycle. Here the ratchets themselves, *cc*, take the form of small rollers held up by springs behind them; the rollers are confined within a driving-ring, *b*, attached to the sprocket-wheel, and when in action jam between this ring and suitably formed surfaces on a ratchet-wheel, *a*, attached to the crank-axle. Such

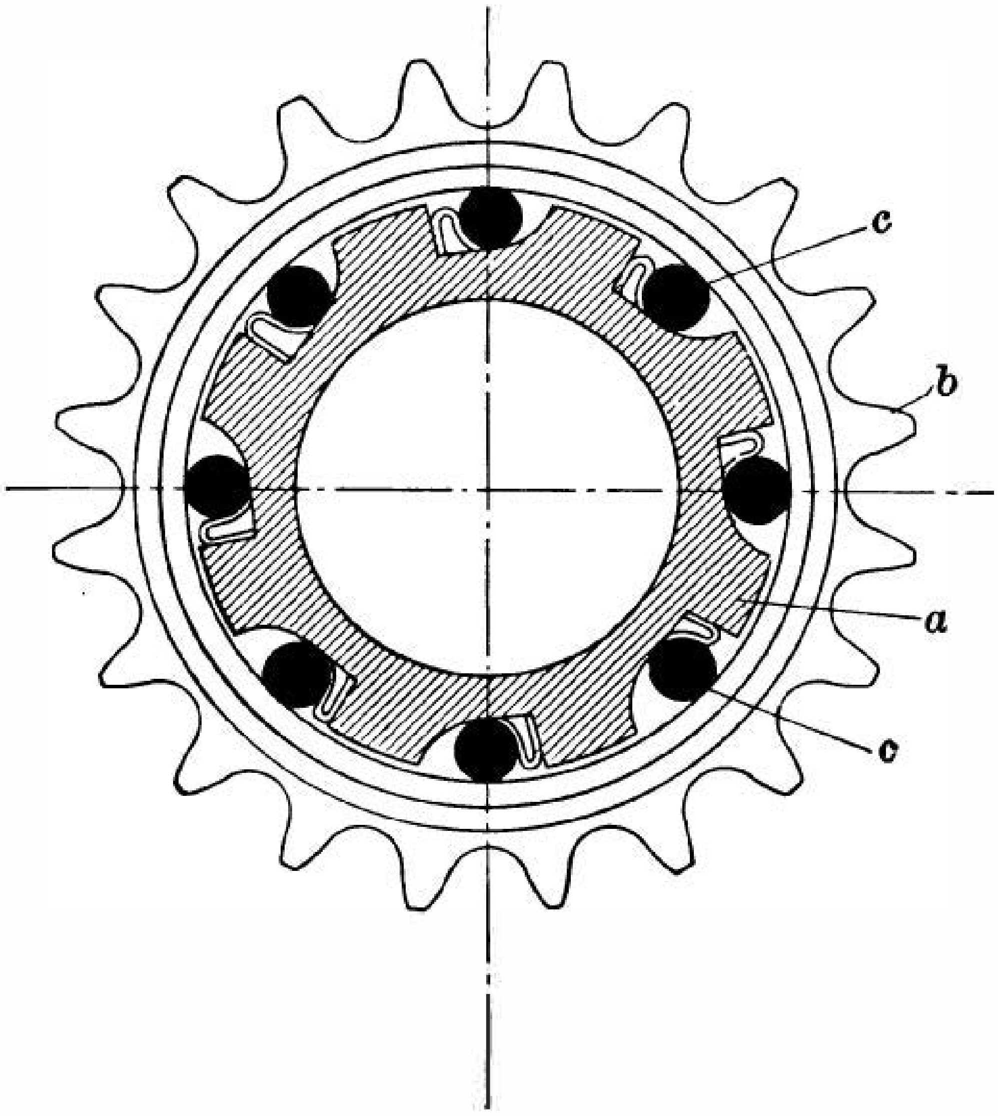


FIG. 152.

frictional ratchet gears are sometimes classed under the head of *silent ratchets*.

It should be noted that while ratchet-trains are used most frequently for controlling the motion of a turning pair, there are many cases in which such trains actuate links which have linear motion.

Fig. 153 shows a running-ratchet gear in which the ratchet *c*, attached to a reciprocating bar *d*, acts on a ratchet-rack *b*, and drives it in one direction only, motion in the opposite direction being prevented by a second ratchet or pawl *c'*, attached to the fixed link *a*. The mechanism is thus a combination of two running-ratchet trains, *abcd* and *abc'*; the former for driving, the latter for checking.

Most running ratchets in common use are really a combination of this kind; for example, in the ratchet-drill the function of the checking ratchet is performed by the frictional resistance of the drill in its hole.

It is important to note that the form of the surfaces on which the pawl and ratchet-wheel or rack engage must be carefully chosen, in order that the mechanism may fulfil its purpose. The shape of the pawl must in fact be such that the pressure between it and the tooth or surface with which it acts does not tend to throw it out of gear. Further, the mechanism must be force-closed, so that the pawl always tends to engage itself; this is commonly effected either by the action of springs (Figs. 151 and 152), or by the weight of the pawl itself (Figs. 150 and 153), or, in some cases, by making the pawl itself a spring. Fig. 154 shows a running friction ratchet which depends for its action on the weight of the ring-shaped pawl itself. Such a mechanism has been employed in certain electric arc lamps for controlling the downward movement of the carbons.

77. Stationary (Checking and Releasing) Ratchets.— Ratchet mechanisms of this type are used where it is necessary to check and release the driven link at will. In most cases a running ratchet or a cam is provided for the purpose of actuating the link whose motion is controlled by the locking ratchet. The mechanism of a *lever-lock* (shown diagrammatically in Fig. 155) is of this kind. The tumbler *c* and the bolt *b* here form a stationary-ratchet mechanism with the frame *a*.

The release of the bolt is effected by the action of the portion *M* of the key, which really forms a cam engaging with the curved surface of the profile *PQ* of the tumbler. When this release has been effected the bolt is shot back by the action of the portion *N* of the key. This part (also a cam) moves the bolt by engaging with the notch seen on the under side of the bolt. In actual lever-locks three, four, or more tumblers are used, with a corresponding number of steps on

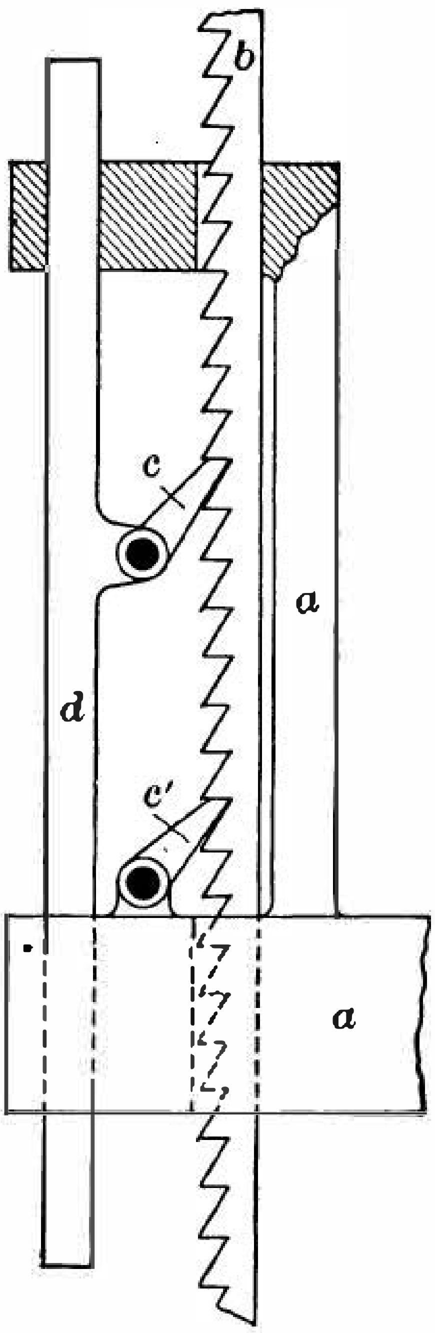


FIG. 153.

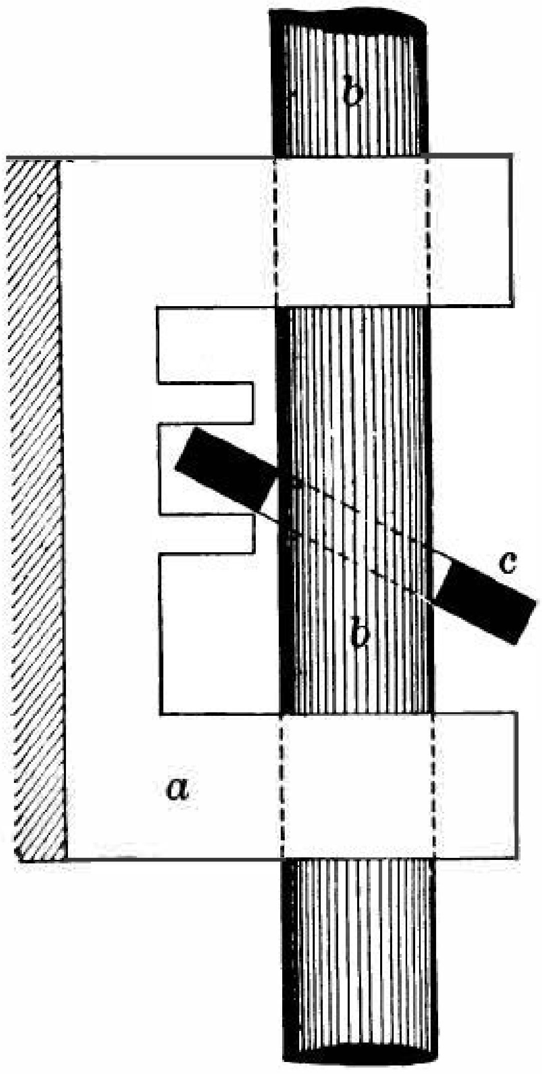


FIG. 154.

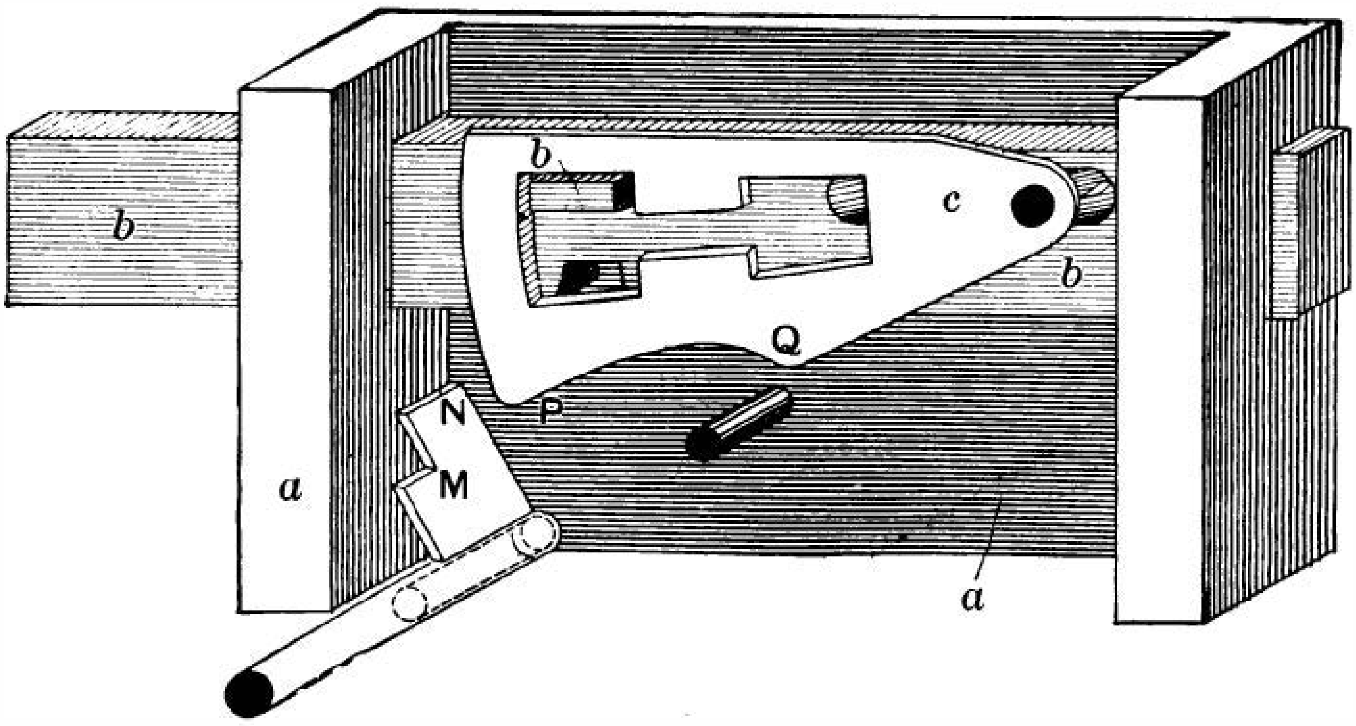


FIG. 155.

the key, and springs are provided so as to press the tumblers against the key.

Releasing and checking ratchets need not necessarily be positive in their action; they may depend on frictional forces just as in the case of the driving ratchet of Fig. 152. Thus, for example, a friction-brake may be looked upon as a frictional checking ratchet.

In Figs. 156*a* and 156*b* we have another example of a checking-ratchet train, in the case of the *Yale lock*. This

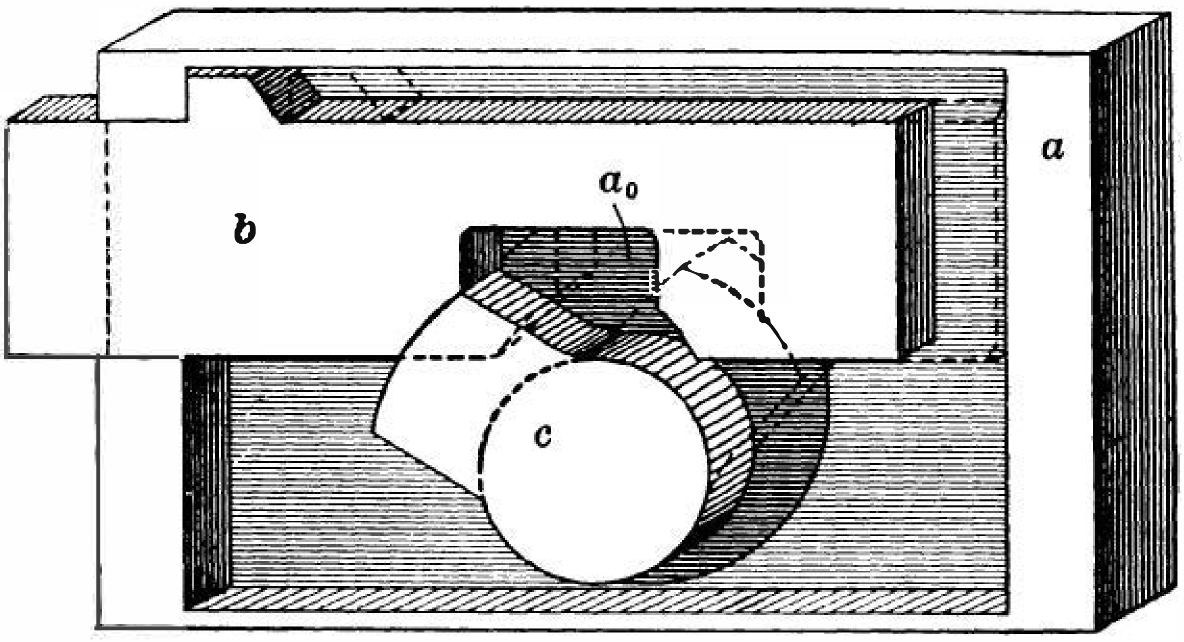


FIG. 156*a*.

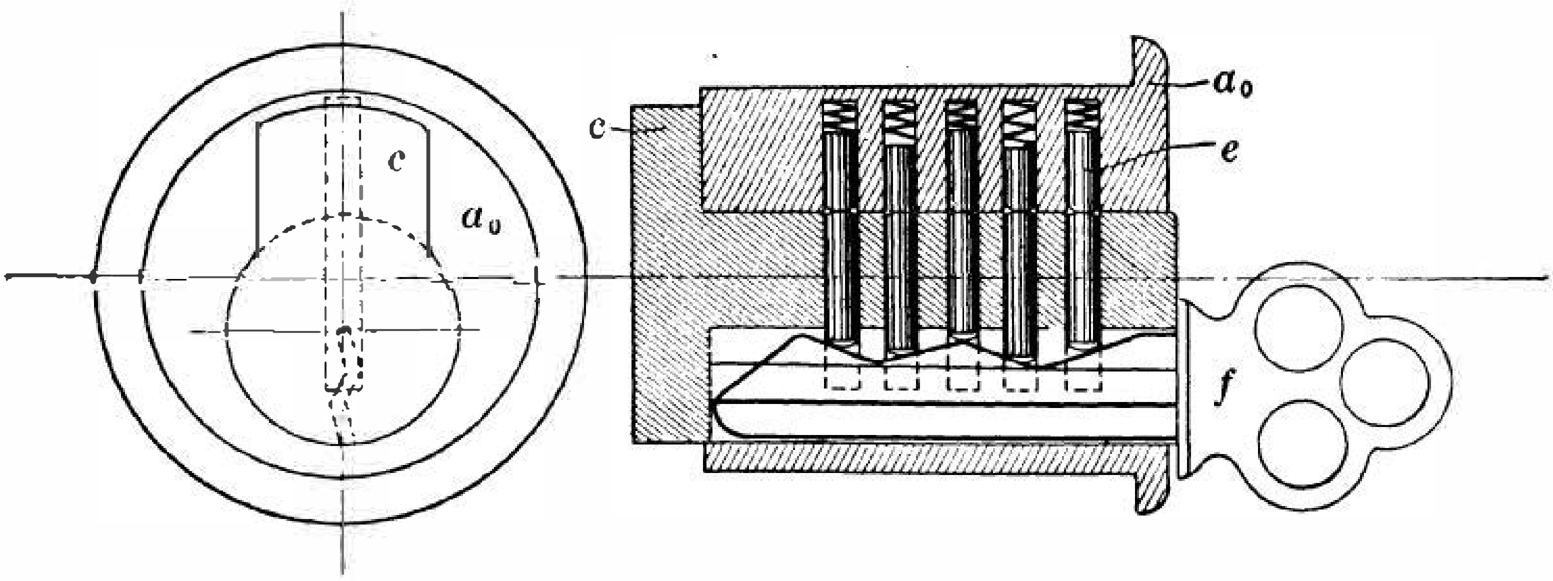


FIG. 156*b*.

lock really contains two distinct mechanisms, one a cam-train *abc*, which actuates the bolt, and the other a locking-ratchet train, which secures the cam, and can only be released by the insertion of the correct form of key. These mechanisms are shown separately. Fig. 156*a* shows the former train, in which the cam *c* is rotated by turning the key, and locks the bolt when in its extreme outer position. Fig 156*b* shows the cam and its bearing; on inserting the notched key *f*, as shown, each of the tumblers or pawls *e* is lifted to such a height that the division between the two portions of the tumbler is flush with the surface of the bearing. The cam can then be rotated and the bolt *b* can be shot or withdrawn. This locking gear is, of course, a stationary-ratchet train. The case a_0 is rigidly connected with the frame of the lock, *a*, when the whole lock is put together.

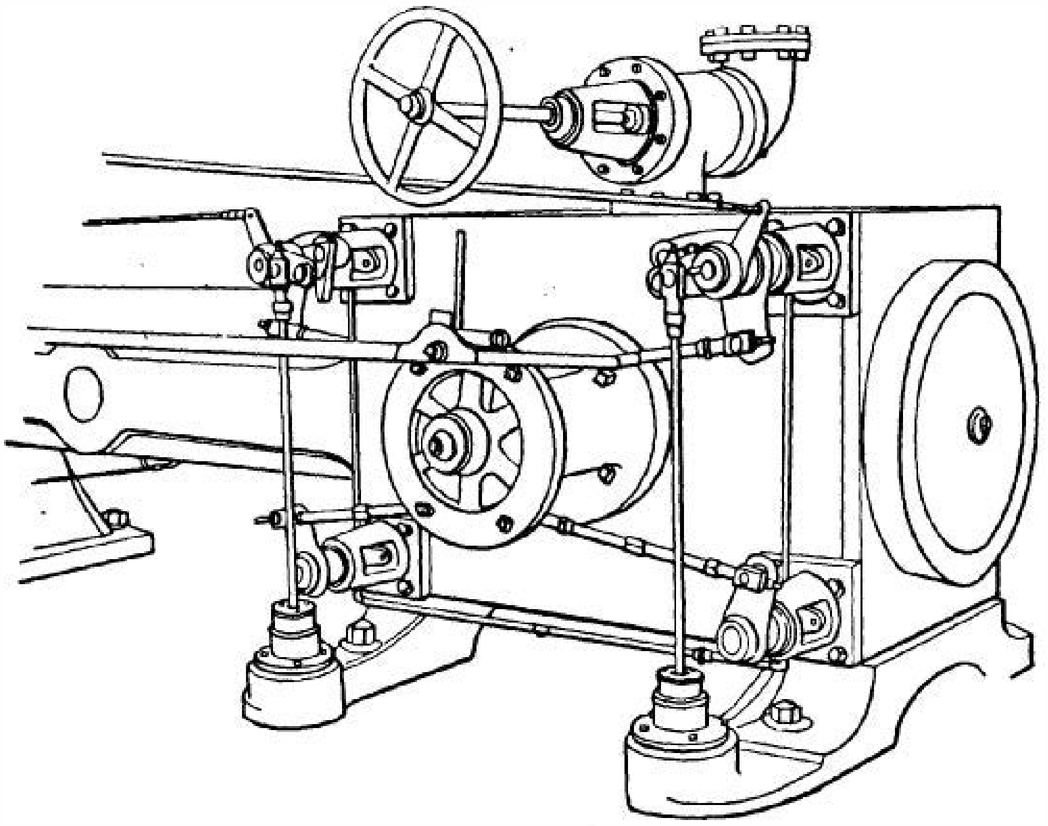


FIG. 157*a*.

Most checking or releasing ratchets are found combined with some form of cam gear, as in the examples above. This is also shown in the case of the releasing-ratchet trains employed for working the steam-valves of a Corliss engine (Figs. 157*a* and 157*b*). Fig. 157*a* represents the engine cylinder and the gear for working its steam- and exhaust-valves; Fig. 157*b* shows in diagrammatic form the ratchet mechanism of the steam-valves. The various parts are arranged somewhat differently in the two figures. The object of such gear is to open the valve at the proper point in the revolution of the engine, and then, after a variable interval, depending on the amount of steam to be admitted, to release the valve so that it may be promptly closed by the action of springs or of gravity. The valve is attached to the spindle and lever *a*, and is opened by rotation in the sense shown by the arrow.

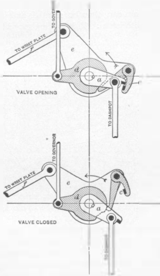


FIG. 157*b*.

In the example shown, the point at which the valve closes is determined by a cam *d* whose position is regulated by the governor of the engine. During the motion of opening, the valve is driven from the rod *f* connected to a rocking wrist-plate (Fig. 157*a*). The wrist-plate thus gives a rocking motion to the lever *e*, and when moving in the direction of the arrow this lever opens the steam-valve by the engagement of the ratchet or pawl *c* with a corresponding stud or projection on *a*. On reaching the proper point the pawl is lifted by the action of the cam *d*; then the weight of the dashpot, or the tension of a spring, causes the lever *a* to drop. Thus the valve is promptly closed. A spring (not shown) is of course required in order to keep the pawl *c* pressed against the cam *d* and in readiness to engage with *a* on the return stroke.

The many forms of brakes and clutches may be regarded in a sense as ratchet mechanisms (checking and releasing ratchets); in many cases their action is independent of the sense in which the wheel or shaft is rotating.

Fig. 158 shows two forms of clutch employed for connecting at will two pieces of shafting, *A* and *B*. To the shaft *B* is secured one portion of the clutch B_1; the shaft *A* carries the other portion, A_1, in such a fashion that A_1 may be made to slide along *A* so that its projections will engage with the corresponding recesses in B_1. At the same time the projecting feather or key A_2 compels A_1 and *A* to rotate together. Thus when the clutch is engaged, the rotary motion

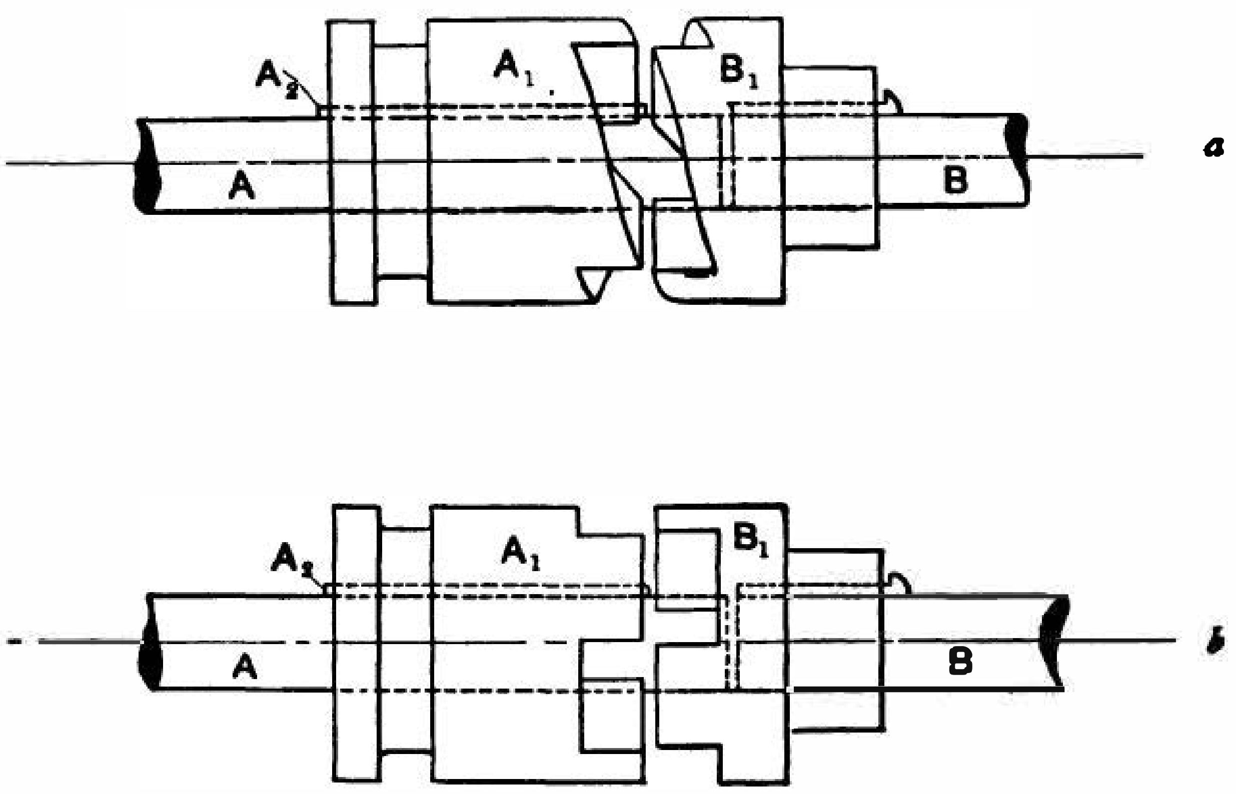


FIG. 158.

of B is necessarily transmitted to A. On comparing Figs. 158 and 150 the reader will see at once that we have in the two forms of clutch an exact equivalent of the running and stationary ratchet of § 75. The clutch shown in Fig. 158 in the upper view will only transmit relative motion in one sense; it is therefore really a running ratchet gear. In the lower view no relative movement of the shafts is possible when the clutch is engaged; the contrivance thus forms a stationary ratchet.

An example of a frictional running ratchet was given in § 76. Fig. 159*a* represents a locomotive wheel and its brake; here we have essentially a frictional stationary-ratchet gear used as a brake, the brake-block corresponding to the ratchet or click. In Fig. 159*b* we have a frictional

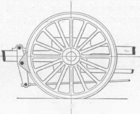


FIG. 159*a*.

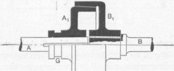


FIG. 159*b*.

stationary ratchet used as a clutch for communicating motion from the shaft B to the shaft A. When the clutch A_1 is pressed along the shaft into contact with B_1 the frictional grip between the two halves of the clutch is sufficient to drive the shaft A. The half clutch A_1 is made to slide along the shaft by the action of a fork whose jaws engage in the groove G shown in the sketch. The same arrangement is employed in the clutches of Fig. 158.

Ratchet mechanisms are of very frequent occurrence in machinery, and it is here impossible to attempt any exhaustive catalogue of their many forms. The subject has been most completely treated by Reuleaux.* Certain ratchet mechanisms containing non-rigid links are discussed in § 88.

78. Escapements (Uniform, Periodical, and Variable).—Under the head of *escapements* may be classed a number of self-acting checking and releasing ratchet mechanisms in which the driven link is alternately released and stopped. The most familiar example is, of course, found in a clock or watch, where the driving weight or spring is permitted to move the clock-work and the hands by a definite amount at regular intervals. Such an escapement is a *uniform escapement*. A second kind of escapement (e.g., the striking mechanism of a clock) allows a train of wheel-work to move at definite intervals, but the amount or range of movement is varied in a predetermined manner, so that, for instance, at every hour the striking gear makes one more stroke than at the preceding hour, up to twelve strokes, after which the cycle commences again. We have here a *periodical escapement* in which, while the period is constant, the range is periodically variable. There is still a third kind, an *adjustable escapement*, in which the range or the period is variable at will or is altered irregularly. We shall take an example of each kind.

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* The Constructor, Chapter XVIII ; Kinematics of Machinery, §§ 119–121.

Graham's Escapement (Fig. 160) belongs to the first class, and its essential parts are an escape-wheel a (connected with the wheel-work of the clock and driven by it in the sense

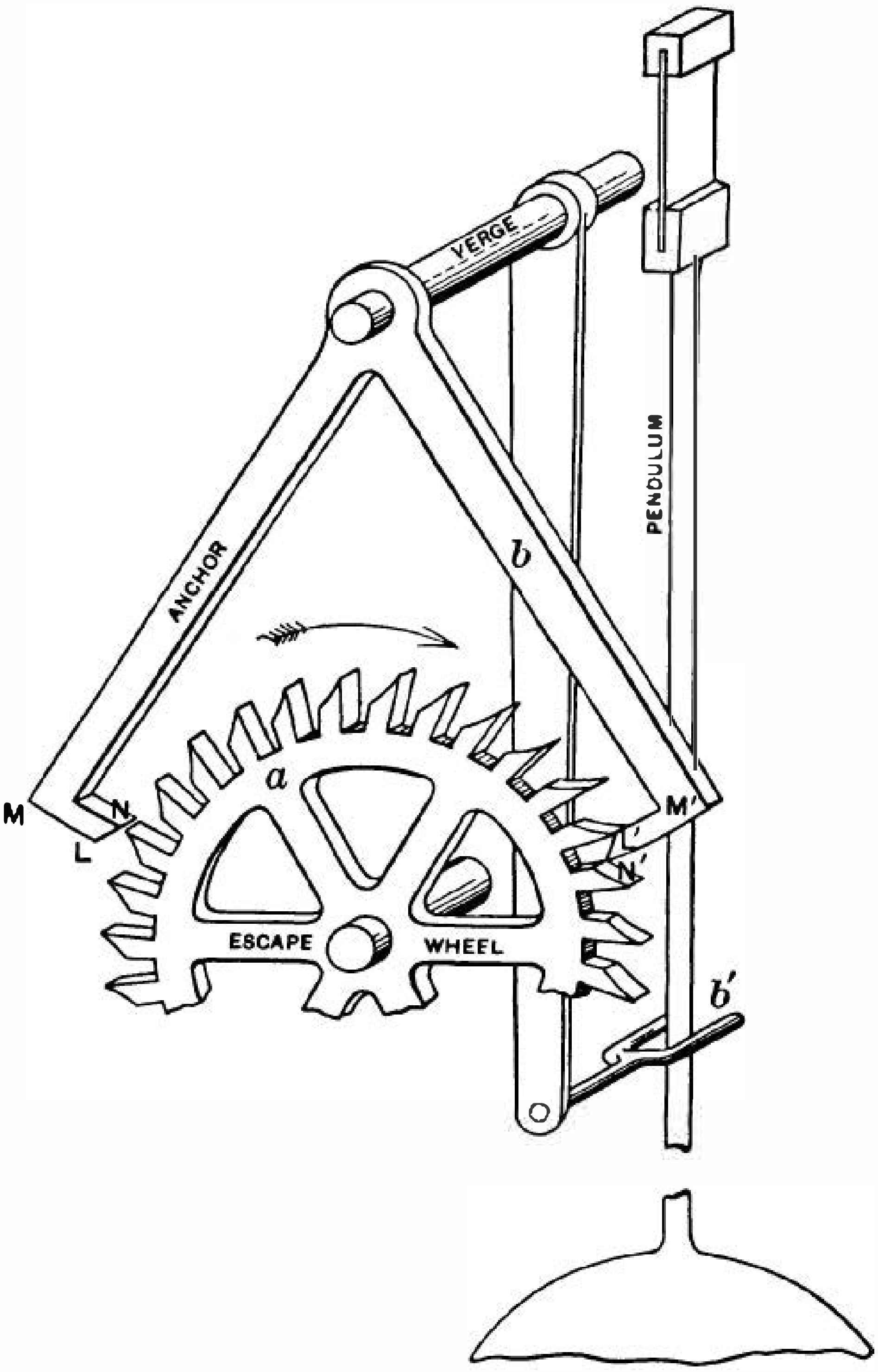

FIG. 160.

shown by the arrow), and an anchor b, whose motion is controlled by the pendulum, with which it is connected through the verge and fork b'. The escapement must (1) permit the escape-wheel to advance by one tooth at each swing of the pendulum, and must also (2) communicate at each swing a minute impulse to the pendulum, so as to maintain its periodic motion. The anchor is really a ratchet, the surfaces *LM*, *L'M'* forming the working faces of the pawl when the motion of the escape-wheel is checked. The faces *LN*, *L'N'* are slightly inclined to the circle passing through the tips of the teeth of the escape-wheel, so that as each tooth is driven past the pallet or point of the anchor, a small impulse is given to the pendulum while near the centre of its swing. Almost immediately after a certain tooth has passed *LN*, for instance, the anchor swings from right to left, and the escape-wheel is checked, because another tooth strikes the face *L'M'* only to be released when the pendulum again swings back. The curved portions of the tooth-outlines are so formed as to clear the points of the pallets while the anchor is receiving its impulse. It is important that a good clock escapement should work well with a very small angular movement of the pendulum; and in this respect Graham's escapement was a great advance on its predecessors.

As an example of a *periodical escapement* we may take the so-called "English" striking-train of a clock. Fig. 161 shows this mechanism in a diagrammatic form, omitting all unnecessary details. It is desired to communicate to the hammer of a bell or gong such a periodic motion that at stated intervals, say of one hour, the bell is struck; the number of strokes increasing by one each time the movement occurs until the cycle is completed. The whole contrivance includes

(1) A train of wheels (c_1gjk) set in motion by its own driving weight or spring and checked by a ratchet which is released every hour by the clock itself.

(2) A mechanism (driven by the clock) which controls the range of movement of the wheel train c_1gjk, and thus varies the number of strokes given by the bell.

The first part of the escapement consists of the wheel c_1, the cam c_0, and the single-toothed wheel c, all rigidly connected; gearing with c_1 is the wheel g, provided with a pin on which the pawl f_0 acts; and gearing with g is the wheel

k, carrying a number of pins which move the hammer of the bell as k rotates. The whole of this gearing is driven in the sense shown by the arrows and is not directly connected with the driving mechanism of the clock itself. Its movement can only take place when the pawl f_0 is dropped so as to clear the pin on g. There is, however, another way of checking the motion of c_1, g, j, and k. Suppose that the pawl f_0 is released and that c_1 moves in the sense of the arrow

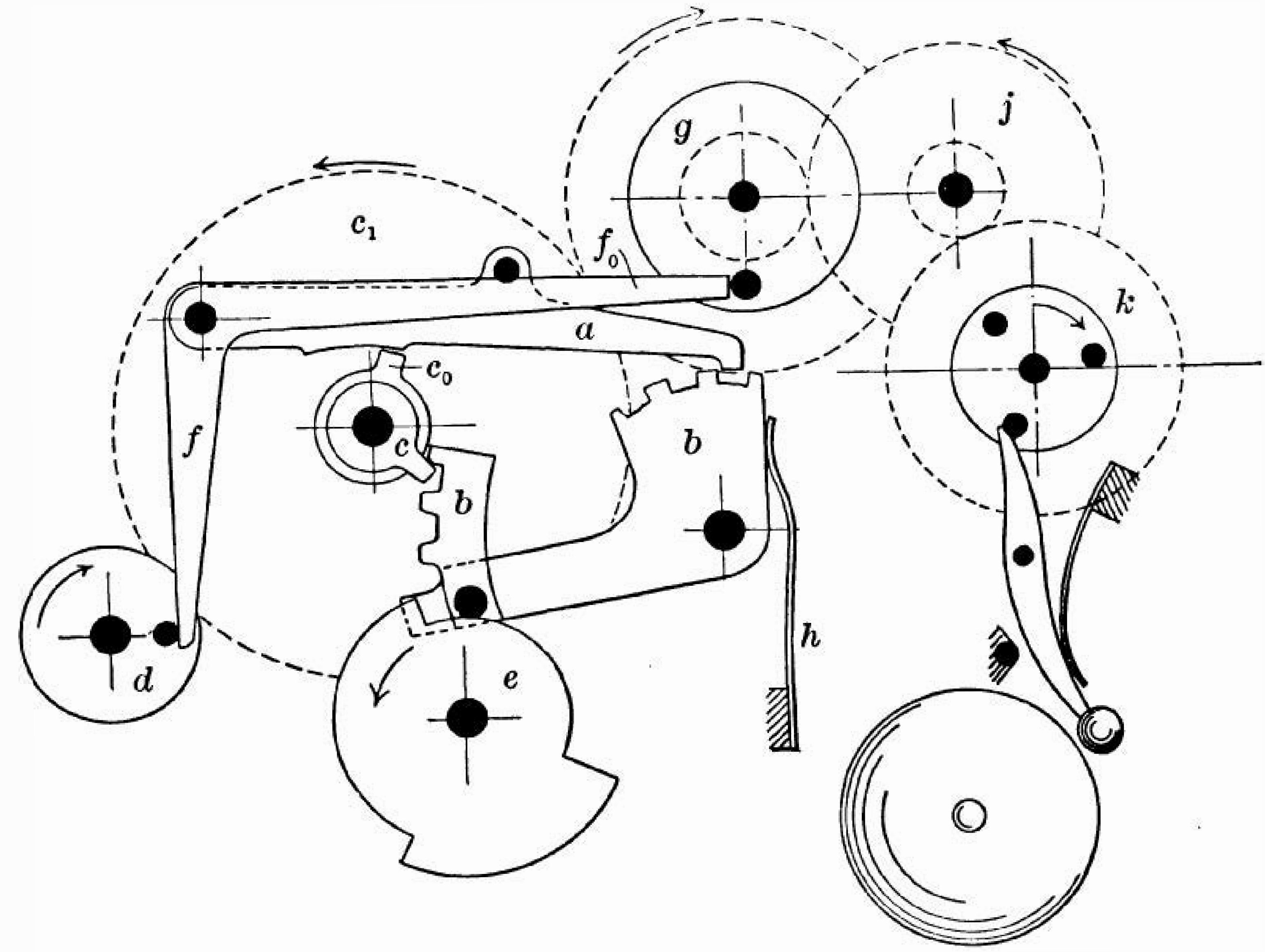

FIG. 161.

from the position shown in the sketch. This motion will continue, and the single tooth of c will engage with the teeth on b until that sector has been lifted to its highest position when c clears the teeth on the sector, and comes in contact with the stop at the lower corner of b. It will be seen that the cam c_0 performs another office, for it lifts the pawl a, and releases b, every time that the tooth on c is in gear, and it also permits this pawl to drop and hold the sector b during the time that the tooth on c is not in gear. The sector, the wheel and cam, and the pawl thus form a separate locking and releasing ratchet-train and act somewhat after the fashion of the train of § 77.

The upper position of the sector is definite; the lower position evidently depends on the position of the "snail" *e*. If this snail is driven by the clock in such a fashion that it advances one division every hour, it is evident that the range of the sector *b* will be altered every hour also. It only remains to arrange that a spring *h* shall tend to make the sector assume its lowest position, and that a pin on *a* shall be lifted by f_0 so as to release the pawl *a* and allow the sector to drop whenever the movement of the train c_1gjk is prevented by f_0.

The action of the whole escapement is then as follows: When the wheel *d* (which is geared with the snail *e*) advances beyond the position shown, f_0 drops and permits the train c_1gjk to be set in motion. The bell is then struck as many times as is permitted by the range of the sector *b*, and that sector is left in its upper position; the motion of *b*, *c*, *g*, and *k* then ceases. When *d* has made another revolution and the snail has advanced one division, f_0 is again lifted, the pawl *a* is also raised, and the sector at once drops, ready for the train to strike again as soon as *g* is released by the further movement of the wheel *d*.

In an actual striking-train there will, of course, be twelve divisions on the snail and a corresponding number of pins on *k*.

The examples here described will serve to give some idea of the nature of escapements of the first two kinds.

Adjustable or variable escapements form a most important class of mechanisms from a practical point of view; they are often of considerable complexity. For instance, the steering-wheel, steering-engine, and rudder of a ship form together a complex variable escapement. This will be understood when it is pointed out that it is necessary for the rudder to move through an angle exactly proportional to that through which the steering-wheel has been turned; the motion of the steering-engine must then cease and the rudder must be held until the steering-wheel is again moved

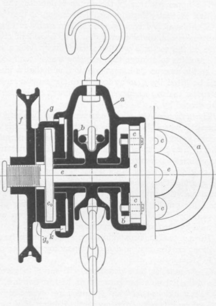

FIG. [illegible]

Many kinds of lifting and hoisting mechanisms form variable escapements of this type; another well-known example is the hydraulically controlled steam reversing-gear, often applied to large marine engines.*

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* See also Fig. 185, § 89.

As an example of an adjustable escapement of a more simple kind, the "Weston Triplex" pulley-block has been selected.* It is shown diagrammatically in section in Fig. 162. The link *a* forms the body of the block and has on it the bearings of the rotating chain-wheel *b*, with which the hoisting-chain engages. By means of an epicyclic train *bace* (in which the fixed annular wheel forms part of the link *a*), *b* is driven by the rotation of a central shaft *e*. The hand-chain drives the wheel *f*, which works on a fine-threaded screw cut on *e*, in such a way that, when screwed up, a flange g_0 is compressed between the face of *f* and a corresponding flange e_0 secured rigidly to *e*. A friction-clutch is thus formed. The flange g_0 forms part of a ratchet-wheel *g*, connected with *a* by a roller ratchet like that of Fig. 152. The action of the block may be summarized thus:

(1) Hoisting. The hand-chain wheel *f* screws up on g_0 and turns the shaft *e* by means of the friction-clutch fg_0e_0. The ratchet gear *gka* runs freely.

(2) Standing. On ceasing to hoist, the load on the hoisting-chain tends to turn *e* in the reverse direction; the ratchet gear engages and holds the load.

(3) Lowering. On turning *f* in the reverse sense, g_0 being held by the ratchet, *f* is screwed back on its thread, the friction-clutch is released, and the load is lowered *so long as f is kept in motion.* On stopping *f* the motion of *e* at once screws up the clutch and checks the load.

The contrivance is thus seen to consist essentially of a rotating shaft driven by an automatic friction-clutch and held by a stationary friction-ratchet, the whole forming an adjustable frictional escapement started and released at will, *the motion of the central shaft imitating that of the hand-chain wheel.* It should be noticed that the action of the machine differs in this important respect from that of a simple hoisting-block provided with an ordinary friction-brake.

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* See *Engineering*, August 22, 1890.