Chapter Three

PENDULUMS, BALANCE WHEELS, ESCAPEMENTS

The heart of the mechanical clock from the point of view of time-keeping is the oscillator (pendulum or balance wheel) and the escapement which it controls. A clock is not as good as its escapement, for a high quality escapement is wasted on worn or poorly cut wheels, but certainly no clock will keep good time over a period unless the design and workmanship of escapement and oscillator are satisfactory.

The Pendulum

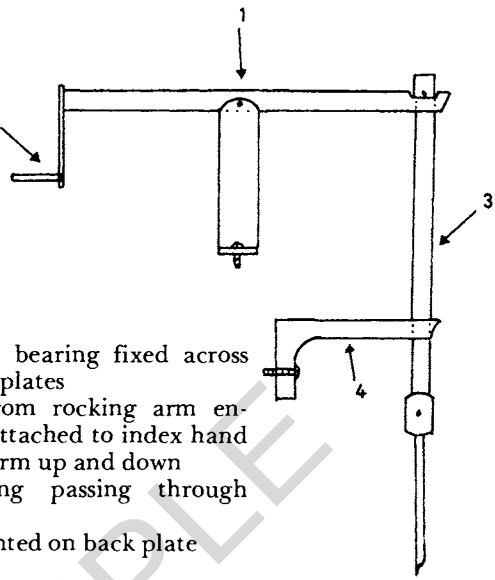
Although still found in high-grade and ornamental clocks, the pendulum has to a considerable extent been superseded as a regulator by the balance wheel and balance spring. There is some irony here in that the pendulum is younger than the balance, which, however, it went some way towards replacing in the 17th and 18th centuries. It has the merit of being robust and simple, but the disadvantage that it must hang vertically, and so is not very portable, and it occupies space, for a large and heavy pendulum is needed for good time-keeping.

Ideally, the pendulum is a weight (the bob) on a weightless line. In practice the line is a rod of straight-grained wood or of metal terminating in a screw by means of which the effective length, and therefore the timing, of the pendulum can be altered. Alternatives to the rod incorporate a series of rods of different metals, some designed to rise and others to fall, so that the pendulum is of a constant length despite expansion caused by increased temperatures, or jars or bulbs of mercury for the same purpose. Both devices may be attractive to look at, if ungainly. In small clocks they are often more ornamental than functional. Wooden and modern specialized metal pendulum rods are virtually free from the effects of temperature variation.

In the oldest clocks the top of the pendulum was screwed to an arbor in the plates and the pendulum hung from a pivot, or the arbor was sharpened to a knife-edge locating in a vee-block. Again, particularly on the Continent, the end of the rod was turned over into a hook which hung over a loop of silk thread, the latter being drawn in or let out by a screw to regulate the clock—in such cases the bob was often fixed to the rod rather than running on a screw.

For several centuries, however, the usual practice has been to suspend the pendulum from a thin suspension spring whose other end is pierced and held by a pin, or has a securing block, between the brass chops of a bracket known as the pendulum or suspension cock. The rod and spring are in some instances, especially American, made in one piece, but more often the spring is clamped into a brass endpiece and screwed to the rod (as in long-case clocks) or it has a pin inserted through it over which the top end of the rod hangs. Suspension springs are available in a variety of sizes and it is essential to replace bent or damaged springs, whose pendulums will never vibrate truly. The cock is usually secured to the movement backplate, but in Vienna Regulators and other good-quality wall clocks and long-case clocks the cock is secured to the backboard of the case independently of the movement.

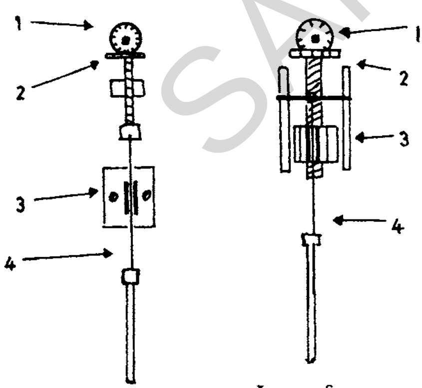
Regulation by turning the screw of a pendulum rod means stopping the movement and often also entering the back of what may be a heavy clock. Therefore there have been several arrangements for regulating from the dial by means of a square or index hand, the latter having the benefit of showing how the regulation has been made from a central point. The method is generally to raise or lower a long suspension spring between close-fitting chops, thus effectively changing its length, or to raise or lower chops on a fixed suspension spring, with the same effect. Neither system is ideal, since both slightly alter the character of the suspension by varying the amount of spring (rather than of actual pendulum length) in use. The older Brocot device and the English rise-and-fall arrangement (widely adopted in economical forms elsewhere, particularly with the moving arm mounted sideways, which can distort the spring) adopt the method using fixed chops, whilst the more usual later Brocot device employs the alternative of moving chops. These French attachments are not easy to illustrate or explain, but they are readily recognized and understood in practice (Fig. 8).



A. English Rise and Fall

1. Rocking arm on bearing fixed across top of movement plates
2. Pin on crank from rocking arm engages with cam attached to index hand on dial, moving arm up and down
3. Suspension spring passing through chops
4. Fixed chops mounted on back plate

B. Brocot



Earlier form

Later form

1. Regulating wheel turned by square at front of dial
2. Screw which moves suspension spring (early) or chops (later), solid with wheel to engage regulating wheel
3. Chops, fixed on earlier version, movable on later version
4. Suspension spring

Fig. 8. Regulating pendulum suspensions

As we shall see, the pendulum's vibrations have to be transmitted to the escapement, where two arms (the pallets) pivot to and fro over a ratchet-type wheel (the scapewheel), alternately holding and releasing its teeth. When the pendulum had no separate cock but was hung by the pivot or knife-edge, it was merely screwed to the pallet arbor. This set-up produced a great deal of wear, since the full weight of even a light pendulum vibrating through a small segment of a circle very quickly ground down the knife-edge or flattened the pivot and enlarged the hole. When the pendulum was separately suspended, however, a connecting link was needed. This is the crutch, for long universal on pendulum clocks.

The crutch is made of light wire or strip and hangs from the pallet arbor much as did the older type of pendulum. At its foot it is bent out so that it will engage with the pendulum rod below the suspension spring, and vibrate with it. This engagement takes various forms and for so apparently simple a matter is surprisingly sensitive, for it transmits the small impulse from the escapement to the pendulum and if too loose will waste power or, if too tight, will bind. Whilst the clock must be set horizontally (or adjusted for being out of the level) it is not material if it leans slightly to front or rear, and a rigid crutch connection would lead to unnecessary friction and a damaged suspension. In practice, therefore, the crutch is a close-fitting fork embracing the pendulum and either open or closed at the back. Sometimes the crutch wire is merely bent round into a loop, or else a fork is carefully shaped and polished from the metal. Alternatively, the crutch may end in a polished pin which locates in a slot in the pendulum rod.

The pallets have to be central (usually, but by no means always, horizontal) over the scapewheel whilst the pendulum hangs vertically, or the clock will be 'out of beat' and run poorly if at all (*see* Chapter 8). It is to some extent possible, but obviously undesirable, to secure this by tilting the clock or the movement in its case. The adjustment is most often made in fact by bending the crutch in relation to the pallets, or sometimes the crutch is mounted friction-tight on the pallet arbor and can be turned to adjust it. There are also, however, adjustment facilities built into some crutches, especially those of Vienna Regulators (weight-driven wall clocks with glazed fronts and brass-covered weights) and some good modern mantel clocks. In the main there are two forms of device; either the crutch pin is located in a screw which may be turned to move the pin towards one side or other of the centre-line of the crutch, or the crutch is in two parts, connected friction-tight, one of which can be set more or less out of the straight in relation to the other.

The Balance Wheel

The balance wheel has likewise to be connected through pallets to the gear train, and the all but universal modern method is by means of a pivoted lever, at the other end of which are the pallets. As the pallets move from side to side, they intersect the circumference of a circle on which the scape-wheel teeth are placed. The connection of lever to balance varies considerably but is generally by means of a pin moving in a forked notch at the lever end. The pin (the impulse pin) may be mounted in a steel disc (the roller) driven on to the balance arbor (the balance staff), this disc having a notch immediately in front of the pin. A point or pin at the tip of the lever passes into this notch so that the wheel can move the lever only when roller and lever are correctly aligned. The impulse pin then engages with the lever fork so that the lever is moved and also so that impulse is passed by the lever to the balance. Alternatively, there is a double roller, in which two steel discs are linked, one holding the impulse pin and the other having the passing notch. In the cheaper pin-pallet escapement there is often no roller as such, the passing bay being formed by a flat in the balance staff and the impulse pin being a steel pin driven into a balance wheel crossing in front of the bay. A lever with an inner and an outer fork is then used, the horns being so designed as to prevent the lever from passing except when the passing bay is aligned with it. (Some lever and roller arrangements are illustrated in Fig. 9.) There are of course other balance wheel escapements and in one, common in 19th century clocks, the cylinder escapement employs no crutch or lever, the balance staff engaging directly with the scapewheel. More will be said of this later.

Modern escapements are 'detached' — for most of the vibration of the balance it revolves without being in contact with

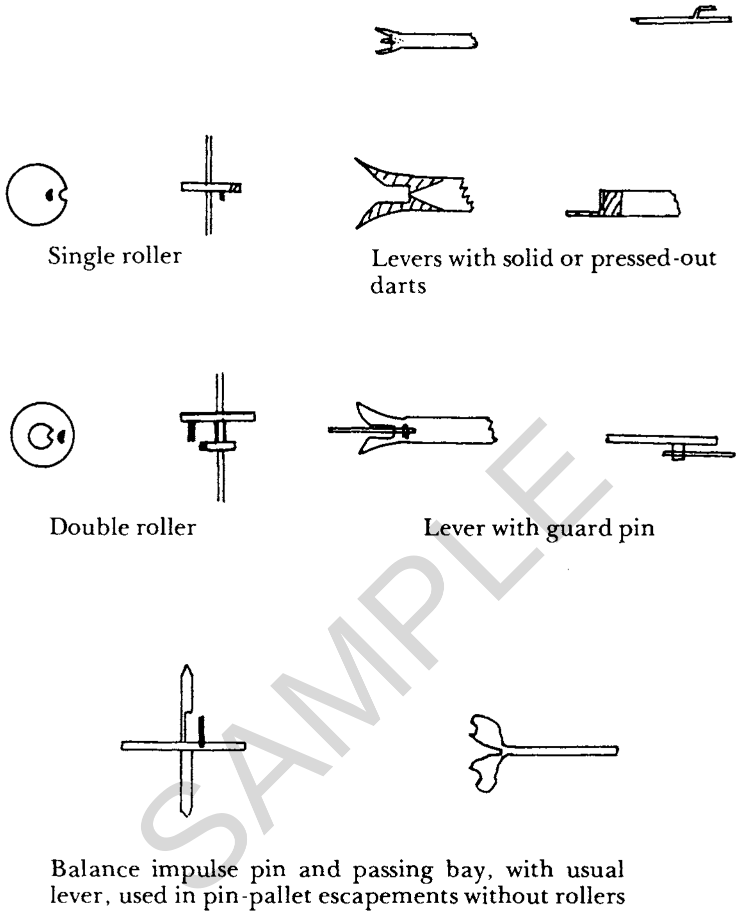


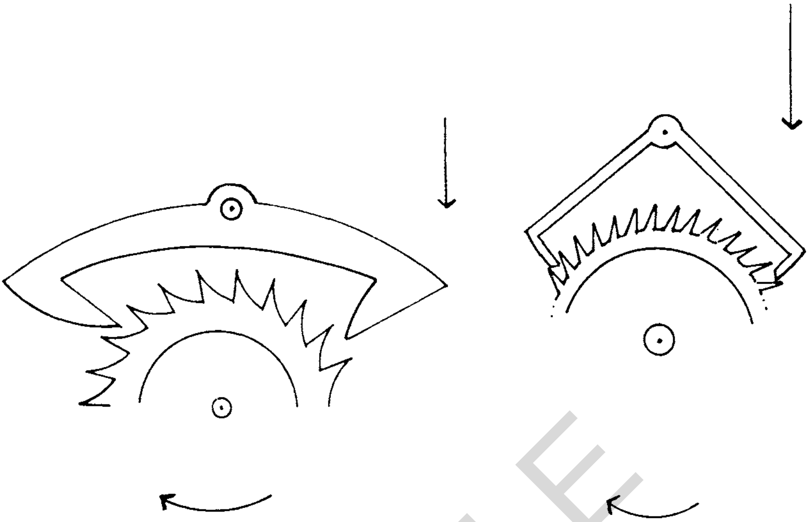
Fig. 9. Balance roller and lever arrangements

the train, and as a result it has to be returned to the central position by a balance spring, for it cannot be returned by the action of the pallets alone as could old frictional escapements where the pallets were solid with the staff and constantly in contact with scapewheel teeth. The balance spring is pinned at its inner end into a brass washer (collet) which is driven on to the balance staff in such a way that the wheel returns to a central position after swinging. The other end is usually pinned into a small brass block mounted on the top bearing for the balance (the balance cock). The timing is finely regulated by an index terminating in two close pins, or a pin and a block, on each side of the balance spring, and these are moved so as to lengthen or shorten the effective length of the balance spring. If regulation is needed beyond the scope of the index, more or less balance spring must be pinned to the balance cock, and the spring will have to be turned on the staff so that the central alignment, which will be impaired by this adjustment, is restored. The balance is thus 'set in beat' again, with the impulse pin in the lever fork and the pallets central to the scapewheel (*see* Chapter 8). Good quality balance wheels may have heavy screws in their rims; turning these out or in varies the distribution of mass so that the wheel can be truly balanced, and the screws are also used for regulation. It is not, however, normally necessary to adjust these on clock balances and they are best left alone.

Pendulum Escapements

The basic pendulum escapements of modern times are the anchor or recoil and the dead-beat, of each of which there are several forms. The outlines are illustrated in Fig. 10. In both escapements, pallets are pivoted over a scapewheel, and on the pallet arbor is fitted the crutch, so that the pallets rock sideways, alternately locking and releasing the teeth of the wheel. The critical point in their operation is the shape of the wheel teeth and pallet nibs, and various combinations are found according to date, whether the clock has a long or short pendulum (the latter with a larger arc of vibration), and for economic reasons, which dictate that pallets of cheaper modern clocks are made of bent steel strip with the edges sharpened to an angle, rather than of a solid steel block. Similar factors also govern how many teeth are embraced by the pallets.

The essential difference between the two forms of escapement is that in the recoil escapement the continued swing of the pendulum after a wheel tooth is locked forces that tooth to move backwards whereas, as the name implies, in the dead-beat escapement the scapewheel does not move once it has been locked, and in practice the pendulum is maintained at a



A. Recoil

B. Dead Beat

Fig. 10. Escapements

smaller arc. This latter is the finer, more accurate escapement, but it is less robust and it will run less well in adverse conditions of dirt, wear, and inconstant power supply. There are also compromise forms in which there is slight recoil, or recoil on only one of the two pallets. In the true recoil escapement, the released scapewheel tooth falls on to the curved face of the pallet, which both holds it whilst the pendulum swings on, and then the tooth imparts impulse to the pendulum on its return swing. The true dead-beat pallets, by contrast, have two distinct surfaces, the first (at the 'side') serving to lock the wheel teeth, and the second (at the 'foot') being the impulse face along which the escaping tooth slides, imparting impulse as it goes. It will be noticed that the recoil pallets are planted close to the scapewheel and that the teeth engage with them fairly deeply, whilst the dead-beat pallet arbor is set further above the wheel and locking on the corner of the pallet is as shallow as it can be with safety. These distances are critical in escapement design.