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MAGNETO-ELECTRIC SYSTEM FOR DRIVING A CLOCKWORK

Filed Jan. 13, 1956

4 Sheets-Sheet 1

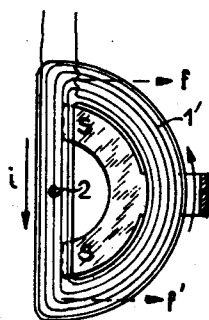
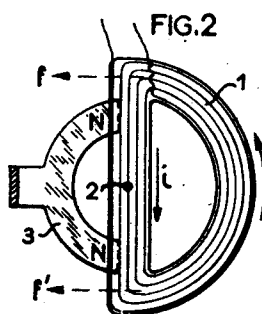
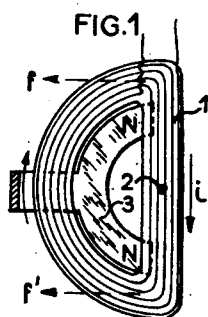


FIG. 3



FIG. 4

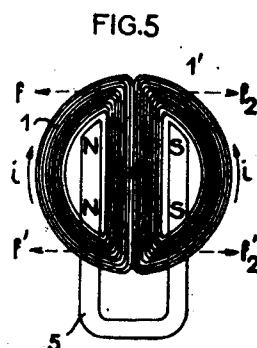


FIG. 5

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FIG. 6

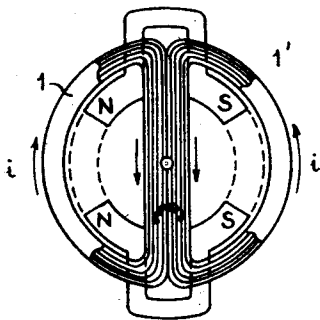


FIG. 7

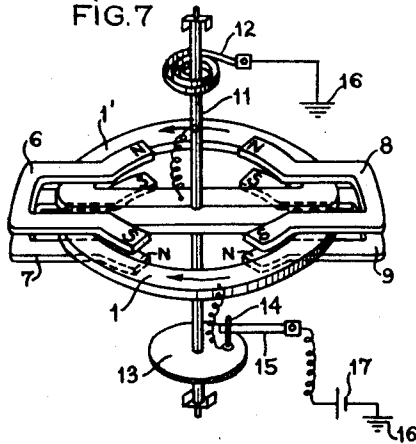


FIG. 8

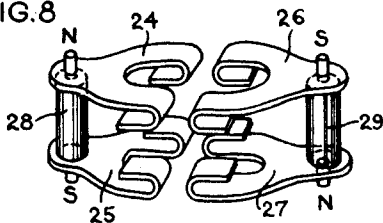


FIG. 9

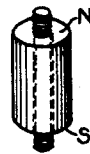


FIG. 10

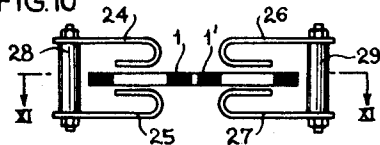


FIG. 11

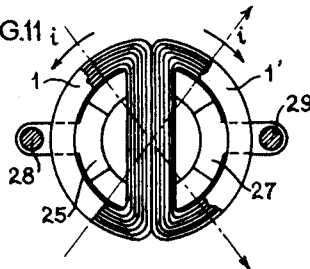


FIG. 12

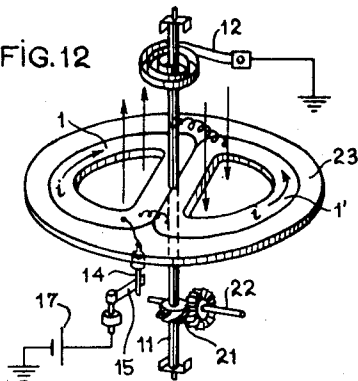
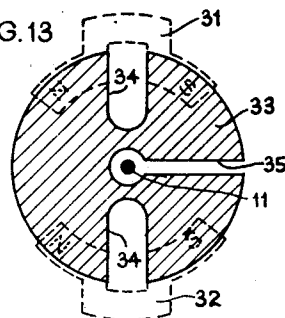


FIG. 13



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FIG. 20

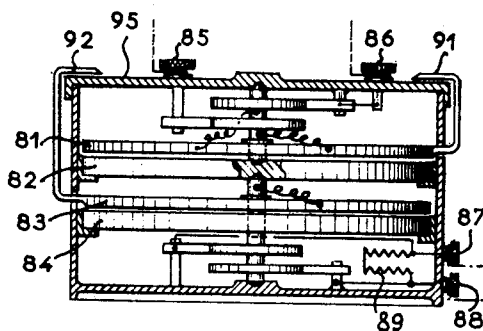


FIG. 21

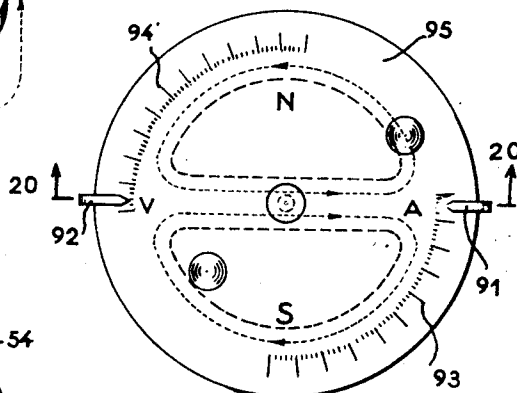


FIG. 22

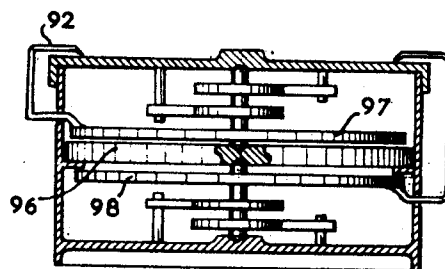


FIG. 14

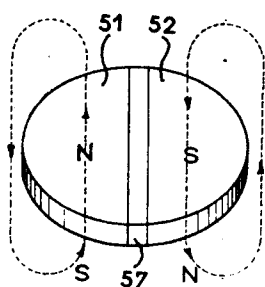
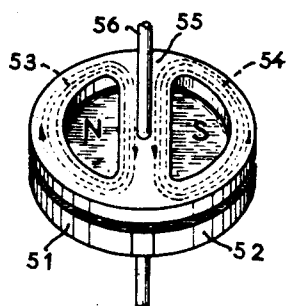


FIG. 15



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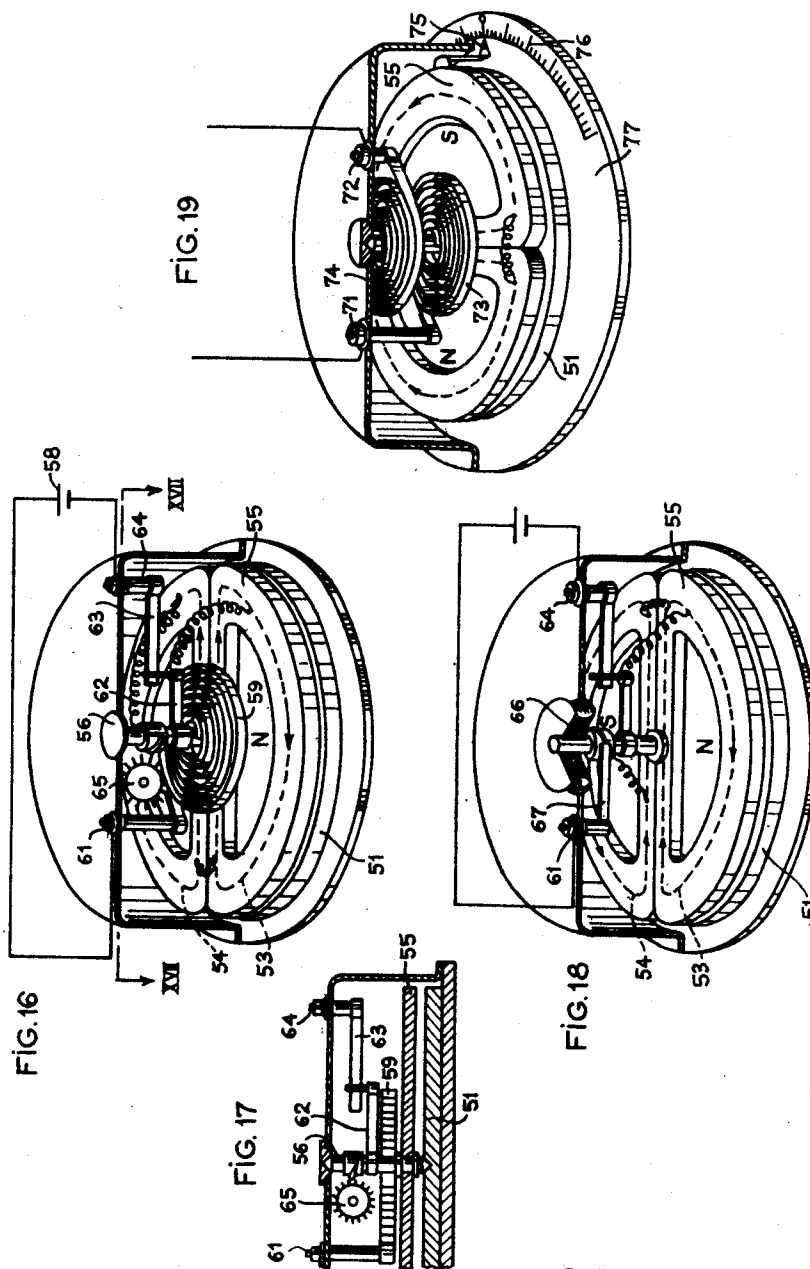
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MAGNETO-ELECTRIC SYSTEM FOR DRIVING A CLOCKWORK

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5 Claims. (Cl. 310—39)

This invention relates to magneto-electric systems capable of generating pulses for sustaining a relative angular motion, e.g. in a time-piece, in an electric measuring instrument, in a magneto-electric pulse motor etc.

The invention relates, more particularly, to systems of this type, wherein a circular member acting as a balancing-wheel is pivoted in a magnetic field and carries at least one energizable winding, the design of the system being such that, whenever the balancing-wheel passes through its position of equilibrium, it is imparted with a pulse tending to amplify its angular displacement.

As known, the balancing-wheel of a time-piece must be adapted to meet a number of mechanical requirements. In particular, it must be perfectly balanced even when the room temperature varies, its friction through air must be reduced to a minimum, its pivoting must be as simple as possible, it must be extremely compact, etc.

In the systems known heretofore, there is provided a coil having the shape of a frame surrounding a magnetic core supported on the apparatus casing. Such an arrangement gives rise to a number of difficulties and none of the above mentioned conditions can be met satisfactorily.

Moreover, from the electrical point of view, the known devices have the drawback of requiring a four-sided frame having only one active side, while the side opposite to the latter is separated from the same by means of a core or a soft-iron plate, the presence of which implies considerable mechanical disadvantages.

The invention has for its purpose to provide a magneto-electric system of the type set forth, capable of meeting all desired mechanical conditions, while offering, from the electrical point of view, a considerable simplification with respect to the known systems.

An object of the invention is to provide a magneto-electric system of said type, comprising a flat coil pivoted around an axis at right-angles to its plane and a permanent magnetic structure including at least two parallel flat poles of opposite polarities extending at right angles to said axis.

Another object of the invention is to design the above mentioned magnetic structure in such a manner that the lines of magnetic field forces generated by said structure are adapted to cooperate with said coil when the same is energized, said lines extending in directions parallel with said axis along a length at least equal to the thickness of said coil added with the distance between the latter and one of said poles.

It is another object of the invention to dispose the active portion of the coil symmetrically on both sides of said common axis, the complementary part of said coil being constituted entirely by wires so arranged that no parasitic forces can be generated therein when current flows through the coil.

A further object of the invention is to provide a system of the type described, wherein said active portion of the coil is rectilinear and passes in the close vicinity of said axis, while said complementary part has the shape of an

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arc of circumference having said active portion for its chord.

This last arrangement offers the essential advantage that the electro-magnetic forces generated in said complementary part have purely radial directions and, therefore, are not capable of perturbing the operation of the system.

Still another object of the invention is to combine the coils, as described in the last paragraph, in one single circular coil with both active portions juxtaposed along a generally diametral direction, said circular coil being associated with a magnetic structure of the type described having, in at least one plane parallel to that of the coil, two poles of opposite polarities located, in the neutral position of said coil, symmetrically on either side of said diametral active portions.

Still another object of the invention is to use as a magnetic structure a pair of flat magnets having semi-circular pole faces and the diametral edges of which are juxtaposed to each other, the said faces being parallel with the plane of the flat coil in the near vicinity thereof, the said magnets being of the type of which the lines of force are parallel along a considerable distance from the pole faces and offering the property of keeping their magnetization during a practically illimited time. The combination of such a magnetic structure with a flat coil, as described above, permits designing magneto-electric systems solely constituted by two flat disks without requiring the usually indispensable magnetic loops implying the necessity of mounting the coil within a gap provided between two mechanical parts.

The flat shape of the above mentioned two members still offers the advantage that any one of them may be used as the movable member of the system.

It is a further object of the invention to provide mechanisms such as a time-piece, an electrical measuring instrument or a magnetic pulse motor including a magneto-electric system as described above to sustain their movement. Such mechanisms may be then considerably simplified and made more compact, due to the absence of any mechanical part in said system, except for its two flat disk members, and due to the very flat shape of the whole assembly.

To use the system according to the invention in any one of the apparatus mentioned above, it suffices to provide the same with suitable switching means for the current to be fed into the coil, as well as the mechanical gears required for transmitting and/or sustaining their movement.

Other objects and advantages of the invention will be apparent to those skilled in the art, from a consideration of the following description of some embodiments of the invention, shown by way of examples, in the accompanying drawings, in which:

Figure 1 diagrammatically shows the fundamental arrangement of the magneto-electric device of the invention.

Figures 2 and 3 show modifications with different relative positions of the coil and permanent magnet.

Figure 4 is a perspective view of a specific magnet structure adapted to be used in the arrangements of Figures 1 to 3.

Figure 5 shows a symmetrical arrangement derived from the one of Figure 1 and comprising two coils and magnet pieces.

Figure 6 is a plan view similar to that of Figure 5 with a different magnetic structure.

Figure 7 is a perspective view of the arrangement of Figure 6.

Figure 8 is a perspective view of a device including a modification of the magnetic structure shown in Figure 7.

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Figure 9 illustrates one of the two magnet studs of the magnetic structure of Figure 8.

Figure 10 shows, in axial section, the position of the coil unit in the magnetic structure.

Figure 11 is a transverse section made on line 11—11 of Figure 10.

Figure 12 diagrammatically shows, in perspective view, the association of the coil unit of the invention with means for driving the clockworks of a time-piece.

Figure 13 is a plan view of a modification of the magnetic structure of Figure 7, in which a soft iron plate is substituted for a pair of permanent magnets.

Figure 14 shows another type of permanent magnet unit particularly suitable for putting the invention into practice.

Figure 15 illustrates, in perspective view, the association of the magnetic unit of Figure 14 with a double coil unit according to the invention.

Figure 16 is a perspective view of the power unit of an electric watch embodying the invention, the case thereof being cut away in part.

Figure 17 is a fragmentary axial section made on line 17—17 of Figure 16.

Figure 18 is a perspective view of a small electric motor embodying the invention, the case of which is partly cut-away.

Figure 19 is also a perspective view of an electric measuring apparatus (for instance a voltmeter) according to the invention, the case of which is partly cut-away.

Figure 20 is an axial section of a double electric measuring apparatus, for instance an ammeter and a voltmeter, the section being made on line 20—20 of Figure 21.

Figure 21 is a plan view of the apparatus of Figure 20, and

Figure 22 is a view similar to that of Figure 20 and shows a modification of a double measuring apparatus.

Referring first to Figure 1, 1 is a flat electric coil rotatably mounted on an axis 2 extending at right angles to the plane of said coil. This coil is semi-circular in shape and has a bundle of diametrical rectilinear conductors and a bundle of semi-circular conductors through which an electric current is assumed to be circulated in the direction of the arrows shown in full lines.

An annular magnetic field has its lines of force at right angles to the plane of the coil and is illustrated in the drawing in the form of a pole piece 3 of a permanent magnet which may be seen in Figure 4. The pole piece 3 lies under the coil 1, coaxially therewith. The pole piece 3 is supposed to be a north pole, the south pole of the magnet lying over the coil which is able to rotate in the air gap between the two pole pieces 3 and 4 of the magnet.

When the coil is in the position shown in the drawing, a position which will be hereinafter called "neutral position," it is subjected to two equal forces f and f' counteracting each other, so that the coil is in a state of unstable equilibrium.

If it is now assumed that the coil 1 is angularly shifted clockwise on its axis 2 while the magnetic field is left stationary, it will be seen that one portion of the diametrical rectilinear bundle of conductors is moved into the magnetic field so that one of the above mentioned forces f' rapidly increases while the other portion of the said bundle of wires is taken away from said field so that the other force f rapidly decreases to zero. The coil is thus subjected to a torque which makes it rotate clockwise, i.e. in the same direction as the direction in which it was originally deviated from the neutral position.

It will be readily seen that, if the coil is deviated from its neutral position counterclockwise, it is subjected to the action of a force $f-f'$ tending to further rotate the coil in this direction.

Thus, as soon as the coil is deviated away from its neutral position of unstable equilibrium, in either direc-

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tion, however slight this deviation may be, the coil is subjected to electromagnetic forces which tend to rotate it further in the same direction, though the current always flows in the same direction through the coil.

Figure 2 shows a modification in which the semi-circular conductors of the coil and the magnetic field are located on either side of the diametrical rectilinear conductors when the coil is in the neutral position. When the coil is deviated away from its neutral position in the clockwise direction, it is again subjected to the action of the force $f'-f$ and, when it is rotated in the opposite direction, it is subjected to the action of the force $f-f'$.

Figure 3 shows a similar arrangement in which the coil is positioned over the south pole of the permanent magnet. The operation is the same as in the embodiments of Figures 1 and 2.

Figure 5 shows a symmetrical embodiment comprising the structure shown in Figure 1 associated with the structure of Figure 3. The two semi-circular coils 1, 1' form a circular coil unit rotatably mounted between the pole pieces of two horse-shoe magnets one of which is indicated as at 5. The magnetized portion of each pole of these magnets spreads over a substantial area thereof as indicated by the letters N and S in the drawing. In this embodiment, each of the two semi-circular coils cooperates with the magnetic field in the same manner as in the embodiments of Figures 1 and 3 considered separately.

The advantages of this last embodiment are that it comprises a circular and, thus, well balanced coil unit and that the coil unit is acted upon by two equal and opposed forces acting at the opposite ends of a same diameter. The said forces are, e.g. when the coil unit is deviated clockwise, at the lower end of said diameter, $f'-f$ (under the action of the north pole), and at the upper end of said diameter f_2-f_2' (under the action of the south pole).

Figures 6 and 7 illustrate an arrangement similar to that of Figure 5, in which the magnetic field is produced by two pairs of permanent magnets 6, 7 and 8, 9 respectively. The coil unit 1, 1' again is shown in its neutral position with respect to the magnetic fields.

Furthermore, the coil unit is shown being carried by a spindle 11 on which is mounted a hair spring 12 adapted to urge the coil unit into neutral position. A plate 13 rigid with the spindle 11 carries a finger 14 adapted to engage one end of a leaf spring 15 the other end of which is stationary. When the coil unit is in neutral position, the finger 14 is in engagement with the leaf spring 15 and remains engaged therewith during a predetermined angular movement of the coil unit away from its neutral position; beyond this extent of movement, the finger 14 releases the leaf spring 15 which is returned into rectilinear position by its own resiliency. In these conditions, another electric contact will be established between the finger 14 and the spring leaf 15 as soon as the coil unit will reach its neutral position again, during the next following stroke of its oscillatory motion under the action of the hairspring 12. Whenever the said electrical contact is established, a circuit is completed through the following members: the earth or casing 16 of the apparatus, a battery 17, leaf spring 15, contact finger 14, coil 1, coil 1', spindle 11, hairspring 12 and casing 16.

It is readily understood that the coil unit oscillates on its axis under the combined action of the hairspring and the magneto-electric device. The hairspring permanently urges the coil unit towards neutral position, and the magneto-electric device imparts an impulse to the coil unit each time the latter passes the neutral position, said impulse extending as long as the contact is maintained between the finger 14 and the leaf spring 15, said impulse being oriented in the same direction as the direction of the coil unit passing the neutral position, i.e. successively clockwise and counterclockwise, though the current al-

ways flows in the same direction through the coil unit, as hereinabove explained.

Such a device may be advantageously used for operating time-pieces as diagrammatically shown in Figure 12, where an escapement mechanism indicated as at 21 is provided to transform the rotational oscillatory movement of the spindle 11 into a unidirectional movement of a further spindle 22 operatively connected to the gears which actuate the hands of a time-piece (not shown). The coils 1, 1' may be embedded, for instance, within a disc 23 of plastic material.

Figure 8 shows a modification of the magnetic structure of the device of Figure 7. The bifurcated pole pieces 24, 25 made of a magnetic metal are respectively secured on the ends of a permanent magnet in the form of a cylindrical bar or stud 28. Similarly, two bifurcated pole pieces 26, 27 are secured to the respective ends of a permanent magnet 29. One of these two magnets is shown in Figure 9. The axial section of Figure 10 and the transverse section of Figure 11 show the position of the coil unit relative to the magnetic structure.

Figure 13 shows a further modification of the magnetic structure which comprises two permanent magnets 31, 32 arranged in a common plane on one side of the coil unit (not shown) and a plate of magnetic metal 33 in a plane parallel with said plane. The space between the magnets and the plate determining the air gap adapted to receive the coil unit. Two deep notches 34 in the plate form the neutral zone and a slot 35 extending to the centre of the plate makes it possible to mount the spindle 11 laterally.

Referring now to Figure 14, it will be seen that the magnetic structure is constituted by two permanent semi-circular magnets 51, 52 united by their diametrical edge in such a manner that each face of the double magnet thus formed has a semi-circular north pole and a semi-circular south pole. Each magnet is of the type having lines of force which remain substantially at right angles to the pole faces, i.e. they extend in a parallel bundle on a relatively long length before being bent backward toward the other pole. Such magnets, therefore, create a magnetic field which is uniform over a substantial area opposite each pole. Magnets of this kind are now available on the market, for instance under the trade name of "Fercolite" manufactured by Société des Lignes Télégraphiques et Téléphoniques. The magnetic structure thus constituted has the further advantage of never giving up its magnetism.

This particular configuration of the flux of lines of force of such a magnetic structure makes it possible to associate therewith a coil unit arranged in its magnetic field without it being necessary in order to compel the lines of force to extend through the coil unit, to guide them within a magnetic structure comprising a plate of magnetic metal or a further magnet, as this was compulsory in devices designed with conventional magnets.

Figure 15 shows an association of this kind with the two magnets 51, 52 above which is arranged a flat coil unit comprising two coils 53, 54 similar to the coil unit provided in the embodiments hereinabove described, i.e. each comprising a bundle of diametrical conductors and a bundle of semi-circular conductors. The bundles of diametrical conductors of said two coils are parallel while the bundles of semi-circular conductors are located near the peripheral portion of the coil unit 55. These coils may be embedded within a disc of plastic material 56 rigid with a rotary spindle 56.

Obviously, since these bundles of conductors have an actual thickness, the conductors in one of said bundles are not all strictly diametrically positioned while those of the other bundle form a set of concentric semi-circles. In particular, the term "diametrical" should be geometrically interpreted in an approximate sense and not strictly.

Furthermore, in some constructional embodiments, it will be found preferable to form the coils by spreading

the turns thereof as diagrammatically shown in Figure 15 rather than in superposed relationship, so that the coil unit retains its flat character. The coil body may also be made considerably thinner or even completely omitted.

The spindle 56 extends between the two magnets 51, 52 through a layer 57 which is of a material adapted to be machined or moulded and which, at the same time serves for uniting the two magnets together. This layer, furthermore, is particularly suitable to form a pivot bearing.

In all practical embodiments such as shown in Figure 15, the windings are adapted to be fed with direct current from a suitable source, the wiring being such that the current (if any) flows in all diametral wires in the same direction. In a given relative position, hereafter called the "neutral position" of the coil and magnet units, the diametrical rectilinear conductors are located in register with the joining plane of the two magnets. As soon as it is deviated away from this neutral unstable position, in one rotational direction or in the other, the coil unit is subjected to an electro-magnetic torque which tends to further rotate it in the same direction.

The device operates in the same manner as the embodiments hereinabove described, but its design is much more simple since it comprises a flat magnetic structure formed by the two aforesaid semi-circular permanent magnets 51, 52 united together along a common diametrical joining plane.

In the coil unit shown in Figure 15, the semi-circular conductors 53, 54 are positioned in the magnetic field, but it should be noted that the forces acting upon any portion of said semi-circular conductors are directed radially and, therefore, do not create any power torque liable to rotate the coil unit.

Of course, it is also possible to make the outer diameter of the magnetic structure equal to or smaller than the inner diameter of the semi-circular conductors, as in the embodiments described with reference to Figures 1 to 13.

Referring now to Figure 16, the drawing shows the main members for driving an electrical time-piece. In this figure, the coil unit is again identified by the reference number 55 and one magnet 51 of the circular magnetic structure is visible. The coils 53, 54 are electrically connected to the source of direct current 58, on one hand, through a hairspring 59 and a terminal 61 and, on the other hand, through a contact finger 62 rigid with the coil unit 55 and a leaf spring 63 electrically connected to a terminal 64. The spindle 56 rigid with the coil unit carries the cam portions of an escapement mechanism, the wheel 65 of which is operatively connected to the gear wheels actuating the hands of the time-piece.

This time-piece operates in the same manner as the one described with reference to Figure 12, but its design is much more simple since it has no air-gap. No difficulty, therefore, is encountered in accommodating the coils and the mounting of the pivots is greatly facilitated. In other words, all the magnetic elements which are reduced to the mere double-magnet 51, 52 may be located on one side of the coil unit while the whole mechanism may be arranged on the other side of said coil unit.

Figure 18 shows a miniature electric motor derived from the structure which has just been described for actuating a time-piece. It differs therefrom only by the fact that the flat coil unit 55 is able to rotate permanently in the same direction. This is the reason why, in this motor, the hairspring has been replaced by a slip ring 66 engaged by a brush 67 electrically connected to the terminal 61.

The coil unit receives an impulse always oriented in the same direction, whenever the contact is made at the moment said coil has just passed the neutral position.

Figure 19 illustrates an electrical measuring apparatus, for instance a voltmeter, the design of which is also de-

rived from that of the time-piece of Figure 16. In this apparatus, there is, however, no contact member for establishing and cutting the current, both ends of the coil unit 55 being electrically connected to two terminals 71, 72 respectively through two hairsprings 73, 74 coiled in the same manner in order to create an increasing passive torque opposing the torque produced by the interaction of the coil unit and magnetic structure. A pointer 75 fixed on the coil unit 55 moves over a graduation 78 carried by the casing 77 in which the magnetic structure is secured.

It will be understood that the deviation of the pointer 75 produced by the pivoting movement of the coil unit 55 is greater when the strength of the current circulating through the coil and, therefore, its voltage, are themselves greater. The pointer stops in register with the graduation for which the driving torque is equal to the resisting torque produced by the hairsprings.

It has been assumed hereinabove that the magnetic structure is stationary and the coil unit movable, but the coil unit might be stationary and the magnetic structure rotatable.

Figure 20 diagrammatically illustrates a double measuring apparatus comprising an ammeter in its upper portion and a voltmeter in its lower portion, both said apparatus being designed similarly to the apparatus of Figure 19. The coil unit and the magnetic structure of the ammeter are indicated at 81 and 82 respectively, whereas the coil unit and the magnetic structure of the voltmeter are indicated at 83 and 84 respectively. The terminals of the ammeter are shown at 85, 86 and those of the voltmeter at 87, 88. The shunt of the voltmeter is diagrammatically shown at 89.

The pointer 91 of the ammeter and the pointer 92 of the voltmeter (see also Figure 21) are respectively rigid with the coil units 81 and 83 and they are adapted to move over the graduations 93 and 94 engraved on the casing 95 of the apparatus. It is, therefore, easy to design a compact double meter having one single dial.

Such an apparatus may be designed still more simply and within smaller overall dimensions by incorporating a single magnetic structure 96 (Figure 22) one face of which cooperates with the coil unit 97 of one of the meters and the other face with the coil 98 of the other meter. The dial of this apparatus may be the same as that of the apparatus of Figure 20, as shown in Figure 21.

What is claimed is:

1. A small magneto-electric system for driving a clock-work, comprising a balance wheel, a spindle carrying said wheel, a return spring, a flat winding and at least two permanent magnets arranged either side of said winding and having their poles of opposite sign facing each other, whereby two magnetic fluxes of opposite direction and separated by a neutral line are produced between said magnets, said fluxes being at right angles to the plane of the winding and parallel to the axis of the spindle, one of the two elements of the motor, winding and magnets, being carried by said balance wheel,

said winding comprising two semi-circular flat coils having their rectilinear diametral parts juxtaposed so that the axis of the balance wheel passes through the centre of the semi-circular parts of said coils, the return spring being arranged to bring back the balance wheel in a median position of rest wherein the neutral line of the magnetic flux coincides with the line separating the rectilinear parts of the coils, contact means actuated by the oscillation of the balance wheel to supply to said coils current impulses of constant direction once during each half oscillation of the balance wheel when said wheel passes through the said median position, said current impulses having the same direction in the rectilinear parts of both coils respectively and opposite directions in the semi-circular parts thereof, said direction of current fed to the winding being such that in said median position of the wheel, the fluxes generated by the two coils forming the winding respectively are opposite to the fluxes flowing through said coils due to the permanent magnets.

2. A small magneto-electric motor according to claim 1 wherein the balance wheel is formed by a disc of insulating plastic material, the two semi-circular coils forming the winding of the motor being embedded within said disc.

3. A small magneto-electric motor according to claim 1 provided with control means actuated by the balance wheel to close the contact means feeding current impulses to the winding once during each half oscillation of the balance wheel when it passes through its median position, and to open said contact means in position symmetrically located either side of said median position respectively.

4. A small magneto-electric motor according to claim 1 wherein the permanent magnets are provided with flat semi-circular poles lying in planes which are parallel to the plane of the flat winding and having a semi-circular shape of substantially the same radius as the semi-circular coils forming the said winding.

5. A small magneto-electric motor according to claim 1 wherein the permanent magnets are provided with flat semi-circular poles lying in planes which are parallel to the plane of the flat winding and having a semi-circular shape of substantially the same radius as the semi-circular coils forming the said winding, said poles being arranged in a closed vicinity to the windings whereby the lines of the magnetic fluxes generated by said magnets are perpendicular to the flat surface of said poles on their path through the winding and through both air-gaps provided either side of said winding.

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