Feb. 17, 1948. J. D. BURKE ET AL 2,436,354

ELECTROMAGNET WITH ARMATURE

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Fig. 1.

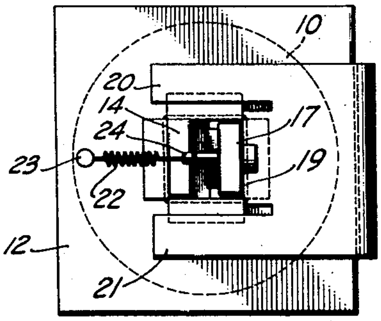


Fig. 4.

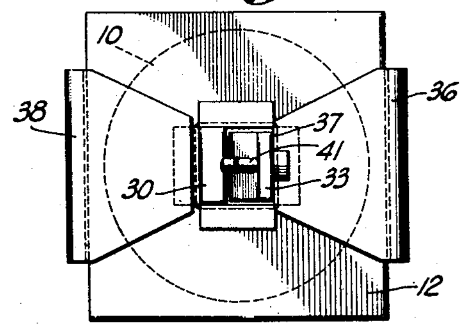


Fig. 2.

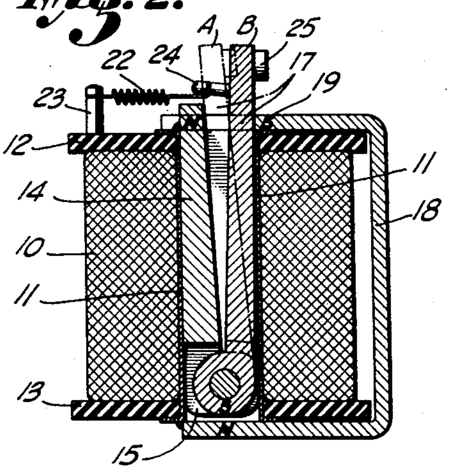
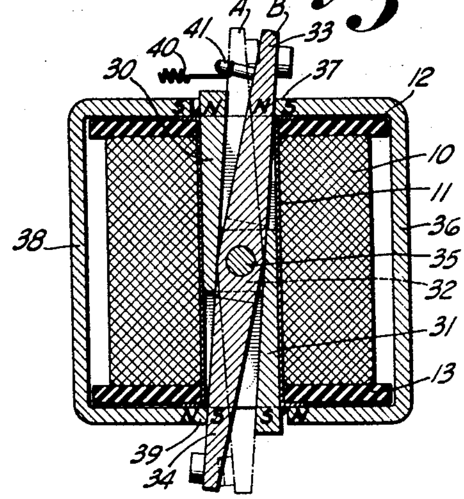


Fig. 5.



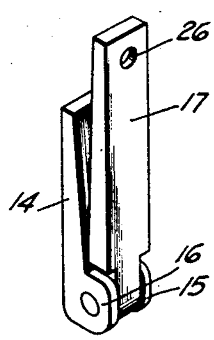


Fig. 3.

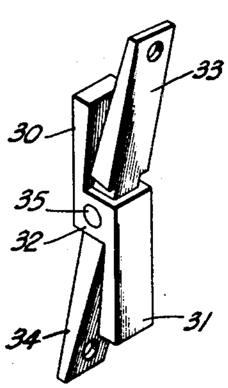


Fig. 6.

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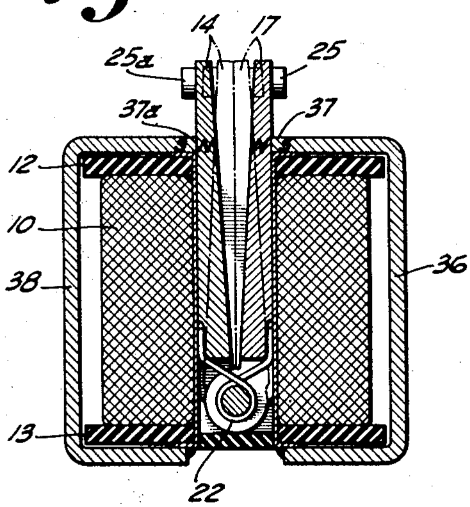
Fig. 7.



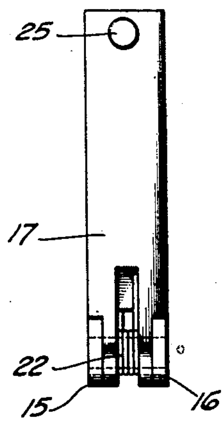


Fig. 8.

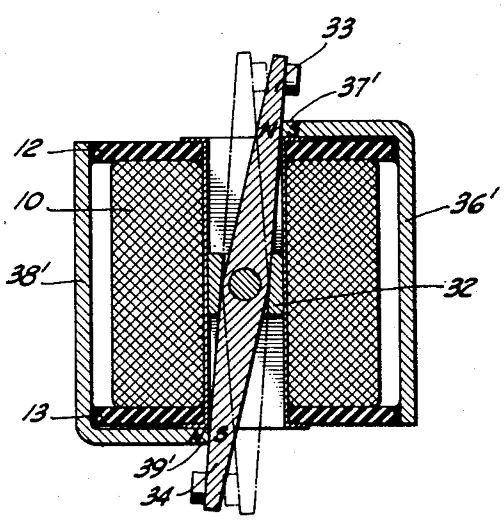


Fig. 10.

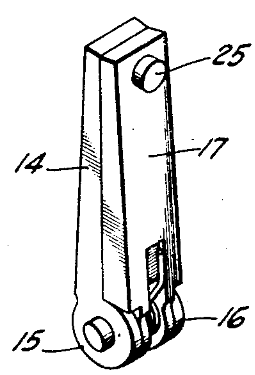


Fig. 9.

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ELECTROMAGNET WITH ARMATURE

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Application October 11, 1943, Serial No. 505,712

18 Claims. (Cl. 175—336)

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Our invention relates generally to electromagnets and particularly to a magnet in which the armature is subjected to both repellent and attractive forces, and hence may be referred to as a push-pull magnet.

It is an object of our invention to provide an electromagnet in which substantially uniform power is exerted upon the armature during its entire movement, resulting in a more rapid and positive action than is possible with conventional types of magnets.

Another object of our invention is to provide an electromagnet which has considerably more power for a given number of ampere turns than other types of magnet, and which has a relatively short flux path with a minimum of flux leakage.

A further object of our invention is to provide an electromagnet having a balanced armature which is subjected to repellent and attractive forces at each end thereof, to thereby increase its power.

An advantage of our invention is the ability of our electromagnet to operate satisfactorily under the most adverse conditions of vibration and shock such as encountered in aircraft and other vehicles.

Another advantage of our electromagnet is the provision of increased armature movement without the sacrifice of contact power which makes it especially valuable in relays where maximum contact dependability is required.

When used in a relay, one form of our invention provides a double break in the control circuits, thereby increasing the arc-rupturing ability when heavy currents are interrupted. Consequently, a relay of this type is capable of high altitude operation without vacuum seals.

These and other objects and advantages of our invention will become apparent from the following description of preferred forms thereof illustrated in the accompanying drawings in which,

Fig. 1 is a top plan view of our invention employing one type of armature,

Fig. 2 is a vertical cross-section of the electromagnet shown in Fig. 1,

Fig. 3 is a perspective of the core and armature of the magnet shown in Figs. 1 and 2,

Fig. 4 is a top plan view of an electromagnet employing a balanced armature,

Fig. 5 is a vertical cross-section of the electromagnet of Fig. 4,

Fig. 6 is a perspective view of the core and armature of the magnet shown in Figs. 4 and 5,

7 is a vertical cross-section of a form of

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our invention wherein both the core and armature are movable,

Fig. 8 is an elevational detail of the armature-core assembly of Fig. 7,

Fig. 9 is a perspective view of the armature-core assembly of Figs. 7 and 8, and

Fig. 10 is a vertical cross-section of a magnet similar to that shown in Fig. 5 but omitting the axial core.

Referring now to the drawings and particularly to Figs. 1, 2 and 3 thereof, the numeral 10 indicates a solenoid preferably wound on a spool of suitable non-magnetic material comprising a central tube 11 having upper and lower face plates 12 and 13 secured thereto. A core 14 which is preferably tapered as shown, and provided with a pair of ears 15 and 16 at its lower end is axially disposed in the solenoid and secured within the tube 11 in any convenient manner, the core being preferably slightly longer than the tube 11 so as to extend a little above the upper end thereof. An armature 17 which is also preferably tapered slightly is pivotally mounted at its lower end on a pin extending between the ears 15 and 16 of core 14. As seen best in Fig. 2, the armature 17 is free to move from position A to position B in response to the magnetic forces created by energization of the solenoid 10.

A yoke 18 of suitable magnetic material preferably formed as a U is secured to the upper and lower plates 12 and 13 of the solenoid spool so as to provide a low-reluctance flux path around the outside of the solenoid. The lower leg of the yoke 18 is preferably separated from the core 14 by a slight air space or a layer of non-magnetic material so as to interrupt the magnetic path. The upper leg of the yoke 18 is preferably formed with a central cut-away portion providing a centrally disposed auxiliary pole portion 19 which confronts the upper end of the armature 17, and a pair of extending fingers 20 and 21 lying on opposite sides of the core and armature. By this formation of the upper leg of the yoke 18 an improved flux path is created which minimizes leakage and facilitates operation of the magnet.

The armature 17 is normally urged against the core 14, i. e., to position A, by suitable spring means, such for example as the coil spring 22 extending between pin 23 on plate 12 and a pin 24 on armature 17. The upper end of the armature may if desired have a contact 25 thereon secured in a hole 26 provided for that purpose. It will be understood of course that the armature 17 can be made of various lengths for various purposes, and can have different types of contacts thereon.

When an electric current is passed through the solenoid 10 it will polarize both core 14 and armature 17, which will of course assume the same polarities, for example as illustrated in Fig. 2 wherein the upper ends of the core and armature are indicated by the letter N for north poles, and the letter S for south poles. The yoke 18 will also be polarized but its upper end or pole piece 19 will assume a polarity opposite to that of the upper end of the armature and core. Assuming the armature to be in its normal position against the core 14, it will be immediately apparent that since the upper ends of the armature and core are of like polarity the armature will be repelled by the core, and since the polarities of the armature and the yoke pole piece 19 are opposite, the armature will be attracted to the pole piece 19. The armature is thus both pushed and pulled from position A to position B, and since magnetic force varies inversely with the distance between the poles, the repellent force between the core and the armature will be maximum at the start of the armature movement, while the attractive force exerted on the armature by the yoke pole 19 will be a minimum at the start. However, as the armature moves farther away from the core 14 and approaches the pole 19 the repellent force decreases while the attractive force increases, so that the total force exerted on the armature is substantially uniform throughout its entire stroke. As soon as the solenoid is de-energized, the spring 22 will of course return the armature to its normal position A.

Referring now to Figs. 4, 5, and 6 illustrating the balanced armature type of our invention, the numerals 10, 11, 12, and 13 again denote a solenoid, a spool tube, and top and bottom spool faces, respectively. In this form of our invention, however, the core is Z-shaped and comprises an upper pole piece 30, an offset lower pole piece 31, and a central cross bar 32 connecting the two pole pieces as indicated, the cross bar being preferably formed with a slot in which an armature comprising upper portion 33 and lower portion 34 is pivoted on a pin 35. The core is preferably secured within the tube 11 so that the upper pole piece 30 rests against one wall of the tube and the lower pole piece 31 rests against the opposite wall of the tube 11, the ends of the pole pieces protruding slightly beyond the walls of the tube.

A yoke 36 which may be similar to yoke 18 is secured about the solenoid in its outer magnetic path and provides a central pole piece 37 confronting the upper portion 33 of the armature as indicated. The lower leg of the yoke 36 is magnetically insulated from the lower pole piece of the core as before. A similar yoke 38 is mounted on the other side of the solenoid and has its lower leg formed similar to the upper leg of the yoke 36 and provided with a central pole piece 39.

The balanced armature is normally held with its two ends against their respective core pieces by suitable means such as spring 40 attached to a pin 41 on the upper end of the armature, or by any other convenient means. Assuming the armature in its normal position A, energization of the solenoid polarizes both the core and the armature as before, with the upper end having one polarity, north for example, and the lower ends having opposite polarity. The yokes 36 and 38 will also be polarized with their upper legs having south polarity and their lower legs, north polarity when the current travels in the appropriate direction. As before, the upper end of the armature is repelled by the upper pole piece 30 of the core and is attracted by the pole piece 37 of the yoke 36 to give a push-pull action to the armature. Similarly the lower end of the armature which has south polarity is repelled by the lower pole piece 31 of the core and is attracted by the lower pole piece 39 of the yoke 38, thus doubling the force exerted on the armature. Since the armature is preferably balanced at its center, it will be apparent that it will be very stable and relatively insensitive to outside forces. When the solenoid is de-energized the armature will of course be returned to its normal rest position A by the resilient means 40.

Referring now to Figs. 7–9, inclusive, the numeral 10 again indicates a solenoid wound on a spool comprising a central tube 11 and upper and lower face plates 12 and 13 respectively. A core 14 and an armature 17 are pivotally connected at their lower ends by means of a pair of ears 15 and 16 having a pin extending between them. In this case, however, both core 14 and armature 17 are mounted for movement, and are normally urged together by suitable resilient means such for example as the spring 22 which centers the core and armature in the tubular portion 11 of the solenoid spool. The armature 17 carries an externally facing contact 25 as before, and the core 14 also carries a contact, which is indicated by the numeral 25—*a*.

In the form shown in Fig. 7 yokes 36 and 38 are provided which may be similar to the yokes of like number in Fig. 5, the yoke 36 providing a pole piece 37 confronting the upper end of armature 17, and the yoke 38 providing a pole piece 37*a* confronting the movable core 14.

In the operation of this form of our invention the core 14 and armature 17 are similarly polarized by energization of the solenoid, and in the example shown, their upper ends assume north polarity, thereby repelling each other and causing both of the axially disposed members 14 and 17 to move outwardly against the urging of the spring 22. In the magnet of Fig. 7 this movement of the members 14 and 17 is facilitated by the pole pieces 37 and 37*a* which assume south polarity and therefore attract their adjacent movable members. We thus get push-pull operation with the additional advantage of having both the core 14 and the armature 17 movable to make contact with suitably placed switch pieces (not shown) or for other purposes. Where the extra force furnished by the auxiliary pole pieces is not desired, they may be omitted. By the construction of Fig. 7 we secure a very fast acting magnet which is particularly suitable for relays subjected to large accelerative forces, such as encountered in aircraft operation. By using the core and armature to provide a double contact in the same circuit, one of them will always be additionally urged to closed contact position by the accelerative forces affecting the magnet, so that if one contact is broken by sudden acceleration, the other one remains closed to keep the circuit from being broken.

Referring now to Fig. 10, the numeral 10 indicates a solenoid wound on a spool comprising tube 11 and face plate 12 and 13. An armature comprising upper and lower portions 33 and 34 similar to that shown in Fig. 5 is pivotally mounted on a pin 36 in a crossblock 32 fastened within the tube 11. A yoke 36′ has an upper leg which provides a pole piece 37′ confronting one face of the upper end of the armature, and adapted to assume a polarity opposite thereto when the solenoid is energized. A second yoke 38' has a lower leg providing a pole piece 39' confronting the opposite face of the other end of the armature. This pole piece also assumes a polarity opposite to that of its confronting armature face. In the example illustrated in Fig. 10 the upper end 33 of the armature becomes a north pole while its lower end 34 becomes a south pole when the solenoid is energized. Consequently the upper yoke pole piece 37' becomes a south pole and the lower yoke pole piece assumes north polarity. By thus arranging the pole pieces in the outer magnetic path of the solenoid we secure a double pull on the balanced armature and provide an electromagnet which is adapted for use where high sensitivity and stability but not excessive power are required.

From the foregoing description of various forms of our invention it is seen that we provide simple and efficient means of greatly increasing the power of an electromagnet without increasing either its size or the current required. Also, by placing the movable member or members inside of the solenoid, we insure that all magnetizing forces acting thereon are created by the same flux lines, thus eliminating the possibility of unbalanced forces which tend to cause flux leakage. Furthermore, by the construction illustrated herein we are able to have a relatively short flux path with consequent small leakage losses.

It will be understood of course that the electromagnet of our invention has a wide range of uses, and that while we have illustrated in detail various simple forms of our invention which are particularly well suited for relay and other uses, we do not mean to limit ourselves to the structures shown, but rather intend that our invention shall be given the full scope defined by the appended claims.

We claim:

1. An electromagnet which includes: a solenoid; a pair of spaced apart unconnected stationary pole pieces, one disposed inside of said solenoid and the other on the outside of said solenoid but in the magnetic path thereof, said poles being arranged to assume opposite polarity; and an armature pivotally mounted within said solenoid having an end movable between said poles and adapted to be polarized, whereby when said solenoid is energized said armature will be repelled by one and attracted by the other of said stationary poles.

2. An electromagnet which includes: a solenoid; a core axially disposed within said solenoid forming a pole piece at each end thereof; and an armature axially disposed within said solenoid adjacent said core and pivotally mounted thereon for movement with respect thereto said pivot point being within said solenoid, whereby when said solenoid is energized said core and armature will be similarly polarized causing said armature to move away from said core.

3. An electromagnet which includes: a solenoid; a core axially disposed within said solenoid forming a pole piece at each end thereof; an armature axially disposed within said solenoid adjacent said core and pivotally mounted on said core for movement with respect thereto, whereby when said solenoid is energized said core and armature will be similarly polarized causing said armature to move away from said core; and a yoke in the outside magnetic path of said solenoid with one end terminating adjacent the movable end of said armature and assuming opposite polarity thereto when said solenoid is energized, and the other end thereof terminating adjacent the other end of said core but magnetically insulated therefrom.

4. An electromagnet which includes: a solenoid; a core axially disposed within said solenoid forming a pole piece at each end thereof; an armature axially disposed within said solenoid adjacent said core and pivotally mounted on said core for movement with respect thereto, whereby when said solenoid is energized said core and armature will be similarly polarized causing said armature to move away from said core; resilient means normally urging said armature against said core; and an external pole piece in the outside magnetic path of said solenoid with one end terminating adjacent the movable end of said armature and assuming opposite polarity thereto when said solenoid is energized, and the other end thereof terminating adjacent the other end of said core but magnetically insulated therefrom.

5. An electromagnet which includes: a solenoid; core means within said solenoid providing pole pieces at each end thereof, but displaced laterally of each other; and an armature pivotally mounted in the central portion of said solenoid with its ends respectively adjacent said pole pieces, whereby said core and armature are polarized upon energization of said solenoid to cause each end of said armature to be repelled by its adjacent pole piece, and to rotate on its pivot mounting.

6. An electromagnet which includes: a solenoid; core means within said solenoid providing pole pieces at each end thereof; and an armature pivotally mounted in the central portion of said core with opposite faces of its opposite ends respectively confronting said core pieces, whereby when said armature and core pieces are polarized by energization of said solenoid, said confronting portions will have the same polarity to thereby exert a repellent force on each end of said armature to rotate the same.

7. An electromagnet which includes: a solenoid; core means axially positioned in said solenoid and providing a north pole piece at one end thereof and a south pole piece at the other end thereof; and an armature axially positioned in said solenoid and providing north and south poles at the opposite ends of said solenoid, said armature and core means being disposed so that a line joining the core pole pieces will at all times intersect a line joining the armature pole pieces at an acute angle, whereby upon energization of said solenoid and polarization of said core and armature, the armature will be additively repelled at each end thereof.

8. An electromagnet which includes: a solenoid; core means axially positioned in said solenoid and providing a north pole piece at one end thereof and a south pole piece at the other end thereof; an armature axially positioned in said solenoid and providing north and south poles at the opposite ends of said solenoid, said armature and core means being disposed so that a line joining the core pole pieces will at all times intersect a line joining the armature pole pieces at an acute angle, whereby upon energization of said solenoid and polarization of said core and armature, the armature will be additively repelled at each end thereof; and yoke means around said solenoid in the outside magnetic path thereof which provides auxiliary north and south

poles on each end of said solenoid adapted to respectively attract each end of said armature.

9. An electromagnet which includes: a solenoid; a Z-shaped member disposed within said solenoid axially thereof; and a second member within said solenoid pivoted near its center on the cross-bar of said Z, both of said members being adapted to be polarized when said solenoid is energized, whereby one of said members is additively repelled by the poles of the other of said members.

10. An electromagnet which includes: a solenoid; a Z-shaped core disposed within said solenoid axially thereof; an armature within said solenoid pivoted near its center on the cross-bar of said Z, both said core and armature adapted to be polarized when said solenoid is energized, whereby said armature is additively repelled by the poles of said core; and yoke means providing auxiliary poles at opposite ends of said solenoid to attract said armature.

11. An electromagnet which includes a solenoid; an armature axially and rotatably mounted within said solenoid; and means in the outside magnetic path of said solenoid forming pole pieces on opposite ends of said solenoid confronting opposite faces of said armature, whereby upon energization of said solenoid said pieces will assume polarities opposite to those assumed by the respective confronting faces of said armature to cause rotation thereof.

12. An electromagnet which includes: a solenoid; means associated with said solenoid in the magnetic path thereof providing pole pieces at each end thereof, but displaced laterally of each other; and an armature pivotally mounted within said solenoid with its ends respectively adjacent said pole pieces, whereby said armature and pole pieces are cooperatively energized upon energization of said solenoid to cause said armature to rotate on its pivot mounting.

13. An electromagnet which includes: a solenoid; means associated with said solenoid in the magnetic path thereof providing a north pole piece at one end of said solenoid and a south pole piece at the other end thereof; and an armature pivotally mounted within said solenoid and providing north and south poles at the opposite ends of said solenoid, said armature and said pole pieces being disposed so that a line joining said pole pieces will at all times intersect a line joining the armature poles at an acute angle, whereby upon energization of said armature and pole pieces, the armature will be rotated on its pivot mounting.

14. As an article of manufacture, a core-armature assembly for insertion in a solenoid, which comprises, a longitudinal core member, and a longitudinal armature member pivotally connected together intermediate their end faces and lying in substantial juxtaposition, whereby they may be inserted into an open end of said solenoid and be similarly polarized upon energization of said solenoid.

15. An electromagnet which includes: a solenoid; a Z-shaped member disposed within said solenoid axially thereof; a second member within said solenoid pivoted near its center on the cross-bar of said Z, both of said members being adapted to be polarized when said solenoid is energized, whereby one of said members is additively repelled by the poles of the other of said members; and yoke means providing auxiliary poles at opposite ends of said solenoid.

16. An electromagnet which includes: a solenoid; an axially extending pole piece rigidly mounted within said solenoid; an axially extending armature pivotally attached within said solenoid to said pole piece at one end of the latter whereby energization of said solenoid causes like magnetization of said armature and said pole piece; and an outer pole piece in the external magnetic circuit of said solenoid, wholly separated from said axial pole piece and from said pivoted end of said armature, said outer pole piece being adapted to have magnetic poles induced therein which are of opposite polarity to adjacent poles of said axial pole piece and said armature, whereby said axial pole piece is attracted to said outer pole piece but is immovable with respect thereto, while said armature is repelled by said axial pole piece and attracted by said outer pole piece when said solenoid is energized.

17. An electromagnet which includes: a solenoid; an axially extending pole piece within said solenoid; an outer pole piece in the external magnetic circuit of said solenoid, wholly separated from said axial pole piece but adjacent one end of the latter; and an armature within said solenoid pivotally attached to said axial pole piece at the end thereof adjacent said outer pole piece, whereby energizing said solenoid induces magnetic fields of like polarity in said axial core and said armature, thereby urging said armature away from said axial pole piece and attracting said armature toward said outer pole piece.

18. An electromagnet which includes: a solenoid; an axially extending pole piece rigidly mounted within said solenoid; an armature within said solenoid and substantially parallel thereto, pivotally attached to said axial pole piece at one end of the latter; and an outer pole piece in the external magnetic circuit of said solenoid wholly separated from said axial pole piece but adjacent the latter at its point of pivotal attachment to said armature, said outer pole piece being adapted to attract the free end of said armature so that the latter bears against it, whereby energization of said solenoid induces magnetic poles of like polarity in said axial pole piece and said armature, and magnetic poles of unlike polarity in said armature and the adjacent portion of said outer pole piece, thereby causing said armature to be repelled from said axial pole piece and attracted toward said outer pole piece.

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