

Lesson 19: Galvanometers & Electric Motors

Galvanometers and **electric motors** are both based on the same basic principle of an external magnetic field exerting a force on a current carrying wire.

- The difference is in how far the device is allowed to move.
 - **Galvanometers** are typically used inside meters (e.g. voltmeters), so the device is only supposed to move a little bit, usually against a restraining spring.
 - **Motors** must be able to move freely and rotate through complete 360° turns.

Galvanometers

Without getting in to all the details of the connections to a meter, the basic parts of a galvanometer are a coil of wire in a magnetic field.

- Although this coil of wire will usually go around and around a bunch of times in a real galvanometer, my diagrams will only show a single loop for simplicity.
- The external magnetic field could be made by two separate magnets, a horseshoe magnet, or an electromagnet; it doesn't really matter.
- The electron flow current is flowing into and out of the loop as shown by the arrows.
- Each section of the wire is labeled by letter so we can keep track of what is happening in each section of wire.

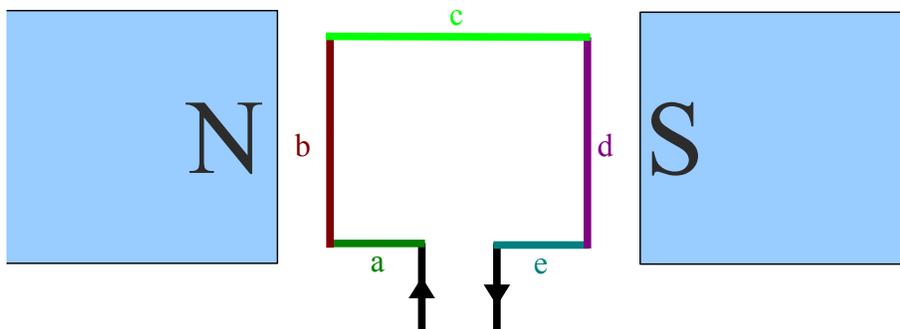


Illustration 1: Simple galvanometer.

Section “a”

- This is the first section of wire truly in the magnetic field. Since it is parallel to the magnetic field (*North to South*), there will be no magnetic force exerted on this section.

Section “b”

- The current is traveling up towards the top of the page in this section of wire.
- Using the third hand rule for this section, **the magnetic force is acting out of the page.**

Section “c”

- Again, the wire is parallel to the magnetic field, so there is no magnetic force acting on it.

Section “d”

- The current is now moving towards the bottom of the page in this section of wire.
- Using the third hand rule the magnetic force is acting into the page.

Section “e”

- This is the last section of wire before the current exits the magnetic field.
- It is parallel, just like “a”, so there is not magnetic force.

So, if we look at the overall magnetic forces acting on the coil...

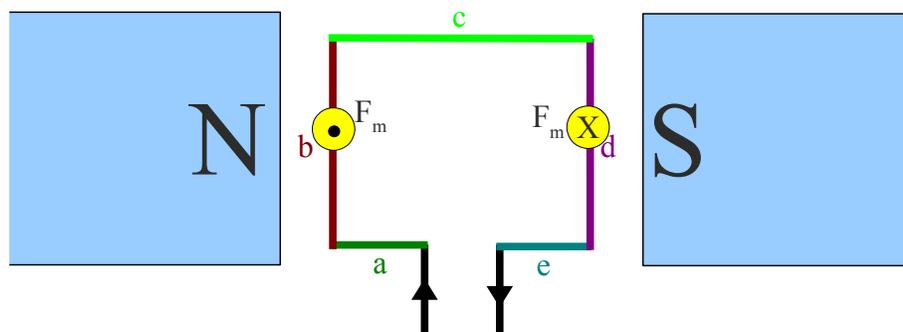


Illustration 2: Magnetic force acting on wires.

Now imagine looking at this edge on (like if you held this page flat in front of your eyes).

- The whole thing is trying to twist itself around.
- If we hooked this up to a spring that pushed back, calibrated with a specific spring constant, we could measure things like the current flowing through the wire depending on how far it pushed the spring.

Example 1: A galvanometer has been built following the sketch shown in Illustration 2. The length of wire at b and d are each 3.8 cm long. A spring ($k = 87.6 \text{ N/m}$) that tries to hold back the motion of the galvanometer is pushed 0.0055 m when current flows through the galvanometer. If the external magnetic field is 1.25 T, **determine** the current flowing in the wire.

The restoring force of the spring ([Hooke's Law](#)) is balanced against the magnetic force twisting the wires. Remember that since there are two sections of the wire, each 3.6 cm long, the entire length of wire in the magnetic field is 7.6 cm, converted to 0.076 m.

$$\begin{aligned}
 F_s &= F_m \\
 kx &= I l B \\
 I &= \frac{kx}{l B} \\
 I &= \frac{87.6(0.0055)}{0.076(1.25)} \\
 I &= 5.0715789 = 5.1 \text{ A}
 \end{aligned}$$

Electric Motors

The defining characteristic of an electric motor is that it must be able to rotate freely through a complete circle and keep on turning.

- To do this, we take the basic design of a galvanometer and modify it to allow it to turn.
- We will use specific names to refer to the parts of a motor:
 - **Stator:** an electromagnet or permanent magnet that creates the external magnetic field.
 - **Armature:** the coil of wire that the current flows through. It will often have many coils inside the external magnetic field before it exits. Armatures are sometimes called rotors.
 - **Commutator:** a ring of metal with a split down the middle that allows current to flow to the armature while still letting it turn freely.

The only part that is really different from the galvanometers is that an electric motor has a commutator.

- Imagine looking edge on at the galvanometer again. There are two wires that need to be connected to something.
- The wires are each connected to one side of the split ring commutator (can't see them in the diagram).
- There are wire brushes (shown in grey, they actually can look like SOS scrubbing pads) connected to the terminals of a battery touching each side of the ring so that one is negative and one is positive. The brushes do not move (*Illustration 3a*).
- As the armature spins, the split ring rotates as well (*Illustration 3b*).
- When we hit a gap in the middle of the ring, no current is flowing and the armature continues to spin because of its inertia (*Illustration 3c*).
- Then there is a connection again and the armature continues to spin (*Illustration 3d*).
- This arrangement guarantees that current will always flow in on the left and out on the right.

When we use this setup as an electric motor, we have electricity as the input and we get mechanical energy (the rotating armature) as an output.

- In the next lesson we will look at how reversing this changes a motor into a generator.

Homework

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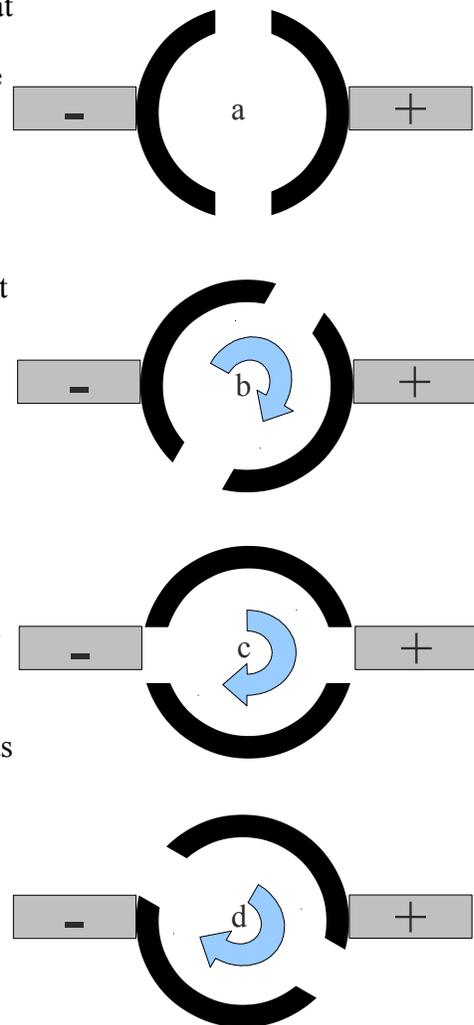


Illustration 3: A split ring commutator spins as it touches the brushes that allow current to flow.