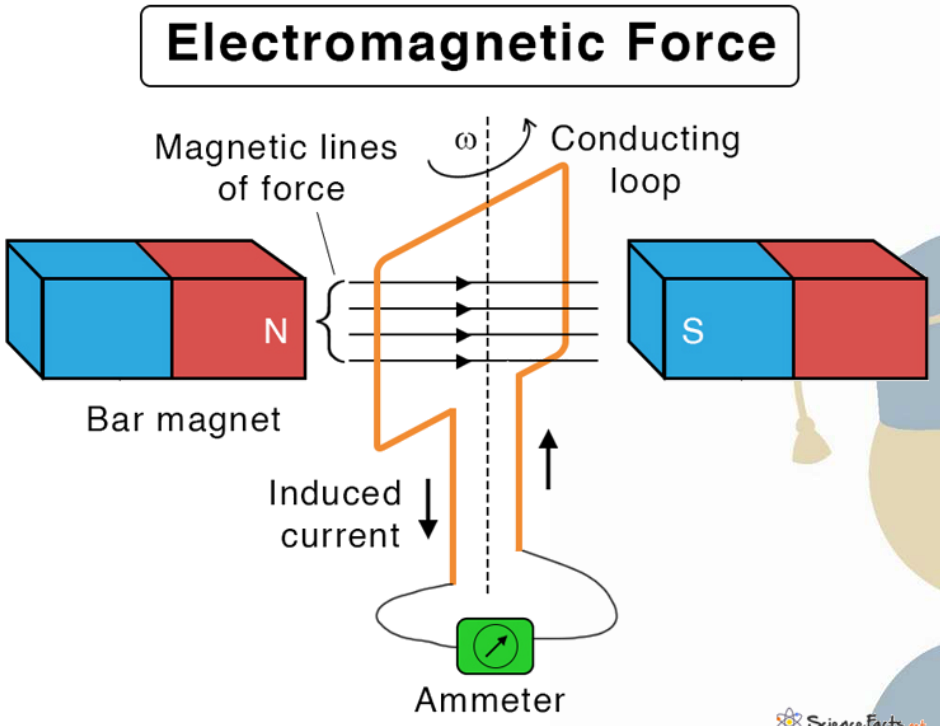
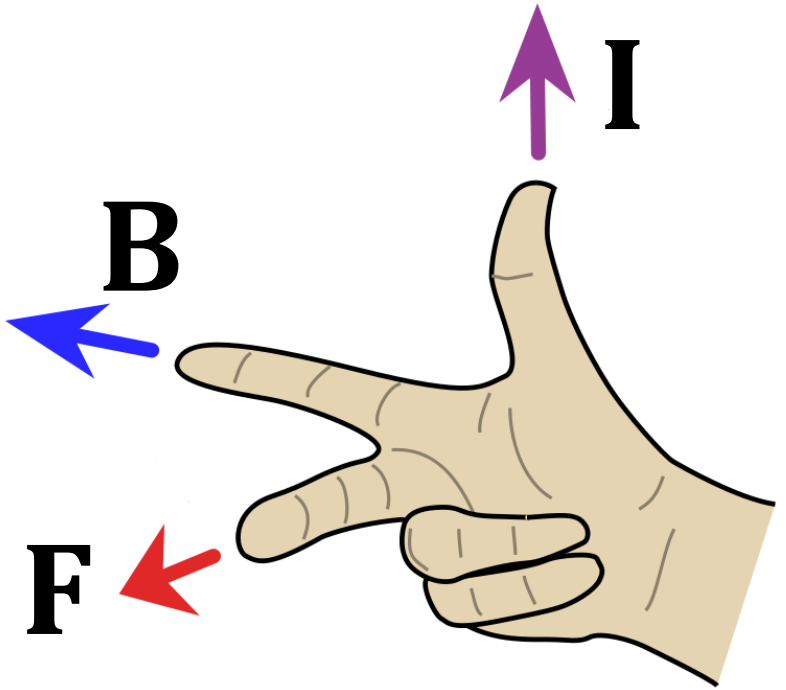




Chapter 19

Electromagnetic force

Prepared & Presented by: Mr. Mohamad Seif

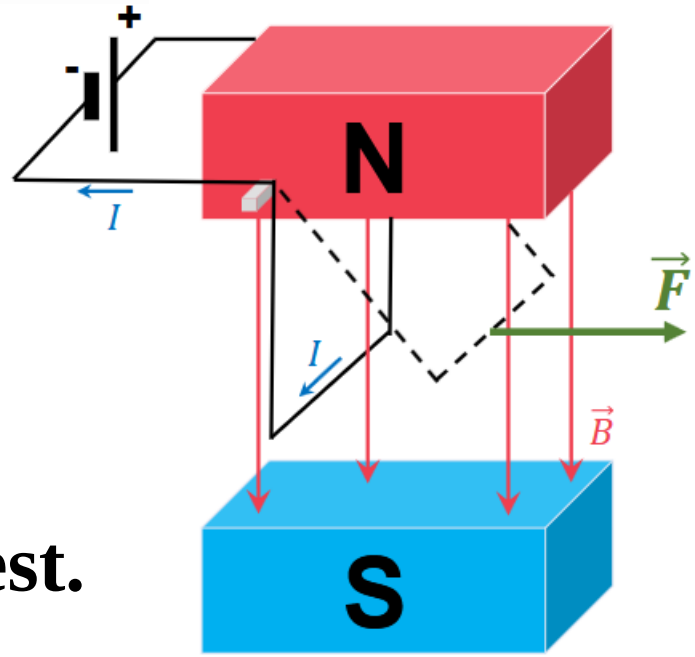
OBJECTIVES

1. **Definition of Laplace force.**

Laplace's force

A wire traversed by an electric current I, and placed in an external magnetic field $\vec{B}$: (the wire is placed between the poles of a magnet)

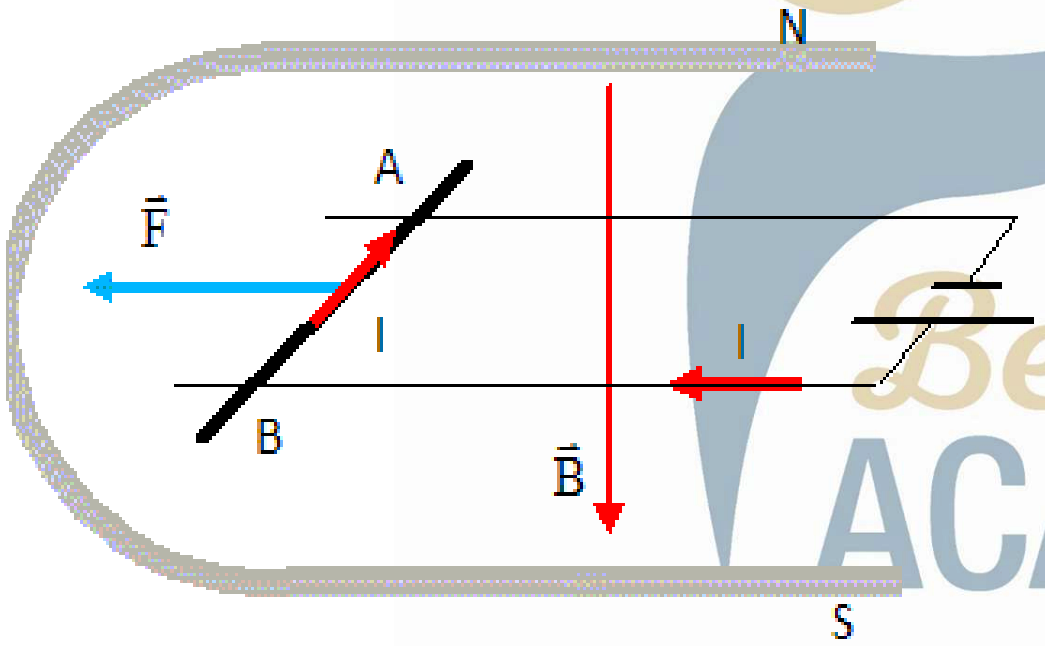
- **The wire is then subjected to a force that leads to displacement of the wire to the right.**
- **If we interchange the poles of the magnet, or the current in the wire is reversed, the direction of the displacement of the wire will also reverse.**
- **In the absence of the magnet, the wire remains at rest.**

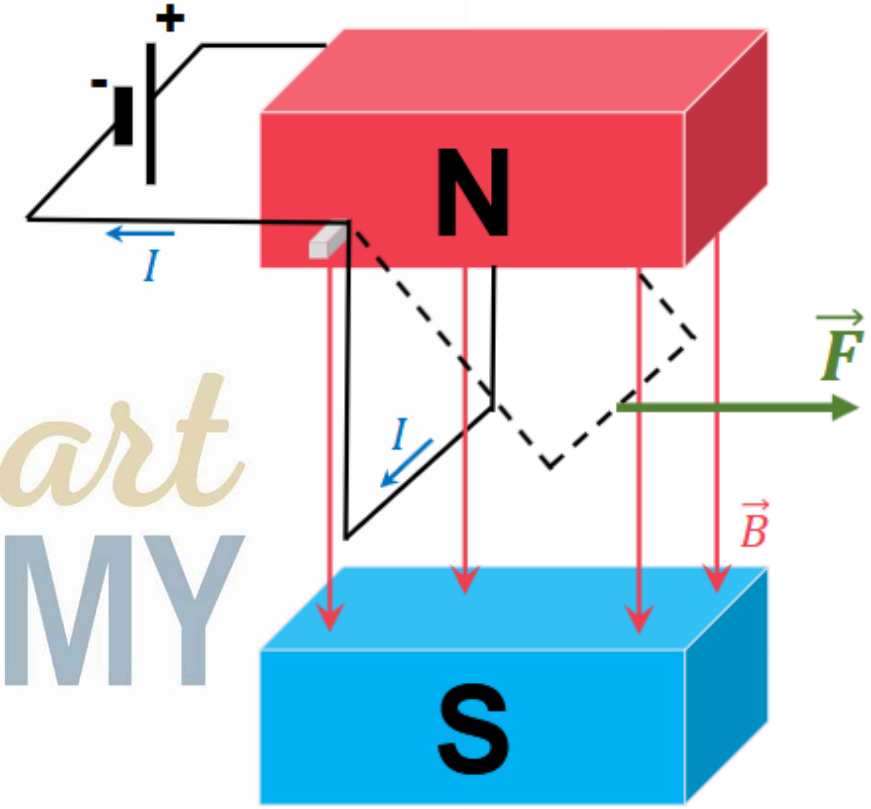


This force is called electromagnetic force (Laplace's force) $\vec{F}$.

Laplace's force

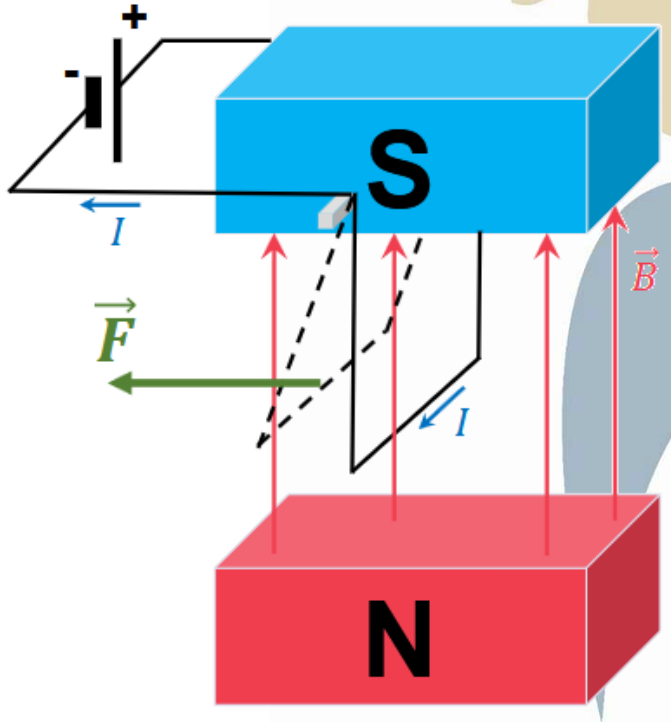
This force is of great importance in the functioning of many electrical instruments, like loudspeakers, ammeters or electric motors



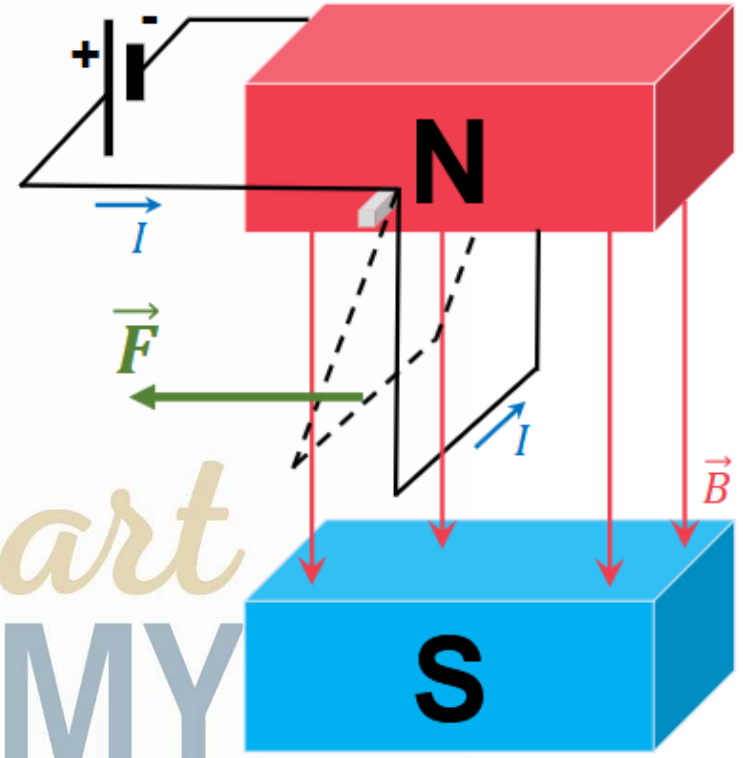


Laplace's force

The poles of the magnet are interchanged.

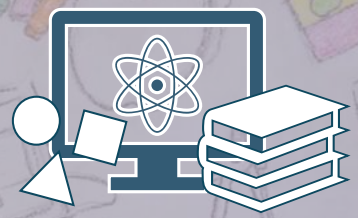


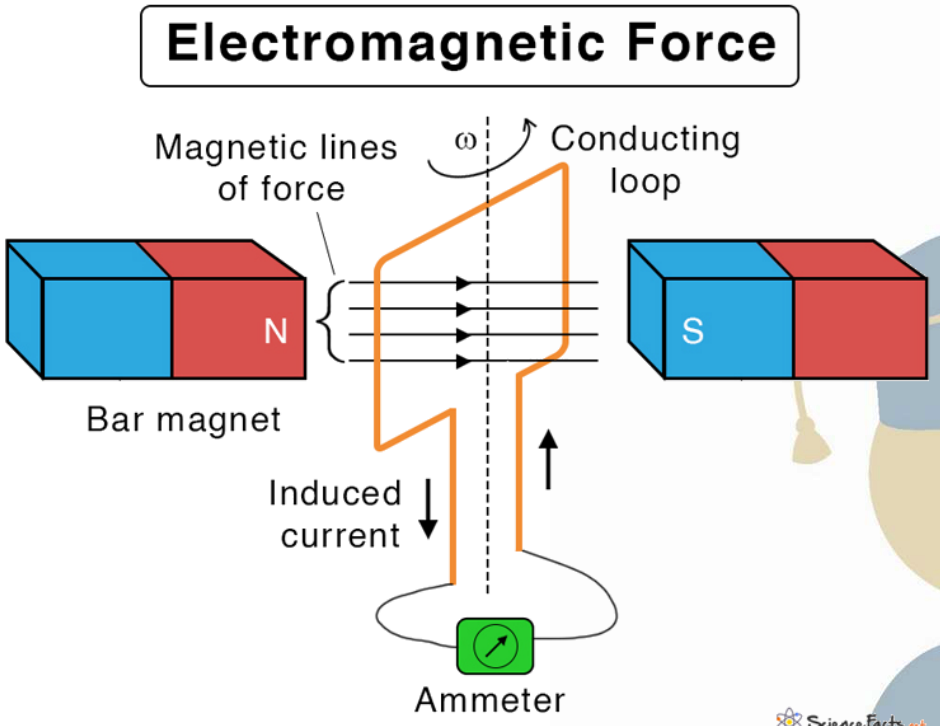
The current is reversed

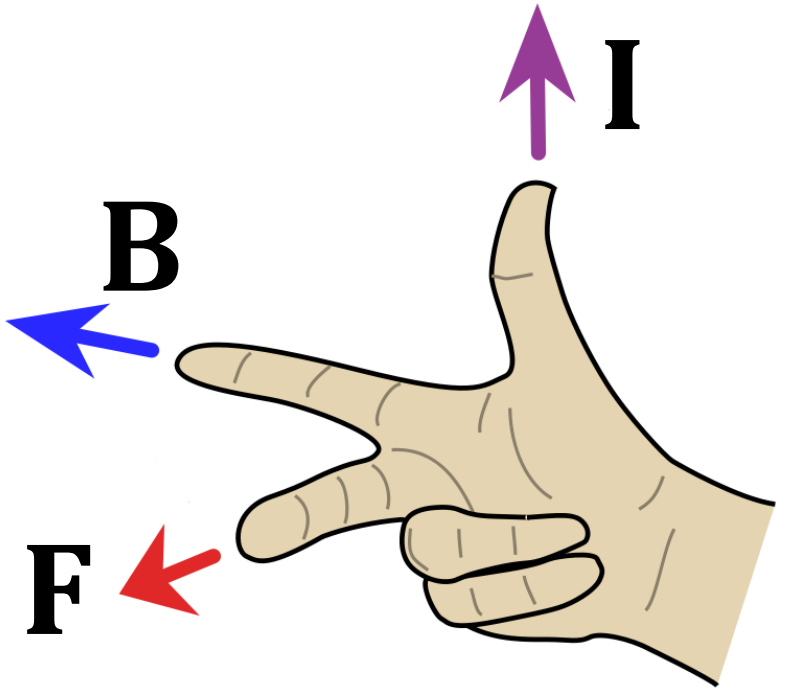


The direction of this force depends on the direction of the current and the polarities of the magnet.

The End







Chapter 19

Electromagnetic force

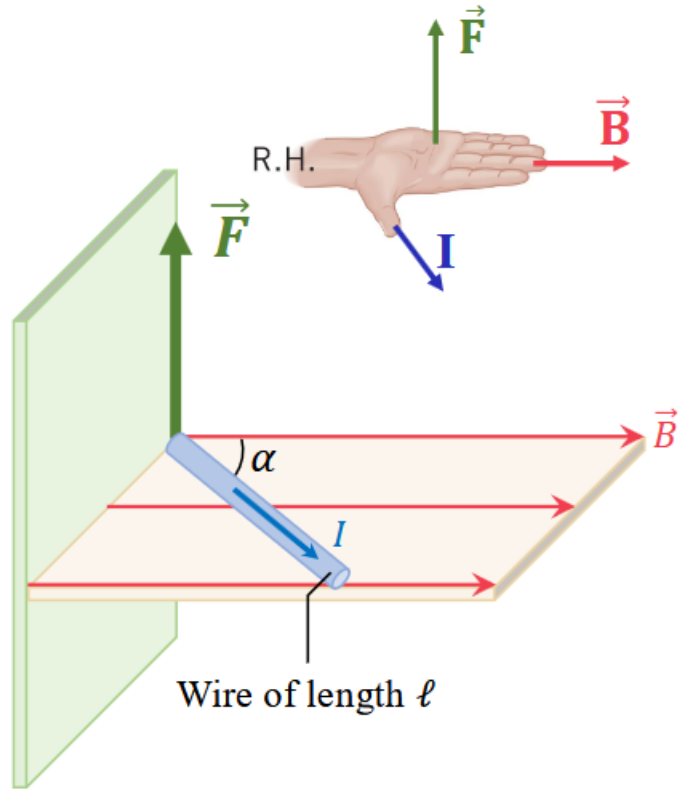
Prepared & Presented by: Mr. Mohamad Seif

OBJECTIVES

1 Characteristics of Laplace's force

Characteristics of Laplace's force ($\vec{F}$)

- **Point of application:** midpoint of the conductor.
- **Line of action:** perpendicular to the plane containing the wire and the magnetic field $\vec{B}$.
- **Direction:** obeys the right hand rule.
- **Magnitude:** $F = I.l.B|\sin\alpha|$



I: current (A)

L: length of conductor (m)

B: magnetic field (T)

α: angle between (I and $\vec{B}$)

Characteristics of Laplace's force ($\vec{F}$)

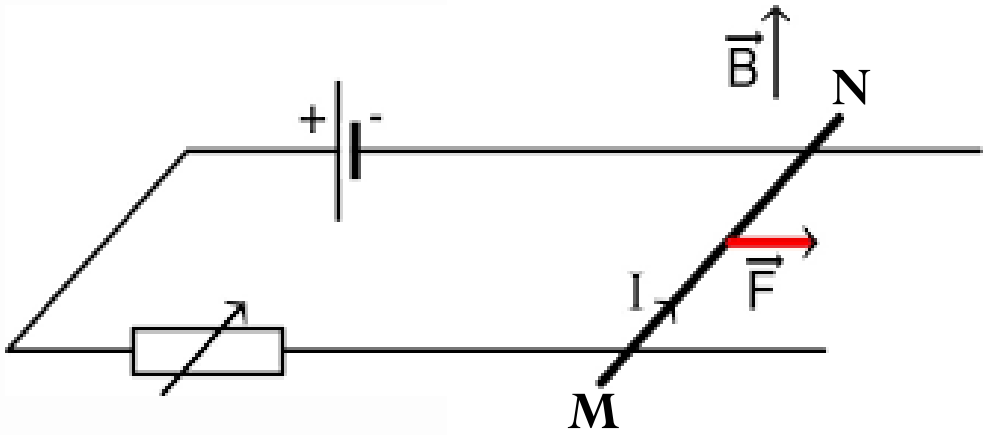
Right hand rule:

1) Point the thumb of the right hand in the direction of the current I.
2) Point the other fingers in the direction of the magnetic field **B**.
3) The direction of the magnetic force is away from the palm of your hand.

Characteristics of Laplace's force

i **and** $\vec{B}$ **may not be perpendicular, but** $\vec{F}$ **is always perpendicular to both of them.**

The direction of $\vec{F}$ **varies as the wire rotates, so that it remains perpendicular to the wire.**



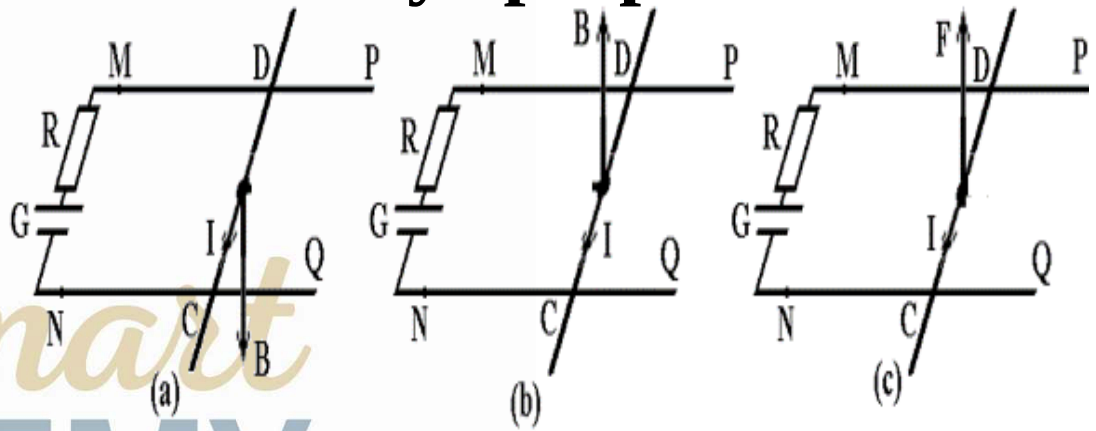
Characteristics of Laplace's force

Application 1:

MP and NQ are two parallel rails that lie in a horizontal plane. M and N are connected in series with a generator G and a resistance R.

The rod CD can slide on the two rails such that it stays perpendicular to the two rails

The circuit becomes closed, and a current I flows in it.



A magnetic field $\vec{B}$ due to an external magnet) exists around the rod CD, then an electromagnetic force is created on it.

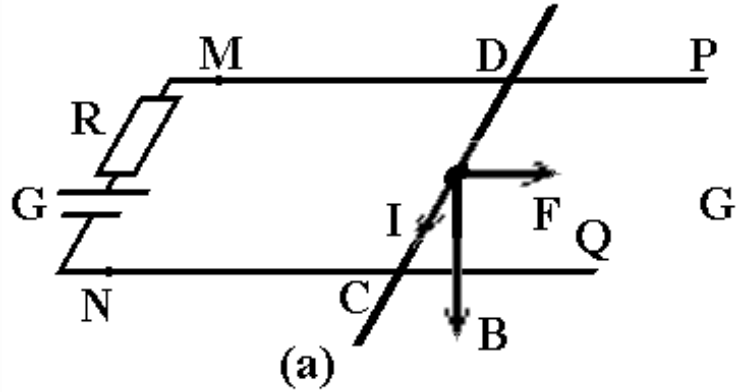
Determine the direction of the force $\vec{F}$ for the following figure:

Characteristics of Laplace's force

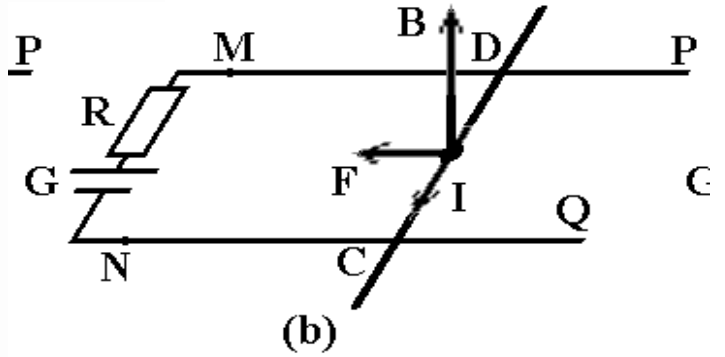
In the case (a): the rod CD slides to the right.

In the case (b): the rod CD slides to the left.

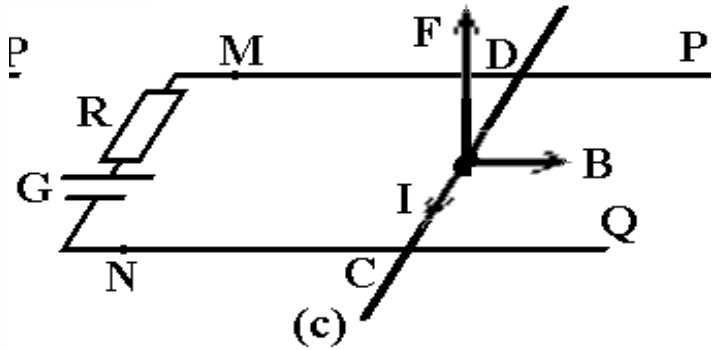
In the case (c) the rod CD rises, but the circuit becomes open, and I and F become zero, and the rod falls back. So it keeps jumping up and down.



(a)



(b)

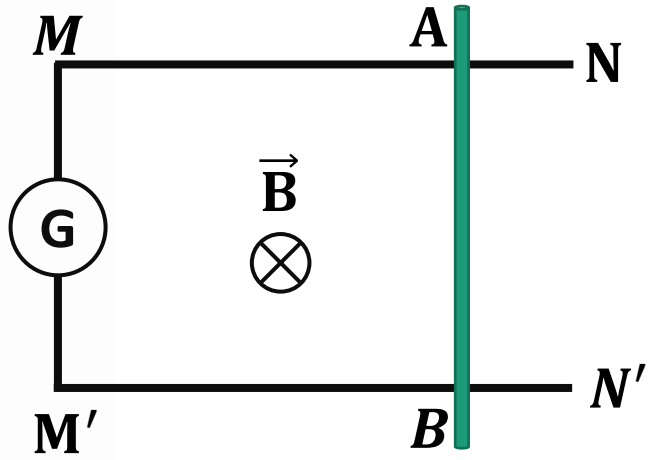


(c)

Characteristics of Laplace's force

Application 2:

A conductor rod AB, of length $l = 20\ cm$, can slide on two parallel horizontal conductors the rails MN and $M'N'$ as shown in the figure.



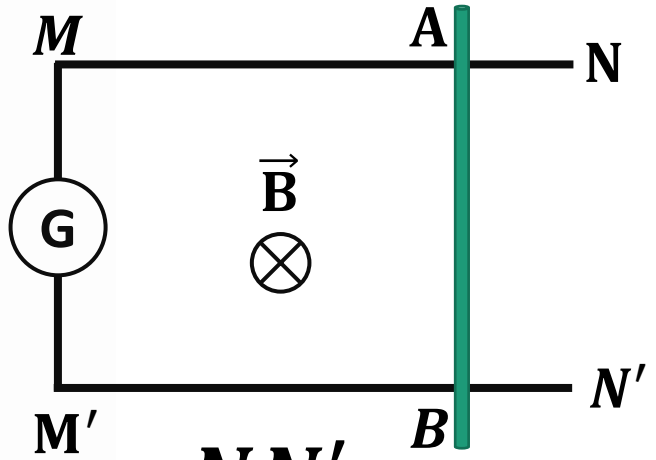
The extremities M and M' of the rails are connected to a generator G and a switch K.

The circuit is traversed by a current I of value $I = 1.2\ A$, then the rod AB moves towards (G).

All the set is placed in a uniform vertical magnetic field $\vec{B}$, as shown in the figure below.

Characteristics of Laplace's force

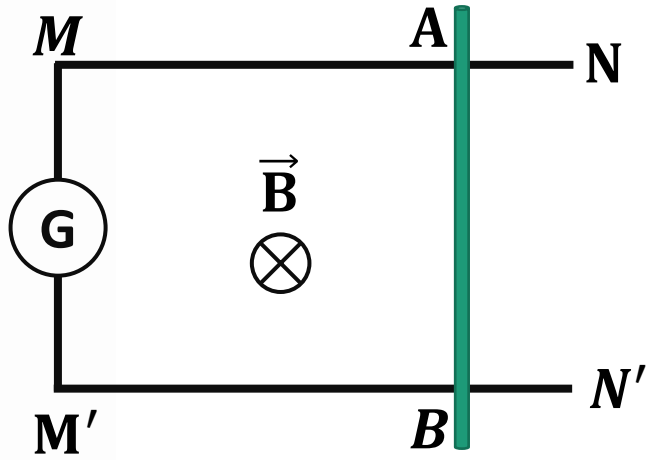
At $t_0 = 0\ s$, the rod initially at rest, we close the switch K. The rod moves toward the generator.



1) **Verify the existence of an electromagnetic force on NN'.**
2) **Determine the direction of the electric current in the circuit and deduce the polarity of the generator.**
3) **Determine the point of application, the line of action and the direction of $\vec{F}$.**
4) **Such that $F = 0.12$ N, calculate the value of the magnetic field.**

Characteristics of Laplace's force

$l = 20\ cm;\ m = ??;\ I = 1.2\ A$



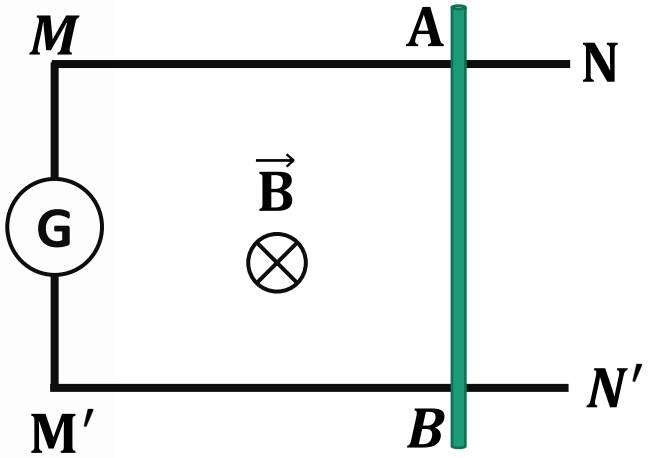
1) Verify the existence of an electromagnetic force on NN'.

Since the rod AB is traversed by an electric current and placed in an external magnetic field hence an electromagnetic force exists on AB.

Great!!

Characteristics of Laplace's force

$l = 20\ cm;\ m = ??;\ I = 1.2\ A$



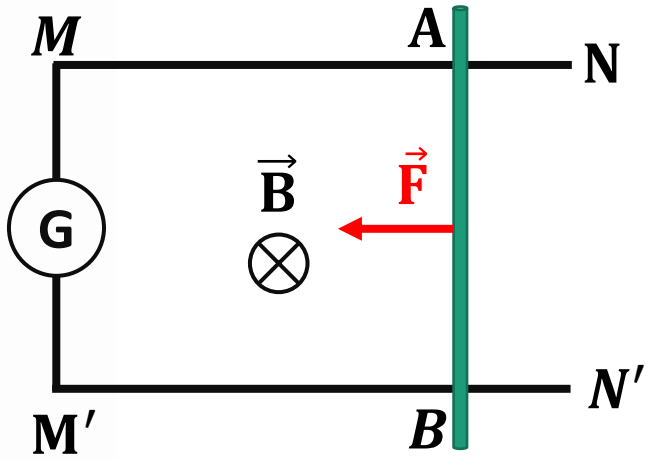
2)Determine the direction of the electric current in the circuit and deduce the polarity of the generator.

The rod AB moves toward the generator (to the left) so according to the right hand rule we deduce the direction of the current from B to A then:

M' is the (+) pole and M is the (-) pole.

Characteristics of Laplace's force

$l = 20\ cm;\ m = ??;\ I = 1.2\ A$

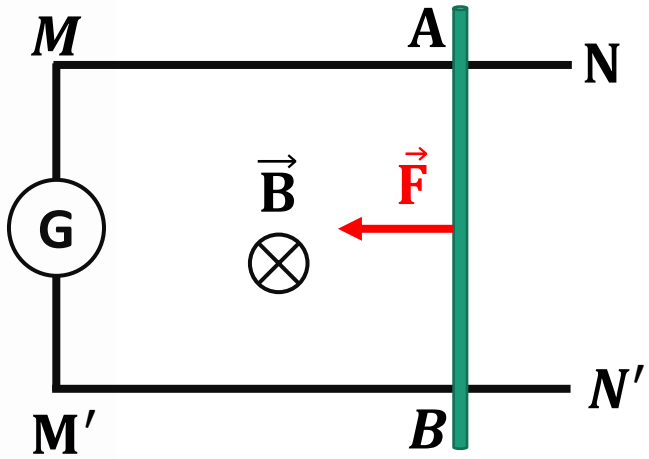


3)Determine the point of application, the line of action and the direction of $\vec{F}$.

- **Point of application:** midpoint of [AB].
- **Line of action:** horizontal.
- **Direction:** the rod moves to the left so the direction is to the left

Characteristics of Laplace's force

$l = 20\ cm;\ m = ??;\ I = 1.2\ A$



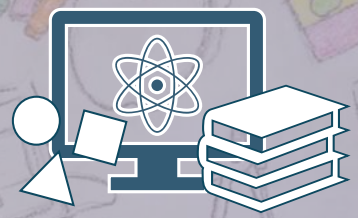
4) Such that $F = 0.12\ N$, calculate the value of the magnetic field.

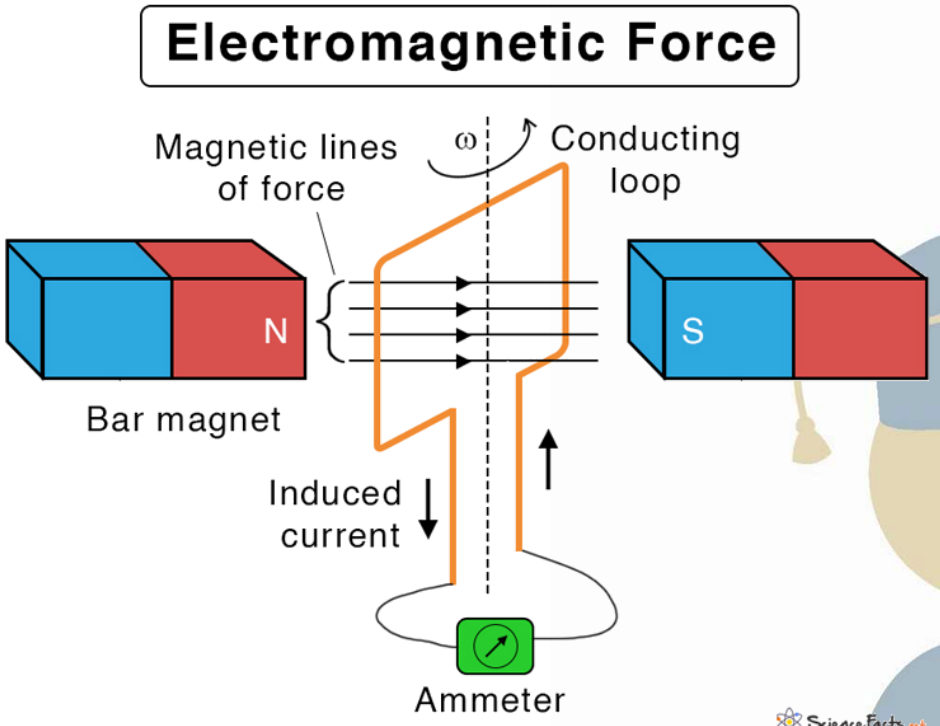
$$F = I.l.B\sin\alpha$$

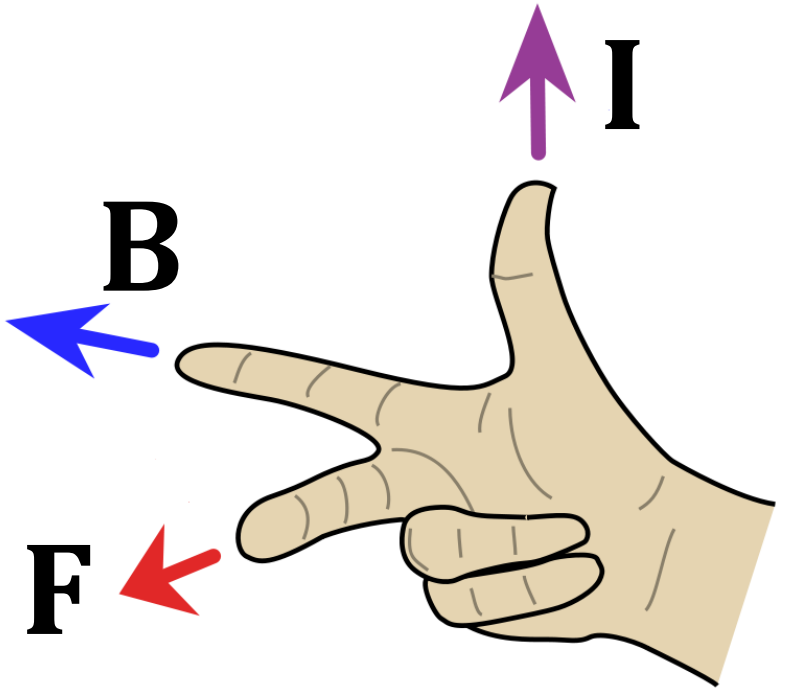
$$0.12 = 1.2 \times 0.2 \times B.\sin 90$$

$$B = \frac{0.12}{1.2 \times 0.2 \times \sin 90} \Rightarrow B = \frac{0.12}{1.2 \times 0.2} = 0.5\ T$$

The End







Chapter 19

Electromagnetic force

Prepared & Presented by: Mr. Mohamad Seif

OBJECTIVES

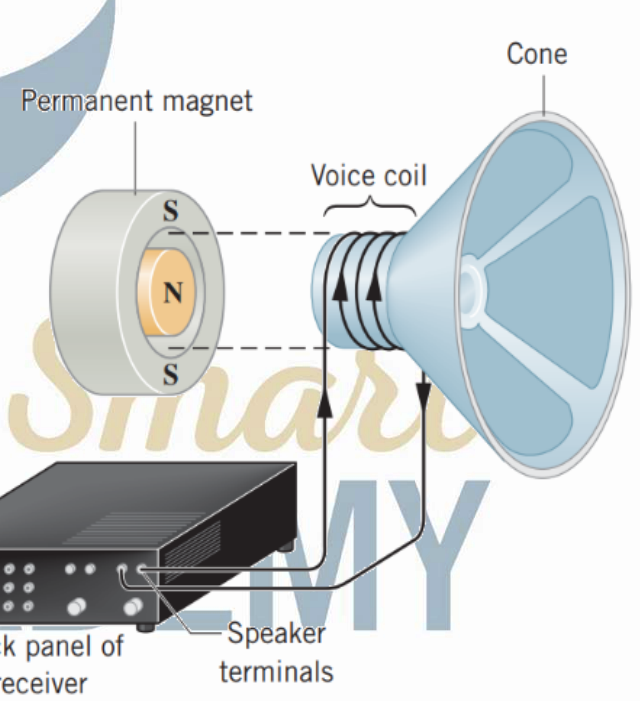
1. Explain the functions of the electrodynamic loudspeaker and the DC motor

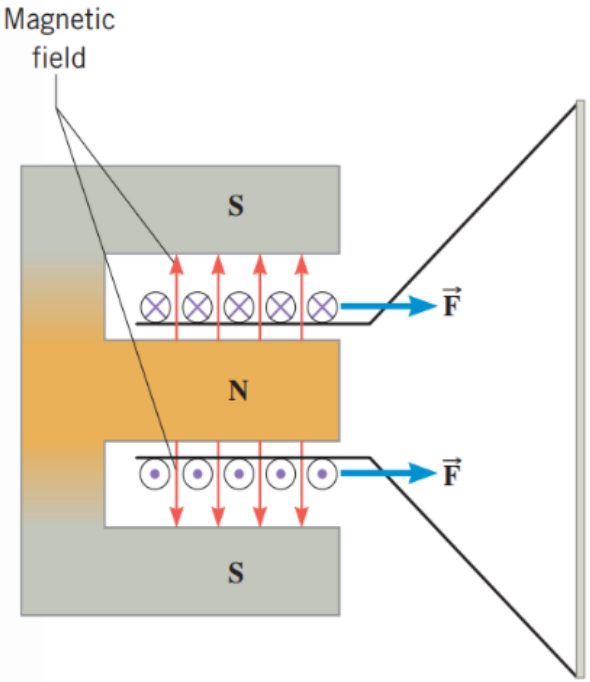
Electromagnetic loudspeaker

Most loudspeakers operate on the principle that a magnetic field exerts a force on a current-carrying wire.

A speaker design consists of three basic parts:

- **A cone.**
- **A voice coil.**
- **A permanent magnet.**

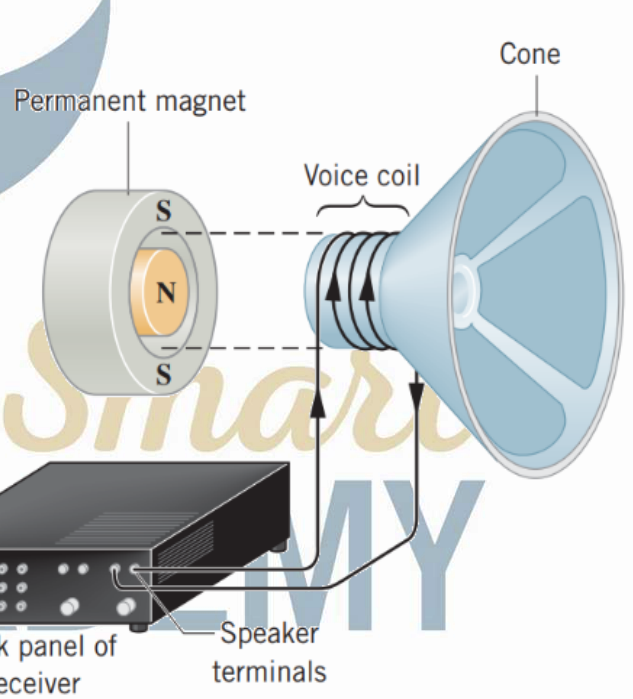


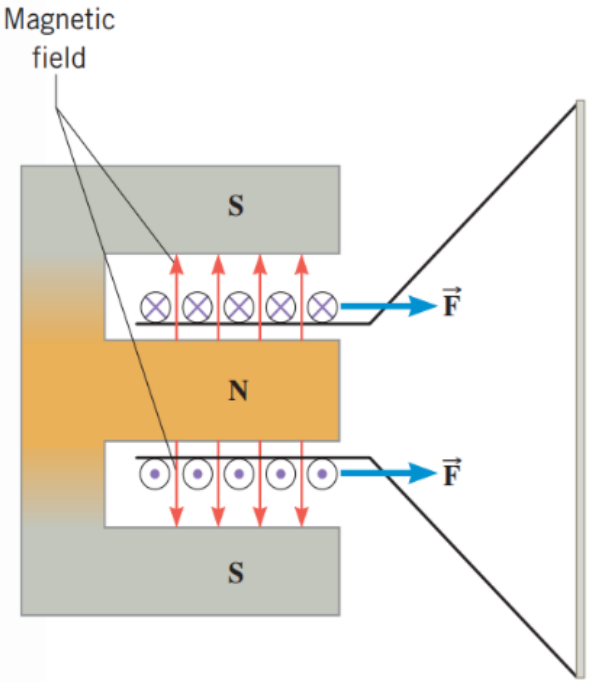


Electromagnetic loudspeaker

An alternating current traversing the coil, interacts with the magnetic field to generate a magnetic force that pushes and pulls on the voice coil and the attached cone.

When vibrating, it pushes and pulls on the air in front of it, thereby creating sound waves.

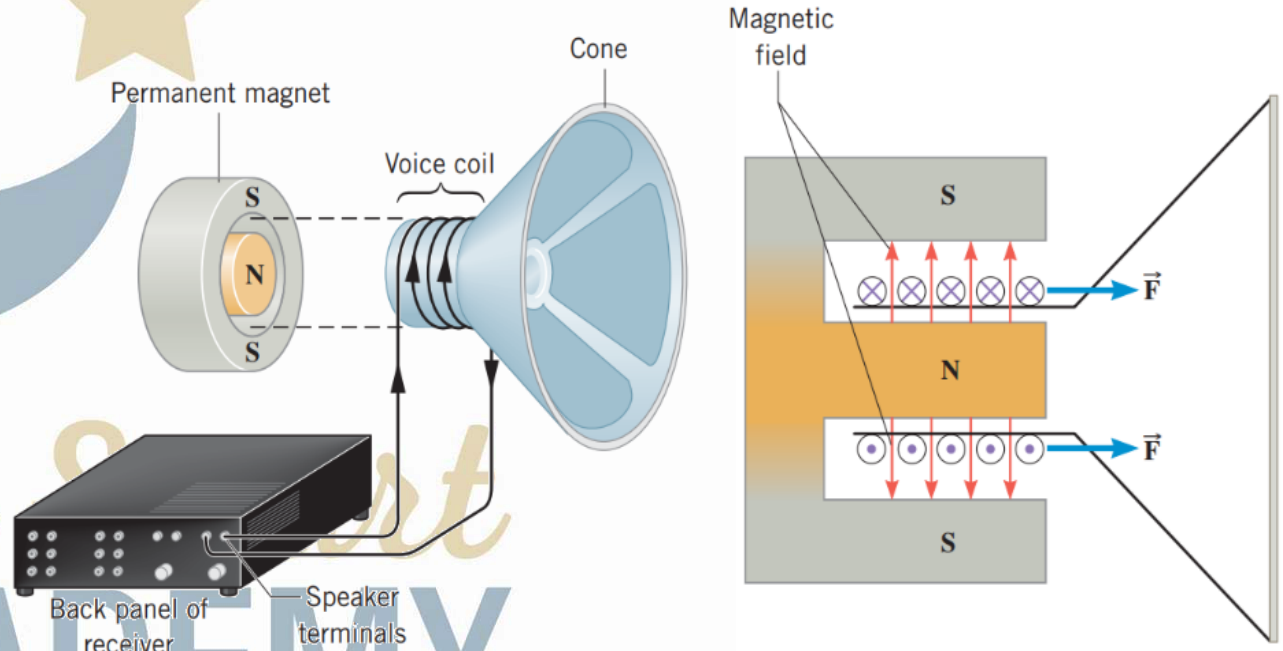




Electromagnetic loudspeaker

The coil is placed in the magnetic field created by the magnet and traversed by alternating current of frequency f sent by the amplifier.

The coil is under the action of a variable electromagnetic force ($\vec{F}$ changes its direction twice during one period).



The electromagnetic force sets the coil in vibratory motion with the same frequency f.

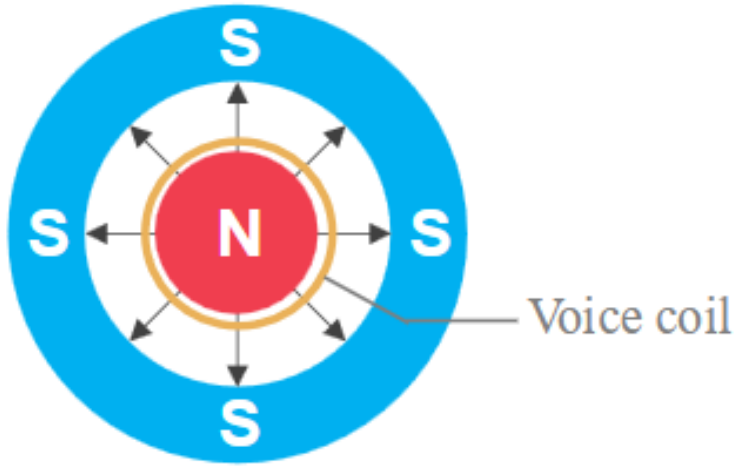
The membrane will vibrate with the frequency f producing sound of the same frequency.

Electromagnetic loudspeaker

Application 3:

The voice coil of a speaker has a diameter d = 0.025 m, contains 55 turns of wire, and is placed in a 0.1 T magnetic field.

The current in the voice coil is 2 A.

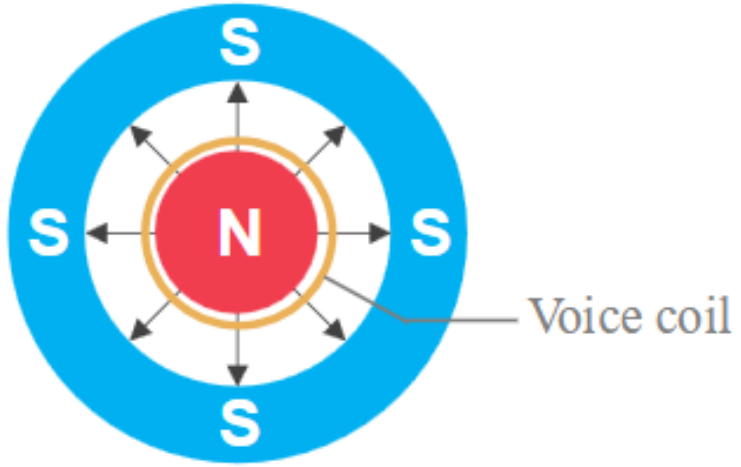


1) **Determine the magnitude of the magnetic force that acts on the voice coil and cone.**
2) **The voice coil and cone have a combined mass of 0.02 kg. Find their acceleration.**

(suppose that the speaker is placed horizontally so the effect of the weight of the coil on its motion is negligible)

Electromagnetic loudspeaker

1) Determine the magnitude of the magnetic force that acts on the voice coil and cone.



First, we have to determine the length of the voice coil:

ℓ = number of turns × perimeter of one turn = $N\,\pi d$

$$l = 55\pi \times 0.025 = 4.32m$$

The magnetic field acts perpendicular to all parts of the wire ($\alpha = 90°$), then:

$$F = IlBsin\alpha = (2)(4.32)(0.1)sin(90)$$

$$F = 0.86N$$

Electromagnetic loudspeaker

2) **The voice coil and cone have a combined mass of 0.02 kg. Find their acceleration.**

(suppose that the speaker is placed horizontally so the effect of the weight of the coil on its motion is negligible)

Only the magnetic force acting on the coil and cone.

According to Newton's 2nd law:

$$F = ma \quad \Rightarrow \quad a = \frac{F}{m} = \frac{0.86}{0.02} \quad \Rightarrow \quad a = 43 m/s^2$$

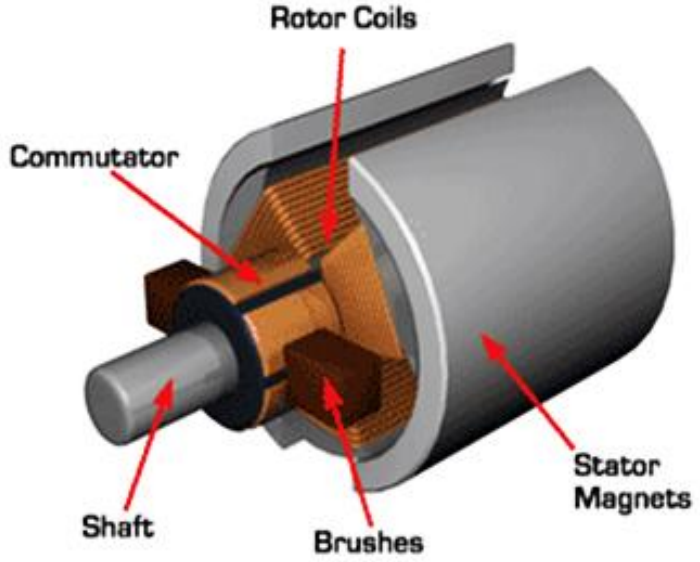
This seems like a reasonable value, since the coil vibrates fast to produce sound waves.

DC electric motor

Direct Current (DC) electric motor is found in many devices, such as CD players, toy cars, washing machines, drilling machines…

The main parts of DC electric motor:

- **Rotor: the rotating part.**
- **Commutator: the terminals of the rotor are connected to it.**
- **Stator magnet: polar pieces creating a magnetic field surrounding the rotor**



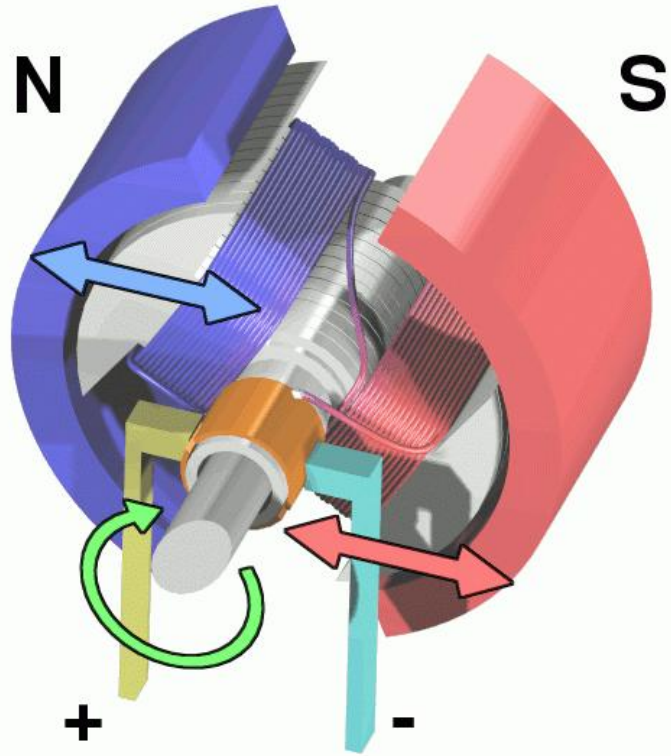
DC electric motor

The coil of the DC motor wire placed in a magnetic field and free to rotate about a vertical shaft.

Each end of the coil is attached to a metallic half-ring.

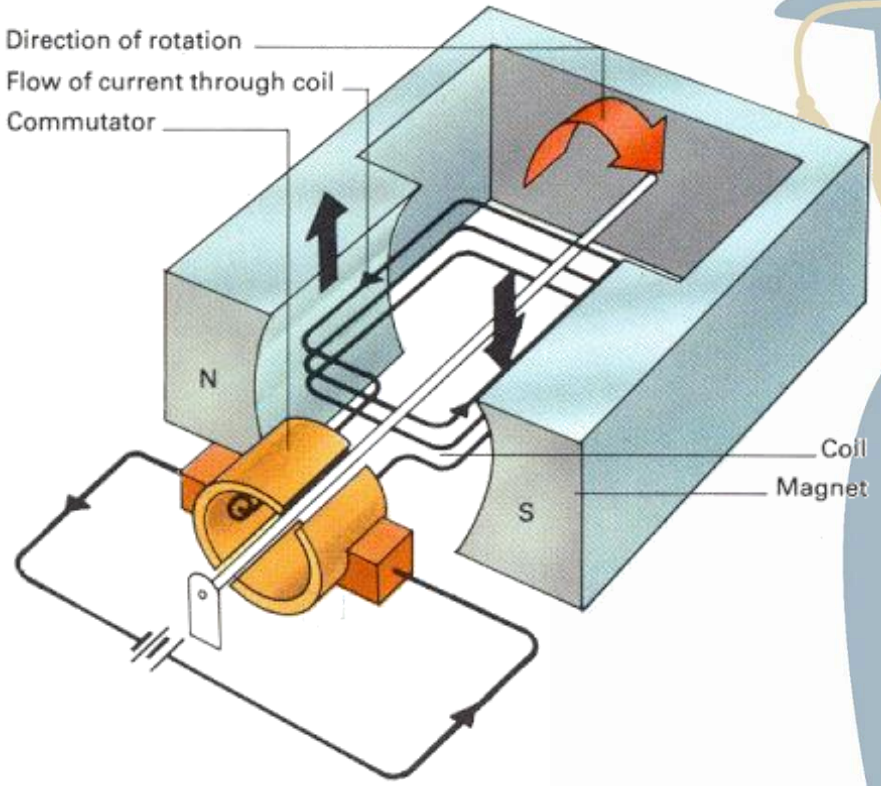
Rubbing against each of the half-rings is a graphite contact called a brush.

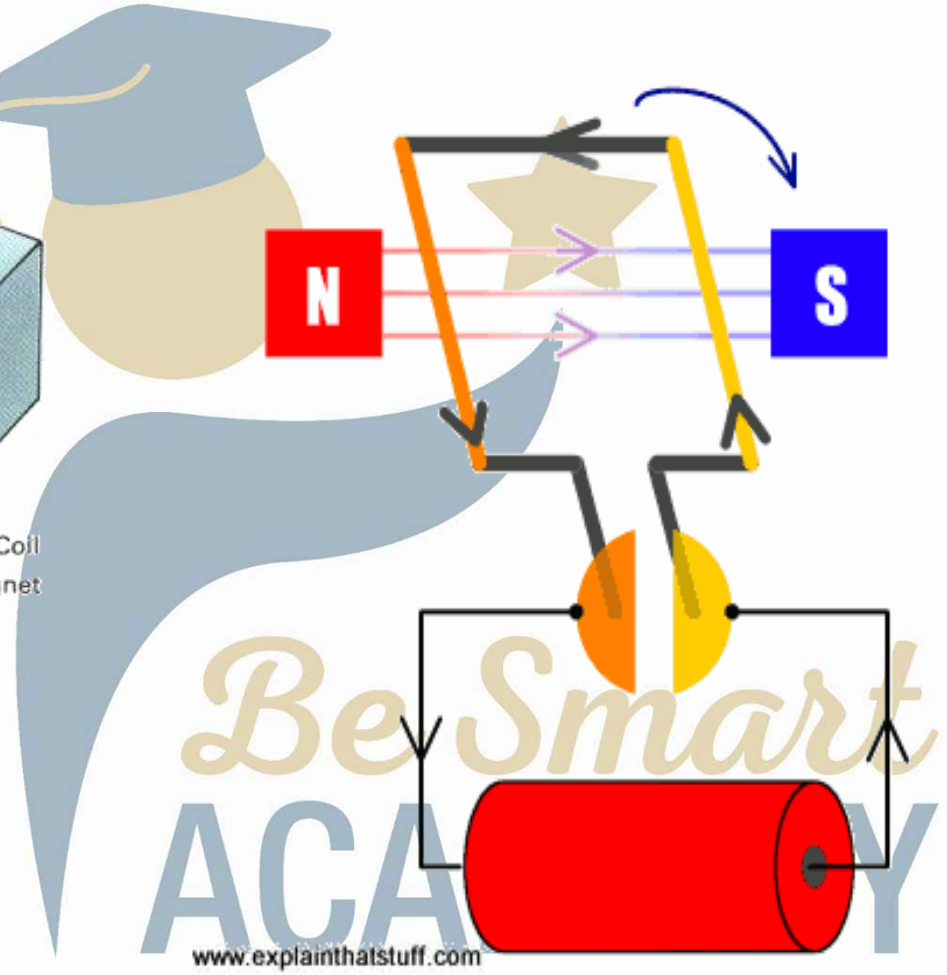
While the half-rings rotate with the coil, the graphite brushes remain stationary.

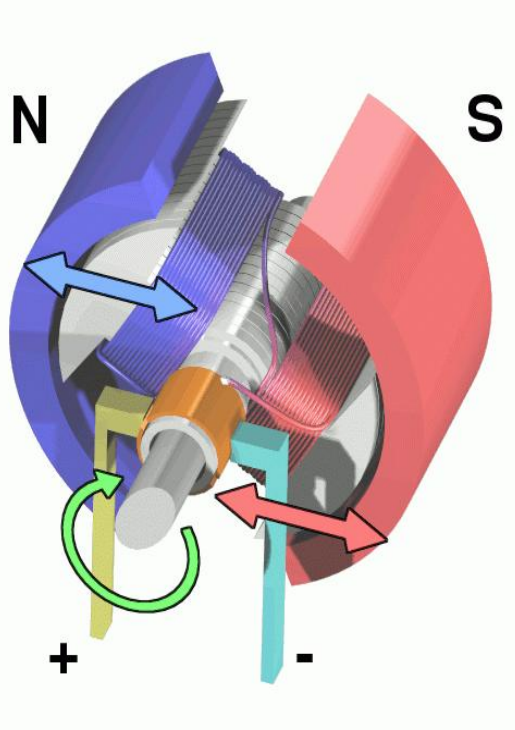


When a current exists in the coil, the coil experiences a torque rotating it in a certain direction.

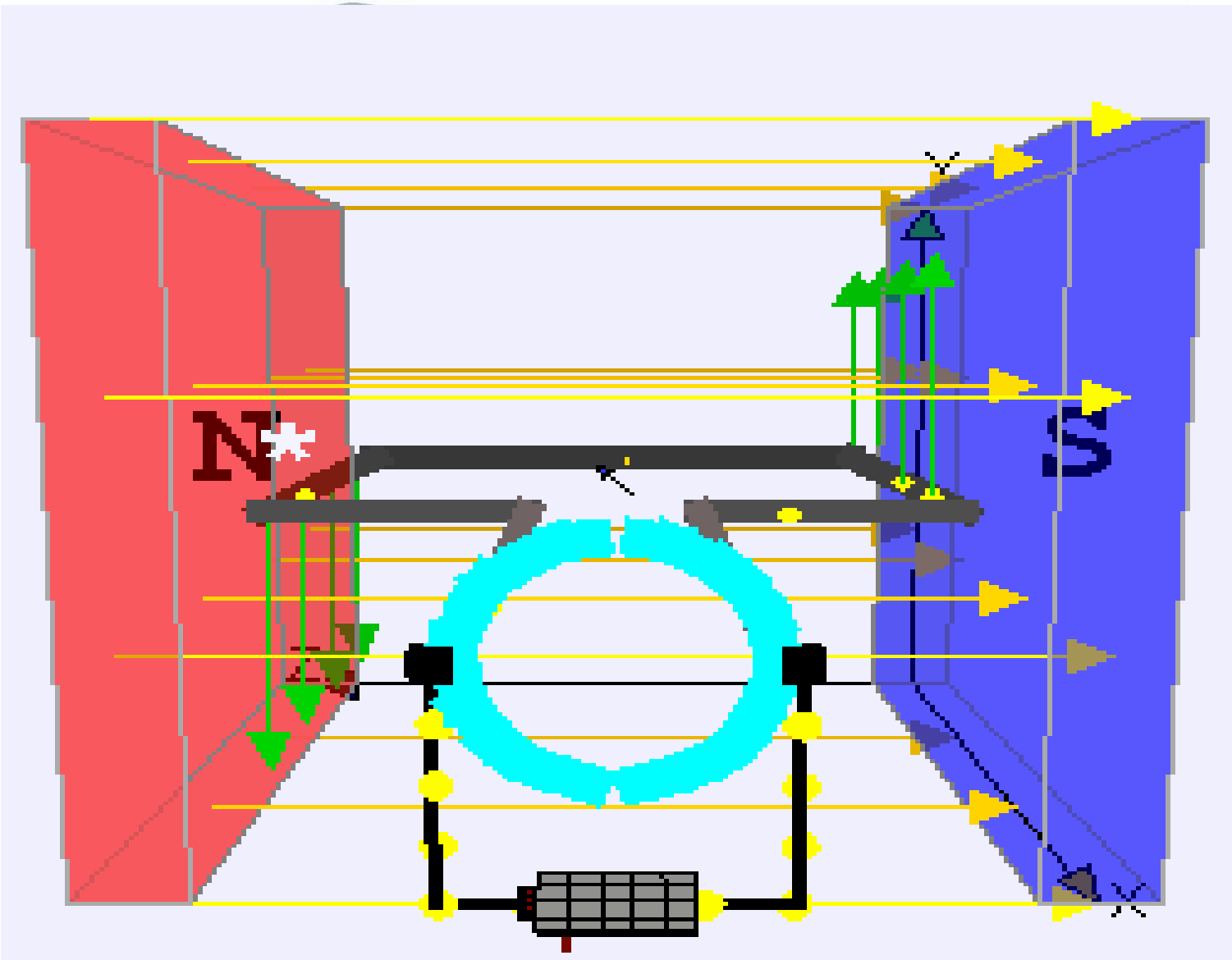
DC electric motor







DC electric motor



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