Course : Statics

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Project title: Home Experiment _ Couple force in a Magnetic field

3rd semester of Bachlor's degree

Islamic Azad University

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Required Material:

✓ two pieces of 15 cm copper wire

✓ one piece of 50 cm copper wire

✓ one strong Magnet

✓ one 1.5 v battery

✓ Tape

procedure:

1. Take one 15 cm copper wire and bend one end into an S-shape,
   Do the same with the other 15 cm wire;
   Then use these two pieces to creat a simple stand.

2. Take the 50 cm copper wire and make nine turns to form a coil.
   fix the two ends of the coil on the stand so that it can rotate freely.

3. connect the free ends of the stand to the 1.5 v battery, Make sure the contact points are clean and firmly attached.

4. place the strong Magnet near the wire coil so that the magnetic field passes trough it.

5. when the electric current flows through the wire, two equal and opposite forces appear on the two sides of the Loop.

6. These two forces form a couple, producing a net torque that causes the Loop to rotate.

Explanation:

This experiment demonstrates that a current carrying conductor in a magnetic field experiences a force.
when two forces of equal magnetide act in opposite directions along different lines of action, they creat a couple, resulting inrotational motion.

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- The characteristic of a couple force are as follows, which we were able to observe in this experiment:

✓ The two forces are equal in magnitude.

✓ The two forces act in opposite directions.

✓ The lines of action of the two forces are parallel but not coincident.

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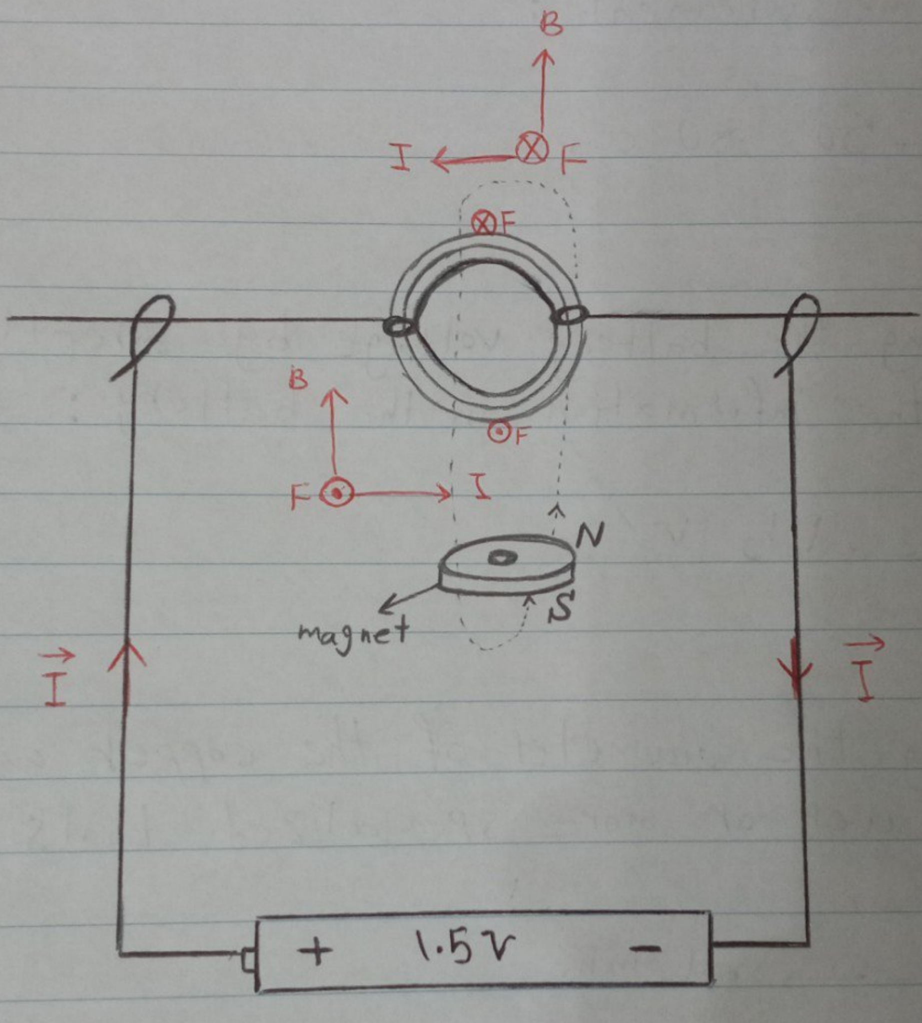
Calculation of the net torque in the constructed structure:



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Befor calculating the net torque, the following steps must be followed:

[1] Determine the total length of the wire by direct measurement:

$15 + 15 + 50 = 80$ cm

[2] calculating the battery voltage by directly reading the information on the battery:

$\longrightarrow 1.5$ V

[3] Measuring the diameter of the copper wire using a ruler or more specialized tools:

$\longrightarrow 0/1$ mm

[4] Determine the number of turns:

$\longrightarrow$ 9 turns

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5 Measure the loop radius and calculate the area:

$r = 0.5\ cm$, $A = r^2 \pi$, $A = (0.5 \times 10^{-2})^2 \cdot 3{,}14$

6 Determine the magnetic field strength by using the magnet's specifications or using a gauss meter sensor:

$\longrightarrow \simeq 0{,}05\ T$

7 Find the angle between the loops normal and the magnetic field direction:

$\longrightarrow \alpha = 90^\circ$

8 Calculate the resistance of the wire:

$\rho = 1.68 \times 10^{-8}\ \Omega.m$

$L = 8 \times 10^{-1}\ m$

$A = r^2 \pi \xrightarrow{r = 10^{-3}\ m} = 3.14 \times 10^{-6}\ m^2$

$R = \rho \frac{L}{A}$

$\longrightarrow R = 1.68 \times 10^{-8} \times \frac{0{,}8}{3.14 \times 10^{-6}}$

$R \simeq 4.3 \times 10^{-3}\ \Omega$

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[9] Find the current passing through the wire:

$$\left.\begin{aligned} V &= 1.5\,V \\ R &= 4.3 \times 10^{-3}\,\Omega \end{aligned}\right\} \longrightarrow \quad I = \frac{V}{R}$$

$$I = \frac{1.5}{4.3} \times 10^{3}$$

$$I \simeq 3.5 \times 10^{2}\,A$$

[10] calculating the magnetic moment for a coil with N turns:

$$\left.\begin{aligned} N &= 9 \\ I &\simeq 3.5 \times 10^{2}\,A \\ A &\simeq 8 \times 10^{-5}\,m^{2} \end{aligned}\right\} \longrightarrow \quad \mu = NIA$$

$$\mu = 9 \times 3.5 \times 10^{2} \times 8 \times 10^{-5}$$

$$\mu \simeq 2.5 \times 10^{-1}\,A.m^{2}$$

« Approximate values and estimations were used in the measurements and calculations »

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«Calculation of net torque»

The net torque can be calculated as follows:

$$\tau = F \times d$$

$$\tau = F\, d \sin\alpha$$

$$\downarrow$$

$$F = N I L B \sin\theta$$

$$\tau = N I L B \sin\theta \sin\alpha\, d$$

$$\begin{cases} d = 2r \\ \alpha = 90^\circ \\ \theta = 90^\circ \\ L = 2r \end{cases}$$

$$\tau = N I\, 2r\, B \sin(90) \sin(90)\, 2r$$

$$\tau = N I\, 2r\, 2r\, B$$

$$4r^2 \sim A \longrightarrow$$

$$\tau = N I A B$$

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$\underrightarrow{NIA = \mu}$

$T = \mu B$

$$\boxed{\begin{aligned} T &= \mu \times B \\ T &= \mu . B \sin\alpha \end{aligned}}$$

$$\begin{cases} \mu = 2.5\ A.m^2 \\ \alpha = 90^\circ \\ B = 5 \times 10^{-2}\ T \end{cases}$$

$T = 2,5 . 5 . 10^{-2} . \sin 90$

$T = 1.25 \times 10^{-1}\ A m^2 T \xrightarrow{T = \frac{N}{A.m}} A m^2 \frac{N}{A.m} = N.m$

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According to the following formula, the torque increases with the increase of the following factors:

$$T = NIAB \sin \alpha$$

✓ number of turns

✓ current

✓ radius of the loop

✓ magnetic field

factors that may cause the experiment to fail:

① low current due a weak battery

② weak magnetic field caused by a low-strength magnet, It is recommended to use a neodymium magnet for this experiment

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③ Poor conductivity of the wire, It is recommended to use a copper wire for this experiment.

④ At the zero position of this experiment, the loop should not be perpendicular to the direction of the magnetic field, because in this case the normal vector of the loop makes a zero degree angle with the magnetic field vector, making $\sin\theta = 0$, and therefore no torque is produced.

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