Chapter - 4 Exercise

4.1) No of turns on the circular coil, n = 100
Radius of each turn, r = 8.0 cm = 0.08 m
Current I = 0.4A

Magnitude of magnetic field, given by eq

$$|B| = \frac{\mu_0}{4\pi}\frac{2\pi n I}{r} \quad \left[\mu_0 = 4\pi \times 10^{-7}\ T m A^{-1}\right]$$

$$|B| = \frac{4\pi \times 10^{-7}}{4\pi} \times \frac{2\pi \times 100 \times 0.4}{0.08}$$

$$= 3.14 \times 10^{-4}\ T$$

(4.2) Current I = 35 A.
Distance of a point from the wire, r = 20 cm
= 0.2 m

$$\Rightarrow |B| = \frac{\mu_0}{4\pi}\frac{2I}{r} \quad \left[\mu_0 = 4\pi \times 10^{-7}\ T m A^{-1}\right]$$

$$B = \frac{4\pi \times 10^{-7} \times 2 \times 35}{4\pi \times 0.2}$$

$$= 3.5 \times 10^{-5}\ T$$

(4.3) Current in the wire I = 50 A.
A point is 2.5m away from the East of the wire
∴ Magnitude of the distance, r = 2.5m

$$\Rightarrow |B| = \frac{\mu_0 2I}{4\pi r} \quad \left[\mu_0 = 4\pi \times 10^{-7}\ T m A^{-1}\right]$$

$$B = \frac{4\pi \times 10^{-7} \times 2 \times 50}{4\pi \times 2.5}$$

$= 4\times10^{-6}$ T. The dirⁿ of current is vertically downward. According to Maxwell's right hand thumb rule, the dirⁿ of $\vec{B}$ at given point is vertically upward.

(4.4) Current in the power line, $I = 90$ A.
Point is located below the power line at distance $r = 1.5$ m

$\Rightarrow |B| = \frac{\mu_0 2I}{4\pi r}$ $[\mu_0 = 4\pi\times10^{-7}\ TmA^{-1}]$

$= \frac{4\pi\times10^{-7}\times2\times90}{4\pi\times1.5} = 1.2\times10^{-5}$ T

The current is flowing from East to West.
Hence acc to maxwell's right hand thumb rule, the dirⁿ of the $\vec{B}$ is towards the south.

(4.5) Current in the wire $= I = 8$ A.
Magnitude of uniform $\vec{B} = 0.15$ T
Angle between wire and $\vec{B} = \theta = 30°$

$\Rightarrow F = BI\sin\theta$
$\Rightarrow 0.15\times8\times1\times\sin30°$
$= 0.6\ Nm^{-1}$

Here force $= 0.6\ Nm^{-1}$

(4.6) Length of wire, $l = 3$ cm $= 0.03$ m.
Current flowing in the wire, $I = 10$ A.
$B = 0.27$ T.
Angle between current and $\vec{B} = \theta = 90°$

$\Rightarrow F = BIl \sin\theta$

$\Rightarrow 0.27 \times 10 \times 0.03 \sin 90°$

$= \underline{8.1 \times 10^{-2} N}$

(4.7) Current flowing in wire A - $I_A = 8.0A$.
Current flowing in wire B - $I_B = 5.0A$.
Distance between two wires, $r = 4.0\ cm = 0.04 m$.
Length of section of wire A - $l = 10cm = 0.1m$.

$$\Rightarrow B = \frac{\mu_0 2 I_A I_B l}{4\pi r} \quad \left[\mu_0 = 4\pi \times 10^{-7}\ TmA^{-1}\right]$$

$$\Rightarrow B = \frac{4\pi \times 10^{-7} \times 2 \times 8 \times 5 \times 0.1}{4\pi \times 0.04}$$

$= \underline{2 \times 10^{-5} N}$

There is an attraction from normal to A to B because the dir^n of the currents in the wires is the same.

(4.8) Length of solenoid, $l = 80cm = 0.8m$.
There are 5 layers of 400 turns each in solenoid.
$\therefore$ Total number of turns of the solenoid, $N = 5 \times 400 = 5000$
Diameter of solenoid, $D = 1.8cm = 0.018m$

$\Rightarrow I = 8.0A$

$$\Rightarrow |B| = \frac{\mu_0 N I}{l} = \frac{4\pi \times 10^{-7} \times 2000 \times 8}{0.8}$$

$= 8\pi \times 10^{-3} = \underline{2.512 \times 10^{-2}\ T}$

(4.9) Length of a side of the square coil: $l = 10\,cm = 0.1\,m$.
Current flowing in the coil, $I = 12\,A$.

No of turns $= n = 20$
Angle made by plane of coil $= \theta = 30^\circ$
$B = 0.80\,T$.

$\Rightarrow T = nBIA\sin\theta$ (A = Area of coil)
$\Rightarrow$ Area $= l \times l = 0.1 \times 0.1 = 0.01\,m^2$.
$\Rightarrow T = 20 \times 0.8 \times 12 \times 0.01 \times \sin 30^\circ$

$= \underline{0.96\,Nm}$

(4.10) For moving coil meter M_1:
$\Rightarrow R_1 = 10\,\Omega$
$\Rightarrow N_1 = 30$
$\Rightarrow A_1 = 3.6 \times 10^{-3}\,m^2$
$\Rightarrow B_1 = 0.25\,T$
$\Rightarrow K_1 = K$

For moving coil meter M_2
$\Rightarrow R_2 = 14\,\Omega$
$\Rightarrow N_2 = 42$
$\Rightarrow A_2 = 1.8 \times 10^{-3}\,m^2$
$\Rightarrow B_2 = 0.50\,T$
$\Rightarrow K_2 = K$

(a) $I_{s_1} = \dfrac{N_1 B_1 A_1}{K_1}$, $I_{s_2} = \dfrac{N_2 B_2 A_2}{K_2}$

$\dfrac{I_{s_2}}{I_{s_1}} = \dfrac{42 \times 0.5 \times 1.8 \times 10^{-3} \times K}{K \times 30 \times 0.25 \times 3.6 \times 10^{-3}} = \underline{1.4}$

Hence $M_2/M_1 = 1.4$

(4) $V_{s2} = \frac{N_2 B_2 A_2}{K_2 R_2}$

$\Rightarrow V_{s1} = \frac{N_1 B_1 A_1}{K_1 R_1}$

$\Rightarrow \frac{V_{s2}}{V_{s1}} = \frac{42 \times 0.5 \times 1.8 \times 10^{-3} \times 10 \times K}{K \times 14 \times 30 \times 0.25 \times 3.6 \times 10^{-3}} = 1$

Hence $M_2/M_1 = 1$ (Vatage Sensitivity)

(4.11) $B = 6.5\,G = 6.5 \times 10^{-4}\,T$

Speed of electron $= 4.8 \times 10^{6}\,m/s$

$e = 1.6 \times 10^{-19}\,C$

$m_e = 9.1 \times 10^{-31}\,kg$

Angle between shot electron and $\vec{B} = 90°$

$\Rightarrow F = evB\sin\theta$

Also centripetal force ::

$F_c = \frac{mv^2}{r}$

$F_c = F$

$\Rightarrow \frac{mv^2}{r} = evB\sin\theta$

$r = \frac{mv}{Be\sin\theta} = \frac{9.1 \times 10^{-31} \times 4.8 \times 10^{6}}{6.5 \times 10^{-4} \times 1.6 \times 10^{-19} \times \sin 90°}$

$= 4.2 \times 10^{-2}\,m = 4.2\,cm$

(4.12) $B = 6.5 \times 10^{-4}\,T$

Charge $e = 1.6 \times 10^{-19}\,C$

$m_e = 9.1 \times 10^{-31}$ Kg
Velocity of electron = 4.8×10^6 m/s
Radius of the orbit = 4.2 cm = 0.042 m
$\Rightarrow \omega = 2\pi v$.
We know
$\boxed{\Rightarrow v = r\omega}$

In circular orbit, the magnetic force on the electron is balanced by centripetal force

$\Rightarrow evB = \frac{mv^2}{r}$

$eB = m/r\,(r\omega) = m/r\,(r2\pi v)$

$\Rightarrow v = Be/2\pi m$

$\Rightarrow v = \frac{6.5 \times 10^{-4} \times 1.6 \times 10^{-19}}{2 \times 3.14 \times 9.1 \times 10^{-31}}$

$= 18.2 \times 10^6$ Hz
$= \underline{18 MHz}$

Hence frequency of $\bar{e}$ is independent of speed of it.

(4.13) No of turns, n = 30
Radius r = 8.0 cm = 0.08 m
$= \pi r^2 = \pi (0.08)^2 = 0.0201\ m^2$
Current flowing I = 6.0 A.
$\Rightarrow B \Rightarrow 1T$
Angle between field lines and normal with coil surface.
$\Rightarrow \theta = 60°$

$\Rightarrow \tau = nIBA \sin\theta$ (i)
$= 30 \times 6 \times 1 \times 0.0201 \times \sin 60^\circ$
$= 3.133 \ Nm$

(b)(i) The magnitude of τ is not dependent on the shape of coil. It depends on area.

(4.14) Radius of $X = r_1 = 16 \ cm = 0.16 \ m$
Radius of $Y = r_2 = 10 \ cm = 0.1 \ m$
$\Rightarrow n_1 = 20$
$\Rightarrow n_2 = 25$
$\Rightarrow I_1 = 16 A$
$\Rightarrow I_2 = 18 A$

$$\boxed{B = \frac{\mu_0 n I}{2r}}$$

$$\Rightarrow B_1 = \frac{4\pi \times 10^{-7} \times 20 \times 16}{2 \times 0.16}$$

$= 4\pi \times 10^{-4} T$ (towards East)

$$B_2 = \frac{4\pi \times 10^{-7} \times 25 \times 18}{2 \times 0.10}$$

$= 9\pi \times 10^{-4} T$ (towards West)

$\Rightarrow B = B_2 - B_1$
$= 9\pi \times 10^{-4} - 4\pi \times 10^{-4}$
$= 5\pi \times 10^{-4} T$
$= 1.57 \times 10^{-3} T$ (towards West)

(4.15) $B = 100 G = 100 \times 10^{-4} T$
No of turns, $n = 1000$ turns m^{-1}

$I = 15A$

$\Rightarrow B = \mu_0 n I$

$\therefore nI = B/\mu_0$

$= \frac{100 \times 10^{-4}}{4\pi \times 10^{-7}} = 7957.74$

$= 8000 \ A/m$

(4.16) Magnitude of $\vec{B}$ at a point on axis at distance x

$\Rightarrow B = \frac{\mu_0 I R^2 N}{2(x^2+R^2)^{3/2}}$

Radius $= R$

No of turns $= N$

Current $= I$

(a) If magnitude of at centre is considered, then $x = 0$

$\therefore B = \frac{\mu_0 I R^2 N}{2R^3} = \frac{\mu_0 I N}{2R}$

(b) Radii of 2 parallel co-axial coils $= R$

No of turns $= N$

Current $= I$

Distance between coils $= R$

$\rightarrow$ One coil is at a distance of $R/2 - d$ from Q

$B_2 = \frac{\mu_0 N I R^2}{2\left[\left(R/2 - d\right)^2 + R^2\right]^{3/2}}$

Total magnetic field

$B = B_1 + B_2$

$$= \frac{\mu_0 I R^2}{2}\left[\left\{\left(\frac{R}{2}-d\right)^2 + R^2\right\}^{3/2} + \left\{\left(\frac{R}{2}+d\right)^2 + R^2\right\}^{3/2}\right]$$

$$= \frac{\mu_0 I R^2}{2}\left[\left(\frac{5R^2}{4} + d^2 - Rd\right)^{3/2} + \left(\frac{5R^2}{4} + d^2 + Rd\right)^{3/2}\right]$$

$$= \frac{\mu_0 I R^2}{2} \times \left(\frac{5R^2}{4}\right)^{3/2}\left[\left(1+\frac{4d^2}{5R^2} - \frac{4}{5}\frac{d}{R}\right)^{3/2} + \left(1+\frac{4d}{5R}\right)^{3/2}\right]$$

$$\Rightarrow \frac{\mu_0 I R^2 N}{2R^3} \times \left(\frac{4}{5}\right)^{3/2}\left[1 - \frac{6d}{5R} + 1 + \frac{6d}{5R}\right]$$

$$\Rightarrow B = \left(\frac{4}{5}\right)^{3/2} \frac{\mu_0 I N}{R} = 0.72\left(\frac{\mu_0 I N}{R}\right)$$

Hence field on the axis around mid-point coils is uniform.

(4.17) Inner radius of toroid, $r_1 = 25\text{ cm} = 0.25\text{ m}$

Outer radius $r_2 = 26\text{ cm} = 0.26\text{ m}$

$N = 3500$.

Current $= I = 11\text{ A}$

(a) Magnetic field outside is 0,

(b) $B = \frac{\mu_0 N I}{l}$

$l = 2\pi\left[\frac{r_1 + r_2}{2}\right]$ (length)

$= \pi(0.25 + 0.26)$

$= 0.51\pi$

$\therefore B = \frac{4\pi \times 10^{-7} \times 3500 \times 11}{0.51\pi}$

$= \underline{3.0 \times 10^{-2} \, T}$

(c) Magnetic field in the empty space is '0'

(4.19) (a) The initial velocity of particle is either parallel or antiparallel. Hence it travels along a straight path without any deflection.

(b) Yes, the final speed of the charged particle will be equal to its speed.

(c) An electron travelling from W to E having uniform & electrostatic force. The moving $\bar{e}$ can remain undeflected if the electrostatic force acting on it is equal.

(4.20) $B = 0.75 T$

Voltage $= 15 \, KV = 15 \times 10^3 V$

$E = 9 \times 10^5 \, Vm^{-1}$

Mass of electron $= m$

Charge of electron $= e$

velocity $= v$

$K.E = eV$

$\Rightarrow \frac{1}{2} mv^2 = eV$

$= e/m = v^2/2V$ — (1)

$\therefore eE = evB$

$= v = E/B$ — (2)

putting (2) in (1)

$$e/m = \frac{1}{2}\frac{(E/B)^2}{V} = \frac{E^2}{2VB^2}$$

$$= \frac{(9.0\times10^5)^2}{2\times15000\times(0.75)^2} = \underline{4.8\times10^7\ C/kg}$$

(4.21) Length of rod $l = 0.45m$
mass suspended $= 60g = 60\times10^{-3}kg$
$\Rightarrow g = 9.8 m/s^2$
Current in the rod, $I = 5A$.

(a) $BlI = mg$
$\therefore B = mg/Il$

$$= \frac{60\times10^{-3}\times9.8}{5\times0.45} = 0.26T.$$

(B) Torque $= 0.26\times5\times0.45 + (60\times10^{-3})\times9.8$
$= \underline{1.176N}$

(4.22) $I = 300A$
Distance between wires, $r = 1.5cm = 0.015m$
$l = 70cm = 0.7m$

$$\Rightarrow F = \frac{\mu_0 I^2}{2\pi r} = \frac{4\pi\times10^{-7}\times(300)^2}{2\pi\times0.015}$$

$= 1.2N/m$

Since dirn of I is oppo, repulsion occurs.

(4.23) $B = 1.5\,T$

Radius of cylindrical, $r = 10\,cm = 0.1\,m$

Current, $I = 7A$.

(a) $l = 2r = 0.2\,m$

$\theta = 90^\circ$

$F = BIl\sin\theta$

$= 1.5 \times 7 \times 0.2 \times \sin 90^\circ = \underline{\underline{2.1\,N}}$ vertically downwards.

(b) $l_1 = l/\sin\theta$

Here $\theta = 45^\circ$

$F = BIl_1\sin\theta$

$= 1.5 \times 7 \times 0.2 = 2.1\,N$ vertically downward

(c) $l_2 = \left(\frac{l_2}{2}\right)^2 = 4(d+r)$

$= 4(10+6) = 4(16)$

$\therefore l_2 = 8 \times 2 = 16\,cm = 0.16\,m$

$\Rightarrow F_2 = BIl_2 = 1.5 \times 7 \times 0.16$

$= 1.68\,N$ vertically downward

(4.25) (a) The total torque on the coil is 0 because field is uniform.

(b) Total force on coil is zero, because field is uniform.

(c) Cross sec area of coil $= A = 10^{-5}\,m^2$

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$\Rightarrow n = 20$
$\Rightarrow r = 0.1 m$
$\Rightarrow B = 0.10 T$
$\Rightarrow$ Charge on $e^- = 1.6 \times 10^{-19} C$
$F = Bevq$

$= I / NeA$ $=$ $F = \frac{BeI}{NeA}$

$= \frac{0.10 \times 5.0}{10^{29} \times 10^{-5}} = 5 \times 10^{-25} N$

(4.27) Resistance of Galvanometer $= G = 12 \Omega$.
$I_s = 3 mA = 3 \times 10^{-3} A$.
Range of voltmeter is '0'
$\therefore V = 18 V$.
$R = V / I_s = G$

$= 18 / 3 \times 10^{-3} - 12 = 6000 - 12 = 5988 \Omega$
Hence resistance of 5988Ω is to be connected in series.

(4.28) Resistance of galvanometer $= G = 15 \Omega$
$I_s = 4 mA = 4 \times 10^{-3} A$
$\therefore$ Current, $I = 6 A$.

A shunt resistor of resistance S is to be connected in parallel.
$\Rightarrow S = \frac{I_s G}{I - I_s} = \frac{4 \times 10^{-3} \times 15}{6 - 4 \times 10^{-3}}$

$= \frac{6 \times 10^{2}}{6 - 004} = \frac{0.06}{5.996}$

$= 0.01\,\Omega = 10\,m\Omega$

Hence a $10\,m\Omega$ resistor is to be connected in parallel.

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