Magnetic effect of current

4.1) Given, $N = 100$

$r = 8\,cm = 0.08\,cm$

$I = 0.40\,A$

$\therefore B = \frac{\mu_0 N I}{2r} = \frac{4\pi \times 10^{-7} \times 100 \times 0.40}{2 \times 0.08}$

$= \pi \times 10^{-4} = 3.1 \times 10^{-4}\,T$

4.2) $I = 35A$

$r = 20\,cm = 0.20\,cm$

$\mu_0 = 4\pi \times 10^{-7}\,TmA^{-1}$

$B = \frac{\mu_0 I}{2\pi r} = \frac{4\pi \times 10^{-7} \times 35}{2\pi \times 0.20} = 3.5 \times 10^{-5}\,T$

4.6) Given, $l = 3\,cm = 0.03\,m$

$I = 10A$

$\theta = 90^\circ$

$B = 0.27\,T$

$F = IlB\sin\theta = 10 \times 0.03 \times 0.27 \times \sin 90^\circ$

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

4.7) Force per unit length of each wire is

$f = \frac{\mu_0 I_1 I_2}{2\pi r} = \frac{4\pi \times 10^{-7} \times 8 \times 5}{2\pi \times 4 \times 10^{-2}} = 2 \times 10^{-4}\,Nm^{-1}$

Force on 10cm section of wire A is

$F = fl = 2 \times 10^{-4} \times 10 \times 10^{-2} = 2 \times 10^{-5}\,N$

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4.8) Number of turn per unit length of the solenoid

$$n = \frac{\text{Number of turn per layer} \times \text{Number of layers}}{\text{length of solenoid}}$$

$$= \frac{400 \times 5}{0.80} = 2500\ m^{-1}$$

Magnetic field inside the solenoid is

$$B = \mu_0 n I = 4\pi \times 10^{-7} \times 2500 \times 8$$

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

$$= 2.5 \times 10^{-2}\ T$$

4.11) The perpendicular, ~~[illegible]~~ magnetic field excert a force on the electron perpendicular to its path. This force continuously deflects the electron from its path and make it move along a circular path.

∴ Magnetic force on the electron = centripetal force

$$ev B \sin 90° = \frac{m_e v^2}{r}$$

$$r = \frac{m_e v}{eB}$$

Now $B = 6.5 G = 6.5 \times 10^{-4}\ T$

$v = 4.8 \times 10^6\ ms^{-1}$

$$\therefore r = \frac{9.1 \times 10^{-31} \times 4.8 \cdot 10^6}{1.6 \times 10^{-19} \times 6.5 \times 10^{-4}} = 4.2 \times 10^{-2}\ m$$

$= 4.2\ cm$

4.12) Frequency of revolution of the electron in its circular orbit.

$$f = \frac{eB}{2\pi m} = \frac{1.6 \times 10^{-19} \times 6.5 \times 10^{-4}}{2 \times 3.14 \times 9.1 \times 10^{-31}}$$

$$= 18.18 \times 10^{6}\ Hz = 18\ MHz$$

No the frequency f does not depend on the speed v of the electron.

4.13) (a) $N = 30$

$r = 8\ cm = 0.08\ m$

$I = 6\ A$

$B = 1\ T$

$\theta = 60°$

Magnitude of counter torque.

= Magnitude of deflecting torque

$= NIBA \sin\theta$

$= 30 \times 6 \times 1 \times (3.14 \times 0.08 \times 0.08) \sin 60°$

$= 30 \times 6 \times 3.14 \times 64 \times 10^{-4} \times 0.866 =$

$= 3.1\ Nm$

(b) No, the answer would not change because the above formula for the torque is true for a plane loop of any shape.

4.14) $r_x = 16\ cm = 0.16\ m$

$N_x = 20,$

$I_x = 16\ A$

$\therefore$ Magnetic field at the centre of coil x is

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$$B_x = \frac{\mu_0 I_x N_x}{2r_x} = \frac{4\pi \times 10^{-7}}{2} \times \frac{16 \times 20}{0.16} \, T$$

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

As the current in the coil X is anticlockwise, the field is directed toward east.

For coil Y : $r_y = 10$ cm $= 0.10$ m

$N_x = 25$

$I = 18$ A

∴ Magnetic field at the centre of coil Y is

$$B_y = \frac{\mu_0 I_y N_y}{2r_y} = \frac{4\pi \times 10^{-7}}{2} \times \frac{18 \times 25}{0.10} \, T$$

$= 9\pi \times 10^{-4}$ T

As the current in the coil Y is clockwise, the field B_y is directed toward west. Since $B_y > B_x$ therefore, the net field in direction toward west and its magnitude is

$B = B_y - B_x = 5\pi \times 10^{-4} \simeq 1.6 \times 10^{-3}$ T

4.15) $B = 100$ G $= 10^{-2}$ T , $I = 15$A

$n = 1000$ turn m^{-1}

Magnetic field inside a solenoid,

$B = \mu_0 n I$

$$nI = \frac{B}{\mu_0} = \frac{10^{-2}}{4\pi \times 10^{-7}} = 7955 \approx 8000$$

We may take $I = 10$, then $n = 800$

The solenoid may have length 50cm and area of cross section 5×10^{-2} m^2 so as to avoid edge effects.

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4.17) $I = 11A$, total number of turns $= 3500$
Mean radius of toroid,
$r = \frac{25+26}{2} = 25.5cm = 25.5 \times 10^{-2} m$

Total length (circumference) of the toroid $= 2\pi r$
$= 2\pi \times 25.5 \times 10^{-2} = 51.0 \times 10^{-2} \pi m$
∴ Number of turn per unit length,
$n = \frac{3500}{51 \times 10^{-2} \pi}$

(a) The field outside the toroid is zero
(b) The field inside the core of the toroid

$B = \mu_0 n I = 4\pi \times 10^{-7} \times \frac{3500}{51.0 \times 10^{-2}} \times 11$
$= 3.02 \times 10^{-2} T$

(c) The field in the empty space surrounded by the toroid is also zero.

4.18) (a) The force on a charged particle moving in a magnetic field is given by
$F = qvB \sin\theta$
The force on a charged particle will be zero or the particle will remain undeflected if $\sin\theta = 0$ or $\theta = 0°, 180°$

initial velocity $\vec{v}$ is either parallel or antiparallel to $\vec{B}$

(b) Yes, a magnetic field exert force on a charged particle in a direction perpendicular to its direction of motion and hence does no work on it. so the charged particle will have its final speed equal to its initial speed.

(c) The electron travelling west to east experience a force towards north due to electrostatic field. It will remain undeflected if it experience an equal force toward south due to the magnetic field. According to Flmeing's left hand rule, the magnetic field must act in the vertically downward direction.

4.19) $V = 2\,kV = 2 \times 10^3\,V$

$B = 0.15\,T$

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

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

potential difference V impacts kinetic energy to the electron given by or velocity gaind by electron.

$v = \sqrt{\frac{2eV}{m}} = 2 \times 1.6 \times 10$

$= 2.65 \times 10^7\,ms^{-1}$

(i) when field $\vec{B}$ is transverse to the intial velocity $\vec{v}$,

$evB \sin 90^\circ = \frac{mv^2}{r}$

$\therefore r = \frac{mv}{eB} = \frac{9.1 \times 10^{-31} \times 2.65 \times 10^7}{1.6 \times 10^{-19} \times 0.15}\,m$

$\simeq 10^{-3}\,m = 1\,mm.$

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(ii) when field $\vec{B}$ make an angle of 30° to the initial velocity $\vec{v}$,

$$v_\perp = v\sin 30^\circ = 2.65\times10^7 \times \frac{1}{2} = 1.33\times 10^7 \, ms^{-1}$$

$$v_{\parallel} = v\cos30^\circ = 2.65\times10^7 \times 0.866 \times 2.3\times10^7 ms^{-1}$$

The radius of the helical path is given by

$$r = \frac{mv_\perp}{eB} = \frac{mv\sin30^\circ}{eB} = \frac{9.1\times10^{-31}\times1.33\times10^7}{1.6\times10^{-19}\times0.15}$$

$$= 50.4\times10^{-5}\,m$$

$$= 0.50\,mm$$

4.20) $B = 0.75\,T$

$E = 9.0\times10^5\, v\,m^{-1}$

$v = 15\,kv = 15\times10^3\,v$

for undeflected beam, velocity of charged particle must be

$$v = \frac{E}{B} = \frac{9.\times10^5}{0.75}\, ms^{-1} = 12\times10^5\, ms^{-1}$$

But the kinetic energy of the charge particle is given by

$$\frac{1}{2}mv^2 = qv$$

$$\frac{q}{m} = \frac{1}{2}\cdot\frac{v^2}{V^2} = \frac{1}{2}\times\frac{(12\times10^5)^2}{15\times10^3}\, C\,kg^{-1}$$

$$= 4.8\times10^7\, C\,kg^{-1}$$

Now for deutrons,

$$\frac{q}{m} = \frac{1.6 \times 10^{-19}}{2 \times 1.67}$$

$$= 4.8 \times 10^{7}\ C\,kg^{-1}$$

4.24) $B = 3000\ G = 3000 \times 4^{-4} = 0.3\ T$

$A = 10 \times 5 = 50\ cm^2 = 50 \times 10^{-4}\ m^2$

$I = 12A$

magnetic moment

$$m = IA = 12 \times 50 \times 10^{-4}$$
$$= 0.06\ Am^2$$

we apply right hand rule to various current loop to decide the direction of $\vec{m}$.

(a) Here $\vec{m} = 0.06\hat{i}\ Am^2$, $B = 0.3\hat{k}\ T$

$$\vec{\tau} = \vec{m} \times \vec{B}$$
$$= 0.06\hat{i} \times 0.3\hat{k} = -1.8 \times 10^{-2}\ Nm$$

Thus a torque of 1.8×10^{-2} Nm acts along negative Y-axis.

(b) Here $\vec{m} = 0.06\hat{i}\ Am^2$, $\vec{B} = 0.3\ T$

clearly $\vec{m}$ and $\vec{B}$ are same as in case (a) in this case also, a torque of 1.8×10^{-2} Nm act along negative Y-axis

(c) Here $\vec{m} = -0.06\hat{j}\ Am^2$, $\vec{B} = 0.3\hat{k}\ T$

$$\vec{\tau} = \vec{m} \times \vec{B}$$
$$= -0.06\hat{i} \times 0.3\hat{k} = -1.8 \times 10^{-2}\hat{i}\ Nm$$

Thus a torque of 1.8×10^{-2} N m acts along ngative x-axis.

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(d) The case is similar to case But here the direction of the torque is 60° anticlockwise with negative x-direction, 240° with positive x-direction.

(e) Here $\vec{m} = 0.006\hat{k}\ Am^2$, $\vec{B} = 0.3\hat{k}\ T$

$\therefore \vec{\tau} = \vec{m} \times \vec{B} = 0.006\hat{k} \times 0.3\hat{k} = 0$

(f) Here $\vec{m} = -0.06\hat{k}\ Am^2$, $\vec{B} = 0.3\hat{k}\ T$

$\vec{\tau} = \vec{m} \times \vec{B} = -0.06\hat{k} \times 0.3\hat{k} = 0$

The net force on the loop is zero in each cash.

4.27) $R_g = 12\Omega$

$I_g = 3mA = 3\times10^{-3} A$

$V = 18V$

$R = \frac{V}{I_g} - R_g = \frac{18}{3\times10^{-3}} - 12$

$= 6000 - 12$

$= 5988\ \Omega$

4.28) $R_g = 15\Omega$

$I_g = 4mA = 0.004 A$

$I = 16A$

$R_s = \frac{I_g}{I - I_g} \times R_g$

$= \frac{0.004}{6 - 0.004} \times 15$

$= 0.010\ \Omega$

$= 10\ m\Omega$