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DB ; 9888 PHYSICS

MOVING CHARGES AND MAGNETISM

NCERT EXCERCISES

EXERCISES

4.1 A circular coil of wire consisting of 100 turns, each of radius 8.0 cm carries a current of 0.40 A. What is the magnitude of the magnetic field **B** at the centre of the coil?

4.2 A long straight wire carries a current of 35 A. What is the magnitude of the field **B** at a point 20 cm from the wire?

4.1

No. of turns on circular coil (n) = 100.
Radius of each turn (r) = 8.0 cm = 0.08 m
Current flowing (I) = 0.4A
Magnitude of magnetic field;

$$|B| = \frac{\mu_0}{4\pi}\frac{2\pi n I}{r}$$

$$= \frac{\mu_0}{2}\frac{nI}{r}$$

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

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

∴ Answer :— 3.14×10^{-4} T.

4.2

Current in wire (I) = 35 A
Distance from a point on a wire, r = 20cm = 0.2 m
~~Magni~~

Now Magnitude of magnetic field.

$$|B| = \frac{\mu_0}{4\pi}\frac{2\pi n I}{r} = \frac{\mu_0 2I}{4\pi r} = \frac{4\pi \times 10^{-7}}{4\pi} \times \frac{2 \times 35}{0.2}$$

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

∴ Answer:- 3.5×10^{-5} T.

direction of a uniform magnetic field of 0.15 T? ... an angle of 30° with the

4.6 A 3.0 cm wire carrying a current of 10 A is placed inside a solenoid perpendicular to its axis. The magnetic field inside the solenoid is given to be 0.27 T. What is the magnetic force on the wire?

4.7 Two long and parallel straight wires A and B carrying currents of 8.0 A and 5.0 A in the same direction are separated by a distance of 4.0 cm. Estimate the force on a 10 cm section of wire A.

4.8 A closely wound solenoid 80 cm long has 5 layers of windings of 400 turns each. The diameter of the solenoid is 1.8 cm. If the current carried is 8.0 A, estimate the magnitude of **B** inside the solenoid near its centre.

4.6

A/Q length of wire (l) = 3cm or 0.03m
magnitude of current flowing (I) = 10A
strength of magnetic field (B) = 0.27T

Angle b/w I and magn — $\theta = 90°$

Now Magnetic force exerted on wire : $F = BIl\sin\theta$.

$\Rightarrow F = BIl\sin\theta$

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

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

Magnetic force on wire = 8.1×10^{-2} N.
Direction of force can be obtained from Fleming's left-hand rule.

4.7

Current flowing in wire A (I_A) = 8.0A
in wire B (I_B) = 5.0A
Distance b/w 2 wires, r = 4.0cm
= 0.04m
length of section of wire A, l = 10cm = 0.1m.
force exerted on length l due to magnetic field

$$B = \mu_0 2 I_A I_B l / 4\pi r = \frac{4\pi \times 10^{-7} \times 2 \times 8 \times 5 \times 0.1}{4\pi \times 0.04}$$

Magnitude of force $= 2 \times 10^{-5}$ N ; Attractive force normal to A towards B as direction of currents in wires is same.

4.8

Length of solenoid, $l = 80cm = 0.8m$

five layers of windings of 400 turns.

∴ Total no. of turns on solenoid.
i.e. $N = 5 \times 400 = 2000$

Diameter of solenoid, $D = 1.8cm = 0.018m$
current carried, $I = 8.0 A$.

Now Magnitude of magnetic field.

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

∴ Magnitude of magnetic field $= 8\pi \times 10^{-3} = 2.512 \times 10^{-2} T$

4.11 In a chamber, a uniform magnetic field of 6.5 G ($1\ G = 10^{-4}$ T) is maintained. An electron is shot into the field with a speed of $4.8 \times 10^6\ m\ s^{-1}$ normal to the field. Explain why the path of the electron is a circle. Determine the radius of the circular orbit. ($e = 1.5 \times 10^{-19}$ C, $m_e = 9.1 \times 10^{-31}$ kg)

4.12 In Exercise 4.11 obtain the frequency of revolution of the electron in its circular orbit. Does the answer depend on the speed of the electron? Explain.

4.13 (a) A circular coil of 30 turns and radius 8.0 cm carrying a current of 6.0 A is suspended vertically in a uniform horizontal magnetic field of magnitude 1.0 T. The field lines make an angle of 60°

with the normal of the coil. Calculate the magnitude of the counter torque that must be applied to prevent the coil from turning.

(b) Would your answer change, if the circular coil in (a) were replaced by a planar coil of some irregular shape that encloses the same area? (All other particulars are also unaltered.)

∴ Magnitude of magnetic field $= 8\pi \times 10^{-3} = 2.512 \times 10^{-2}$ T

4.11

Magnetic field strength, $B = 6.5\,G = 6.5 \times 10^{-4}$ T
Speed of electron, $v = 4.8 \times 10^{6}$ m/s.
Charge on electron, $e = 1.6 \times 10^{-19}$ C
Mass of electron, $m_e = 9.1 \times 10^{-31}$ kg.
Angle b/w shot electron and magnetic field $\theta = 90°$
Magnetic force exerted. $F = evB\sin\theta$.
Centripetal force to move e^-. Thus e^- starts moving in circular path in radius (r)
i.e $F_c = mv^2/r$; In equilibrium central force = magnetic force.
i.e $F_c = F \Rightarrow \frac{mv^2}{r} = evB\sin\theta \Rightarrow r = \frac{mv}{Be\sin\theta} = \frac{9.1 \times 10^{-31} \times 4.8 \times 10^{6}}{6.5 \times 10^{-4} \times 1.6 \times 10^{-19} \times \sin 90°}$
i.e $F_c = 4.2 \times 10^{-2}$ m $= 4.2$ m ← Radius of circular orbit.

4.12

A|Q

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

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

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

$v = 4.8 \times 10^{6}\,m/s$.

$r = 4.2\,cm = 0.042\,m$.

frequency of revolution $= \nu$.

Angular frequency $= \omega = 2\pi\nu$

Now $v = r\omega$.

Magnetic force on electron balanced by centripetal force.

$evB = mv^2/r \Rightarrow eB = \frac{m}{r}(r\omega) = \frac{m}{r}(r 2\pi\nu)$

$\Rightarrow \nu = Be/2\pi m$; independent of speed of electron

~~$\Rightarrow \nu = 6.5$~~

$\Rightarrow \nu = \dfrac{6.5 \times 10^{-4} \times 1.6 \times 10^{-19}}{2 \times 3.14 \times 9.1 \times 10^{-31}} = 18.2 \times 10^{6}\,Hz = 18\,MHz$

$\therefore$ frequency of electron $= 18\,MHz$ and independent of speed of electron

4.13

a) No. of turns, $n = 30$.
radius of coil, $r = 8.0\ cm = 0.08\ m$
Area $= \pi r^2 = \pi(0.08)^2 = 0.0201 m^2$.
current flowing $(I) = 6.0 A$
Magnetic field $B = 1 T$
Angle b/w field lines $= \theta = 60°$

Now Coil experiences torque in magnetic field thus turns
Couter torque to prevent from turning.

$$T = nIBA \sin\theta \quad ...(1)$$
$$= 30 \times 6 \times 1 \times 0.0201 \times \sin 60°$$
$$= 3.133\ Nm$$

~~b) It can be infer~~

b)

- It can be inferred from relation (i) that magnitude of applied ~~force~~ torque not dependent on shape of coil;
- Depends on area of coil.
- Thus, ~~or~~ result won't change if circular coil given ~~an~~ replaced by a planar coil of some irregular shape that encloses the same area.

ADDITIONAL EXERCISES

4.14 Two concentric circular coils X and Y of radii 16 cm and 10 cm, respectively, lie in the same vertical plane containing the north to south direction. Coil X has 20 turns and carries a current of 16 A; coil Y has 25 turns and carries a current of 18 A. The sense of the current in X is anticlockwise, and clockwise in Y, for an observer looking at the coils facing west. Give the magnitude and direction of the net magnetic field due to the coils at their centre.

4.15 A magnetic field of 100 G (1 G = 10^{-4} T) is required which is uniform in a region of linear dimension about 10 cm and area of cross-section about 10^{-3} m^2. The maximum current-carrying capacity of a given coil of wire is 15 A and the number of turns per unit length that can be wound round a core is at most 1000 turns m^{-1}. Suggest some appropriate design particulars of a solenoid for the required purpose. Assume the core is not ferromagnetic.

4.14

Coil X

$r_1 = 16cm = 0.16m$
$n_1 = 20$
$I_1 = 16A$.

Coil Y

$r_2 = 10cm = 0.1m$
$n_2 = 25$
$I_2 = 18A$.

Magnetic field due coil X at centre

$B_1 = \mu_0 n_1 I_1 / 2r_1 = 4\pi \times 10^{-7} \times 20 \times 16 / 2 \times 0.16$
$= 4\pi \times 10^{-4}\ T$ (towards East)

Magnetic field due coil Y at centre.

$B_2 = \mu_0 n_2 I_2 / 2r_2 = \frac{4\pi \times 10^{-7} \times 25 \times 18}{2 \times 0.10}$

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

∴ Net magnetic field

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

4.15

A/Q $B = 100\,G = 100 \times 10^{-4}\,T$

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

$I = 15\,A$

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

Now $B = \mu_0 n I$

$\therefore nI = B/\mu_0$

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

i.e 8000 A/m (approx)

If length of coil = 50cm, r = 4cm

n = 400 and I = 10A, then values given are not unique for the said purpose.

- There's a possibility of some adjustments with limits.

4.17

field over a small region is known as *Helmholtz coils*.]

4.17 A toroid has a core (non-ferromagnetic) of inner radius 25 cm and outer radius 26 cm, around which 3500 turns of a wire are wound. If the current in the wire is 11 A, what is the magnetic field (a) outside the toroid, (b) inside the core of the toroid, and (c) in the empty space surrounded by the toroid.

4.18 Answer the following questions:

(a) A magnetic field that varies in magnitude from point to point but has a constant direction (east to west) is set up in a chamber. A charged particle enters the chamber and travels undeflected along a straight path with constant speed. What can you say about the initial velocity of the particle?

(b) A charged particle enters an environment of a strong and non-uniform magnetic field varying from point to point both in magnitude and direction, and comes out of it following a complicated trajectory. Would its final speed equal the initial speed if it suffered no collisions with the environment?

(c) An electron travelling west to east enters a chamber having a uniform electrostatic field in north to south direction. Specify the direction in which a uniform magnetic field should be set up to prevent the electron from deflecting from its straight line path.

4.19 An electron emitted by a heated cathode and accelerated through a potential difference of 2.0 kV, enters a region with uniform magnetic field of 0.15 T. Determine the trajectory of the electron if the field (a) is transverse to its initial velocity, (b) makes an angle of 30º with the initial velocity.

4.20 A magnetic field set up using Helmholtz coils (described in Exercise 4.16) is uniform in a small region and has a magnitude of 0.75 T. In the same region, a uniform electrostatic field is maintained in a direction normal to the common axis of the coils. A narrow beam of (single species) charged particles all accelerated through 15 kV enters this region in a direction perpendicular to both the axis of the coils and the electrostatic field. If the beam remains undeflected when the electrostatic field is 9.0×10^{-5} V m^{-1}, make a simple guess as to what the beam contains. Why is the answer not unique?

4.17

Inner radius of toroid, $r_1 = 25cm = 0.25m$
Outer radius of the toroid, $r_2 = 26cm = 0.26m$
No. of turns on coil, $N = 3500$
Current in the coil, $I = 11A$

a) Magnetic field outside a toroid is zero. It is non-zero only inside the core of a toroid.

b) Magnetic field inside core of toroid; $B = \frac{\mu_0 N I}{l}$ $= 2\pi\left[\frac{r_1 + r_2}{2}\right]$
$= \pi(0.25 + 0.26) = 0.51\pi$ $\therefore B = (4\pi \times 10^{-7}) \times (3500 \times 11 / 0.51\pi) = 3.0 \times 10^{-2} T$

c) Magnetic field in the empty space surrounded by the toroid is zero.

4.18

a)

The initial velocity of the particle is either parallel or anti parallel to the magnetic field.

Hence, it travels along a straight path without suffering any deflection in the field.

b)

Yes, the final speed of the charged particle will be equal to its initial speed.

This is because magnetic force can change the direction of velocity, but not its magnitude.

c)

An electron travelling from West to East enters a chamber having uniform electrostatic field in the North - South direction. This moving electron can remain undeflected if the electric force acting on it is equal and opposite of magnetic field.

Magnetic force is directed towards the South. According to Fleming's left hand rule, magnetic field should be applied in a vertically downward direction.

4.19

A/Q Mag $B = 0.15\ T$
$e = 1.6 \times 10^{-19} C$
$m = 9.1 \times 10^{-31} kg$
$V = 2.0 kV = 2 \times 10^{3} V$

thus, kinetic energy of the electron $= eV$

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

$\Rightarrow v = \sqrt{\frac{2eV}{m}}$ ...(1)

a) Magnetic force on electron provides required centripetal force of the electron.
Hence, the electron traces a circular path of radius r.
Magnetic force on electron;
$Bev = mv^2/r$
Centripetal force
$\therefore Bev = mv^2/r \Rightarrow r = mv/Be$ — (2)
from (1) & (2)

$$r = \frac{m}{Be}\left(\frac{2eV}{m}\right)^{1/2}$$

$$= \frac{9.1 \times 10^{-31}}{0.15 \times 1.6 \times 10^{-19}} \times \left(\frac{2 \times 1.6 \times 10^{-19} \times 2 \times 10^{3}}{9.1 \times 10^{-31}}\right)^{1/2}$$

$= 100.55 \times 10^{-5}$
$= 1.01 \times 10^{-3} m = 1 mm$

Hence, electron has a circular trajectory of radius 1.0 mm normal to the magnetic field.

b)

When field makes an angle θ of 30° with initial velocity:

$r_1 = v \sin\theta$

from eq (2)

$$r_1 = mv_1/Be = mv\sin\theta/Be$$

$$= \frac{9.1\times10^{-31}}{0.15\times1.6\times10^{-19}} \times \left[\frac{2\times1.6\times10^{-19}\times2\times10^{3}}{9\times10^{-31}}\right]^{\frac{1}{2}} \times \sin 30°$$

$$= 0.5\times10^{-3}\ m$$

$$= 0.5\ mm$$

Hence, electron has a helical trajectory of radius 0.5 mm along the magnetic field direction.

4.20

Ⓢ

$B = 0.75\ T$

$V = 15kV = 15\times10^{3} V$

$E = 9\times10^{5}\ Vm^{-1}$

Mass of electron = m

Charge of electron = e

Velocity of electron = v

Kinetic energy = eV

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

$\therefore \frac{e}{m} = v^2/2V$ — (1)

∵ Particles remains undeflected by electric and magnetic fields.

∴ $eE = evB$

$v = E/B$ — (2)

Putting eq (2) in eq (1)

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

$$= \frac{(9.0\times10^{5})^2}{2\times15000\times(0.75)^2}$$

$$= 4.8\times10^{7}\ C/kg$$

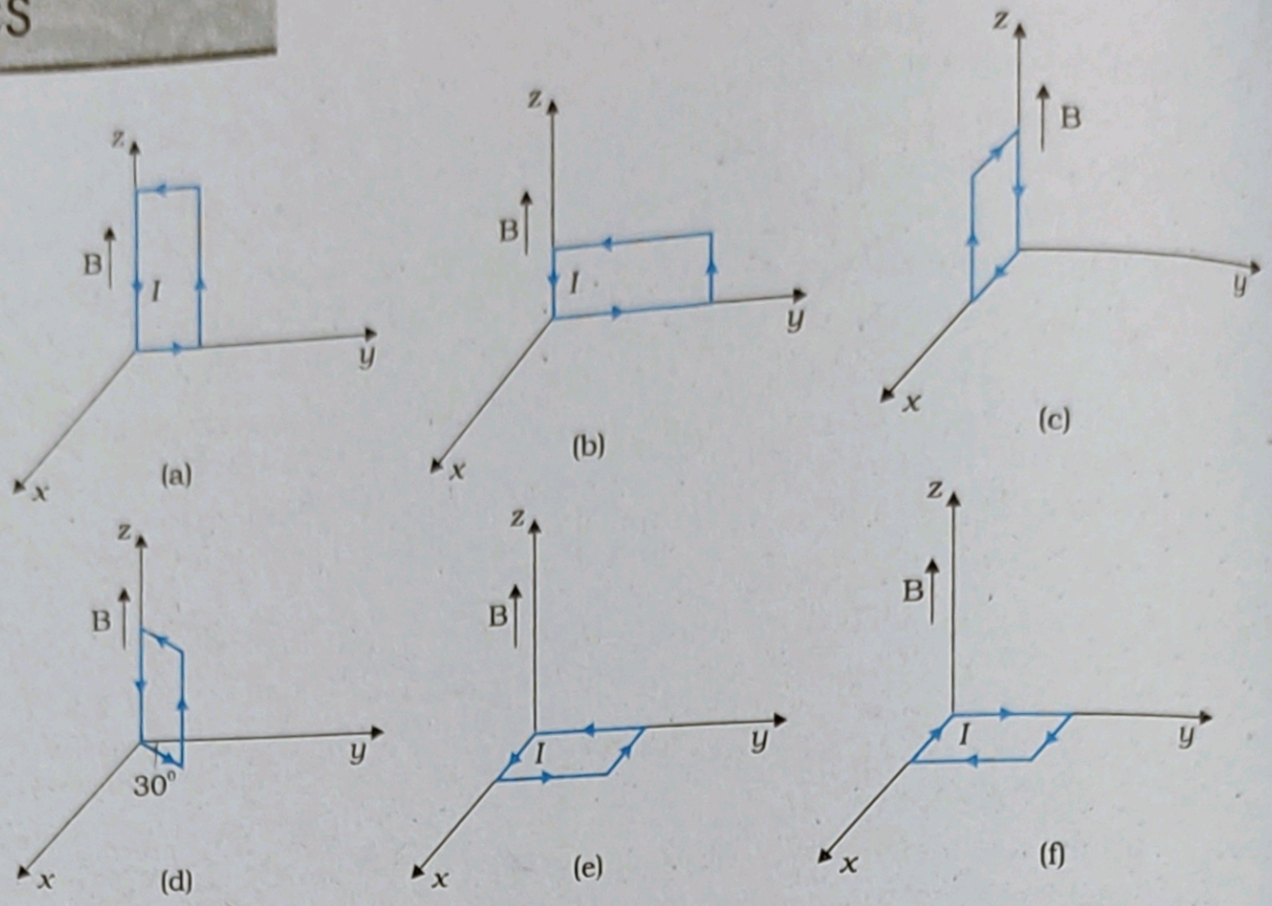
This value of specific charge e/m = value of deuteron or deuterium ions.

This is not a unique answer. Other possible answers H^{++}, Li^{++}, etc.

point
amber.
flected

of 6.0 cm?

4.24 A uniform magnetic field of 3000 G is established along the positive z-direction. A rectangular loop of sides 10 cm and 5 cm carries a current of 12 A. What is the torque on the loop in the different cases shown in Fig. 4.28? What is the force on each case? Which case corresponds to stable equilibrium?


z
B
I
y
x
(a)
z
B
I
y
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(b)
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B
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x
(c)
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B
30°
y
x
(d)
z
B
I
y
x
(e)
z
B
I
y
x
(f)

4.24

$B = 3000\,G = 3000 \times 10^{-4}\,T = 0.3\,T$

$l = 10\,cm$

$b = 5\,cm$

Area $= A = l \times b = 10 \times 5$

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

$I = 12A$

Taking anti clock wise direction of current '+ve' & vice verse.

a)

Torque $= \bar{\tau} = I\vec{A} \times \vec{B}$

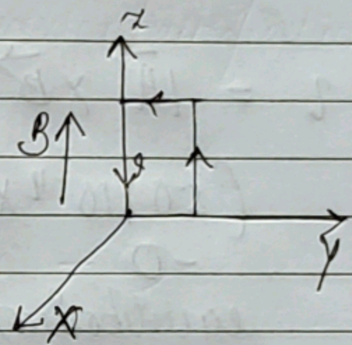
$\therefore \tau = 12 \times (50 \times 10^{-4})\hat{i} \times 0.3\hat{k}$

$= -1.8 \times 10^{-2}\,\hat{j}$ Nm.

along '-ve' y - direction

force on loop = zero (0)

as angle b/w A & B = zero



b)

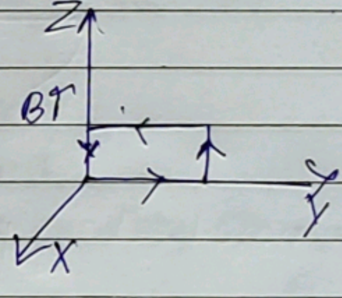
Similar case of (a)

i.e

τ along '-ve' y - direction

force on loop = (0)

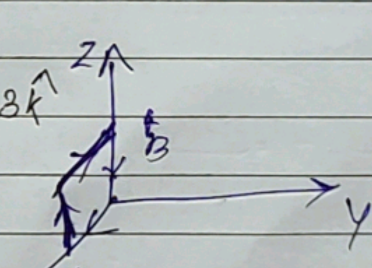
angle b/w ~~A B~~ = zero.



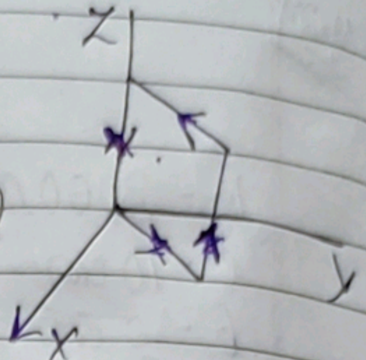
c) $\tau = I\vec{A} \times \vec{B} = -12 \times (50 \times 10^{-4})\hat{j} \times 0.3\hat{k}$

$= -1.8 \times 10^{-2}\,\hat{i}$ N m

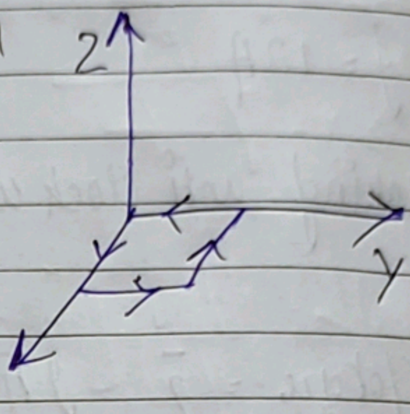
'-ve' 'x' direction; force = 0



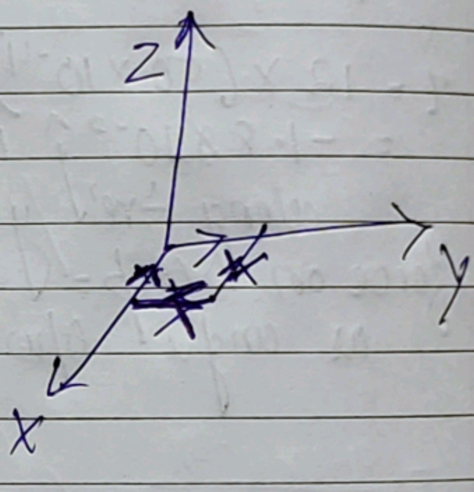
d $|\tau| = IAB$
$= 12 \times 50 \times 10^{-4} \times 0.3$
$= 1.8 \times 10^{-2}$ N m
at angle 240°, positive x direction
force = 0



e $\tau = I\vec{A} \times \vec{B} = (50 \times 10^{-4} \times 12)\hat{k} \times 0.3\hat{k}$
$= 0$
'τ' is 0. force = 0.
equilibrium stable.



f $\tau = I\vec{A} \times \vec{B}$
$(50 \times 10^{-4} \times 12)\hat{k} \times 0.3\hat{k}$
$= 0$
equilibrium unstable.



the solenoid can support the weight of the wire? $g = 9.8 \text{ m s}^{-2}$.

4.27 A galvanometer coil has a resistance of 12 Ω and the metre shows full scale deflection for a current of 3 mA. How will you convert the metre into a voltmeter of range 0 to 18 V?

4.28 A galvanometer coil has a resistance of 15 Ω and the metre shows full scale deflection for a current of 4 mA. How will you convert the metre into an ammeter of range 0 to 6 A?

4.27

Resistance galvano- $G = 12\Omega$

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

Voltmeter range = 0 converts to 18V.

$V = 18 V$.

R = Resistor in series with G

$R = (V/I_g) - G = (18/(3\times10^{-3})) - 12$.

$= 6000 - 12 = 5988\ \Omega$ (A).

4.28

$G = 15\Omega$, $I_g = 4mA = 4\times10^{-3} A$.

$I = 6A$. Range ammeter 0

Shunt resistor S, parallel with G to ammeter.

$S = I_g G / I - I_g = \frac{4\times10^{-3}\times15}{6-4\times10^{-3}}$

$\therefore S = \frac{6\times10^{-2}}{6-0.0004} = \frac{0.06}{5.996} = 0.01\ \Omega = 10m\Omega$ shunt resistor.


THANK YOU !