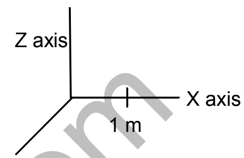
CHAPTER – 35
MAGNETIC FIELD DUE TO CURRENT

1. $F = q\vec{\upsilon} \times \vec{B}$ or, $B = \frac{F}{q\upsilon} = \frac{F}{IT\upsilon} = \frac{N}{A.sec./sec.} = \frac{N}{A-m}$

$B = \frac{\mu_0 I}{2\pi r}$ or, $\mu_0 = \frac{2\pi r B}{I} = \frac{m \times N}{A - m \times A} = \frac{N}{A^2}$

2. i = 10 A, d = 1 m



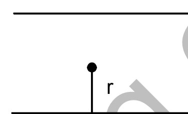
$B = \frac{\mu_0 i}{2\pi r} = \frac{10^{-7} \times 4\pi \times 10}{2\pi \times 1} = 20 \times 10^{-6}$ T = 2 μT

Along +ve Y direction.

3. d = 1.6 mm

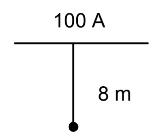
So, r = 0.8 mm = 0.0008 m

i = 20 A



$\vec{B} = \frac{\mu_0 i}{2\pi r} = \frac{4\pi \times 10^{-7} \times 20}{2 \times \pi \times 8 \times 10^{-4}} = 5 \times 10^{-3}$ T = 5 mT

4. i = 100 A, d = 8 m



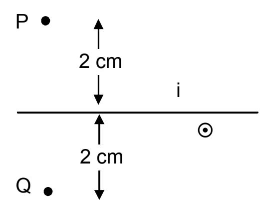
$B = \frac{\mu_0 i}{2\pi r}$

$= \frac{4\pi \times 10^{-7} \times 100}{2 \times \pi \times 8} = 2.5\ \mu$T

5. $\mu_0 = 4\pi \times 10^{-7}$ T-m/A

r = 2 cm = 0.02 m, I = 1 A, $\vec{B} = 1 \times 10^{-5}$ T

We know: Magnetic field due to a long straight wire carrying current = $\frac{\mu_0 I}{2\pi r}$



$\vec{B}$ at P = $\frac{4\pi \times 10^{-7} \times 1}{2\pi \times 0.02} = 1 \times 10^{-5}$ T upward

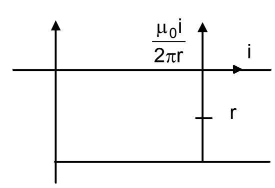
net B = 2 × 1 × 10^{-7} T = 20 μT

B at Q = 1 × 10^{-5} T downwards

Hence net $\vec{B}$ = 0

6. (a) The maximum magnetic field is $B + \frac{\mu_0 I}{2\pi r}$ which are along the left keeping the sense along the direction of traveling current.

(b)The minimum $B - \frac{\mu_0 I}{2\pi r}$

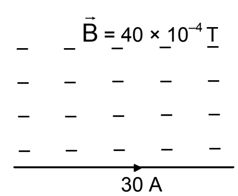


If $r = \frac{\mu_0 I}{2\pi B}$ B net = 0

$r < \frac{\mu_0 I}{2\pi B}$ B net = 0

$r > \frac{\mu_0 I}{2\pi B}$ B net = $B - \frac{\mu_0 I}{2\pi r}$

7. $\mu_0 = 4\pi \times 10^{-7}$ T-m/A, I = 30 A, B = 4.0 × 10^{-4} T Parallel to current.



$\vec{B}$ due to wore at a pt. 2 cm

$= \frac{\mu_0 I}{2\pi r} = \frac{4\pi \times 10^{-7} \times 30}{2\pi \times 0.02} = 3 \times 10^{-4}$ T

net field = $\sqrt{(3 \times 10^{-4})^2 + (4 \times 10^{-4})^2} = 5 \times 10^{-4}$ T

8. $i = 10$ A. $(\hat{K})$

$B = 2 \times 10^{-3}$ T South to North $(\hat{J})$

To cancel the magnetic field the point should be choosen so that the net magnetic field is along $-\hat{J}$ direction.

$\therefore$ The point is along $-\hat{i}$ direction or along west of the wire.

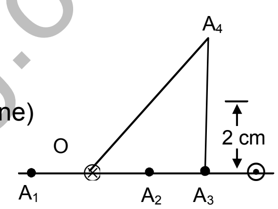
$B = \dfrac{\mu_0 I}{2\pi r}$

$\Rightarrow 2 \times 10^{-3} = \dfrac{4\pi \times 10^{-7} \times 10}{2\pi \times r}$

$\Rightarrow r = \dfrac{2 \times 10^{-7}}{2 \times 10^{-3}} = 10^{-3}$ m = 1 mm.

9. Let the tow wires be positioned at O & P

$R = OA, = \sqrt{(0.02)^2 + (0.02)^2} = \sqrt{8 \times 10^{-4}} = 2.828 \times 10^{-2}$ m



(a) $\vec{B}$ due to Q, at $A_1 = \dfrac{4\pi \times 10^{-7} \times 10}{2\pi \times 0.02} = 1 \times 10^{-4}$ T ($\perp$r towards up the line)

$\vec{B}$ due to P, at $A_1 = \dfrac{4\pi \times 10^{-7} \times 10}{2\pi \times 0.06} = 0.33 \times 10^{-4}$ T ($\perp$r towards down the line)

net $\vec{B} = 1 \times 10^{-4} - 0.33 \times 10^{-4} = 0.67 \times 10^{-4}$ T

(b) $\vec{B}$ due to O at $A_2 = \dfrac{2 \times 10^{-7} \times 10}{0.01} = 2 \times 10^{-4}$ T $\perp$r down the line

$\vec{B}$ due to P at $A_2 = \dfrac{2 \times 10^{-7} \times 10}{0.03} = 0.67 \times 10^{-4}$ T $\perp$r down the line

net $\vec{B}$ at $A_2 = 2 \times 10^{-4} + 0.67 \times 10^{-4} = 2.67 \times 10^{-4}$ T

(c) $\vec{B}$ at A_3 due to O $= 1 \times 10^{-4}$ T $\perp$r towards down the line

$\vec{B}$ at A_3 due to P $= 1 \times 10^{-4}$ T $\perp$r towards down the line

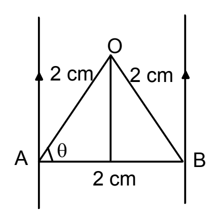
Net $\vec{B}$ at $A_3 = 2 \times 10^{-4}$ T

(d) $\vec{B}$ at A_4 due to O $= \dfrac{2 \times 10^{-7} \times 10}{2.828 \times 10^{-2}} = 0.7 \times 10^{-4}$ T towards SE

$\vec{B}$ at A_4 due to P $= 0.7 \times 10^{-4}$ T towards SW

Net $\vec{B} = \sqrt{\left(0.7 \times 10^{-4}\right)^2 + \left(0.7 \times 10^{-4}\right)^2} = 0.989 \times 10^{-4} \approx 1 \times 10^{-4}$ T

10. $\cos\theta = ½$, $\theta = 60°$ & $\angle AOB = 60°$



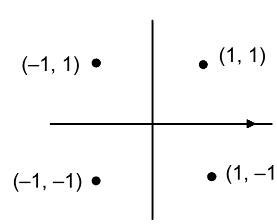
$B = \dfrac{\mu_0 I}{2\pi r} = \dfrac{10^{-7} \times 2 \times 10}{2 \times 10^{-2}} = 10^{-4}$ T

So net is $[(10^{-4})^2 + (10^{-4})^2 + 2(10^{-8}) \cos 60°]^{1/2}$

$= 10^{-4}[1 + 1 + 2 \times ½]^{1/2} = 10^{-4} \times \sqrt{3}$ T $= 1.732 \times 10^{-4}$ T

11. (a) $\vec{B}$ for X = $\vec{B}$ for Y

Both are oppositely directed hence net $\vec{B} = 0$



(b) $\vec{B}$ due to X = $\vec{B}$ due to X both directed along Z–axis

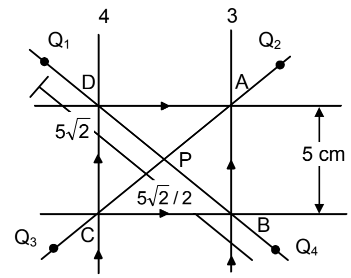
Net $\vec{B} = \dfrac{2 \times 10^{-7} \times 2 \times 5}{1} = 2 \times 10^{-6}$ T = 2 μT

(c) $\vec{B}$ due to X = $\vec{B}$ due to Y both directed opposite to each other.

Hence Net $\vec{B} = 0$

(d) $\vec{B}$ due to X = $\vec{B}$ due to Y $= 1 \times 10^{-6}$ T both directed along (–) ve Z–axis

Hence Net $\vec{B} = 2 \times 1.0 \times 10^{-6} = 2$ μT



12. (a) For each of the wire

Magnitude of magnetic field

$= \frac{\mu_0 i}{4\pi r}(\text{Sin}45° + \text{Sin}45°) = \frac{\mu_0 \times 5}{4\pi \times (5/2)}\frac{2}{\sqrt{2}}$

For AB $\odot$ for BC $\odot$ For CD $\otimes$ and for DA $\otimes$.

The two $\odot$ and $2\otimes$ fields cancel each other. Thus $B_{net} = 0$

(b) At point Q_1

due to (1) $B = \frac{\mu_0 i}{2\pi \times 2.5 \times 10^{-2}} = \frac{4\pi \times 5 \times 2 \times 10^{-7}}{2\pi \times 5 \times 10^{-2}} = 4 \times 10^{-5}$ $\odot$

due to (2) $B = \frac{\mu_0 i}{2\pi \times (15/2) \times 10^{-2}} = \frac{4\pi \times 5 \times 2 \times 10^{-7}}{2\pi \times 15 \times 10^{-2}} = (4/3) \times 10^{-5}$ $\odot$

due to (3) $B = \frac{\mu_0 i}{2\pi \times (5 + 5/2) \times 10^{-2}} = \frac{4\pi \times 5 \times 2 \times 10^{-7}}{2\pi \times 15 \times 10^{-2}} = (4/3) \times 10^{-5}$ $\odot$

due to (4) $B = \frac{\mu_0 i}{2\pi \times 2.5 \times 10^{-2}} = \frac{4\pi \times 5 \times 2 \times 10^{-7}}{2\pi \times 5 \times 10^{-2}} = 4 \times 10^{-5}$ $\odot$

$B_{net} = [4 + 4 + (4/3) + (4/3)] \times 10^{-5} = \frac{32}{3} \times 10^{-5} = 10.6 \times 10^{-5} \approx 1.1 \times 10^{-4}$ T

At point Q_2

due to (1) $\frac{\mu_o i}{2\pi \times (2.5) \times 10^{-2}}$ $\odot$

due to (2) $\frac{\mu_o i}{2\pi \times (15/2) \times 10^{-2}}$ $\odot$

due to (3) $\frac{\mu_o i}{2\pi \times (2.5) \times 10^{-2}}$ $\otimes$

due to (4) $\frac{\mu_o i}{2\pi \times (15/2) \times 10^{-2}}$ $\otimes$

$B_{net} = 0$

At point Q_3

due to (1) $\frac{4\pi \times 10^{-7} \times 5}{2\pi \times (15/2) \times 10^{-2}} = 4/3 \times 10^{-5}$ $\otimes$

due to (2) $\frac{4\pi \times 10^{-7} \times 5}{2\pi \times (5/2) \times 10^{-2}} = 4 \times 10^{-5}$ $\otimes$

due to (3) $\frac{4\pi \times 10^{-7} \times 5}{2\pi \times (5/2) \times 10^{-2}} = 4 \times 10^{-5}$ $\otimes$

due to (4) $\frac{4\pi \times 10^{-7} \times 5}{2\pi \times (15/2) \times 10^{-2}} = 4/3 \times 10^{-5}$ $\otimes$

$B_{net} = [4 + 4 + (4/3) + (4/3)] \times 10^{-5} = \frac{32}{3} \times 10^{-5} = 10.6 \times 10^{-5} \approx 1.1 \times 10^{-4}$ T

For Q_4

due to (1) $4/3 \times 10^{-5}$ $\otimes$

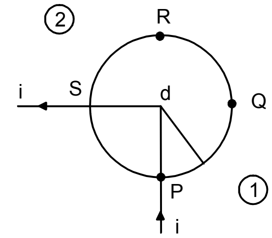
due to (2) 4×10^{-5} $\otimes$

due to (3) $4/3 \times 10^{-5}$ $\otimes$

due to (4) 4×10^{-5} $\otimes$

$B_{net} = 0$

13. Since all the points lie along a circle with radius = ‘d’
Hence ‘R’ & ‘Q’ both at a distance ‘d’ from the wire.
So, magnetic field $\vec{B}$ due to are same in magnitude.
As the wires can be treated as semi infinite straight current carrying conductors. Hence magnetic field $\vec{B} = \frac{\pi_0 i}{4\pi d}$



At P

B_1 due to 1 is 0

B_2 due to 2 is $\frac{\pi_0 i}{4\pi d}$

At Q

B_1 due to 1 is $\frac{\pi_0 i}{4\pi d}$

B_2 due to 2 is 0

At R

B_1 due to 1 is 0

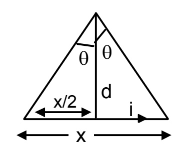
B_2 due to 2 is $\frac{\pi_0 i}{4\pi d}$

At S

B_1 due to 1 is $\frac{\pi_0 i}{4\pi d}$

B_2 due to 2 is 0

14. $B = \frac{\pi_0 i}{4\pi d}\ 2 \text{ Sin } \theta$



$$= \frac{\pi_0 i}{4\pi d} \frac{2 \times x}{2 \times \sqrt{d^2 + \frac{x^2}{4}}} = \frac{\mu_0 i x}{4\pi d\sqrt{d^2 + \frac{x^2}{4}}}$$

(a) When d >> x

Neglecting x w.r.t. d

$$B = \frac{\mu_0 i x}{\mu \pi d\sqrt{d^2}} = \frac{\mu_0 i x}{\mu \pi d^2}$$

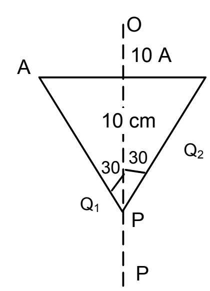
$$\therefore B \propto \frac{1}{d^2}$$

(b) When x >> d, neglecting d w.r.t. x

$$B = \frac{\mu_0 i x}{4\pi d x/2} = \frac{2\mu_0 i}{4\pi d}$$

$$\therefore B \propto \frac{1}{d}$$

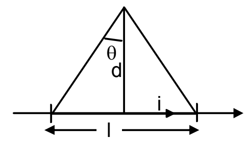
15. I = 10 A, a = 10 cm = 0.1 m



$$r = OP = \frac{\sqrt{3}}{2} \times 0.1 \text{ m}$$

$$B = \frac{\mu_0 I}{4\pi r}(\text{Sin}\phi_1 + \text{Sin}\phi_2)$$

$$= \frac{10^{-7} \times 10 \times 1}{\frac{\sqrt{3}}{2} \times 0.1} = \frac{2 \times 10^{-5}}{1.732} = 1.154 \times 10^{-5} \text{ T} = 11.54\ \mu\text{T}$$



16. $B_1 = \dfrac{\mu_0 i}{2\pi d}$, $\quad B_2 = \dfrac{\mu_0 i}{4\pi d}(2 \times \text{Sin}\theta) = \dfrac{\mu_0 i}{4\pi d}\dfrac{2 \times \ell}{2\sqrt{d^2 + \dfrac{\ell^2}{4}}} = \dfrac{\mu_0 i \ell}{4\pi d\sqrt{d^2 + \dfrac{\ell^2}{4}}}$

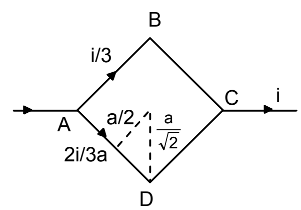
$$B_1 - B_2 = \frac{1}{100} B_2 \Rightarrow \frac{\mu_0 i}{2\pi d} - \frac{\mu_0 i \ell}{4\pi d\sqrt{d^2 + \dfrac{\ell^2}{4}}} = \frac{\mu_0 i}{200\pi d}$$

$$\Rightarrow \frac{\mu_0 i \ell}{4\pi d\sqrt{d^2 + \dfrac{\ell^2}{4}}} = \frac{\mu_0 i}{\pi d}\left(\frac{1}{2} - \frac{1}{200}\right)$$

$$\Rightarrow \frac{\ell}{4\sqrt{d^2 + \dfrac{\ell^2}{4}}} = \frac{99}{200} \qquad \Rightarrow \frac{\ell^2}{d^2 + \dfrac{\ell^2}{4}} = \left(\frac{99 \times 4}{200}\right)^2 = \frac{156816}{40000} = 3.92$$

$$\Rightarrow \ell^2 = 3.92\, d^2 + \frac{3.92}{4}\ell^2$$

$$\left(\frac{1 - 3.92}{4}\right)\ell^2 = 3.92\, d^2 \Rightarrow 0.02\, \ell^2 = 3.92\, d^2 \Rightarrow \frac{d^2}{\ell^2} = \frac{0.02}{3.92} = \frac{d}{\ell} = \sqrt{\frac{0.02}{3.92}} = 0.07$$



17. As resistances vary as r & 2r

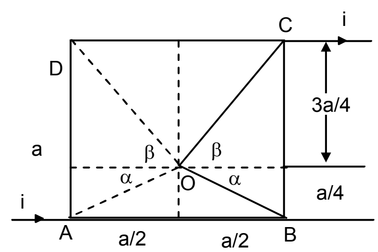
Hence Current along ABC = $\dfrac{i}{3}$ & along ADC = $\dfrac{2}{3i}$

Now,

$$\vec{B} \text{ due to ADC} = 2\left[\frac{\mu_0 i \times 2 \times 2 \times \sqrt{2}}{4\pi 3a}\right] = \frac{2\sqrt{2}\mu_0 i}{3\pi a}$$

$$\vec{B} \text{ due to ABC} = 2\left[\frac{\mu_0 i \times 2 \times \sqrt{2}}{4\pi 3a}\right] = \frac{2\sqrt{2}\mu_0 i}{6\pi a}$$

$$\text{Now } \vec{B} = \frac{2\sqrt{2}\mu_0 i}{3\pi a} - \frac{2\sqrt{2}\mu_0 i}{6\pi a} = \frac{\sqrt{2}\mu_0 i}{3\pi a} \otimes$$



18. $A_0 = \sqrt{\dfrac{a^2}{16} + \dfrac{a^2}{4}} = \sqrt{\dfrac{5a^2}{16}} = \dfrac{a\sqrt{5}}{4}$

$$D_0 = \sqrt{\left(\frac{3a}{4}\right)^2 + \left(\frac{a}{2}\right)^2} = \sqrt{\frac{9a^2}{16} + \frac{a^2}{4}} = \sqrt{\frac{13a^2}{16}} = \frac{a\sqrt{13}}{4}$$

Magnetic field due to AB

$$B_{AB} = \frac{\mu_0}{4\pi} \times \frac{i}{2(a/4)}(\text{Sin }(90 - i) + \text{Sin }(90 - \alpha))$$

$$= \frac{\mu_0 \times 2i}{4\pi a} 2\text{Cos}\alpha = \frac{\mu_0 \times 2i}{4\pi a} \times 2 \times \frac{(a/2)}{a(\sqrt{5}/4)} = \frac{2\mu_0 i}{\pi\sqrt{5}}$$

Magnetic field due to DC

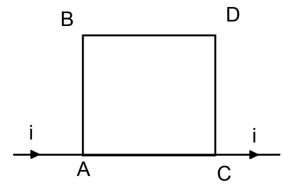
$$B_{DC} = \frac{\mu_0}{4\pi} \times \frac{i}{2(3a/4)} 2\text{Sin }(90° - B)$$

$$= \frac{\mu_0 i \times 4 \times 2}{4\pi \times 3a}\text{Cos}\beta = \frac{\mu_0 i}{\pi \times 3a} \times \frac{(a/2)}{(\sqrt{13a}/4)} = \frac{2\mu_0 i}{\pi a 3\sqrt{13}}$$

The magnetic field due to AD & BC are equal and appropriate hence cancle each other.

$$\text{Hence, net magnetic field is } \frac{2\mu_0 i}{\pi\sqrt{5}} - \frac{2\mu_0 i}{\pi a 3\sqrt{13}} = \frac{2\mu_0 i}{\pi a}\left[\frac{1}{\sqrt{5}} - \frac{1}{3\sqrt{13}}\right]$$

19. $\vec{B}$ due t BC &
$\vec{B}$ due to AD at Pt 'P' are equal ore Opposite
Hence net $\vec{B}$ = 0
Similarly, due to AB & CD at P = 0
$\therefore$ The net $\vec{B}$ at the Centre of the square loop = zero.



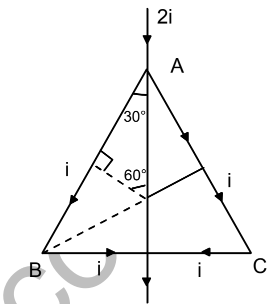
20. For AB B is along $\odot$ $B = \frac{\mu_0 i}{4\pi r}(\text{Sin}60° + \text{Sin}60°)$

For AC B $\otimes$ $B = \frac{\mu_0 i}{4\pi r}(\text{Sin}60° + \text{Sin}60°)$

For BD B $\odot$ $B = \frac{\mu_0 i}{4\pi r}(\text{Sin}60°)$

For DC B $\otimes$ $B = \frac{\mu_0 i}{4\pi r}(\text{Sin}60°)$

$\therefore$ Net B = 0

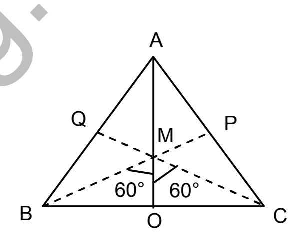


21. (a) ΔABC is Equilateral
AB = BC = CA = $\ell/3$
Current = i

$AO = \frac{\sqrt{3}}{2}a = \frac{\sqrt{3}\times\ell}{2\times 3} = \frac{\ell}{2\sqrt{3}}$

$\phi_1 = \phi_2 = 60°$

So, $MO = \frac{\ell}{6\sqrt{3}}$ as AM : MO = 2 : 1



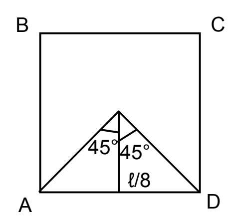
$\vec{B}$ due to BC at <.

$= \frac{\mu_0 i}{4\pi r}(\text{Sin}\phi_1 + \text{Sin}\phi_2) = \frac{\mu_0 i}{4\pi}\times i \times 6\sqrt{3}\times\sqrt{3} = \frac{\mu_0 i\times 9}{2\pi\ell}$

net $\vec{B} = \frac{9\mu_0 i}{2\pi\ell}\times 3 = \frac{27\mu_0 i}{2\pi\ell}$

(b) $\vec{B}$ due to AD = $\frac{\mu_0 i\times 8}{4\pi\times\ell}\sqrt{2} = \frac{8\sqrt{2}\mu_0 i}{4\pi\ell}$

Net $\vec{B} = \frac{8\sqrt{2}\mu_0 i}{4\pi\ell}\times 4 = \frac{8\sqrt{2}\mu_0 i}{\pi\ell}$



22. $\text{Sin}(\alpha/2) = \frac{r}{x}$

$\Rightarrow r = x\,\text{Sin}(\alpha/2)$

Magnetic field B due to AR

$\frac{\mu_0 i}{4\pi r}[\text{Sin}(180 - (90 - (\alpha/2))) + 1]$

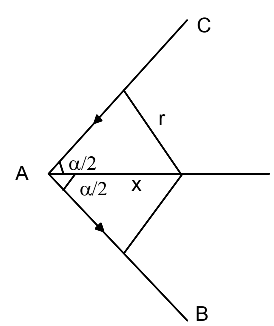
$\Rightarrow \frac{\mu_0 i[\text{Sin}(90 - (\alpha/2)) + 1]}{4\pi\times\text{Sin}(\alpha/2)}$

$= \frac{\mu_0 i(\text{Cos}(\alpha/2) + 1)}{4\pi\times\text{Sin}(\alpha/2)}$

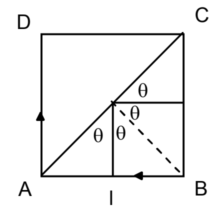
$= \frac{\mu_0 i 2\text{Cos}^4(\alpha/4)}{4\pi\times 2\text{Sin}(\alpha/4)\text{Cos}(\alpha/4)} = \frac{\mu_0 i}{4\pi x}\text{Cot}(\alpha/4)$

The magnetic field due to both the wire.

$\frac{2\mu_0 i}{4\pi x}\text{Cot}(\alpha/4) = \frac{\mu_0 i}{2\pi x}\text{Cot}(\alpha/4)$



23. $\vec{B}AB$



$$\frac{\mu_0 i \times 2}{4\pi b} \times 2\text{Sin}\theta = \frac{\mu_0 i\text{Sin}\theta}{\pi b}$$

$$= \frac{\mu_0 i\ell}{\pi b\sqrt{\ell^2 + b^2}} = \vec{B}DC \qquad \therefore \text{Sin }(\ell^2 + b) = \frac{(\ell/2)}{\sqrt{\ell^2/4 + b^2/4}} = \frac{\ell}{\sqrt{\ell^2 + b^2}}$$

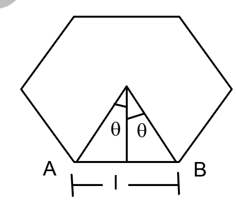
$\vec{B}BC$

$$\frac{\mu_0 i \times 2}{4\pi\ell} \times 2 \times 2\text{Sin}\theta' = \frac{\mu_0 i\text{Sin}\theta'}{\pi\ell} \qquad \therefore \text{Sin }\theta' = \frac{(b/2)}{\sqrt{\ell^2/4 + b^2/4}} = \frac{b}{\sqrt{\ell^2 + b^2}}$$

$$= \frac{\mu_0 ib}{\pi\ell\sqrt{\ell^2 + b^2}} = \vec{B}AD$$

$$\text{Net } \vec{B} = \frac{2\mu_0 i\ell}{\pi b\sqrt{\ell^2 + b^2}} + \frac{2\mu_0 ib}{\pi\ell\sqrt{\ell^2 + b^2}} = \frac{2\mu_0 i(\ell^2 + b^2)}{\pi\ell b\sqrt{\ell^2 + b^2}} = \frac{2\mu_0 i\sqrt{\ell^2 + b^2}}{\pi\ell b}$$

24. $2\theta = \frac{2\pi}{n} \Rightarrow \theta = \frac{\pi}{n}$, $\qquad \ell = \frac{2\pi r}{n}$



$$\text{Tan }\theta = \frac{\ell}{2x} \Rightarrow x = \frac{\ell}{2\text{Tan}\theta}$$

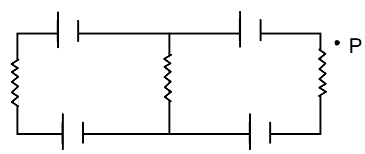
$$\frac{\ell}{2} = \frac{\pi r}{n}$$

$$B_{AB} = \frac{\mu_0 i}{4\pi(x)}(\text{Sin}\theta + \text{Sin}\theta) = \frac{\mu_0 i 2\text{Tan}\theta \times 2\text{Sin}\theta}{4\pi\ell}$$

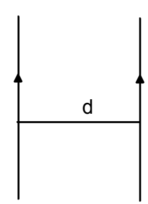
$$= \frac{\mu_0 i 2\text{Tan}(\pi/n)2\text{Sin}(\pi/n)n}{4\pi 2\pi r} = \frac{\mu_0 in\text{Tan}(\pi/n)\text{Sin}(\pi/n)}{2\pi^2 r}$$

For n sides, $B_{net} = \frac{\mu_0 in\text{Tan}(\pi/n)\text{Sin}(\pi/n)}{2\pi^2 r}$

25. Net current in circuit = 0
Hence the magnetic field at point P = 0
[Owing to wheat stone bridge principle]



26. Force acting on 10 cm of wire is 2×10^{-5} N



$$\frac{dF}{dl} = \frac{\mu_0 i_1 i_2}{2\pi d}$$

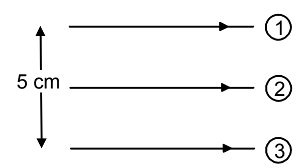
$$\Rightarrow \frac{2 \times 10^{-5}}{10 \times 10^{-2}} = \frac{\mu_0 \times 20 \times 20}{2\pi d}$$

$$\Rightarrow d = \frac{4\pi \times 10^{-7} \times 20 \times 20 \times 10 \times 10^{-2}}{2\pi \times 2 \times 10^{-5}} = 400 \times 10^{-3} = 0.4 \text{ m} = 40 \text{ cm}$$

27. i = 10 A
Magnetic force due to two parallel Current Carrying wires.

$$F = \frac{\mu_0 I_1 I_2}{2\pi r}$$

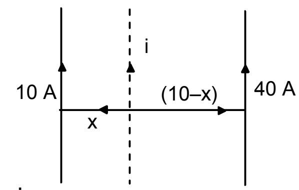
So, $\vec{F}$ or 1 = $\vec{F}$ by 2 + $\vec{F}$ by 3



$$= \frac{\mu_0 \times 10 \times 10}{2\pi \times 5 \times 10^{-2}} + \frac{\mu_0 \times 10 \times 10}{2\pi \times 10 \times 10^{-2}}$$

$$= \frac{4\pi \times 10^{-7} \times 10 \times 10}{2\pi \times 5 \times 10^{-2}} + \frac{4\pi \times 10^{-7} \times 10 \times 10}{2\pi \times 10 \times 10^{-2}}$$

$$= \frac{2 \times 10^{-3}}{5} + \frac{10^{-3}}{5} = \frac{3 \times 10^{-3}}{5} = 6 \times 10^{-4} \text{ N} \quad \text{towards middle wire}$$

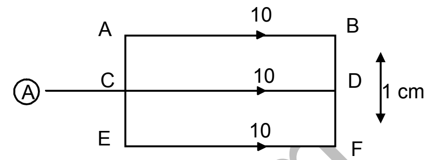


28. $\frac{\mu_0 10i}{2\pi x} = \frac{\mu_0 i40}{2\pi(10-x)}$

$\Rightarrow \frac{10}{x} = \frac{40}{10-x} \Rightarrow \frac{1}{x} = \frac{4}{10-x}$

$\Rightarrow 10 - x = 4x \Rightarrow 5x = 10 \Rightarrow x = 2$ cm

The third wire should be placed 2 cm from the 10 A wire and 8 cm from 40 A wire.



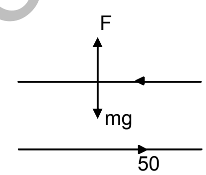
29. $F_{AB} = F_{CD} + F_{EF}$

$= \frac{\mu_0 \times 10 \times 10}{2\pi \times 1 \times 10^{-2}} + \frac{\mu_0 \times 10 \times 10}{2\pi \times 2 \times 10^{-2}}$

$= 2\times 10^{-3} + 10^{-3} = 3 \times 10^{-3}$ downward.

$F_{CD} = F_{AB} + F_{EF}$

As F_{AB} & F_{EF} are equal and oppositely directed hence F = 0



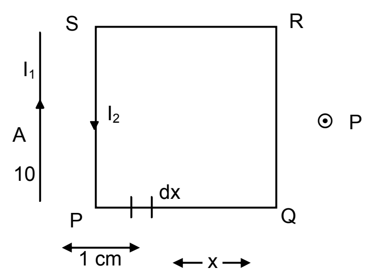
30. $\frac{\mu_0 i_1 i_2}{2\pi d}$ = mg (For a portion of wire of length 1m)

$\Rightarrow \frac{\mu_0 \times 50 \times i_2}{2\pi \times 5 \times 10^{-3}} = 1 \times 10^{-4} \times 9.8$

$\Rightarrow \frac{4\pi \times 10^{-7} \times 5 \times i_2}{2\pi \times 5 \times 10^{-3}} = 9.8 \times 10^{-4}$

$\Rightarrow 2 \times i_2 \times 10^{-3} = 9.3 \times 10^{-3} \times 10^{-1}$

$\Rightarrow i_2 = \frac{9.8}{2} \times 10^{-1} = 0.49$ A



31. $I_2 = 6$ A

$I_1 = 10$ A

F_{PQ}

'F' on dx $= \frac{\mu_0 i_1 i_2}{2\pi x} dx = \frac{\mu_0 i_1 i_2}{2\pi} \frac{dx}{x} = \frac{\mu_0 \times 30}{\pi} \frac{dx}{x}$

$\vec{F}_{PQ} = \frac{\mu_0 \times 30}{x} \int_1 \frac{dx}{x} = 30 \times 4 \times 10^{-7} \times [\log x]_1^2$

$= 120 \times 10^{-7} [\log 3 - \log 1]$

Similarly force of $\vec{F}_{RS} = 120 \times 10^{-7} [\log 3 - \log 1]$

So, $\vec{F}_{PQ} = \vec{F}_{RS}$

$\vec{F}_{PS} = \frac{\mu_0 \times i_1 i_2}{2\pi \times 1 \times 10^{-2}} - \frac{\mu_0 \times i_1 i_2}{2\pi \times 2 \times 10^{-2}}$

$= \frac{2 \times 6 \times 10 \times 10^{-7}}{10^{-2}} - \frac{2 \times 10^{-7} \times 6 \times 6}{2 \times 10^{-2}} = 8.4 \times 10^{-4}$ N (Towards right)

$\vec{F}_{RQ} = \frac{\mu_0 \times i_1 i_2}{2\pi \times 3 \times 10^{-2}} - \frac{\mu_0 \times i_1 i_2}{2\pi \times 2 \times 10^{-2}}$

$= \frac{4\pi \times 10^{-7} \times 6 \times 10}{2\pi \times 3 \times 10^{-2}} - \frac{4\pi \times 10^{-7} \times 6 \times 6}{2\pi \times 2 \times 10^{-2}} = 4 \times 10^{-4} + 36 \times 10^{-5} = 7.6 \times 10^{-4}$ N

Net force towards down

$= (8.4 + 7.6) \times 10^{-4} = 16 \times 10^{-4}$ N

32. B = 0.2 mT, i = 5 A, n = 1, r = ?

$B = \frac{n\mu_0 i}{2r}$

$\Rightarrow r = \frac{n \times \mu_0 i}{2B} = \frac{1 \times 4\pi \times 10^{-7} \times 5}{2 \times 0.2 \times 10^{-3}} = 3.14 \times 5 \times 10^{-3}$ m $= 15.7 \times 10^{-3}$ m $= 15.7 \times 10^{-1}$ cm = 1.57 cm

33. $B = \dfrac{n\mu_0 i}{2r}$

$n = 100, \quad r = 5 \text{ cm} = 0.05 \text{ m}$

$\vec{B} = 6 \times 10^{-5}$ T

$i = \dfrac{2rB}{n\mu_0} = \dfrac{2 \times 0.05 \times 6 \times 10^{-5}}{100 \times 4\pi \times 10^{-7}} = \dfrac{3}{6.28} \times 10^{-1} = 0.0477 \approx 48$ mA

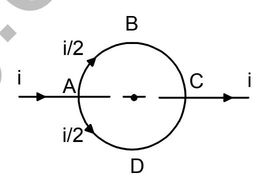
34. 3×10^5 revolutions in 1 sec.

1 revolutions in $\dfrac{1}{3 \times 10^5}$ sec

$i = \dfrac{q}{t} = \dfrac{1.6 \times 10^{-19}}{\left(\dfrac{1}{3 \times 10^5}\right)}$ A

$B = \dfrac{\mu_0 i}{2r} = \dfrac{4\pi \times 10^{-7}.16 \times 10^{-19} 3 \times 10^5}{2 \times 0.5 \times 10^{-10}} \quad \dfrac{2\pi \times 1.6 \times 3}{0.5} \times 10^{-11} = 6.028 \times 10^{-10} \approx 6 \times 10^{-10}$ T

35. I = i/2 in each semicircle



ABC = $\vec{B} = \dfrac{1}{2} \times \dfrac{\mu_0 (i/2)}{2a}$ downwards

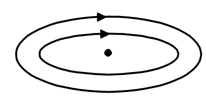
ADC = $\vec{B} = \dfrac{1}{2} \times \dfrac{\mu_0 (i/2)}{2a}$ upwards

Net $\vec{B} = 0$

36. $r_1 = 5$ cm $\qquad r_2 = 10$ cm

$n_1 = 50 \qquad n_2 = 100$

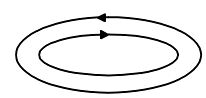
$i = 2$ A



(a) $B = \dfrac{n_1 \mu_0 i}{2r_1} + \dfrac{n_2 \mu_0 i}{2r_2}$

$= \dfrac{50 \times 4\pi \times 10^{-7} \times 2}{2 \times 5 \times 10^{-2}} + \dfrac{100 \times 4\pi \times 10^{-7} \times 2}{2 \times 10 \times 10^{-2}}$

$= 4\pi \times 10^{-4} + 4\pi \times 10^{-4} = 8\pi \times 10^{-4}$

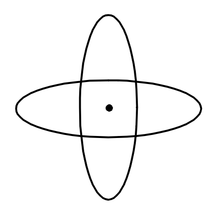


(b) $B = \dfrac{n_1 \mu_0 i}{2r_1} - \dfrac{n_2 \mu_0 i}{2r_2} = 0$

37. Outer Circle

$n = 100, \quad r = 100\text{m} = 0.1$ m

$i = 2$ A



$\vec{B} = \dfrac{n\mu_0 i}{2a} = \dfrac{100 \times 4\pi \times 10^{-7} \times 2}{2 \times 0.1} = 4\pi \times 10^{-4}$ horizontally towards West.

Inner Circle

$r = 5 \text{ cm} = 0.05 \text{ m}, \qquad n = 50, \; i = 2$ A

$\vec{B} = \dfrac{n\mu_0 i}{2r} = \dfrac{4\pi \times 10^{-7} \times 2 \times 50}{2 \times 0.05} = 4\pi \times 10^{-4}$ downwards

Net $B = \sqrt{(4\pi \times 10^{-4})^2 + (4\pi \times 10^{-4})^2} = \sqrt{32\pi^2 \times 10^{-8}} = 17.7 \times 10^{-4} \approx 18 \times 10^{-4} = 1.8 \times 10^{-3} = 1.8$ mT

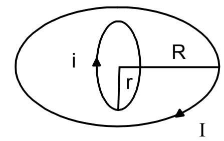
38. $r = 20$ cm, $\qquad i = 10$ A, $\qquad V = 2 \times 10^6$ m/s, $\qquad \theta = 30°$

$F = e(\vec{V} \times \vec{B}) = eVB \sin\theta$

$= 1.6 \times 10^{-19} \times 2 \times 10^6 \times \dfrac{\mu_0 i}{2r} \sin 30°$

$= \dfrac{1.6 \times 10^{-19} \times 2 \times 10^6 \times 4\pi \times 10^{-7} \times 10}{2 \times 2 \times 20 \times 10^{-2}} = 16\pi \times 10^{-19}$ N

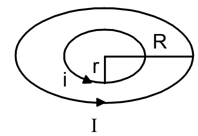
39. $\vec{B}$ Large loop = $\frac{\mu_0 I}{2R}$



'i' due to larger loop on the smaller loop

= i(A × B) = i AB Sin 90° = i × πr^2 × $\frac{\mu_0 I}{2r}$

40. The force acting on the smaller loop

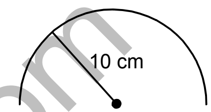


F = ilB Sin θ

= $\frac{i2\pi r\mu_o I1}{2R \times 2}$ = $\frac{\mu_0 iI\pi r}{2R}$

41. i = 5 Ampere, r = 10 cm = 0.1 m

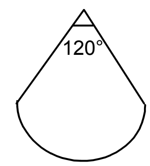
As the semicircular wire forms half of a circular wire,



So, $\vec{B}$ = $\frac{1}{2}\frac{\mu_0 i}{2r}$ = $\frac{1}{2} \times \frac{4\pi \times 10^{-7} \times 5}{2 \times 0.1}$

= 15.7 × 10^{-6} T ≈ 16 × 10^{-6} T = 1.6 × 10^{-5} T

42. B = $\frac{\mu_0 i}{2R}\frac{\theta}{2\pi}$ = $\frac{2\pi}{3 \times 2\pi} \times \frac{\mu_0 i}{2R}$

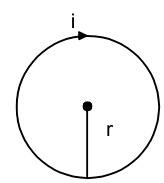


= $\frac{4\pi \times 10^{-7} \times 6}{6 \times 10^{t10^{-2}}}$ = 4π × 10^{-6}

= 4 × 3.14 × 10^{-6} = 12.56 × 10^{-6} = 1.26 × 10^{-5} T

43. $\vec{B}$ due to loop $\frac{\mu_0 i}{2r}$

Let the straight current carrying wire be kept at a distance R from centre. Given I = 4i



$\vec{B}$ due to wire = $\frac{\mu_0 I}{2\pi R}$ = $\frac{\mu_0 \times 4i}{2\pi R}$

Now, the $\vec{B}$ due to both will balance each other

Hence $\frac{\mu_0 i}{2r}$ = $\frac{\mu_0 4i}{2\pi R}$ ⇒ R = $\frac{4r}{\pi}$

Hence the straight wire should be kept at a distance 4π/r from centre in such a way that the direction of current in it is opposite to that in the nearest part of circular wire. As a result the direction will $\vec{B}$ will be oppose.

44. n = 200, i = 2 A, r = 10 cm = 10 × 10^{-2}n

(a) B = $\frac{n\mu_0 i}{2r}$ = $\frac{200 \times 4\pi \times 10^{-7} \times 2}{2 \times 10 \times 10^{-2}}$ = 2 × 4π × 10^{-4}

= 2 × 4 × 3.14 × 10^{-4} = 25.12 × 10^{-4} T = 2.512 mT

(b) B = $\frac{n\mu_0 ia^2}{2(a^2+d^2)^{3/2}}$ ⇒ $\frac{n\mu_0 i}{4a}$ = $\frac{n\mu_0 ia^2}{2(a^2+d^2)^{3/2}}$

⇒ $\frac{1}{2a}$ = $\frac{a^2}{2(a^2+d^2)^{3/2}}$ ⇒ $(a^2 + d^2)^{3/2}\ 2a^3$ ⇒ $a^2 + d^2 = (2a^3)^{2/3}$

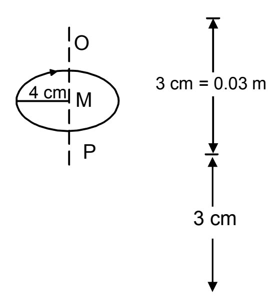
⇒ $a^2 + d^2 = (2^{1/3}a)^2$ ⇒ $a^2 + d^2 = 2^{2/3}a^2$ ⇒ $(10^{-1})^2 + d^2 = 2^{2/3}\ (10^{-1})^2$

⇒ $10^{-2} + d^2 = 2^{2/3}\ 10^{-2}$ ⇒ $(10^{-2})(2^{2/3} - 1) = d^2$ ⇒ $(10^{-2})\ (4^{1/3} - 1) = d^2$

⇒ $10^{-2}(1.5874 - 1) = d^2$ ⇒ $d^2 = 10^{-2} \times 0.5874$

⇒ d = $\sqrt{10^{-2} \times 0.5874}$ = 10^{-1} × 0.766 m = 7.66 × 10^{-2} = 7.66 cm.

45. At O P the $\vec{B}$ must be directed downwards



We Know B at the axial line at O & P

= $\frac{\mu_0 ia^2}{2(a^2+d^2)^{3/2}}$ a = 4 cm = 0.04 m

= $\frac{4\pi \times 10^{-7} \times 5 \times 0.0016}{2((0.0025)^{3/2}}$ d = 3 cm = 0.03 m

= 40 × 10^{-6} = 4 × 10^{-5} T downwards in both the cases

46. $q = 3.14 \times 10^{-6}$ C, $r = 20$ cm $= 0.2$ m,

$w = 60$ rad/sec., $i = \frac{q}{t} = \frac{3.14 \times 10^{-6} \times 60}{2\pi \times 0.2} = 1.5 \times 10^{-5}$

$$\frac{\text{Electric field}}{\text{Magnetic field}} = \frac{\dfrac{xQ}{4\pi\varepsilon_0 (x^2 + a^2)^{3/2}}}{\dfrac{\mu_0 i a^2}{2(a^2 + x^2)^{3/2}}} = \frac{xQ}{4\pi\varepsilon_0 (x^2 + a^2)^{3/2}} \times \frac{2(x^2 + a^2)^{3/2}}{\mu_0 i a^2}$$

$$= \frac{9 \times 10^9 \times 0.05 \times 3.14 \times 10^{-6} \times 2}{4\pi \times 10^{-7} \times 15 \times 10^{-5} \times (0.2)^2}$$

$$= \frac{9 \times 5 \times 2 \times 10^3}{4 \times 13 \times 4 \times 10^{-12}} = \frac{3}{8}$$

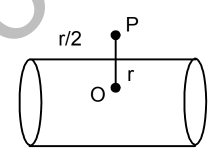
47. (a) For inside the tube $\vec{B} = 0$

As, $\vec{B}$ inside the conducting tube = o

(b) For $\vec{B}$ outside the tube

$d = \frac{3r}{2}$

$\vec{B} = \frac{\mu_0 i}{2\pi d} = \frac{\mu_0 i \times 2}{2\pi 3r} = \frac{\mu_0 i}{2\pi r}$

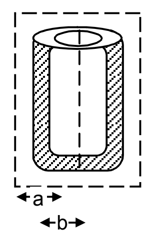


48. (a) At a point just inside the tube the current enclosed in the closed surface = 0.

Thus $B = \frac{\mu_0 o}{A} = 0$

(b) Taking a cylindrical surface just out side the tube, from ampere's law.

$\mu_0 i = B \times 2\pi b \quad \Rightarrow B = \frac{\mu_0 i}{2\pi b}$



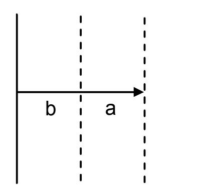
49. i is uniformly distributed throughout.

So, 'i' for the part of radius a $= \frac{i}{\pi b^2} \times \pi a^2 = \frac{ia^2}{b^2} = I$

Now according to Ampere's circuital law

$\oint B \times d\ell = B \times 2 \times \pi \times a = \mu_0 I$

$\Rightarrow B = \mu_0 \frac{ia^2}{b^2} \times \frac{1}{2\pi a} = \frac{\mu_0 ia}{2\pi b^2}$



50. (a) $r = 10$ cm $= 10 \times 10^{-2}$ m

$x = 2 \times 10^{-2}$ m, $i = 5$ A

i in the region of radius 2 cm

$\frac{5}{\pi(10 \times 10^{-2})^2} \times \pi(2 \times 10^{-2})^2 = 0.2$ A

$B \times \pi (2 \times 10^{-2})^2 = \mu_0(0\text{-}2)$

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

(b) 10 cm radius

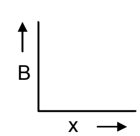
$B \times \pi (10 \times 10^{-2})^2 = \mu_0 \times 5$

$\Rightarrow B = \frac{4\pi \times 10^{-7} \times 5}{\pi \times 10^{-2}} = 20 \times 10^{-5}$

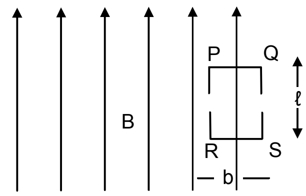
(c) x = 20 cm

$B \times \pi \times (20 \times 10^{-2})^2 = \mu_0 \times 5$

$\Rightarrow B = \frac{\mu_0 \times 5}{\pi \times (20 \times 10^{-2})^2} = \frac{4\pi \times 10^{-7} \times 5}{\pi \times 400 \times 10^{-4}} = 5 \times 10^{-5}$



51. We know, $\int B \times dl = \mu_0 i$. Theoritically B = 0 a t A



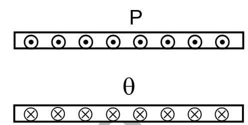
If, a current is passed through the loop PQRS, then

$B = \dfrac{\mu_0 i}{2(\ell + b)}$ will exist in its vicinity.

Now, As the $\vec{B}$ at A is zero. So there'll be no interaction

However practically this is not true. As a current carrying loop, irrespective of its near about position is always affected by an existing magnetic field.

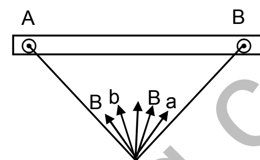
52. (a) At point P, i = 0, Thus B = 0

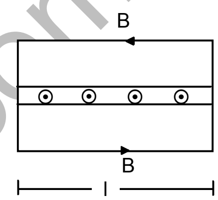


(b) At point R, i = 0, B = 0

(c) At point θ,

Applying ampere's rule to the above rectangle





$B \times 2l = \mu_0 K_0 \int_o^l dl$

$\Rightarrow B \times 2l = \mu_0 kl \Rightarrow B = \dfrac{\mu_0 k}{2}$

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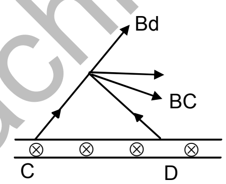
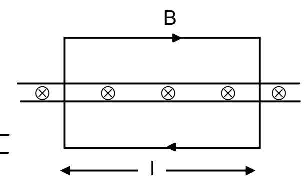




Since the $\vec{B}$ due to the 2 stripes are along the same direction, thus.

$B_{net} = \dfrac{\mu_0 k}{2} + \dfrac{\mu_0 k}{2} = \mu_0 k$

53. Charge = q, mass = m

We know radius described by a charged particle in a magnetic field B

$r = \dfrac{m\upsilon}{qB}$

Bit B = μ_0K [according to Ampere's circuital law, where K is a constant]

$r = \dfrac{m\upsilon}{q\mu_0 k} \Rightarrow \upsilon = \dfrac{rq\mu_0 k}{m}$

54. i = 25 A, B = 3.14 × 10^{-2} T, n = ?

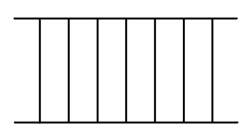
B = $\mu_0$ni

$\Rightarrow 3.14 \times 10^{-2} = 4 \times \pi \times 10^{-7}\ n \times 5$

$\Rightarrow n = \dfrac{10^{-2}}{20 \times 10^{-7}} = \dfrac{1}{2} \times 10^4 = 0.5 \times 10^4 = 5000$ turns/m

55. r = 0.5 mm, i = 5 A, B = $\mu_0$ni (for a solenoid)

Width of each turn = 1 mm = 10^{-3} m



No. of turns 'n' = $\dfrac{1}{10^{-3}} = 10^3$

So, B = $4\pi \times 10^{-7} \times 10^3 \times 5 = 2\pi \times 10^{-3}$ T

56. $\dfrac{R}{l}$ = 0.01 Ω in 1 m, r = 1.0 cm Total turns = 400, ℓ = 20 cm,

B = 1× 10^{-2} T, $n = \dfrac{400}{20 \times 10^{-2}}$ turns/m

$i = \dfrac{E}{R_0} = \dfrac{E}{R_0 / l \times (2\pi r \times 400)} = \dfrac{E}{0.01 \times 2 \times \pi \times 0.01 \times 400}$

B = $\mu_0$ni

$\Rightarrow 10^2 = 4\pi \times 10^{-7} \times \dfrac{400}{20 \times 10^{-2}} \times \dfrac{E}{400 \times 2\pi \times 0.01 \times 10^{-2}}$

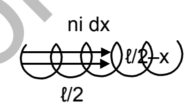
$\Rightarrow E = \dfrac{10^{-2} \times 20 \times 10^{-2} \times 400 \times 2\pi \times 10^{-2} 0.01}{4\pi \times 10^{-7} \times 400} = 1\text{ V}$

57. Current at '0' due to the circular loop = $dB = \dfrac{\mu_0}{4\pi} \times \dfrac{a^2 indx}{\left[a^2 + \left(\dfrac{l}{2} - x\right)^2\right]^{3/2}}$

$\therefore$ for the whole solenoid $B = \int_0^B dB$

$= \int_0^\ell \dfrac{\mu_0 a^2 nidx}{4\pi\left[a^2 + \left(\dfrac{\ell}{2} - x\right)^2\right]^{3/2}}$

$= \dfrac{\mu_0 ni}{4\pi}\int_0^\ell \dfrac{a^2\, dx}{a^3\left[1 + \left(\ell - \dfrac{2x}{2a}\right)^2\right]^{3/2}} = \dfrac{\mu_0 ni}{4\pi a}\int_0^\ell \dfrac{dx}{\left[1 + \left(\ell - \dfrac{2x}{2a}\right)^2\right]^{3/2}} = 1 + \left(\ell - \dfrac{2x}{2a}\right)^2$

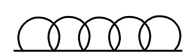


58. $i = 2$ a, $f = 10^8$ rev/sec, $n = ?$, $m_e = 9.1 \times 10^{-31}$ kg,

$q_e = 1.6 \times 10^{-19}$ c, $B = \mu_0 ni \Rightarrow n = \dfrac{B}{\mu_0 i}$

$f = \dfrac{qB}{2\pi m_e} \Rightarrow B = \dfrac{f 2\pi m_e}{q_e} \Rightarrow n = \dfrac{B}{\mu_0 i} = \dfrac{f 2\pi m_e}{q_e \mu_0 i} = \dfrac{10^8 \times 9.1 \times 10^{-31}}{1.6 \times 10^{-19} \times 2 \times 10^{-7} \times 2A} = 1421$ turns/m

59. No. of turns per unit length = n, radius of circle = r/2, current in the solenoid = i,
Charge of Particle = q, mass of particle = m $\therefore B = \mu_0 ni$



Again $\dfrac{mV^2}{r} = qVB \Rightarrow V = \dfrac{qBr}{m} = \dfrac{q\mu_0 nir}{2m} = \dfrac{\mu_0 niqr}{2m}$

60. No. of turns per unit length = ℓ
(a) As the net magnetic field = zero

$\therefore \vec{B}_{plate} = \vec{B}_{Solenoid}$

$\vec{B}_{plate} \times 2\ell = \mu_0 k d\ell = \mu_0 k\ell$

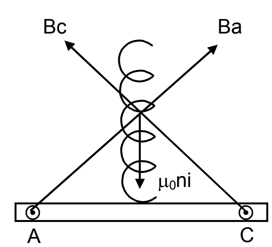
$\vec{B}_{plate} = \dfrac{\mu_0 k}{2}$ ...(1) $\quad\quad \vec{B}_{Solenoid} = \mu_0 ni$ …(2)

Equating both $i = \dfrac{\mu_0 k}{2}$

(b) $B_a \times \ell = \mu k\ell \quad \Rightarrow B_a = \mu_0 k \;\; BC = \mu_0 k$

$B = \sqrt{{B_a}^2 + {B_c}^2} = \sqrt{2(\mu_0 k)^2} = \sqrt{2}\mu_0 k$

$2\mu_0 k = \mu_0 ni \quad\quad i = \dfrac{\sqrt{2}k}{n}$



61. $C = 100\ \mu f$, $Q = CV = 2 \times 10^{-3}$ C, $t = 2$ sec,
$V = 20$ V, $V' = 18$ V, $Q' = CV = 1.8 \times 10^{-3}$ C,

$\therefore i = \dfrac{Q - Q'}{t} = \dfrac{2 \times 10^{-4}}{2} = 10^{-4}$ A $\quad\quad n = 4000$ turns/m.

$\therefore B = \mu_0 ni = 4\pi \times 10^{-7} \times 4000 \times 10^{-4} = 16\pi \times 10^{-7}$ T

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