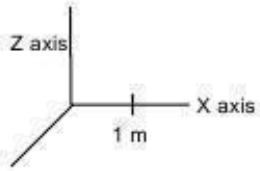
CHAPTER – 35
MAGNETIC FIELD DUE TO CURRENT

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

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

2. $i = 10$ A, $d = 1$ m



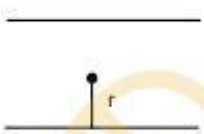
   $B = \frac{\mu_0 i}{2\pi r} = \frac{10^{-7} \times 4\pi \times 10}{2\pi \times 1} = 20 \times 10^{-6}$ T $= 2\ \mu$T

   Along +ve Y direction.

3. $d = 1.6$ mm

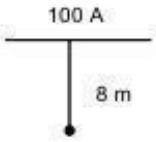
   So, $r = 0.8$ mm $= 0.0008$ m

   $i = 20$ 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

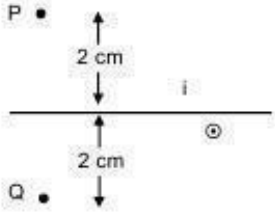


   $B = \frac{\mu_0 i}{2\pi r}$

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

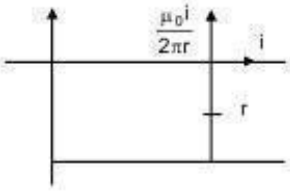
   net B $= 2 \times 1 \times 10^{-7}$ T $= 20\ \mu$T

   B at Q $= 1 \times 10^{-5}$ 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 $B - \frac{\mu_0 I}{2\pi r}$

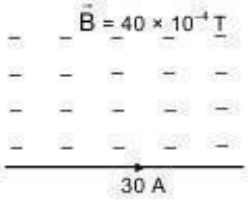


   If $r = \frac{\mu_0 I}{2\pi B}$ B net $= 0$

   $r < \frac{\mu_0 I}{2\pi B}$ 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, $B = 4.0 \times 10^{-4}$ 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.

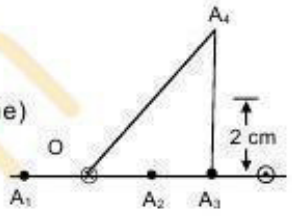
$B = \frac{\mu_0 I}{2\pi r}$

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

$\Rightarrow r = \frac{2 \times 10^{-7}}{2 \times 10^{-3}} = 10^{-3}$ 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 $A_1 = \frac{4\pi \times 10^{-7} \times 10}{2\pi \times 0.02} = 1 \times 10^{-4}$ T ($\perp$r towards up the line)

$\vec{B}$ due to P, at $A_1 = \frac{4\pi \times 10^{-7} \times 10}{2\pi \times 0.06} = 0.33 \times 10^{-4}$ 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 $A_2 = \frac{2 \times 10^{-7} \times 10}{0.01} = 2 \times 10^{-4}$ T $\perp$r down the line

$\vec{B}$ due to P at $A_2 = \frac{2 \times 10^{-7} \times 10}{0.03} = 0.67 \times 10^{-4}$ 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 = 1×10^{-4} T $\perp$r towards down the line

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

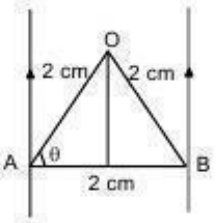
Net $\vec{B}$ at $A_3 = 2 \times 10^{-4}$ T

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

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

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

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



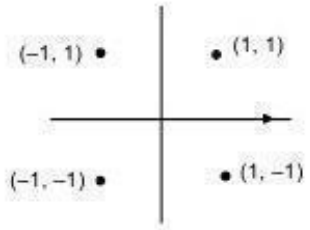
$B = \frac{\mu_0 I}{2\pi r} = \frac{10^{-7} \times 2 \times 10}{2 \times 10^{-2}} = 10^{-4}$ T

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

$= 10^{-4}[1 + 1 + 2 \times ½]^{1/2} = 10^{-4} \times \sqrt{3}$ 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 $\vec{B} = \frac{2 \times 10^{-7} \times 2 \times 5}{1} = 2 \times 10^{-6}$ 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 = 1×10^{-6} T both directed along (–) ve Z–axis

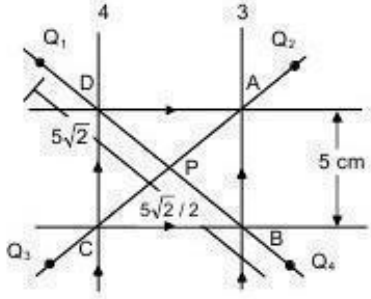
Hence Net $\vec{B} = 2 \times 1.0 \times 10^{-6} = 2$ μT

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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 ⊙ for BC ⊙ For CD ⊗ and for DA ⊗.

The two ⊙ and 2⊗ fields cancel each other. Thus $B_{net} = 0$

(b) At point Q_1

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

$\frac{\mu_0 i}{}$ $\frac{4\pi \times 5 \times 2 \times 10^{-7}}{}$

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

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

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

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

At point Q_2

due to (1) $\frac{\mu_0 i}{2\pi \times (2.5) \times 10^{-2}}$ ⊙

due to (2) $\frac{\mu_0 i}{2\pi \times (15/2) \times 10^{-2}}$ ⊙

due to (3) $\frac{\mu_0 i}{2\pi \times (2.5) \times 10^{-2}}$ ⊗

due to (4) $\frac{\mu_0 i}{2\pi \times (15/2) \times 10^{-2}}$ ⊗

$B_{net} = 0$

At point Q_3

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

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

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

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

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

For Q_4

due to (1) $4/3 \times 10^{-5}$ ⊗

due to (2) 4×10^{-5} ⊗

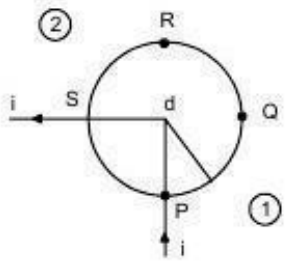
due to (3) $4/3 \times 10^{-5}$ ⊗

due to (4) 4×10^{-5} ⊗

$B_{net} = 0$

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 $\frac{\pi_0 i}{4\pi d}$

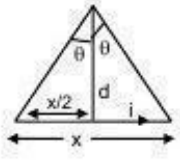
At S

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

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

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

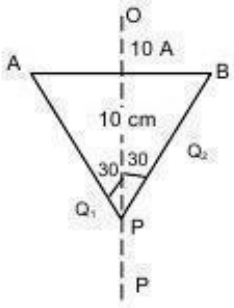
(b) When x >> d, neglecting d w.r.t. x

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

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

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

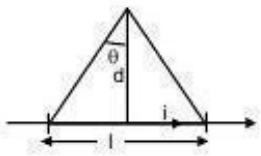
$r = OP = \frac{\sqrt{3}}{2}\times 0.1\ \text{m}$



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

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

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



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

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

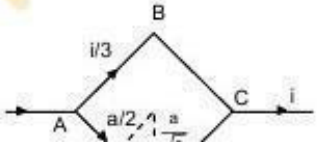
$\Rightarrow \frac{\ell}{4\sqrt{d^2+\frac{\ell^2}{4}}} = \frac{99}{200} \quad \Rightarrow \frac{\ell^2}{d^2+\frac{\ell^2}{4}} = \left(\frac{99\times 4}{200}\right)^2 = \frac{156816}{40000} = 3.92$

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

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

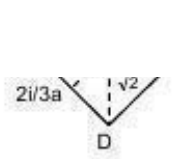
17. As resistances vary as r & 2r

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



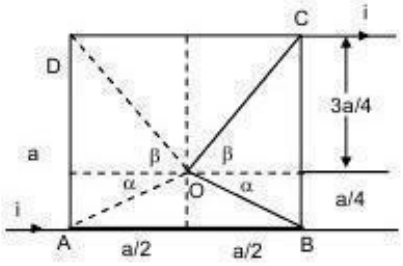
Now,

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



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

Now $\vec{B} = \dfrac{2\sqrt{2}\mu_0 i}{3\pi a} - \dfrac{2\sqrt{2}\mu_0 i}{6\pi a} = \dfrac{\sqrt{2}\mu_0 i}{3\pi a}$ ⊗



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

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

Magnetic field due to AB

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

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

Magnetic field due to DC

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

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

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

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

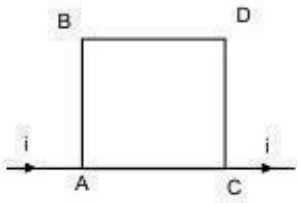
19. $\vec{B}$ due t BC &

$\vec{B}$ due to AD at Pt 'P' are equal ore Opposite

Hence net $\vec{B} = 0$

Similarly, due to AB & CD at P = 0

∴ The net $\vec{B}$ at the Centre of the square loop = zero.



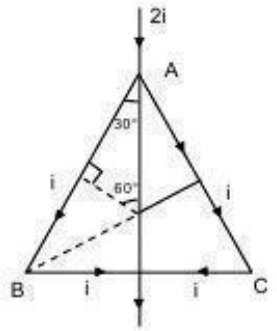
20. For AB B is along ⊙ $B = \dfrac{\mu_0 i}{4\pi r}(\text{Sin}60° + \text{Sin}60°)$

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

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

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

∴ Net B = 0



21. (a) ΔABC is Equilateral

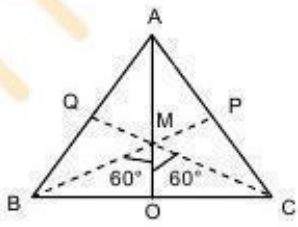
AB = BC = CA = ℓ/3

Current = i

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

$\phi_1 = \phi_2 = 60°$

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



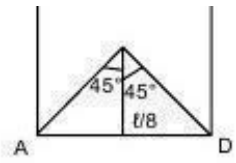
$\vec{B}$ due to BC at <.

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

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



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

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

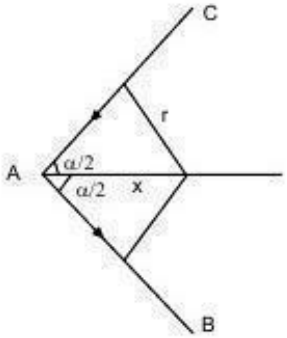
Magnetic field B due to AR

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

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

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

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



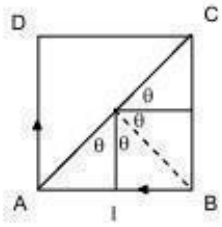
The magnetic field due to both the wire.

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

23. $\vec{B}AB$

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

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



$\vec{B}BC$

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

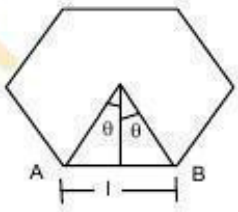
$= \frac{\mu_0 i b}{\pi\ell\sqrt{\ell^2 + b^2}} = \vec{B}AD$

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

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

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

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



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

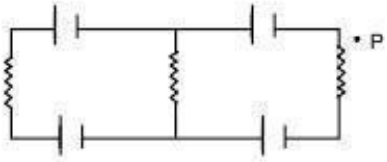
$= \frac{\mu_0 i 2\text{Tan}(\pi/n)2\text{Sin}(\pi/n)n}{4\pi 2\pi r} = \frac{\mu_0 in\text{Tan}(\pi/n)\text{Sin}(\pi/n)}{2\pi^2 r}$

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]



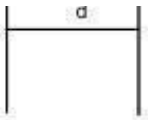
26. Force acting on 10 cm of wire is 2×10^{-5} N

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

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



$\Rightarrow d = \dfrac{4\pi\times10^{-7}\times20\times20\times10\times10^{-2}}{2\pi\times2\times10^{-5}} = 400\times10^{-3} = 0.4\text{ m} = 40\text{ cm}$

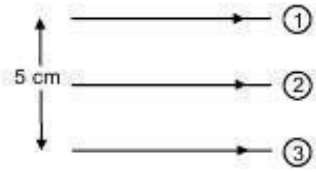


27. $i = 10$ A

Magnetic force due to two parallel Current Carrying wires.

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

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

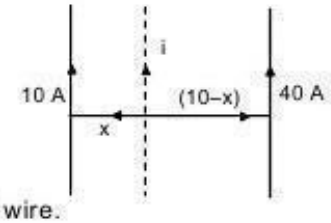


$= \dfrac{\mu_0\times10\times10}{2\pi\times5\times10^{-2}} + \dfrac{\mu_0\times10\times10}{2\pi\times10\times10^{-2}}$

$= \dfrac{4\pi\times10^{-7}\times10\times10}{2\pi\times5\times10^{-2}} + \dfrac{4\pi\times10^{-7}\times10\times10}{2\pi\times10\times10^{-2}}$

$= \dfrac{2\times10^{-3}}{5} + \dfrac{10^{-3}}{5} = \dfrac{3\times10^{-3}}{5} = 6\times10^{-4}$ N towards middle wire

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

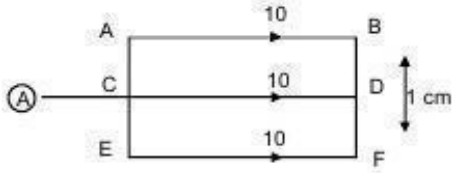


$\Rightarrow \dfrac{10}{x} = \dfrac{40}{10-x} \Rightarrow \dfrac{1}{x} = \dfrac{4}{10-x}$

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

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

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



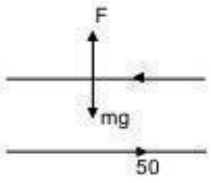
$= \dfrac{\mu_0\times10\times10}{2\pi\times1\times10^{-2}} + \dfrac{\mu_0\times10\times10}{2\pi\times2\times10^{-2}}$

$= 2\times10^{-3} + 10^{-3} = 3\times10^{-3}$ downward.

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

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

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



$\Rightarrow \dfrac{\mu_0\times50\times i_2}{2\pi\times5\times10^{-3}} = 1\times10^{-4}\times9.8$

$\Rightarrow \dfrac{4\pi\times10^{-7}\times5\times i_2}{2\pi\times5\times10^{-3}} = 9.8\times10^{-4}$

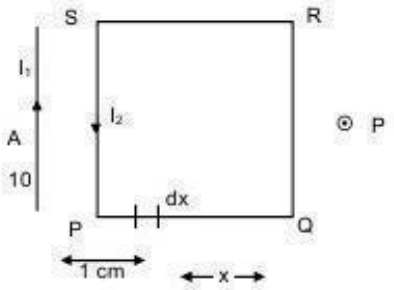
$\Rightarrow 2\times i_2\times10^{-3} = 9.3\times10^{-3}\times10^{-1}$

$\Rightarrow i_2 = \dfrac{9.8}{2}\times10^{-1} = 0.49$ A

31. $I_2 = 6$ A

$I_1 = 10$ A

F_{PQ}



'F' on dx = $\dfrac{\mu_0 i_1 i_2}{2\pi x}dx = \dfrac{\mu_0 i_1 i_2}{2\pi}\dfrac{dx}{x} = \dfrac{\mu_0\times30}{\pi}\dfrac{dx}{x}$

$\vec{F}_{PQ} = \dfrac{\mu_0\times30}{x}\int_1 \dfrac{dx}{x} = 30\times4\times10^{-7}\times[\log x]_1^2$

$= 120\times10^{-7}[\log 3 - \log 1]$

Similarly force of $\vec{F}_{RS} = 120\times10^{-7}[\log 3 - \log 1]$

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

$\vec{F}_{PS} = \dfrac{\mu_0\times i_1 i_2}{2\pi\times1\times10^{-2}} - \dfrac{\mu_0\times i_1 i_2}{2\pi\times2\times10^{-2}}$

$= \dfrac{2\times6\times10\times10^{-7}}{10^{-2}} - \dfrac{2\times10^{-7}\times6\times6}{2\times10^{-2}} = 8.4\times10^{-4}$ N (Towards right)

$\vec{F}_{RQ} = \dfrac{\mu_0\times i_1 i_2}{2\pi\times3\times10^{-2}} - \dfrac{\mu_0\times i_1 i_2}{2\pi\times2\times10^{-2}}$

$= \dfrac{4\pi\times10^{-7}\times6\times10}{} - \dfrac{4\pi\times10^{-7}\times6\times6}{} = 4\times10^{-4} + 36\times10^{-5} = 7.6\times10^{-4}$ N

$\frac{2\pi\times3\times10^{-2}}{}$ $\frac{2\pi\times2\times10^{-2}}{}$

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 = ?

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

$\Rightarrow r = \frac{n\times\mu_0 i}{2B} = \frac{1\times4\pi\times10^{-7}\times5}{2\times0.2\times10^{-3}} = 3.14 \times 5 \times 10^{-3}$ m $= 15.7\times 10^{-3}$ m $= 15.7 \times 10^{-1}$ cm $= 1.57$ cm

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

n = 100, r = 5 cm = 0.05 m

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

$i = \frac{2rB}{n\mu_0} = \frac{2\times0.05\times6\times10^{-5}}{100\times4\pi\times10^{-7}} = \frac{3}{6.28} \times 10^{-1} = 0.0477 \approx 48$ mA

34. 3×10^5 revolutions in 1 sec.

1 revolutions in $\frac{1}{3\times10^5}$ sec

$i = \frac{q}{t} = \frac{1.6\times10^{-19}}{\left(\frac{1}{3\times10^5}\right)}$ A

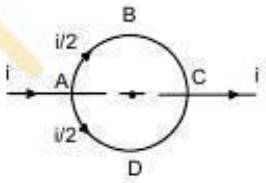
$B = \frac{\mu_0 i}{2r} = \frac{4\pi\times10^{-7}.16\times10^{-19}3\times10^5}{2\times0.5\times10^{-10}}$ $\frac{2\pi\times1.6\times3}{0.5}\times10^{-11} = 6.028 \times 10^{-10} \approx 6 \times 10^{-10}$ T

35. I = i/2 in each semicircle

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

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

Net $\vec{B} = 0$



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

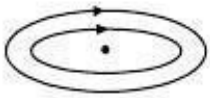
$n_1 = 50$ $n_2 = 100$

i = 2 A

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

$= \frac{50\times4\pi\times10^{-7}\times2}{2\times5\times10^{-2}} + \frac{100\times4\pi\times10^{-7}\times2}{2\times10\times10^{-2}}$

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



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

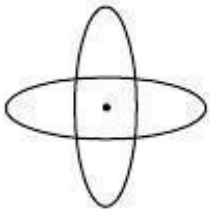


37. Outer Circle

n = 100, r = 100m = 0.1 m

i = 2 A

$\vec{B} = \frac{n\mu_0 i}{2a} = \frac{100\times4\pi\times10^{-7}\times2}{2\times0.1} = 4\pi \times 10^{-4}$ horizontally towards West.



Inner Circle

r = 5 cm = 0.05 m, n = 50, i = 2 A

$\vec{B} = \frac{n\mu_0 i}{2r} = \frac{4\pi\times10^{-7}\times2\times50}{2\times0.05} = 4\pi \times 10^{-4}$ downwards

Net $B = \sqrt{\left(4\pi\times10^{-4}\right)^2 + \left(4\pi\times10^{-4}\right)^2} = \sqrt{32\pi^2\times10^{-8}} = 17.7 \times 10^{-4} \approx 18 \times 10^{-4} = 1.8 \times 10^{-3} = 1.8$ mT

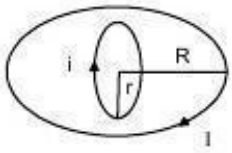
38. r = 20 cm, i = 10 A, V = 2×10^6 m/s, $\theta = 30°$

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

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

$= \frac{1.6\times10^{-19}\times2\times10^{6}\times4\pi\times10^{-7}\times10}{2\times2\times20\times10^{-2}} = 16\pi\times10^{-19}\ N$

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

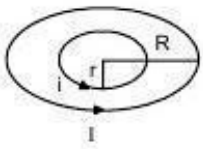


'i' due to larger loop on the smaller loop

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

40. The force acting on the smaller loop

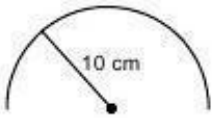
$F = ilB\ Sin\ \theta$



$= \frac{i2\pi r\mu_o I1}{2R\times2} = \frac{\mu_0 iI\pi r}{2R}$

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

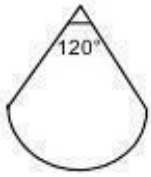
As the semicircular wire forms half of a circular wire,



So, $\vec{B} = \frac{1}{2}\frac{\mu_0 i}{2r} = \frac{1}{2}\times\frac{4\pi\times10^{-7}\times5}{2\times0.1}$

$= 15.7\times10^{-6}\ T \approx 16\times10^{-6}\ T = 1.6\times10^{-5}\ T$

42. $B = \frac{\mu_0 i}{2R}\frac{\theta}{2\pi} = \frac{2\pi}{3\times2\pi}\times\frac{\mu_0 i}{2R}$

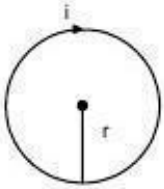


$= \frac{4\pi\times10^{-7}\times6}{6\times10^{t10^{-2}}} = 4\pi\times10^{-6}$

$= 4\times3.14\times10^{-6} = 12.56\times10^{-6} = 1.26\times10^{-5}\ T$

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 $= \frac{\mu_0 I}{2\pi R} = \frac{\mu_0\times4i}{2\pi R}$

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

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

Hence the straight wire should be kept at a distance $4\pi/r$ 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, $r = 10\ cm = 10\times10^{-2}n$

(a) $B = \frac{n\mu_0 i}{2r} = \frac{200\times4\pi\times10^{-7}\times2}{2\times10\times10^{-2}} = 2\times4\pi\times10^{-4}$

$= 2\times4\times3.14\times10^{-4} = 25.12\times10^{-4}\ T = 2.512\ mT$

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

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

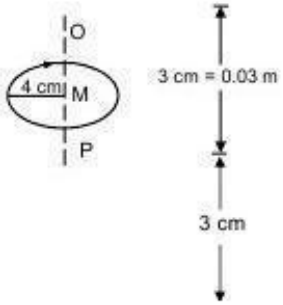
$\Rightarrow a^2+d^2 = (2^{1/3}a)^2 \Rightarrow a^2+d^2 = 2^{2/3}a^2 \Rightarrow (10^{-1})^2+d^2 = 2^{2/3}(10^{-1})^2$

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

$\Rightarrow 10^{-2}(1.5874-1) = d^2 \Rightarrow d^2 = 10^{-2}\times0.5874$

$\Rightarrow d = \sqrt{10^{-2}\times0.5874} = 10^{-1}\times0.766\ m = 7.66\times10^{-2} = 7.66\ cm.$

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



We Know B at the axial line at O & P

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

$= \frac{4\pi\times10^{-7}\times5\times0.0016}{2((0.0025)^{3/2}}$ $d = 3\ cm = 0.03\ m$

$= 40\times10^{-6} = 4\times10^{-5}\ T$ downwards in both the cases

46. $q = 3.14\times10^{-6}\ C$, $r = 20\ cm = 0.2\ m$,

$w = 60$ rad/sec., $i = \frac{q}{} = \frac{3.14\times10^{-6}\times60}{} = 1.5\times10^{-5}$

$t \qquad 2\pi \times 0.2$

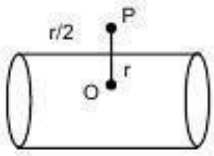
$$\frac{\text{Electric field}}{\text{Magnetic field}} = \frac{\frac{xQ}{4\pi\varepsilon_0\left(x^2+a^2\right)^{3/2}}}{\frac{\mu_0 ia^2}{2\left(a^2+x^2\right)^{3/2}}} = \frac{xQ}{4\pi\varepsilon_0\left(x^2+a^2\right)^{3/2}} \times \frac{2\left(x^2+a^2\right)^{3/2}}{\mu_0 ia^2}$$

$$= \frac{9\times10^9\times0.05\times3.14\times10^{-6}\times2}{4\pi\times10^{-7}\times15\times10^{-5}\times(0.2)^2}$$

$$= \frac{9\times5\times2\times10^3}{4\times13\times4\times10^{-12}} = \frac{3}{8}$$

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

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

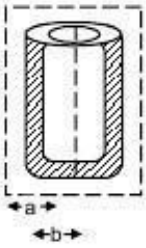


(b) For $\vec{B}$ outside the tube

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

$$\vec{B} = \frac{\mu_0 i}{2\pi d} = \frac{\mu_0 i\times2}{2\pi3r} = \frac{\mu_0 i}{2\pi r}$$

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

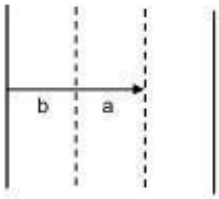


Thus $B = \frac{\mu_0 O}{A} = 0$

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

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

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

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

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

50. (a) r = 10 cm = 10×10^{-2} m

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

i in the region of radius 2 cm

$$\frac{5}{\pi(10\times10^{-2})^2}\times\pi(2\times10^{-2})^2 = 0.2 \text{ A}$$

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

$$\Rightarrow B = \frac{4\pi\times10^{-7}\times0.2}{\pi\times4\times10^{-4}} = \frac{0.2\times10^{-7}}{10^{-4}} = 2 \times 10^{-4}$$

(b) 10 cm radius

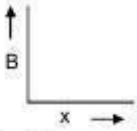
$B \times \pi (10 \times 10^{-2})^2 = \mu_0 \times 5$

$$\Rightarrow B = \frac{4\pi\times10^{-7}\times5}{\pi\times10^{-2}} = 20 \times 10^{-5}$$

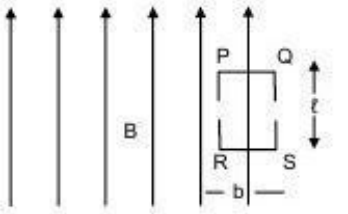
(c) x = 20 cm

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

$$\Rightarrow B = \frac{\mu_0\times5}{\pi\times(20\times10^{-2})^2} = \frac{4\pi\times10^{-7}\times5}{\pi\times400\times10^{-4}} = 5 \times 10^{-5}$$



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

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

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

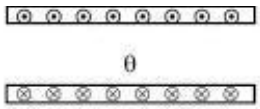
However practically this is not true. As a current carrying loop, irrespective of its near about position is always affected by an existing magnetic field.

P

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

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

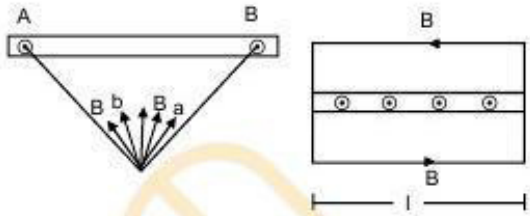
(c) At point θ,



Applying ampere's rule to the above rectangle

$$B \times 2l = \mu_0 K_0 \int_0^l dl$$

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

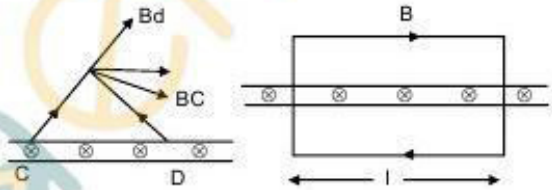


$$B \times 2l = \mu_0 K_0 \int_0^l dl$$

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

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

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



53. Charge = q, mass = m

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

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

Bit B = $\mu_0 K$ [according to Ampere's circuital law, where K is a constant]

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

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

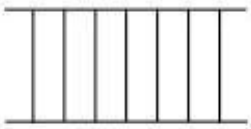
$B = \mu_0 ni$

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

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

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' = $\frac{1}{10^{-3}} = 10^3$

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

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

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

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

$B = \mu_0 ni$

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

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

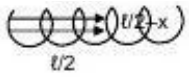
57. Current at '0' due to the circular loop = $dB = \frac{\mu_0}{4\pi} \times \frac{a^2 indx}{\left[a^2 + \left(\frac{l}{2} - x\right)^2\right]^{3/2}}$

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

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

ni dx

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



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, $B = \mu_0 ni \Rightarrow n = \frac{B}{\mu_0 i}$

$$f = \frac{qB}{2\pi m_e} \Rightarrow B = \frac{f2\pi m_e}{q_e} \Rightarrow n = \frac{B}{\mu_0 i} = \frac{f2\pi m_e}{q_e \mu_0 i} = \frac{10^8 \times 9.1\times 10^{-31}}{1.6\times 10^{-19}\times 2\times 10^{-7}\times 2A} = 1421 \text{ turns/m}$$

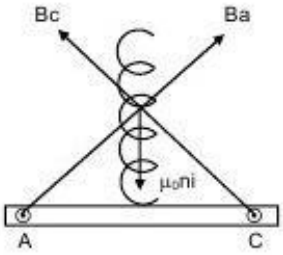
59. No. of turns per unit length = n, radius of circle = r/2, current in the solenoid = i,
Charge of Particle = q, mass of particle = m $\therefore B = \mu_0 ni$



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

60. No. of turns per unit length = ℓ
(a) As the net magnetic field = zero
$\therefore \vec{B}_{plate} = \vec{B}_{Solenoid}$
$\vec{B}_{plate} \times 2\ell = \mu_0 kd\ell = \mu_0 k\ell$

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



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

(b) $B_a \times \ell = \mu k\ell \Rightarrow B_a = \mu_0 k$ $BC = \mu_0 k$
$B = \sqrt{B_a^2 + B_c^2} = \sqrt{2(\mu_0 k)^2} = \sqrt{2}\mu_0 k$

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

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,

$\therefore i = \frac{Q-Q'}{t} = \frac{2\times 10^{-4}}{2} = 10^{-4}$ A $n = 4000$ 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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