1. \[ F = \frac{q \mathbf{u} \times \mathbf{B}}{q_0} \] or \[ B = \frac{F}{q \mathbf{u}} \]

\[ B = \frac{\mu_0 l}{2\pi r} \]

or \[ \mu_0 = \frac{2\pi r B}{l} = \frac{m \times N}{A - m \times A} = \frac{N}{A^2} \]

2. \( i = 10 \, \text{A} \), \( d = 1 \, \text{m} \)

\[ B = \frac{\mu_0 l}{2\pi r} = \frac{10^{-7} \times 4\pi \times 10}{2\pi \times 1} = 2 \times 10^{-6} \, \text{T} = 2 \, \mu\text{T} \]

Along +ve Y direction.

3. \( d = 1.6 \, \text{mm} \)

So, \( r = 0.8 \, \text{mm} = 0.0008 \, \text{m} \)

\( i = 20 \, \text{A} \)

\[ B = \frac{\mu_0 l}{2\pi r} = \frac{4\pi \times 10^{-7} \times 20}{2\pi \times 8 \times 10^{-4}} = 5 \times 10^{-4} \, \text{T} = 5 \, \text{mT} \]

4. \( i = 100 \, \text{A} \), \( d = 8 \, \text{m} \)

\[ B = \frac{\mu_0 l}{2\pi r} \]

\[ = \frac{4\pi \times 10^{-7} \times 100}{2\pi \times 8} = 2.5 \, \mu\text{T} \]

5. \( \mu_0 = 4\pi \times 10^{-7} \, \text{T-m/A} \)

\[ r = 2 \, \text{cm} = 0.02 \, \text{m}, \quad i = 1 \, \text{A}, \quad B = 1 \times 10^{-3} \, \text{T} \]

We know: Magnetic field due to a long straight wire carrying current \( = \frac{\mu_0 l}{2\pi} \)

\[ B \text{ at } P = \frac{4\pi \times 10^{-7} \times 1}{2\pi \times 0.02} = 1 \times 10^{-5} \, \text{T} \] upward

net \( B = 2 \times 1 \times 10^{-7} \, \text{T} = 20 \, \mu\text{T} \)

\[ B \text{ at Q} = 1 \times 10^{-5} \, \text{T} \] downwards

Hence net \( B = 0 \)

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

(b) The minimum \( B = \frac{\mu_0 l}{2\pi} \)

If \( r = \frac{\mu_0 l}{2\pi B} \) net = 0

\( r < \frac{\mu_0 l}{2\pi B} \) net = 0

\( r > \frac{\mu_0 l}{2\pi B} \) B net = \( \frac{\mu_0 l}{2\pi} \)

7. \( \mu_0 = 4\pi \times 10^{-7} \, \text{T-m/A}, \quad i = 30 \, \text{A}, \quad B = 4.0 \times 10^{-4} \, \text{T} \) Parallel to current.

\[ B \text{ due to wire at a pt. } 2 \, \text{cm} \]

\[ = \frac{\mu_0 l}{2\pi} \]

\[ = \frac{4\pi \times 10^{-7} \times 30}{2\pi \times 0.02} = 3 \times 10^{-4} \, \text{T} \]

\[ \text{net field} = \sqrt{(3 \times 10^{-4})^2 + (4 \times 10^{-4})^2} = 5 \times 10^{-4} \, \text{T} \]
8. \( i = 10 \text{ A.} \ ( \mathbf{\hat{K}} ) \)
\( B = 2 \times 10^{-3} \text{ T} \) South to North (\( \mathbf{\hat{J}} \))
To cancel the magnetic field the point should be chosen so that the net magnetic field is along -\( \mathbf{\hat{J}} \) direction.
\[ r = \frac{2 \times 10^{-7}}{2 \times 10^{-3}} = 10^{-3} \text{ m} = 1 \text{ mm}. \]

9. Let the tow wires be positioned at O & P
\[ R = OA = \sqrt{(0.02)^2 + (0.02)^2} = \sqrt{8} \times 10^{-4} = 2.828 \times 10^{-2} \text{ m} \]
(a) \( \vec{B} \) due to O at \( A_1 \) = \( \frac{4 \pi \times 10^{-7} \times 10}{2 \pi \times 0.02} = 1 \times 10^{-4} \text{ T} \) (\( \perp \)r towards up the line)
\( \vec{B} \) due to P at \( A_1 \) = \( \frac{4 \pi \times 10^{-7} \times 10}{2 \pi \times 0.06} = 0.33 \times 10^{-4} \text{ T} \) (\( \perp \)r towards down the line)
net \( \vec{B} = 1 \times 10^{-4} - 0.33 \times 10^{-4} = 0.67 \times 10^{-4} \text{ T} \)
(b) \( \vec{B} \) due to O at \( A_2 \) = \( \frac{2 \times 10^{-7} \times 10}{0.01} = 2 \times 10^{-4} \text{ T} \) \( \perp \)r down the line
\( \vec{B} \) due to P at \( A_2 \) = \( \frac{2 \times 10^{-7} \times 10}{0.03} = 0.67 \times 10^{-4} \text{ T} \) \( \perp \)r down the line
net \( \vec{B} \) at \( A_2 \) = \( 2 \times 10^{-4} + 0.67 \times 10^{-4} = 2.67 \times 10^{-4} \text{ T} \)
(c) \( \vec{B} \) at \( A_3 \) due to O = \( 1 \times 10^{-4} \text{ T} \) \( \perp \)r towards down the line
\( \vec{B} \) at \( A_3 \) due to P = \( 1 \times 10^{-4} \text{ T} \) \( \perp \)r towards down the line
Net \( \vec{B} \) at \( A_3 \) = \( 2 \times 10^{-4} \text{ T} \)
(d) \( \vec{B} \) at \( A_4 \) due to O = \( \frac{2 \times 10^{-7} \times 10}{2.828 \times 10^{-2}} = 0.7 \times 10^{-4} \text{ T} \) towards SE
\( \vec{B} \) at \( A_4 \) due to P = \( 0.7 \times 10^{-4} \text{ T} \) towards SW
Net \( \vec{B} = \sqrt{(0.7 \times 10^{-4})^2 + (0.7 \times 10^{-4})^2} = 0.989 \times 10^{-4} = 1 \times 10^{-4} \text{ T} \)

10. \( \cos \theta = \frac{1}{2} \), \( \theta = 60^\circ \) & \( \angle AOB = 60^\circ \)
\[ B = \frac{\mu_0 I}{2\pi r} = \frac{10^{-7} \times 2 \times 10}{2 \times 10^{-3}} = 10^{-4} \text{ T} \]
So net is \( (10^{-4})^2 + (10^{-4})^2 + 2(10^{-4}) \cos 60^\circ \)^{\frac{1}{2}} \]
\[ = 10^{-8}[1 + 1 + 2 \times \frac{1}{2}]^{\frac{1}{2}} = 10^{-4} \times \sqrt{3} \text{ T} = 1.732 \times 10^{-4} \text{ T} \]

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 \( \vec{B} = 2 \times 10^{-4} \times 2 \times 5 = 2 \times 10^{-4} \text{ T} = 2 \mu \text{T} \)
(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 \( Y = 1 \times 10^{-4} \text{ T} \) both directed along (-) ve Z-axis
Hence Net \( \vec{B} = 2 \times 1 \times 10^{-4} = 2 \mu \text{T} \)
12. (a) For each of the wires

Magnitude of magnetic field

\[ B = \frac{\mu_0 l_1}{4\pi} (\sin 45^\circ + \sin 45^\circ) = \frac{\mu_0 l_1}{4\pi \left(\frac{5}{2}\right)\sqrt{2}} \]

For \( AB \), \( BC \), \( CD \), and \( DA \), the two fields cancel each other. Thus \( B_{\text{net}} = 0 \)

(b) At point \( Q_1 \)

\[ \text{due to (1)} \quad B = \frac{\mu_0 l_1}{2\pi \times 2.5 \times 10^{-2}} = \frac{4\pi \times 5 \times 2 \times 10^{-7}}{2\pi \times 5 \times 10^{-2}} = 4 \times 10^{-5} \text{ T} \]

\[ \text{due to (2)} \quad B = \frac{\mu_0 l_1}{2\pi \times (15/2) \times 10^{-2}} = \frac{4\pi \times 5 \times 2 \times 10^{-7}}{2\pi \times 15 \times 10^{-2}} = (4/3) \times 10^{-5} \text{ T} \]

\[ \text{due to (3)} \quad B = \frac{\mu_0 l_1}{2\pi \times (5 + 5/2) \times 10^{-2}} = \frac{4\pi \times 5 \times 2 \times 10^{-7}}{2\pi \times 15 \times 10^{-2}} = (4/3) \times 10^{-5} \text{ T} \]

\[ \text{due to (4)} \quad B = \frac{\mu_0 l_1}{2\pi \times 2.5 \times 10^{-2}} = \frac{4\pi \times 5 \times 2 \times 10^{-7}}{2\pi \times 5 \times 10^{-2}} = 4 \times 10^{-5} \text{ T} \]

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

At point \( Q_2 \)

\[ \text{due to (1)} \quad \frac{\mu_0 l_1}{2\pi \times (2.5) \times 10^{-2}} \]

\[ \text{due to (2)} \quad \frac{\mu_0 l_1}{2\pi \times (15/2) \times 10^{-2}} \]

\[ \text{due to (3)} \quad \frac{\mu_0 l_1}{2\pi \times (2.5) \times 10^{-2}} \]

\[ \text{due to (4)} \quad \frac{\mu_0 l_1}{2\pi \times (15/2) \times 10^{-2}} \]

\[ B_{\text{net}} = 0 \]

At point \( Q_3 \)

\[ \text{due to (1)} \quad \frac{4\pi \times 10^{-7} \times 5}{2\pi \times (15/2) \times 10^{-2}} = 4/3 \times 10^{-5} \text{ T} \]

\[ \text{due to (2)} \quad \frac{4\pi \times 10^{-7} \times 5}{2\pi \times (5/2) \times 10^{-2}} = 4 \times 10^{-5} \text{ T} \]

\[ \text{due to (3)} \quad \frac{4\pi \times 10^{-7} \times 5}{2\pi \times (5/2) \times 10^{-2}} = 4 \times 10^{-5} \text{ T} \]

\[ \text{due to (4)} \quad \frac{4\pi \times 10^{-7} \times 5}{2\pi \times (15/2) \times 10^{-2}} = 4/3 \times 10^{-5} \text{ T} \]

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

For \( Q_4 \)

\[ \text{due to (1)} \quad 4/3 \times 10^{-5} \text{ T} \]

\[ \text{due to (2)} \quad 4 \times 10^{-5} \text{ T} \]

\[ \text{due to (3)} \quad 4/3 \times 10^{-5} \text{ T} \]

\[ \text{due to (4)} \quad 4 \times 10^{-5} \text{ T} \]

\[ B_{\text{net}} = 0 \]
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 $\vec{B} = \frac{\pi d I}{4\pi d}$

At P 
$B_1$ due to 1 is 0 
$B_2$ due to 2 is $\frac{\pi d I}{4\pi d}$

At Q 
$B_1$ due to 1 is $\frac{\pi d I}{4\pi d}$ 
$B_2$ due to 2 is 0

At R 
$B_1$ due to 1 is 0 
$B_2$ due to 2 is $\frac{\pi d I}{4\pi d}$

At S 
$B_1$ due to 1 is $\frac{\pi d I}{4\pi d}$ 
$B_2$ due to 2 is 0

14. $B = \frac{\pi d I}{4\pi d} \cdot 2 \sin \theta$

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

(a) When $d \gg x$
Neglecting $x$ w.r.t. $d$
$B = \frac{\mu_0 I}{\mu_0 \sigma (d^2)} = \frac{\mu_0 I}{\mu_0 d^2}$
\[ \therefore B \approx \frac{1}{d^2} \]

(b) When $x \gg d$, neglecting $d$ w.r.t. $x$
$B = \frac{\mu_0 I}{4\pi d} \cdot 2 \frac{1}{\mu_0 I} = \frac{1}{4\pi d}$
\[ \therefore B \approx \frac{1}{d} \]

15. $I = 10 \text{ A}, \quad a = 10 \text{ cm} = 0.1 \text{ m}$
$\quad \quad r = OP = \frac{\sqrt{3}}{2} \times 0.1 \text{ m}$

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

$= \frac{10^{-7} \times 10 \times 1}{\sqrt{3}} \times 0.1 = 2 \times 10^{-5} = 1.154 \times 10^{-5} \text{ T} = 11.54 \mu T$
16. \( B_1 = \frac{\mu_0 l}{2 \pi d} \), \( B_2 = \frac{\mu_0 l}{4 \pi d} (2 \times \sin \theta) = \frac{\mu_0 l}{4 \pi d} \left( \frac{2 \times \ell}{d^2 + \frac{\ell^2}{4}} \right) = \frac{\mu_0 l}{4 \pi d} \left( \frac{2 \times \ell}{d^2 + \frac{\ell^2}{4}} \right) \)

\[ \Rightarrow \frac{B_1 - B_2}{2 \pi d} = \frac{\mu_0 l}{4 \pi d} \left( \frac{1}{2} \frac{1}{200} \right) \]

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

\[ \Rightarrow \ell = 3.92 \text{ d}^2 + \frac{3.92 \ell^2}{4} \]

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

17. As resistances vary as \( r \) & \( 2r \)

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

Now, \( \bar{B} \text{ due to } ADC = 2 \left[ \frac{\mu_0 l \times 2 \times 2 \times \sqrt{2}}{4 \pi 3a} \right] = \frac{2 \sqrt{2} \mu_0 l}{3 \pi a} \)

\( \bar{B} \text{ due to } ABC = 2 \left[ \frac{\mu_0 l \times 2 \times \sqrt{2}}{4 \pi 3a} \right] = \frac{2 \sqrt{2} \mu_0 l}{6 \pi a} \)

Now \( \bar{B} = \frac{2 \sqrt{2} \mu_0 l}{3 \pi a} - \frac{2 \sqrt{2} \mu_0 l}{6 \pi a} = \frac{\sqrt{2} \mu_0 l}{3 \pi a} \)

18. \( A_0 = \left( \frac{a^2}{16} + \frac{a^2}{16} \right) = \frac{5a^2}{4} = \frac{a \sqrt{5}}{4} \)

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

Magnetic field due to \( AB \)

\( B_{AB} = \frac{\mu_0 l}{4 \pi a} \times \frac{1}{2(a/4)} \left( \sin (90 - i) + \sin (90 - a) \right) \)

\[ = \frac{\mu_0 l}{4 \pi a} \times 2 \cos \theta = \frac{\mu_0 l}{4 \pi a} \times \frac{2 \times (a/2)}{a \sqrt{5}/4} = \frac{2 \mu_0 l}{\pi \sqrt{5}} \]

Magnetic field due to \( DC \)

\( B_{DC} = \frac{\mu_0 l}{4 \pi a} \times \frac{1}{2(3a/4)} \left( \sin (90^\circ - B) \right) \)

\[ = \frac{\mu_0 l}{4 \pi a} \times \frac{4 \times 2}{a \times 3a} \cos \beta = \frac{\mu_0 l}{4 \pi a} \times \frac{(a/2)}{a \times 3a} \left( \sqrt{13a^2/4} \right) = \frac{2 \mu_0 l}{\pi a 3 \sqrt{13}} \]

The magnetic field due to \( AD \) & \( BC \) are equal and appropriate hence cancel each other.

Hence, net magnetic field is

\[ \frac{2 \mu_0 l}{\pi \sqrt{5}} - \frac{2 \mu_0 l}{\pi a 3 \sqrt{13}} = \frac{2 \mu_0 l}{\pi a} \left[ \frac{1}{\sqrt{5}} - \frac{1}{3 \sqrt{13}} \right] \]
19. \( \vec{B} \) due to BC &
\( \vec{B} \) due to AD at Pt 'P' are equal \& 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 \( \vec{B} \) is along \( \odot \) \( B = \frac{\mu_0 I}{4\pi r} (\sin 90^\circ + \sin 90^\circ) \)
For AC \( \vec{B} \) \( \odot \) \( B = \frac{\mu_0 I}{4\pi r} (\sin 90^\circ + \sin 90^\circ) \)
For BD \( \vec{B} \) \( \odot \) \( B = \frac{\mu_0 I}{4\pi r} (\sin 90^\circ) \)
For DC \( \vec{B} \) \( \odot \) \( B = \frac{\mu_0 I}{4\pi r} (\sin 90^\circ) \)
\( \therefore \) Net \( \vec{B} = 0 \)

21. (a) \( \triangle ABC \) is Equilateral
\( AB = BC = CA = \ell/3 \)
Current = \( I \)
\[ AO = \frac{\sqrt{3}}{2} a = \frac{\sqrt{3} \times \ell}{2 \times 3} = \frac{\ell}{2\sqrt{3}} \]
\( \phi_1 = \phi_2 = 60^\circ \)
So, \( MO = \frac{\ell}{6\sqrt{3}} \) as AM : MO = 2 : 1
\( \vec{B} \) due to BC at \(<\)
\[ = \frac{\mu_0 I}{4\pi r} (\sin \phi_1 + \sin \phi_2) = \frac{\mu_0 I}{4\pi} \times \frac{\ell}{2\sqrt{3}} \times \frac{\sqrt{3}}{\sqrt{3}} = \frac{\mu_0 I \times 0}{2\pi \ell} \]
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
\[ = \frac{\mu_0 I}{4\pi \ell} \times \sqrt{2} = \frac{8\sqrt{2}\mu_0 I}{4\pi \ell} \]
Net \( \vec{B} = \frac{8\sqrt{2}\mu_0 I}{4\pi \ell} \times 4 = \frac{8\sqrt{2}\mu_0 I}{\pi \ell} \)

21. (a) \( \triangle ABC \) is Equilateral
\( AB = BC = CA = \ell/3 \)
Current = \( I \)
\[ AO = \frac{\sqrt{3}}{2} a = \frac{\sqrt{3} \times \ell}{2 \times 3} = \frac{\ell}{2\sqrt{3}} \]
\( \phi_1 = \phi_2 = 60^\circ \)
So, \( MO = \frac{\ell}{6\sqrt{3}} \) as AM : MO = 2 : 1
\( \vec{B} \) due to BC at \(<\)
\[ = \frac{\mu_0 I}{4\pi r} (\sin \phi_1 + \sin \phi_2) = \frac{\mu_0 I}{4\pi} \times \frac{\ell}{2\sqrt{3}} \times \frac{\sqrt{3}}{\sqrt{3}} = \frac{\mu_0 I \times 0}{2\pi \ell} \]
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
\[ = \frac{\mu_0 I}{4\pi \ell} \times \sqrt{2} = \frac{8\sqrt{2}\mu_0 I}{4\pi \ell} \]
Net \( \vec{B} = \frac{8\sqrt{2}\mu_0 I}{4\pi \ell} \times 4 = \frac{8\sqrt{2}\mu_0 I}{\pi \ell} \)