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DEPARTMENT: DENTISTRY

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COVID-19 HOLIDAY ASSIGNMENT

SECTION A

1. a. Explain with the aid of a diagram how you can produce a negatively charged sphere by method of induction.

Charging by Induction:

Electric charges can be obtained on an object without touching it, by a process called electrostatic induction.

Consider a negatively charged rubber rod brought near a neutral (uncharged) conducting sphere that is insulated so that there is no conducting path to ground as shown below. The repulsive force between the electrons in the rod and those in the sphere causes a redistribution of charges on the sphere so that some electrons move to the side of the sphere farthest away from the rod (fig. 1.3a). The region of the sphere nearest the negatively charged rod has an excess of positive charge because of the migration of electrons away from this location. If a grounded conducting wire is then connected to the sphere, as in (fig. 1.3b), some of the electrons leave the sphere and travel to the earth. If the wire to ground is then removed (fig 1.3c), the conducting sphere is left with an excess of induced positive charge.

Finally, when the rubber rod is removed from the vicinity of the sphere (fig. 1.3d), the induced positive charge remains on the ungrounded sphere and becomes uniformly distributed over the surface of the sphere.

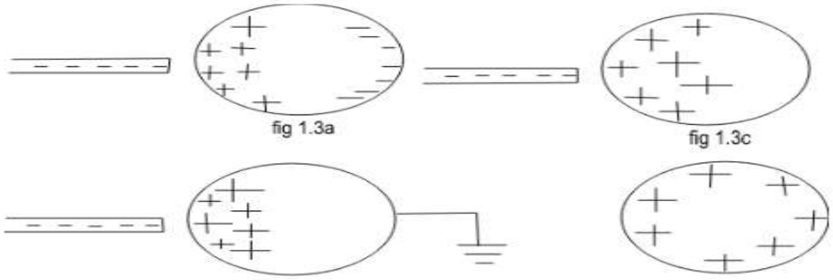


fig 1.3a fig 1.3c fig 1.3b fig 1.3d

1b.

16. $q_1 + q_2 = 5 \times 10^{-5} C$ —— (1)

$F = 1.0N$; $r = 2.0m$

Recall

$F = \frac{kq_1q_2}{r^2}$ —— (2)

$q_1 = (5 \times 10^{-5}) - q_2$ —— (3)

$1 = \frac{9 \times 10^9 (5 \times 10^5 - q_2) \times q_2}{2^2}$

Cross multiply

$4 = 9 \times 10^9 (5 \times 10^5 q_2 - q_2^2)$

$4 = 4.5 \times 10^5 q_2 - 9 \times 10^9 q_2^2$

collect like terms

$9 \times 10^9 q_2^2 - 4.5 \times 10^5 q_2 + 4 = 0$

Solving the quadratic Equation

$\therefore q = 3.84 \times 10^{-5}$ or $q = 1.16 \times 10^{-5}$

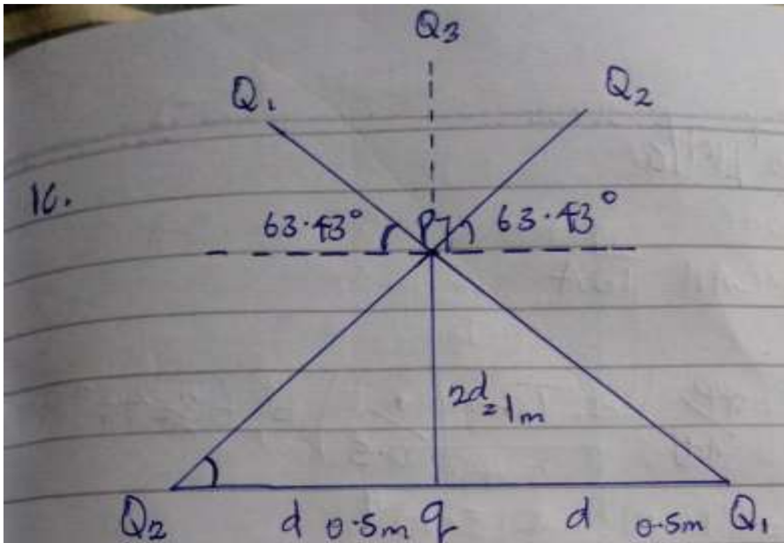
The values of q_1 and q_2 are;

$q_1 = 3.84 \times 10^{-5}$ and $q_2 = 1.16 \times 10^{-5}$

or

$q_1 = 1.16 \times 10^{-5}$ and $q_2 = 3.84 \times 10^{-5}$

1c.



From Pythagoras theorem

$Q_2P = \sqrt{1^2 + 0.5^2} = 1.12m$, $Q_2P = Q_1P$

$Q_1 = Q_2 = 8\mu C = 8 \times 10^{-6} C$

$E_p = 0$

$\vec{E_p} = \vec{E_1} + \vec{E_2} + \vec{E_3}$

$E_p = \sqrt{(\Sigma F_x)^2 + (\Sigma F_y)^2}$

$F_1 = \frac{kQ_1}{(r_1p)^2} = \frac{(9 \times 10^9) \times (8 \times 10^{-6})}{1.12^2}$

$= \frac{7.2 \times 10^4}{1.25} = 5.76 \times 10^4 \, N/C$

$F_2 = F_1 = 5.76 \times 10^4 \, N/C$

$F_3 = \frac{kQ_3}{(r_3P)^2} = \frac{(9 \times 10^9) \times (q)}{(1)^2}$

$= \underline{9\times10^9 q} \ N/C$

Using SOH CAH TOA

$\theta_1 = \theta_2$.

$\theta_1 = Tan^{-1}\left(\frac{opp}{Adj}\right) = Tan^{-1}\left(\frac{1}{0.5}\right) = 63.44°$

Vector	Angle(θ°)	X-component	Y-component
$F_1 = 5.76 \times 10^4 N/C$	$63.44°$	$F_1 \cos\theta$ $= -2.58\times10^4 N/C$	$F_1 \sin\theta$ $= 5.15\times10^4 N/C$
$F_2 = 5.76 \times 10^4 N/C$	$63.44°$	$F_2 \cos\theta$ $= +2.58\times10^4 N/C$	$F_2 \sin\theta$ $= 5.15\times10^4 N/C$
$F_3 = 9\times10^9 q \ N/C$	$90°$	$F_3 \cos\theta$ $= 0 N/C$	$= F_3 \sin\theta$ $= 9\times10^9 q \ N/C$
		$\Sigma f_x = 0 N/C$	$\Sigma f_y = (1.03\times10^5 + 9\times10^9 q) N/C$

The Magnitude of the resultant electric field at point P is

$$E_p = \sqrt{\Sigma f_x^2 + \Sigma f_y^2}$$

$$E_p = \sqrt{(0)^2 + (1.03\times10^5 + 9\times10^9 q)^2}$$

$$E_p = \sqrt{(1.03\times10^5 + 9\times10^9 q)^2}$$

$$E_p = 0$$

$$0 = 1.03\times10^5 + 9\times10^9 q$$

Collect like terms

$$-1.03\times10^5 = 9\times10^9 q$$

$$q = \frac{-1.03\times10^5}{9\times10^9}$$

$$q = -1.14\times10^{-5} C$$

$$\simeq -11.4 \mu C$$

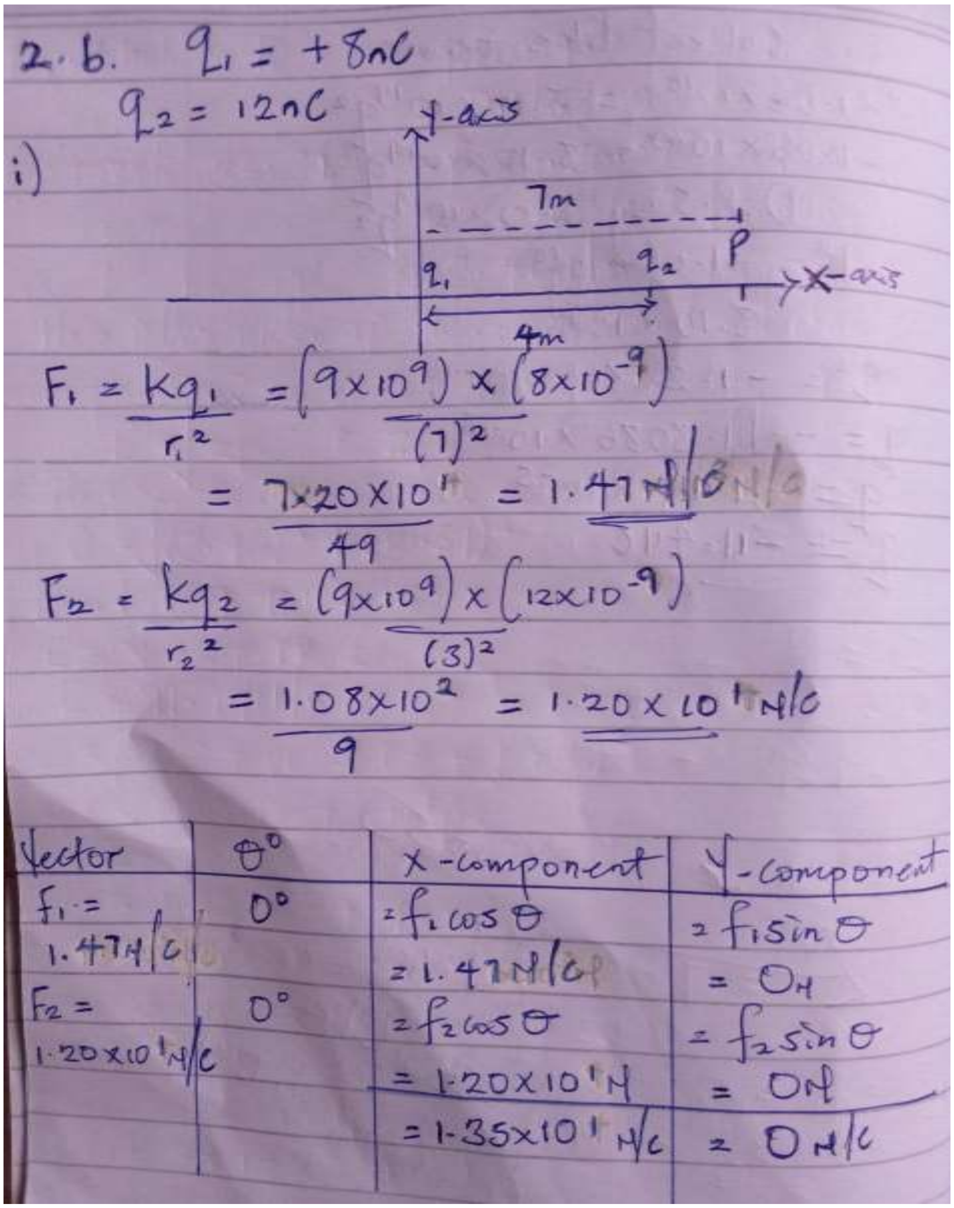
2a. ELECTRIC FIELD

An electric field is a region of space in which an electric charge will experience an electric force.

ELECTRIC FEILD ITENSITY

electric field strength (intensity) E, can be defined as the force per unit charge.It is measured in Newton per coulomb.

2b. i. & ii.



2.b. $q_1 = +8nC$

$q_2 = 12nC$

i)

$F_1 = \frac{kq_1}{r_1^2} = \frac{(9\times10^9)\times(8\times10^{-9})}{(7)^2}$

$= \frac{7\times20\times10^{1}}{49} = 1.47N/C$

$F_2 = \frac{kq_2}{r_2^2} = \frac{(9\times10^9)\times(12\times10^{-9})}{(3)^2}$

$= \frac{1.08\times10^2}{9} = 1.20\times10^1 N/C$

Vector	θ°	x-component	y-component
$f_1 =$ 1.47N/C	0°	$= f_1\cos\theta$ = 1.47N/C	$= f_1\sin\theta$ = 0N
$F_2 =$ 1.20×10^1N/C	0°	$= f_2\cos\theta$ = 1.20×10^1N	$= f_2\sin\theta$ = 0N
		$= 1.35\times10^1$ N/C	= 0 N/C

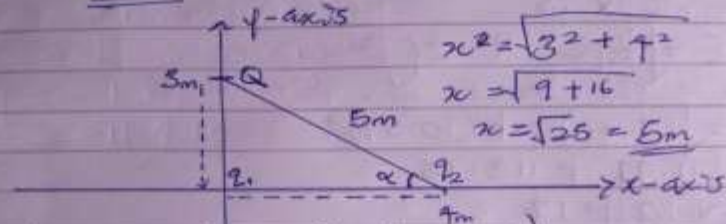
The magnitude of the resultant electric field at point P is

$$E = \sqrt{\sum f_x^2 + \sum f_y^2}$$

$$E = \sqrt{(1.35 \times 10^1)^2 + (0)^2}$$

$$E = 1.35 \times 10^1 \, N/C \simeq 13.5 \, N/C$$

ii)



$$x^2 = \sqrt{3^2 + 4^2}$$

$$x = \sqrt{9 + 16}$$

$$x = \sqrt{25} = 5m$$

$$F_1 = \frac{kq_1}{r_1^2} = \frac{(9 \times 10^9) \times (8 \times 10^{-9})}{(3)^2}$$

$$= \frac{7.20 \times 10^1}{9} = 8.0 \, N/C$$

$$F_2 = \frac{kq_2}{r_2^2} = \frac{(9 \times 10^9) \times (12 \times 10^{-9})}{(5)^2}$$

$$= \frac{1.08 \times 10^2}{25} = 4.32 \, N/C$$

using SOH CAH TOA

$$\sin\alpha = \frac{opp}{Hyp}, \quad \alpha = \sin^{-1}\left(\frac{3}{5}\right) = 36.87°$$

Vector	Angle = θ°	X-component	Y-component
$F_1 = 8.0 \, N/C$	90°	$= F_1 \cos 90°$ $= 0 \, N/C$	$= F_1 \sin 90°$ $= 8.0 \, N/C$
$F_2 = 4.32 \, N/C$	36.87°	$= F_2 \sin 36.87°$ $= 3.46 \, N/C$	$= F_2 \sin 36.87$ $= 2.59 \, N/C$
		$\sum f_x = 3.46 \, N/C$	$\sum f_y = 10.59 \, N/C$

The Magnitude of the resultant electric field at point Q is

$$E = \sqrt{\sum f_x^2 + \sum f_y^2}$$

$$E = \sqrt{(3.46)^2 + (10.59)^2}$$

$$E = \sqrt{11.97 + 112.15}$$

$$E = \sqrt{124.12}$$

$$E = 11.14 \, N/C$$

SECTION B

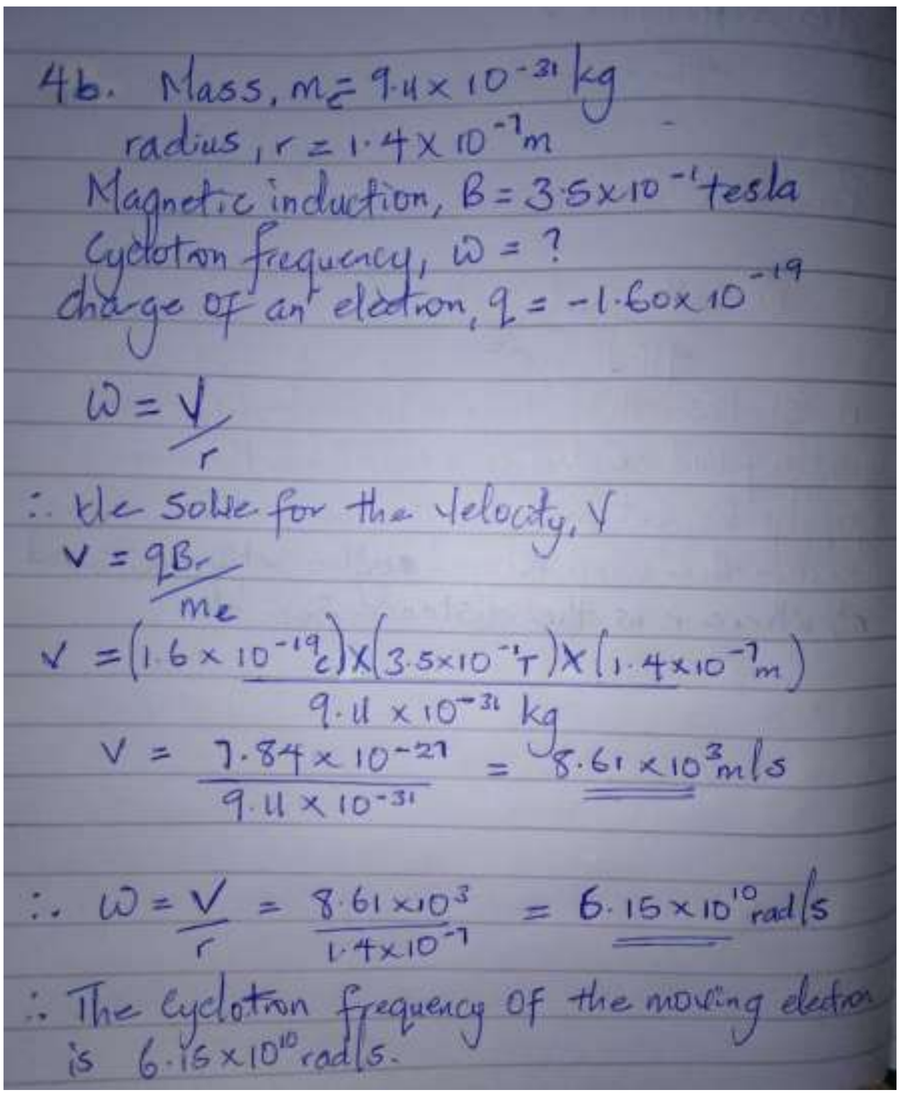
4a. Magnetic flux

The magnetic flux is defined as the strength of magnetic field represented by lines of force. It is usually represented by the symbol ϕ. It is expressed mathematically as;

$$\phi = B.d\,A$$

$$\phi = BA\cos 0^0$$

4b.i.



4b. Mass, $m_e = 9.11 \times 10^{-31}$ kg

radius, $r = 1.4 \times 10^{-7}$ m

Magnetic induction, $B = 3.5 \times 10^{-1}$ tesla

Cyclotron frequency, $\omega = ?$

charge of an electron, $q = -1.60 \times 10^{-19}$

$\omega = \frac{V}{r}$

∴ We solve for the velocity, V

$V = \frac{qBr}{m_e}$

$V = \frac{(1.6 \times 10^{-19} c) \times (3.5 \times 10^{-1} T) \times (1.4 \times 10^{-7} m)}{9.11 \times 10^{-31} kg}$

$V = \frac{7.84 \times 10^{-27}}{9.11 \times 10^{-31}} = 8.61 \times 10^3 m/s$

∴ $\omega = \frac{V}{r} = \frac{8.61 \times 10^3}{1.4 \times 10^{-7}} = 6.15 \times 10^{10} rad/s$

∴ The cyclotron frequency of the moving electron is 6.15×10^{10} rad/s.

ii. we were given the following parameters:

mass of the electron, m_e= 9.11×10^-31

radius of circular path, r = 1.4×10^-7

magnetic field, B= 3.5×10^-1

The answer above means that the particle (electron) completes 6.15×10^{10}radian in 1 second.

The Cyclotron frequency is also reffered to as the angular speed. It is called the cyclotron frequency because the charged particle circulates at this angular frequency or speed in the type of accelerator called cyclotron.

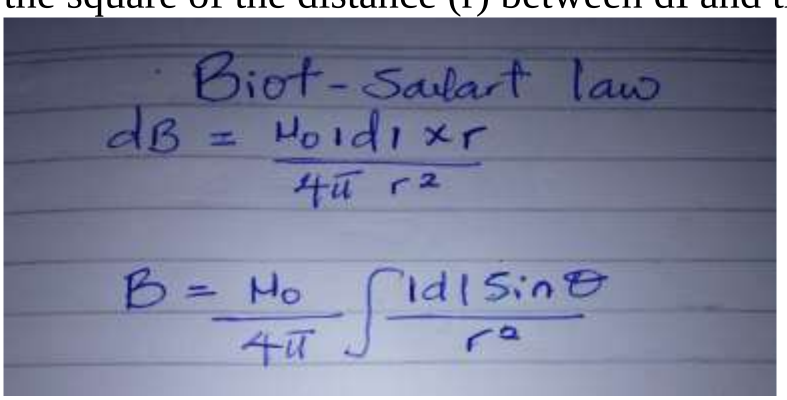
The cyclotron frequency is the ratio between the velocity(v) of the particle and the radius(r) of the circular path. In order to get the cyclotron frequency I had to solve for the velocity of the electron, from the known values of the mass(m_e), magnetic induction(B) and the charge of the electron(q), using the equation;

V= qBr/ m_e and then inputing the value of V into the equation;

w= v/r ,where w is the cyclotron frequency.

5a. BIOT-SAVART LAW

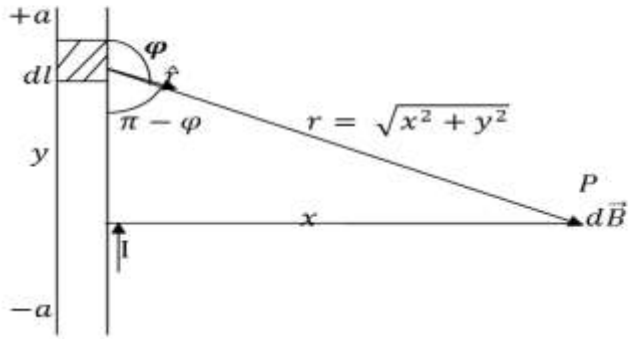
It states that the magnitudeof the magnetic field created at a point by the current is directly proportional to the current (I) and the magnitude of the length element (dI) and inversely proportional to the square of the distance (r) between dI and the point(P).



Where u_0 is a constant, permeability of free space.

5b. Magnetic Field of a Straight Current Carrying Conductor

A section of a Straight Current Carrying Conductor



Applying the Biot-Savart law, we find the magnitude of the field d B

$$B = \frac{\mu_o I}{4\pi}\int_{-a}^{a} \frac{dl\sin\Phi}{r^2}$$

$$\sin(\pi - \Phi) = \sin\Theta$$

$$\therefore B = \frac{\mu_o I}{4\pi}\int_{-a}^{a} \frac{dl\sin(\pi - \Phi)}{r^2}$$

From diagram, $r^2 = x^2 + y^2$ (Pythagoras theorem)

$$B = \frac{\mu_o I}{4\pi}\int_{-a}^{a} \frac{dl\sin(\pi - \Phi)}{x^2 + y^2} \quad \ldots \quad (\ast)$$

$$\text{But } \sin(\pi - \Phi) = \frac{x}{\sqrt{x^2 + y^2}} = \frac{x}{(x^2 + y^2)^{1/2}} \quad \ldots \quad (\ast\ \ast)$$

Substituting (* *) into (*), we have

$$B = \frac{\mu_o I}{4\pi}\int_{-a}^{a} dl \frac{x}{(x^2 + y^2)(x^2 + y^2)^{1/2}}$$

$$B = \frac{\mu_o I}{4\pi}\int_{-a}^{a} dl \frac{x}{(x^2 + y^2)^{3/2}}$$

Recall $dl = dy$

$$B = \frac{\mu_o I}{4\pi}\int_{-a}^{a} \frac{x}{(x^2 + y^2)^{3/2}} dy$$

$$B = \frac{\mu_o I x}{4\pi}\int_{-a}^{a} \frac{1}{(x^2 + y^2)^{3/2}} dy \quad \ldots \quad (\ast\ \ast\ \ast)$$

Using special integrals:

$$\int \frac{dy}{(x^2 + y^2)^{3/2}} = \frac{1}{x^2}\frac{y}{(x^2 + y^2)^{1/2}}$$

Equation (* * *) therefore becomes

$$B = \frac{\mu_o I x}{4\pi}\left[\frac{y}{x^2(x^2 + y^2)^{1/2}}\right]_{-a}^{a}$$

$$B = \frac{\mu_o I x}{4\pi}\left(\frac{2a}{x^2(x^2 + a^2)^{1/2}}\right)$$

$$B = \frac{\mu_o I}{4\pi x}\left(\frac{2a}{(x^2 + a^2)^{1/2}}\right)$$

When the length 2a of the conductor is very great in comparison to its distance x from point P, we consider it infinitely long. That is, when a is much largerthan x,

$$(x^2 + a^2)^{1/2} \cong a, \text{ as } a \to \infty$$

$$\therefore B = \frac{\mu_o I}{2\pi x}$$

In a physical situation, we have axial symmetry about the y- axis. Thus, at all points in a circle of radius r, around the conductor, the magnitude of B is

$$B = \frac{\mu_o I}{2\pi r} \qquad \ldots \qquad (\#)$$

Equation (#) defines the magnitude of the magnetic field of flux density B near a long, straight current carrying conductor.