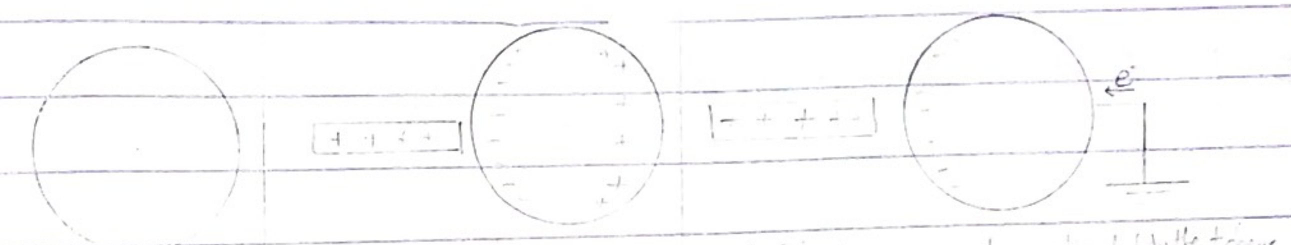
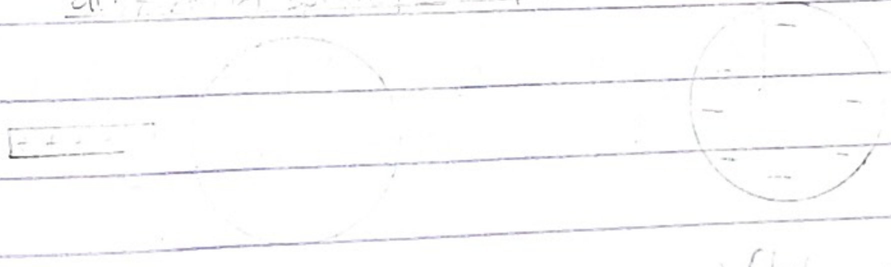
1.

a. A positively charged rod is brought near a neutral sphere which is insulated so there is no connection to ground. The electrons in the sphere migrate towards the side closest to the positively charged rod, so the region farthest from the rod has an excess of positive charge, the sphere is polarized.

When a grounded conducting wire is connected to the sphere, electrons enter the sphere, attracted to the +vely charged rod, and the +ve charges in the sphere. The wire is removed, leaving the sphere with an excess of negative charge. Finally, the rod is removed, the induced negative charge becoming uniformly distributed over the sphere.



ai) [illegible] | aii) Sphere becomes polarised | aiii) Electrons enter sphere, attracted to the +charge



aiv) [illegible] charge | av) Electrons redistribute [illegible]

b. Let the spheres be q_1 & q_2

$F_{12} = 1.0N$, $q_1 + q_2 = 5.0 \times 10^{-5} C$

$r = 2.0m$, $r^2 = 4m^2$

From Coulomb's Law; $F = \frac{kq_1q_2}{r^2}$

$$\frac{Fr^2}{k} = q_1q_2 = \frac{1 \times 4}{9 \times 10^9} = 4.44 \times 10^{-10} C^2$$

6.

a. In an electric guitar, the coil [the pickup coil] is placed near the vibrating guitar string which is made up of a metal that can be magnetised. A permanent magnet inside the coil magnetises the portion of the string nearest the coil. When the string vibrates at some frequency, its magnetised segment produces a changing magnetic flux through the coil. The changing flux induces an emf in the coil that is fed to an amplifier. The output of the amplifier is sent to the loudspeaker, which produces the sound waves we hear.

b. $N = 300$ $A = (0.1)^2 = 0.01 m^2$ $|e| = ?$

$R = 2.0 \Omega$ $\Delta \phi_B = 10T$ $\Delta t = 0.5s$

i. Induced emf $|e| = \frac{N \Delta \phi}{\Delta t} = \frac{300 \times 0.01 \times 10}{0.5} = 60V$

ii. Induced current $= \frac{|e|}{R} = \frac{60}{2} = 30A$

c. $A = 0.05 \times 0.08 = 4 \times 10^{-3} m^2$ $I = 0.1A$

$N = 75$ $R = 8\Omega$ $\Delta \phi_B = ?$ $\Delta t = ?$

$I = \frac{|e|}{R}$ $|e| = 8 \times 0.1A = 0.8V$

$|e| = \frac{N \Delta B}{\Delta t}$ $\therefore \frac{\Delta B}{\Delta t} = \frac{0.8}{75 \times 4 \times 10^{-3}} = 2.7 T/s$

3.

a. i. Volume charge density, $\rho = \frac{dQ}{dv} \rightarrow dQ = \rho\, dv$

ii. Surface charge density, $\sigma = \frac{dQ}{dA} \rightarrow dQ = \sigma dA$

iii. Linear charge density, $\lambda = \frac{dQ}{dL} \rightarrow dQ = \lambda dL$

b. In moving a charge from a point A to another point B along an arbitrary path in an electric field, an external force, $F = -q_0 E$ must act to counter the force, $F = q_0 E$, which the field exerts on the charge.

Work done on the charge dW is given as,

$$dW = F \cdot dL \quad \text{--- (1)}$$

$$dW = -q_0 E\, dL \quad \text{--- (2)} \qquad [\because F = -q_0 E]$$

Total work done in moving test charge from A to B;

$$W(A \rightarrow B)_{Ag} = -q_0 \int_A^B E\, dL \quad \text{--- (3)}$$

From the definition of potential difference;

$$V_B - V_A = \frac{W(A \rightarrow B)_{Ag}}{q_0} \quad \text{--- (4)}$$

Putting (4) in (3);

$$V_B - V_A = -\int_A^B E\, dL$$

c. Let the point where $V = 0$ be x.

$\therefore r_1 = |x|,\ r_2 = |4 - x|$ $\qquad V = K\left[\frac{Q_1}{r_1} + \frac{Q_2}{r_2}\right] = 0$

$$\frac{Q_1}{r_1} = -\frac{Q_2}{r_2}, \quad \frac{10 \times 10^{-6}}{|x|} = \frac{-(-2 \times 10^{-6})}{|4 - x|}$$

$$\frac{2 \times 10^{-6}|x|}{2 \times 10^{-6}} = \frac{10 \times 10^{-6}|4 - x|}{2 \times 10^{-6}}; \quad |x| = 5|4 - x|$$

5.

a. The Biot-Savart Law asserts that, the magnetic intensity at any point due to a steady current in an infinitely long wire is directly proportional to the current, and inversely proportional to the square of the distance from each point to the wire.

$$d\vec{B} = \frac{\mu_0}{4\pi} \frac{I\, d\vec{l} \times \hat{r}}{r^2}$$

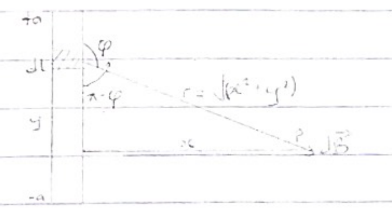
μ_0 - permeability of free space

r - distance from dl to P

The magnitude of the total magnetic field is,

$$B = \frac{\mu_0}{4\pi} \int \frac{I\,dl \sin\theta}{r^2}.$$

b.



← A section of a straight current carrying conductor

Applying the Biot-Savart law, the magnitude of field $d\vec{B}$ is,

$$B = \frac{\mu_0 I}{4\pi} \int_{-a}^{a} \frac{dl \sin\theta}{r^2} \qquad B = \frac{\mu_0 I}{4\pi} \int_{-a}^{a} \frac{dl \sin(\pi-\varphi)}{r^2} \quad \left[\sin\theta = \sin(\pi-\varphi)\right]$$

From the diagram, $r^2 = x^2 + y^2$ [Pythagoras theorem]

$$B = \frac{\mu_0 I}{4\pi} \int_{-a}^{a} \frac{dl \sin(\pi-\varphi)}{x^2+y^2}$$

$$B = \frac{\mu_0 I}{4\pi} \int_{-a}^{a} dl \frac{x}{(x^2+y^2)(x^2+y^2)^{1/2}} = \frac{\mu_0 I}{4\pi} \int_{-a}^{a} dl \frac{x}{(x^2+y^2)^{3/2}} \quad \left[\sin\theta = \frac{x}{\sqrt{(x^2+y^2)}} = \sin(\pi-\varphi)\right]$$

$$B = \frac{\mu_0 I x}{4\pi} \int_{-a}^{a} \frac{1}{(x^2+y^2)^{3/2}} dy \quad [dy = dl]$$

Using special integrals;

$$B = \frac{\mu_0 I x}{4\pi} \left[\frac{y}{x^2 (x^2+y^2)^{1/2}}\right]_{-a}^{a} = \frac{\mu_0 I}{4\pi x} \left(\frac{2a}{(x^2+a^2)^{1/2}}\right)$$

When length $2a$ of the conductor is >> than distance x from point P, it is considered infinitely long $(a >> x)$. $\therefore (x^2+a^2)^{1/2} \cong a$, as $a \to \infty$ $\therefore B = \frac{\mu_0 I}{2\pi x}$. At all points in a circle of radius r around the conductor: $B = \frac{\mu_0 I}{}$