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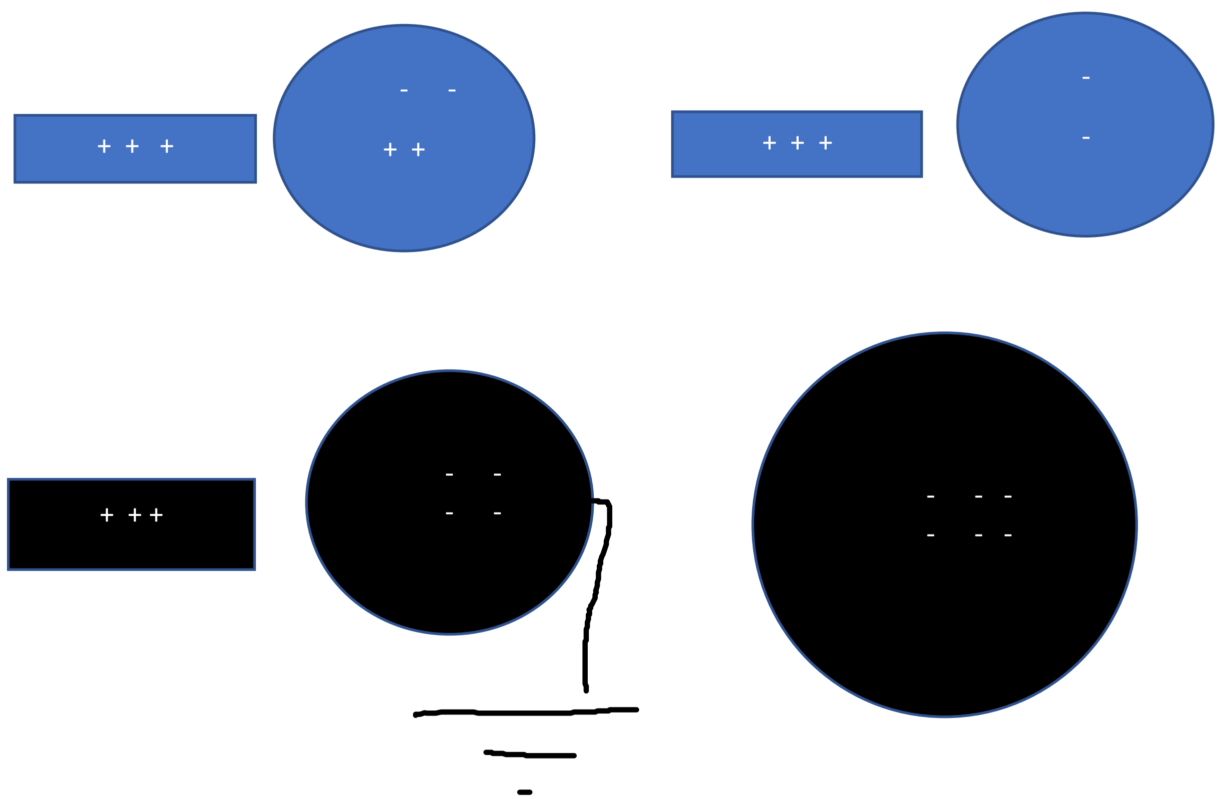
1a. Charging by Induction:

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

Consider a positively 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 protons in the rod and those in the sphere causes a redistribution of charges on the sphere so that some protons move to the side of the sphere farthest away from the rod (fig. 1.3a). The region of the sphere nearest the positively charged rod has an excess of negative charge because of the migration of protons away from this location. If a grounded conducting wire is then connected to the sphere, as in (fig. 1.3b), some of the protons 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 negative charge.

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

Diagram:



$k = ...$

1b. $q_1 + q_2 = 5 \times 10^{-5} C$

$f = 1N$

$d = 2M$

Calculate the charge on each sphere

Recall that

$k = 9 \times 10^9$

$$f = \frac{k q_1 q_2}{r^2}$$

$$1 = \frac{9 \times 10^9 (q_1 \, q_2 \, 5 \times 10^{-5})}{2^2}$$

$4 = 9 \times 10^9 \times 5 \times 10^{-5} q_1 + 9 \times 10^9 q^2$

$4 = 4.5 \times 10^5 q_1 + 9 \times 10^9 q^2$

it is a quadratic equation

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

$q_1 = 0.0000111C$

$q_2 = 0.000038C$

$\simeq q_1 = 1.11 \times 10^{-5} C$

$\simeq q_2 = 3.8 \times 10^{-5} C$

1C. $Q_1 = Q_2 = 84C$

$d = 0.5m$

determine Q if electric field at a point P is zero

Tan θ = opp/adj

Tan $\theta = 1/0.5 = 2$

$\theta = \tan^{-1}(2)$

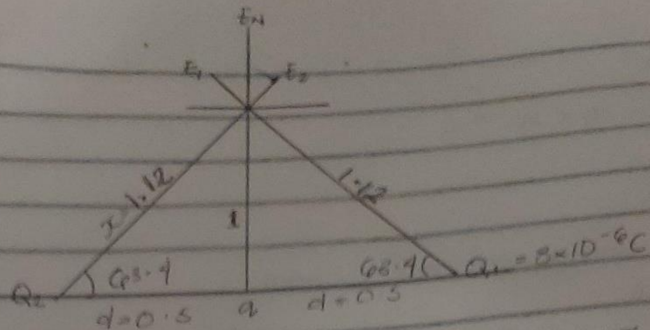
$\theta = 63.4$

$x^2 = 1^2 + 0.6^2$

$\sqrt{x^2} = \sqrt{1.25}$

$x = \sqrt{1.25}$

$x = 1.12$



$E_1 = \frac{kq}{r_1^2} = \frac{9\times10^9 \times 8\times10^{-6}}{(1.12)^2} = 5737.795918$

$E_2 = \frac{kq_2}{r^2} = \frac{9\times10^9\times8\times10^{-6}}{(1.12)^2} = 5787.795918$

$E_q = \frac{kq}{r^2} = \frac{9\times10^9 \times q}{1} = 9\times10^9 q$

	Angle	x-Comp	y-Comp
$E_1 = 5739.795918$	$63.4°$	$E_1 \times \cos\theta$	
	E_1	-2570.065785	5132.262839
$E_2 = 5739.795918$	$63.4°$	2570.045785	5132.262839
$E_q = 9\times10^9 q$	$90°$	$E_q\cos\theta = 0$	$9\times10^9 q$
		$\mathcal{E}_x = 0$	$\mathcal{E}_y = 10264.52568$

Magnitude $= \sqrt{(\mathcal{E}_x)^2 + (\mathcal{E}_y)^2}$

$E_q = \sqrt{(0)^2 + (10264.52568)^x}$

Since $\mathcal{E} = 0$

$0 = 9\times10^9 q + 10264.52565$

Making q subject of formulae

$q = \frac{-10264.52568}{9\times10^9}$

$q = 1.140502853\times10^{-6}$

$\simeq q = 11.44C$

2. Electric Field	Electric Field Intensity
It is a region of space in which an electric charge will experience an electric force	It is the force per unit charge

28. $q_1 = 8nC$ at Origin, $q_2 = 12nC$ on x axis at $x = 4m$
i) net electric field at point P on the x-axis at $x = 7m$
ii) electric field at a point Q on the y axis at $y = 3m$ due to the charges

i)

$$E_1 = \frac{kQ_1}{r^2} = \frac{9\times10^9 \times 8\times10^{-9}}{7^2} = 1.469\ N/C \approx 1.5N/C$$

$$E_2 = \frac{kQ_2}{r^2} = \frac{9\times10^9 \times 12\times10^{-9}}{7^2} = 12N/C$$

$$E_{net} = \vec{E_1} + \vec{E_2} = 1.5 + 12 = 13.5N/C$$

ii) E at point Q on the y axis at $y = 3m$ due to charge

$$C^2 = a^2 + b^2$$

$$C^2 = 4^2 + 3^2$$

$$C^2 = 16 + 9$$

$$C^2 = 25$$

$$C = \sqrt{25} = 5$$

$$E_1 = \frac{kQ_1}{r^2} = \frac{9\times10^9 \times 8\times10^{-9}}{3^2} = \vec{E_1} = 8N/C$$

$$E_2 = \frac{kQ_2}{r^2} = \frac{9\times10^9 \times 12\times10^{-9}}{5^2} = 4.32\ N/C$$

Vector	Angle	x - comp	y = comp
$E_1 = 8N/C$	$90°$	$0N/C$	$8N/C$
$E_2 = 4.32\ N/C$	36.87	$-3.45\ N/C$	$2.59\ N/C$
		$E_{fx} = -3.45N/C$	$E_{fy} = 10.59N/C$

$$E_{net} = \sqrt{E_{fx}^2 + E_{fy}^2}$$

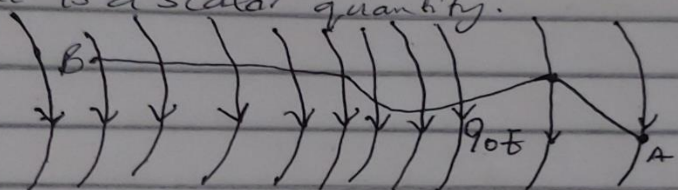
5a. Volume charge density, $\rho = \frac{dQ}{dV} \rightarrow dQ = \rho dV$

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

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

5b. Electric Potential Difference

The electric potential difference between two points in an electric field can be defined as the work done per unit charge against electrical forces when a charge is transported from one point to the other. It is measured in Volt (v) or Joules per Columb (J/C). Electric potential difference is a scalar quantity.



due to a single ~~potential~~ point charge

$$V_B - V_A = \frac{Q}{4\pi\varepsilon_0}\left[\frac{1}{r_B} - \frac{1}{r_A}\right]$$

where Q = point charge

r_B = distance of Q to point B

r_A = distance of Q to point A

V = Electric potential

* due to several point charges

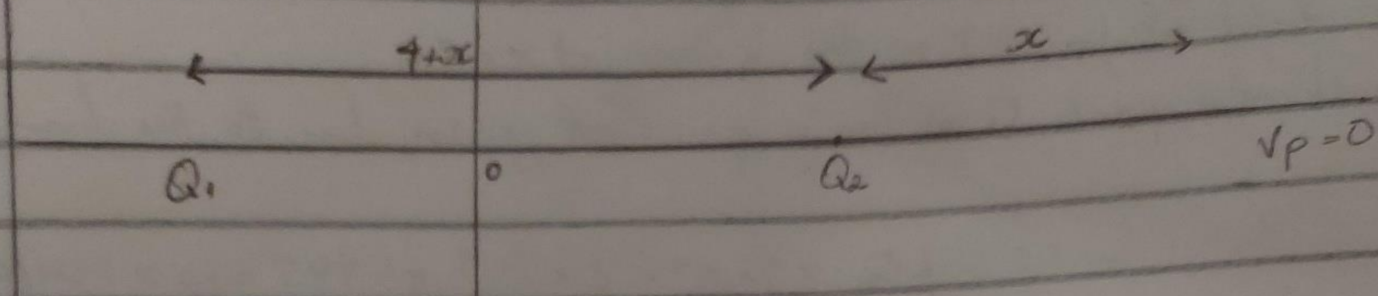
$$V_P = \frac{1}{4\pi\varepsilon_0}\left[\frac{Q_1}{r} + \frac{Q_2}{r_2}\right]$$

where V = electric potential

Q = point charge

r = distance of Q

3C



$r_1 = 4 + x \quad , \quad Q_1 = 10 \times 10^{-6}\, C$

$r_2 = x \qquad\qquad Q_2 = -2 \times 10^{-6}\, C$

$$V_p = k \left[\frac{Q_1}{r_1} + \frac{Q_2}{r_2} \right]$$

$$0 = 9 \times 10^9 \left[\frac{10 \times 10^{-6} x + (4+x)(-2 \times 10^{-6} x)}{x(4+x)} \right]$$

$$0 = 9 \times 10^9 \left[\frac{8 \times 10^{-6} x - 8 \times 10^{-6}}{x(4+x)} \right]$$

$$0 = 7.2 \times 10^4 x - 7.2 \times 10^4$$

$$\frac{\cancel{+7.2 \times 10^4}\, x}{\cancel{+7.2 \times 10^4}} = \frac{7.2 \times 10^4}{7.2 \times 10^4}$$

$r_2 = x_1 = 1m$

$r_1 = 4 + x = 4 + 1$

$r_1 = 5$

Positions are 1m and 5m

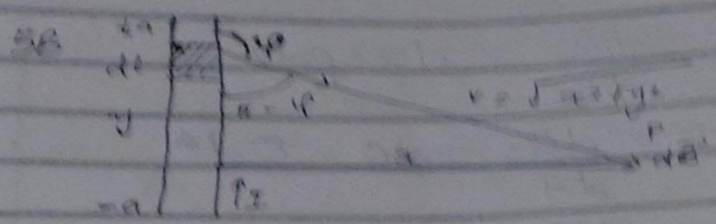
5a.Biot-savart law states that the magnetic field is directly proportional to the product permeability of free space (μ), the current (I), the change in length, the radius and inversely proportional to square of radius (r2). It can be represented mathematically by

$$\vec{dB} = \frac{\mu_0 I dl \times r}{4\pi r^2}$$

where μ_0 a constant is called permeability of free space

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

The unit of B is weber / metre square.



Magnitude of the field B

$$B = \frac{\mu_0 I}{4\pi}\int_{-a}^{a} \frac{dl \sin\varphi}{r^2}$$

$$\sin(\pi - \varphi) = \sin\theta$$

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

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

$$B = \frac{\mu_0 I}{4\pi}\int_{-a}^{a} \frac{dl \sin(\pi-\varphi)}{x^2+y^2} \quad \ldots \text{①}$$

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

Substituting eqn ② into eqn ①

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

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

Recall $dl = dy$

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

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

Using special

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

$$B = \frac{\mu_0 I}{4\pi x}\left(\frac{2a}{(x^2+a^2)^{1/2}}\right); \quad (x^2+a^2)^{1/2} = a = \infty$$

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