1. (a) Calculate the value of two equal charges if they repel one another with a force of 0.1 N when situated 50 cm apart in a vacuum.
   (b) What would be the size of the charges if they were situated in an insulating liquid whose permittivity was ten times that of a vacuum?

<table>
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Data:

(a)

$q_1 = q$

$q_2 = q$

$F = 0.1$

$r = 50\,cm = 0.5\,m$

(b)

$q_1 = q$

$q_2 = q$

$\epsilon_r = 10\ \epsilon_0$

SOLUTION:

Coulomb force given by:

$$F = \frac{k\ q_1 q_1}{r^2}$$

$$F = \frac{k\ q\ \ q}{r^2}$$

$$0.1 = \frac{9 \times 10^9\ \ q^2}{(0.5)^2}$$

$$9 \times 10^9\ \ q^2 = 0.1 \times (0.5)^2$$

$$q^2 = \frac{0.1 \times (0.5)^2}{9 \times 10^9}$$

$$q^2 = 2.77 \times 10^{-12}$$

Squaring both the sides

$$\sqrt{q^2} = \sqrt{2.77 \times 10^{-12}}$$

$$q = 1.66 \times 10^{-6}\ C$$

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(b)

$$F' = \frac{F}{10}$$

$$F' = \frac{k\ q_1 q_1}{r^2}$$

$$F' = \frac{k\ q\ \ q}{r^2}$$

$$\frac{F}{10} = \frac{k\ q^2}{r^2}$$

$$\frac{0.1}{10} = \frac{9 \times 10^9\ \ q^2}{(0.5)^2}$$

$$10 \times 9 \times 10^9\ \ q^2 = 0.1 \times (0.5)^2$$

$$q^2 = \frac{0.1 \times (0.5)^2}{10 \times 9 \times 10^9}$$

$$q^2 = 2.77 \times 10^{-13}$$

$$\sqrt{q^2} = \sqrt{2.77 \times 10^{-13}}$$

$$q = 5.266 \times 10^{-7}\ C$$

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</table>

2 How far apart must two protons be if the magnitude of the electrostatic force acting on either one due to the other is equal to the magnitude of the gravitational force on a proton at Earth's surface?

(Mass of proton = 1.67×10^{27} kg, charge of proton = 1.6×10^{-19} C)

Data:

(a)

$q_1 = 1.6 \times 10^{-19}$ C

$q_2 = 1.6 \times 10^{-19}$ C

$m = 1.67 \times 10^{-27}$ kg

$r = ?$

SOLUTION:

Electric force = weight of the object

$$F_e = W$$

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

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

$$\frac{9 \times 10^9 \times 1.6 \times 10^{-19} \times 1.6 \times 10^{-19}}{1.67 \times 10^{27} \times 9.8} = r^2$$

$$\frac{2.304 \times 10^{-28}}{1.6366 \times 10^{-26}} = r^2$$

$$0.01407 = r^2$$

$$\sqrt{0.01407} = \sqrt{r^2}$$

$$0.118\ m = r$$

3 An electron of charge 1.6×10^{-19} C is situated in a uniform electric field of intensity 1200-volt cm. Find the force on it, its acceleration, and the time it takes to travel 2 cm from rest (electronic mass, m, = 9.1×10^{31} kg).

Data:

$q = 1.6 \times 10^{-19}$ C

$m = 9.1 \times 10^{-31}$ kg

$E = 1200 \frac{\text{volt}}{cm}$

$E = 1200 \frac{\text{volt}}{10^{-2}\ m}$

$E = 120000 \frac{\text{volt}}{m}$

$S = 2\ cm = 0.02\ m$

$F = ?$

$a = ?$

$t = ?$

SOLUTION:

$$F_e = q\ E$$

$$F_e = 1.6 \times 10^{-19} \times 120000$$

$$F_e = 1.92 \times 10^{-14}\ N$$

$$\frac{F}{m} = a$$

$$\frac{1.92 \times 10^{-14}}{9.1 \times 10^{-31}} = a$$

$$2.109 \times 10^{16}\ m/s^2 = a$$

$$S = v_i\, t + \frac{1}{2}\, a\, t^2$$

$$0.02 = (0 \times t) + \frac{1}{2}\,(2.109 \times 10^{16})\, t^2$$

$$0.02 = 0 + 1.0545 \times 10^{16} \times t^2$$

$$\frac{0.02}{1.0545 \times 10^{16}} = t^2$$

$$1.8958 \times 10^{-18} = t^2$$

$$\sqrt{1.8958 \times 10^{-18}} = \sqrt{t^2}$$

$$1.37 \times 10^{-9}\ s = t$$

4 **An alpha particle (the nucleus of a helium atom) has a mass of 6.64×10^{-27} kg and a charge of 2e. What are the (a) magnitude and (b) direction of the electric field that will balance the gravitational force on the particle?**

Data:

$q = 2\,e$

$q = 2 \times 1.6 \times 10^{-19}\,C = 3.2 \times 10^{-19}\,C$

$m = 6.64 \times 10^{-27}$ kg

$E = ?$

SOLUTION:

$$Electric\ force = weight$$

$$F_e = W$$

$$q\,E = mg$$

$$E = \frac{mg}{q}$$

$$E = \frac{6.64 \times 10^{-27} \times 9.8}{3.2 \times 10^{-19}}$$

$$E = 2.033 \times 10^{-7}\ N/C$$

Electric field is directed upward

5 **A proton and an electron form two corners of an equilateral triangle of side length 2.0×10^{-6} m. What is the magnitude of the net electric field these two particles produce at the third corner?**

Data:

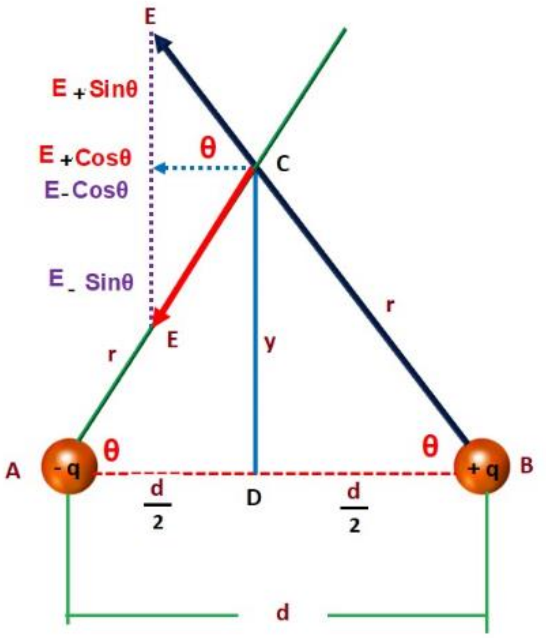
$r = 2.0 \times 10^{-6}\ m$

$(charge\ of\ electron)\ q = 1.6 \times 10^{-19}\ C$

$(charge\ of\ proton)\ q = 1.6 \times 10^{-19}\ C$

$E = ?$

SOLUTION:



Net electric field at third corner of a triangle is:

$$E_{net} = E_{(+)}cos\theta + E_{(-)}cos\theta$$

$$E_{net} = Ecos\theta + Ecos\theta = 2\,E\,cos\theta$$

$$E_{net} = 2\,(E)\,cos\theta \qquad \left\{\therefore E = \frac{k\,q}{r^2}\right\}$$

$$E_{net} = 2\left(\frac{K\,q}{r^2}\right) cos\theta$$

$$E_{net} = 2\left(\frac{9 \times 10^9 \times 1.6 \times 10^{-19}}{(2.0 \times 10^{-6})^2}\right) cos60^0$$

$$E_{net} = \frac{2 \times 9 \times 10^9 \times 1.6 \times 10^{-19}}{(2.0 \times 10^{-6})^2} \times 0.5$$

$$E_{net} = \frac{1.44 \times 10^{-9}}{4 \times 10^{-12}}$$

$$E_{net} = 360\ N/C$$

6 **Figure shows two charged particles on an x axis: -q = 3.20 X10^{-19} C at x = -3.00 m and q = 3.20 X10^{-19} C at x= 3.00 m. What are the (a) magnitude and (b) direction (relative to the positive direction of the x axis) of the net electric field produced at point P at y = 4.00 m?**

Data:

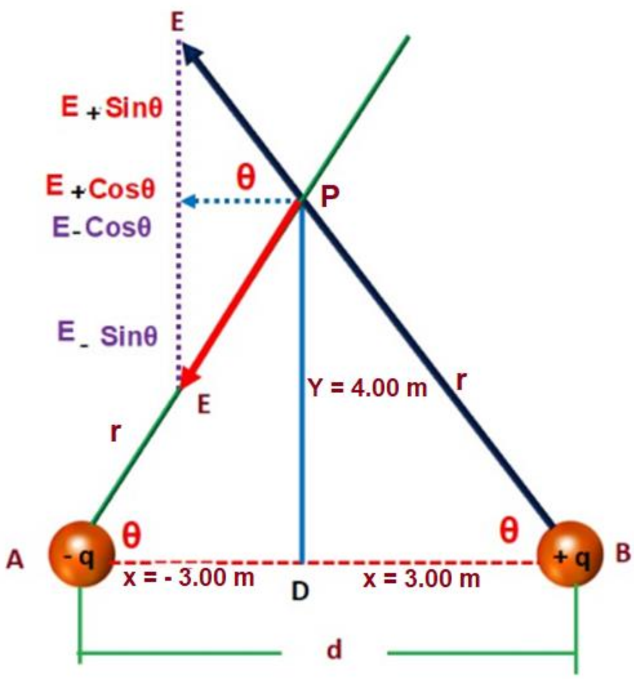
$r = 2.0 \times 10^{-6}\, m$

$(charge\ of\ electron)\ q = 1.6 \times 10^{-19}\, C$

$(charge\ of\ proton)\ q = 1.6 \times 10^{-19}\, C$

$E = ?$

SOLUTION:



Net electric field at third corner of a triangle at point P is given by

$$E_{net} = E_{(+)}cos\theta + E_{(-)}cos\theta$$

$$E_{net} = Ecos\theta + Ecos\theta = 2\,E\,cos\theta$$

$$E_{net} = 2\,(E)\,cos\theta \qquad \left\{\therefore E = \frac{k\,q}{r^2}\right\}$$

$$E_{net} = 2\left(\frac{K\,q}{r^2}\right) cos\theta \ldots\ldots\ldots\ldots\ldots\ldots (i)$$

Solve for the distance r

Consider a triangle ADP

$$(hyp)^2 = (base)^2 + (per)^2$$

$$(r)^2 = (3.00)^2 + (4.00)^2$$

$$\sqrt{(r)^2} = \sqrt{9.00 + 16.00}$$

$$r = \sqrt{25.00}$$

$$r = 5.00\, m$$

Solve for the cos θ

$$cos\theta = \frac{base}{hyp}$$

$$cos\theta = \frac{BD}{r}$$

$$cos\theta = \frac{3}{5}$$

$$E_{net} = Ecos\theta + Ecos\theta = 2\,E\,cos\theta$$

$$E_{net} = 2\,(E)\,cos\theta \qquad \left\{\therefore E = \frac{k\,q}{r^2}\right\}$$

$$E_{net} = 2\left(\frac{K\,q}{r^2}\right) cos\theta$$

$$E_{net} = 2\left(\frac{9 \times 10^9 \times 3.2 \times 10^{-19}}{(5)^2}\right)\frac{3}{5}$$

$$E_{net} = \frac{2 \times 9 \times 10^9 \times 3.2 \times 10^{-19} \times 3}{(5)^2 \times 5}$$

$$E_{net} = \frac{1.728 \times 10^{-8}}{125}$$

$$E_{net} = 1.382 \times 10^{-10}\, N/C$$

7 A proton and an electron form two corners of an equilateral triangle of side length 5 μ m. What is the magnitude of the net electric field these two particles produce at the third corner?

Data:

$r = 5\,\mu\, m$

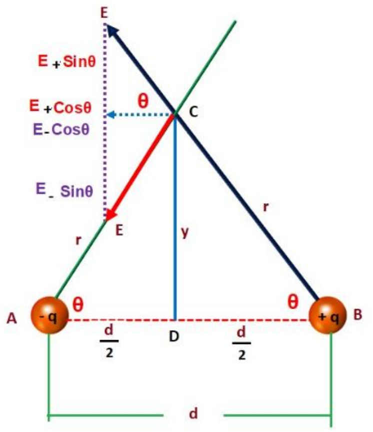
$r = 5 \times 10^{-6}\, m$

$(charge\ of\ electron)\ q = 1.6 \text{ x } 10^{-19}\, C$

$(charge\ of\ proton)\ q = 1.6 \text{ x } 10^{-19}\, C$

$E = ?$

SOLUTION:



Net electric field at third corner of a triangle is:

$$E_{net} = E_{(+)}cos\theta + E_{(-)}cos\theta$$

$$E_{net} = Ecos\theta + Ecos\theta = 2\, E\, cos\theta$$

$$E_{net} = 2\,(E)\, cos\theta \qquad \left\{\therefore E = \frac{k\, q}{r^2}\right\}$$

$$E_{net} = 2\left(\frac{K\, q}{r^2}\right) cos\theta$$

$$E_{net} = 2\left(\frac{9 \times 10^9 \times 1.6 \text{ x } 10^{-19}}{(5 \times 10^{-6})^2}\right) cos60^0$$

$$E_{net} = \frac{2 \times 9 \times 10^9 \times 1.6 \text{ x } 10^{-19}}{(5 \times 10^{-6})^2} \times 0.5$$

$$E_{net} = \frac{1.44 \text{ x } 10^{-9}}{25 \times 10^{-12}}$$

$$E_{net} = 57.6\ \ N/C$$

8 The square surface shown in figure measures 3.2 mm on each side. It is immersed in a uniform electric field with magnitude E =1800 N/C and with field lines at an angle of = 35° with a normal to the surface, as shown. Take that normal to be directed "outward," as though the surface were one face of a box. Calculate the electric flux through the surface

Data:

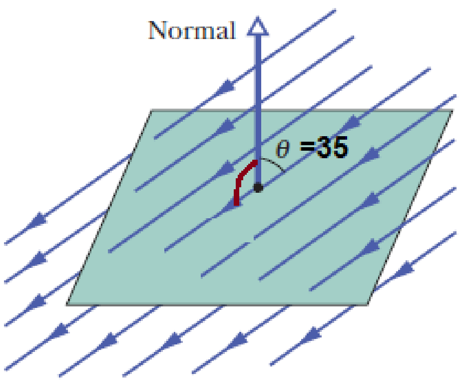
$side(a) = 3.2\, mm = 3.2 \times 10^{-3}\, m$

$E = 1800\, N/C$

$\theta = 35^0$

$\alpha = 180 - 35 = 145^0$

$\Phi = ?$



SOLUTION:

Area of rectangle is

$$A = 3.2 \times 10^{-3} \times 3.2 \times 10^{-3}$$

$$A = 1.024 \times 10^{-5}\, m$$

$$\Phi = E\, A\, cos\theta$$

$$\Phi = 1800 \times 1.024 \times 10^{-5}\, cos(145)$$

$$\Phi = 1800 \times 1.024 \times 10^{-5}\, (-0.8191)$$

$$\Phi = -0.01509\, N\, m^2 / C$$

$$\Phi = -1.509 \times 10^{-2}\ \ N\, m^2 / C$$

9 **An electron is liberated from the lower of two large parallel metal plates separated by a distance h = 2 cm. The upper plate has a potential of 2400 volts relative to the lower. How long does the electron take to reach it.**

Data and solution	Solution (continued)
Data:	$\frac{F}{m} = a$
$q = 1.6 \text{ x } 10^{-19} \; C$	$\frac{1.92 \text{ x } 10^{-14}}{9.1 \text{ X } 10^{-31}} = a$
$m = 9.1 \text{ X } 10^{-31}$ kg	$2.109 \times 10^{16} \; m/s^2 = a$
$V = 2400 \; volt$	$S = v_i \, t + \frac{1}{2} \, a \, t^2$
$(h) \; d = 2 \; cm = 0.02 \; m$	$0.02 = (0 \times t) + \frac{1}{2} \; (2.109 \times 10^{16}) \; t^2$
$t = ?$	$0.02 = 0 + 1.0545 \times 10^{16} \times t^2$
SOLUTION:	$\frac{0.02}{1.0545 \times 10^{16}} = t^2$
$V = E \, d$	$1.8958 \times 10^{-18} = t^2$
$\frac{V}{d} = E$	$\sqrt{1.8958 \times 10^{-18}} = \sqrt{t^2}$
$\frac{2400}{0.02} = E$	$1.37 \times 10^{-9} \; s = t$
$120000 \; N/C = E$	
$F = q \, E$	
$F = 1.6 \text{ x } 10^{-19} \times 120000$	
$F = 1.92 \text{ x } 10^{-14} \; N$	

10 **Two large parallel metal plates are 1.5 cm apart and have charges of equal magnitudes but opposite signs on their facing surfaces. Take the potential of the negative plate to be zero. If the potential halfway between the plates is then 5.0 V, what is the electric field in the region between the plates?**

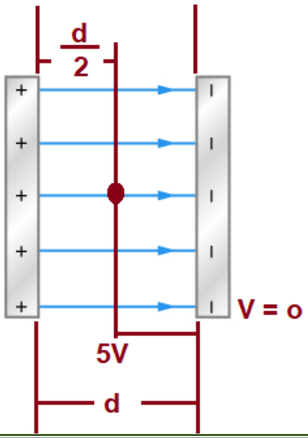
Data:

$d = 1.5 \; cm = 1.5 \times 10^{-2} \; m$

$V_1 = 0$ V

$V_2 = 5$ V

$E = ?$



SOLUTION:

$$E = \frac{\Delta V}{\frac{d}{2}} = \frac{2 \; \Delta V}{d}$$

$$E = \frac{2 \; (V_2 - V_1)}{d}$$

$$E = \frac{2 \; (5 - 0)}{1.5 \times 10^{-2}}$$

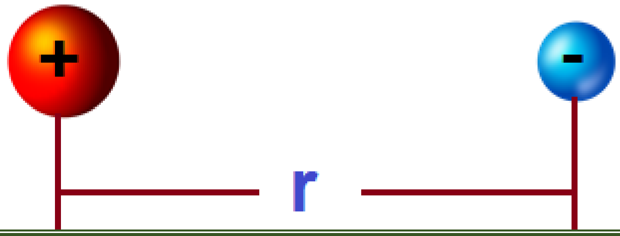
$$E = \frac{10}{1.5 \times 10^{-2}}$$

$$E = 6.66 \times 10^2 \; V/m$$

ELECTRIC FIED

CHAPTER = 8 **ADDITIONAL NUMERICAL**

1 The electron and proton of a hydrogen atom (figure) are separated by approximately 5.3 x 10^{-11} m. Find the magnitudes of (a) the electric force and (b) the gravitational force between the two particles. (c) What is your conclusion about these forces



Data:

$q = 1.6 \text{ x } 10^{-19}\ C$

$m_p = 1.67 \text{ X } 10^{-27}$ kg

$m_e = 9.1 \text{ X } 10^{-31}$ kg

$r = 5.3 \times 10^{-11}\ m$

$F_e = ?$

$F_G = ?$

SOLUTION:

$$F_e = \frac{k\, q_e\, q_p}{r^2}$$

$$F_e = \frac{9 \times 10^9\ (1.6 \text{ x } 10^{-19}\ C)\ (1.6 \text{ x } 10^{-19}\ C)}{(5.3 \times 10^{-11})^2}$$

$$F_e = 8.2 \times 10^{-8}\ N$$

$$F_g = \frac{G\, m_e\, m_p}{r^2}$$

$$F_g = \frac{6.67 \times 10^{-11}\ (9.1 \text{ x } 10^{-31}\ C)\ (1.67 \text{ x } 10^{-27}\ C)}{(5.3 \times 10^{-11})^2}$$

$$F_g = 8.2 \times 10^{-8}\ N$$

The gravitational force between electron and proton is negligible as compared to the electric force, which implies that electric force is strong force

2 Find the intensity of electric field at a point such that a proton placed at it would experience a force equal to its weight.

Data:

$q = 1.6 \text{ x } 10^{-19}\ C$

$m = 1.67 \text{ X } 10^{-27}$ kg

$E = ?$

SOLUTION:

$$Electric\ force = weight$$

$$F_e = W$$

$$q\,E = mg$$

$$E = \frac{mg}{q}$$

$$E = \frac{1.67 \text{ X } 10^{-27} \times 9.8}{1.6 \text{ x } 10^{-19}}$$

$$E = 1.022 \times 10^{-9}\ N/C$$

3 **Three charges q_1 = + 2 μC, q_2 = +3 μC, and q_3 = +4 μC are placed in air at the vertices of an equilateral triangle of sides 10 cm (see figure). Calculate the magnitude of the resultant force acting on the charge q_3?**

Data:

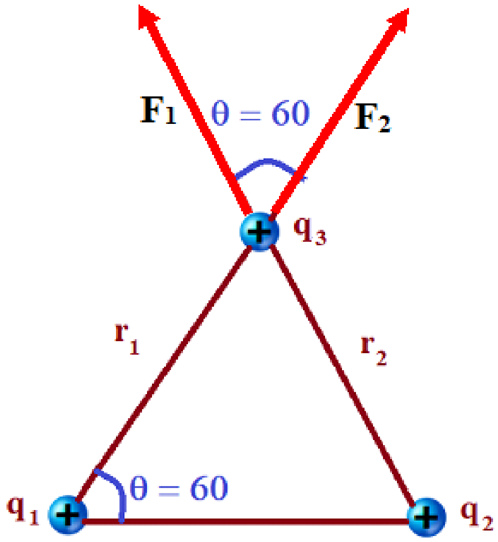
$q_1 = 2\mu\, C = 2 \times 10^{-6}\, C$

$q_2 = 3\mu\, C = 3 \times 10^{-6}\, C$

$q_3 = 4\mu\, C = 4 \times 10^{-6}\, C$

$r_1 = r_2 = r_3 = 10\text{ cm} = 0.1\text{ m}$

$F = ?$



SOLUTION:

$$F_1 = \frac{k\, q_1\, q_3}{r_1^2}$$

$$F_1 = \frac{9 \times 10^9\, (2 \times 10^{-6}\, C)\, (4 \times 10^{-6}\, C)}{(0.1)^2}$$

$$F_1 = 7.2\ N$$

$$F_2 = \frac{k\, q_2\, q_3}{r_2^2}$$

$$F_2 = \frac{9 \times 10^9\, (3 \times 10^{-6}\, C)\, (4 \times 10^{-6}\, C)}{(0.1)^2}$$

$$F_2 = 10.8\ N$$

$$F = \sqrt{(7.2)^2 + (10.8)^2 + 2\,(7.2)(10.8)cos60}$$

$$F = \sqrt{(7.2)^2 + (10.8)^2 + 2\,(7.2)(10.8)(0.5)}$$

$$F = \sqrt{246.24}$$

$$F = 15.69\ N$$

PROF:IMRAN HASHMI

4. How many electrons should be removed from each of the two similar spheres each of 10 g so that electrostatic repulsion is balanced by gravitational force.

DATA

$m_1 = 10\ g$

$m_1 = 0.01\ Kg$

$m_2 = 0.01\ Kg$

$q_1 = q_2 = q$

TO-DETERMINE

No of electrons n = ?

SOLUTION

According to the given condition

Electrostatic force = gravitational force

$$\frac{K q_1 q_2}{r^2} = \frac{G m_1 m_2}{r^2}$$

$$K q_1 q_2 = G m_1 m_2$$

$$K q q = G m_1 m_2$$

$$9 \times 10^9 q^2 = 6.67 \times 10^{-12} \times 0.01 \times 0.01$$

$$q^2 = 74.1 \times 10^{-26}$$

Taking square root on both the sides

$$q = \sqrt{74.1 \times 10^{-26}}$$

$$q = 8.608 \times 10^{-13}\ C$$

$$\text{Number of electron} = \frac{\text{magnitude of the charge}}{\text{cahrge of electron}}$$

$$\text{number of electrons} = \frac{8.608 \times 10^{-13}}{1.6 \times 10^{-19}}$$

number of electrons = 5.38×10^6 electrons

PROF:IMRAN HASHMI

5: **A proton of mass 1.67 x 10^{-27} kg and charge 1.6 x 10^{-19} C is to be held motionless between two horizontal parallel plates 10 cm apart. Find the Voltage required to be applied between the plates**

DATA

$q = 1.6 \times 10^{-19}$ C

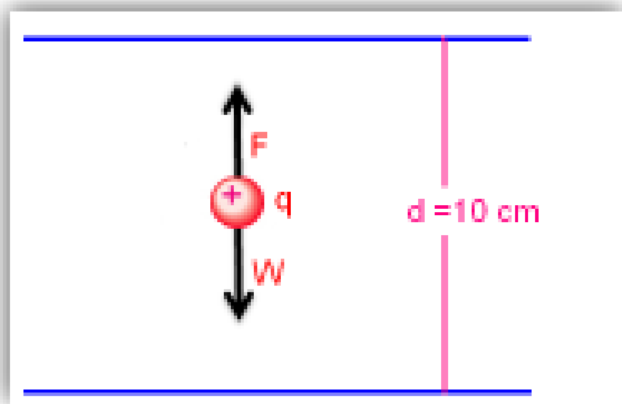
$m_p = 1.67 \times 10^{-27}$ kg

d = 10 cm

TO-DETERMINE

V = ?

SOLUTION



When the proton is in equilibrium

Gravitational force = electric force

$$F_G = F_e$$

$$mg = qE$$

$$1.67 \times 10^{-27} \times 9.8 = 1.6 \times 10^{-19}\ E$$

$$16.366 \times 10^{-27} = 1.6 \times 10^{-19}\ E$$

$$1.0228 \times 10^{-7} = E \quad \text{.......................(i)}$$

We know that the electric filed is equal to the potential gradient

$$E = \frac{V}{d}$$

$$V = E \times d$$

Put the value of E From equation (i) and d=0.1m in above equation, we get

$$V = 1.0228 \times 10^{-7} \times 0.1$$

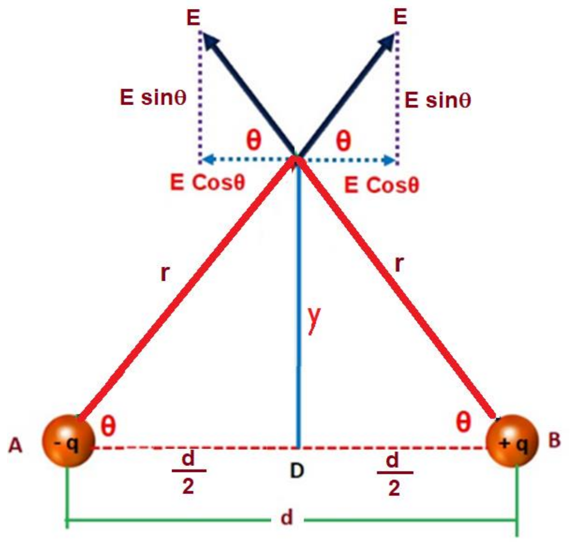
$$V = 1.0228 \times 10^{-8}$$

$$V = 1.02 \times 10^{-8} \text{ Volt}$$

PROF:IMRAN HASHMI

6 **Calculate the electric field intensity at point P of two positive charges of the same magnitude separated by a small distance "d" as given in the figure.**

SOLUTION:



Net electric field at third corner of a triangle at point P is given by

$$E_{net} = E_{(+)}sin\theta + E_{(+)}sin\theta$$

$$E_{net} = Esin\theta + Esin\theta = 2\,E\,sin\theta$$

$$E_{net} = 2\,(E)\,sin\theta \qquad \left\{\therefore E = \frac{k\,q}{r^2}\right\}$$

$$E_{net} = 2\left(\frac{K\,q}{r^2}\right) sin\theta \,...\,(i)$$

Solve for the cos θ

$$sin\theta = \frac{perp}{hyp}$$

$$sin\theta = \frac{y}{r}$$

$$sin\theta = \frac{y}{r}$$

Substituting sinθ expression in equation (i)

$$E_{net} = 2\left(\frac{K\,q}{r^2}\right)\frac{y}{r}$$

$$E_{net} = 2\left(\frac{K\,q\;y}{r^3}\right) \,...\,...\,...\,....\,(ii)$$

Solve for the distance r

Consider a triangle ADP

$$(hyp)^2 = (per)^2 + (base)^2$$

$$(r)^2 = (y)^2 + \left(\frac{d}{2}\right)^2$$

$$\sqrt{(r)^2} = \sqrt{(y)^2 + \left(\frac{d}{2}\right)^2}$$

$$r = \left\{(y)^2 + \left(\frac{d}{2}\right)^2\right\}^{\frac{1}{2}}$$

Substituting the expression for **r** in eq (2)

$$E_{net} = 2\frac{K\,q\,y}{\left(\left\{(y)^2 + \left(\frac{d}{2}\right)^2\right\}^{\frac{1}{2}}\right)^3}$$

that $y \gg d$ .At such large distances, we can neglect the $\left(\frac{d}{2}\right)^2$ term in the denominator

$$E_{net} = 2\frac{K\,q\,y}{\left(\{(y)^2 + 0\}^{\frac{1}{2}}\right)^3}$$

$$E_{net} = 2\frac{K\,q\,y}{y^3}$$

$$E_{net} = 2\frac{K\,q}{y^2}$$

$$E_{net} = 2\left(\frac{1}{4\pi\epsilon_0}\right)\frac{q}{y^2}$$

$$E_{net} = \left(\frac{1}{2\pi\epsilon_0}\right)\frac{q}{y^2}$$

PROF:IMRAN HASHMI

SELF ASSESSMENT QUESTIONS

1 Calculate the separation between two electrons (in vacuum) for which the electric force between them is equal to the gravitation force on one of them at the earth's surface

<table>
<tr>
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Data:

$q_1 = 1.6 \text{ x } 10^{-19}\ C$

$q_2 = 1.6 \text{ x } 10^{-19}\ C$

$m = 9.1 \text{ X } 10^{-31} \text{ kg}$

$e = ?$

SOLUTION:

According to the given condition

$Electric\ force = gravitation\ force$

$$F_e = F_g$$

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

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

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<td>

$$\frac{9 \times 10^9\ 1.6 \text{ x } 10^{-19} \times 1.6 \text{ x } 10^{-19}}{9.1 \text{ X } 10^{-31} \times 9.8} = r^2$$

$$\frac{2.304 \times 10^{-28}}{8.918 \times 10^{-30}} = r^2$$

$$25.835 = r^2$$

$$\sqrt{25.835} = \sqrt{r^2}$$

$$r = 5.08\, m$$

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</table>

2 If a dielectric medium of dielectric constant ϵ_r is filled in between the charges placed at distance r, then shows that the force between the charges decreases as compare to the force when these charges are placed in the air at the same distance.

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The electric force between two charges when there is air or vacuum between them which are placed at a distance r is given by Coulomb's law

$$F = \frac{1}{4\,\pi\,\epsilon_0}\ \frac{q_1\, q_2}{r^2}$$

When a dielectric medium of dielectric constant ϵ_r is filled in between the charges then Coulomb's law can be written as

$$F' = \frac{1}{4\,\pi\,\epsilon_0\,\epsilon_r}\ \frac{q_1\, q_2}{r^2}$$

</td>
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$$F' = \frac{1}{\epsilon_r} \times \frac{1}{4\,\pi\,\epsilon_0}\ \frac{q_1\, q_2}{r^2}$$

$$F' = \frac{1}{\epsilon_r} \times F$$

$$F' = \frac{F}{\epsilon_r}$$

The above expression shows that the force between the charges is reduced by a factor of dielectric constant ϵ_r

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</table>

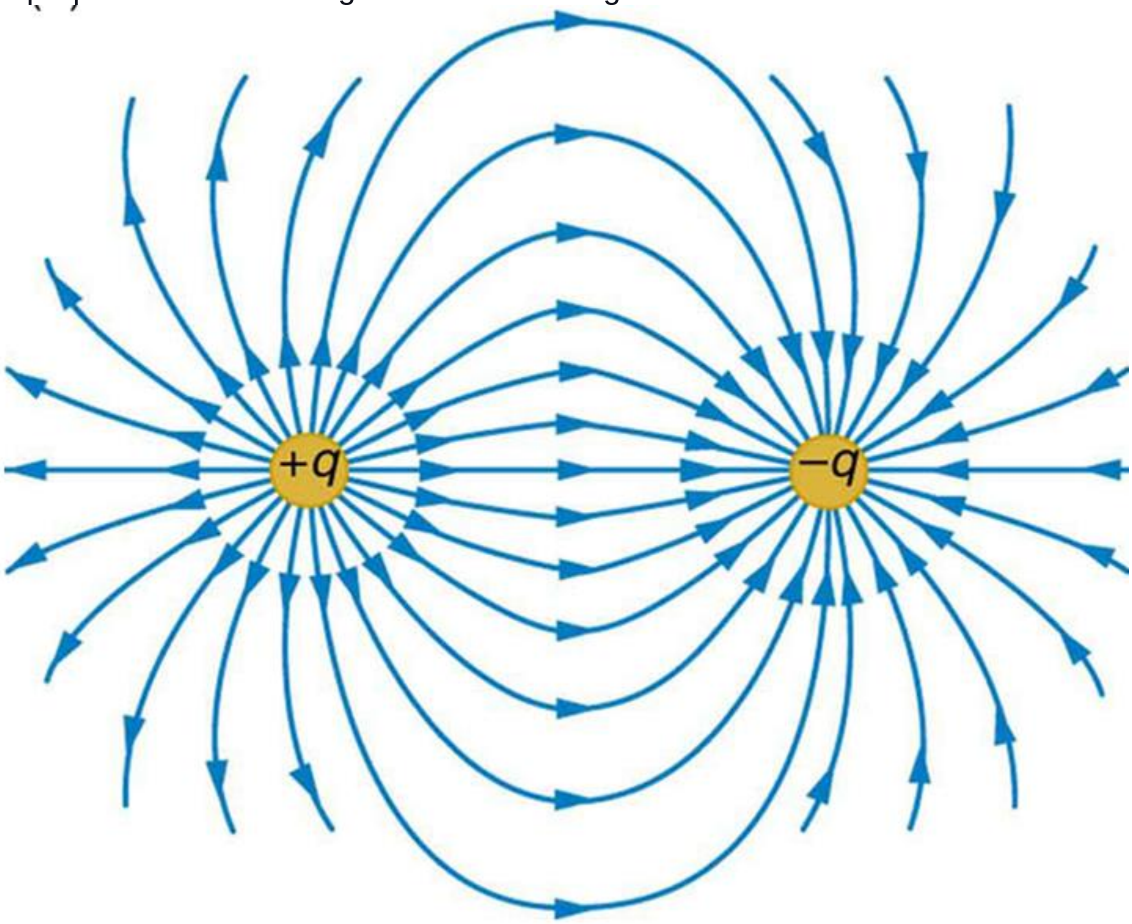
3 **A certain gas is filled in a tube and when the electric field reaches a certain maximum value across the due then the gas becomes conducting**

Ans **it is the phenomenon called electric discharge or electric breakdown in gas when a high voltage (say 1000 volt) is connected across the cathode and the anode of the gas tube, the gas in tube breaks into ions (i.e. ionized). The positive ions move toward the cathode while the negative ions and free electrons move toward the anode and the gas becomes a conductor.**

4 **Sketch the electric field lines for two equal and opposite point charges placed near each other**

Ans Two opposite charges produce the field shown, which is stronger in the region between the charges.

The number of field lines leaving a positive charge or entering a negative charge is proportional to the magnitude of the charge

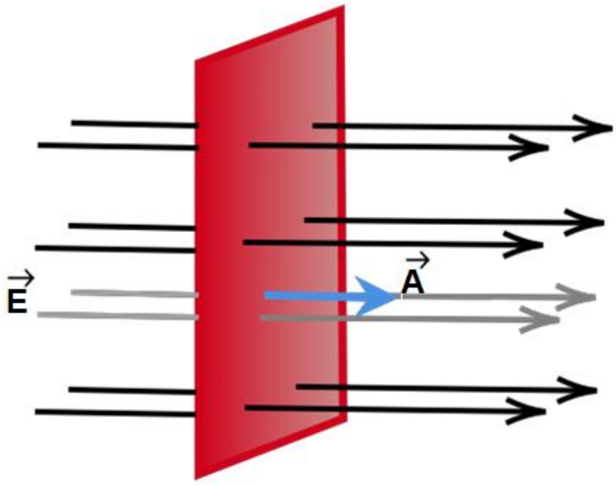


5 **Calculate the flux of a uniform electric field strength $\vec{E} = 6\,\hat{\imath}\ \frac{N}{C}$ through surface of vector area $\vec{A} = (3\hat{\imath} + 5\hat{\jmath})\ m^2$**

Data: $\vec{E} = 6\,\hat{\imath}\ N/C$ $\vec{A} = (3\hat{\imath} + 5\hat{\jmath})\ m^2$ $\Phi = ?$ **SOLUTION:** $\Phi = \vec{E}\,.\,\vec{A}$ $\Phi = (6\,\hat{\imath})\,.\,(3\hat{\imath} + 5\,\hat{\jmath})$	$\Phi = 18\ (\hat{\imath}\,.\,\hat{\imath}) + 30\,(\hat{\imath}.\hat{\jmath})$ $\Phi = 18\ (1) + 30\,(0)$ $\Phi = 18\ N.m^2/C.$

6 A plane surface is rotating in a uniform electric field. When is the fluxed of the electric field through the surface maximum? explain with diagram.

Ans **If the electric field line penetrating through a surface in such a way that the vector area $\vec{A}$ is parallel to the field, then the maximum field lines will penetrate through the surface. As shown in figure**



When $\theta = 0^o$ & $Cos0^o = 1$

$\Phi = E\ A \cos\theta$

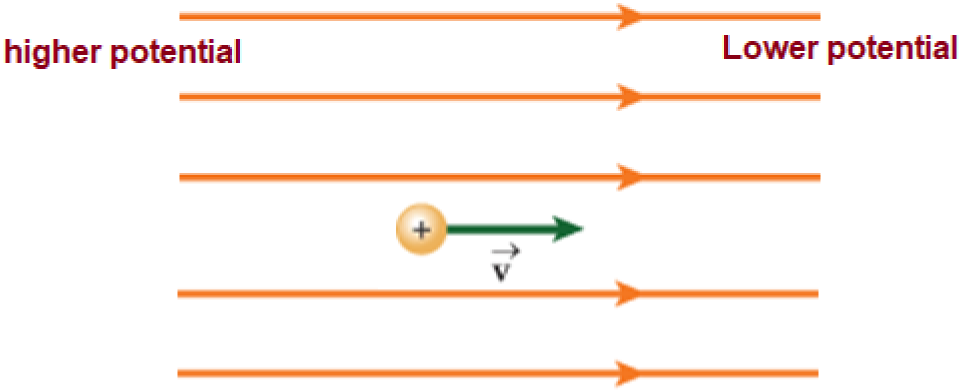
$\Phi = E\ A \cos 0$

$\Phi = E\ A\ (1)$

$\Phi = E\ A$

7 **If a proton is released from rest in an electric field, will it move in the direction of increasing or decreasing potential? Explain why.**

Ans Proton is released from rest in an electric field it will move in the direction of decreasing potential because positively charged particles like Proton moves in the direction of the field which is from higher electric potential to lower electric potential accelerate in the direction of the electric field moving towards region of the lower electric potential



WORKED EXAMPLE

1 An alpha particle (+2e) in a nuclear accelerator moves from one terminal at the potential of 6.5 x 10^6 V to another terminal at zero potential. What is the corresponding change in the potential energy of the system?

Data:	SOLUTION:
$q = 2e$ $q = 2 \times 1.6 \text{ x } 10^{-19}\ C = 3.2 \text{ x } 10^{-19}\ C$ $V_1 = 6.5 \times 10^6\ V$ $V_2 = 0$ $\Delta U = ?$	$\Delta U = q\,(V_2 - V_1)$ $\Delta U = 3.2 \text{ x } 10^{-19}\ (0 - 6 \times 10^6)$ $\Delta U = 3.2 \text{ x } 10^{-19} \times 6.5 \times 10^6$ $\Delta U = -2.08 \times 10^{-12}\ J$

2 For what value of change in electric potential to remove the six electrons from the carbon atom if the change in potential energy is 120 k eV.

Data:	
$q = 6e = 6 \times 1.6 \times 10^{-19}$ $q = 9.6 \times 10^{-19}\ C$ $\Delta U = 120 \text{ k eV}$ $\Delta U = 120 \times 1000 \times 1.6 \times 10^{-19}$ $\Delta U = 1.92 \times 10^{-14}$ J $\Delta V = ?$ OLUTION: $\Delta U = q\,\Delta V$ $\frac{\Delta U}{q} = \Delta V$	$\Delta V = \frac{\Delta U}{q}$ $\Delta V = \frac{1.92 \times 10^{-14}}{9.6 \times 10^{-19}}$ $\Delta V = 20000\ V$ $\Delta V = 2 \times 10^4\ V$

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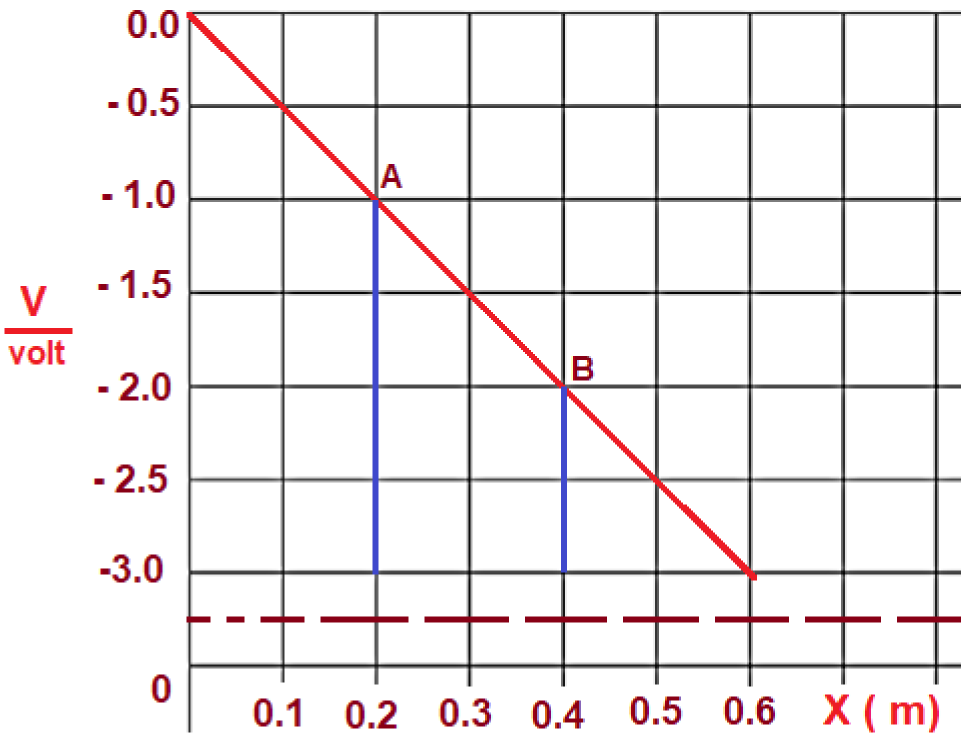
3 An electron is placed in an xy plane where the electric potential depends on x and y as shown in figure. The scale of the vertical axis is set by one square box equal to 500 V. Find the electric field (both cases) acting on the electron between two points as shown in the graph?



Data:

$V_1 = at\ point\ A$

$V_1 = -1.0 \times 500 = -500\,V$

$V_2 = at\ point\ B$

$V_2 = -2.0 \times 500 = -1000\,V$

$\Delta V = V_2 - V_1$

$\Delta V = -1000 - (-500)$

$\Delta V = -1000 + 500$

$\Delta V = -\,500\,V$

$x_1 = at\ point\ A$

$x_1 = 0.2\,m$

$x_2 = at\ point\ B$

$x_2 = 0.6\,m$

$\Delta x = x_2 - x_1$

$\Delta x = 0.4 - 0.2$

$\Delta x = 0.2\,m$

$$E = -\left(\frac{\Delta V}{\Delta x}\right)$$

$$E = -\left(\frac{-\,500}{0.2}\right)$$

$$E = 2500\,V/m$$

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