Physics 1 Assignment

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Section: B7

1. a) Positive change: When an object contains more protons than electrons is called positive change.

Negative change: When an object contains more electrons than protons is called negative changed.

Quantization of change means that when we say something has given a change, we mean that is how many times the charge of a single electron it has. Quantization simply means that the values are not continuous but are rather discrete. The charge of a single electron is $q_e = 1.6 \times 10^{-19} C$. This is known as charge quantization. The equation of charge quantization $q = ne$ here n is integer value.

b) Electric force: Electric force exists between charges. Here, we observes forces between objects. Electric charge is ~~that~~ the property of objects that gives rise to this observed force. We use Coulomb's Law to describe electric force.

The equation of electric force:

$$F = \frac{1}{4\pi\epsilon_0} \cdot \frac{q_0 q_1}{r^2}$$

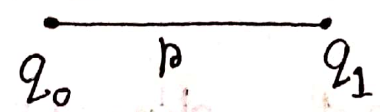


Figure: Electric force

Electric field: Electric fields are created by electric charges. Electric fields are manifestations of the electromagnetic force. An electric field surrounds an electric change and exerts force on other changes in the field, attracting or repelling them. On the other hand, an electric field is a vector field because it is responsible for conveying the information for a force, which involves bot magnitude and direction.

The equation of electric field:

$$E = \frac{F}{q_0}$$

$$= \frac{1}{4\pi\epsilon_0} \frac{q_0}{r^2}$$

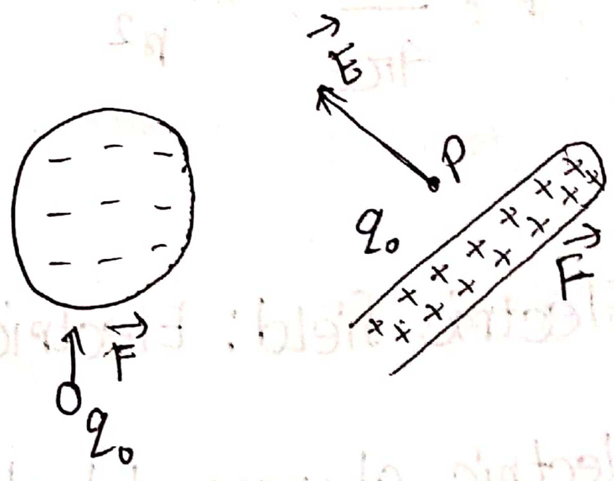


Figure: Electric field

c) Have given,

$$q = +5e$$

$$= 5 \times 1.6 \times 10^{-19} C$$

$$= 8 \times 10^{-19} C$$

$r = 3 \mu m$

$= 3 \times 10^{-6} m$

Electric force $F = \frac{1}{4\pi\epsilon_0} \cdot \frac{q \cdot q}{r^2}$

$= 9 \times 10^9 \times \frac{8 \times 10^{-19} \times 8 \times 10^{-19}}{(3 \times 10^{-6})^2}$

$= 6.4 \times 10^{-16}$ N

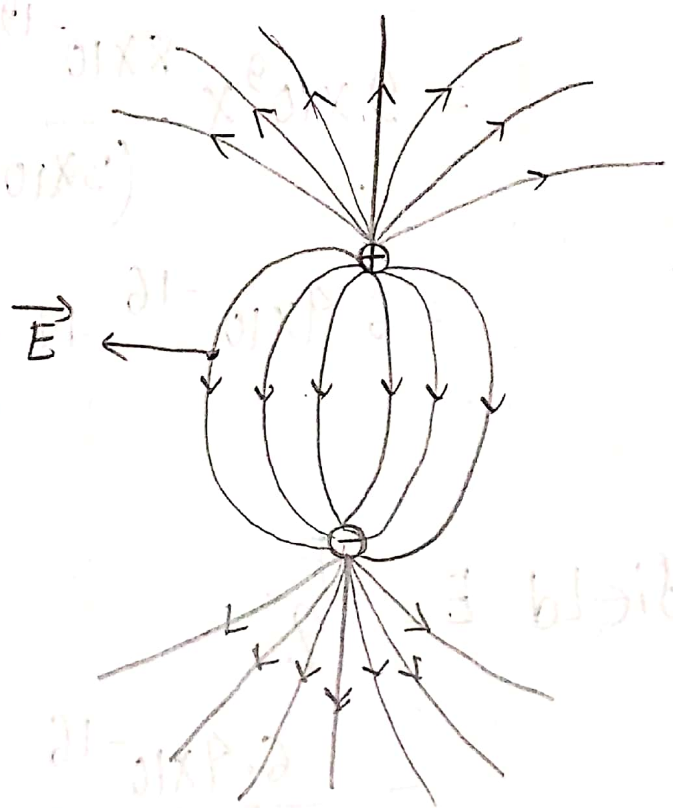
(Answer)

Electric field $E = \frac{F}{q}$

$= \frac{6.4 \times 10^{-16}}{8 \times 10^{-19}}$

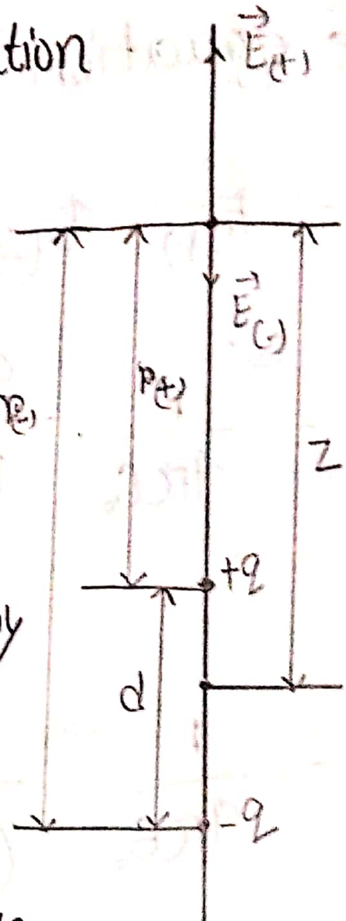
$= 800$ N/C (Answer)

2. a) The figure of the pattern of electric field lines around an electric dipole is given below:



This is the diagram of the electric lines of force and resultant electric field for a dipole.

An electric dipole is a separation of positive and negative changes. Here we see the magnitude and direction of the electric field $\vec{E}$ at an orbitrary point P along the dipole axis at distance z from the dipole's midpoint.



The nearer particle with change +q sets up field $E_{(+)}$ in the positive direction of the z axis. The farther particle with change -q sets up a smaller field $E_{(-)}$ in the negative direction of z axis.

The equation for ~~ee~~ electrical dipole:

$$E = E_{(+)} - E_{(-)}$$

$$= \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{r^2_{(+)}} - \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{r^2_{(-)}}$$

$$= \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{(z - \frac{1}{2}d)^2} - \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{(z + \frac{1}{2}d)^2}$$

$$= \frac{q}{4\pi\epsilon_0 z^2} \left(\frac{1}{(1 - d/2z)^2} - \frac{1}{(1 + d/2z)^2} \right)$$

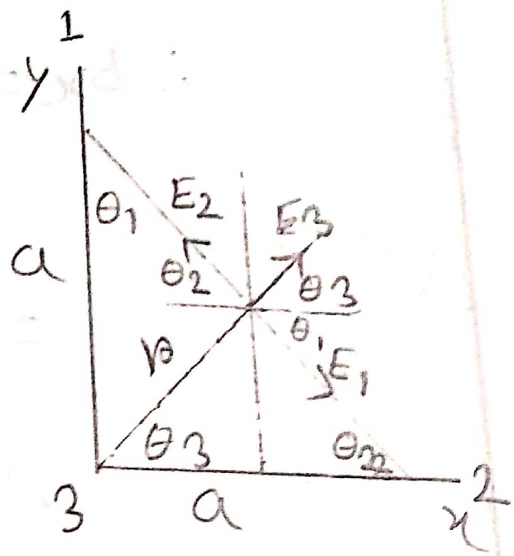
$$= \frac{q}{4\pi\epsilon_0 z^2} \frac{2d/z}{(1 - (d/2z)^2)^2}$$

$$= \frac{q}{2\pi\epsilon_0 z^3} \frac{d}{(1 - (d/2z)^2)^2}$$

$$= \frac{1}{2\pi\epsilon_0} \frac{2d}{z^3}$$

$$= \frac{1}{2\pi\epsilon_0} \frac{p}{z^3}$$

Here, p = electric dipole moment



b) $r = \sqrt{(a/2)^2 + (a/2)^2}$

$= a/\sqrt{2}$

$= \frac{6\times10^{-6}}{\sqrt{2}} m \; [a = 6\times10^{-6} m]$

$= 4.24\times10^{-6} m$

$\theta_1 = \theta_2 = \theta_3 = 45^\circ$

$q_1 = q_2 = +e = 1.6\times10^{-19} C$

$q_3 = +2e = 2\times1.6\times10^{-19} C = 3.2\times10^{-19} C$

The electric field due to the three changes at x direction is $E_x = E_3\cos\theta_3 + E_1\cos\theta_1 - E_2\cos\theta_2$

here, $q_1 = q_2$

So, the equation is $E_x = E_3 \cos\theta_3$

Similarly the equation is $E_y = E_3 \sin\theta_3$

$$\therefore E_x = E_3\cos\theta_3 = \frac{1}{4\pi\epsilon_0} \cdot \frac{q_3}{r^2} \cos 45^\circ$$

$$= 9\times10^9 \times \frac{3.6\times10^{-19} \times \cos 45^\circ}{(4.24\times10^{-6})^2}$$

$$= 113 \text{ N/C}$$

$E_y = E_3 \sin\theta_3$

$= \frac{1}{4\pi\epsilon_0} \cdot \frac{q_3}{r^2} \cdot \sin 45^\circ$

$= 9\times10^9 \times \frac{3.6\times10^{-19} \times \sin 45}{(4.24\times10^{-6})^2}$

$= 113\ N/C$

Electric field $E_{net} = \sqrt{E_x^2 + E_y^2}$

$= \sqrt{113^2 + 113^2}$

$= 159.8\ N/C$ (Answer)

Direction of the net electric field

$\tan\theta = \frac{E_y}{E_x}$

$\Rightarrow \theta = \tan^{-1}\left(\frac{113}{113}\right)$

$\Rightarrow \theta = +45^\circ$ (Answer)

3. a) Gaussian surface: A Gaussian surface is a closed surface in three-dimensional space through which the flux of a vector field is calculated, usually the gravitional field, the electric field or magnetic field.

Electric flux: Electric flux is the measure of the electric field through a given surface although an electric field in itself cannot flow. It is a way of describing the electric field strength at any distance from the charge causing the field. It is the rate of flow of the electric field through a given area.

Gauss's Law: The total of the electric flux out of a closed surface is equal to the charge enclosed divided by the permitivity. The electric flux through an area is defined as the electric field mutiplied by the area of

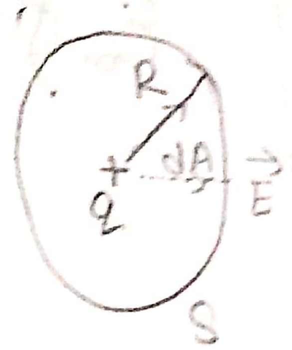


Figure: A closed spherical surface surrounding a point charge q of the surface projected in a place perpendicular to the field.

The equation of Gauss's Law:

$$\varepsilon_0 \oint \vec{E} \cdot d\vec{A} = q_{ence}$$

b) $L = 1.40m$

$\vec{E} = (3.00y\,\hat{j})\,N/C$

Net flux $\phi = \int \vec{E} \cdot d\vec{A}$

$$= \int (3.00y\,\hat{j}) \cdot d\vec{A}$$

$$= 3 \cdot \int d\vec{A}$$

$= 3 \cdot (1.40)^3$

$= 8.23 \ N m^2/C$

Change $q_{enc} = \varepsilon_0 \oint \vec{E} \cdot d\vec{A}$

$= 8.854 \times 10^{-12} \times 3 \times (1.40)^3$

$= 7.29 \times 10^{-11} C$

Net flux $\phi = \int \vec{E} \cdot d\vec{A}$

$= \int [-4.00\hat{i} + (6.00 + 3.00y)\hat{j}] \cdot d\vec{A}$

$= 3 \int \cdot d\vec{A}$

$= 3 \times (1.40)^3$

$= 8.23 \ Nm^2/C$

Charge $q_{enc} = \varepsilon_0 \oint \vec{E} \cdot d\vec{A}$

$= 8.854 \times 10^{-12} \times \oint [-4.00\hat{i} + (6.00 + 3.00y)\hat{j}] \times d\vec{A}$

$= 8.854 \times 10^{-12} \times 3 \times (1.40)^3$

$= 7.29 \times 10^{-11}$ C

(Answer)

4. a) Electric potential: An electric potential is the amount of work needed to move a unit of change from a referrence point

to a specific point inside the field without producing an acceleration. V is the symbol of electric potential.

Electric potential energy: Electric potential energy is a potential energy that results from conservative Coulomb forces and it is associated with the configuration of a particular set of point changes within a defined system.

There is a relationship between electric potential and electric potential energy. We know that an electric potential is set up at every point in the rod's electric field. Every charged object sets up electric potential V at points throughout it's electric field. If we happen to place a particle with charge q at a point where we know the pre-existing V, we can immediately find the potential energy of the configuration:

electric potential energy = particle's charge X $\frac{\text{electric potential energy}}{\text{unit charge}}$

$U = qV$

This is the relationship between electric potential and electric potential energy.

b) Have given, $V = 1.2 \times 10^{9}\ V$

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

Electric potential energy $U = qV$

$= 1.6 \times 10^{-19} \times 1.2 \times 10^{9}$

$= 1.2 \times 10^{9}\ eV$

(Answer

5. a) Any surface over which the potential is ~~called~~ constant is called an equipotential surface. The potential difference between any two points on an equipotential surface is zero. Work done in moving a charge over an equipotential surface is zero.

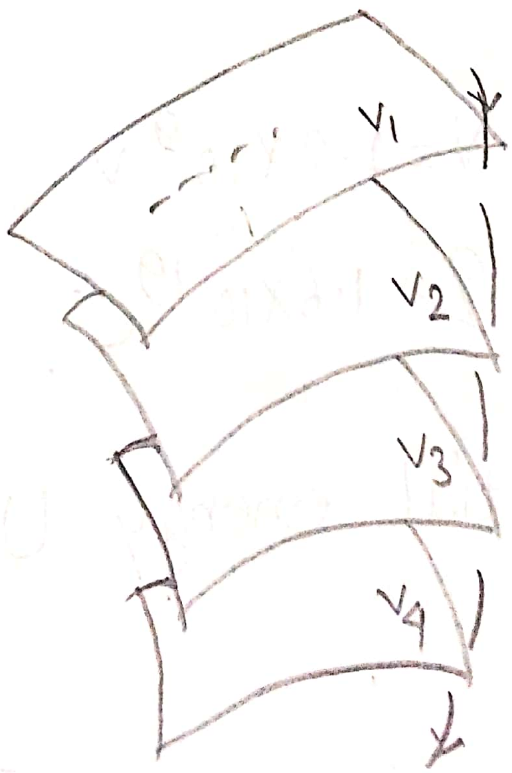


Figure: Equipotential surface

b) Have given,

$$W = 3.94 \times 10^{-19} J$$

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

Electric potential difference

$$V_B - V_A = \frac{W}{e} = \frac{3.94 \times 10^{-19}}{1.6 \times 10^{-19}}$$

$$= 2.46 V$$

Electric potential difference

$$V_C - V_A = \frac{W}{e} = \frac{3.94 \times 10^{-19}}{1.6 \times 10^{-19}}$$

$$= 2.46 V$$

Electric potential difference

$$V_C - V_B = 0$$

Cause electric potential difference

between electric field line in same equipotential surface is zero.

(Answer)

6. a) To find the potential of the charged particle, we move the test charge out to infinity. In this figure, the particle with positive charge q produces an electric field $\vec{E}$ and an electric potential V at point P. We find the potential by

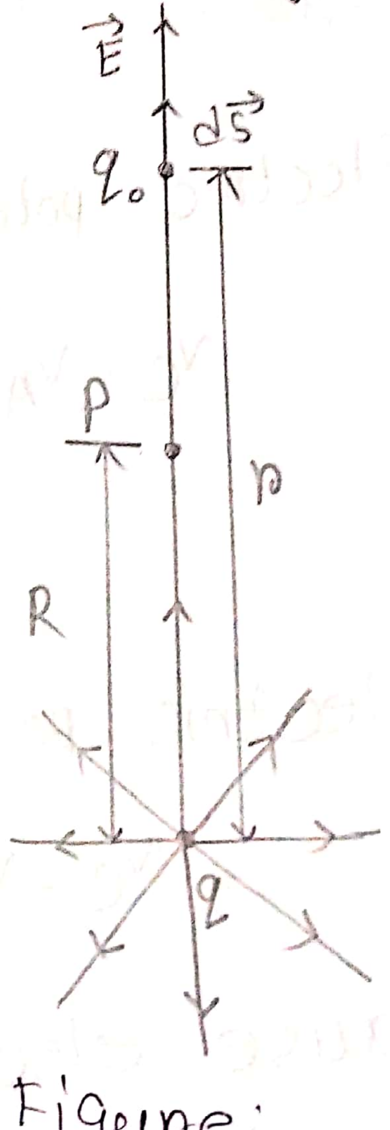


Figure:

moving a test change q_0 from P to infinity.

The test change is shown at distance r from the particle, during differential displacement $d\vec{s}$.

Here, we can write.

$$\vec{E} \cdot d\vec{s} = E \cos\theta . ds \ ; E = \frac{1}{4\pi\epsilon_0} \frac{q}{r^2}$$

$$V_f - V_i = -\int_R^{\infty} E . dr$$

$$\Rightarrow 0 - V = -\frac{q}{4\pi\epsilon_0} \int_R^{\infty} \frac{1}{r^2} dr$$

$$\Rightarrow V = \frac{q}{4\pi\epsilon_0} \left[\frac{1}{r} \right]_R^{\infty}$$

$$\Rightarrow V = -\frac{1}{4\pi\epsilon_0} \frac{q}{R}$$

Now, we can switch and write, $V = \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{r}$

b) Have given,

$$q = 1\,\mu C$$
$$= 1 \times 10^{-6} C$$

$$d_1 = 2m$$
$$d_2 = 1m$$

Electric potential difference, in figure 1,

$$V_A - V_B = \frac{q}{4\pi\epsilon_0}\left[\frac{1}{d_1} - \frac{1}{d_2}\right]$$

$$= 9\times10^{9} \times 1\times10^{-6} \times \left(1 - \frac{1}{2}\right)$$

$$= -4.5\times10^{3} V$$

We know, the potential depends only on the distance.

So, the electric potential difference in figure 2,

$$V_A - V_B = \frac{q}{4\pi\epsilon_0}\left[\frac{1}{d_1} - \frac{1}{d_2}\right]$$

$$= 9\times10^9 \times 1\times10^{-6} \times (1-\tfrac{1}{2})$$

$$= -4.5\times10^3\ V$$

So, the result remains same.

(Answer)

7. a) The ability of a capacitor to store electric charge is called capacitance. The capacitance of a capacitor is mainly depends

on the size of the plates facing each other, the spacing between two conductive plates and the dielectric constant of the material between the plates. A capacitor is made of two electrically conductive plates placed close to each other but they do not touch each other. These conductive plates are normally made of materials such as aluminum, brass or copper.

Basic uses of capacitors:

i) Capacitors for energy storage: Capacitors have been used for store electrical energy. Individual capacitors generally do not hold a great deal of energy, providing only enough power for electronic devices to use during temporary power outages, or when the need additional power.

ii) Capacitors for power conditioning: One important application of capacitors is the conditioning of power supplies. Capacitors allow AC signals to pass but block DC signals when they are changed. They can effectively split these two signal types, cleaning the supply of power. This effect has been exploited to separate or decouple diffenent parts of electrical circuits to reduce noise which could lead to reduction of efficiency.

b) Have given,

$a = 38 mm$

$= 0.038 m$

$b = 40 mm$

$= 0.04 m$

$\epsilon_0 = 8.854 \times 10^{-12} C^2/Nm^2$

Capacitance $C = 4\pi\epsilon_0 \frac{ab}{b-a}$

$= 4 \times 3.14 \times 8.854 \times 10^{-12} \times \frac{0.04 \times 0.038}{0.04 - 0.038}$

$= 8.45 \times 10^{-11}$ F

Here, $d = b - a$

$= 0.04 - 0.038$

$= 0.002$ m

$C = 8.45 \times 10^{-11}$ F

Now, the equation

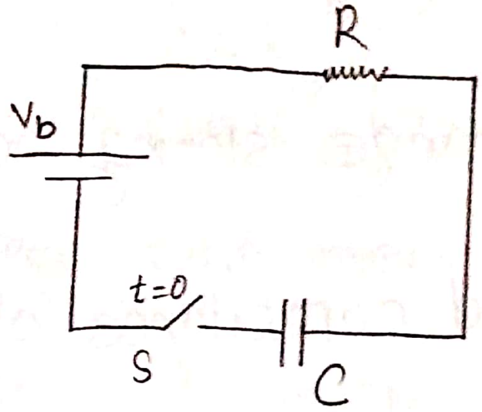
$$C = \frac{A \epsilon_0}{d}$$

$$\Rightarrow A = \frac{Cd}{\epsilon_0} = \frac{8.45 \times 10^{-11} \times 0.002}{8.854 \times 10^{-12}}$$

$= 0.019$ m^2

(Answer)

8. When a battery is connected to a series resistor and capacitor, the initial current is high as the battery transports charge from one plate of the capacitor to the other. The changing current asympotically approaches zero as the capacitor becomes charged up to the battery voltage. Changing the capacitor stores energy in the electric field between the capacitor plates. The rate of changing is typically described in terms of a time constant RC.



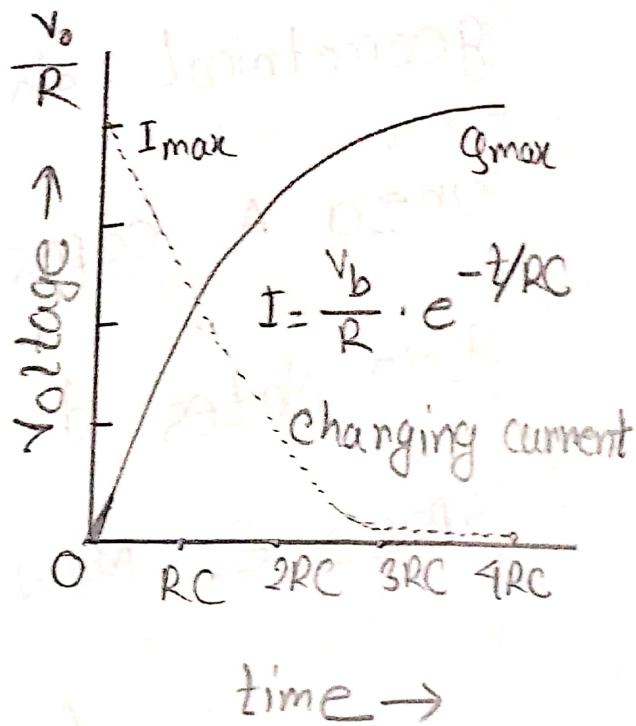
$$V_b = V_R + V_C$$

$$V_b = IR + \frac{q}{C}$$

As changing progresses

$$V_b = \underset{\downarrow}{IR} + \frac{q}{C}\uparrow$$

Here, current decreases and change increases.



Graph: Voltage Vs Time

Here,

At $t=0$	As $t \to \infty$
$q=0$	$q \to CV_b$
$V_C = 0$	$V_C \to V_b$
$I = \frac{V_b}{R}$	$I \to 0$

~~9.a) Changing~~

9.a) Change storing capability of a capacitor is called capacitance of capacitor. The capacitance of a capacitor depends on their geometrical shape. In a capacitor, the plate area A, capacitance C, the distance between two plates d and permitivity of free space ϵ_0. Now, the equation is

$$C = \frac{A\epsilon_0}{d}$$

Here, if we increase A, capacitance C will increase and if we decrease A, Capacitance C will decrease.

Capacitance of two parallel plates is proportioned to their area and inversely proportional to the distance between them.

Moreover, parallel plate capacitor, cylindrical capacitor, spherical capacitor and isolated capacitor have their own capacitance. Their capacitance are different because they have different geometrical shape. So, the capacitance of a capacitor depends on their geometrical shape.

b) Have given,

$$A = 1 m^2$$

$$C = 1 F$$

$$\epsilon_0 = 8.854 \times 10^{-12} \; C^2/Nm^2$$

Capacitance $C = \frac{A\epsilon_0}{d}$

$\therefore$ Distance $d = \frac{A\epsilon_0}{C}$

$$= \frac{1 \times 8.854 \times 10^{-12}}{1}$$

$$= 8.854 \times 10^{-12} \; m$$

$$= 8.854 \; pm$$

After solving the problem, we find distance 8.854 pm, we know distance is inversely proportion to the capacitance.

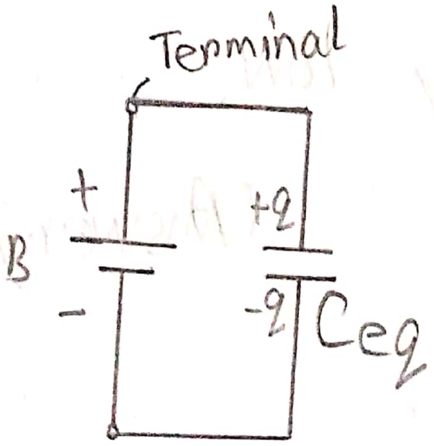
If the distance of a capacitor is very low, the capacitance of a capacitor will be very big. We have no technology to make these type of capacitor. So, we can't ~~cont~~ construct this capacitor because it's distance is very low.

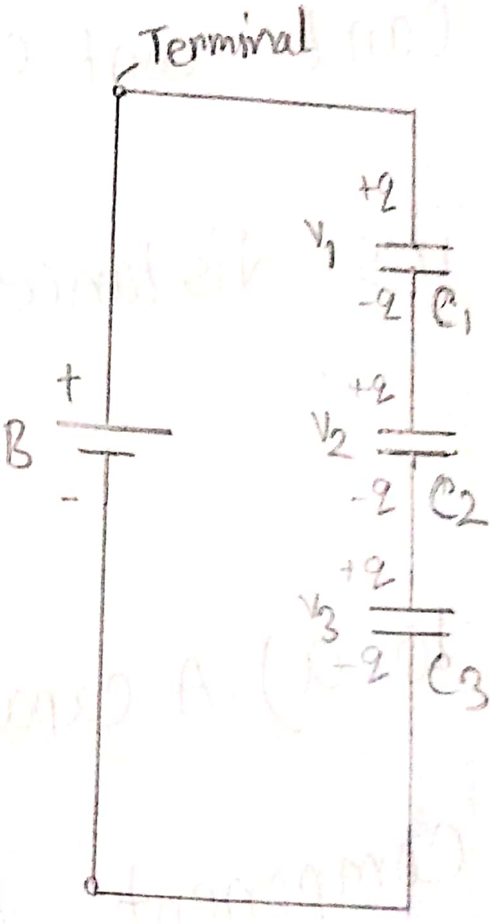
(Answer)

10. a) A capacitor is a passive electronic component that stores energy in the

form of an electrostatic field. A capacitor consists of two conducting plates separated by an insulating material called the dielectric.

Series capacitors:





Three capacitors connected in series to battery B. The battery maintains potential difference V between the top and bottom plates of the series combination. The equivalent capacitor, with capacitance C_{eq}, replaces the series combination. Series capacitors and equivalent have the same q.

Potential difference of each capacitor:

$$V_1 = \frac{q}{C_1}$$

$$V_2 = \frac{q}{C_2}$$

$$V_3 = \frac{q}{C_3}$$

The total potential difference:

$$V = V_1 + V_2 + V_3$$

$$= q\left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right)$$

The equivalent capacitance:

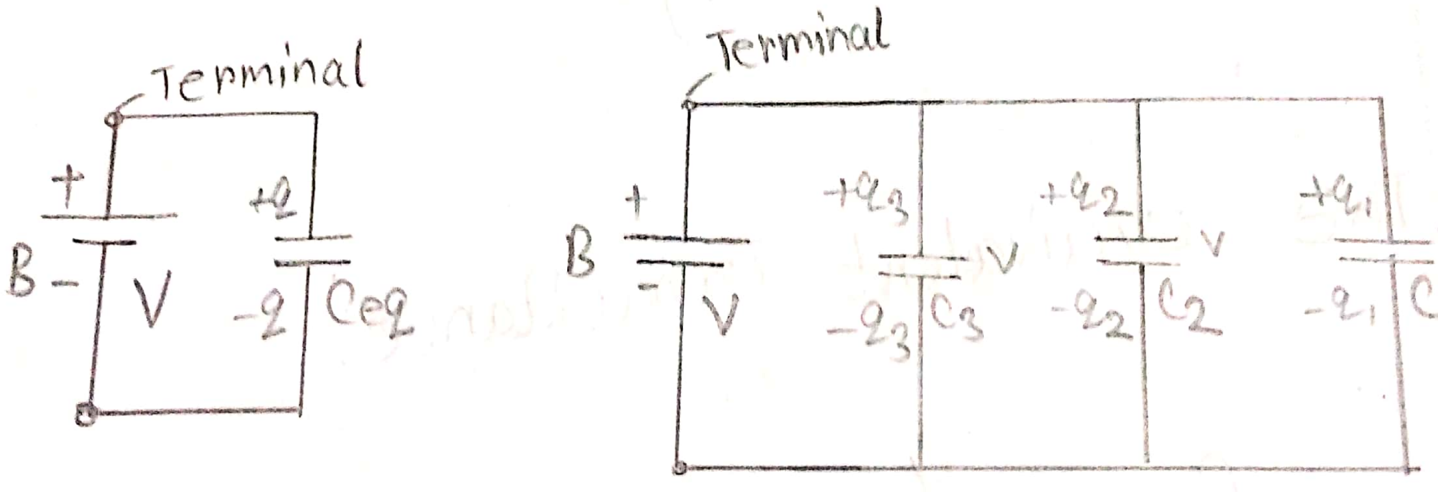
$$C_{eq} = \frac{q}{V}$$

$$\Rightarrow C_{eq} = \frac{1}{1/C_1 + 1/C_2 + 1/C_3}$$

$$\Rightarrow \frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

Parallel capacitors:

Three capacitors connected in parallel to battery B. The battery maintains potential difference V across its termination terminals and thus across each capacitor. The equivalent capacitor, with capacitance Ceq. replace the parallel combination. Parallel capacitors and their equivalent have the same V.



Charge of each capacitor:

$q_1 = C_1 V$

$$q_2 = C_2 V$$

$$q_3 = C_3 V$$

The total charge:

$$q = q_1 + q_2 + q_3$$

$$= (C_1 + C_2 + C_3) V$$

The equivalent capacitance:

$$C_{eq} = \frac{q}{V}$$

$$= C_1 + C_2 + C_3$$

b) Have given,

$$C_1 = 10\mu F = 10\times10^{-6} F$$

$$C_2 = \cancel{5\mu F}\ 5\mu F = 5\times10^{-6} F$$

$$C_3 = 4\mu F = 4\times10^{-6} F$$

$$\frac{1}{C_{eq(series)}} = \frac{1}{C_1} + \frac{1}{C_2}$$

$$\Rightarrow \frac{1}{C_{eq(sr)}} = \frac{1}{10\times10^{-6}} + \frac{1}{5\times10^{-6}}$$

$$\Rightarrow \frac{1}{C_{eq(sr)}} = \frac{1\times10^{-6} + 2\times10^{-6}}{10\times10^{-6}}$$

$$\Rightarrow C_{eq(sr)} = 3.33\times10^{-6} F$$

$$= 3.33\mu F$$

Equivalent capacitance of the combination:

$$C_{eq} = C_{eq(sr)} + C_3$$

$$= 3.33 \times 10^{-6} + 4 \times 10^{-6}$$

$$= 7.33 \times 10^{-6} \, F$$

$$= 7.33 \, \mu F$$

(Answer)