Chapter = 12

Electrostatics

INTRODUCTION

*__Electrostatics__: "**The branch of Physics which deals with the study of charges at rest under the action of electric force is called Electrostatics**".

Electric charge: "An intrinsic property of fundamental particles which takes parts in conduction process is called electric charge. Either they repel or attract each other".

Kinds of charges

There are **two** types of charge, **positive** and **negative**, charge on proton is positive and charge on electron is negative.

SI unit of charge: SI unit of charge is **coulomb**

How many electrons one Coulomb: 6.25×10^{18} electrons

Electric force: The force which holds the positive and negative charges to make up atoms and molecules is called electric force.

***Types of electric force**

Repulsive force: The force b/w two same charges(The force b/w two electrons)

Attractive force: The force b/w two different charges(The force b/w electron and proton)

***Basic law of electrostatics for knowing the nature of charge**

"Like/same charges **repel** each other, while unlike/different charges **attract** each other"

Q. STATE AND EXPLAIN COLOMB LAW. DISCUSS ITS VECTORIAL FORM AND GIVE EFFECT OF MEDIUM ON IT.

In **1784**, French military engineer **Charles Coulomb** deduced a law known as Colomb law which measures the force b/w two charges.

Statement: - "**The force of attraction or repulsion b/w two charges is directly proportional to the product of the magnitude of charges and inversely proportional to the square of distance b/w them**".

Mathematically: - $F \propto q_1 q_2$ and $F \propto \frac{1}{r^2}$ ……..> $F = K\frac{q_1 q_2}{r^2}$

K (Colomb Constant): K is called Colomb constant, whose value is **9×10^{9} Nm^{2}C^{-2}**.

The value of K depends upon: - a) the system of units b) Nature of medium b/w charges

If medium is free space then $K=\frac{1}{4\pi\varepsilon_o}$, ε_o is permittivity of free space its value in SI unit is

$8.85*10^{-12}\ N^{-1}m^{-2}c^{2}$, so Colomb law becomes **F=** $\frac{1}{4\pi\varepsilon_o}\frac{q_1q_2}{r^2}$,

This is mathematical form of Colomb law.

Vectorial form of Colomb law: Let us consider two point charges q_1 and q_2, if q_1 exert a for on q_2 then q_2 also exert a force on q_1 which is equal in magnitude but opposite in direction as shown in fig

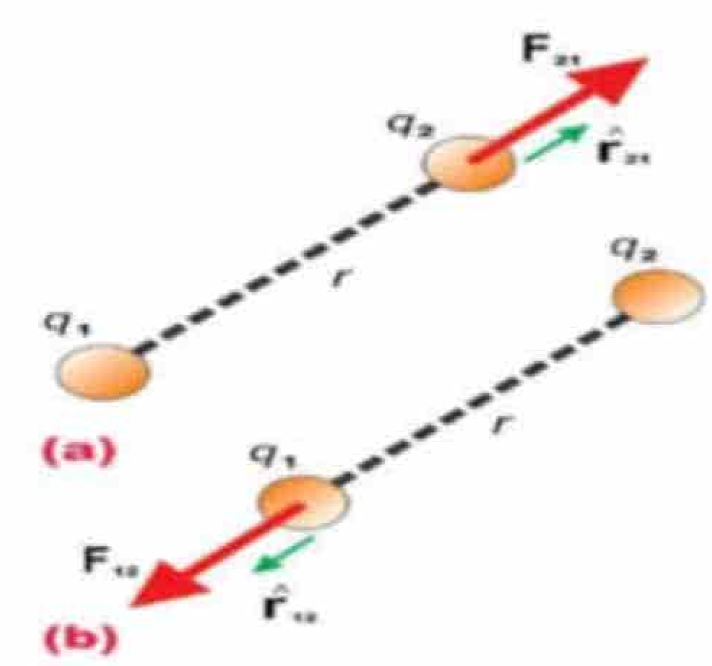
$$\vec{F}_{12}=\frac{1}{4\pi\varepsilon_o}\frac{q_1q_2}{r^2}\hat{r}_{12}-----(1$$

$$\vec{F}_{21}=\frac{1}{4\pi\varepsilon_o}\frac{q_1q_2}{r^2}\hat{r}_{21}-----(2$$

Both forces are equal but opposite in direction so

$$\vec{F}_{12}=-\vec{F}_{21}$$

This is called Vectorial form of Colomb Law. this is mutual force.



Effect of medium on Colomb force: Coulomb force is reduced when medium is placed b/w two charges. The insulating medium placed b/w two charges is called dielectric like Teflon etc. so formula for Colomb force becomes **F=**$\frac{1}{4\pi\varepsilon_o\varepsilon_r}\frac{q_1q_2}{r^2}$ **ε_r** is relative permittivity, its value is different for different dielectrics, and its value is **greater than one** other than vacuum. For air ε_r=1.0006, for vacuum ε_r=1.

Limitation of Colomb law: Colomb law is applied only on point charges.

Multiple Choice Questions

1	SI unit of Coulomb constant	**Nm^2C^{-2}**	$C^2N^{-1}m^2$	$C^2N^2m^{-2}$	$Nm^{-2}C^2$
2	The electric force of repulsion between two electrons at distance of 1m is	1.8N	$1.5x10^{-9}$ N	**$2.3x10^{-28}$ N**	$2.3x10^{-30}$N
3	If the distance between two point charges is doubled then force between them will becomes	Half	Double	Four times	**One fourth**
4	If the distance between two charges is half then force becomes	Half	One fourth	Two times	**Four times**

5	Two point charges +2C and +6C repel each other if a charge of -2C is given to each of them then electric force will be	**Zero N**	8×10^{9} N(attractive)	108×10^{9}N (repulsive)	12×10^{9} N (attractive)
6	SI unit of Ɛo is	$Nm^{2}C^{-2}$	**$C^{2}N^{-1}m^{-2}$**	$C^{2}N^{2}m^{-2}$	$Nm^{-2}C^{2}$
7	The value of relative permittivity for all the dielectrics other than air or vacuum is unit:	Less than unity	**Greater then unity**	Equal to unity	Zero
8	Presence of dielectric other than air or vacuum always	Increase the electric force	**Decrease the electric force**	Does not affect electric force	Double the electric force
9	The force between two charges separated by air is 4N. When separated by a medium of relative permittivity 2. The force between them becomes	½ N	**2N**	4N	8N
10	Dielectric constant for Teflon is	1	2	**2.1**	2.94
11	One coulomb charge is created by	10 electron	1.6×10^{-19} electron	**6.25×10^{18} electrons**	6.25×10^{21} electron
12	The force b/w two charges is 28N, if dielectric of value 2.8 is kept then force becomes	**10 N**	20 N	30 N	40 N
13	The value of coulomb constant in SI	6.25×10^{-18}	8.85×10^{-12}	**9×10^{9}**	1.6×10^{-19}
14	SI unit of charge	Ampere	Volt	eV	**Coulomb**

What is Electric field and electric field intensity? Derive its formula.

***Electric field**:"**The space or region around a charge within which another charge experience a force is called electric field**".

Michal Faraday introduced the concept of electric field.

***Electric field intensity:**

"The force experience by unit positive charge placed a point in electric field is called electric field strength or field intensity", its unit N/C and formula $\vec{E} = \frac{\vec{F}}{q}$

it is vector quantity and its direction along the direction of force.

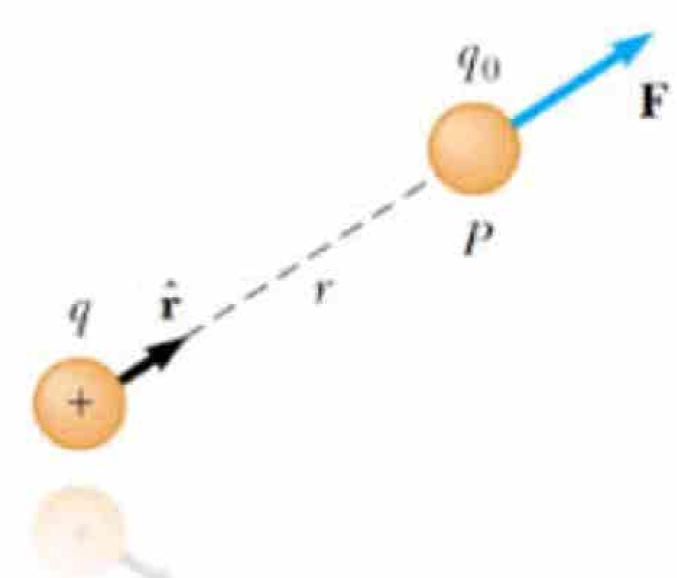
***Electric field intensity due to a point charge q:**

The force experienced by test charge qo placed in the field of charge q is calculated by Colomb law and electric field intensity is calculated by putting in formula of field intensity.

$$\vec{E} = \frac{\vec{F}}{q_o} \quad ------(1$$

$$\vec{F} = \frac{1}{4\pi\varepsilon_o}\frac{qq_o}{r^2}\hat{r} \quad ---(2 \quad \text{put this value in equation (1)}$$

$$\vec{E} = \frac{1}{q_o} * \frac{1}{4\pi\varepsilon_o}\frac{qq_o}{r^2}\hat{r} = \frac{1}{4\pi\varepsilon_o}\frac{q}{r^2}\hat{r} \quad \text{also written as } \vec{E} = K\frac{q}{r^2}\hat{r}$$



Electric field intensity depends upon a) magnitude of charge b) medium c) distance from charge

What are Electric field lines? Write its properties.

Definition: "**The direction of electric field intensity is represented by lines which are called electric field lines**".

- **Michal Faraday introduced the concept of field lines**.
- The field due to positive point charge is directed **radially outward**
- The field due to negative charge is directed **radially inward**
- The middle region b/w two same charges has no field due to repulsion of like charges, is called zero field sport or **neutral zone**.

Properties of Electric field lines: There are following properties field lines

i) Electric field lines starts from positive charges and end on negative charges.
ii) The tangent to a field line at any point gives the direction of the electric field intensity at that point.
iii) The lines are closer where the field is strong; the lines are farther apart where

the field is weak.
iv) No two lines cross each other because at a single point electric field has only one direction.

PRACTICE MCQS

1	Concepts of electric field lines was given by	Colomb	**Faraday**	Joule	Millikan
2	The field created by positive charge	**Radially outward**	Radially inward	Both A&B	None of these
3	The field created by negative charge	Radially outward	**Radially inward**	Both A&B	None of these
4	The value of field at middle region b/w two same charges	Maximum	Minimum	**Zero**	None
5	The lines which provide information about the electric force exerted on charged particle are	Magnetic field lines	**Electric field lines**	Tangent lines	Curved lines
6	Electric field lines are	Real	**Imaginary**	Perpendicular	Parallel
7	Electric field lines never –each other	Attract	**Intersect**	Repel	None
8	Electric lines are closer where the field	Weak	**Strong**	Negligible	Zero
9	Electric field lines due to a charge in	One D	Two-D	**Three-D**	Four-D
10	Closeness of field lines is the measure of	Direction of potential	Direction of field	**Strength of field**	Uniformity of field
11	A charge of 4 C is in the field of 4 N/C, the force on charge is	8N	**16N**	4 N	1 N
12	The force on an electron in a field of	$2.6*10^{-8}$ N	**$2.88*10^{-11}$ N**	$2.6*10^{-19}$N	$1.6*10^{-27}$ N

	$1.8*10^8$ N/C				
13	The unit of electric field intensity is	Newton	Coulomb	Joule/coulomb	**Newton/coulomb**
14	An electric field can deflect	Neutron	Gamma rays	**Beta particles**	Gamma particle
15	If the magnitude of charge and distance are both doubled then intensity of field	Doubled	**Halved**	Unaffected	One fourth

There are two applications of Electrostatics: a) Xerography b) Inkjet printers

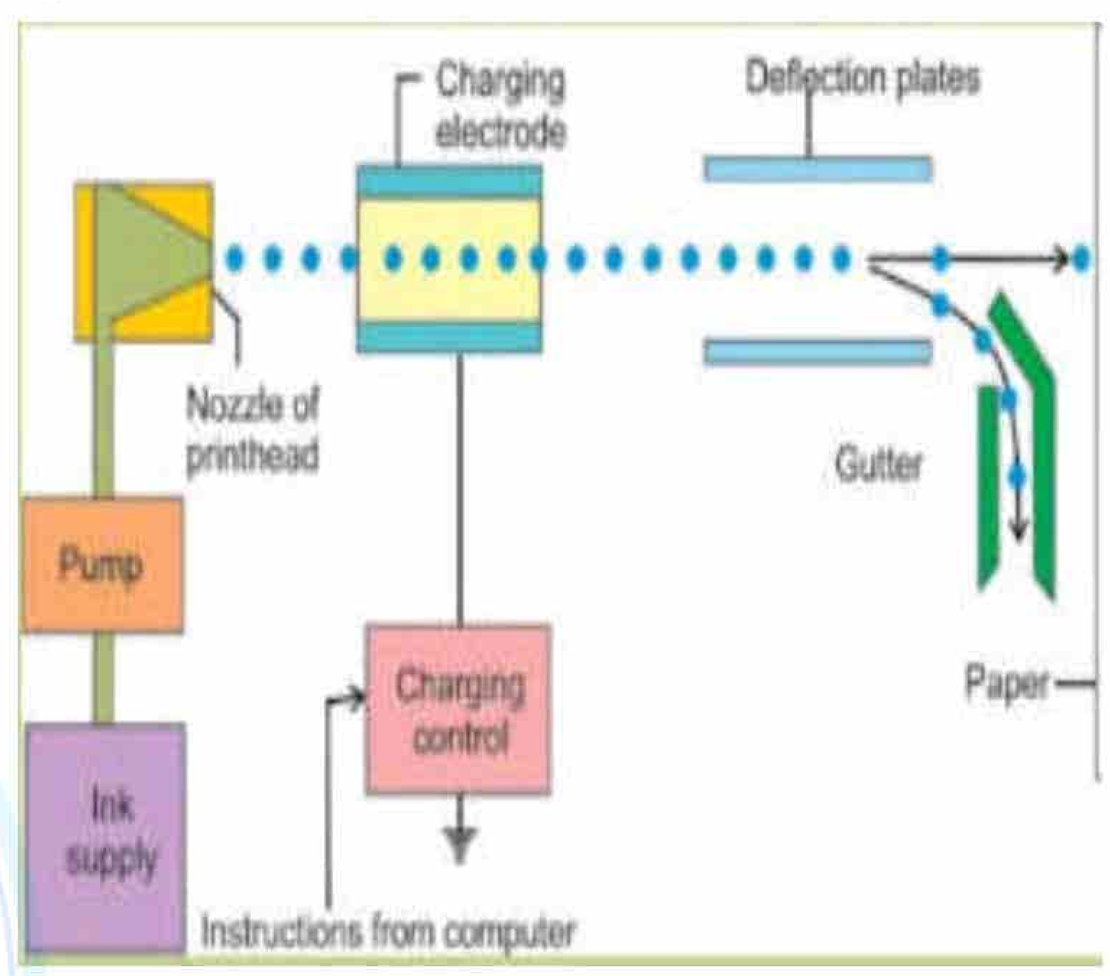
What is inkjet printer? Write principle and working.

Inkjet printer: "**Such a printer which uses electric charge in its working is called inkjet printer**".

Principle: Inkjet printers works on the principle of Electrostatics.

"It eject a thin stream of ink when shuttling back and forth across the paper and ink is ejected from small nozzle and break into small droplets".

Working:



An inkjet print head eject a steady flow
Of ink droplets. The charging electrodes are used
To charge the droplet that are not need on the paper
Charged droplets are deflected into a gutter by the
Deflection plates, while uncharged droplets fly straight
Onto the paper.
Inkjet printer also produce colored images.

Q. Write A Note On Xerography?

Xerography (Photo copier): It is Greek word, Xero mean dry; graphos mean writing, and Xerography mean dry writing. "The copying process is called Xerography".

Photocopier works on the following principle: Photocopier works on the principle of Electrostatics.

"The lamp transfer image of page to the drum which leaves the static charge. The drum collects the toner dust and transfer it to the paper, the toner is melted on page".

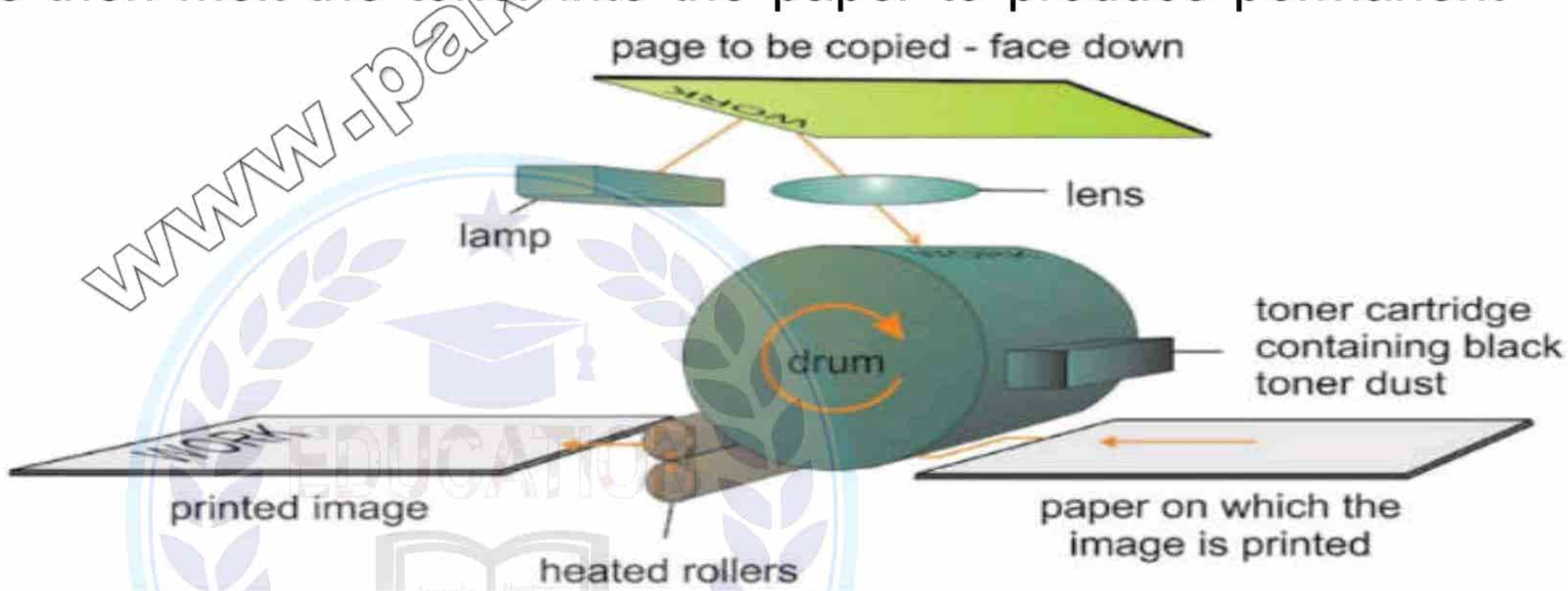
Main parts of photocopier: 1) Drum 2) toner 3) heated rollers

Drum is the heart of photocopier machine. Dum is an aluminum cylinder coated with layer of selenium.

Such materials which show conduction only when light falls on them, otherwise they are insulators in absence of light are called photoconductors like selenium.

Working: If the drum is exposed to an image of document to be copied, the dark and light areas of document produce same dark and light areas on the drum.

The dark areas retain their positive charge but light areas becomes conducting, in this way a positive charge image of document remains on the selenium surface, then a special dry black powder called "Toner" is given a negative charge and spread over the drum, where it sticks to the positive charge areas, the toner from the drum is transferred on to a sheet of paper on which document is to be copied, heated pressure rollers then melt the toner into the paper to produce permanent image of document.



Multiple choice questions

1	Photo copier and inkjet printers are the applications of	Electronics	Electricity	Magnetism	**Electrostatics**
2	One of the practical application of electrostatic induction is	Laser	x-ray machine	**Photo copier**	WC chamber
3	Which one is photo conductor	Copper	**Selenium**	Mercury	Aluminum

4	word" Xerography " means	Writing by left hand	Writing be children	**Dry writing**	Writing by water colors
5	Photocopying process is called	photography	**Xerography**	Scanning	Holography
6	In photocopier special black powder called toner gives	Positive charge	**Negative charge**	Neutral charge	none

Q. DEFINE ELECTRIC FLUX. CALCULATE THE ELECTRIC FLUX THROUGH A SURFACE ENCLOSING A CHARGE

Definition: "**Total number of electric field line passing normally through certain area is called electric flux.**

OR: The scalar or dot product of electric field intensity and vector area is called electric flux"

Equation with unit: $\varphi_e = \vec{E}.\vec{A}$,= $EA\cos\theta$ its unit is Nm^2C^{-1},

it is scalar quantity. is Greek letter. Electric flux depends on electric field intensity, vector area and orientation of surface.

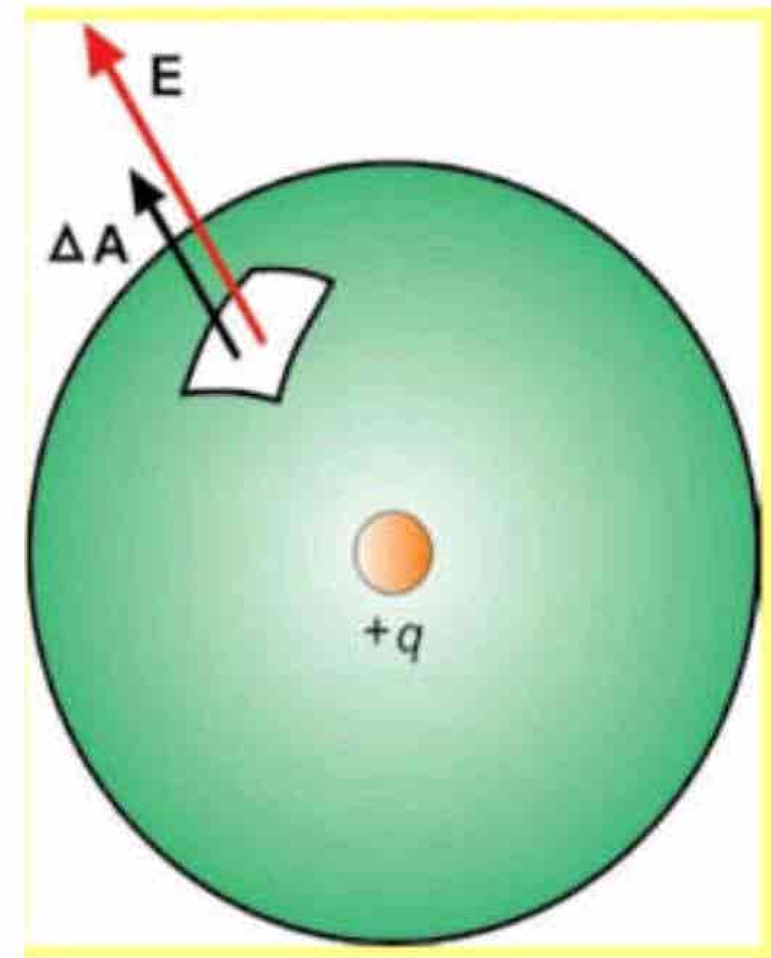
Cases of electric flux: When angle b/w electric field and vector area =0° =EAcos0°=EA= maximum electric flux

When angle b/w electric field and vector area =90°, =EAcos90°=0= minimum electric flux

Vector area: An area whose magnitude is equal to surface area A of the element but its direction is normal to this area is called vector area.

ELECTRIC FLUX THROUGH A SURFACE ENCLOSING A CHARGE

Consider a closed surface in the form of sphere of radius r having charge q. The surface is divided into n small patches of vector area are $\Delta \mathbf{A_1}$, ΔA_2,ΔA_3…..$\Delta \mathbf{A_n}$ so that each patch is a flat. Electric intensity for each patch are E_1, E_2, E_3,E_n respectively.



for first patch $\varphi_{e1} = \vec{E}_1.\Delta\vec{A}_1,$

for 2nd patch $\varphi_{e2} = \vec{E}_2.\Delta\vec{A}_2$

for 3rd patch $\varphi_{e3} = \vec{E}_3.\Delta\vec{A}_3$

and so on...similarly

for nth patch $\varphi_{en} = \vec{E}_n.\Delta\vec{A}_n$

Total electric flux through closed surface will be

$\varphi_{total} = \varphi_1 + \varphi_2 + \varphi_3 + ...\varphi_n$ putting values

$$\varphi_{total} = \vec{E}_1.\Delta\vec{A}_1 + \vec{E}_2.\Delta\vec{A}_2 + \vec{E}_3.\Delta\vec{A}_3 + ...\vec{E}_n.\Delta\vec{A}_n$$

$$\varphi_{total} = E_1\Delta A_1 \cos\theta + E_2\Delta A_2 \cos\theta + E_3\Delta A_3 \cos\theta + ...E_n\Delta A_n \cos\theta$$

As the direction of electric intensity and vector area is same at each patch so $\theta = 0^o$

$$\varphi_{total} = E_1\Delta A_1 \cos 0^o + E_2\Delta A_2 \cos 0^o + E_3\Delta A_3 \cos 0^o + ...E_n\Delta A_n \cos 0^o \qquad \cos 0^o = 1$$

$\varphi_{total} = E_1\Delta A_1 + E_2\Delta A_2 + E_3\Delta A_3 + ...E_n\Delta A_n$ As we know that $E_1 = E_2 = E_3 ... = E_n = E$ for each patch

$$\varphi_{total} = E(\Delta A_1 + \Delta A_2 + \Delta A_3 + ...\Delta A_n) = E(\text{ Total Area of sphere})$$

As $E = \frac{1}{4\pi\varepsilon_o}\frac{q}{r^2}$ surface Area of sphere $= 4\pi r^2$

$$\varphi_e = \frac{1}{4\pi\varepsilon_o}\frac{q}{r^2}(4\pi r^2) = \frac{q}{\varepsilon_o}$$

$\varphi_e = \frac{q}{\varepsilon_o}$...........Req Result,

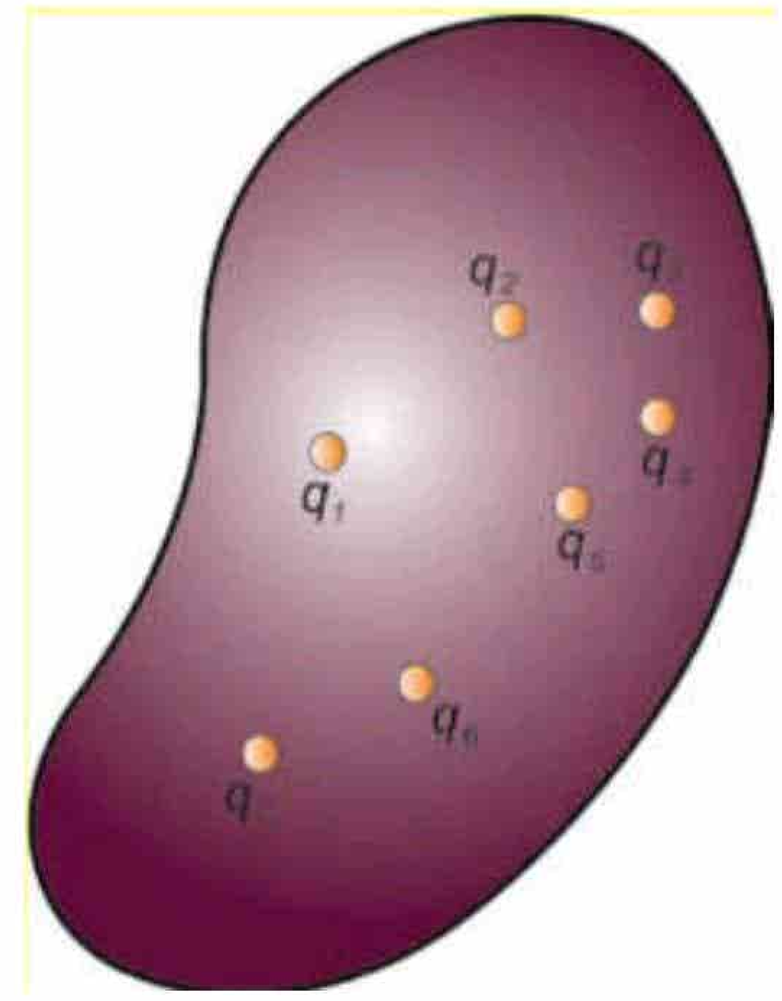
This shows that electric flux through closed surface depends upon medium and charge enclosed.

State and prove Gauss's law?

Statement:"**Electric flux through any closed surface is equal to $1/\varepsilon_o$ times the total charge enclosed in it**"

Mathematically it can be written as $\varphi_e = \frac{1}{\varepsilon_o} * Q$

Proof: consider a closed surface having n point charges q_1,q_2,…on, total electric flux is calculated as



flux due to first point charge $q_1 = \varphi_1 = \frac{q_1}{\varepsilon_o}$ ------ (1)

flux due to2nd point charge $q_2 = \varphi_2 = \frac{q_2}{\varepsilon_o}$ ------ (2)

flux due to 3rd point charge $q_3 = \varphi_3 = \frac{q_3}{\varepsilon_o}$ ------ (3)

flux due to nth point charge $q_n = \varphi_n = \frac{q_n}{\varepsilon_o}$ ------ (n)

$$\varphi_{\text{total}} = \varphi_1 + \varphi_2 + \varphi_3 + \dots\dots\dots\dots\dots\varphi_n$$

$$\varphi_{\text{total}} = \frac{q_1}{\varepsilon_o} + \frac{q_2}{\varepsilon_o} + \frac{q_3}{\varepsilon_o} + \dots\dots\frac{q_n}{\varepsilon_o}$$

$$\varphi_{\text{total}} = \frac{1}{\varepsilon_o} * (q_1 + q_2 + q_3 + \dots\dots\dots q_n)$$

$$\varphi_{\text{total}} = \frac{1}{\varepsilon_o} * (\mathit{Total}\text{ charge enclosed surface}) = \frac{1}{\varepsilon_o} * Q = \text{Req result}$$

Applications of Gauss law

To calculate the electric field intensity we take following steps.

Step 01: Construct a Gaussian surface and charge enclosed by it.

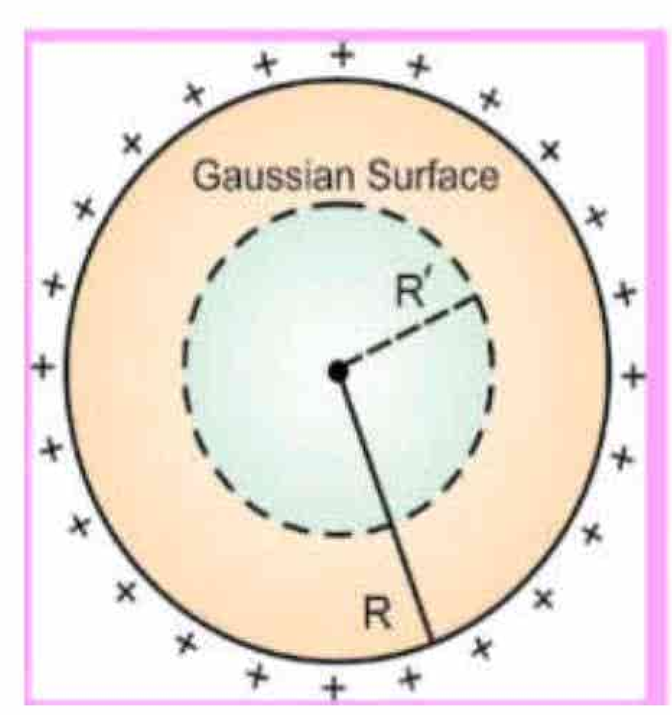
Gaussian Surface: "**An Imaginary closed surface which passes through point we want to calculate field is called Gaussian surface**".

Step 02: Calculate the electric flux through the surface

Step 03: Calculate the electric field by applying Gauss's law.

Q. Calculate the Intensity of field inside a hollow charged sphere?

To calculate the field intensity inside a charged sphere.



Step 01: Construct a Gaussian surface of R'

inside the sphere in which there is no charge q=0

Step 02: To calculate the flux use formula $\varphi_e = \vec{E}.\vec{A}$ ---------------- (1

Step 03: Using Gauss's law $\varphi_{\text{total}} = \frac{1}{\varepsilon_o} * q$ as there is no charge

in surface so flux is zero then

Equation 1) $\varphi_e = \vec{E}.\vec{A}$ =0 so this result into $\overline{E}$=0 inside the sphere.

Q.CALCULATE THE ELECTRIC INTENSITY DUE TO AN INFINITE SHEET OF

CHARGE.

Consider an infinite sheet on which positive charge is uniformly distributed.

To calculate the electric intensity at any point

<u>Step 01</u>: consider a Gaussian surface in the form of cylinder passing through sheet having Area A and σ is uniform **surface charge density**, so the charge enclosed by it is **q=σA**

<u>Step 02</u>: For calculation of electric flux through each surface of Gaussian cylinder

$$total\ flux = flux\ t\ \ roug\ \ \ rig\ \ t\ flat\ surface + flux\ t\ \ roug\ \ \ left\ flat + flux\ t\ \ roug\ \ \ curved\ surface$$

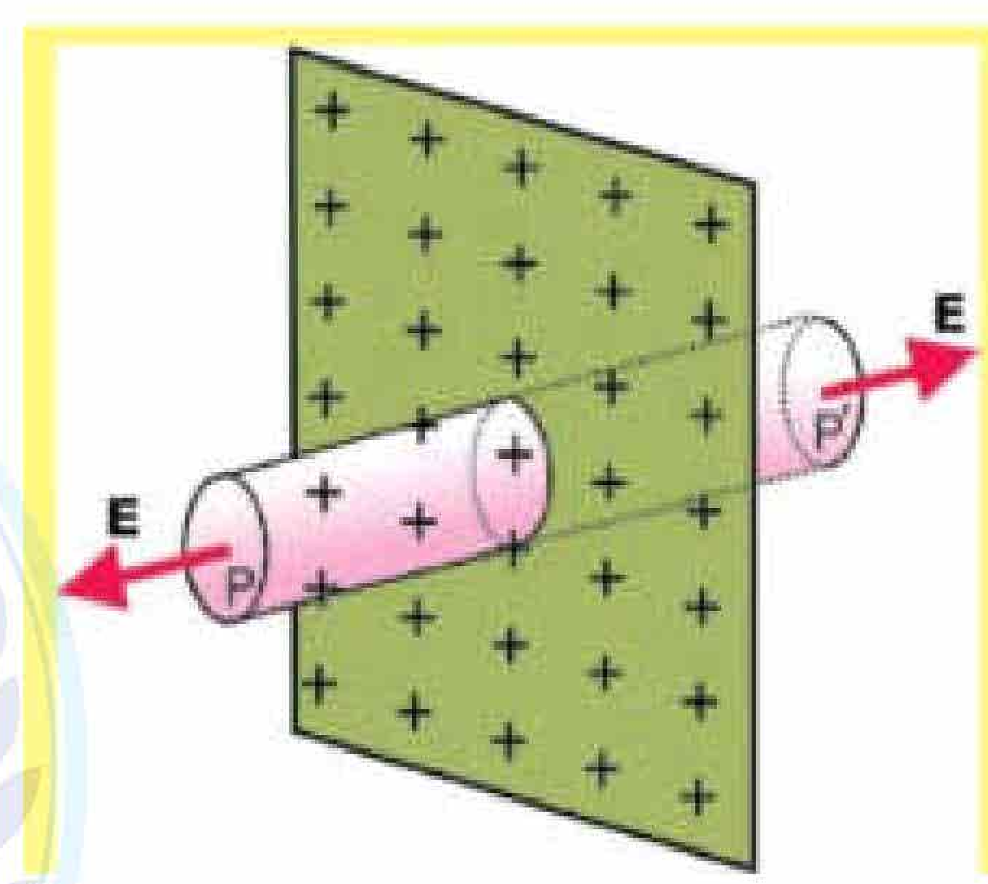
$$\varphi = \bar{E}.A + \bar{E}.A + no\ field\ lines\ passing\ t\ \ roug\ \ \ cuved\ surface$$

$\varphi = EAcos\theta + EAcos\theta + 0$ as E and A are parallel so angle Ɵ=0°

$\varphi e = EAcos0° + EAcos0°$ = $EA + EA$ =2EA ---------- (1

<u>Step 03</u>: According to Gauss's law $\varphi_{\text{total}} = \frac{1}{\varepsilon_o} * q$ ------------- (2

Comparing both eqs.



2EA=$\frac{1}{\varepsilon_o} * q$ putting the value of q so

2EA =$\frac{1}{\varepsilon_o}$(σA) $\mathrm{E} = \frac{\sigma}{2\varepsilon_o}$

In vectorial form $\vec{\mathrm{E}} = \frac{\sigma}{2\varepsilon_o}\hat{r}$

Q. CALCULATE THE ELECTRIC INTENSITY B/W TWO OPPOSITELY CHARGED PARALLEL PLATES

Consider two parallel plate of closely spaced having opposite uniform distributed charge.. Electric field lines start from positive plate and end on negative plate

<u>Step 01</u>: Consider a Gaussian surface in the form of hollow box having Area A and σ is uniform surface charge density, so the charge enclosed by it is q=σA

Step 02: For Calculating electric flux through each surface of hollow box we follow

Total electric flux= flux through upper surface of box**+** flux through lower surface of box**+** flux through sides of box

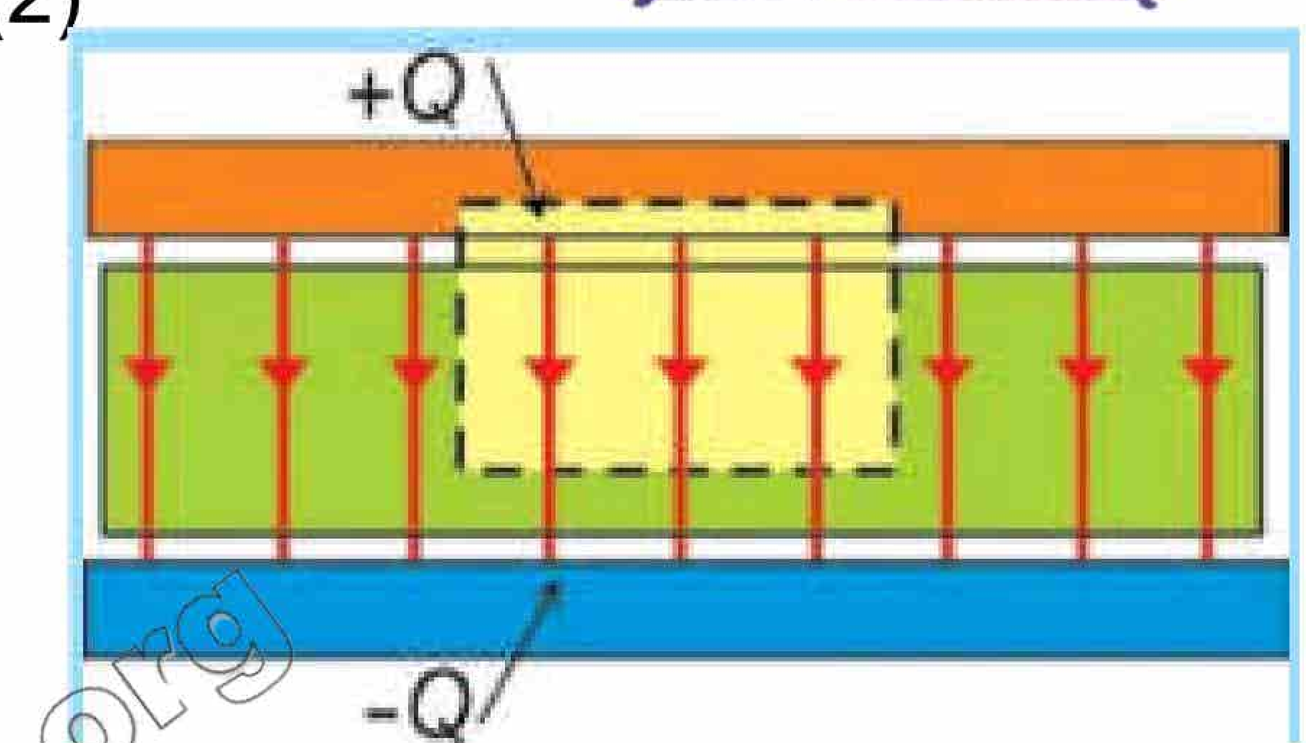
As there is no field through upper end of box so flux through it will be zero

Flux through lower surface= $\varphi = EAcos\theta = EAcos0° = EA$

Flux through side of box is zero because they are parallel to field lines

So total electric flux becomes= φ_e=0+EA+0=EA ------------(1)

Step 03: According to Gauss's law $\varphi_{total} = \frac{1}{\varepsilon_o} * q$ ----(2)



comparing both equations to get the result

$$EA = \frac{1}{\varepsilon_o} * q \Rightarrow EA = \frac{1}{\varepsilon_o} * \sigma A \Rightarrow E = \frac{\sigma}{\varepsilon_o}$$

in vectorial for $\vec{E} = \frac{\sigma}{\varepsilon_o} \hat{r}$

Multiple choice questions

1	For the computation of electric flux the surface should be	**Closed**	Curved	Inclined	Spherical
2	SI unit of electric flux is	Nm^2C^{-2}	**Nm^2C^{-1}**	NCm^{-2}	$Nm^{-2}C^{-3}$
3	When vector area L is held perpendicular to electric field lines then magnitude of electric flux is	Maximum	**Minimum**	Either maximum or minimum	Negative
4	Electric flux depends upon	Electric intensity	Area of surface	Orientation of area	**All of these**
5	Electric flux is a:	Vector, Nm^2C^{-1}	Scalar, Nm^2C	**Scalar ,Nm^2C^{-1}**	Vector,Nm^2C^{-2}
6	What does Nm^2C^{-1} stands for quantity	Electric field	Electric potential	**Electric flux**	Electric force
7	Equation Ø=**E.A** is applicable to surface	Spherical	Cylindrical	Conical	**Flat**
8	The value of	90°	**0°**	270°	180°

	maximum electric flux is obtained when angle between $\overline{\boldsymbol{E}}$ and $\overline{\boldsymbol{A}}$ is				
9	Which one of the following can be taken as measure of electric field intensity	$\frac{F}{A}$	$\underline{\frac{\phi_e}{A}}$	$\frac{qA}{\varepsilon_o}$	$\frac{\varphi_e \varepsilon_o}{A}$
10	Electric field intensity inside a hollow charge sphere	$\frac{\sigma}{\varepsilon_o}$	$\frac{\sigma}{2\varepsilon_o}$	**Zero**	None
11	Electric field intensity due to infinite sheet of charge	$\frac{\sigma}{\varepsilon_o}$	$\underline{\frac{\sigma}{2\varepsilon_o}}$	Zero	None
12	Electric field intensity between two oppositely parallel plates	$\underline{\frac{\sigma}{\varepsilon_o}}$	$\frac{\sigma}{2\varepsilon_o}$	Zero	None
13	Electric field due to infinite sheet is ----of between two oppositely parallel plates	**Half**	Double	Four times	Same as
14	Surface charge density is equal to	**Charge/area**	Charge/field	Field/ charge	Force/ charge
15	SI unit of surface charge density	**C/m^2**	C/m	Nm	N/C
16	Special organ called ampullae of lonrenzini that are sensitive to E	Bats	Cats	Dogs	**Sharks**
17	Electric flux does not depend upon	Charge enclosed	Medium	Both A&B	**Shape of closed surface**
18	Statement $\varphi_e = \frac{Q}{\varepsilon_o}$ given by	Fermi	Coulomb	Farad	**Gauss**

19	Negative sign in electric potential gradient shows that electric intensity is along	Increasing potential	Increasing strength	**<u>Decreasing potential</u>**	Negative potential
20	Gauss law is applied only to a surface which is	Open	Straight	**<u>Closed</u>**	All of these
21	A rubber ball of radius 2cm has charge 5C on its surface, E at its center is	10 N/C	2.5 N/C	**<u>Zero</u>**	5 N/C

What is Electric potential and potential difference? Write SI unit with formula.

<u>Electric potential:</u> "The electric potential energy per unit charge is called electric potential". V=W/q. Its unit is J/C which is equal to volt.

<u>Potential difference</u>: "The amount of work done in moving a charge from one point to other against electric field keeping the charge in equilibrium is called potential difference". OR

The difference of potential energy per unit charge b/w two points is called potential difference $\Delta V = \frac{\Delta U}{q}$ and unit is volt.

<u>Volt</u>: SI unit of electric potential and potential difference is volt

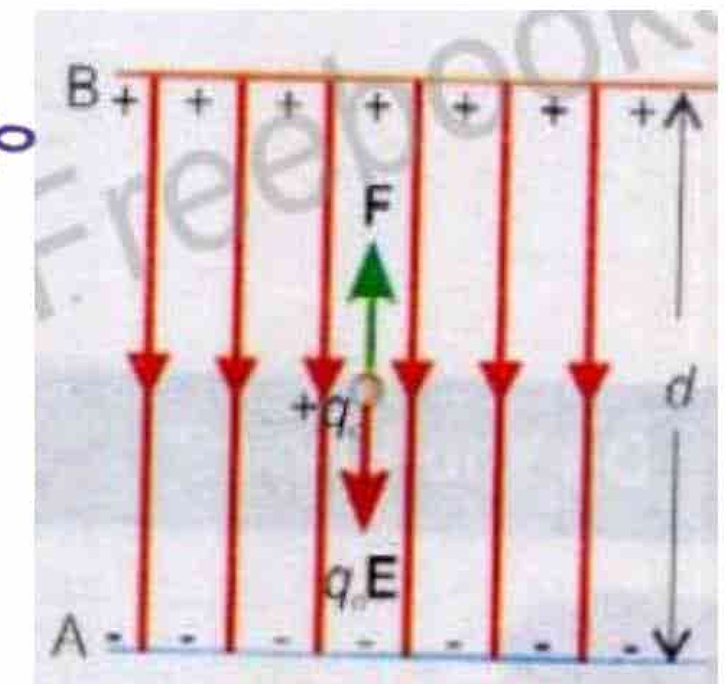
<u>Definition of volt</u>: "If one joule of work is done in carrying a unit positive charge of 1 coulomb from one point to other keeping the charge in rest position, then potential difference will be one volt".

1 joule/Coulomb=1 volt

Q. What is Potential gradient? Derive its relation.

Definition: **"The quantity $\frac{-\Delta V}{\Delta r}$ gives the maximum rate of change of potential with respect to distance which is called the potential gradient".** Its unit is **V/m.**

Relation: consider uniform Electric field E b/w two oppositely charged parallel plates and charge is moved again field



The potential difference b/w two points

$$V_B - V_A = \frac{W_{AB}}{q_o} = \frac{\vec{F}.\vec{d}}{q_o} = \frac{q_o Ed\cos\theta}{q_o} = \frac{q_o Ed\cos 180^o}{q_o} = -Ed \qquad \cos 180^o = -1$$

as the distance b/w plates is small so d = Δr then above equation becomes

$$V_B - V_A = \Delta V = -E(\Delta r)$$

$$E = -\frac{\Delta V}{\Delta r}$$

Prove that $\frac{1\,\text{newton}}{1\,\text{colomb}} = \frac{1\,\text{Volt}}{1\,\text{meter}}$

$$E = -\frac{\Delta V}{\Delta r} = \frac{V}{m} - - - - - - - - - - - - - - - -$$

as we know that 1volt= 1J/C, and joule= Nm

$$\frac{V}{m} = \frac{J/C}{m} = \frac{J}{Cm} = \frac{Nm}{Cm} = \frac{N}{C} - - - -$$

Required result

Q. What is absolute potential? Calculate the Electric potential due to a point charge.

Definition: "**The work done in bringing a unit positive charge from infinity to that point keeping electrostatic equilibrium is called absolute potential or electric potential at a point**".

Calculation of potential: Consider a positive point charge q is moved from infinity to that point keeping it in equilibrium, since electric field intensity changes inversely to square of distance, so it does not remains same so taken two points A and B close to each other so that E remains same

The distance of point A from charge $q = r_A$

The distance of point B from charge $q = r_B$

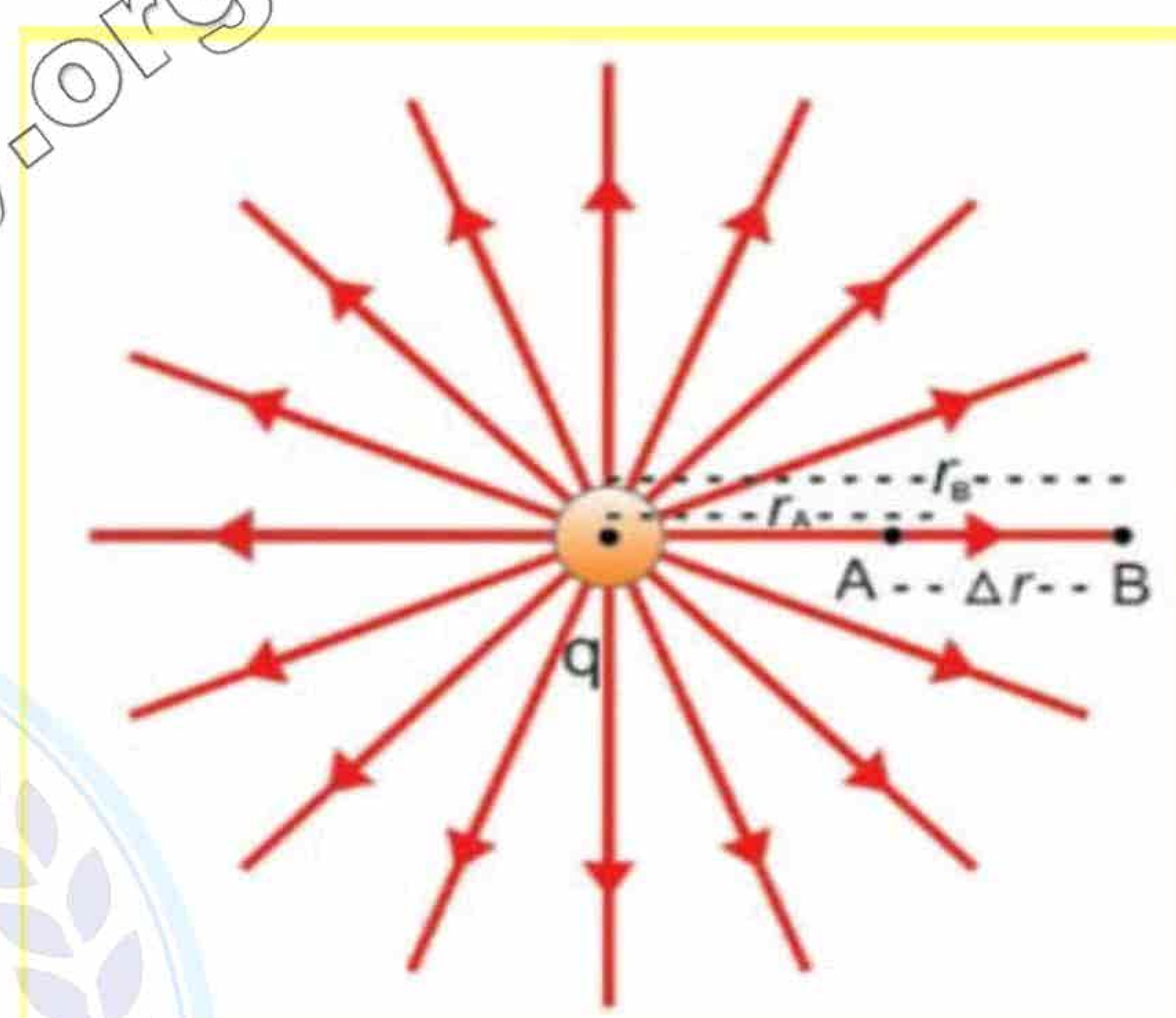
$$\Delta r = r_B - r_A \text{ ---------------- } (1)$$

The mid point b/w A and B is given as $r = \frac{r_A + r_B}{2}$, and the magnitude of field at this point

$E = \frac{1}{4\pi\varepsilon_o}\frac{q}{r^2}$, since the points are close to each other so we take approximations

$r_A \approx r_B = r$ so we can say that $r^2 = rxr = r_A r_B$ so the field becomes

$$E = \frac{1}{4\pi\varepsilon_o}\frac{q}{r_A r_B}$$



now using the formula of potential gradient $\Delta V = -E\Delta r$

$V_B - V_A = -E(r_B - r_A)$ it may also written as

$V_A - V_B = -E(r_A - r_B)$, applying minus inside the bracket

$V_A - V_B = E(r_B - r_A)$ putting the value of field

$$V_A - V_B = \frac{1}{4\pi\varepsilon_o}\frac{q}{r_A r_B}(r_B - r_A) = \frac{q}{4\pi\varepsilon_o}(\frac{r_B - r_A}{r_A r_B})$$

$$V_A - V_B = \frac{q}{4\pi\varepsilon_o}(\frac{r_B}{r_A r_B} - \frac{r_A}{r_A r_B}) = \frac{q}{4\pi\varepsilon_o}(\frac{1}{r_A} - \frac{1}{r_B})$$

As the point B is at infinity so $r_B = \infty$ and $V_B = 0$ and $\frac{1}{r_B} = \frac{1}{\infty} = 0$

$$V_A - 0 = \frac{q}{4\pi\varepsilon_o}(\frac{1}{r_A} - 0) = \frac{q}{4\pi\varepsilon_o}\frac{1}{r_A}$$

in general $V = \frac{q}{4\pi\varepsilon_o}\frac{1}{r}$, this is electric potential due to a point charge.

What is eV? Prove that 1eV=1.6*10^{-19} J.

Electron volt: "The amount of energy acquired or lost by an electron as it moves through a potential difference of one volt is called electron volt". This change in potential energy appears as kinetic energy $q=e=1.6*10^{-19}$ C

$\Delta(K.E)=q\Delta V$

$1eV=(1.6*10^{-19}C)(1volt)$

$1eV=1.6*10^{-19}(CV)$ as we know that CV=joule (J)

$1eV=1.6*10^{-19}$ J

$1eV=1.6*10^{-19}$ J **Electron Volt (eV) is the unit of energy**

Q. Write two similarities b/w electric force and gravitational force.

1) Both forces are conservative
2) Both obey inverse square law

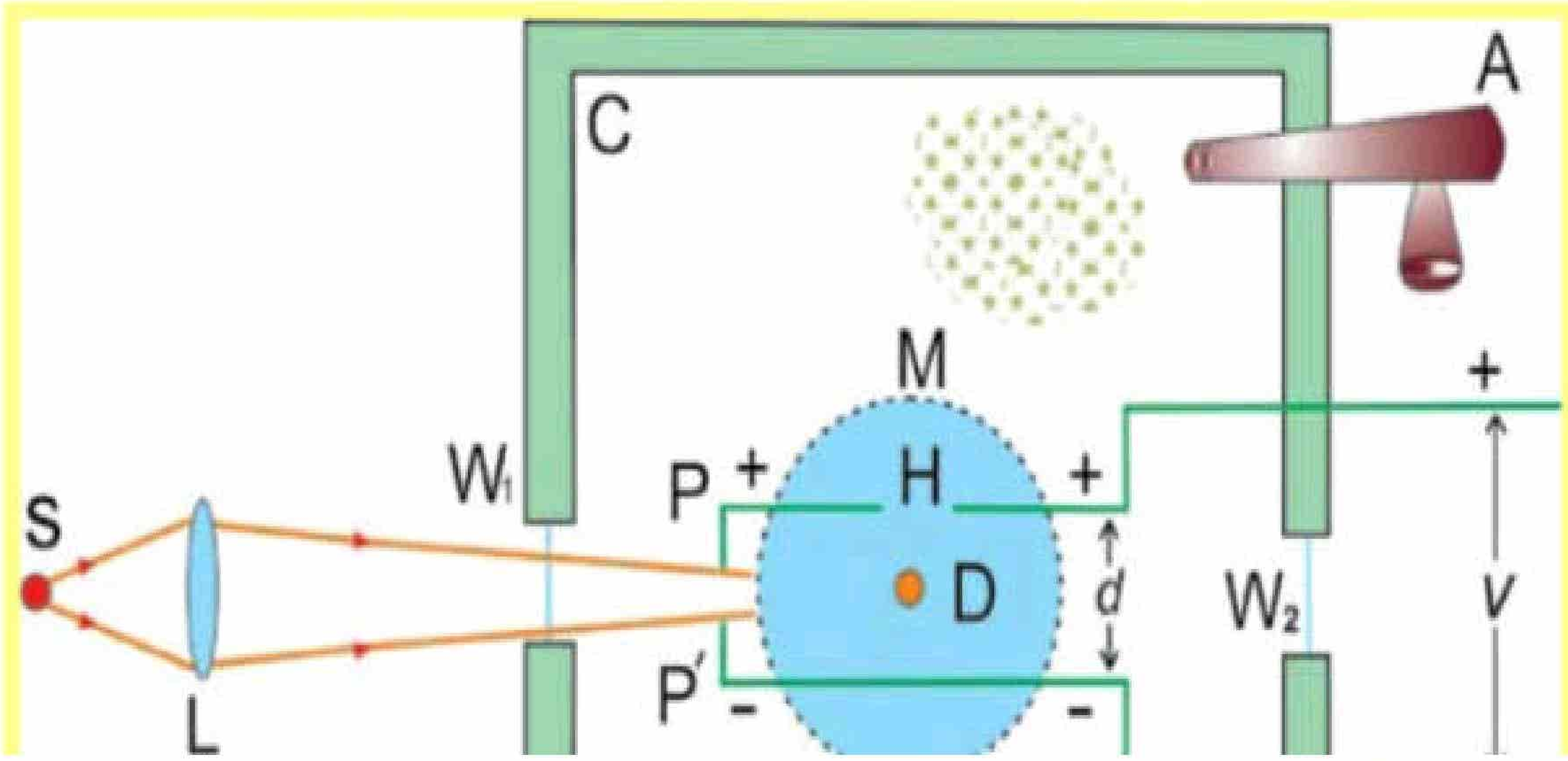
Q. Write four differences b/w electric and gravitational force.

Electric force	Gravitational force
Formula $F = K\frac{q_1 q_2}{r^2}$	**Formula** $F = G\frac{m_1 m_2}{r^2}$
It is explained by Coulomb law	It is explained by Gravitation law
It is stronger than gravitational force	It is weaker than electric force
It may be attractive or repulsive	It is attractive force only
It is medium dependent	It is medium independent
It is short range	It is long range

Q. DESCRIBE EXPERIMENT FOR FINDING THE CHARGE ON ELECTRON BY MILLIKAN OIL DROP METHOD.

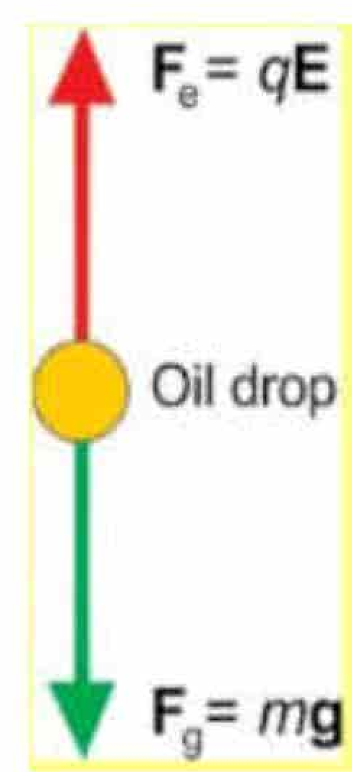
Definition: **"Such a technique which is used for finding the charge on electron devised by Millikan in 1909".**

Construction: The apparatus of this experiment consists of a evacuated chamber in which two parallel plates P and P' are placed at separation d, upper plate has small hole H. A potential difference is applied b/w plates to produce E. An atomizer is used for spraying oil drops into the chamber and light source S make the drops visible.



Working: The tiny oil droplets are sprayed into the chamber through small nozzle of atomizer which get charged negatively due to friction b/w walls of atomizer and oil drops. A potential difference is applied in such a way that electric force F=qE becomes equal to gravitational force(mg).

Charge on droplet: When electric force is equal to weight of droplet then



$$F_e = F_g \quad \Rightarrow \text{ also we know } F_e = qE, \quad F_g = mg$$

$$qE = mg \qquad \text{also we know that } E = \frac{V}{d}$$

$$q\frac{V}{d} = mg$$

$$q = \frac{mgd}{V} \qquad \text{which is the result for charge on droplet}$$

Mass and radius of droplet: For calculation of mass of droplet the electric field is switched off so droplet falls under the action of gravity through air with terminal speed Vt. In this case weight must equal to drag force so

$$F = 6\pi\eta r v_t = mg \text{ --- (1), where r is radius of droplet, if } \rho \text{ is density then } \rho = \text{m/volume}$$

$$m = \rho * \text{volume} = \rho * 4/3\,\pi\, r^3 \qquad \text{putting the value in equation (1)}$$

$$6\pi\eta r v_t = \rho * 4/3\,\pi\, r^3 g$$

$$r^2 = \frac{18\eta v_t}{4\rho g} = \frac{9\eta v_t}{2\rho g}$$

$$r = \sqrt{\frac{9\eta v_t}{2\rho g}}, \text{ this is the value of radius by knowing it we can find the mass of droplet}$$

Conclusion: Millikan measured the charge on many droplets and found each droplet is the integral multiple of $1.6*10^{-19}$C and concluded that the minimum value of charge in nature is the charge on an electron

Multiple Choice Questions

1	An ECG records, between points on human skin generated by electrical process in the heart	Current	**Voltage**	Resistance	Capacitanc
2	The amount of energy equal to 1.6×10^{-19}J is called	One volt	One milli volt	**One electron volt**	One mega electron vo
3	1 volt is equal to	$J^{-1}C^{-1}$	**JC^{-1}**	$J^{-1}C$	JC
4	Electron Volt is the unit of	Electricity	Voltage	Charge on electron	**Energy**
5	Electric potential at mid point in an electric dipole	**0 V**	5 V	1V	1.5 V
6	Electrical energy is measured in	Watt	Horse power	Killo watt	**Killo watt hour**
7	A particle having charge 2e falls through a potential difference of 5V. energy acquired by it is	2.5eV	20eV	0.4eV	**10eV**
8	If an electron of charge is accelerated through a potential difference V, it will acquire energy	**Ve**	V/2	E/2	Ve^2
9	Potential gradient is defined as	**$\frac{V}{r}$**	$\frac{E}{r}$	$\frac{V}{E}$	None of these
10	A particle carrying a charge of 2e falls through a potential difference of 3V, energy acquired by it	9.6×10^{-16}J	9.6×10^{-20}J	9.6×10^{-15}J	**9.6×10^{-19}J**

	is				
11	The amount of energy acquired or lost by an alpha particle as it moves through potential difference of 1V is	$3.2x10^{-19}$J	$6.4x10^{-19}$J	**$1.6x10^{-19}$J**	Zero
12	Absolute potential difference due to point charge of 1C at a distance of 1m	$9x10^{6}$ V	$9x10^{7}$V	$9x10^{8}$V	**$9x10^{9}$V**
13	1 joule is equal to	**$6.25x10^{18}$eV**	$6.25x10^{-18}$eV	$1.6x10^{-19}$eV	$9.1x10^{-31}$eV
14	A particle carrying a charge of 2e falls through a potential difference of 3V, energy acquired by it is	1.5 eV	0.66eV	**6eV**	3eV
15	Two opposite point charge of same magnitude separated by distance 2d, electric potential mid way between them is	1V	2V	0.5V	**0 V**
16	In Electroene Phalography the P.D by the electrical activity of --- are used for diagnose	Heart	Liver	**Brain**	Hands
17	The electrical activity of retina of eye generate—used in electro ritino graphy	Current	**Potential difference**	Resistance	Capacitance
18	1 N/C=?	1 mC	**1V/m**	V/C	C/N
19	SI unit of electric potential and potential difference are	joule	**Volt**	Colomb	Farad

20	SI unit of potential gradient is same as that of	Electric potential	**Electric field intensity**	Capacitance	None
21	1 joule/colomb is equal to	Farad	**Volt**	joule	Newton
22	If 5J of work done of an object having charge 5C than what will be potential	2 V	**1 Volt**	4 volt	25 Volt
23	Which is the property of electric force	Obey inverse square law	Conservative force	Short range than gravity	**All of these**
24	Charge on electron determined by Millikan in	1906	1907	1908	**1909**
25	Millikan and Fleter could find the charge on oil droplets in	Thermal equilibrium	**Electrical equilibrium**	Mechanical equilibrium	Unstable equilibrium
26	The name electron was suggested by	Thomson	Rutherford	Millikan	**Stoney**
27	The electrical activity of retina of eye generate—used in electro ritino graphy	Current	**Potential difference**	Resistance	Capacitance
28	minimum value of charge in nature is the charge on	**Electron**	Alpha particle	Neutron	Muon
29	The minimum charge on an object in nature cannot be less than	Zero	**1.6×10^{-19} C**	-1.6×10^{-19}C	$\pm1.6\times10^{-19}$C
30	The unit of electric field intensity other than N/C is	V/A	**V/m**	V/C	N/V
31	$-\frac{\Delta V}{\Delta r}$ is called	Electric field	**Potential gradient**	Electric potential	Capacitance
32	SI unit of electric	Kgm^2s^{-1}/C	**Kgm^2s^{-2}/C**	Kgm^2/C	$Kgms^{-2}/C$

	potential is				
33	The charge on oil droplet in Millikan oil drop experiment is calculated using	q=mg/V	**mgd/V**	v/mgd	d/mgV
34	A charged conductor has charge on	**Outer surface**	Inner surface	Middle surface	None
35	If a charge is moved against electric field, will gain	**Electric potential energy**	Kinetic energy	Both A&B	None
36	Strength of field in order to suspend a charge q and mass m	**E=mg/q**	E=m/q	E=q/mg	Both A&B
37	In Millikan experiment, if the direction field is reversed then acceleration of particle	**2g**	g	g/2	4g

Q. WHAT IS CAPACITOR? CALCULAT THE CAPACITANCE OF PARALLEL PLATE CAPACITOR.

Definition: "A Device which is used to store charge as well as electrical energy is called capacitor".

Construction: A capacitor consists of two parallel plates having opposite charge connected to potential difference V. let the Q charge on either of plate. So

$Q \propto V \quad \Rightarrow Q = CV$, C is constant of proportionality called capacitance of capacitance

Capacitance: **The ability of capacitor to store charge is called capacitance**. C=Q/V, its unit is farad.

Farad: If a charge of one coulomb given to plates of capacitor produces a potential difference of one volt b/w them then capacitance is 1 farad.**1 Farad= 1C/1V**.

Capacitance of parallel plate capacitor: Let us consider a parallel plate capacitor consisting of two metal plates each of area A separated by small distance d as shown in fig

Case A: When medium is air or vacuum b/w plates

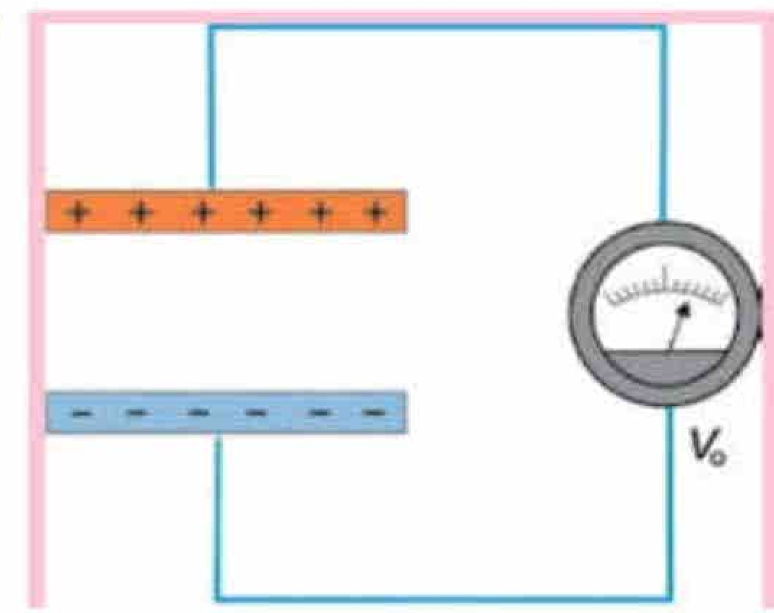
If Q is the charge on the capacitor and V is the potential difference then

$C_{vac} = \frac{Q}{V}$ - - - (1) , the magnitude of electric intensity E is related with distance and potential

$E = \frac{V}{d}$, V = Ed also we know that Electric field intensity b/w two oppositely plates is $E = \sigma/\varepsilon_o$

$V = \frac{\sigma}{\varepsilon_o} d$ also we know $\sigma = \frac{Q}{A}$

$Q = \sigma A$ putting these values in eq (1)



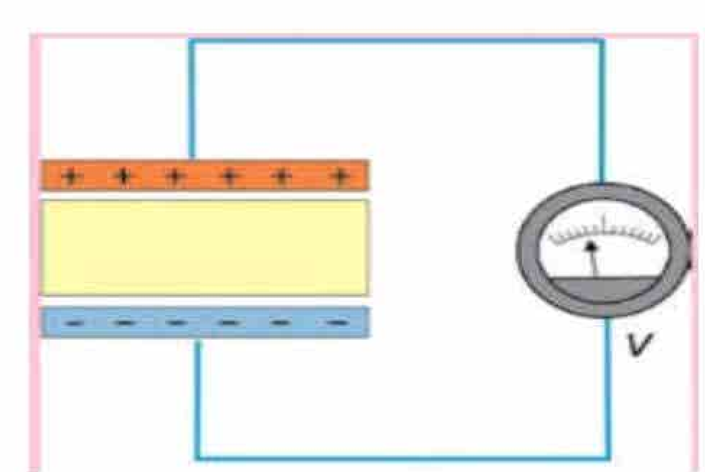
$$C_{vac} = \frac{\sigma A}{\frac{\sigma}{\varepsilon_o} d},$$

$C_{vac} = \frac{A\varepsilon_o}{d}$ this is the capacitance of parallel plate capacitor when air is placed b/w plates

case B : If insulating medium called dielectric of relative permitivity ε_r is placed b/w plates then capacitance is increased by the factor ε_r and the formula for this is $C_{med} = \frac{A\varepsilon_o \varepsilon_r}{d}$

<u>Dielectric constant</u>: "The ratio of capacitance of parallel plate capacitor with dielectric as medium to its capacitance when air as medium b/w plates is called dielectric constant".

Its formula is $\varepsilon_r = \frac{C_{med}}{C_{vac}}$ having no unit.



$$\frac{C_{med}}{C_{vac}} = \frac{\frac{A\varepsilon_o \varepsilon_r}{d}}{\frac{A\varepsilon_o}{d}} = \varepsilon_r$$

Q.What is ELECTRIC POLARIZATION OF DIELECTRIC and also define electric dipole.

<u>Electric Dipole:</u> "Two equal and opposite charges placed at small distance d formed an electric dipole".

<u>Polarization and polarized</u>: "A process in which the molecules of the dielectric under the action of external electric field become dipoles is called electric polarization" and dielectric is called polarized.

OR "The phenomenon in which negative and positive charges of atoms/molecules of dielectric are slightly displaced when a dielectric is placed in an electric field is called polarization".

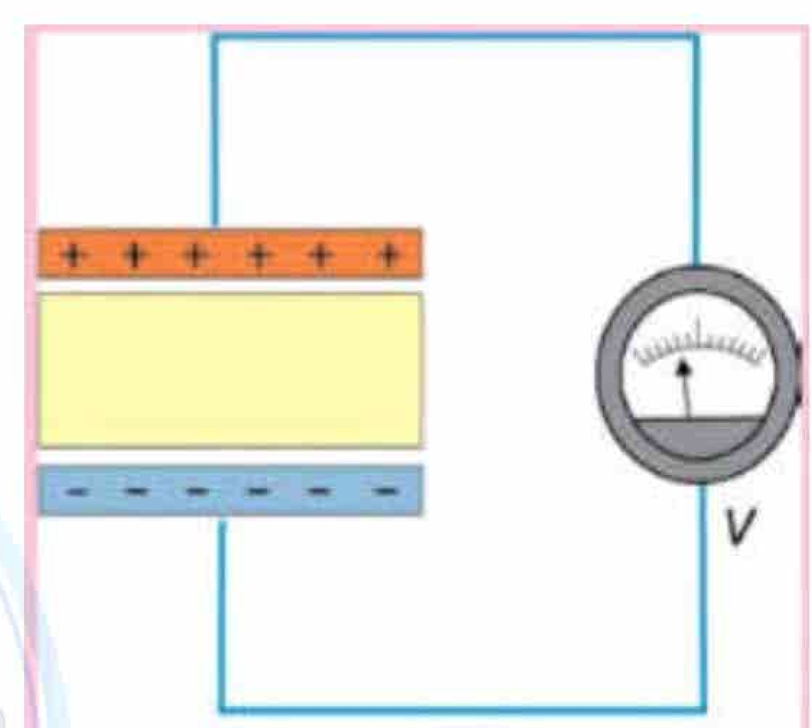
Q. What is the effect of polarization on capacitance of capacitor?

Ans: When the dielectric is placed b/w plates then capacitance of capacitor is increased. Because dielectric material decrease surface charge density on plates which decrease electric field intensity $E = \sigma/\varepsilon_o$, with this potential difference V is decreased V=Ed and capacitance is increased C=Q/V.

Q. CALCULATE THE ENERGY STORED IN CAPACITOR IN TERMS OF ELECTRIC FIELD.

Capacitor is device which is used for storing charge as well as electric energy".

When a capacitor is uncharged, the potential difference b/w plates is zero and finally it becomes V when charge q is deposited on each plate.



$$\text{Average potential} = \frac{0+V}{2} = \frac{V}{2}$$

electric potential energy = *Average* potential x charge

$$P.E = \frac{V}{2}q \qquad \text{Also we know that } q = CV$$

$$\text{Energy} = \frac{V}{2}(CV) = \frac{1}{2}CV^2 \text{ ------------- (1)}$$

Energy stored in an electric field

As we know that capacitance of capacitance C when medium is placed $C = \frac{A\varepsilon_o \varepsilon_r}{d}$, $V = Ed$

then Equation (1) becomes $\quad \text{Energy} = \frac{1}{2}\frac{A\varepsilon_o \varepsilon_r}{d}(Ed)^2 = \frac{1}{2}(E^2\varepsilon_o \varepsilon_r)(Ad)$

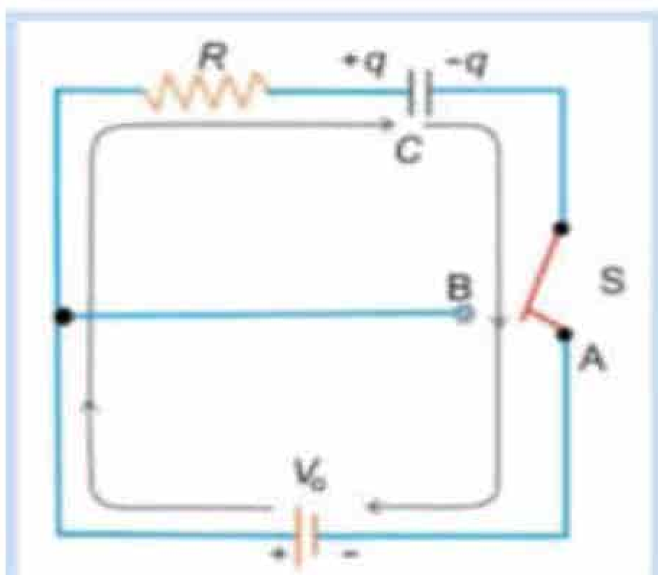
. $\text{Energy} = \frac{1}{2}(E^2\varepsilon_o \varepsilon_r)(volume)$

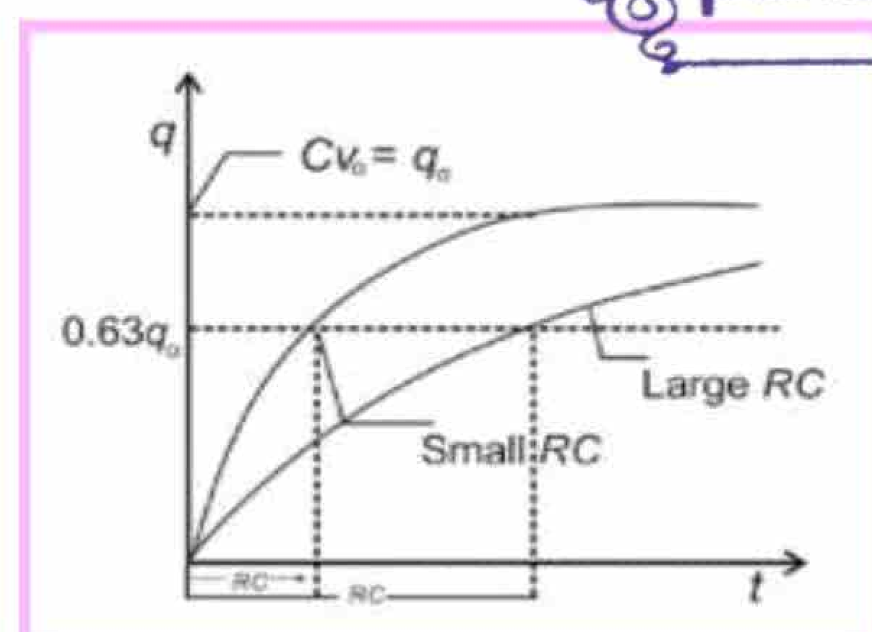
$\text{Energy/Volume} = \text{Energy density} = \frac{1}{2}E^2\varepsilon_o \varepsilon_r$, This is required result

Q. DISCUSS CHARGING AND DISCHARGING OF CAPACITOR

RC circuit: The circuit consists of capacitor of capacitance C and resistor of resistance R is called RC circuit.

Charging of capacitor: When the switch S is set at terminal A connected to battery V which starts charging the capacitor through R. capacitor is not charged immediately and charges take some time to attain maximum value on capacitor qo=CVo

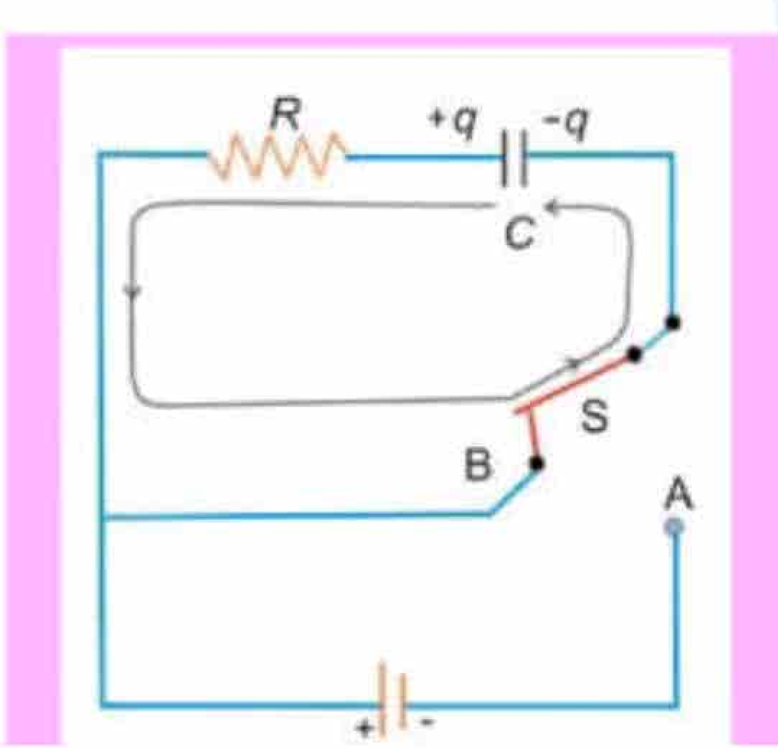


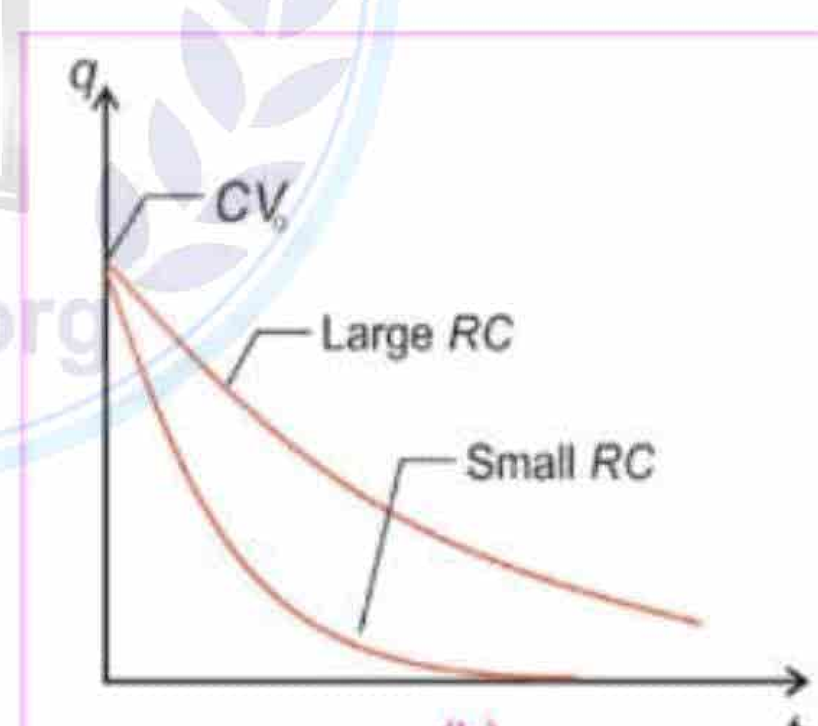


Time constant: "**The time required by capacitor to charge 63% of its maximum value is called time constant". OR "the product of resistance and capacitance is called time constant t=RC"**. Its unit is second.

For small value of time constant capacitor rapidly/fastly charge and discharge.

Discharging of capacitor: When switch is set at a point B, charge on positive plate start to discharge through R and neutralize the negative plate and graph of discharging is shown in fig





(b)

Graph of charging and discharging of capacitor is exponential

USEFUL INFORMATION AND TID BITS

- **Write the principle of working of windshield wipers of cars?**

Charging and discharging of capacitor enable windshield wipers to be used. The time of the on-off cycle is found by the time constant of resistor capacitor combination.

- **If a surface encloses a positive as well as negative charge of same value. Then what is the value net flux?**

The net value of flux will be zero

- **Why electronic circuits such as T.V and computer are often enclosed within metal boxes?**

To eliminate stray electric field interference circuits of such devices are enclosed within metal boxes.

- **What is ECG?**

ECG stands for electro cardio gram. An ECG records the voltage b/w points on human skin generated by electrical process in the heart.

- **What is EEG?**

EEG stands for electro enephalo graph, in this potential difference created by the electrical activity of brain are used for diagnosing abnormal behavior.

- **What is ERG?**

ERG stands for Electro retino graphy, in which electrical activity of the retina of eye generates the potential difference.

- ✓ **How shark and other sea creatures locate their prey very precisely?**

Fish and other sea creatures produces electric field in variety of ways, sharks have special organ called ampullae of lorezini that are sensitive to field and can detect potential difference of **nanovolt** and can locate their prey very precisely

Multiple choice questions

1	Wind shield wipers of car to be used	**Charging/ Discharging**	Potential effect	Compton effect	Ohm law
2	A 5Mega ohm resistor is connected with 2 micro farad capacitor. Time constant	0.1 sec	1 sec	2.5 sec	**10 sec**
3	Net charge on a capacitor is	Infinity	q	2q	**0**
4	The energy stored in capacitor is given by the relation	$\frac{1}{2}\varepsilon_o\varepsilon_r E^2$	**$\frac{1}{2}\varepsilon_o\varepsilon_r E^2(Ad)$**	$\frac{1}{2}\varepsilon_o\varepsilon_r E^2(A)$	$\frac{1}{2}\varepsilon_r E^2$
5	The product of resistance and capacitance is called	Force	**Time Constant**	Velocity	Current constant
6	The capacitance of a parallel plate capacitor is given by C=?	**$\frac{A \in 0}{d}$**	$\frac{A \in 0}{q}$	$\frac{q \in 0}{d}$	None of these
7	If time constant in RC circuit is small, then capacitor is charged or discharged	**Rapidly**	Slowly	At constant rate	Nil
8	A charge of 10^{-10}C b/w two parallel plates 1cm apart experience a force of 10^{-5}N, the P.D is	10	100V	**1000V**	1V
9	Farad is defined as	**C/V**	A/V	C/J	J/C
10	The expression of energy stored in a capacitor is given by	$E=cV^2$	**$E=1/2\ CV^2$**	$E=1/2\ C^2V$	$E=1/2(CV)^2$
11	In capacitor, energy is stored in the	Magnetic field	**Electric field**	Gravitational field	Nuclear field
12	In the time constant of RC circuit, how much charge is	0.37qo	0.51qo	**0.63qo**	0.90qo

	stored out of maximum charge qo				
13	Energy density in case of capacitor is always proportional to	**E^2**	ε_o	V^2	C
14	The increase in capacitance of a capacitor due to presence of dielectric is due to ------ of dielectric	**Electric polarization**	Electrification	Ionization	Electrolysis
15	Energy stored per unit volume inside capacitor is called	Electric intensity	Electric flux	**Energy density**	Electrical energy
16	The unit of RC is	Volt	**Second**	Coulomb	Ampere
17	Product of resistance and capacitance is called	Gas constant	Resistivity	Boltzmann constant	**Time constant**
18	Farad is the unit of	Charge	Current	Electric flux	**Capacitance**
19	A capacitor is perfect insulator for	AC	**DC**	Both A&B	None
20	Sec/ohm is equal to	**Farad**	Coulomb	Joule	Ampere
21	If potential difference between plates of parallel plate capacitor is doubled then energy stored in it will	Two times	Eight times	**Four times**	Remains same
22	SI unit of energy density of electric field is	J/C	J/V	**J/m^3**	J/F^3
23	The term "RC" has same unit as that of	Potential	Capacitance	Energy	**Time**
24	A parallel plate capacitor with oil between plates dielectric constant=2 has capacitance C. if the oil removed than capacitance becomes	C	$C/\sqrt{2}$	2C	**C/2**
25	The capacitor stores energy in the form of	Magnetic field	Heat energy	Mechanical energy	**Electrical energy**

26	If the dielectric is inserted between the plates of a capacitor, the potential difference	Does not change	increase	Becomes zero	**Decrease**
27	Which material is used to increase the capacitance of	copper	Iron	Tin	**Mica**

EXERCISE SHORT QUESTIONS

1.The potential is constant throughout a given region of space. Is the electric field zero or non-zero in this region? Explain

Electric field will be zero in this region

We know that $E=\frac{-\Delta V}{\Delta r}$ for constant potential ΔV=0

Then E=0

2. Suppose that you follow an electric field line due to a positive point charge. Do electric field and the potential increases or decreases?

Both electric field and potential will decrease as we know that $E \propto \frac{1}{r^2}$ and $V \propto \frac{1}{r}$ when we move away r increase and E and V will be decreased.

3. How can you identify that which plate of capacitor is positively charged?

To identify the plate of a capacitor a gold leaf electroscope is used

If the positive charged disc of gold leaf electroscope is touched with any plate of the charged capacitor and the divergence of the leaves increases, the plate of capacitor is positively charged (due to repulsion of similar charged plates). If the divergence of leaves decreases, then that plate of capacitor is negatively charged (due to force of attraction b/w different charged plates).

4. Describe the force or forces on a positive point charge when placed between parallel plates'. with similar and equal charges ii. With opposite and equal charges?

i. Net force acting on the positive charge is zero as electric field intensity due to equal and opposite plate is zero so F=qE=0

ii. Net force acting on the positive charge will be maximum due to maximum value of field in this case F=qE

5. Electric lines of force never cross. Why?

Electric lines of force never cross each other. This is because of the reason that electric field intensity has only one direction at any given pint. If the lines cross, electric intensity could have more than one direction which is physically impossible.

6. If a point charge of mass m is released in a non-uniform electric field with field lines in the same direction pointing, will it make a rectilinear motion?

Yes, it will make a rectilinear motion, If a point charge q of mass m is placed at any point in the field, it will follow straight or rectilinear path along the field line due to repulsive force.

7. Is E necessarily zero inside a charged rubber balloon if the balloon is spherical?

Yes, E is necessarily zero inside a charged rubber balloon. Because there is no charge enclosed by it so electric field will be zero.

$$\varphi_e = \frac{q}{\varepsilon_o} = \frac{0}{\varepsilon_o} = 0$$

$\varphi_e = EA$, so $EA = 0$ then $E = 0$ as $A \neq 0$

8.Is it true that Gauss's law states that the total number of lines of force crossing any closed surface in the outward direction is proportional to the net positive charge enclosed within surface?

Yes it is true statement, as Gauss's law states that number of electric field lines through any closed surface is 1/εo times the total charge enclosed in it as flux is directly proportional to charge so this statement is true.

9. Do electrons tend to go to region of high potential or of low potential?

The electrons being negatively charge particle when released in electric field moves from a region of lower potential (negative end) to a region of high potential (positive end).

CHAPTER = 12 NUMERICALS

12.1: Compare magnitudes of electrical and gravitational forces exerted on an object (mass = 10.0g, charge = 20.0μC) by an identical object that is placed 10.0cm from the first. $(G = 6.67\times10^{-11}\,Nm^2kg^{-2})$

Given Data : Mass $m_1 = m_2 = m = 10g = 10/1000\,kg = 0.1\,kg$, Charge $q_1 = q_2 = 20\mu C = 20*10^{-6}C$, $r = 10cm = 10/100 = 0.1m$

$$solution: \frac{F_e}{F_G} = ? \Rightarrow \frac{F_e}{F_G} = \frac{Kq_1q_2/r^2}{Gm_1m_2/r^2} = \frac{Kqq/r^2}{Gmm/r^2} = \frac{Kq^2}{Gm^2} = \frac{9*10^9(20*10^{-6})^2}{6.67*10^{-11}(0.1)^2} = 5.4*10^{14}$$

12.3: A point charge $q = -8.0\times10^{-8}\,C$ is placed at the origin. Calculate electric field at a point 2.0m from the origin on the z-axis.

Given Data : Charge = 1 = -8 * 10^{-8} C, r = 2m, E = ?

$$\text{solution}: E = \frac{Kq}{r^2} = \frac{9*10^9*(-8*10^{-8})}{(2)^2} = -(1.8*10^2\,\hat{K})N/C, \qquad \vec{E}\text{ is along negative Z - axis}$$

12.4: Determine the electric field at the position $r = (4\hat{i} + 3\hat{j})m$ caused by a point charge $q = 5.0\times10^{-6}C$ placed at origin.

$$\text{Given Data}: r = (4\hat{i}+3\hat{j})m,\ q = 5*10^{-6}C,\ E = ?\ \hat{r} = \frac{\vec{r}}{|\vec{r}|} = \frac{(4\hat{i}+3\hat{j})}{\sqrt{4^2+3^2}} = \frac{(4\hat{i}+3\hat{j})}{\sqrt{16+9}} = \frac{(4\hat{i}+3\hat{j})}{5}$$

$$\text{Solution}: \text{As } E = \frac{Kq}{r^2}\hat{r} = \frac{9*10^9*5*10^{-6}}{5^2}*\frac{(4\hat{i}+3\hat{j})}{5} = 360*(4\hat{i}+3\hat{j}) = (1440\hat{i}+1080\hat{j})\ N/C$$

12.5: Two point charges, $q_1 = -1.0\times10^{-6}C$ and $q_2 = +4.0\times10^{-6}C$, are separated by a distance of 3.0m. Find and justify the zero-field location.

Given Data : $q_1 = -1*10^{-6}C, q_2 = 4*10^{-6}C, r = 3m$, Location at which $\vec{E} = 0 = ?$

solution : consider P be a point at a distance x from charge q_1 at which E is zero

$$E_1 = \frac{Kq_1}{x^2},\quad E_2 = \frac{Kq_2}{(x+3)^2} \qquad \text{As } E_1 = E_2 \Rightarrow \frac{Kq_1}{x^2} = \frac{Kq_2}{(x+3)^2} \Rightarrow \frac{q_1}{x^2} = \frac{q_2}{(x+3)^2}$$

$$\frac{1*10^{-6}C}{x^2} = \frac{4*10^{-6}C}{(x+3)^2} \Rightarrow \frac{1}{x^2} = \frac{4}{(x+3)^2} \Rightarrow (x+3)^2 = 4x^2 \Rightarrow x+3 = 2x \Rightarrow x = 3m$$

12.6: Find the electric field strength required to hold suspended a particle of mass and $1.0\times10^{-6}kg$ charge $1.0\mu c$ between two plates 10.0cm apart.

Given Data : mass = m = $1*10^{-6}$ kg, q = 1μμ = $1*10^{-6}$C, d = 10cm = 10/100 m = 0.1 m, $\vec{E} = ?$

$$\text{solution : As } \vec{F}_e = \vec{F}_g \Rightarrow q\vec{E} = mg \Rightarrow \vec{E} = \frac{mg}{q} = \frac{1*10^{-6}*9.8}{1*10^{-6}} = 9.8N/C \text{ or } 9.8V/m$$

12.7: A particle having a charge of 20 electrons on it falls through a potential difference of 100 volts. Calculate the energy acquired by it in electron volts (eV).

Given data : Nof electrons = n = 20, charge on electron = $1.6*10^{-19}$C, q = ne = $20*1.6*10^{-19}$C

$q = 3.2*10^{-18}$C , potential difference = ΔV = 100V, $\Delta(K.E) = ?$

$$\Delta(K.E) = q\Delta V = 3.2*10^{-18}C*100V = 3.2*10^{-16}J \Rightarrow \text{or } \Delta(K.E) = \frac{3.2*10^{-16}}{1.6*10^{-19}}eV = 2*10^3 eV$$

12.8: In Millikan's experiment, oil droplets are introduced into the space between two flat horizontal plates, 5.00 mm apart. The plate voltage is adjusted to exactly 780V so that the droplet is held stationary. The plate voltage is switched off and the selected droplet is observed to fall a measured distance of 1.50 mm in 11.2s. Given that the density of the oil used is 900kgm^{-3}, and the viscosity of air at laboratory temperature is $1.80\times10^{-5}Nm^{-2}s$, calculate...(a) The mass, and (b) The charge on the droplet (Assume g = 9.8ms^{-2})

Given Data : d = 5mm = $5*10^{-3}$m, V = 780V, S = $1.55*10^{-3}$m, t = 11.2 sec, η = $1.8*10^{-5}Nm^{-2}S$, ρ = 900kgm^{-3}

m = ? q = ? As we know that ρ = mass/Volume, ⇒ m = ρ * volume = $\rho * 4/3\,\pi r^3$ ----(1)

$$\text{As } v = s/t = 1.55*10^{-3}/11.2 = 0.13*10^{-3}\ ms^{-1}, r = \sqrt{\frac{9\eta\eta}{2\rho\rho}} = \sqrt{\frac{9(1.8*10^{-5})0.13*10^{-3}}{2*900*9.8}} = 0.011*10^{-4}m, \text{putting in (1)}$$

$$m = \rho*4/3\,\pi r^3 = 900*4/3*3.14*(0.011*10^{-4})^3 = 5.01*10^{-15}kg$$

$$\text{charge} = q = \frac{mgd}{V} = \frac{5.01*10^{-15}*9.8*5*10^{-3}}{780} = 3.15*10^{-19}C$$

12.9: A proton placed in a uniform electric field of 5000 NC^{-1} directed to right is allowed to go a distance of 10.0cm from A to B. Calculate.

(a) Potential difference between the two points

(b) Work done by the field

(c) The change in P.E. of proton

(d) The change in K.E. of the proton

(e) Its velocity (mass of proton is $1.67\times10^{-27}kg$)

Given Data : $q = 1.6*10^{-19}$ C, $m = 1.67*10^{-27}$ Kg, E = 5000 N/C, d = 0.1 m,

(a) V = ? $V = -Ed = -5000*0.1 = -500$ V (b) W = ? $W = qV = 1.6*10^{-19} C*500 V = -500eV$

(c) $\Delta U = ?$ $\Delta U = qV = 1.6*10^{-19} C*(-500 V) = -500eV$, (d) $\Delta K.E = ?$ $\Delta K.E = qV = 1.6*10^{-19} C*500 V = 500eV$

(e) v = ? $\Delta K.E = \frac{1}{2}mv^2 \Rightarrow v = \sqrt{\frac{2\Delta K.E}{m}} = \sqrt{\frac{21.6*10^{-19} C*500 V}{1.67*10^{-27}}} = 3.09*10^5 m/s$

12.10: Using zero reference point at infinity, determine the amount by which a point charge of $4.0\times10^{-8}C$ alters the electric potential at a point 1.2m away, when (a) Charge is positive (b) Charge is negative.

Given Data : $q = 4*10^{-8}$ C, r = 1.2 m, V+ = ? V- = ?

$$V+ = \frac{K(+q)}{r} = \frac{9*10^9(4*10^{-8})}{1.2} = +300V, V- = \frac{K(-q)}{r} = \frac{9*10^9(-4*10^{-8})}{1.2} = -300V$$

12.11 In Bohr's atomic model of hydrogen atom, the electron is in an orbit around the nuclear proton at a distance of $5.29\times10^{-11}m$ with a speed of $2.18\times10^6 ms^{-1}$.
$(e = 1.60\times10^{-19}C,\quad mass\ of\ electron = 9.10\times10^{-31}kg)$.Find

(a) The electric potential that a proton exerts this distance
(b) Total energy of the atom in eV
(c) The ionization energy for the atom in eV

Given Data : $r = 5.29*10^{-11}$ m, $v = 2.18*10^6$ m/s, charge on electron = q = e = $1.6*10^{-19}$ C

mass of electron = m = $9.1*10^{-31}$ kg, V = ? Total energy in eV = ? Ionization energy = ?

$$\text{Electric potential} = V = \frac{Kq}{r} = \frac{9*10^9 * 1.6*10^{-19}C}{5.29*10^{-11}} = 27.22\ V$$

$$\text{Total energy} = \frac{-Ke^2}{2r} = -\frac{9*10^9(1.6*10^{-19})^2}{2*5.29*10^{-11}} = -13.6eV$$

$$\text{Ionization Energy} = E_\infty - E_{ground} = 0-(-13.6eV) = 13.6eV$$

12.12 The electronic flash attachment for a camera contains a capacitor for storing the energy used to produce the flash. In one such unit, the potential difference between the plates of a 750μF capacitor is 330V. Determine the energy that is used to produce the flash.

Given Data : C = 750μ5 = $750*10^{-6}$ F, V = 330V, Energy = E = ?

$$E = \frac{1}{2}CV^2 = \frac{1}{2}(750*10^{-6})(330)^2 = 40.8\ J$$

12.13: A capacitor has a capacitance of $2.5\times10^{-8}F$. In the charging process, electrons are removed from one plate and placed on the other one. When the potential difference between the plates is 450V, how many electrons have been transferred? $(e = 1.60\times10^{-19}C)$.

Given Data : $C = 2.5*10^{-8}$ F, V = 450V, $e = 1.6*10^{-19}$ C, n = ?

$$Q = CV = (2.5*10^{-8})(450) = 1125*10^{-8} C$$

$$\text{no electrons} = n = \frac{Q}{e} = \frac{1125*10^{-8} C}{1.6*10^{-19} C} = 7*10^{13}$$