Vision

To be the centre of excellence in the field of technical education.

Program Code:- First Semester – All Program

Course Name:- Basic Science (PHYSICS)

Course Code : - BSC (22102)

Course coordinator: Mr. S. K. Rawat

Course Name:- Basic Science (PHYSICS)

Unit No:2

Unit Name: Electric field, potential and potential difference

Unit Outcomes (UO2a): Calculate electric field, potential and potential difference of given static charge.

Learning Outcomes (LOs):

LO2: Student will be able to explain electric field, potential and potential difference.

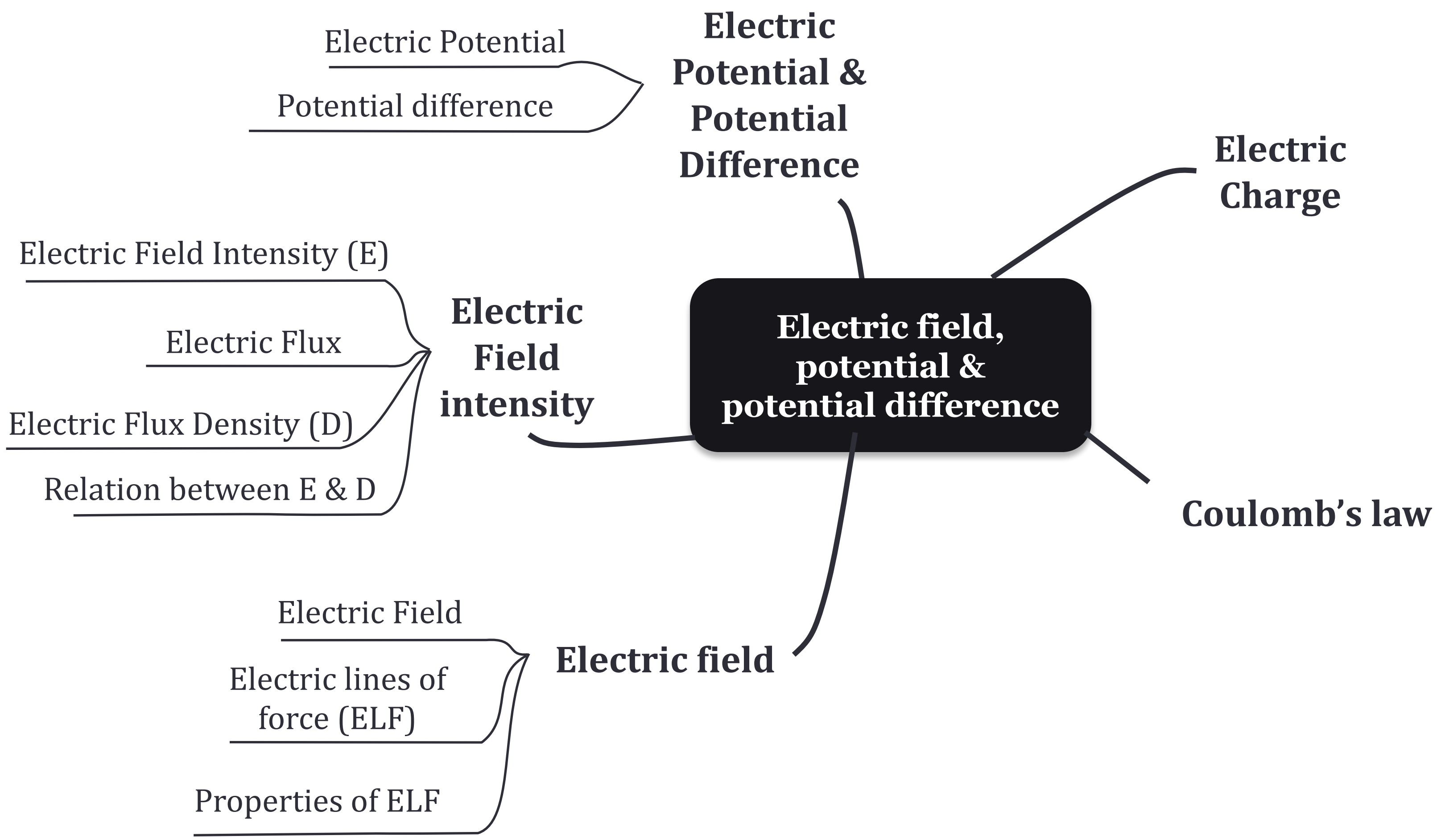
CONTENT

- Electric field
- Electric field intensity
- Electric potential and potential difference

LEARNING OBJECTIVES

- Student will be able to explain electric field, potential and potential difference.

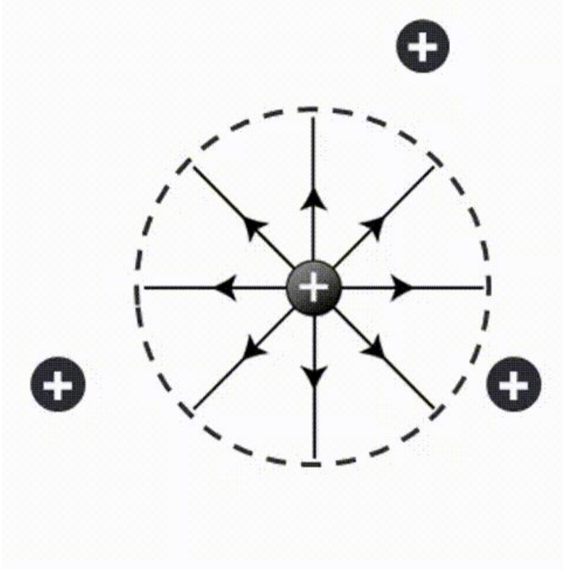
Concept Map

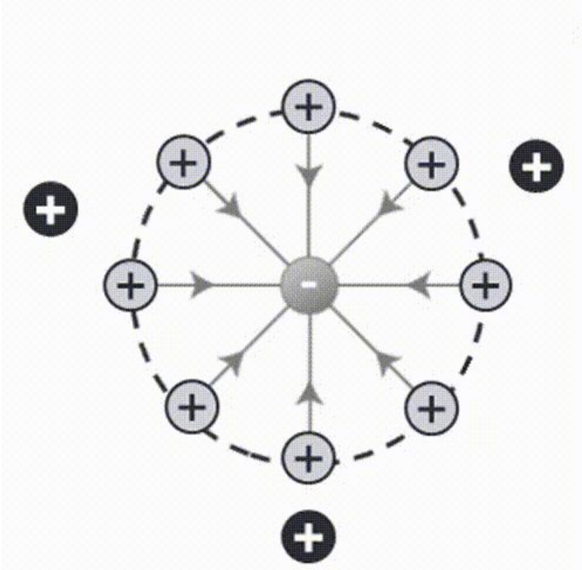

Electric field, potential & potential difference
Electric Potential & Potential Difference
Electric Potential
Potential difference
Electric Charge
Electric Field intensity
Electric Field Intensity (E)
Electric Flux
Electric Flux Density (D)
Relation between E & D
Coulomb's law
Electric field
Electric Field
Electric lines of force (ELF)
Properties of ELF

Electric Field
& Electric lines of Force

- **Electric Field** is defined as the space around a charge where force of attraction or repulsion can be observed or felt.

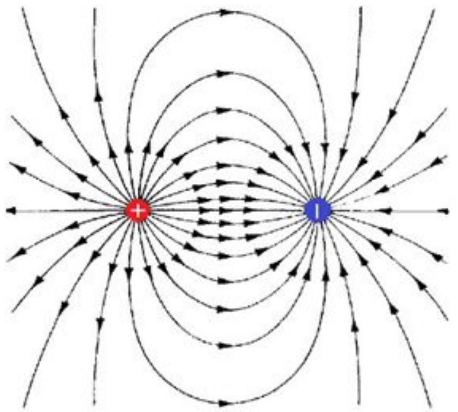
- **Electric lines of Force** is defined as the path along which a unit positive charge moves when placed in an Electric field.



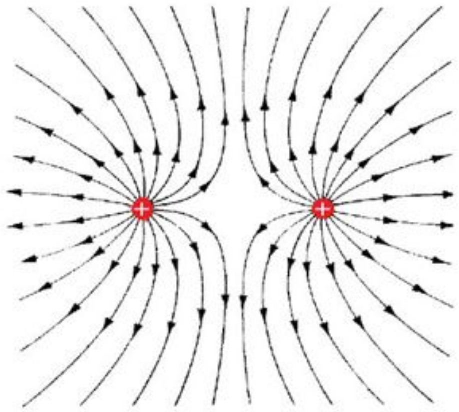


Properties of Electric lines of Force

- Electric lines of force starts from positive charge and terminates to negative charge.
- Electric lines of force never intersect each other.
- Electric lines of force are curve in nature.
- The tangent drawn to the Electric lines of force at any point indicates the direction of electric field[E].
- Electric lines of force are always perpendicular to the surface of charged conductor.
- Electric lines of force are more crowded in the region of strong electric field and less crowded in the region of weak electric field.
- Electric lines of force exerts lateral pressure on each other.

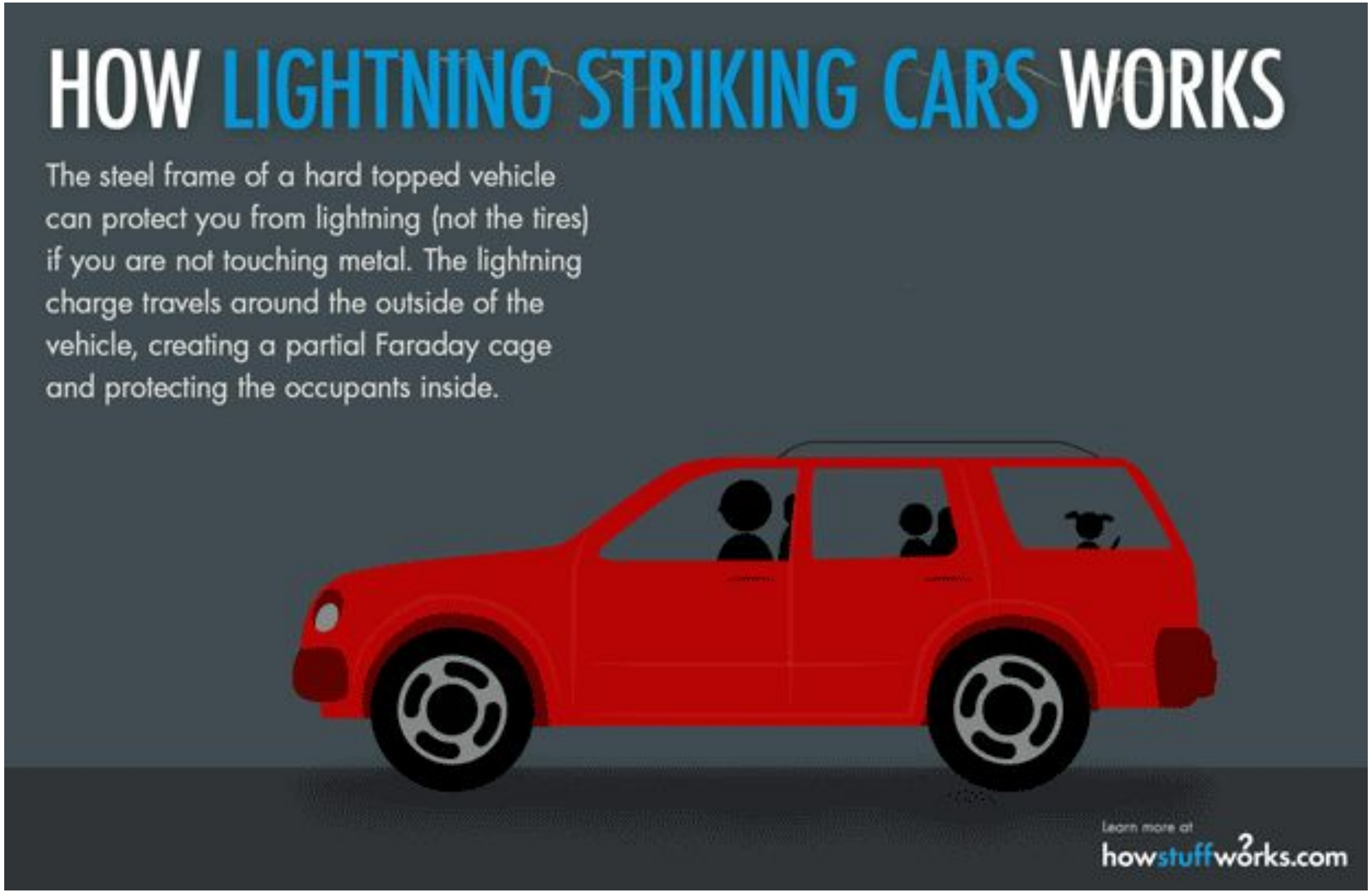


unlike charges



like charges

Electric field within conductor

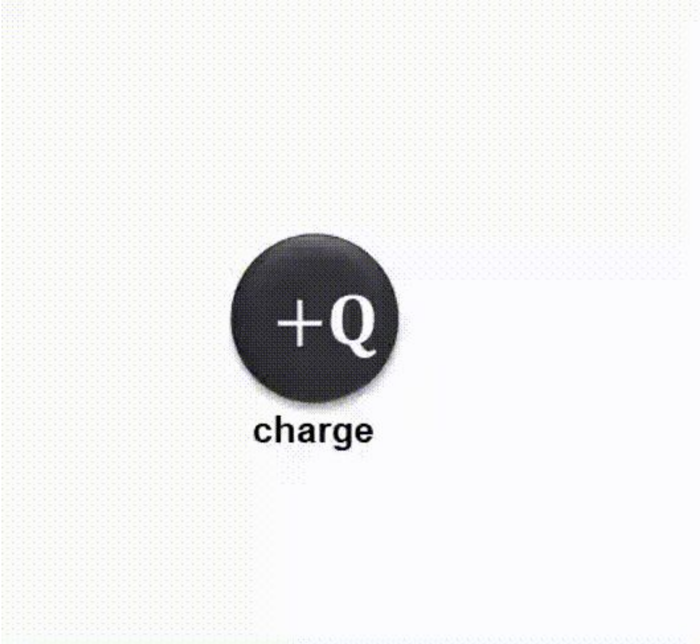


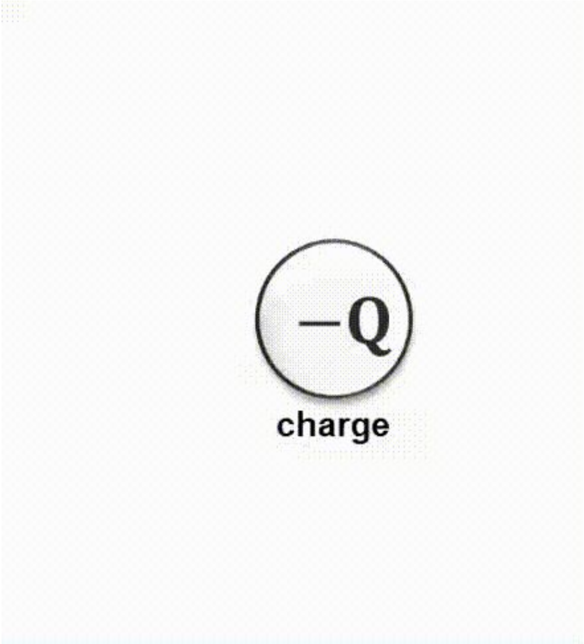
Why are the person in the car protected from the lighting?

The metal cage on the inside of the car is uncharged, but the outside surface becomes charged.

Electric Field intensity

- Electric Field intensity is defined as force acting on a unit positive charge when placed in an electric field.





- We know $F = 9 \times 10^9 \times \frac{Q_1 Q_2}{d^2}$, now if $Q_1 = Q$ and $Q_2 = q$

Electric Field intensity

- We know $F = 9 \times 10^9 \frac{Q_1 Q_2}{d^2}$, now if Q_1 = Q and Q_2 = q
- Then $F = 9 \times 10^9 \frac{Qq}{kd^2}$
- By definition $E = \frac{F}{q}$
- Thus $E = 9 \times 10^9 \frac{Q}{kd^2}$ or $E = \frac{1}{4\pi\epsilon_0} \frac{Q}{kd^2}$
- UNIT of E: Newton/Coulomb (N/C)

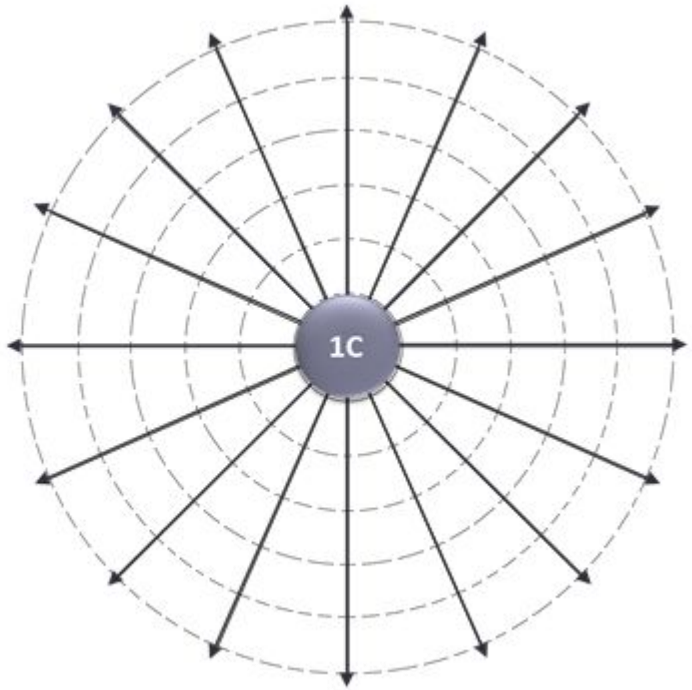
Attempt Set 1 MCQs

Question No	Question No. 1	Question No. 2	Question No. 3
Statement of Question	The space around an electric charge where it has a force of attraction or repulsion is called	The imaginary lines representing the electric field are known as	Calculate the electric field intensity 10cm from a charge Q = 5nC
Level of Question	Remembering	Understanding	Application
Option (a)	electric field	electric field	450 N/C
Option (b)	magnetic field	electric lines of force	900 N/C
Option (c)	electromagnetic field	electric flux	4.5×10^3 N/C
Option (d)	nuclear field	electric field intensity	9.0×10^3 N/C
Correct Option	**(a) electric field**	**(b) Electric lines of force**	**(c) 4.5×10^3 N/C**

START

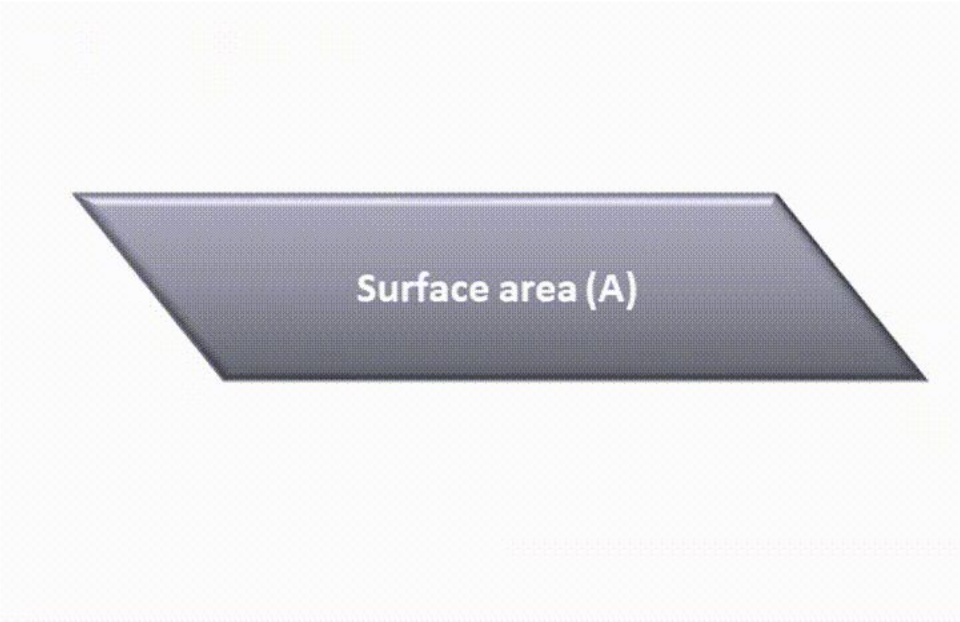
ELECTRIC FLUX

- Electric Flux is defined as total number of electric lines of force starting from a unit positive charge.
- By Definition, $\emptyset = Q$ … Coulomb(C)
- Hence 1 electric flux = 1 C



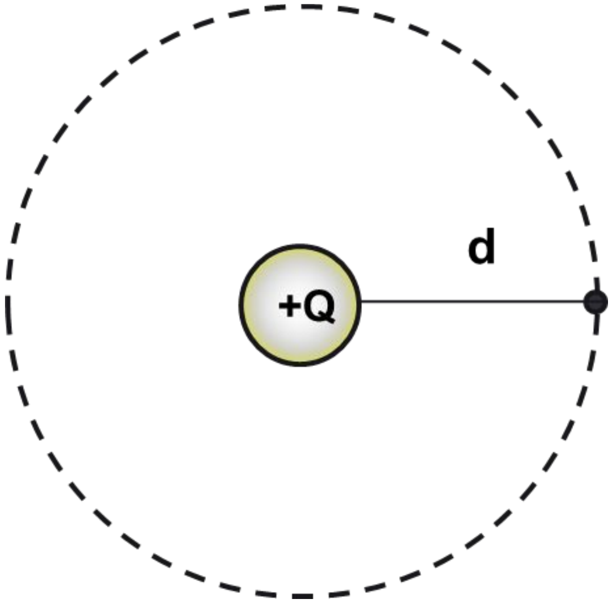
ELECTRIC FLUX DENSITY

- Electric Flux Density is defined as total number of electric line of force passing through a surface area.
- i.e., Electric flux density = (charge or total flux)/area
- i.e., D = Q/A



Relation between E and D

- Let us consider a point at a distance (d) inside the electric field of charge +Q.
- (i) By definition, electric field intensity at any point is given as E = $\frac{1}{4\pi\epsilon_0}\frac{Q}{kd^2}$
- (ii) By definition, electric flux density of a charge +Q is given as D = Q/A = $\frac{Q}{4\pi d^2}$. Here area is considered as area of sphere. i.e., A = $1/4\pi d^2$
- Note for electric flux density, the distance d is the radius of the sphere.
- Thus from (i) and (ii), we get E = $\frac{D}{\epsilon_0 k}$
- Thus D = ϵ_0 k E is the relation between E and D.



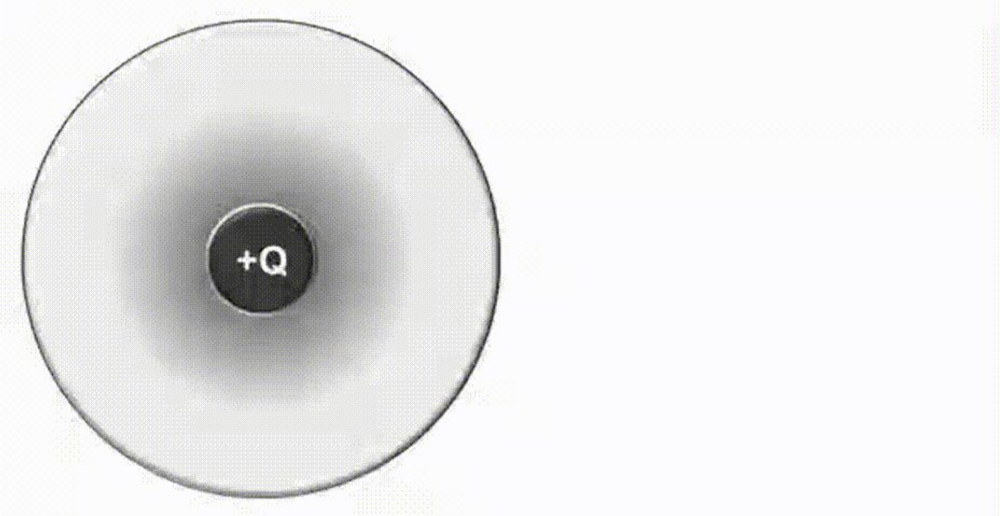
Attempt Set 2 MCQs

Question No	Question No. 1	Question No. 2	Question No. 3
Statement of Question	The symbol for electric flux is _______	The formula for permittivity of a material is given by _______	The relation between electric flux density and intensity of electric field is given as -
Level of Question	Remembering	Understanding	Understanding
Option (a)	φ		$E = \epsilon_0 kD$
Option (b)	ρ	E/D	$D = \epsilon_0 kE$
Option (c)	X	2D/E	$E/D = \epsilon_0 k$
Option (d)	ϱ	D/E	$D/E = 1/\epsilon_0 k$
Correct Option	**(a) φ**	**(d) D/E**	**(b) $D = \epsilon_0 kE$**

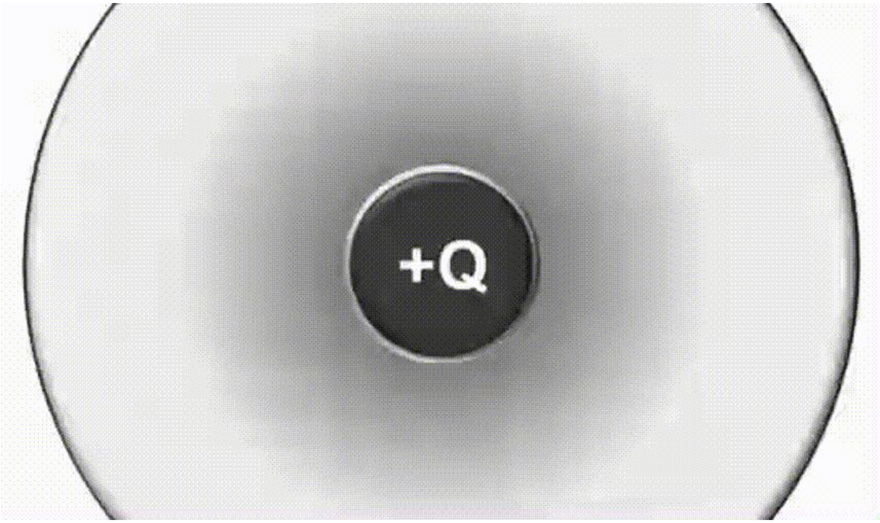
START

ELECTRIC Potential & POTENTIAL DIFFERENCE

- **Electric Potential:** It is defined as amount of work done in bringing a unit positive charge from infinity to any point inside electric field.
- **Potential Difference:** It is defined as amount of work done in bringing a unit positive charge from one point to another point inside electric field.



Electric Potential



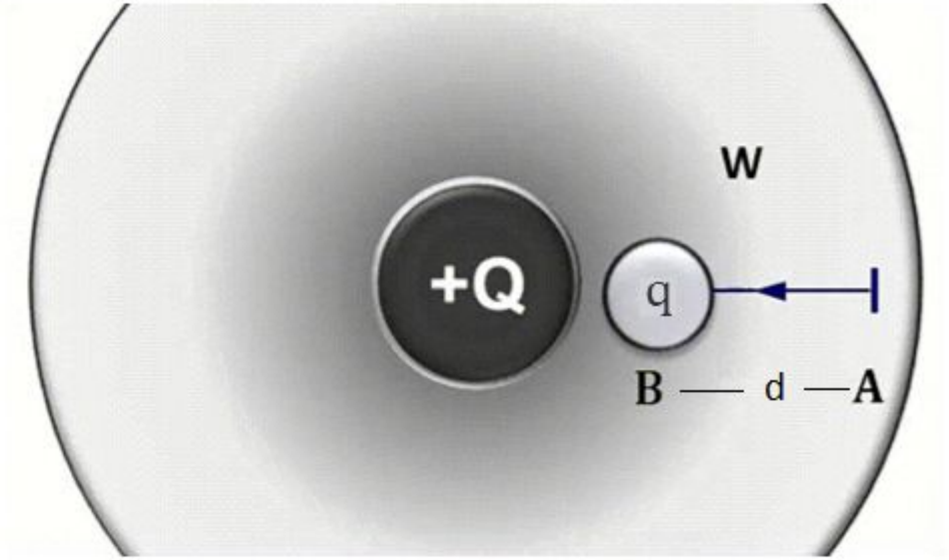
Potential Difference

Unit of Potential

- **Electrical potential** is defined as amount of work done in bringing a unit positive charge from infinity to that point.
- **Electric potential (V)** = $\frac{\text{Work (W)}}{\text{Charge (Q)}}$ i.e., V = $\frac{W}{Q}$
- **Potential difference** is defined as difference in potential of two charged bodies.
- **Symbol & SI Unit:** Electric potential or potential difference is denoted by V & measured in volt (V).
- **Note:** If W = 1J, Q = 1C, then 1 volt = $\frac{1 \text{ joule}}{1 \text{ coulomb}}$
- **One volt (1V):** If one joule of work is done in bringing a charge of one coulomb then the potential is said to be one volt.

Potential due to point charge

- Let a point charge q moves from point A to B, i.e., AB = d.
- By definition, electric potential (V) = $\dfrac{\text{Work (W)}}{\text{Charge (q)}}$
- We know work done (W) = Force (F) × distance (d)
- Hence according to Coulomb's law, F = $\left(\dfrac{1}{4\pi\epsilon_0 k}\dfrac{Qq}{d^2}\right)$
- ∴ W = F × d = $\left(\dfrac{1}{4\pi\epsilon_0 k}\dfrac{Qq}{d^2}\right) \times d$
- ∴ Electric Potential V = $\dfrac{\frac{1}{4\pi\epsilon_0 k}\frac{Qq}{d}}{q} = \dfrac{1}{4\pi\epsilon_0}\dfrac{Q}{kd}$
- ∴ Electric Potential V = $\dfrac{1}{4\pi\epsilon_0}\dfrac{Q}{kd}$

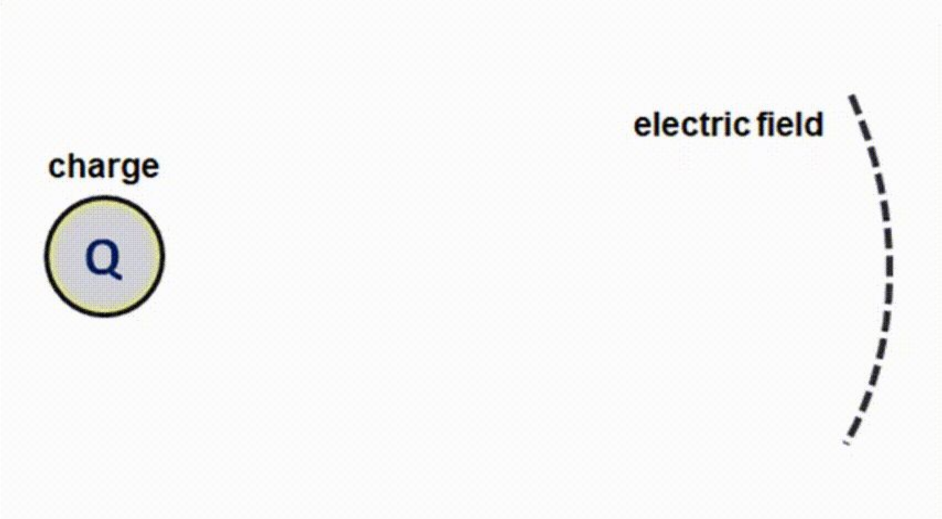


P.D between two points

- Potential Difference between two points is defined as the work done in carrying unit positive charge from one point to another point against electric field.
- P.D between points 'A' & 'B' is defined as the work done in carrying a unit positive charge from B to A, and is given by V_{AB}. i.e., $V_{AB} = V_A - V_B$
- We know potential at A is $V_A = \frac{1}{4\pi\epsilon_0}\frac{Q}{kd}$ and potential at B is $V_B = \frac{1}{4\pi\epsilon_0}\frac{Q}{kD}$
- $V_{AB} = V_A - V_B = \left[\frac{1}{4\pi\epsilon_0}\frac{Q}{kd} - \frac{1}{4\pi\epsilon_0}\frac{Q}{kD}\right]$

$$= \frac{Q}{4\pi\epsilon_0 k}\left(\frac{1}{d} - \frac{1}{D}\right)$$

- $V_{AB} = 9 \times 10^9 \times \frac{Q}{k}\left(\frac{1}{d} - \frac{1}{D}\right)$

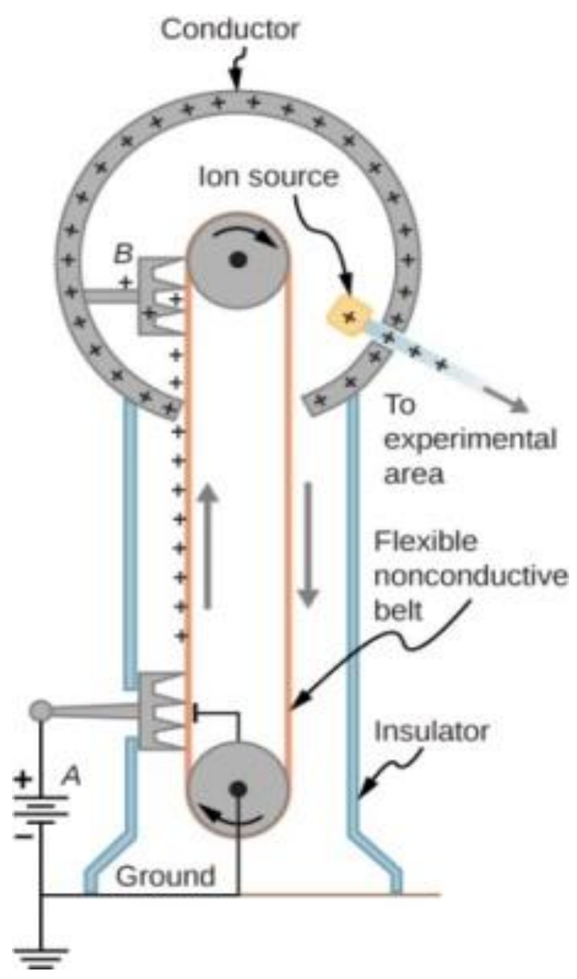


Application of ELECTROSTATICS in real life

- As we have already seen the applications of Coulomb's Law in the previous study materials. Other than these application some other applications are as follows -

Van de Graaff generators

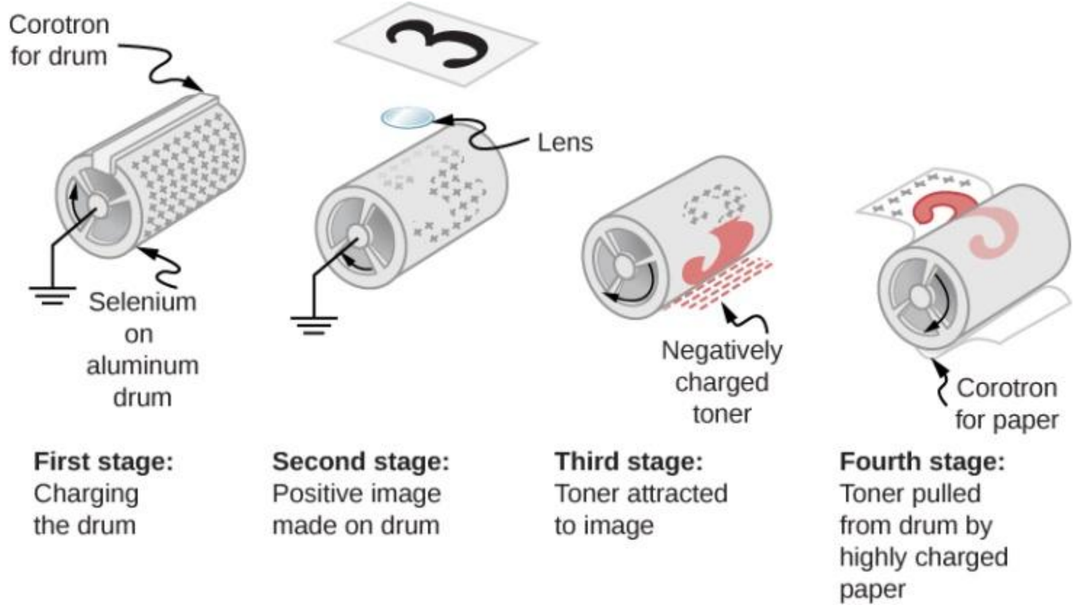
- A battery (A) supplies excess positive charge to a pointed conductor, the points of which spray the charge onto a moving insulating belt near the bottom.
- The pointed conductor (B) on top in the large sphere picks up the charge. (The induced electric field at the points is so large that it removes the charge from the belt.)
- This can be done because the charge does not remain inside the conducting sphere but moves to its outside surface.
- An ion source inside the sphere produces positive ions, which are accelerated away from the positive sphere to high velocities.



Application of Coulomb law in real life

Xerography

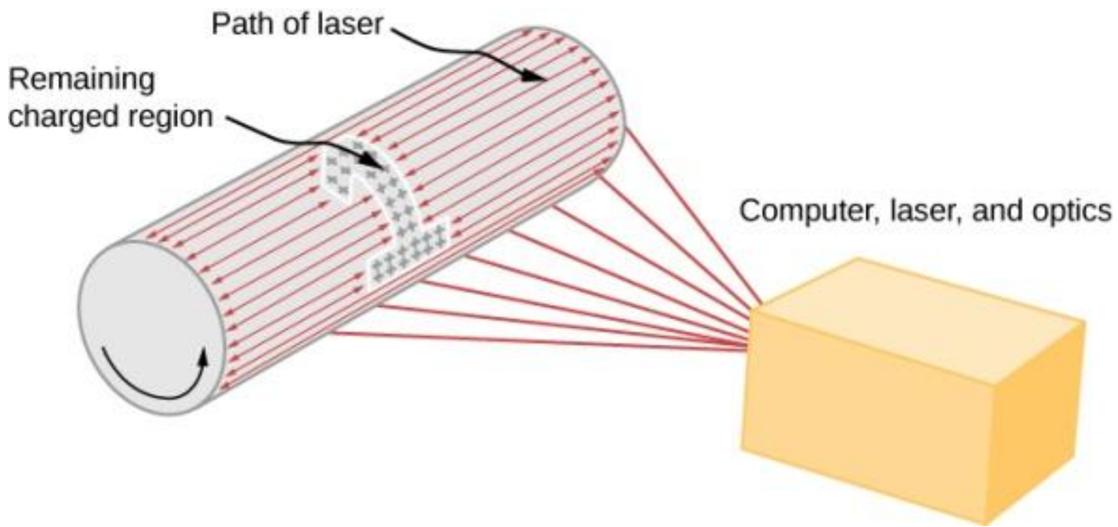
- Xerography is a dry copying process based on electrostatics.
- The major steps in the process are the charging of the photo conducting drum, transfer of an image, creating a positive charge duplicate, attraction of toner to the charged parts of the drum, and transfer of toner to the paper.
- Not shown are heat treatment of the paper and cleansing of the drum for the next copy.



Application of Coulomb law in real life

Laser Printers

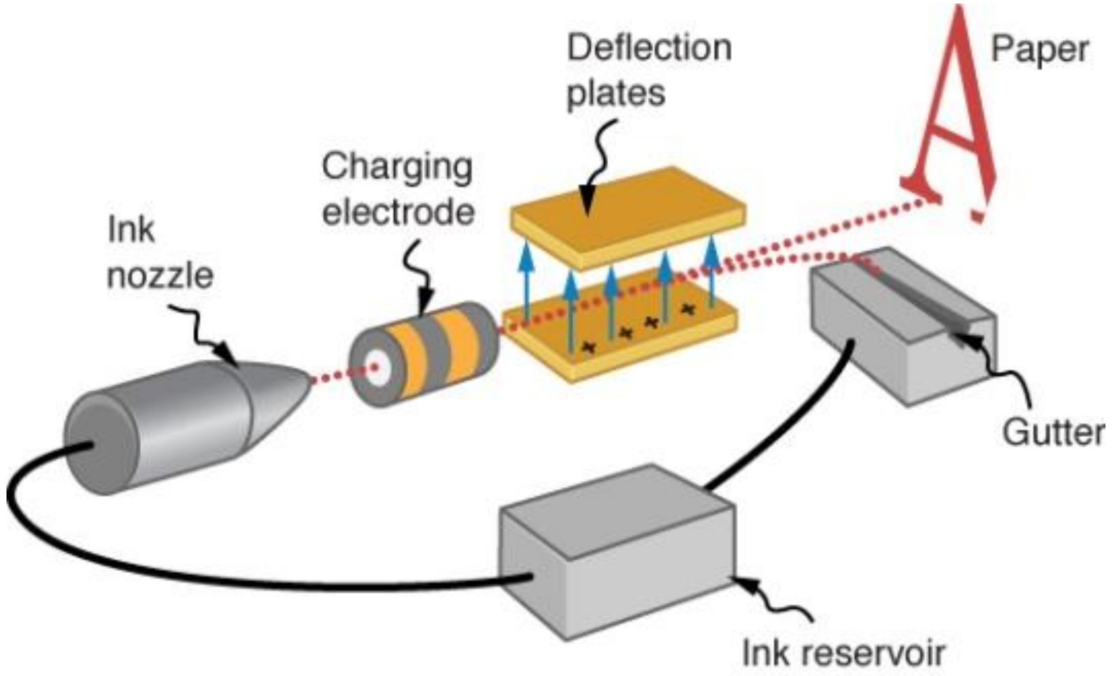
- In a laser printer, a laser beam is scanned across a photo conducting drum, leaving a positively charged image.
- The other steps for charging the drum and transferring the image to paper are the same as in xerography.
- Laser light can be very precisely controlled, enabling laser printers to produce high-quality images.



Application of Coulomb law in real life

Ink Jet Printers and Electrostatic Painting

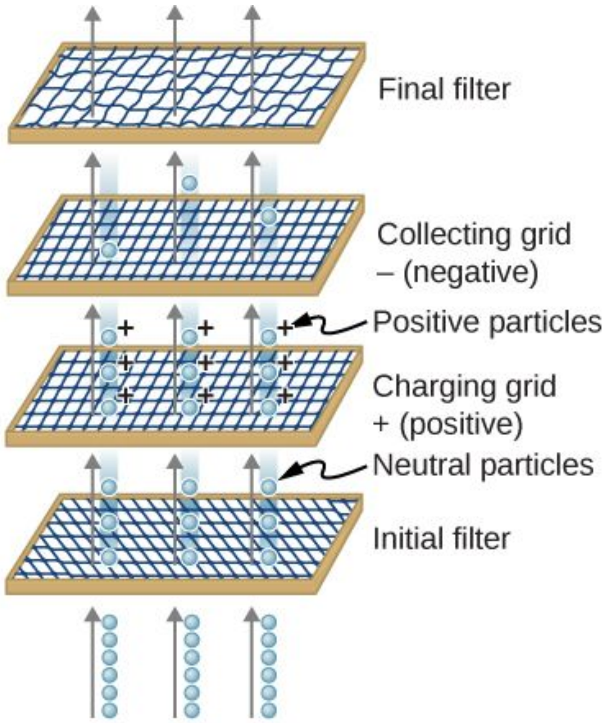
- The nozzle of an ink-jet printer produces small ink droplets, which are sprayed with electrostatic charge.
- Various computer-driven devices are then used to direct the droplets to the correct positions on a page.



Application of Coulomb law in real life

Smoke Precipitators and Electrostatic Air Cleaning

- Schematic of an electrostatic precipitator.
- Air is passed through grids of opposite charge.
- The first grid charges airborne particles, while the second attracts and collects them.



- The dramatic effect of electrostatic precipitators is seen by the absence of smoke from this power plant.

Important Formulas/ Points to Remember

- Electric field intensity $E = \frac{F}{Q} = 9 \times 10^9 \times \frac{Q}{kd^2}$
- Electric flux $\emptyset = Q$
- Electric flux density $D = \frac{\emptyset}{A} = \frac{Q}{A} = \epsilon_0 kE$
- Electric potential $V = \frac{W}{Q} = 9 \times 10^9 \times \frac{Q}{kd}$
- Potential due to point charge $V = 9 \times 10^9 \times \frac{Q}{kr}$
- P.D between two points $V = 9 \times 10^9 \times \frac{Q}{k}\left[\frac{1}{d} - \frac{1}{D}\right]$
- Potential due to charged sphere $V = 9 \times 10^9 \times \frac{Q}{kr}$

Word Problem

PROBLEM 1

Calculate the potential if work done to move a charge of 25 C is 1600 J.

- Given: Q = 25 C, W = 1600 J
- Find: V
- Solution: $V = W/Q$
- $V = \frac{1600}{25} = 64\ \mathrm{V}$

Word Problem

PROBLEM 2

Calculate the potential due to charge of 0.05 μC at a point 0.4m in a dielectric of 2.5.

- Given: $Q = 0.05\ \mu C = 50 \times 10^{-9}\ C$, $r = 0.4\ m$, $k = 2.5$
- Find: V
- Solution: $V = 9 \times 10^9 \times \frac{Q}{kr}$
- $V = 9 \times 10^9 \times \frac{Q}{kr} = 9 \times 10^9 \times \frac{50\times10^{-9}}{0.4\times2.5}$ **= 450 volt**

Attempt Set 3 MCQs

Question No	Question No. 1	Question No. 2	Question No. 3
Statement of Question	The work done in bringing a unit charge from infinity to a given point in electric field is called ____________.	1 volt = _____.	A charged body in free space produces 10V at a distance 25 cm away. What will be the potential at 50 cm away?
Level of Question	Remembering	Understanding	Application
Option (a)	electric charge	1 J/C	5 V
Option (b)	electric current	1 C/J	7.5 V
Option (c)	electric potential	1 W	10 V
Option (d)	electric power	1 N/C	15 V
Correct Option	**(c) electric potential**	**(a) 1 J/C**	**(a) 5 V**

START