Electrostatic Potential And Capacitance

Que 1: If the distance between the plates of a capacitor is halved then what happens to its capacitance? ***Marks :(1)***

Ans: The value of capacitance become double

Que 2: Why is it safer to be inside a car than standing under a tree during lightning? ***Marks :(2)***

Ans: Electrostatic shielding

Que 3: A parallel plate capacitor has plates of area 200 cm2 and separation between the plates 1 mm. Calculate (i) the potential difference between the plates if 1n C charge is given to the capacitor (ii) with the same charge (1n C) if the plate separation is increased to 2 mm, what is the new potential difference and (iii) electric field between the plates. ***Marks :(4)***

Ans:

$$C = \frac{\varepsilon_0 A}{d} = \frac{8.85 \times 10^{-12} \times 200 \times 10^{-4}}{1 \times 10^{-3}}$$

$$C = 0.177 \times 10^{-9}\ F = 0.177\ nF$$

(i) The potential difference between the plates

$$V = \frac{q}{C} = \frac{1 \times 10^{-9}}{0.177 \times 10^{-9}} = 5.65\ V$$

(ii) If the plate separation is increased from 1 mm to 2 mm, the capacitance is decreased by 2, the potential difference increases by the factor 2

$\therefore$ New potential difference is 5.65×2

$= 11.3\ V$

(iii) Electric field is,

$$E = \frac{\sigma}{\varepsilon_0} = \frac{q}{A\varepsilon_0} = \frac{1 \times 10^{-9}}{8.85 \times 10^{-12} \times 200 \times 10^{-4}}$$

$= 5650\ N\ C^{-1}$

Que 4: Define electric potential difference between two points ? ***Marks :(1)***

Ans: It is the work done to move a unit positive charge from one point to another point.

Potential difference between A and B is given by

$$V_{AB} = \frac{W_{BA}}{q}$$

Que 5: "Electric potential at a point is 5 volt" .what do you mean by the statements ? ***Marks :(1)***

Ans: The work done to bring 1 C of charge from infinity to that point is 5J.

Que 6: Give the unit and dimensions of electric potential ***Marks :(1)***

Ans: Volt (V).

$$[V]=[M L^2 T^{-3} A^{-1}]$$

Que 7: If " W " is the work done to bring a charge " q " from infinity to a point then what is the electric potential at that point ? ***Marks :(1)***

Ans: Electric potential at that point is given by

V = W/q

Que 8: What do you meant by electric potential at a point ? ***Marks :(1)***

Ans: It is defined as the work done to bring a unit positive test charge from infinity to that point.

Que 9: What is meant by equipotential surface? ***Marks :(1)***

Ans: It is an imaginary surface in which all points are of same potential at every point.

Que 10: Inside a hollow charged spherical conductor, the potential ***Marks :(1)***

A) Is constant

B) Varies directly as the distance from the centre

C) Varies inversely as the distance from the centre

D) Varies inversely as the square of the distance from the centre

Ans: A) Is a constant

Que 11: Two electrons are held 3μm apart. When released from rest, what is the velocity of each electron when they are 8μm apart? ***Marks :(3)***

Ans: Let Up1 be the potential electric energy at rest (distance r = 3μm) and Up2 be the potential electric energy when they are 8μm apart and moving. The total (potential and kinetic energies) at each position are given by

Ut1 = Up1 + (1/2) m $(0)^2$ = Up1

Ut2 = Up2 + (1/2) m v^2 + (1/2) m v^2 = Up2 + m v^2

Formula for electric potential energy due to charges q1 and q2 distant by r is:

Ep = k q1 q2 / r

No external energy is used and no energy is lost, therefore there is conservation of energy such that potential energy is converted into kinetic energy.

Up1 = Up2 + m v^2 where v is the velocity when 8μm apart.

Charge of electron, e = -1.60×10^{-19}C,

Mass of electrum, m = 9.109×10^{-31}Kg

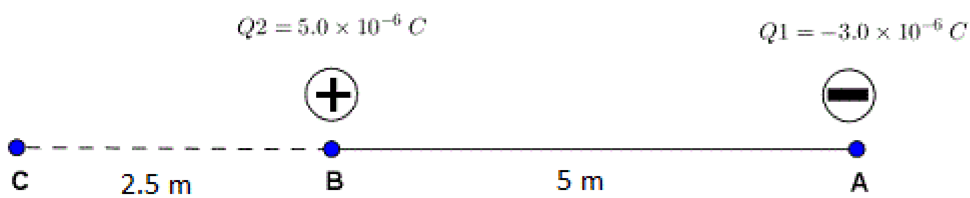
m v^2 = Up1 - Up2

= k×e×e / (3×10^{-6}) - k×e×e / (8×10^{-6})

= $9\times10^9(1.6\times10^{-19})^2$ [1 / (3×10^{-6}) - 1 / (8×10^{-6})]

v ≈ 3.48×10^4 m/s

Que 12: The distance AB between charges Q1 and Q2 shown below is 5.0 m. How much work must be done to move charge Q2 to a new location at point C so that the distance BC = 2.5 m? ***Marks :(3)***



Ans: If W is the work to be done to move Q2 from a position where its potential energy is Up1 and kinetic energy 0 (from rest) to another position where its potential energy is Up2 and kinetic energy 0 (to rest), then by the conservation of energy, we have.

Up1+W=Up2

which gives

W = Up2 - Up1

Ep1 = k Q1 Q2 / AB

Ep2 = k Q1 Q2 / AC

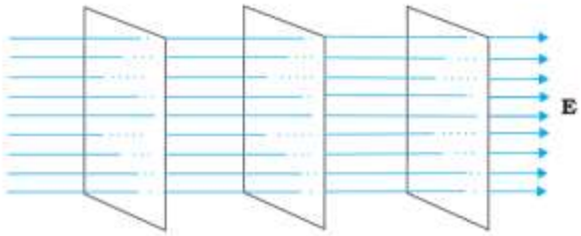
W = k Q1 Q2 (1/AB - 1/AC)

= $9.00\times10^9\times5\times10^{--6}\times-3\times10^{--6}$ (1/7.5 - 1/5)

= $9\times10^{--3}$ J

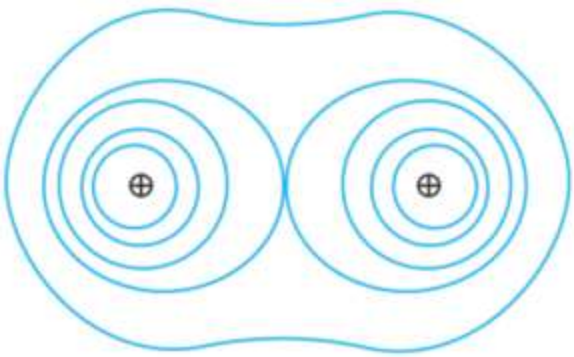
Que 13: Draw the equipotential surface in a uniform electric field? ***Marks :(1)***

Ans:



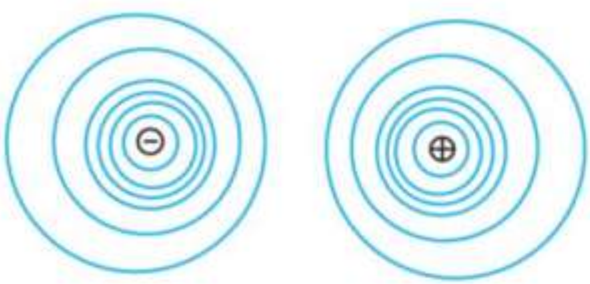
Que 14: Draw the equipotential surface for two like charges separated by a small distance ? ***Marks :(1)***

Ans:



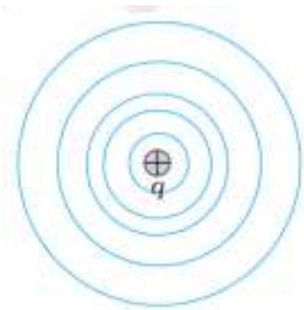
Que 15: Draw the equipotential surface for an electric dipole? ***Marks :(1)***

Ans:



Que 16: Draw the equipotential surface for a point charge? ***Marks :(1)***

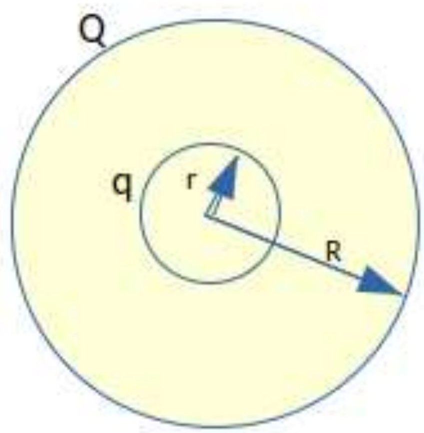
Ans:



Que 17: Write the expression for the potential at a point on the surface of

i) The inner sphere and

ii) The outer sphere. ***Marks :(3)***



Ans:

i)

$$V(r) = \frac{1}{4\pi\varepsilon_0}\left(\frac{Q}{R} + \frac{q}{r}\right)$$

ii)

$$V(R) = \frac{1}{4\pi\varepsilon_0}\left(\frac{Q}{R} + \frac{q}{R}\right)$$

Que 18: a) What is the use of van de Graff generator?

b) States the principle of van de Graff generator?

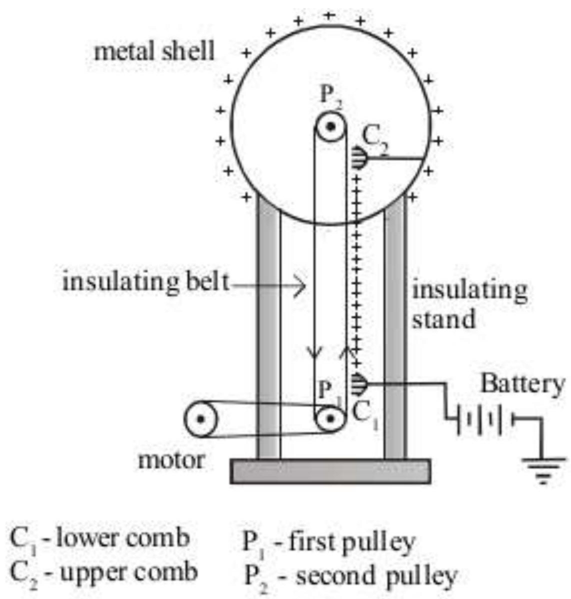
c) Explain its working with a neat diagram ? ***Marks :(5)***

Ans: a) It is used to produce high voltage of the order of a few million volt.

b) 1) Discharging action of sharp points(corona discharge) : Electric discharge takes place in air or gases readily at pointed conductors

2) When a charged conductor is brought in internal contact with a hollow conductor all the charges are transferred to the surface of the hollow conductor irrespective of the potential of the hollow conductor.

c)



Construction

It consists of a large conducting shell supported on an insulator column of several meters height. There is an insulating belt wound around two pulleys, moving continuously by a driven motor. The spray comb is connected to a high tension (10kV) battery. The collector comb is connected to the shell.

Working

The high electric field applied to the spray comb ionizes the air near to it. The positive charges produced in air are repelled and get deposited on the moving belt, by a corona discharge. As the belt moves up the charges reach the upper pulley. A similar discharge takes place at the collector comb and finally charges are transferred to the conducting shell, raising its potential to a few million volts.

Que 19: State the principle/s of van de Graff generator? ***Marks :(2)***

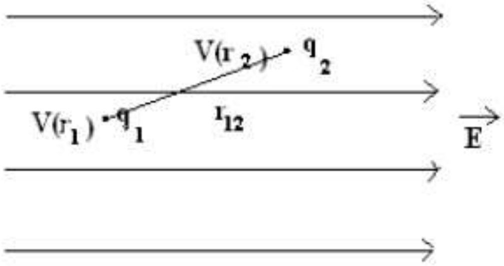
Ans: 1) Discharging action of sharp points: Electric discharge takes place in air or gases readily at pointed conductors

2) When a charged conductor is brought in internal contact with a hollow conductor all the charges are transferred to the surface of the hollow conductor irrespective of the potential of the hollow conductor.

Que 20: a) Find the work done to assemble two charges q_1 and q_2 at the points of potentials $V_{(r1)}$ and $V_{(r2)}$ respectively? ***Marks :(5)***

b) If there is no external electric field what is the work done to separate them far apart.

Ans: a)



PE of the system of charges is the total work done to assemble the charges from infinity.

Work done to bring $q_1 = q_1V(r_1)$

Work done to bring $q_2 = q_2V(r_2) + \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r_{12}}$

$\therefore$ PE of the system $= q_1V(r) + q_2V(r_2) + \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r_{12}}$

b) When there is no field, $V_{(r1)}=0$ and $V_{(r2)}=0$

$$W = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r}$$

Que 21: An electric dipole is placed in a uniform electric field at an angle θ with the field E.

a) What happens to the dipole

b) Obtain the expression for energy of the above system.

c) Give the conditions for stable and unstable equilibrium of the dipole system. ***Marks :(5)***

Ans: a) It experiences a torque.

b)

Consider a dipole of moment **p** placed in a uniform electric field of intensity **E** at an angle θ. Then,

Torque acting on the dipole, $\tau = pE \sin\theta$.

Now let the dipole be turned through an angle $d\theta$ against the torque. Then work done, $dw = pE \sin\theta \, d\theta$.

Therefore, work done in rotating the dipole from θ_1 to θ_2;

$$W = \int dw = \int_{\theta_1}^{\theta_2} pE\sin\theta \, d\theta = pE[-\cos\theta]_{\theta_1}^{\theta_2} \quad \text{i.e. } \underline{\underline{W = pE[\cos\theta_1 - \cos\theta_2]}}$$

This work done is stored in the dipole as potential energy.

Case I

When $\theta = 0^0$ (Stable equilibrium)

U = -PE cos0 = -PE

U = -PE (minimum)

Case II

When $\theta = 90^0$

U = -PE cos90^0 = -PE × 0

U = 0

Case III

When $\theta = 180^0$

= -PE × -1

U = PE

[Maximum potential energy]

Therefore, unstable equilibrium.

Que 22: N identical and equally charged (q) liquid drops coleases to form a single big drop. What is the charge and capacitance of the big drop. ?*Marks :(3)*

Ans:

Volume of N drops = Volume of big drop

$$N\frac{4}{3}\pi r^3 = \frac{4}{3}\pi R^3$$

R = $N^{1/3}$r

Charge on big drop , Q = Nq

Capacitance of a small drop, $C = 4\pi\epsilon_0 r$

Capacitance , $C^1 = N^{\frac{1}{3}} 4\pi\epsilon_0 R = N^{1/3} C$

Que 23: a) Define electric polarization and give its unit ? *Marks :(2)*

b) Writes the relation between polarization and electric field ?

Ans: a) It is the dipole moment per unit volume.

Unit: C/m^2

b) $P = \chi_E \cdot E$ Where χ_E - Electric susceptibility.

Que 24: Distinguish between polar and non-polar dielectrics with examples? ***Marks :(2)***

Ans: Polar dielectrics

They possess permanent dipole moment.

The centres of positive charges and negative charges don't coincide each other.

Eg: Hcl, H_2O etc.

Non-polar dielectrics

They do not possess permanent dipole moment.

The two centres of charges coincide each other.

Eg: CO_2 H_2 etc.

Que 25: The work done to move half a revolution of electron in an Orbit is zero. Why? ***Marks :(1)***

Ans: Orbit is an equipotential surface. So work done is zero.

Que 26: Prove that electric field is always perpendicular to an equipotential surface.

Work done to move a charge q from one point to another point on an equipotential is zero. ***Marks :(2)***

Ans: Ie, W = 0

F.dA =0

But F = qE

Therefore, qE.dA = 0

$$qE\, dA \cos\theta = 0$$

If $E \neq 0$ and $dA \neq 0$,

then cosθ = 0

ie, θ = 90^0

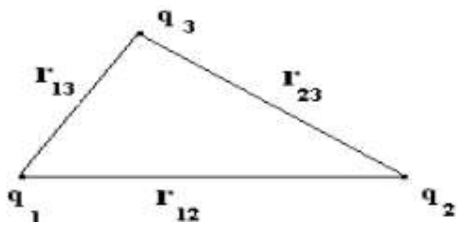
Electric field is perpendicular to the equipotential surface.

Que 27: a) What do you meant by energy of a system of three charges ?

b) Obtain the expression for the potential energy of the above system of charges? ***Marks :(4)***

Ans: a) It is the work done to assemble the three charges.

b)



Total potential energy of this system

=

$$\frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r_{12}} + \frac{1}{4\pi\varepsilon_0}\frac{q_2q_3}{r_{23}} + \frac{1}{4\pi\varepsilon_0}\frac{q_1q_3}{r_{13}}$$

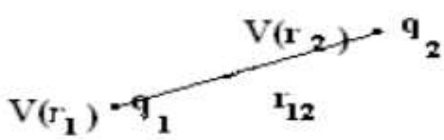
$$PE = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_1q_2}{r_{12}} + \frac{q_2q_3}{r_{23}} + \frac{q_1q_3}{r_{13}}\right]$$

Que 28: a) What do you meant by energy of a system of two charges ?

b) Obtain the expression for the potential energy of a system of two charges?
Marks :(4)

Ans: a) It is the work done to assemble the two charges.

b)



Work done to bring q_1= 0

The work done to bring q_2 to the point B from infinity in presence of q_1 is

= Potential at B due to q_1 charge × q_2

$$= \frac{1}{4\pi\varepsilon_0}\frac{q_1}{r} \times q_2$$

$$W = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r}$$

$$\boxed{P.E. = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r}}$$

Que 29: what are the different methods to increase the capacitance of a parallel plate capacitor. ***Marks :(2)***

Ans:

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

Increase A, decrease d and introduce a dielectric medium between the plates of the capacitor (Increase K).

Que 30: a) What is the use of a capacitor ?

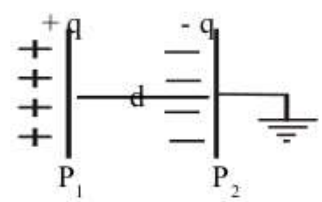
b) Obtain the expression for the capacitance of a parallel plate capacitor ?

c) What are the methods to increase the capacitance of a parallel plate capacitor? ***Marks :(5)***

Ans: a) A capacitor is a device used to store electrical energy and charge.

b)

A parallel plate capacitor consists of two similar, large, flat conducting plates arranged parallel to each other with a small distance d between them. Let A be the area of each plate. Let plate P_1, be charged +q and P_2 be charged –q. The electric field is uniform between the plates.



Its capacity, $C = \frac{q}{V}$; where V is the pd between the plates.

If σ is the charge density on one plate, q = σA.

But $\sigma = \varepsilon_0 E$

$\therefore q = \varepsilon_0 E A$

Also V = E d; where E is the electric field between the plates.

$\sigma = q/A \quad \therefore q = \sigma A$

Also $E \cdot S = q/\varepsilon_0$

$\therefore \varepsilon_0 E = q/S = \sigma$

$$\therefore \quad C = \frac{q}{Ed} = \frac{\varepsilon_0 A}{d} \qquad \text{i.e} \quad C = \frac{\varepsilon_0 A}{d}$$

c) Increase A, decrease d and introduce a dielectric medium between the plates of the capacitor(Increase K).

Que 31: Where does the energy stored in a capacitor ? ***Marks :(1)***

Ans: The energy is stored in the electric field between the plates of a capacitor.

Que 32: When a dielectric slab is introduced between the plates of a capacitor what happens to its capacitance ? ***Marks :(1)***

Ans: Capacitance increases since

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

Que 33: When a dielectric is introduced between the plates of a charged but source less parallel plates capacitor then what happens to the electric field between the plates ? ***Marks :(2)***

Ans: Electric field decreases.

$E = \frac{\sigma}{K \epsilon_0}$ and σ remains constant since no source is connected. Hence as K increases, E decreases.

Que 34: Define one Farad ? ***Marks :(1)***

Ans: The capacitance of a conductor is said to be one Farad if one coulomb of charge increases its potential by one volt.

1F = 1C / 1V

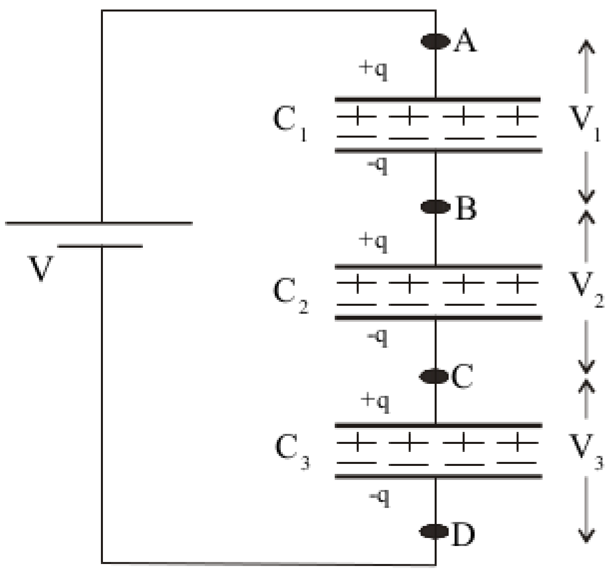
Que 35: Give the unit and dimensions of capacitance ? ***Marks :(2)***

Ans: Unit : Farad (F).

$[C] = [\ M^{-1}L^{-2}T^{-4}A^{2}\ ]$

Que 36: Find the resultant capacitance when three capacitors of capacitance C1, C2 and C3 are connected in series ? ***Marks :(3)***

Ans:



If V 1,V 2 and V 3 are the pd's of capacitors respectively,

V = V 1 +V 2 +V 3 ; where V = pd between the three capacitors

If V_1, V_2 and V_3 are the pd's of capacitors respectively,
$V = V_1 + V_2 + V_3$; where V = pd between the three capacitors.

Now $V_1 = \frac{q}{C_1}$; $V_2 = \frac{q}{C_2}$; $V_3 = \frac{q}{C_3}$

Also $V = \frac{q}{C}$; where C is called equivalent or effective capacitance.

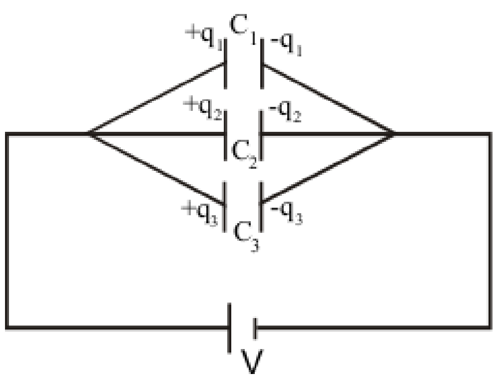
$$\therefore \quad \frac{q}{C} = \frac{q}{C_1} + \frac{q}{C_2} + \frac{q}{C_3}$$

$$\text{i.e} \quad \frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

Here C = effective or equivalent capacitance of the combination.

Que 37: You are provided with three capacitors of capacitance C_1, C2 and C_3. How will you connect them to get maximum capacitance. Obtain the expression for total capacitance of the combination. ***Marks :(3)***

Ans: Capacitors are connected in parallel.



Total charge, q = q1 +q 2 +q3, q1 = C1.V, q2 = C2.V, q3 = C3.V

q = (C 1 +C 2 +C 3) V.

Now if the three capacitors are replaced by a capacitor of

Capacitance C, then q = C V.

C V = (C 1 +C 2 +C 3) V.

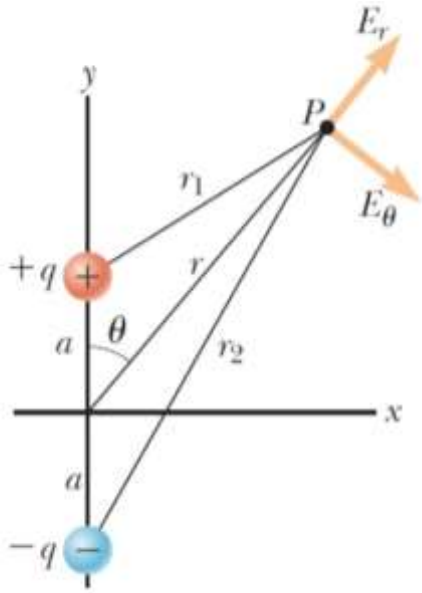
C= C 1 + C 2 + C 3.

Que 38: a) obtain the expression for the potential due to a electric dipole at any point.

b) What is the potential at a point on the axial and equatorial lines of the dipole. ***Marks :(5)***

Ans: Algebraic sum of potential due to each charge,

$$V_P = V_{+q} + V_{-q} = k\left(\frac{q}{r_1} + \frac{-q}{r_2}\right) = kq\left(\frac{r_2 - r_1}{r_1 r_2}\right)$$



When r >> a, then r_1, r_2 and r are approximately equal and $r_2 - r_1 = 2a\cos\theta$. Therefore,

$$V_p = \frac{k2aq\cos\theta}{r^2} = k\frac{p\cos\theta}{r^2} = \left(k\frac{p\cdot r}{r^3}\right)$$

$$V = \frac{1}{4\pi\varepsilon_0}\frac{p\cos\theta}{r^3}$$

b) At the axial line,

$$\theta = 0^0$$

$$V = \frac{1}{4\pi\varepsilon_0}\frac{p}{r^3}$$

At the equatorial line

$$\theta = 90^0$$

V = 0

Que 39: a) what do you mean by energy of a capacitor

b) Obtain an expression for energy stored in a capacitor.

c) A capacitor is charged and disconnected from the cell and a dielectric slab is introduced between the plates of the capacitor what happens to the energy of the capacitor and why? ***Marks :(5)***

Ans: a) It is the work done in charging a capacitor.

b) Work done to move a charge dq to the capacitor, dw = V . dq

Total work done , W = $\int_0^Q V \, . dq$

This work is stored as potential energy in the capacitor, U = $\frac{Q^2}{2C}$

c) Energy of the capacitor decreases since the capacitance increases, C = $\frac{\varepsilon_0 \varepsilon_r A}{d}$

Que 40: What is the work done by the field of a nucleus in a complete circular orbit of the electron? What if the orbit is elliptical? Justify your answer. ***Marks :(2)***

Ans: Whenever the electron completes an orbit, either circular or elliptical, the work done by the field of a nucleus is zero.

W = F.s= Fs cosØ, where the electrostatic force provides the centripetal force .hence Ø is always 90^0.

Que 41: In a Van de Graaff type generator a spherical metal shell is to be a 15 × 10^6 V . The dielectric strength of the gas surrounding the electrode is 5 × 10^7 Vm^{-1}. What is the minimum radius of the spherical shell required? ***Marks :(2)***

Ans: Minimum radius of the spherical shell required for the purpose is given by,

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

$$= \frac{15 \times 10^6}{5 \times 10^7} = 0.3 \text{ m} = 30 \text{ cm}$$

Hence, the minimum radius of the spherical shell required is 30 cm.

Que 42: Describe schematically the equipotential surfaces corresponding to

(a) a single positive charge at the origin, and

(b) a uniform grid consisting of long equally spaced parallel charged wires in a plane. ***Marks :(2)***

Ans: (a) Concentric spheres centered at the origin are equipotential surfaces.

(b) A periodically varying shape near the given grid is the equipotential surface. This shape gradually reaches the shape of planes parallel to the grid at a larger distance.

Que 43: Describe schematically the equipotential surfaces corresponding to

(a) a constant electric field in the *z*-direction,

(b) a field that uniformly increases in magnitude but remains in a constant (say, *z*) direction, ***Marks :(2)***

Ans: a) Equidistant planes parallel to the *x-y* plane are the equipotential surfaces.

(b) Planes parallel to the *x-y* plane are the equipotential surfaces with the exception that when the planes get closer, the field increases.

Que 44: A bird perches on a bare high power line, and nothing happens to the bird. A man standing on the ground touches the same line and gets a fatal shock. Why? ***Marks :(1)***

Ans: Current passes only when there is difference in potential.

Que 45: Ordinary rubber is an insulator. But special rubber tyres of aircraft are made slightly conducting. Why ? ***Marks :(2)***

Ans: To enable them to conduct charge (produced by friction) to the ground. As too much of static electricity accumulated may result in spark and it result in fire.

Que 46: A comb run through one's dry hair attracts small bits of paper. Why? What happens if the hair is wet or if it is a rainy day? ***Marks :(2)***

Ans: This is because the comb gets charged by friction. The molecules in the paper gets polarised by the charged comb, resulting in anet force of attraction.

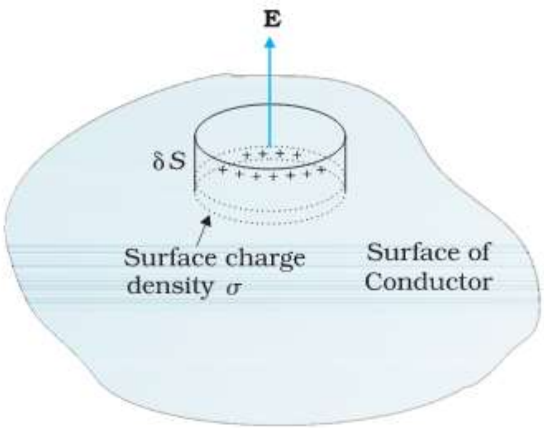
If the hair is wet, or if it is rainy day, friction between hair and the comb reduces. The comb does not get charged and thus it will not attract small bits of paper.

Que 47: Prove that electric field at the surface of a charged conductor, $E=\frac{\sigma}{\varepsilon_0}\hat{n}$ ***Marks :(3)***

Ans: Choose a pill box (a short cylinder) as the Gaussian surface about any point P on the surface, as shown in figure. The pillbox is partly inside and partly outside the surface of the conductor. It has a small area of cross section δS and negligible height.

The flux through the curved surface = 0 ($\theta = 90^0$)

By Gauss's law,



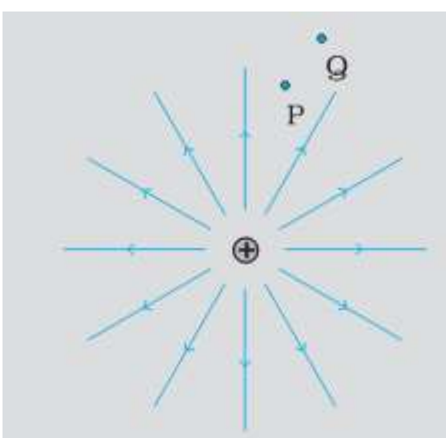
$$E\,\delta S = \frac{\sigma \delta S}{\varepsilon_0}$$

$$E = \frac{\sigma}{\varepsilon_0}\hat{n}$$

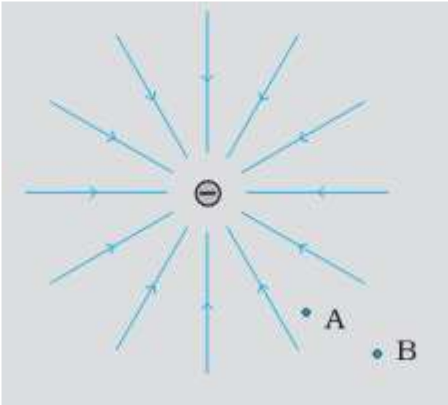
Que 48: Vehicles carrying inflammable materials usually have metallic ropes touching the ground during motion. Why? ***Marks :(2)***

Ans: To enable them to conduct the accumulated charge (produced by friction) to the ground; As too much of static electricity accumulated may result in spark and result to fire.

Que 49: Does the kinetic energy of a small negative charge increase or decrease in going from Q to P ? ***Marks :(2)***

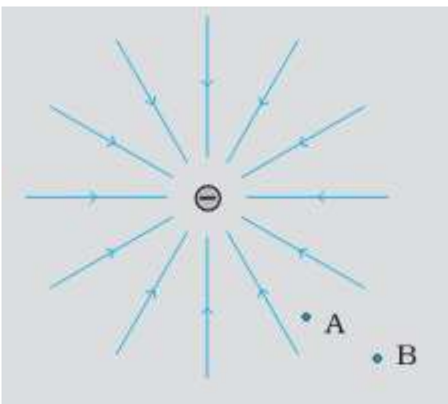


Que 50: Does the kinetic energy of a small negative charge increase or decrease in going from B to A? ***Marks :(2)***



Ans: Due to force of repulsion on the negative charge, velocity decreases and hence the kinetic energy decreases in going from B to A.(Potential energy increases)

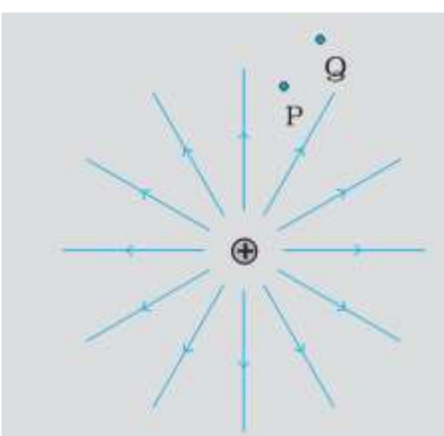
Que 51: Give the sign of the work done by the external agency in moving a small negative charge from B to A ? ***Marks :(2)***



Ans: Work done = potential energy difference of a small negative charge between the points A and B = U_A - U_B = -q (V_A – V_B)

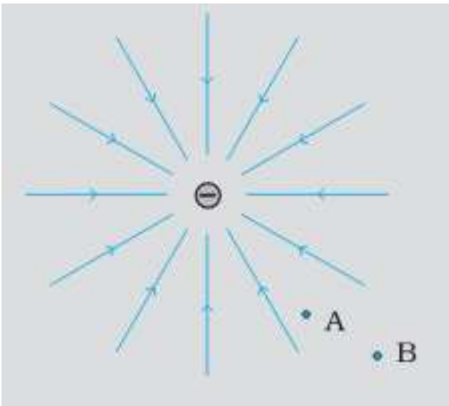
(V_A – V_B) is negative. Therefore (U_A - U_B) is positive.

Que 52: Give the sign of the work done by the field in moving a small positive charge from Q to P. ***Marks :(2)***



Ans: In moving a small positive charge from Q to P, work has to be done by an external agency against the electric field. Therefore, work done by the field is negative.

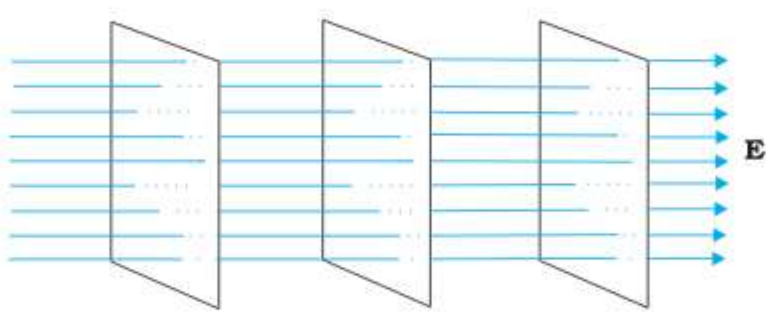
Que 53: Give the sign of the potential energy difference of a small negative charge between the points A and B ? ***Marks :(2)***



Ans: Potential energy difference of a small negative charge between the points A and B = $U_A - U_B = -q (V_A – V_B)$

$(V_A – V_B)$ is negative. Therefore $(U_A - U_B)$ is positive.

Que 54: Chose the correct one from the following ?Give reason. ***Marks :(2)***



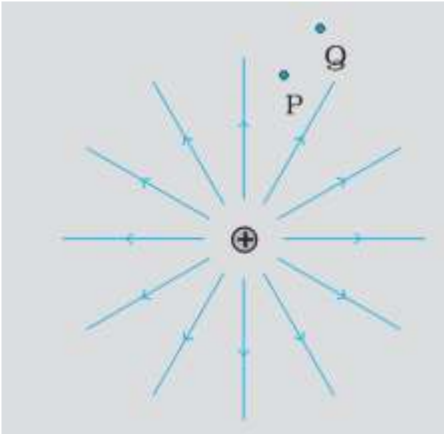
a) VA<VB<VC **b) VA >VB >VC**

c) VA =VB=VC **c) VA<VB>VC**

Ans: Ans: b

E = -(dV/dx). Negative sign indicates that potential gradient decreases in the direction of electric field.

Que 55: Give the sign of the potential energy difference of a small negative charge between the points Q and P ? ***Marks :(2)***



Ans: As V α 1/r , $V_P > V_Q$. Thus, $(V_P – V_Q)$ is positive.

Potential energy when the negative charge (say -q) is at Q, $U_Q = -qV_Q$

Potential energy when the negative charge (say -q) is at P, $U_P = -qV_P$

Potential energy difference between Q and P, $U_Q – U_P = -q(V_Q - V_Q)$

But $(V_Q - V_Q)$ is negative. Therefore $U_Q – U_P$ is positive.

OR

A small negative charge will be attracted towards positive charge. The negative charge moves from higher potential energy to lower potential energy. Therefore the sign of potential energy difference of a small negative charge between Q and P is positive.

Que 56: A molecule of a substance has a permanent electric dipole moment of magnitude $10^{–29}$ C m. A mole of this substance is polarised (at low temperature) by applying a strong electrostatic field of magnitude 10^6 V $m^{–1}$. The direction of the field is suddenly changed by an angle of 60º. Estimate the heat released by the substance in aligning its dipoles along the new direction of the field. For simplicity, assume 100% polarisation of the sample? ***Marks :(3)***

Ans: Dipole moment of each molecules = $10^{–29}$ C m

As 1 mole of the substance contains 6 × 1023 molecules,

Total dipole moment of all the molecules,

$p = 6 \times 10^{23} \times 10^{–29}$ C m = $6 \times 10^{–6}$C m

Initial potential energy, $U_i = –pE \cos \theta$

= –6×10–6×106 cos 0° = –6 J

Final potential energy (when θ = 60°),

$U_f = –6 \times 10^{–6} \times 10^6 \cos 60° = –3$ J

Change in potential energy = –3 J – (–6J) = 3 J

So, there is loss in potential energy. This must be the energy released by the substance in the form of heat in aligning its dipoles