NeetPreparation

Electrostatic Potential and Capacitance Important Questions With Answers

NEET Physics 2023

1. In a certain region of space with volume 0.2 m^3, the electric potential is found to be 5 V throughout. The magnitude of electric field in this region is _______.
   a) 5 N/C **b) Zero** c) 0.5 N/C d) 1 N/C

   Solution : -
   Since detract potential is constant throughout the volume
   $\therefore$ Electric field is zero.

2. The capacitance of a parallel plate capacitor with air as medium is 6 mf. With the introduction of a dielectric medium, the capacitance becomes 30 mF. The permittivity of the medium is
   $\left(\Sigma_0 = 8.85 \times 10^{-12} C^2\ N^{-1}\ m^{-2}\right)$
   a) $5.00 C^2N^{-1}m^{-2}$ b) $0.44 \times 10^{-13} C^2N^{-1}m^{-2}$ c) $1.77 \times 10^{-12} C^2N^{-1}m^{-2}$ **d) $0.44 \times 10^{-10} C^2N^{-1}m^{-2}$**

   Solution : -
   $C_m = e_r C_0$
   $\varepsilon_r = \frac{30}{6} = 5$
   $\epsilon = \epsilon_0 \cdot \epsilon_r = 8.85 \times 10^{-12} \times 5$
   $\epsilon = 0.44 \times 10^{-10}$

3. A hollow metal sphere of radius R is uniformly charged. The electric field due to the sphere at a distance r from the centre ______.
   a) Zero as r increases for r < R, decreases as r increases for r>R
   b) Zero as r increases for r < R, increases as r increases for r> R
   c) Decreases as r increases for r < R and for r > R d) Increases as r increases for r < R and for r > R

   Solution : -
   Charge Q will be distributed over the surface of hollow metal sphere.
   (i) For r < R (inside)
   By Gauss law $\oint \vec{E}_{in} \cdot \overline{dS} = \frac{q_{en}}{\varepsilon_0} = 0$
   $\Rightarrow E_{jn} = 0 \quad (\because q_{en} = 0)$

4. A parallel plate capacitor of capacitance 20 mF is being charged by a voltage source whose potential is changing at the rate of 3 V/s. The conduction current through the connecting wires, and the displacement current through the plates of the capacitor, would be, respectively.
   a) 60 mA, 60 mA b) 60 mA, zero c) Zero, zero d) Zero,60 mA

   Solution : -
   Capacitance of capacitor C = 20 mF = 20 x 10^{-6}F
   Rate of change of potential
   $= \left(\frac{dV}{dt}\right) = 3 v/s$
   q = Cv

$\frac{dq}{dt} = \mathrm{C}\frac{d\,\mathrm{V}}{dt}$
i_c = 20 x 10^{-6} x 3
= 60 x 10^{-6} A
= 60 mA
As we know that $i_d = i_c$ = 60 mA

5. A parallel plate air capacitor of capacitance C is connected to a cell of emf Zand then disconnected from it.A dielectric slab of dielectric constant K, which can just fill the air gap of the capacitor, is now inserted in it. Which of the following is incorrect.
   a) The energy stored in the capacitor decreases K times.
   b) The chance in energy stored is $\frac{1}{2}CV^2\left(\frac{1}{K}-1\right)$ c) The charge on the capacitor is not conserved.
   d) The potential difference between the plates decreases K times.
   Solution : -
   Capacitance of the capacitor, $C = \frac{Q}{V}$
   After inserting the dielectric, new capacitance
   C^1= K.C
   New potential difference
   $V^1 = \frac{V}{K}$
   $u_i = \frac{1}{2}cv^2 = \frac{Q^2}{2C}(\because Q = cv)$
   $u_f = \frac{Q^2}{2f} = \frac{Q^2}{2kc} = \frac{C^2V^2}{2KC} = \left(\frac{u_i}{k}\right)$
   $\Delta u = u_f - u_i = \frac{1}{2}cv^2\left\{\frac{1}{k}-1\right\}$
   As the capacitor is isolated, so change will remain conserved. Therefore, potential difference between two plates of the capacitor
   $= L = \frac{Q}{KC} = \frac{V}{K}$
6. In a region, the potential is represented by V(x, y, z') = 6x - 8xy - 8y + 6yz, where V is in volts and x, y, z are in metres. The electric force experienced by a charge of 2 coulomb situated at point (1, 1, 1) is ________.
   a) $6\sqrt{5}$N b) 30 N c) 24 N **d) $4\sqrt{35}$ N**
   Solution : -
   $\vec{E} = -\frac{\partial V}{\partial x}\hat{i} - \frac{\partial V}{\partial y}\hat{j} - \frac{\partial V}{\partial z}\hat{k}$
   $= -[(6-8y)\hat{i} + (-8x-8+6z)\hat{j} + (6y)\hat{k}]$
   $\text{At } (1,1,1), \vec{E} = 2\hat{i} + 10\hat{j} - 6\hat{k}$
   $\Rightarrow (\vec{E}) = \sqrt{2^2+10^2+6^2} = \sqrt{140}$
   = $2\sqrt{35}$
   $\therefore \quad F = q\vec{E} = 2\times 2\sqrt{35} = 4\sqrt{35}\ \mathrm{N}$
7. A conducting sphere of radius R is given a charge Q. The electric potential and the electric field at the centre of the sphere respectively are _______.
   a) $\text{Zero and } \frac{Q}{4\pi\varepsilon_0 R^2}$ **b)** $\frac{Q}{4\pi\varepsilon_0 R}$ and Zero c) $\frac{Q}{4\pi\varepsilon_0 R}$ and $\frac{Q}{4\pi\varepsilon_0 R^2}$ d) Both are zero
   Solution : -
   Because of conducting sphere
   At centre, electric field E = 0
   Andelectricpotential V = $\frac{Q}{4\pi\varepsilon_0 R}$

8. A parallel plate capacitor has a uniform electric field E in the space between the plates. If the distance between the plates is d and area of each plate is A, the energy stored in the capacitor is __________.

a) $\frac{1}{2}\varepsilon_0 E^2$ b) $\mathrm{E}^2\mathrm{Ad}/\varepsilon_0$ **c)** $\frac{1}{2}\varepsilon_0 E^2 Ad$ d) ε_0 EAd

Solution : -

The energy stored in a capacitor

$U = \frac{1}{2}CV^2$ ....(i)

The capacitance of the parallel plate capacitor.

V=E.d

$C = \frac{A\varepsilon_0}{d}$

Substituting the value of C in equation (i), We have

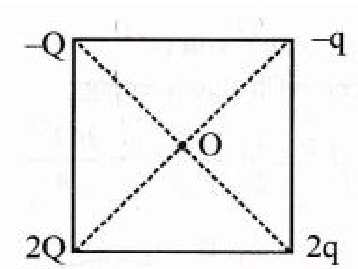
$\mathrm{U} = \frac{1}{2}\frac{A\varepsilon_0}{d}(Ed)^2 = \frac{1}{2}\frac{A\varepsilon_0 E^2 d}{d}$

9. Four point charges -Q. -q, 2q and 2Q are placed, one at each corner of the square. The relation between e and q for which the potential at the centre of the square is zero is _______.

a) Q = -q b) $Q = -\frac{1}{q}$ c) Q = q d) $Q = \frac{1}{q}$

Solution : -

Let the side of square be 'a' then potential at centre O is



$V = \frac{k(-Q)}{\left(\frac{a}{\sqrt{2}}\right)} + \frac{k(-q)}{\frac{a}{\sqrt{2}}} + \frac{k(-2q)}{\frac{a}{\sqrt{2}}} + \frac{k(2Q)}{\left(\frac{a}{\sqrt{2}}\right)}$ = 0

=-Q-q+2q+2Q=0-Q+q=0

=Q=-q

10. The potential energy of particle in a force field is $U = \frac{A}{r^2} - \frac{B}{r}$ where A and B are positive constants and r is the distance of particle from the centre of the field. For stable equilibrium, the distance of the particle is _________.

a) B/2A **b) 2A/B** c) A/B d) B/A

Solution : -

For equilibrium

$\frac{dU}{dr} = 0 \Rightarrow \frac{-2A}{r^3} + \frac{B}{r^2} = 0$

$r = \frac{2A}{B}$

For stable equilibrium

$\frac{d^2U}{dr^2}$ should be positive for the value of r.

Here $\frac{d^2U}{dr^2} = \frac{6A}{r^4} - \frac{2B}{r^3}$ is +ve value for $r = \frac{2A}{B}$.

11. A parallel plate condenser has a uniform electric field E(V/ m) in the space between the plates. If the distance between the plates is d(m) and area of each plate is A(m^2) the energy joules) stored in the condenser is _______.

a) $\mathrm{E}^2\mathrm{Ad}/\varepsilon_0$ b) $\frac{1}{2}\varepsilon_0 E^2$ c) $\varepsilon_0\mathrm{EAd}$ **d)** $\frac{1}{2}\varepsilon_0 E^2 Ad$

Solution : -

$U=\frac{1}{2} C V^2$
$\mathrm{U}=\frac{1}{2}\left(\frac{A \varepsilon_0}{d}\right)(E d)^2=\frac{1}{2} A \varepsilon_0 E^2 d$

12. Two parallel metal plates, having charges +Q and -Q face each other at a certain distance between them. If the plates are now dipped in kerosene oil tank, the electric field between the plates will
a) remains same b) becomes zero c) increases **d) decreases**

Solution : -
Electric field
$E=\frac{\sigma}{\varepsilon}=\frac{Q}{A \varepsilon}$
e of kerosene oil is more than that of air. As e increases. E decreases.

13. A condenser of capacity C is charged to a potential difference of V_1. The plates of the condenser are then connected to an ideal inductor of inductance L. The current through the inductor when the potential difference across the condenser reduces to V_2 is
a) $\left(\frac{C\left(V_1^2-V_2^2\right)}{L}\right)^{1 / 2}$ b) $\left(\frac{C\left(V_1-V_2\right)^2}{L}\right)^{1 / 2}$ c) $\frac{C\left(V_1^2-V_2^2\right)}{L}$ d) $\frac{C\left(V_1-V_2\right)}{L}$

Solution : -
q = CV_1 cos Wt
$\Rightarrow i=\frac{d q}{d t}=-\omega C v_1 \sin \omega t$
$\text{Also, } \omega^2=\frac{1}{L C} \text{ and } V=V_1 \cos \omega t$
$\text{At t}=t_1, V=V_2 \text{ and } i=-\omega C V_1 \sin \omega t_1$
$\therefore \cos \omega t_1=\frac{V_2}{V_1}(-\text{ vesign shows direction })$
$\text{Hence, } i=V_1 \sqrt{\frac{C}{L}}\left(1-\frac{V_2^2}{V_1^2}\right)^{1 / 2}$
$=\left(\frac{C\left(V_1^2-V_2^2\right)}{L}\right)^{1 / 2}$

14. A series combination ofrr, capacitors, each of value C_1 is charged by a source of potential difference 4V. When another parallel combination of n_2 capacitors, each of value C_2, is charged by a source of potential difference V, it has the same (total) energy stored in it, as the first combination has. The value of C_2, in terms of C_1, is then ________.
a) $\frac{2 C_1}{n_1 n_2}$ b) $16 \frac{n_2}{n_1} C_1$ c) $2 \frac{n_2}{n_1} C_1$ **d)** $\frac{16 C_1}{n_1 n_2}$
Solution : -
The series combination of capacitors,
$C_{eff}=\frac{C_1}{n_1}$
$\therefore$ Energy stored
$E_S=\frac{1}{2} \mathrm{C}_{\mathrm{eff}} V_S^2=\frac{1}{2} \frac{C_1}{n_1} 16 \mathrm{~V}^2$
$=8 \mathrm{~V}^2 \frac{C_1}{n_1}$
In parallel combination $C_{eff} = n_2C_2$
$\therefore$ Energy stored, $E_p=\frac{1}{2} n_2 C_2 V^2$
$\therefore \frac{8 V^2 C_1}{n_1}=\frac{1}{2} n_2 C_2 V^2$
$\Rightarrow C_2=\frac{16 C_1}{n_1 n_2}$

15. The electric potential at a point 6, y, r) is given by Z = $x^2y - xz^3 + 4$. The electric field $\vec{E}$ at that point is ______.

a) $\vec{E} = \hat{i}\,2xy + \hat{j}\left(x^2 + y^2\right) + \hat{k}\left(3xz - y^2\right)$ b) $\vec{E} = \hat{i}\,z^3 + \hat{j}xyz + \hat{k}z^2$

c) $\vec{E} = \hat{i}\,\left(2xy - z^3\right) + \hat{j}xy^2 + \hat{k}3z^2x$ **d)** $\vec{E} = \hat{i}\,\left(2xy + z^3\right) + \hat{j}x^2 + \hat{k}3xz^2$

Solution : -

The electric field at a point: negative of potential gradient at that point.

$$\vec{E} = -\frac{\partial V}{\partial r} = \left[-\frac{\partial V}{\partial x}\hat{i} - \frac{\partial V}{\partial y}\hat{j} + \frac{\partial V}{\partial z}\hat{k}\right]$$

$$= \left[\left(2xy + z^3\right)\hat{i} + \hat{j}\cdot x^2 + \hat{k}3xz^2\right]$$

16. Three capacitors each of capacitance C and of breakdown voltage V are joined in series. The capacitance and breakdown voltage of the combination will be ______.

a) $3\mathrm{C}, \frac{V}{3}$ **b)** $\frac{C}{3}, 3\ \mathrm{V}$ c) 3C, 3V d) $\frac{C}{3}, \frac{V}{3}$

Solution : -

n series combination of capacitors, we have V_{eff} = V + V + V = 3V

$$\frac{1}{\mathrm{C_{eff}}} = \frac{1}{C} + \frac{1}{C} + \frac{1}{C} = \frac{3}{C}$$

$$\Rightarrow \mathrm{C_{eff}} = \frac{C}{3}$$

Therefore the capacitance and breakdown voltage of the combination = $\frac{C}{3}$ and $3\ \mathrm{V}$ respectively.

17. Three concentric spherical shells have radii a, b and c (a < b < c) and have surface charge densities s, -s and s respectively. If V_A, V_B and V_C denotes the potentials of the three Shells, then for c = a+b,we have ______.

a) $\mathrm{V_C} = \mathrm{V_B} \neq \mathrm{V_A}$ b) $\mathrm{V_C} \neq \mathrm{V_B} \neq \mathrm{V_A}$ c) $V_C = V_B = V_A$ **d)** $\mathrm{V_C} = \mathrm{V_A} \neq \mathrm{V_B}$

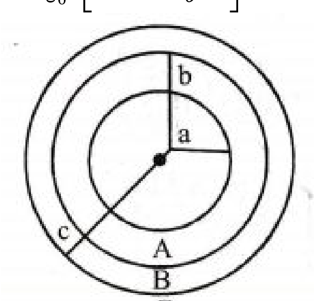
Solution : -

c = a + b

$$V_A = \frac{\sigma a}{\varepsilon_0} - \frac{\sigma b}{\varepsilon_0} + \frac{\sigma c}{\varepsilon_0} = \frac{\sigma}{\varepsilon_0}[c - (b - a)]$$

$$V_B = \frac{-\sigma b}{\varepsilon_0} + \frac{1}{4\pi\varepsilon_0}\cdot\frac{\sigma\times 4\pi a^2}{b} + \frac{\sigma c}{\varepsilon_0}$$

$$= \frac{\sigma}{\varepsilon_0}\left[c - \frac{b^2 - a^2}{b}\right]$$



$$V_C = \frac{\sigma c}{\varepsilon_0} - \frac{1}{4\pi\varepsilon_0}\cdot\frac{\sigma\times 4\pi b^2}{c} + \frac{1}{4\pi\varepsilon_0}\cdot\frac{\sigma\times 4\pi a^2}{c}$$

$$= \frac{\sigma}{\varepsilon_0}\left[c - \frac{\left(b^2 - a^2\right)}{c}\right]$$

$$= \frac{\sigma}{\varepsilon_0}[c - (b - a)]$$

$$V_A = V_C \neq V_B$$

18. The energy required to charge a parallel plate condenser of plate separation d and plate area of cross-section A such that the uniform electric field betwen the plates is E, is _______.

a) $\frac{1}{2}\varepsilon_0 E^2/Ad$ b) $\mathrm{e_0}E^2/\mathrm{Ad}$ c) $\mathrm{e_0}E^2\mathrm{Ad}$ **d)** $\frac{1}{2}\varepsilon_0 E^2 Ad$

Solution : -

The energy required to charge a parallel plate condenser $U=\frac{1}{2}CV^2$

$\text{As } C=\frac{\varepsilon_0 A}{d} \text{ and } V=E\cdot d$

$\therefore \mathrm{U}=\frac{1}{2}\cdot\frac{\varepsilon_0 A}{d}\cdot E^2 d^2=\frac{1}{2}\varepsilon_0 E^2 A d$

19. The electric potential at a point in free space due to a charge Q coulomb is Q x 10^{11} volts. The electric field at that point is ______.

a) $4\pi\varepsilon_0 Q\times 10^{22}$ volt /m   b) $12\pi\varepsilon_0 Q\times 10^{20}$ volt /m   c) $4\pi\varepsilon_0 Q\times 10^{20}$ volt /m
d) $12\pi\varepsilon_0 Q\times 10^{22}$ volt /m

Solution : -

Given that, V = Q x l0^{11} volts Electric potential at point is given by

$V=\frac{1}{4\pi\varepsilon_0}\cdot\frac{Q}{r} \text{ or }, Q\times 10^{11}=\frac{1}{4\pi\varepsilon_0}\cdot\frac{Q}{r}$

$\Rightarrow r=\frac{1}{4\pi\varepsilon_0}\cdot 10^{-11}\ \mathrm{m}$

$\text{As } |E|=\frac{|V|}{r}=\frac{Q\times 10^{11}}{\frac{1}{4\pi\varepsilon_0}.10^{-11}}$

$=4\pi\varepsilon_0 Q\times 10^{22}\ \text{volt m}^{-1}$

20. A parallel plate air capacitor is charged to a potential difference of V volts. After disconnecting the charging battery the distance between the plates of the capacitor is increased using an insulating handle. As a result the potential difference between the plates.

a) does not change   b) becomes zero   **c) increases**   d) decreases

Solution : -

If the distance between the plates is increased, capacity decreases and results in higher potential as we know Q = CV. Since Q is constant as battery has been disconnected on decreasing C, V will increases.

21. A bullet of mass 2 g is having a charge of 2mC. Through what potential difference must it be accelerated, starting from rest, to acquire a speed of 10 m/s?

a) 50 V   b) 5 KV   **c) 50 KV**   d) 5V

Solution : -

$\because qV=\frac{1}{2}mv^2$

$\Rightarrow 2\times 10^{-6}\times V=\frac{1}{2}\times\frac{2}{1000}\times 10\times 10$

$\therefore$ V = 50 KV

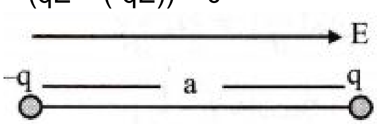
22. An electric dipole has the magnitude of its charge as q and its dipole moment is p. It is placed in uniform electric field E. If its dipole moment is along the direction of the field, the force on it and its potential energy are respectively.

a) zero and min.   b) q.E and max.   c) 2q.E and min.   d) q.E and p.E

Solution : -

When the dipole is the direction of field the net force

= (qE + (-qE)) = 0



and its potential energy is minimum = -p.E. = -qaE

23. Three capacitors each of capacity 7mF are to be connected in such a way that the effective capacitance is 6mF. This can be done by __________.

a) connecting two in parallel and one in series   b) connecting all of them in series
c) connecting all of them in parallel   **d) connecting two in series and one in parallel**

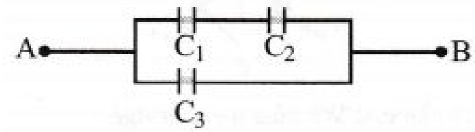
Solution : -

For series, combination of capacitors,

$$C' = \frac{C_1 \times C_2}{C_1 + C_2} = \frac{4 \times 4}{4+4} = 2\mu F$$

For parallel combination of capacitors,

$$C_{eq} = \mathrm{C}' + \mathrm{C}_3 = 2 + 4 = 6\mathrm{mF}$$



24. Each corner of a cube of side / has a negative charge, -q. The electrostatic potential energy of a charge q at the centre of the cube is _______.

a) $-\frac{4q^2}{\sqrt{2}\pi\varepsilon_0 l}$ b) $\frac{\sqrt{3}q^2}{4\pi\varepsilon_0 l}$ c) $\frac{4q^2}{\sqrt{2}\pi\varepsilon_0 l}$ **d)** $-\frac{4q^2}{\sqrt{3}\pi\varepsilon_0 l}$

Solution : -

Length of diagonal = $\sqrt{3}l$

$\therefore$ Distance of centre of cube from each corner $r = \frac{\sqrt{3}}{2}l$

P.E. at centre

= 8 x Potential Energy due to charge at A

$$= 8 \times \frac{kq \times (-q)}{r}$$

$$= 8 \times \frac{1}{4\pi\varepsilon_0\sqrt{3}l} \times 2 \times q \times (-q) = \frac{-4q^2}{\sqrt{3}\pi\varepsilon_0 l}$$

25. A solid spherical conductor is given a charge. The electrostatic potential of the conductor is ______.

a) constant throughout the conductor b) largest at the centre c) largest on the surface

d) largest somewhere between the centre and the surface

Solution : -

Electric potential $\left(\frac{\kappa q}{R}\right)$ is constant Within or on the surface of conductor.

26. A capacitor C_1 is charged to a potential difference V. The charging battery is then removed and the capacitor is connected to an uncharged capacitor C_2. The potential difference across the combination is _____________.

a) $\frac{VC_1}{(C_1+C_2)}$ b) $V\left(1+\frac{C_2}{C_1}\right)$ c) $V\left(1+\frac{C_1}{C_2}\right)$ d) $\frac{VC_2}{(C_1+C_2)}$

Solution : -

Charge Q = C_1V

For parallel combination

C = C1 + C_2

$$\text{P.D.} = \frac{Q}{C_n} = \frac{C_1 V}{C_1 + C_2}$$

27. Energy stored in a capacitor is ________.

a) $\frac{1}{2}QV$ b) QV c) $\frac{1}{QV}$ d) $\frac{2}{QV}$

Solution : -

Energy stored in the capacitor

$$= \frac{1}{2}CV^2 = \frac{1}{2}\frac{Q}{V} \cdot V^2 \quad (Q = CV)$$

$$= \frac{1}{2}QV$$

28. The capacity of a parallel plate condenser is 10 mF, when the distance between its plates is 8 cm. If the distance between the plates is reduced to 4 cm then the capacity of this parallel plate condenser will be _______.

a) 5 mF b) 10 mF **c) 20 mF** d) 40 mF

Solution : -

C = 10 mf d = 8 cm

c' = ? d' = 4 cm

$C=\frac{A\varepsilon_0}{d} \Rightarrow C\alpha\frac{1}{d}$

If d is halved, C will be doubled.

Hence, C'=2C=2 x 10mf=20mF

29. A parallel plate condenser with oil (dielectric constant 2) between the plates has capacitance C. If oil is removed, the capacitance of capacitor becomes _______.

a) $\sqrt{2}C$ b) 2C c) $\frac{C}{\sqrt{2}}$ **d)** $\frac{C}{2}$

Solution : -

The capacitance of a parallel plate capacitor with dielectric (oil) between its plates is

$C=\frac{K\varepsilon_0 A}{d}$ ....(i)

where,

e_0 = electric permittivity of free space

K = dielectric constant of oil

A = area of each plate of capacitor

d = distance between two plates

When dielectric (oil) is removed, so capacitance of capacitor becomes,

$C_0=\frac{\varepsilon_0 A}{d}$ ....(ii)

Comparing Eqs. (i) and (ii). we get

C = KC_0

$\Rightarrow \quad C_0=\frac{c}{K}=\frac{c}{2} \quad (K=2)$

30. In bringing an electron towards another electron, the electrostatic potential energy of the system.

a) decreases **b) increases** c) remains same d) becomes zero

Solution : -

The electron has negative charge. When an electron is brought towards another electron, then due to same negative charges repulsive force is produced between them. So, to bring them closer a work is done against this repulsive force. This work is stored in the form of electrostatic potential energy. Thus, electrostatic potential energy of system increases.

Alternative

Electrostatic potential energy of system of two electrons

$U=\frac{1}{4\pi\varepsilon_0}\frac{(-e)(-e')}{r}$

$=\frac{1}{4\pi\varepsilon_0}\frac{e^2}{r}$

Thus, as r decreases, potential energy U increases.

31. When air is replaced by a dielectric medium of constant K, the maximum force of attraction between two charges, separated by a distance.

a) decreases K times b) increases K times c) remains unchanged d) becomes $\frac{1}{K^2}$ times

Solution : -

According to Coulomb's law, force between two charges is directly proportional to product of charges and inversely proportional to square of distance between them. Thus

$F=\frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$ ....(i)

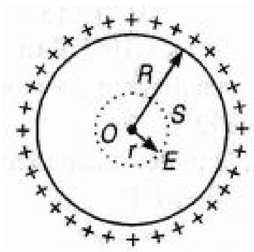
where $\frac{1}{4\pi\varepsilon_0}$ = proportionality constant.

If a dielectric medium of constant K is placed between them, then new force between them,

$F_1 = \frac{1}{4\pi\varepsilon_0 K} \cdot \frac{q_1 q_2}{r^2}$
Dividing Eq. (ii) by Eq. (i), we have
$\frac{F_1}{F} = \frac{1}{K}$
or $F' = \frac{F}{K}$
Thus, new force decrease K times.

32. A hollow insulated conducting sphere is given a positive charge of l0 mC. What will be the electric field at the centre of the sphere if its radius is 2 m?
a) zero b) 5 mCm^{-2} c) 20 mCm^{-2} d) 8 mCm^{-2}

Solution : -
Charge resides on the outer surface of a conducting hollow or solid sphere of radius R (say). We consider a spherical surface of radius r < R.



By Gauss' theorem
$\sum \mathbf{E} \cdot \mathbf{ds} = \frac{q_{\text{inside}}}{\varepsilon_0}$
or $E \times 4\text{p}r^2 = \frac{1}{\varepsilon_0} \times q_{\text{inside}}$
and know that inside = 0
So, E = 0
i.e., electric field inside a hollow sphere is zero.

33. A particle of mass m and charge q is placed at rest in a uniform electric field E and then released. The kinetic energy attained by the particle after moving a distance y is _______.
a) qEy^2 b) qE^2y **c) qEy** d) q^2Ey

Solution : -
Electric force on charged particle is given by
F = qE
Kinetic energy attained by particle
= work done
= force x displacement
= qE x y
Alternative
Force on charged particle in a uniform electric field is
F=ma=Eq
or $a = \frac{Eq}{m}$ ....(i)
From the equation of motion, we have
$y^2 = u^2 + 2ay$
$= 0 + 2 \times \frac{Eq}{m} \times y$ [u=0]
$= \frac{2Eqy}{m}$
Now, kinetic energy of the particle
$K = \frac{1}{2}mv^2$
$= \frac{m}{2} \times \frac{2Eqy}{m}$ = qEy

34. A point Q lies on the perpendicular bisector of an electric dipole of dipole moment p. If the distance of Q from the dipole is r, (much larger than the size of the dipole) then electric field at Q is proportional to _______.

a) p^{-1} and r^2 b) p and r^{-2} c) p^2 and r^{-3} **d) p and r^{-3}**

Solution : -

Electric field due to a dipole at bisector or at a point on its broadside on position or equatorial position is given by

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

or $E\propto\frac{p}{r^3}$ ....(i)

where r is the distance of that point from centre of dipole and p is dipole moment.

So, from Eq. (i)

$E\mu p \text{ and } E\mu r^{-3}$

35. The formation of a dipole is due to two equal and dissimilar point charges placed at a ___________.

a) short distance b) long distance c) above each other d) None of these

Solution : -

An electric dipole consists of a pair of equal and opposite point charges separated by a very small distance. Atoms or molecules of ammonia, water, alcohol, carbon dioxide, HCl etc., are some of the examples of electric dipoles, because in these cases, the centers of positive and negative charge distributions are separated by some small distance.

36. Intensity of an electric field (E) depends on distance r due to a dipole, is related as _____.

a) $E\propto\frac{1}{r}$ b) $E\propto\frac{1}{r^2}$ **c)** $E\propto\frac{1}{r^3}$ d) $E\propto\frac{1}{r^4}$

Solution : -

Field intensity on axial line of electric dipole is given by

$E=\frac{1}{4\pi\varepsilon_0}\cdot\frac{2p}{r^3}$ ....(i)

and electric field at equatorial position is given by

$E=\frac{1}{4\pi\varepsilon_0}\times\frac{p}{r^3}$ ....(ii)

where p is electric dipole moment. From Eqs. (i) and (ii), we get

$E\propto\frac{1}{r^3}$

37. A point charge + q is placed at mid-point of a cube of side L. The electric flux emerging from the cube is ________.

a) $\frac{q}{\varepsilon_0}$ b) $\frac{6qL^2}{\varepsilon_0}$ c) $\frac{q}{6qL^2}$ d) zero

Solution : -

By Gauss's theorem, total electric flux over the closed surface is $\frac{1}{\varepsilon_0}$ times the total charges contained inside surface

$\therefore$ Total electric flux = $\frac{totalchargeinsidecube}{e_0}$

or $\mathrm{f}=\frac{q}{\varepsilon_0}$

38. There is an electric field E in x-direction. If the work done on moving a charge of 0.2C through a distance of 2m along a line making an angle 60^o with x-axis is 4J, then what is the value of E?

a) 3 N/C b) 4 N/C c) 5 N/C **d) 20 N/C**

Solution : -

Work done in moving the charge, W= Fd cosθ

As F = qE

$\therefore$ W = qEd cosθ

or $E=\frac{W}{qd\cos\theta}$

Here θ= 0.2, C, d= 2m

θ = 60°, W = 4 J

$\therefore E = \frac{4}{0.2 \times 2 \times \cos 60^{\circ}}$ = 20 N/C

Alternative

As we know that potential at any point in the direction of q and electric field E is given by dV = - E . dr (negative sign indicates decreasing potential in direction of electric field) So, for the given situation

dr= d cos θ

So, dV = Ed cosθ

Now work done for a charge moving in potential difference dV is givenby W = qdV

$\Rightarrow$ W = qEdcos θ

Given, q = 0.2C,d = 2m,θ = 60°, W = 4J

So, 4J = 0.2 x E x 2 x cos60°

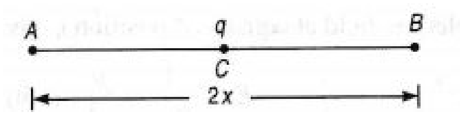
$\Rightarrow \quad E = \frac{4}{0.2 \times 2} \times 2 = 20 \text{ J}$

39. A charge 4 is placed at the centre of the line joining two exactly equal positive charges Q. The system of three charges will be in equilibrium if q is equal to ________.

a) $-\frac{Q}{4}$ b) +Q c) -Q d) $\frac{Q}{2}$

Solution : -

Let two equal charges Q each be held at A and B, where AB = 2x. C is the centre of AB, where charge q is held. Net force on q is zero. So, q is already in equilibrium.



For the three charges to be in equilibrium, net force on each charge must be zero. Now total force on Q at B is

$$\frac{1}{4\pi\varepsilon_0} \cdot \frac{Qq}{x^2} + \frac{1}{4\pi\varepsilon_0} \cdot \frac{QQ}{(2x)^2} = 0$$

$$\text{or} \quad \frac{1}{4\pi\varepsilon_0} \cdot \frac{Qq}{x^2} = -\frac{1}{4\pi\varepsilon_0} \cdot \frac{Q^2}{4x^2}$$

$$\text{or} \quad q = -\frac{Q}{4}$$

40. If the potential of a capacitor having capacity 6 mF is increased from 10 V to 20 V then increase in its energy will be __________.

a) 4 x 10^{-4}J b) 4 x 10^{-14}J **c) 9 x 10^{-4}J** d) 12 x 10^{-6} J

Solution : -

Energy stored in a charged capacitor is in the form of electric field energy and it resides in the dielectric medium between the plates. This energy stored in the capacitor is given by

$$U = \frac{1}{2}CV^2$$

If initial potential is V_1 and final potential is V_2 then increase in energy (DL)

$$\text{D}U = \frac{1}{2}C\left(V_2^2 - V_1^2\right)$$

$$= \frac{1}{2} \times \left(6 \times 10^{-6}\right) \times \left[(20)^2 - (10)^2\right]$$

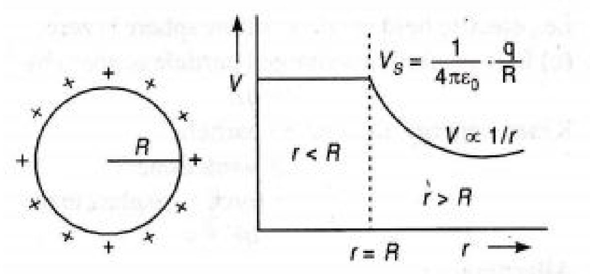
= (3 x 10^{-6}) x 300 = 9 x 10^{-4} J

41. A hollow metal sphere of radius 10 cm is charged such that the potential on its surface is 80 V. The potential at the centre of the sphere is _______.

a) zero **b) 80 V** c) 800 V d) 8 V

Solution : -

In case of spherical metal conductor hollow or solid for an interpoint (i.e., r < R) potential everywhere inside is same. It is maximum at the surface of sphere and further going out of sphere its value decreases.



So, according to above graph

$$V_{\text{in}} = V_{\text{centre}} = V_{\text{surface}}$$
$$= \frac{1}{4\pi\varepsilon_0} \times \frac{q}{r} = 80\ \text{V}$$

42. The electric field strength in air at NTP is 3 x 106 V/m. The maximum charge that can be given to a spherical conductor of radius 3 m is __________.

a) 3 x 10^4C **b) 3 x 10^{-3}C** c) 3 x 10^{-2}C d) 3 x 10^{-1}C

Solution : -

Given, E_{max} = 3 x 10^6 V/m and R = 3 m We know that,

$$E = \frac{1}{4\pi\varepsilon_0} \times \frac{Q}{R^2}$$
$$\Rightarrow \quad Q_{\max} = 4\text{pe}_0 R^2 E_{\max}$$
$$= \frac{3\times3\times3\times10^6}{9\times10^9} = 3 \times 10^{-3}\text{C}$$

43. Two spherical conductors I and B of radii 1 mm and 2 mm are separated by a distance of 5 cm and are uniformly charged. If the spheres are connected by a conducting wire then in equilibrium condition, the ratio of the magnitude of the electric fields at the surfaces of spheres A and B is _______.

a) 4:1 b) 1:2 c) 2:1 d) 1:4

Solution : -

Concept. The electric field at any point, outside or inside, the conducting sphere can depend only on r (the radial distance from the centre of the sphere to the point). When the two conducting spheres are connected by a conducting wire, charge will flow from one sphere (having higher potential) to other (having lower potential) till both acquire the same potential.

As $E = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{r^2}$

So, for different cases, $\frac{E_1}{E_2} = \left(\frac{r_2}{r_1}\right)^2 = 4 : 1$

44. Two concentric spheres of radii R and r have similar charges with equal surface charge densities (s). What is the electric potential at their common centre?

a) $\frac{\sigma}{\varepsilon_0}$ b) $\frac{\sigma}{\varepsilon_0}(R - r)$ **c)** $\frac{\sigma}{\varepsilon_0}(R + r)$ d) None of these

Solution : -

Let Q and q be the charges on the spheres. The potential at the common centre will be

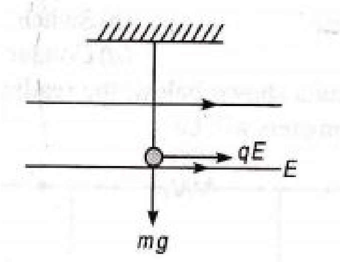
$$V = \frac{1}{4\pi\varepsilon_0}\left(\frac{Q}{R}\right) + \frac{4}{4\pi\varepsilon_0}\left(\frac{q}{r}\right)$$
$$= \frac{1}{\varepsilon_0}\left[\frac{Q}{4\pi R^2} \times R + \frac{q}{4\pi r^2} \times r\right]$$
$$\text{But,} \quad \frac{Q}{4\pi R^2} = \frac{q}{4\pi r^2} = \text{s}$$
$$\therefore \quad V = \frac{1}{\varepsilon_0}[\sigma R + \sigma r] = \frac{\sigma}{\varepsilon_0}(R + r)$$

45. A pendulum bob of mass 30.7 x 10^{-6} kg and carrying a charge 2 x 10^{-8} C is at rest in a horizontal uniform electric field of 20000 V/m. The tension in the thread of the pendulum is (g = 9.8 m/s^2)

a) 3×10^{4}N   b) 4×10^{-4}N   **c) 5×10^{-4} N**   d) 6×10^{-4}N

Solution : -

There are 2 forces acting on pendulum (i) its weight



(i) Weight

mg = $30.7 \times 10^{-6} \times 9.8$

= 3 x l0^{-4} N vertically downward, and

(ii) Force F = qE

= $2 \times 10^{-8} \times 2000$

= 4×10^{-4} N

In the horizontal direction.

So, net tension, $T = \sqrt{(mg)^2 + F^2}$

$= \sqrt{\left(3 \times 10^{-4}\right)^2 + \left(4 \times 10^{-4}\right)^2}$

= 5×10^{-4}N