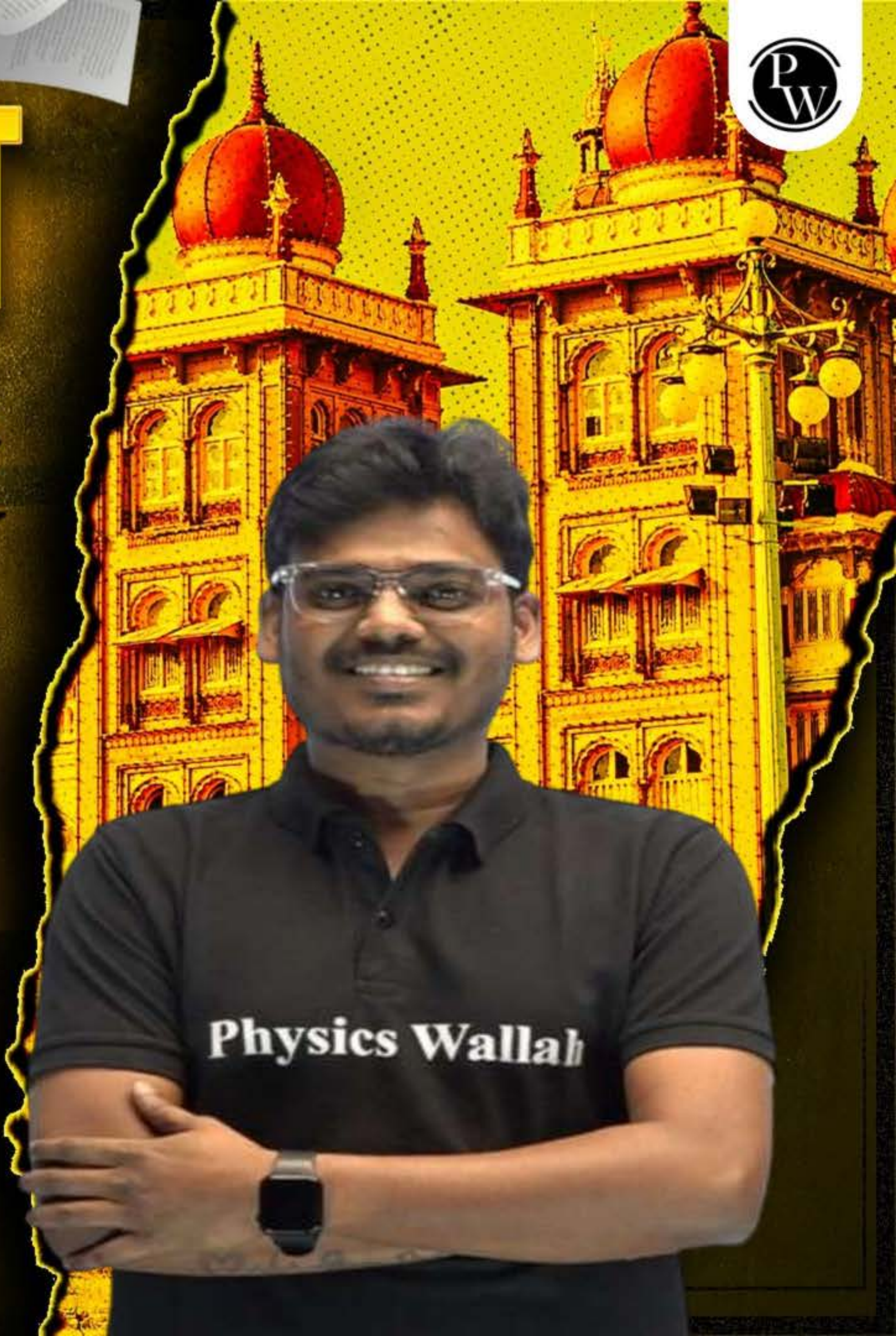
ULTIMATE KCET

CRASH COURSE 2026

PHYSICS | Lecture - 01

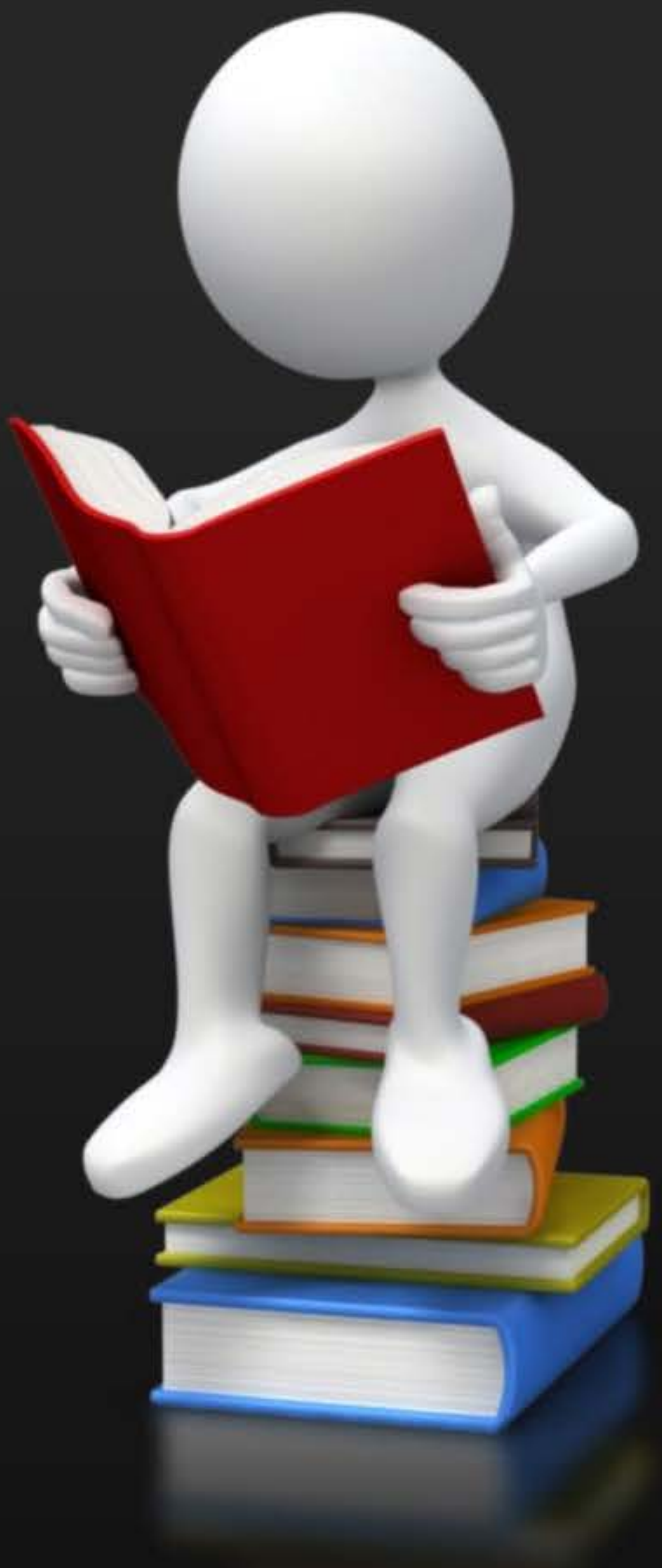
ELECTROSTATIC POTENTIAL AND CAPACITANCE

By – AK SIR



Topics *to be covered*

1. ELECTRIC POTENTIAL AND POTENTIAL DIFFERENCE
2. ELECTRIC POTENTIAL DUE TO A POINT CHARGE
3. ELECTRIC POTENTIAL DUE TO A SYSTEM OF CHARGES CHARGES
4. ELECTRIC POTENTIAL DUE TO A ELECTRIC DIPOLE



Applications of Gauss Law

4. Electric field due to a uniformly charged thin spherical shell OR conducting sphere OR Hollow sphere.

(i) $r > R$: External point

$$E = \frac{Kq}{r^2}, \quad E \propto \frac{1}{r^2}$$

(ii) $r = R$: Surface point

$$E = \frac{Kq}{R^2}$$

(iii) $r < R$: Internal point

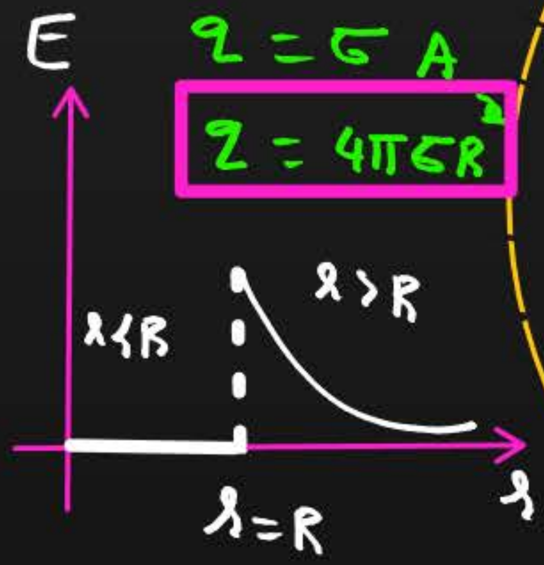
$$E = 0 \qquad q = 0$$

$$\sigma = \frac{q}{A}$$

$$A = 4\pi R^2$$

$$q = \sigma A$$

$$q = 4\pi\sigma R^2$$



Applications of Gauss Law

5.Electric field due to Non-conducting sphere.

$\sigma = \frac{q}{A}, A = 4\pi R^2$

$q = 4\pi\sigma R^2$

(i) $r > R$, External point

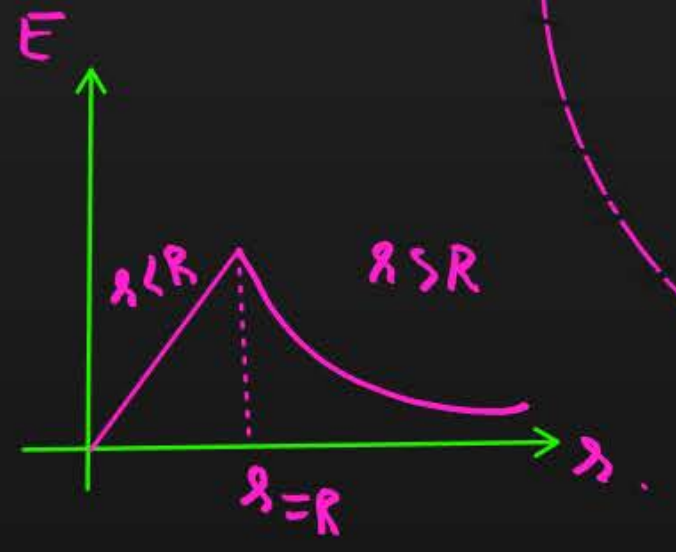
$$E = \frac{Kq}{r^2}, \quad E \propto \frac{1}{r^2}$$

(ii) $r = R$, surface point

$$E = \frac{Kq}{R^2}$$

(iii) $r < R$, Internal point

$$E = \frac{Kqr}{R^3}, \quad E \propto r$$



Question

Electric field due to infinite, straight uniformly charged wire varies with distance ‘r’ as

(A) r

(B) $\frac{1}{r}$

(C) $\frac{1}{r^2}$

(D) r^2

$E = \frac{2K\lambda}{r}$

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

Question

An infinitely long thin straight wire has uniform charge density of $\frac{1}{4} \times 10^{-2}$ C/m. What is the magnitude of an electric field at a distance 20 cm from the axis of the wire

(A) $1.12 \times 10^{8}\ NC^{-1}$

(B) $4.5 \times 108\ NC^{-1}$

(C) $2.25 \times 10^{8}\ NC^{-1}$

(D) $9 \times 10^{8}\ NC^{-1}$

$E = \frac{2K\lambda}{r}$

$E = \frac{2 \times 9 \times 10^{9} \times \frac{1}{4} \times 10^{-2}}{20 \times 10^{-2}}$

$E = 0.225 \times 10^{9}$

$E = 2.25 \times 10^{8}$ N/C

Question

Two parallel infinite line charges with linear charge densities +λ. and –λ are placed at a distance of $2r$ in free space. What is the electricity field intensity mid-way between the two-line charges

A. $\vec{E} = \frac{2\sqrt{2}k\lambda}{r}\hat{\imath}$

B. $\vec{E} = \frac{\sqrt{2}k\lambda}{r}\hat{\imath}$

C. $\vec{E} = \frac{4k\lambda}{r}\hat{\imath}$

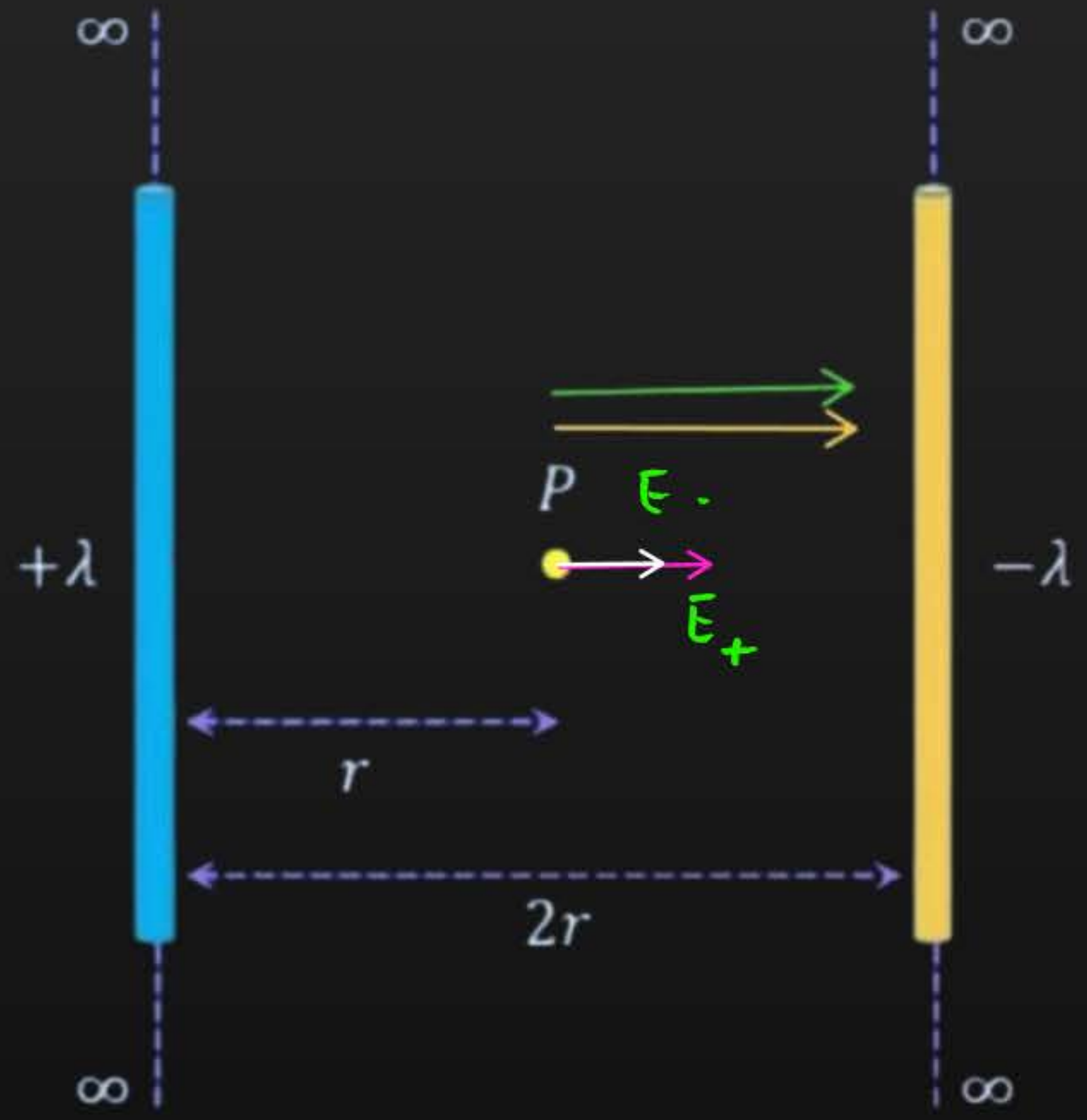
D. 0

$\vec{E}_+ = \frac{2k\lambda}{r}\hat{i}$

$\vec{E}_- = \frac{2k\lambda}{r}\hat{i}$

$\vec{E} = \vec{E}_+ + \vec{E}_-$

$\vec{E} = \frac{4k\lambda}{r}\hat{i}$



Question

Find the force exerted by a positively charged infinitely long, thin rod having linear charge density λ on charge +q in its vicinity.

(A) $\vec{F} = \frac{2\sqrt{2}k\lambda q}{r}\hat{i}$

(B) $\vec{F} = \frac{\sqrt{2}k\lambda q}{r}\hat{i}$

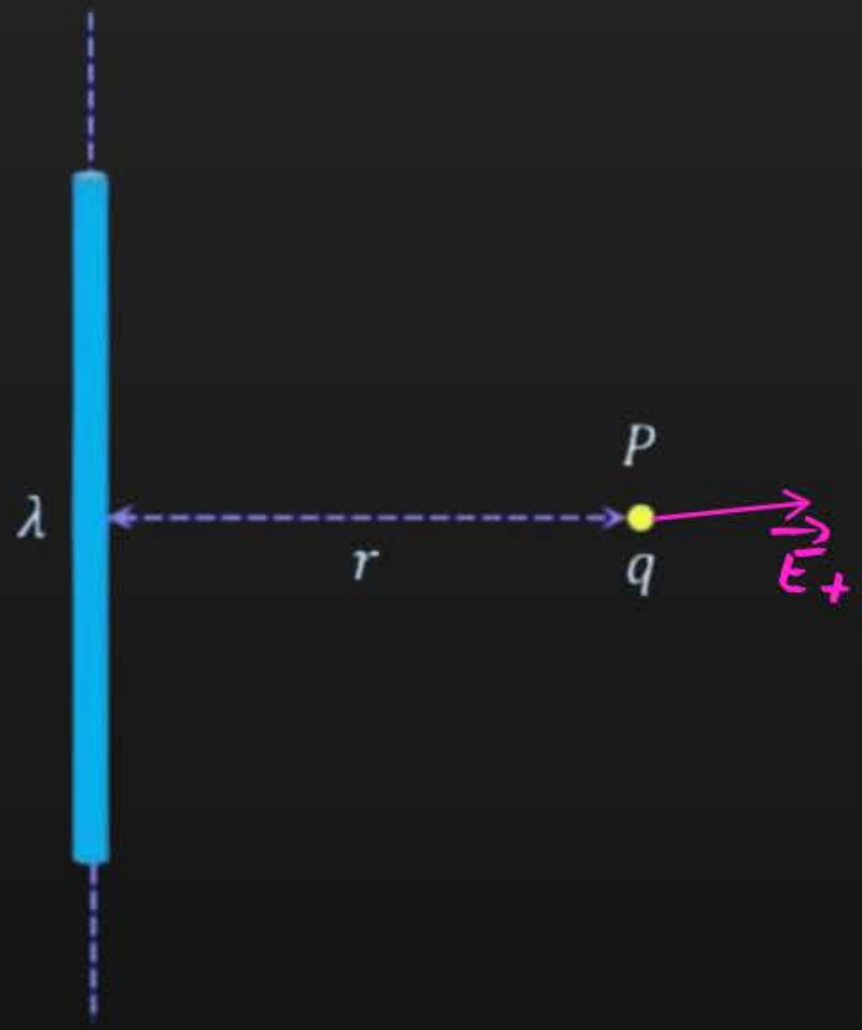
(C) $\vec{F} = \frac{2k\lambda q}{r}\hat{i}$

(D) None of these

$\vec{E}_+ = \frac{2k\lambda}{r}\hat{i}$

$\vec{F} = q\vec{E} = q\vec{E}_+$

$\vec{F} = \frac{2k\lambda q}{r}\hat{i}$



Question

A uniformly charged spherical shell of radius 10 cm has surface charge density of $16\,\mu C - m^{-2}$. Find the electric field due to shell at a distance of 20 cm from the centre of the shell.

$r = 20\,cm$

$R = 10\,cm$

$r > R$

$E = \frac{Kq}{r^2}$

$\sigma = \frac{q}{A}$

$q = \sigma \times A = \sigma \times 4\pi R^2$

$q = 16\times10^{-6} \times 4\pi \times (10\times10^{-2})^2$

$q = 200.96\times10^{-6}\times10^{-2}$

$q = 2\times10^{-6}\,C$

$E = \frac{9\times10^{9}\times2\times10^{-6}}{(20\times10^{-2})^2}$

$E = \frac{18\times10^{3}}{4\times10^{-2}} =$

$E = 4.5\times10^{5}\,N/C$

$q = 16\times10^{-6}\times4\times3\times(10^{-1})^2$

$q = 16\times12\times10^{-6}\times10^{-2}$

$q = 196\times10^{-6}\times10^{-2}$

$q = 1.96\times10^{-6}\,C$

Question

Intensity of electric field at a perpendicular distance of 0.5 m from an infinitely long line charge having linear charge density(λ) $3.6 \times 10^3\ V/m$. Find the value of λ.

E

$$E = \frac{2K\lambda}{r}$$

$$3.6 \times 10^3 = \frac{2 \times 9 \times 10^9 \times \lambda}{0.5}$$

$$\lambda = \frac{3.6 \times 10^3 \times 0.5}{2 \times 9 \times 10^9} = 0.1 \times 10^{-6}$$

$$\boxed{\lambda = 1 \times 10^{-7}\ C/m}$$

Question

A charge of 17.7×10^{-4}C is distributed uniformly over a large sheet of area $200\,m^2$. Calculate the electric field intensity at a distance 20 cm from it in air. Given $\epsilon_0 = 8.85 \times 10^{-12} C^2 N^{-1} m^{-2}$.

$$E = \frac{\sigma}{2\varepsilon_0} = \frac{q}{A \times 2\varepsilon_0}$$

$$E = \frac{17.7 \times 10^{-4}}{200 \times 2 \times 8.85 \times 10^{-12}}$$

$$E = 0.005 \times 10^{8}$$

$$E = 5 \times 10^{5}\ N/C$$

Question

A spherical conductor of radius 2 cm is uniformly charged with 3 nC. What is the electric field at a distance of 3 cm from the centre of the sphere?

(A) $3\times10^{6}\ Vm^{-1}$

(B) $3\ Vm^{-1}$

(C) $3\times10^{4}\ Vm^{-1}$

(D) $3\times10^{-4}\ Vm^{-1}$

$r > R$

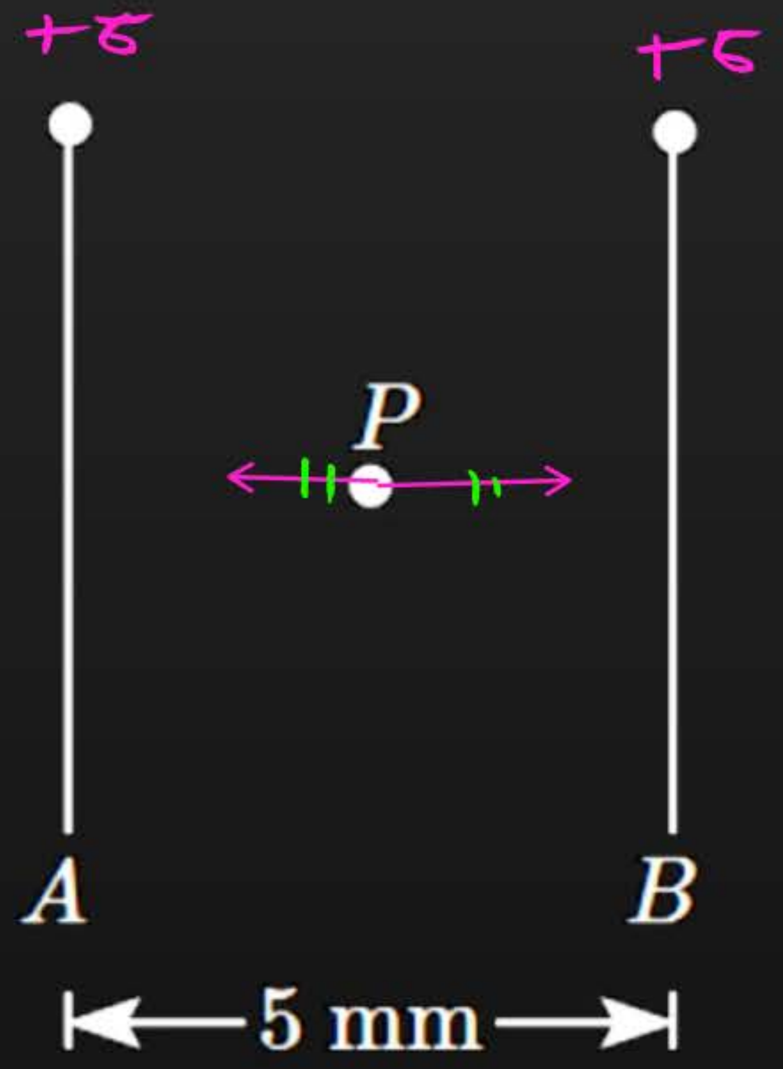
$E = \frac{Kq}{r^2}$

$E = \frac{9\times10^{9}\times3\times10^{-9}}{(3\times10^{-2})^2} = \frac{9\times3}{9\times10^{-4}}$

$E = 3\times10^{4}\ V/m$

Question

Two identical rectangular plane sheet A and B each of surface charge density ε_0 Cm^{-2} are placed parallel to each other as shown in figure. The electric field at the mid point P will be:



(A) $2\ NC^{-1}$

(B) $1\ NC^{-1}$

(C) $0.5\ NC^{-1}$

(D) zero

Question

Two parallel infinite line charges with linear charge densities $+\lambda$ C/m and $+\lambda$ C/m are placed at a distance R. The electric field mid-way between the two line charges is:

(A) $\frac{\lambda}{2\pi\varepsilon_0 R}$ N/C

(B) zero

(C) $\frac{2\lambda}{\pi\varepsilon_0 R}$ N/C

(D) $\frac{\lambda}{\pi\varepsilon_0 R}$ N/C

Question

Match List – I with List – II:

List-I (Application of Gauss Law)	List-II (Value of $\lvert E \rvert$
A. The field inside a thin shell	I. $\frac{\lambda}{2\pi\varepsilon_0 r}\hat{n}$
B. The field outside a thin shell	II. $\frac{q}{4\pi\varepsilon_0 R^2}\hat{r}$
C. The field of thin shell at the surface	III. $\frac{q}{4\pi\varepsilon_0 r^2}\hat{r}$
D. The field due to a long charged wire	IV. Zero

(Here symbols have their usual meaning and Ris the radius of the thin shell)
Choose the correct answer from the options given below:

(A) A-IV, B-III, C-I, D-II

(B) A-I, B-II, C-III, D-IV

(C) A-IV, B-III, C-II, D-I

(D) A-I, B-III, C-II, D-IV

Question

A spherical conductor of radius 10 cm has a charge of 3.2×10^{-7} C distributed uniformly. What is the magnitude of the electric field at a point 15 cm from the centre of the sphere? $\left(\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9\, N - m^2/C^2\right)$ [Home work]

(A) 1.28×10^5 N/C

(B) 1.28×10^6 N/C

(C) 1.28×10^7 N/C

(D) 1.28×10^4 N/C

Question

$r > R,\ E = \frac{kQ}{r^2}$ $r\uparrow\ E\downarrow$

$r < R,\ E = 0$

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) Decreases as r increases for $r < R$ and for $r > R$

(B) Increases as r increases for $r < R$ and for $r > R$

(C) Is zero as r increases for $r < R$, decreases as r increases for $r > R$ ✓

(D) Is zero as r increases for $r < R$, increases as r increases for $r > R$

Question

$r = 1.5R,\ r > R \Rightarrow E = \frac{kq}{r^2}$

The electric field at a distance $\frac{3R}{2}$ from the centre of a charged conducting spherical shell of radius R is E. The electric field at a distance $\frac{R}{2}$ from the centre of the sphere is

$r < R,\ E = 0$

(A) Zero

(B) E

(C) $\frac{E}{2}$

(D) $\frac{E}{3}$

Question

(A) $E = \frac{Kq}{r^2} = \frac{1}{4\pi\epsilon_0} \times \frac{\sigma A}{r^2} = \frac{1}{4\pi\epsilon_0} \times \frac{\sigma \times 4\pi R^2}{r^2} = \frac{\sigma}{\epsilon_0}\left(\frac{R}{r}\right)^2$

Match List - I with List - II.

List - I	List – II
Electric field inside (distance r > 0 from center)	
(A) A uniformly charged spherical shell with surface charge density σ, and radius R. Electric field at distance r > R.	(I) $\frac{\sigma}{\epsilon_0}$
(B) charged infinite plane sheet with surface charge density σ. Electric field outside (distance r > 0 from center) $E = \frac{\sigma}{2\epsilon_0}$	(II) $\frac{\sigma}{2\epsilon_0}$
(C) A uniformly charged spherical shell with surface charge density σ, and radius R. Electric field inside the shell.	(III) 0
(D) infinite plane parallel sheets with uniform surface charge density . Electric field between 2 oppositely charged sheets. $E = E_+ + E_- = 2E$	(IV) $\frac{\sigma R^2}{\epsilon_0 r^2}$

A → IV

B → II

C → III

D → I

$E = 2\frac{\sigma}{2\epsilon_0} = \frac{\sigma}{\epsilon_0}$

Question

A (A)-(III), (B)-(II), (C)-(IV), (D)-(I)

B (A)-(IV), (B)-(II), (C)-(III), (D)-(I)

C (A)-(II), (B)-(I), (C)-(IV), (D)-(III)

D (A)-(IV), (B)-(I), (C)-(III), (D)-(II)

Question

A metal cube of side 5 cm is charged with $6\mu C$. The surface charge density on the cube is

(A) $0.125 \times 10^{-3} \text{Cm}^{-2}$

(B) $4 \times 10^{-3} \text{Cm}^{-2}$

(C) $0.25 \times 10^{-3} \text{Cm}^{-2}$

(D) $0.4 \times 10^{-3} \text{Cm}^{-2}$

$$\sigma = \frac{q}{A} = \frac{q}{6a^2}$$

$$\sigma = \frac{6 \times 10^{-6}}{6 \times (5 \times 10^{-2})^2}$$

$$\sigma = \frac{10^{-6}}{25 \times 10^{-4}} = 0.04 \times 10^{-2}$$

$$\sigma = 0.4 \times 10^{-3} \text{ C/m}$$

Circle → $A = \pi r^2$

Rectangle → $A = l \times b$

Sphere → $A = 4\pi r^2$

Cube → $A = 6a^2$

Cylinder → $A = 2\pi r l$

$2\pi r^2$

Question

R q

A hollow sphere of radius 1 m is given a positive charge of $10\mu C$. The electric field at the centre of hollow sphere will be:

$r < R$, $E = 0$

(A) $60 \times 10^3 Vm^{-1}$

(B) Zero

(C) $90 \times 10^3 Vm^{-1}$

(D) Infinite

Question

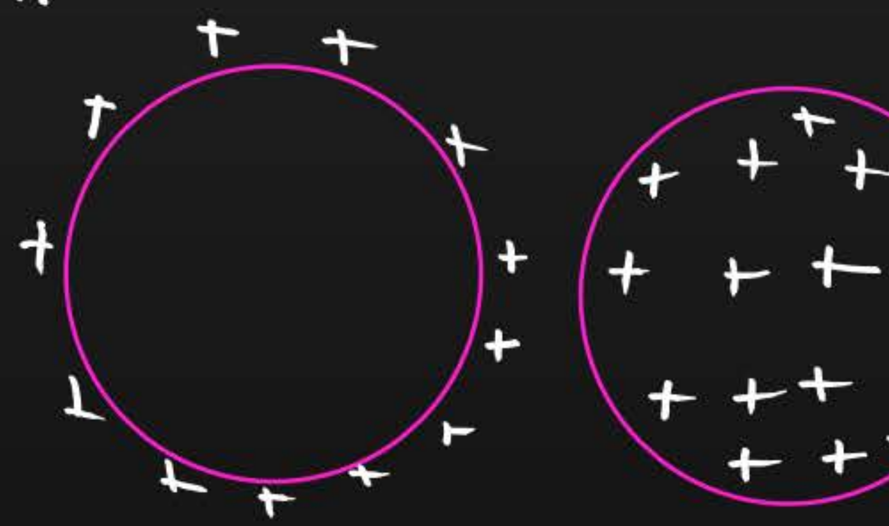
Charges are uniformly spread on the surface of a conducting sphere. The electric field from the center of the sphere in a point outside the sphere varies with distance r from the center as

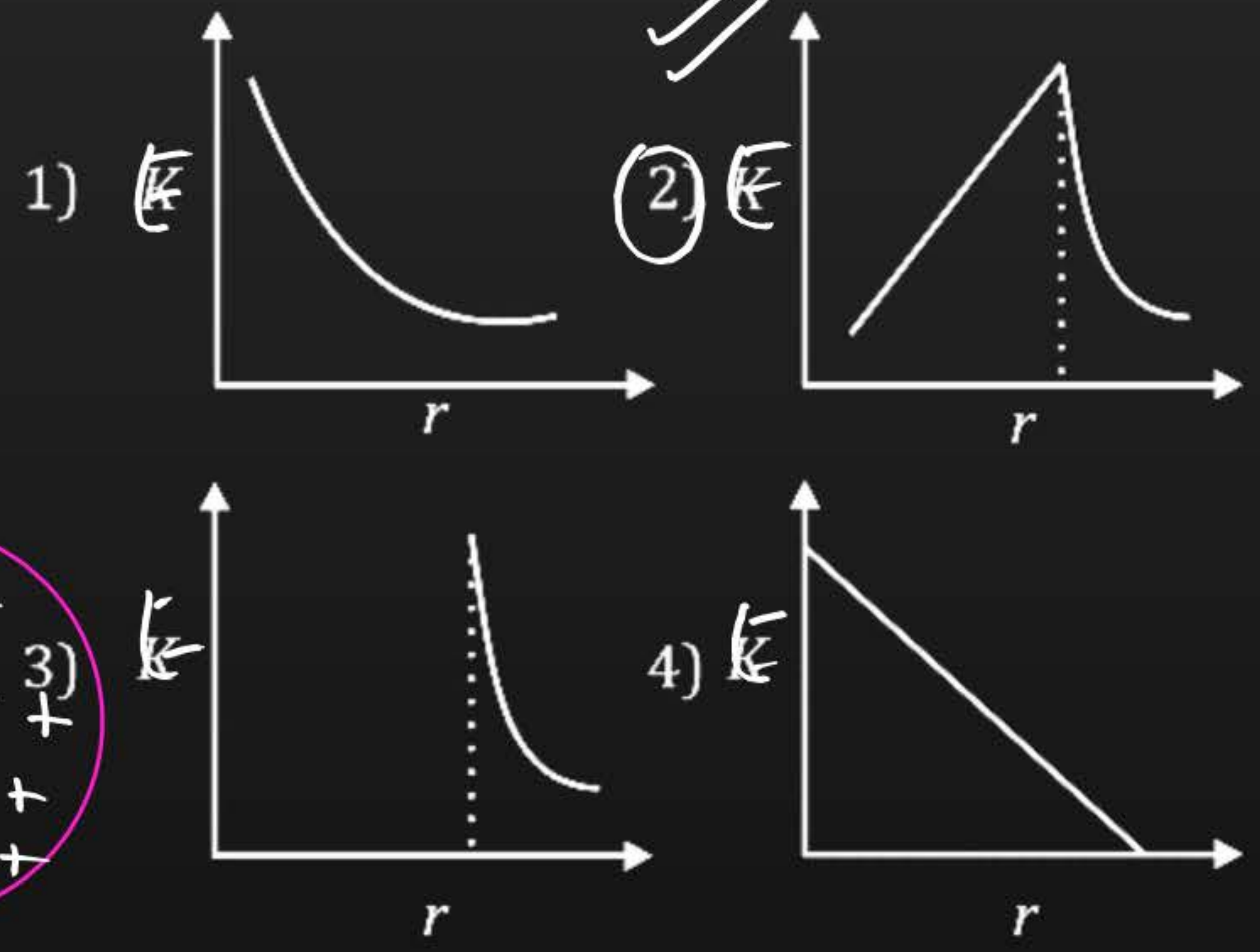
A $E \propto r^2$

B $E \propto 1/r^2$

C $E \propto r$

D $E \propto 1/r$





Question

Which of the following is a correct statement?

$\phi = \int \vec{E} \cdot d\vec{A} = \frac{q}{\varepsilon_0}$

(A) Gauss's law does not hold good for a charge situated outside the Gaussian surface. ✗

(B) Gauss's law is true for any closed surface. ✓

(C) Gauss's law is true for any open surface. ✗

(D) Gauss's law is not applicable when charges are not symmetrically distributed over a closed surface.

KCET analysis of chapter - Marks weightage

2-3Q

Year	Topic
2025 (2Q)	Work done and Equipotential surface
2024(2Q)	Electric susceptibility, Energy stored in a capacitor
2023(3Q)	Parallel plate capacitor, The potential energy and Equivalent capacitance
2022(2Q)	Electric potential due to dipole and Parallel plate capacitor
2021(5Q)	Spherical capacitance, Parallel plate capacitor, Polar and non-polar molecules, Equivalent capacitance and Energy stored in capacitor
2020(3Q)	Equivalent capacitance, Potential gradient and Potential

KCET analysis of chapter - Marks weightage

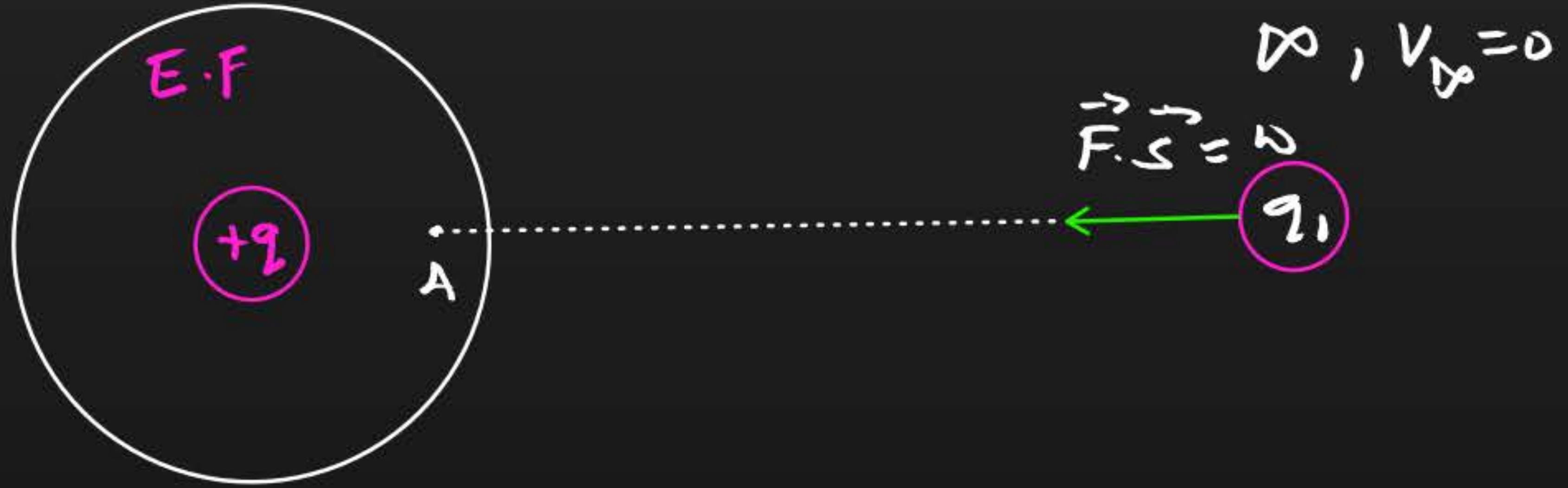
Year	Topic
2019(5Q)	Potential gradient, Equivalent capacitance, Charging & discharging capacitor, Potential gradient and potential energy
2018(4Q)	Potential difference, Equivalent capacitance, Equipotential surface and Equivalent capacitance
2017(2Q)	Energy stored and Equivalent capacitance
2016(4Q)	Equipotential surface, potential energy, charging of capacitor and parallel plate capacitors
2015(2Q)	Parallel plate capacitor and Potential due to spherical shell

Electric potential

Electric potential at a point in electric field is defined as amount of work done by external agent in bringing a unit test positive charge from infinity to that point against the electric field.

$$V = \frac{W}{q_0} = \frac{J}{C}$$

$$\Rightarrow 1V = 1JC^{-1}$$



- ✓ It is scalar quantity
- ✓ Potential can be positive, negative and even zero. Hence charges must be taken with sign.
- ✓ Electric potential always decreases in the direction of electric field

Electric potential

$$E = \frac{Kp}{r^3}\sqrt{3\cos^2\theta + 1}$$

Workdone

$$V = \frac{W_{ext}}{q_0}$$

$$V = \frac{-W_{EF}}{q_0}$$

$$\Delta V = \frac{W_{ext}}{q_0} \Rightarrow W = q_0 \Delta V$$

$$\Delta V = \frac{-W_{E.F}}{q_0} \qquad W = q_0[V_f - V_i]$$

Point charges

$$V = \pm \frac{KQ}{r}$$ Isolated charge

multiple charges

$$V = V_1 + V_2 + V_3 + \cdots$$

Electric Dipole

$$V = \pm \frac{Kp\cos\theta}{r^2}$$

If $\theta = 0^\circ$, Axial point

$V = +\frac{Kp}{r^2}$, $\theta = 180^\circ$, $V = -\frac{Kp}{r^2}$

If $\theta = 90^\circ$, Equitorial point

$$V = 0$$

Question

A point charge of 20 μC is brought from infinity to a point in an electric field. If -40 μ J of work had to be done against the field then find potential at that point.

$$V_P = \frac{W_{ext}}{q} = \frac{-40\times10^{-6}}{20\times10^{-6}}$$

$$\boxed{V_P = -2V}$$

Question

The amount of work done in bringing a point charge of 3 mC from infinity to a point P is 0.06 J. Find the electric potential at the point P.

$$V_P = \frac{W_{ext}}{q}$$

$$V_P = \frac{0.06}{3 \times 10^{-3}} = \frac{6 \times 10^{-2}}{3 \times 10^{-3}}$$

$$\boxed{V_P = 20V}$$

Question

$\Rightarrow He_2^4 \Rightarrow q_\alpha = 2e = 2 \times 1.6 \times 10^{-19} C$

What work must be done in carrying an α-particle across a potential difference of 1 volt? [Given charge on electron 1.6×10^{-19} C]

2eV

$W_{ext} = q_\alpha \Delta V$

$= 2 \times 1.6 \times 10^{-19} \times 1$

$W_{ext} = 3.2 \times 10^{-19} J$

$W_{ext} = 2 eV$

Question

If 100 J of work must be done to move an electric charge of magnitude of 4C from a place A, where potential is -10 V to another place B where potential is V volt. Find the value of V.

$V_i = V_A$

$V_f = V_B$

$\Delta V = \frac{Work}{q} = \frac{100}{4} = 25$

$\Delta V = 25$

$V_f - V_i = 25$

$V_B - (-10) = 25$

$V_B + 10 = 25$

$V_B = 25 - 10 = 15V$

$A \to B \quad V_A \to V_B$

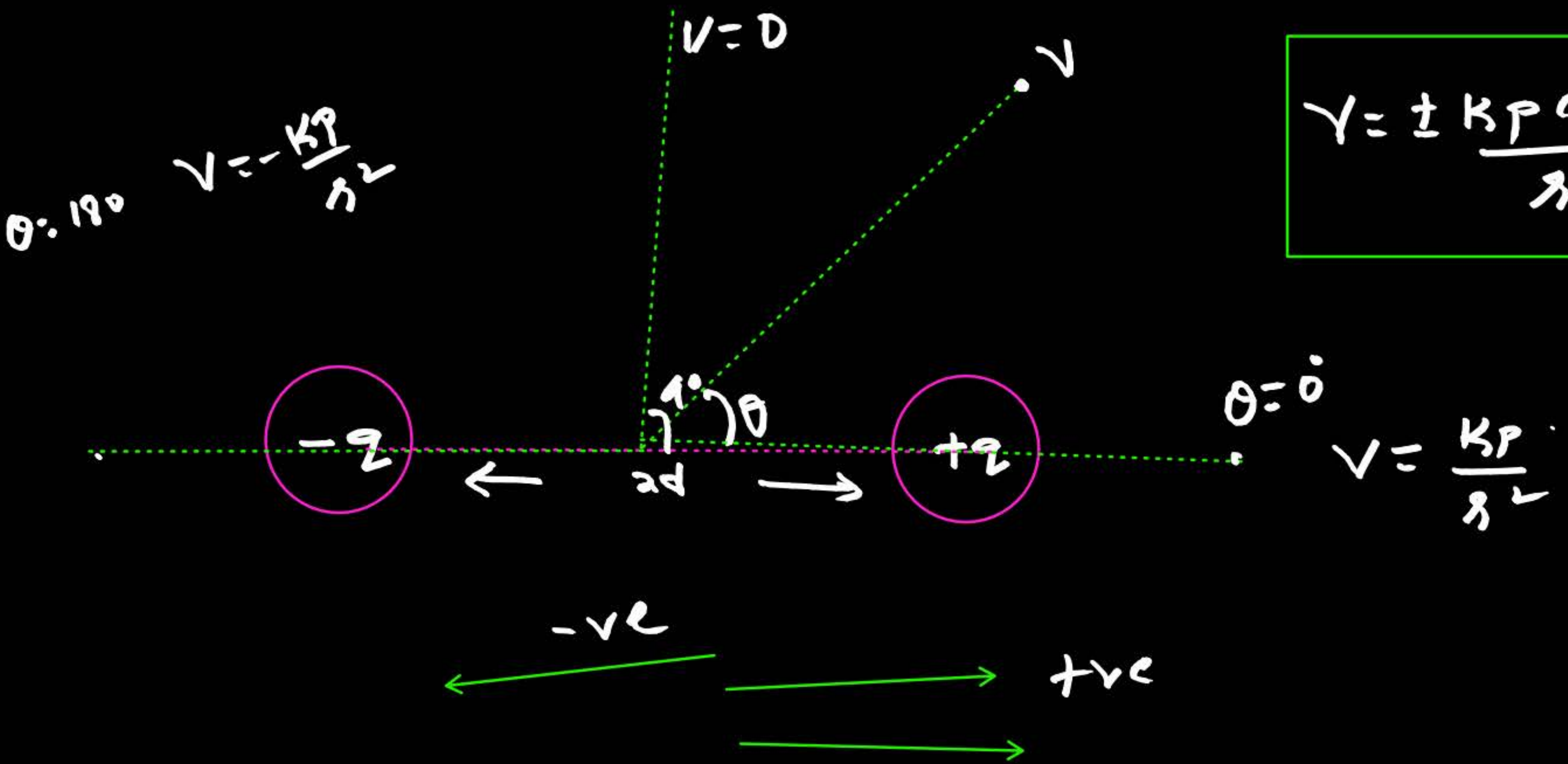
$\Delta V = V_B - V_A$

$\Delta V = \frac{W}{q} = \frac{100}{4} = 25$

$V_B - V_A = 25$

$V - (-10) = 25$

$V = 15V$



$$V = \pm \frac{Kp\cos\theta}{r^2}$$

Question

When a point charge of 20 μ C is brought from infinity to a point in an electric field, -20 μ J of work is done by the electric field. Then what amount of work would have to be done by the external agent, if a 40 μ C charge brought from infinity to the same point ?

$W_{E.F}$

$$V_P = -\frac{W_{E.F}}{q} = -\frac{(-20 \times 10^{-6})}{20 \times 10^{-6}}$$

$$V_P = 1\,V$$

$$V_P = \frac{W_{ext}}{q}$$

$$1 = \frac{W_{ext}}{40 \times 10^{-6}}$$

$$W_{ext} = 40 \times 10^{-6}\,J = 40\,\mu J$$

Question

$q \quad U=0 \qquad V_P$

A charge particle of 2C is released from a point where electric potential is 10V. Find kinetic energy of the particle when charge particle reaches to infinity.

$$W = \Delta K$$

$$W = K_f - K_i$$

$$qV = K_f - 0$$

$\hookrightarrow U=0$

$$K_f = 2 \times 10 = 20\ J$$

Question

Calculate potential due to a charge 5×10^{-7}C at a point P located 9 cm away. Also find work done in bringing an another charge of 3×10^{-8}C from infinity to the point.

$$V_P = \frac{W}{q}$$

$$V_P = \frac{kq}{r} = \frac{9 \times 10^9 \times 5 \times 10^{-7}}{9 \times 10^{-2}}$$

$$\boxed{V_P = 5 \times 10^4 \text{ V}}$$

$$W = qV_P$$

$$= 3 \times 10^{-8} \times 5 \times 10^4$$

$$= 15 \times 10^{-4}$$

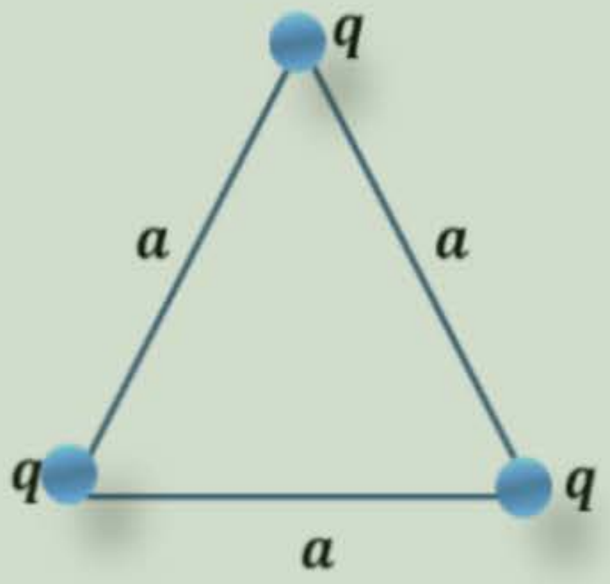
$$\boxed{W = 1.5 \times 10^{-3} \text{ J}}$$

$$\boxed{W = 1.5 \text{ mJ}}$$

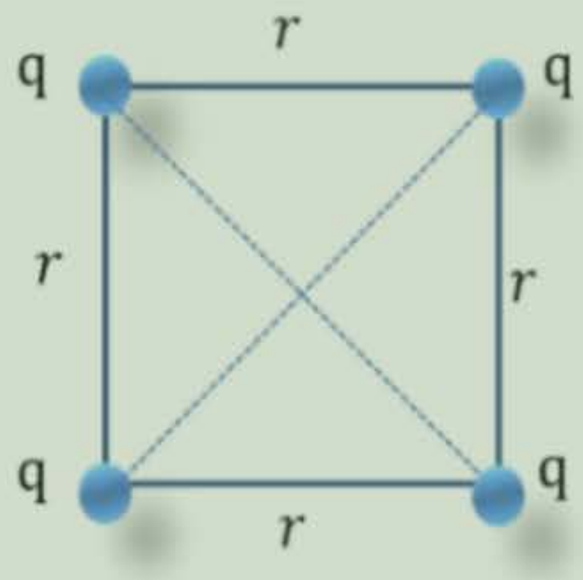
Question

Find potential at the centre of the charge systems shown-

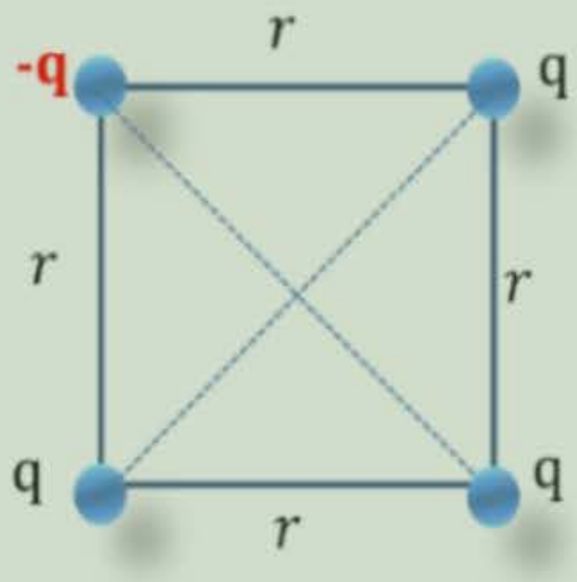
(i)



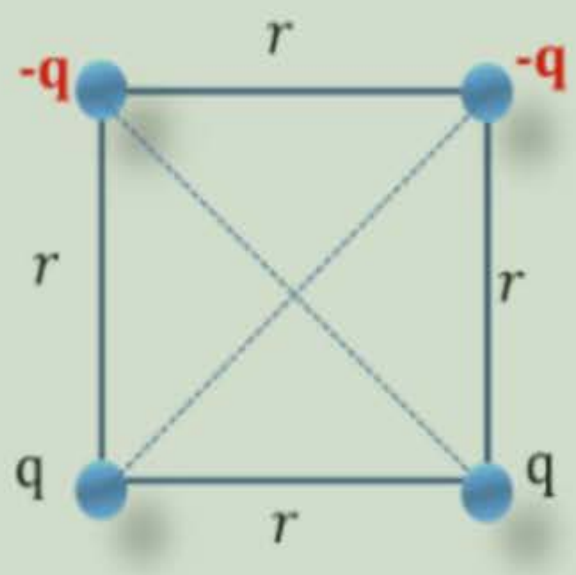
(ii)



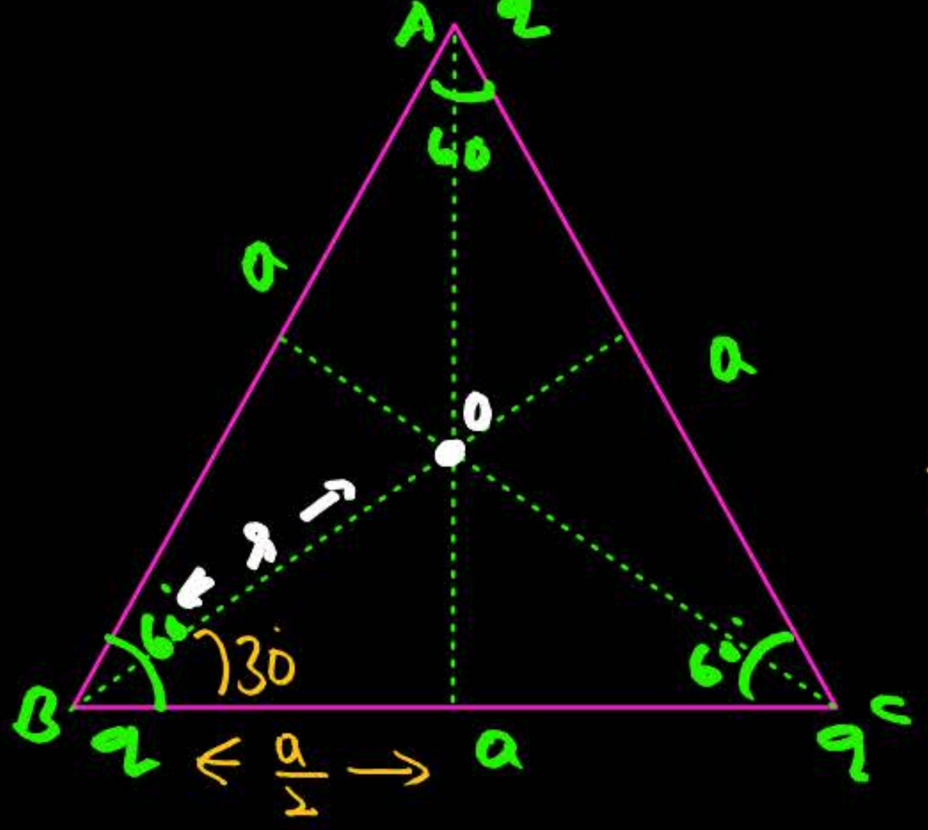
(iii)

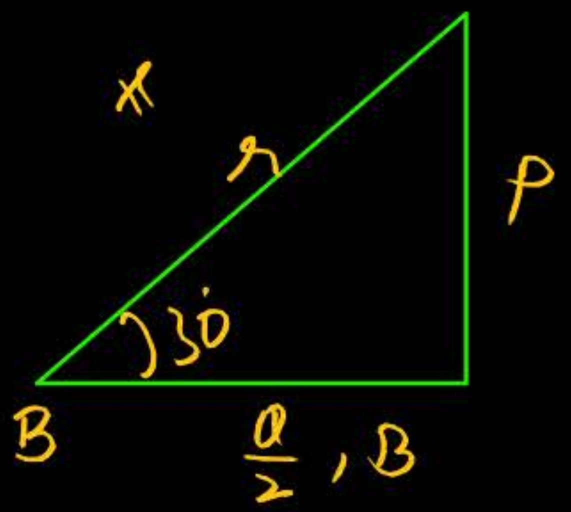


(iv)



(a)





$$V_0 = V_A + V_B + V_C$$

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

$$\cos\theta = \frac{B}{H}$$

$$\cos 30° = \frac{a/2}{r}$$

$$\frac{\sqrt{3}}{2} = \frac{a}{2r}$$

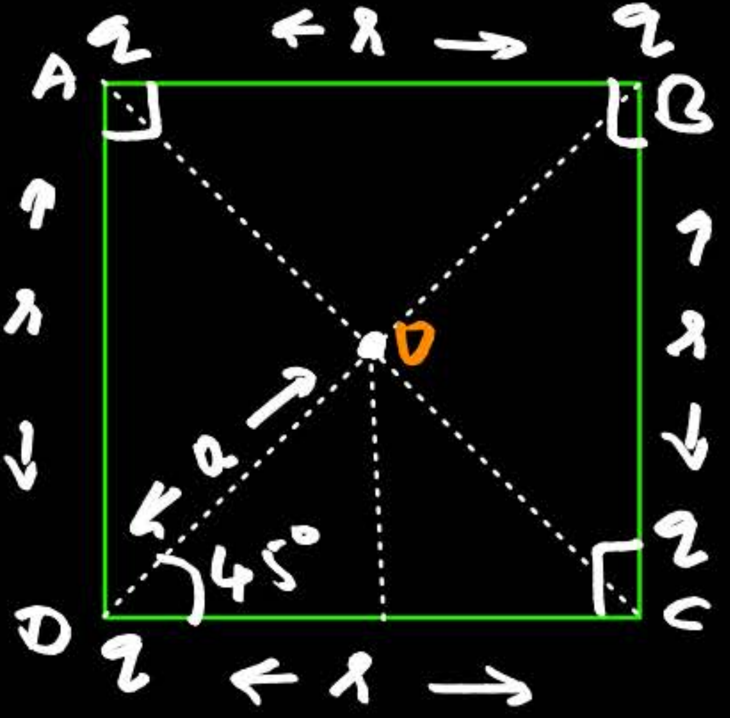
$$r = \frac{a}{\sqrt{3}}$$

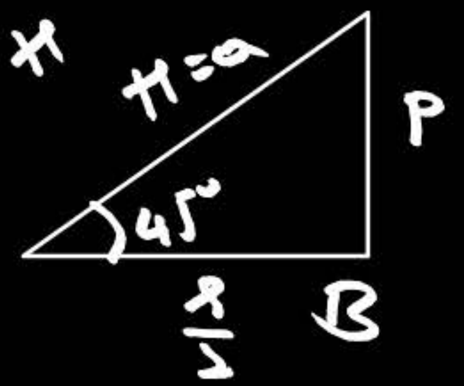
$$V_0 = \frac{Kq_A}{r_a} + \frac{Kq_B}{r_b} + \frac{Kq_C}{r_c}$$

$$V_0 = \frac{Kq}{\frac{a}{\sqrt{3}}} + \frac{Kq}{\frac{a}{\sqrt{3}}} + \frac{Kq}{\frac{a}{\sqrt{3}}}$$

$$V_0 = 3 \times \sqrt{3}\,\frac{Kq}{a}$$

(b)





$a = \frac{\sqrt{2}\, r}{2}$

$a = \sqrt{\frac{2}{4}}\, r$

$a = \frac{r}{\sqrt{2}}$

$\cos\theta = \frac{B}{H}$

$\cos 45^\circ = \frac{r}{2a}$

$\frac{1}{\sqrt{2}} = \frac{r}{2a}$

$V_O = V_A + V_B + V_C + V_D$

$V_O = \frac{Kq}{a} + \frac{Kq}{a} + \frac{Kq}{a} + \frac{Kq}{a}$

$V_O = \frac{4Kq}{a} = \frac{4Kq}{\frac{r}{\sqrt{2}}}$

$V_O = 4\sqrt{2}\,\frac{Kq}{r}$

(iii) $q_A = -q$

$V_O = \frac{K(-q)}{a} + \frac{Kq}{a} + \frac{Kq}{a} + \frac{Kq}{a}$

$V_O = \frac{2Kq}{a} = \frac{2Kq}{\frac{r}{\sqrt{2}}}$

$V_O = 2\sqrt{2}\,\frac{Kq}{r}$

(iv) $q_A = -q$, $q_B = -q$

$V_O = \frac{K(-q)}{a} + \frac{K(-q)}{a} + \frac{Kq}{a} + \frac{Kq}{a}$

$V_O = 0$

Question

What is the electric potential at a distance of 9 cm from 3 nC?

(A) 270 V

(B) 3 V

(C) 300 V

(D) 30 V

$$V_P = \frac{Kq}{r} = \frac{9 \times 10^{9} \times 3 \times 10^{-9}}{9 \times 10^{-2}}$$

$$V_P = 300\,V$$

Question

Electric potential at a point P due to a point charge of 5×10^{-9} C is 50 V. The distance of P from the point charge is: (Assume, $\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9\ \mathrm{N\ m^2 C^{-2}}$)

(A) 9 cm

(B) 3 cm

(C) 0.9 cm

(D) 90 cm

$V_P = \frac{Kq}{r}$

$r = \frac{Kq}{V_P} = \frac{9 \times 10^{9} \times 5 \times 10^{-9}}{50} = \frac{45}{50}$ m

$r = \frac{45}{50} \times 100$ cm

$r = 90$ cm

Question

A potential at a point A is -3 V and that at another point B is 5 V. What is the work done in carrying a charge of 5 mC from B to A?

(A) –0.04 J

(B) –40 J

(C) 40 J

(D) –0.4 J

$V_B = V_i \quad V_A = V_f$

$V_i = 5V \quad V_f = -3V$

$W = q\Delta V = q(V_f - V_i)$

$W = 5\times10^{-3}(-3-5)$

$W = 5\times10^{-3}\times -8$

$W = -40\times10^{-3} = -0.040\,J$

Question

The electrostatic potential due to an electric dipole at a distance r varies as :

(A) r

(B) $\frac{1}{r^2}$

(C) $\frac{1}{r^3}$

(D) $\frac{1}{r}$

$$V = \pm \frac{Kp\cos\theta}{r^2}$$

$$V \propto \frac{1}{r^2}$$

Electrostatic Potential due to a Charged Conducting Sphere or Spherical Shell

Surface charge density : $\sigma = \frac{q}{A} = \frac{q}{4\pi R^2}$

(i) $r > R$, $V = \frac{Kq}{r}$

(ii) $r = R$, $V = \frac{Kq}{R}$

(iii) $r < R$, $V = \text{constant}$

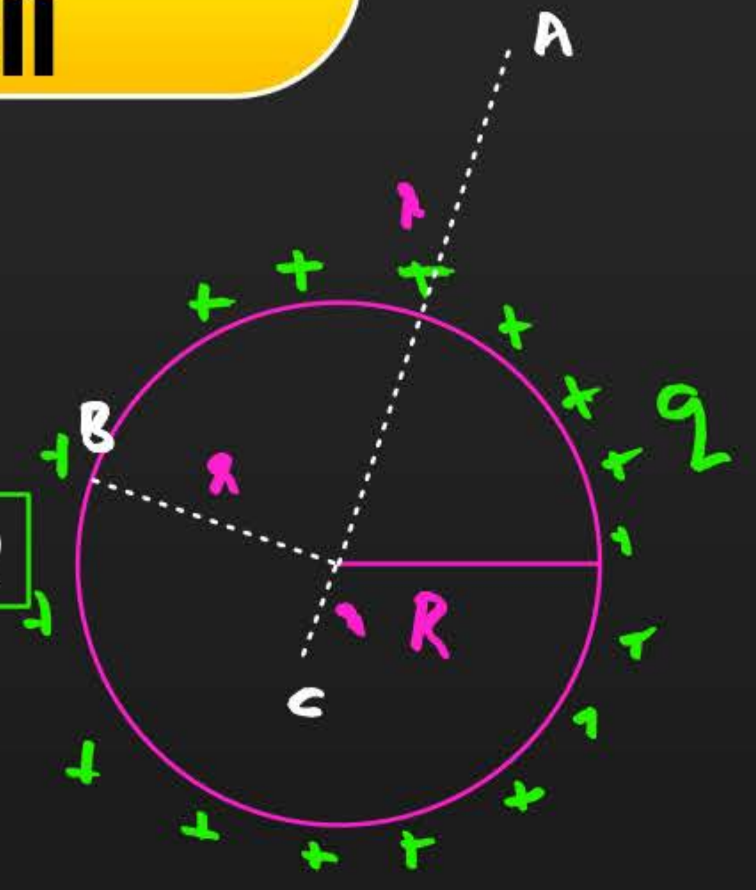
$E = 0$

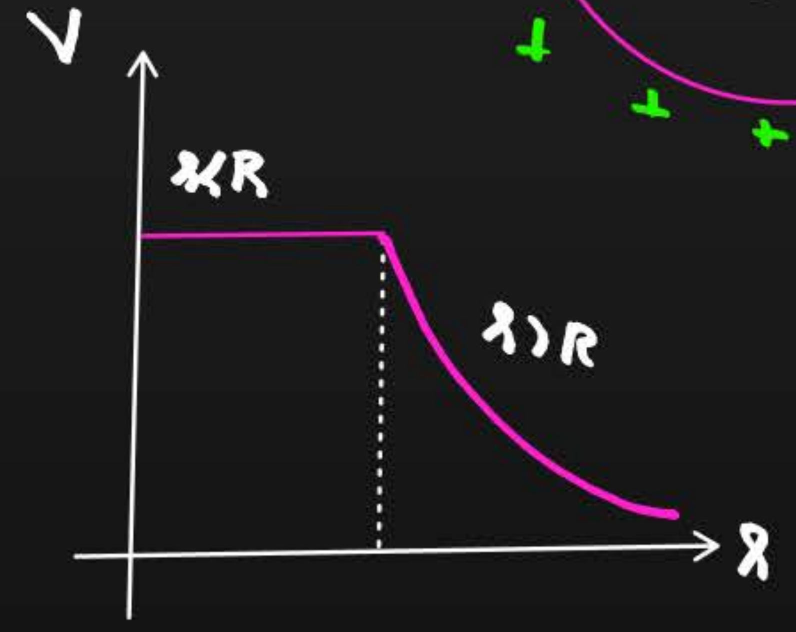
$$V_{inside} = V_{surface} = \frac{Kq}{R}$$

$E = -\frac{dV}{dr}$

$0 = -\frac{dV}{dr}$

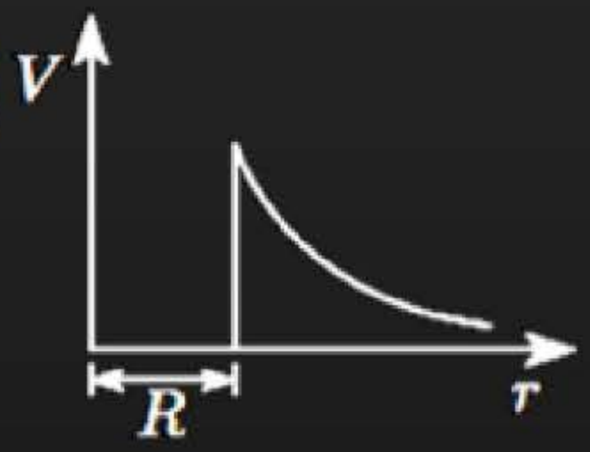
$V = \text{constant}$

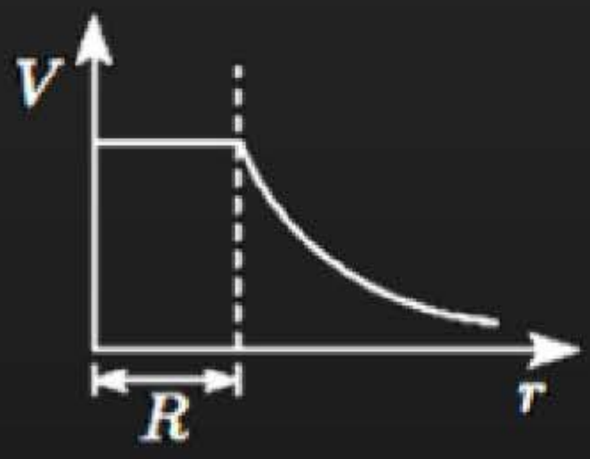


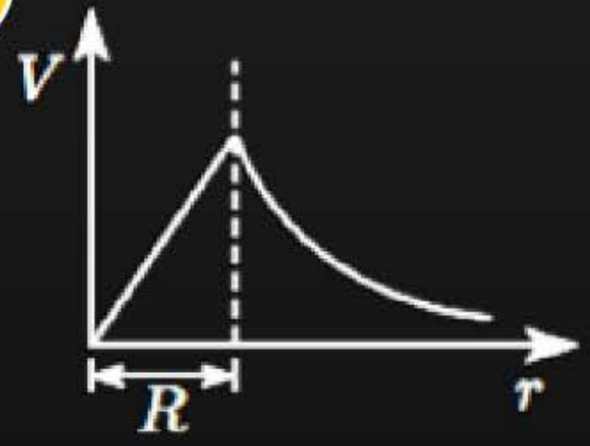


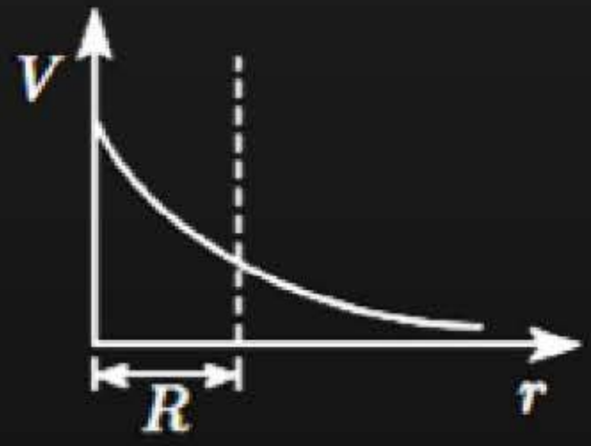
Question

The variation of electrostatic potential with radial distance from the centre of a positively charged metallic thin shell of radius R is given by the graph:

A


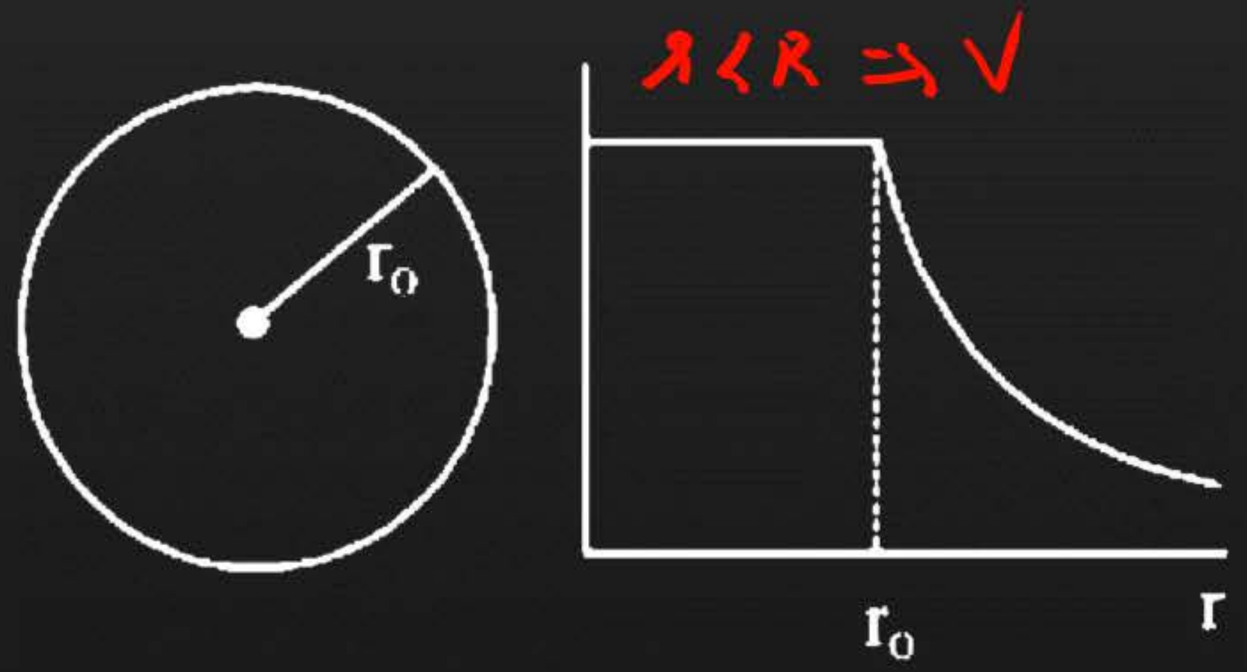
B


C


D


Question

The given graph shows variation (with distance r from centre) of



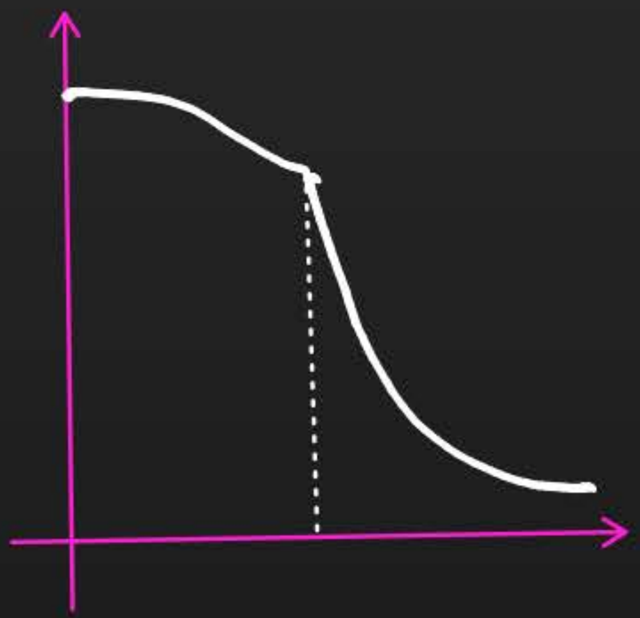
(A) Electric field of a uniformly charged sphere ✗

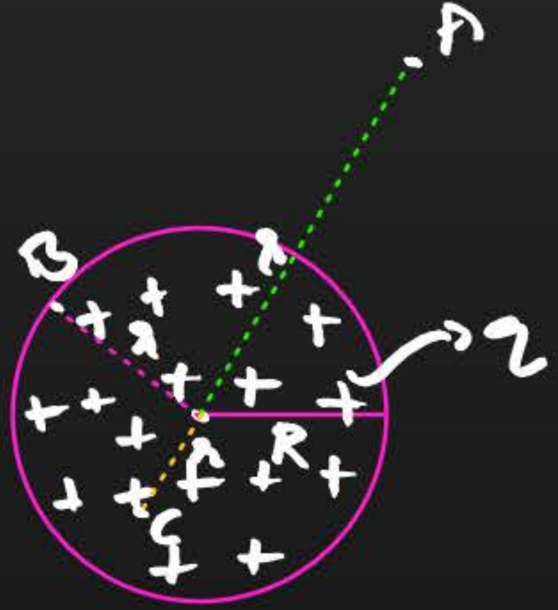
(B) Potential of a uniformly charged spherical shell

(C) Potential of a uniformly charged sphere

(D) Electric field of a uniformly charged spherical ✗ shell

Electric Potential due to Uniformly Charged Non-conducting Sphere





Surface charge density : $\sigma = \frac{q}{A} = \frac{q}{4\pi R^2}$

(i) $r > R$, $V = \frac{Kq}{r}$

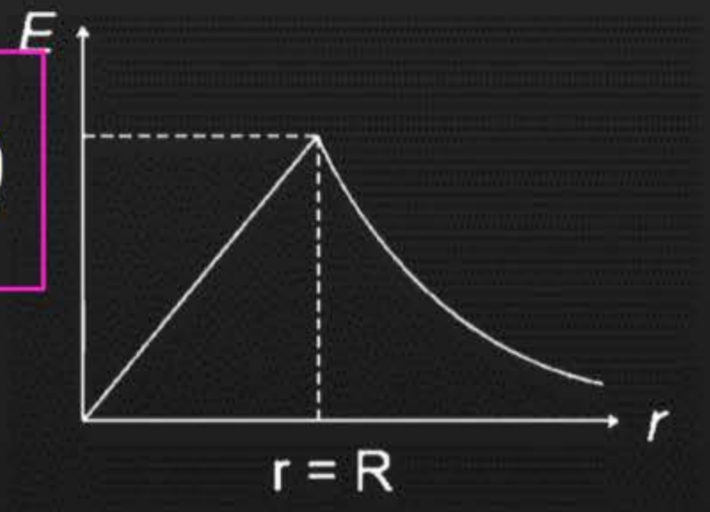
(ii) $r = R$, $V = \frac{Kq}{R}$

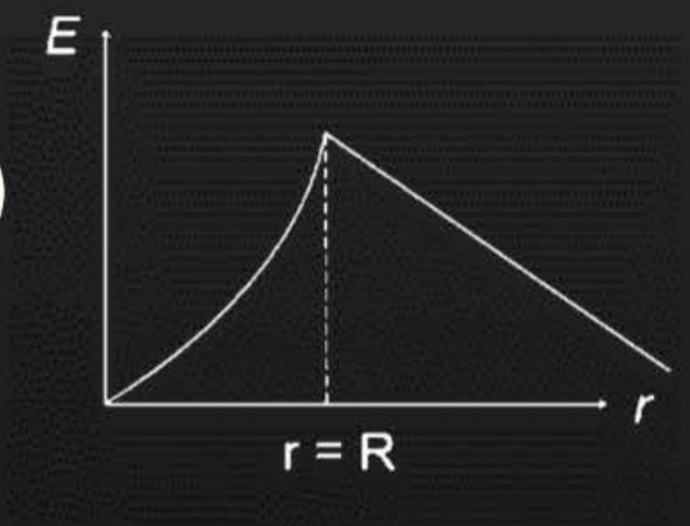
(iii) $r < R$, $V = \frac{Kq}{2R^3}(3R^2 - r^2)$

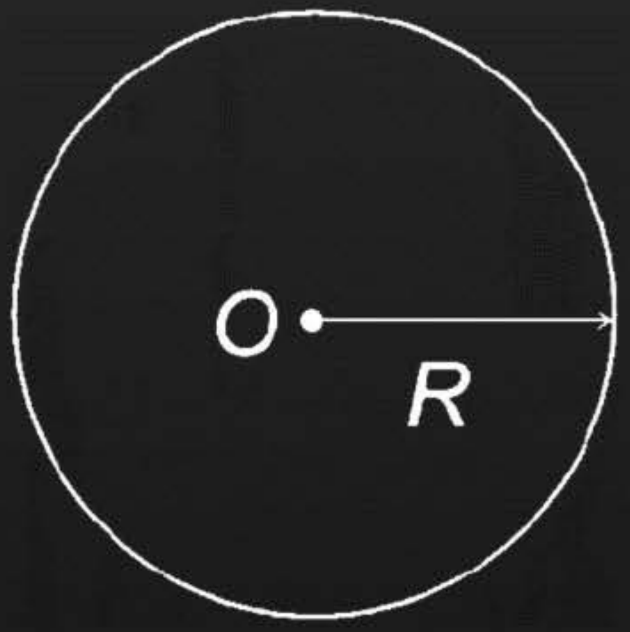
At centre, $r = 0$, $V_c = \frac{Kq}{2R^3} \times 3R^2 = \frac{3}{2}\left(\frac{Kq}{R}\right) \Rightarrow V_{centre} = 1.5\,V_{surface}$

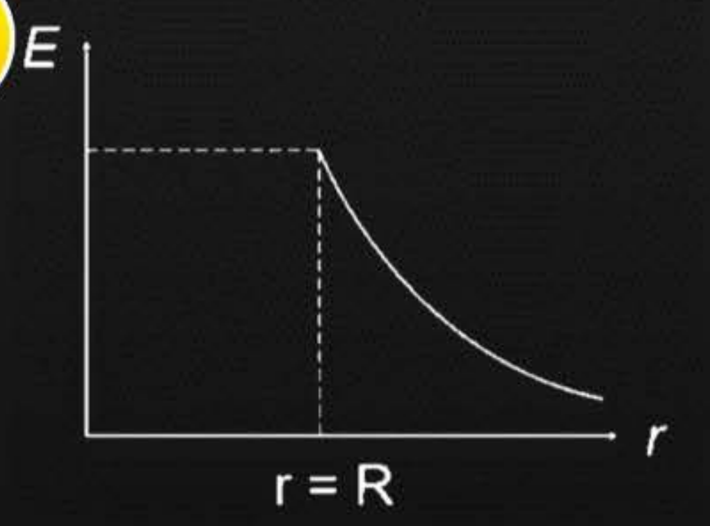
Question

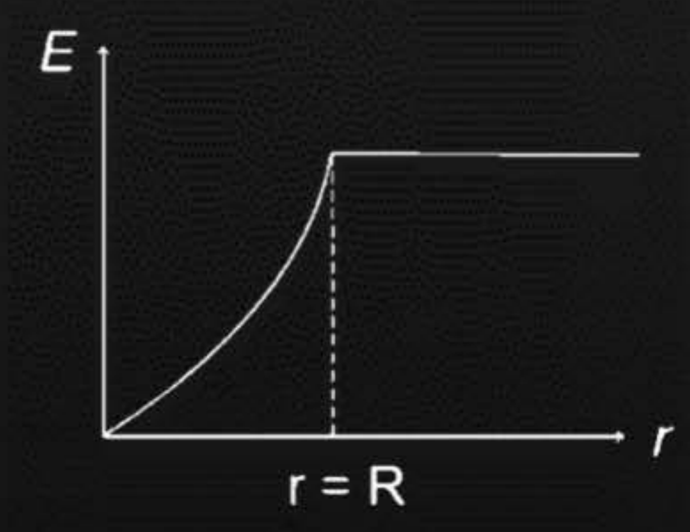
Graphical variation of electric field due to a uniformly charged insulating solid sphere of radius R, with distance r from the centre O is represented by:

(A)


(B)




(C)


(D)


Question

The value of electric potential at a distance of 9 cm from the point charge 4×10^{-7} C is $\left[\text{Given } \frac{1}{4\pi\varepsilon_0} = 9 \times 10^{9} \mathrm{Nm^2C^{-2}}\right]$:

(A) 4×10^{2} V

(B) 44.4 V

(C) 4.4×10^{5} V

(D) 4×10^{4} V

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

Question

A conducting sphere of radius R is given a charge Q. The electric potential and the electric field at the center of the spheres respectively are:

(A) 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

$V_{in} = V_s = \frac{KQ}{R} = \frac{1}{4\pi\varepsilon_0} \frac{Q}{R}$.

$E = 0$

Question

A hollow metallic sphere of radius 10 cm is charged such that potential of its surface is 80 V . The potential at the centre of be sphere would be

$V_{inside} = V_{surface} = 80V$

(A) 80 V

(B) 800 V

(C) Zero

(D) 8 V

Question

Given below are two statements: one is labelled as Assertion **A** and the other is labelled as Reason **R**.

Assertion A: The potential (V) at any axial point, at 2 m distance (r) from the centre of the dipole of dipole moment vector $\vec{P}$ of magnitude, 4×10^{-6} Cm, is $\pm 9 \times 10^{3}$ V. (Take $\frac{1}{4\pi\epsilon_0} = 9 \times 10^{9}$ SI Units)

Reason R: $V = \pm \frac{2P}{4\pi\epsilon_0 r^2}$, where r is the distance of any axial point, situated at 2 m from the centre of the dipole. In the light of the above statements, choose the correct answer from the options given bel w.

(A) A is true but R is false.

(B) A is false but R is true.

(C) Both A and R are true and R is the correct explanation of A.

(D) Both A and R are true and R is NOT the correct explanation of A .

Question

If a conducting sphere of radius R is charged. Then the electric field at a distance $r(r > R)$ from the centre of the sphere would be, ($V =$ potential on the surface of the sphere)

$r > R$

(A) $\frac{rV}{R^2}$

$E = \frac{Kq}{r^2}$

$V = \frac{Kq}{R}$

(B) $\frac{R^2 V}{r^3}$

$E = \frac{VR}{r^2}$

$Kq = VR$

(C) $\frac{RV}{r^2}$

(D) $\frac{V}{r}$

Question

Two hollow conducting sphere of radii R_1 and $R_2 (R_1 \gg R_2)$ have equal charges. The potential would be:

$V = \frac{kq}{r}$ $V \propto \frac{1}{r}$.

$R_1 \gg R_2$
$V_1 \ll V_2$

$V_2 > V_1$

(A) Dependent on the material property of the sphere

(B) More on bigger sphere

(C) More on smaller sphere

(D) Equal on both the sphere

Question

A short electric dipole has a dipole moment of $16 \times 10^{-9} Cm$ The electric potential due to the dipole at a point at a distance of 0.6 m from the centre of the dipole, situated on a line an angle of 60° with the dipole axis is : $\left(\frac{1}{4\pi\epsilon_0} = 9 \times 10^9 \text{ N m}^2/\text{C}^2\right)$

(A) 200 V

(B) 400 V

(C) Zero

(D) 50 V

$V = \frac{Kp\cos\theta}{r^2} = \frac{9 \times 10^9 \times 16 \times 10^{-9} \times \cos 60^\circ}{(0.6)^2}$

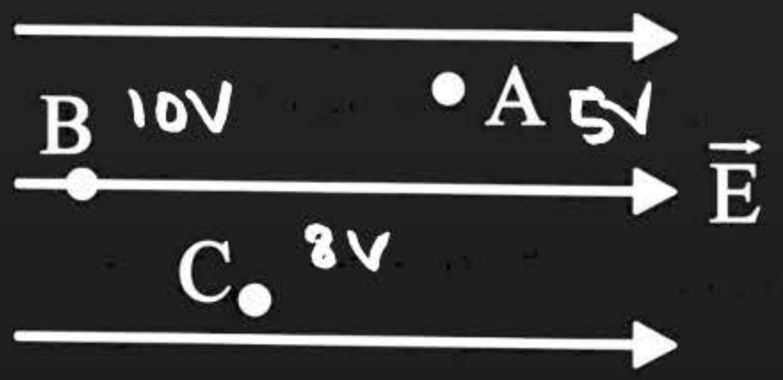
$V = \frac{9 \times 16}{36 \times 10^{-2} \times 2}$

$V = 2 \times 10^2 = 200 V$

Question

A, B and C are three points in a uniform electric field. The electric potential is:

$$E = (-)\frac{dV}{ds}$$



A Same at all the three points A, B and C ✗

B Maximum at A

C Maximum at B

D Maximum at C

Question

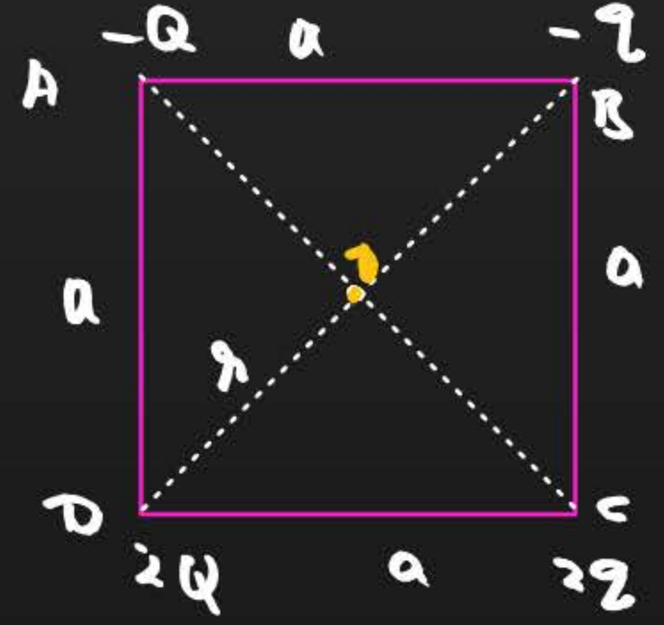
Four point charges $-Q, -q, 2q$ and $2\,Q$ are placed on 4 each corner of the square. The relation between Q and q for which the potential at the center of the square is zero is

(A) $Q = -q$

(B) $Q = -\frac{1}{q}$

(C) $Q = q$

(D) $Q = \frac{1}{q}$



$r = \frac{a}{\sqrt{2}}$

$V_O = V_A + V_B + V_C + V_D$

$V_O = \frac{K(-Q)}{r} + \frac{K(-q)}{r} + \frac{K(2q)}{r} + \frac{K(2Q)}{r}$

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

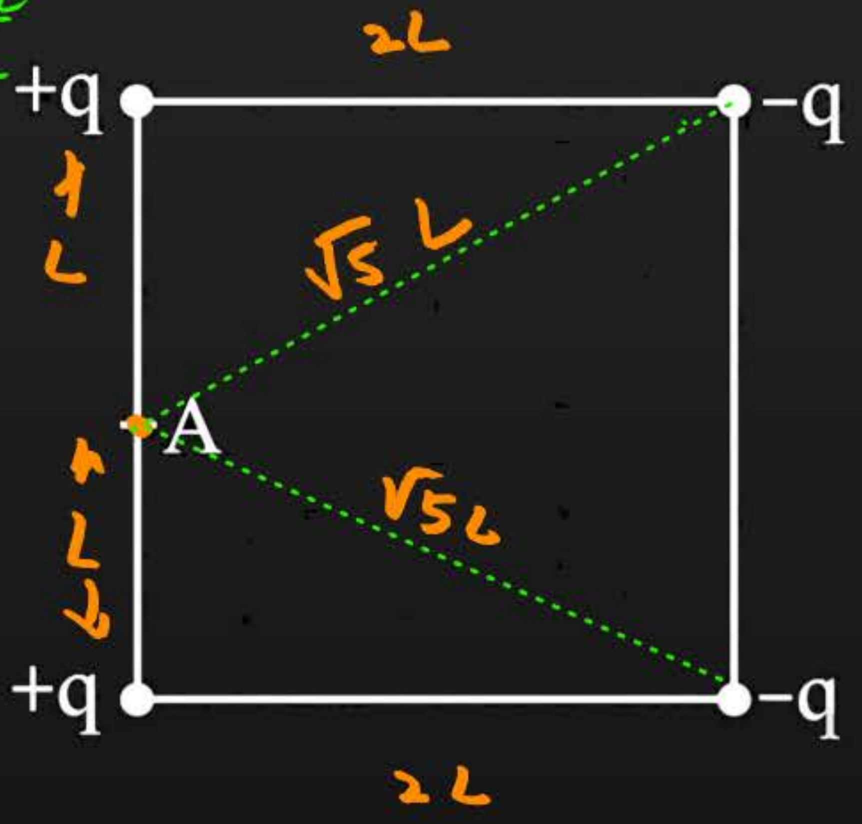
$0 = Q + q$

$Q = -q$

Question

H.W

Four electric charges $+q, +q, -q$ and $-q$ are placed at the corner of a square of side 2 L (see figure). The electric potential at point A, midway between the two charges $+q$ and $+q$, is:



A $\frac{1}{4\pi\varepsilon_0}\frac{2q}{L}(1+\sqrt{5})$

B $\frac{1}{4\pi\varepsilon_0}\frac{2q}{L}\left(1+\frac{1}{\sqrt{5}}\right)$

C $\frac{1}{4\pi\varepsilon_0 L}2q\left(1-\frac{1}{\sqrt{5}}\right)$

D Zero

$V_A = \frac{Kq}{L} + \frac{K(-q)}{\sqrt{5}L} + \frac{K(-q)}{\sqrt{5}L} + \frac{Kq}{L}$

$V_A = \frac{2Kq}{L} - \frac{2Kq}{\sqrt{5}L}$

$V_A = \frac{2Kq}{L}\left(1-\frac{1}{\sqrt{5}}\right)$

$V_A = \frac{2q}{4\pi\varepsilon_0}\left(1-\frac{1}{\sqrt{5}}\right)$

Question

Some charge is being given to a conductor. Then its potential:

$V_{inside} = V_{surface} = \frac{Kq}{R}$

(A) Is maximum at surface

(B) Is maximum at centre

(C) Is same throughout the conductor ✓

(D) Is maximum somewhere between surface and centre

Electric potential energy of a system of charges

Electrostatic potential energy of a point charge, is the amount of work done in bringing the charge from infinity to the present position without changing its kinetic energy.

- EPE of a system of charges, is the minimum amount of work done in assembling the given charge system.

- An object may have EPE by virtue of

(i) Its own charge called self-energy and

(ii) Its relative position in the system of charges, called interaction energy.

Therefore, total EPE = self-energy + interaction energy

- EPE is defined only for conservative field like gravitational field, electrostatic field etc.

Properties of conservative field

- ✓ Work done is independent of path followed.
- ✓ Work done against conservative field/force, gets stored in the form of potential energy.
- ✓ Sum of KE and PE at any instant remains constant [Conservation of Mechanical Energy (COME)].

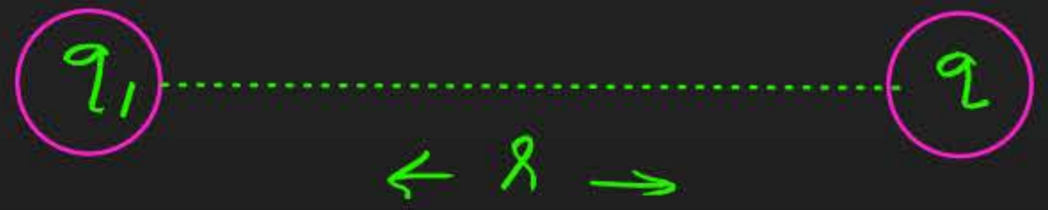
$$E = K + U = \text{constant}$$

$$E_i = E_f$$

$$K_i + U_i = K_f + U_f$$

Electrostatic Potential Energy (EPE) of two point charge system

$$U = \pm K \frac{q_1 q_2}{r}$$

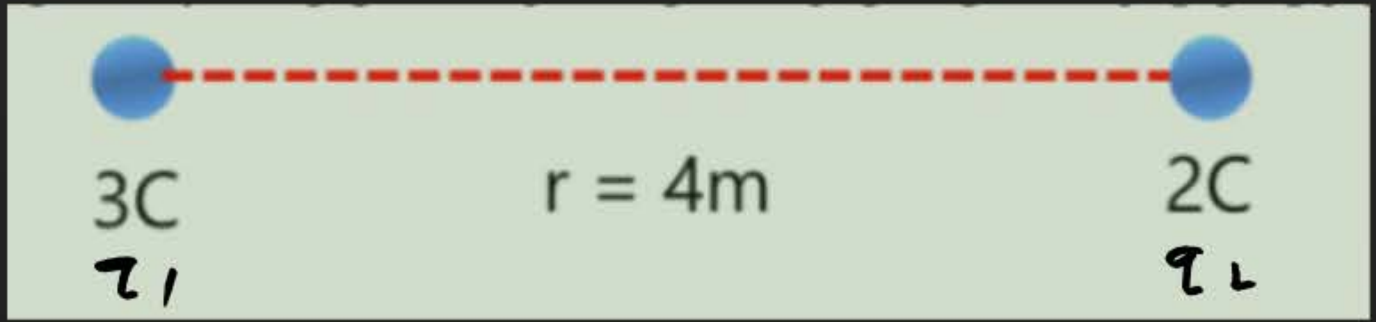


Note : Always put sign of the charge in this formula.

- ✓ Potential energy under repulsive forces is positive.
- ✓ Potential energy under attractive forces is negative.

Question

Find potential energy of the system shown. Also find work done in decreasing the distance by 1m.



(i) $U_1 = \frac{Kq_1q_2}{r}$

$U_1 = \frac{9\times10^9 \times 3 \times 2}{4_2}$

$U_1 = \frac{27\times10^9}{2}$

$U_1 = 13.5\times10^9$

$r' = r - 1 = 4 - 1 = 3m$

$U_2 = \frac{Kq_1q_2}{r'}$

$U_2 = \frac{9\times10^9 \times 3\times2}{3}$

$U_2 = 18\times10^9 J$

$W = \Delta U$

$W = U_f - U_i$

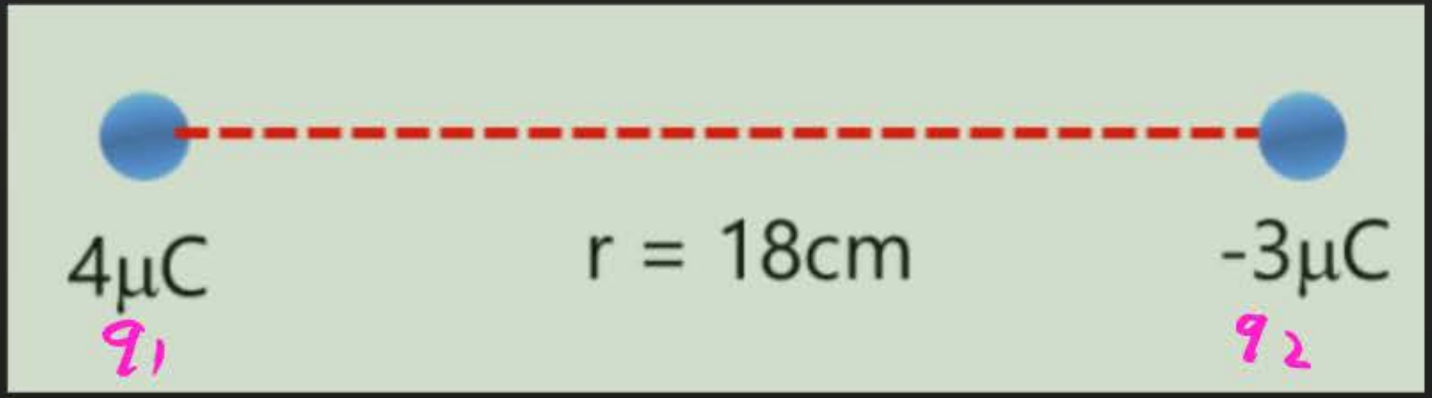
$W = U_2 - U_1$

$W = 18\times10^9 - 13.5\times10^9$

$W = 4.5\times10^9 J$

Question

For the given charge system, find – (1) PE of system (2) Work done in carrying a charge to infinity



(i) $U = \frac{k q_1 q_2}{r}$

$U = \frac{9\times10^{9} \times 4\times10^{-6} \times (-3)\times10^{-6}}{18\times10^{-2}}$

$U = -6\times10^{-1}$

$\boxed{U = -0.6\,J} \Rightarrow U_i$

(ii) $W = \Delta U = U_f - U_i$

$W = U_\infty - U = 0 - (-0.6)$

$\boxed{W = 0.6\,J}$

Question

A system of two charges separated by a certain distance apart stores electrical potential energy. If the distance between them is increased, the potential energy of the system

(A) increases in any case

(B) decreases in any case

(C) may increase or decrease

(D) remains the same

$U = (\pm) \frac{K q_1 q_2}{r}$

Like charge $U = \frac{K q_1 q_2}{r}$

$r \uparrow \; U \downarrow$

$r \downarrow \; U \uparrow$

Unlike charges

$U = (-) \frac{K q_1 q_2}{r}$

$r \uparrow \; U \uparrow$

$r \downarrow \; U \downarrow$

Electrostatic Potential Energy of a System of Charges

It is defined as work done by external agent or work done against electric field in bringing charges from infinity to their respective positions, in forming system of charges.

Example –

$n=3 \quad q_1, q_2, q_3, q_4$

(i) For 3-point charge system

$$U = U_{12} + U_{13} + U_{23}$$

$$U = \frac{Kq_1q_2}{r_{12}} + \frac{Kq_1q_3}{r_{13}} + \frac{Kq_2q_3}{r_{23}}$$

(ii) For 4-point charge system

$$U = U_{12} + U_{13} + U_{14} + U_{23} + U_{24} + U_{34}$$

No. of pairs $= \frac{N(N-1)}{2} = 3$ ✓

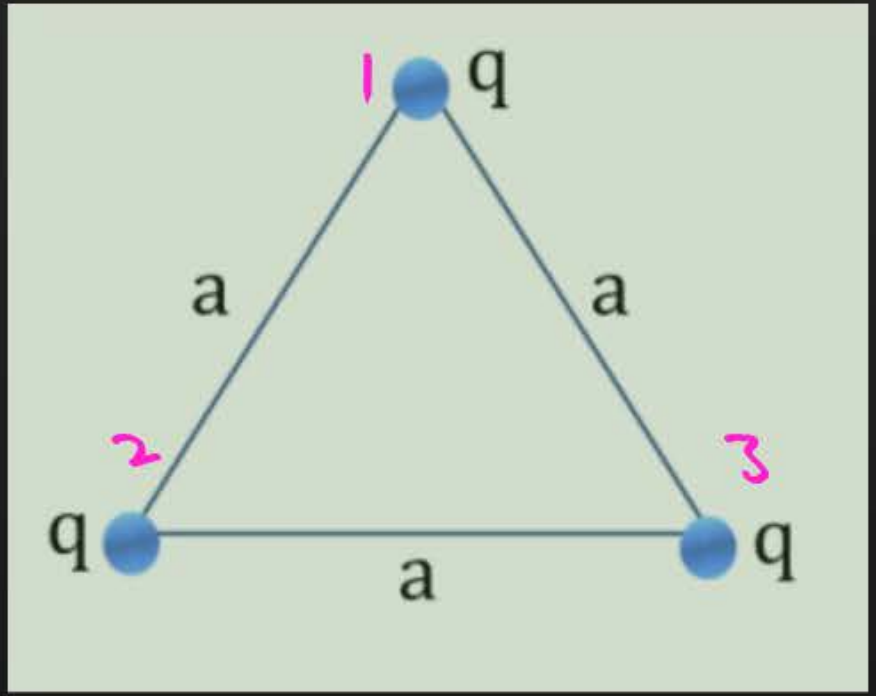
$= 6$ ✓

$N = 3,$

$N = 4$

Question

Consider the charge system shown, find (i) Potential energy of any one of the charges. (ii) Potential energy of the system. (iii) Work done in associating the system. $\frac{N(N-1)}{2} = 3$



(i) $U = U_{12} + U_{13} = \frac{Kq_1q_2}{r_{12}} + \frac{Kq_1q_3}{r_{13}}$

$$U = \frac{Kq^2}{a} + \frac{Kq^2}{a} = \frac{2Kq^2}{a}$$

(ii) $U = U_{12} + U_{13} + U_{23} = \frac{Kq^2}{a} + \frac{Kq^2}{a} + \frac{Kq^2}{a}$

$$U = \frac{3Kq^2}{a} = U_f$$

(iii) $W = \Delta U = U_f - U_i$

$$W = U_f - U_\infty = \frac{3Kq^2}{a}$$

Question

The charges Q, $+q$ and $+q$ are placed at the vertices of an equilateral triangle of side l. If the net electrostatic potential energy of the system is zero, then Q is equal to

(A) $-q/2$

(B) $-q$

(C) $+q/2$

(D) Zero

$$U = U_{12} + U_{13} + U_{23}$$

$$U = \frac{KQq}{l} + \frac{KQq}{l} + \frac{Kqq}{l}$$

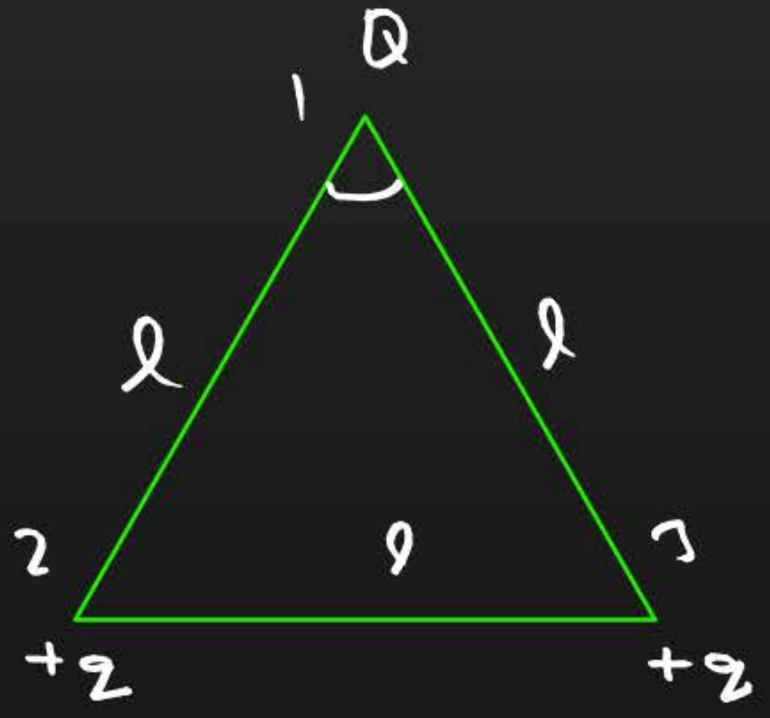
$$0 = Qq + Qq + q^2$$

$$= 2Qq + q^2$$

$$2Qq = -q^2$$

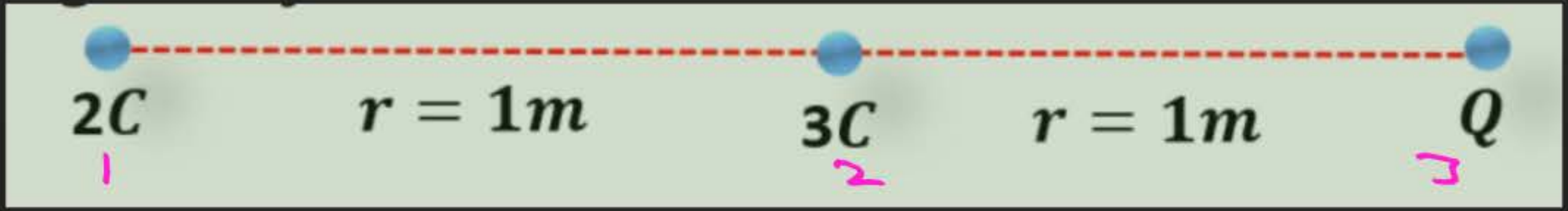
$$2Q = -q$$

$$Q = -q/2$$



Question

For what value of Q, EPE of the given system is zero.



$$U = U_{12} + U_{13} + U_{23}$$

$$U = \frac{k q_1 q_2}{r_{12}} + \frac{k q_1 q_3}{r_{13}} + \frac{k q_2 q_3}{r_{23}}$$

$$0 = \frac{k \times 2 \times 3}{1} + \frac{k \times 2 \times Q}{2} + \frac{k \times 3 \times Q}{1}$$

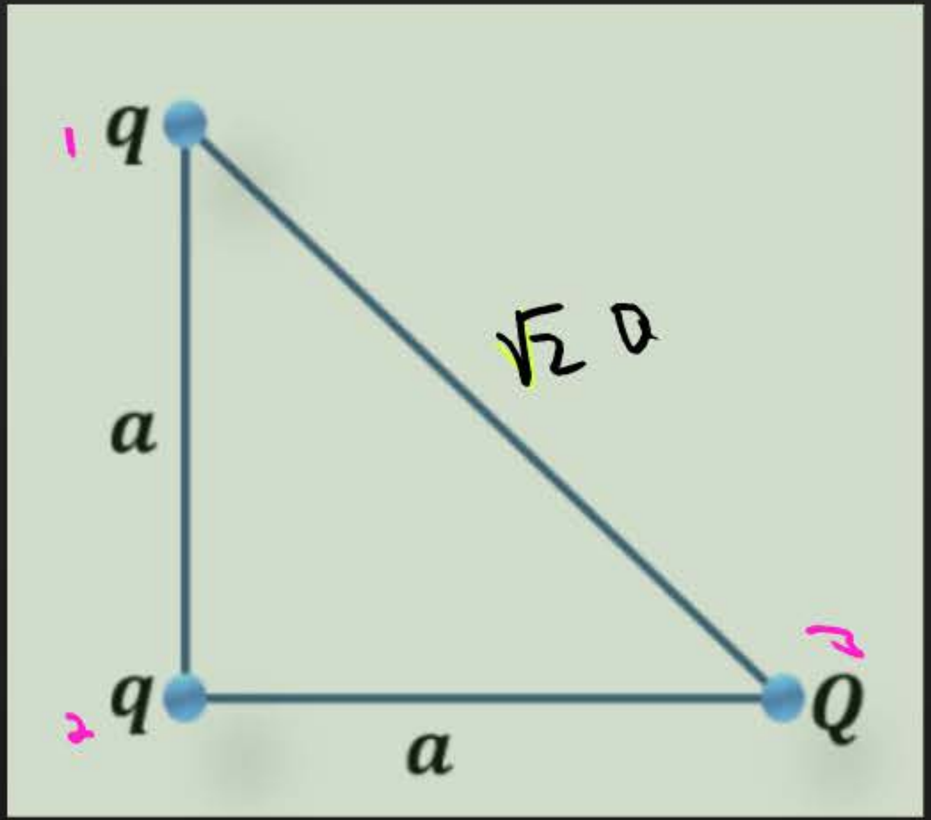
$$0 = 6 + Q + 3Q$$

$$0 = 6 + 4Q \Rightarrow 4Q = -6$$

$$\boxed{Q = -\frac{3}{2}C = -1.5C}$$

Question

For what value of Q, EPE of the system shown is zero.



$$U = U_{12} + U_{13} + U_{23}$$

$$U = \frac{kq^2}{a} + \frac{kqQ}{\sqrt{2}a} + \frac{kqQ}{a}$$

$$0 = q + \frac{Q}{\sqrt{2}} + Q$$

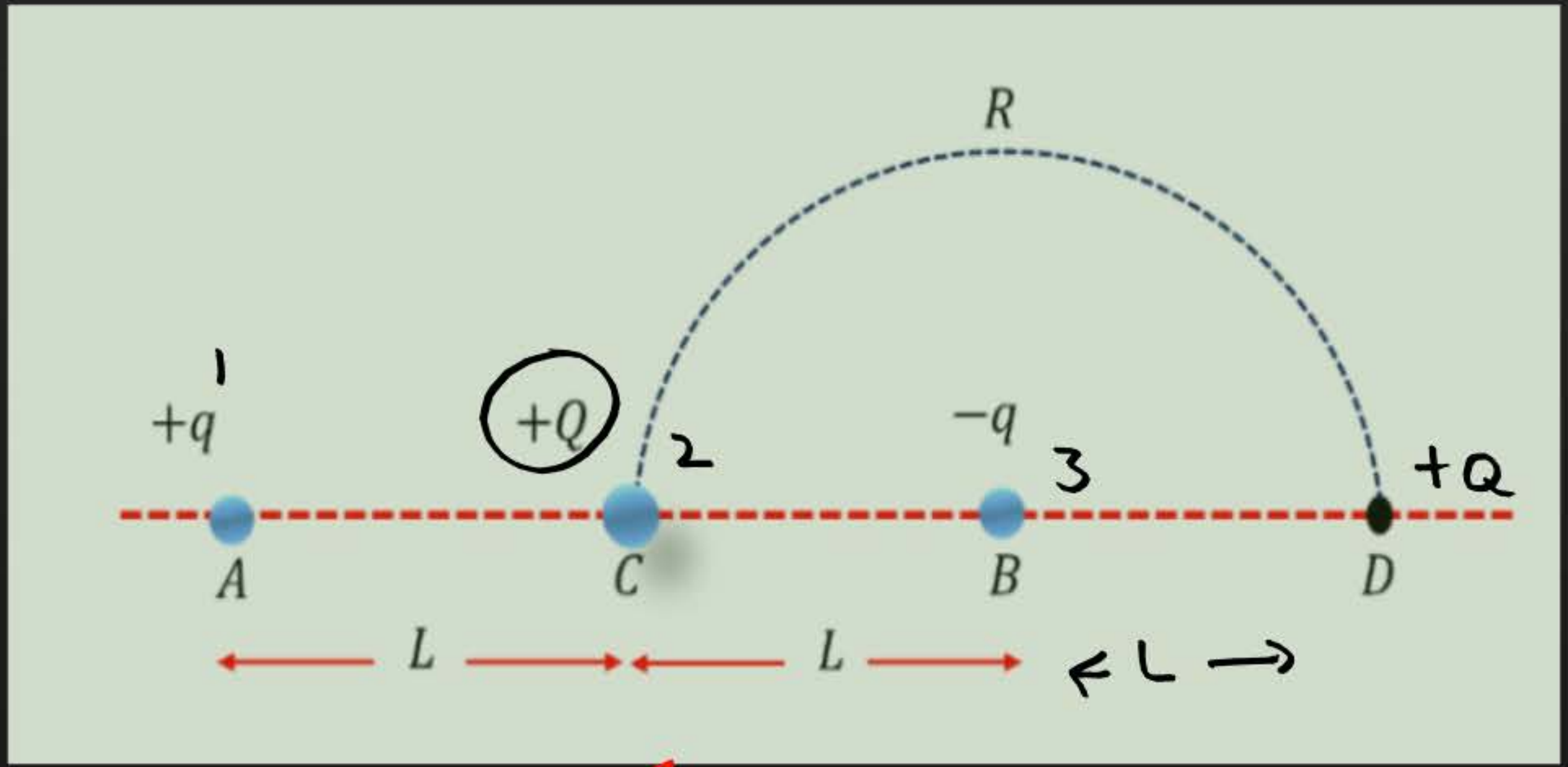
$$\frac{Q}{\sqrt{2}} + Q = -q$$

$$\frac{Q + \sqrt{2}Q}{\sqrt{2}} = -q \Rightarrow Q\left[\frac{1+\sqrt{2}}{\sqrt{2}}\right] = -q$$

$$Q = -\sqrt{2}q / (1+\sqrt{2})$$

Question

Find work done in transferring the charge +Q via semicircular path CRD centered at B.



$\hookrightarrow W = \Delta U = U_f - U_i$

$U_i = \frac{Kq_1q_2}{r_{12}} + \frac{Kq_1q_3}{r_{13}} + \frac{Kq_2q_3}{r_{23}}$

$U_i = \frac{K \times q \times Q}{L} + \frac{Kq(-q)}{2L} + \frac{KQ(-q)}{L}$

$U_i = -\frac{Kq^2}{2L}$ — (1)

$U_f = -\frac{Kq^2}{2L} + \frac{KqQ}{3L} - \frac{KqQ}{L}$

$W = U_f - U_i = -\frac{Kq^2}{2L} + \frac{KqQ}{3L} - \frac{KqQ}{L} + \frac{Kq^2}{2L}$

$W = \frac{KqQ}{L}\left[\frac{1}{3} - 1\right] = -\frac{2}{3}\frac{KqQ}{L}$

Question

A hot filament liberates an electron with zero initial velocity. The anode potential is 1200 V. The speed of the electron when it strikes the anode is

$W = q\Delta V$

$K = q\Delta V$

$\frac{1}{2}mv^2 = q\Delta V$

(A) $1.5 \times 10^{5}\ ms^{-1}$

(B) $2.5 \times 10^{6}\ ms^{-1}$

(C) $2.1 \times 10^{7}\ ms^{-1}$

(D) $2.5 \times 10^{8}\ ms^{-1}$

Potential Gradient

→ Vector.

The rate of change of potential with distance in the electric field is called "The potential gradient"

potential gradient $= \frac{dV}{dr}$

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

$\frac{dV}{dx}, \frac{dV}{dy}, \frac{dV}{dz}$

Thank

You