

ELECTROSTATIC POTENTIAL AND POTENTIAL ENERGY

H.W.

Total Electrostatic Energy $\Rightarrow ???$

\Rightarrow (Self Energy) + (Mutual P.E)

$\Rightarrow (U_{\text{self}})_{\text{conducting sphere}} + (U_{\text{self}})_{\text{non conducting sphere}} + (\text{Mutual P.E})$

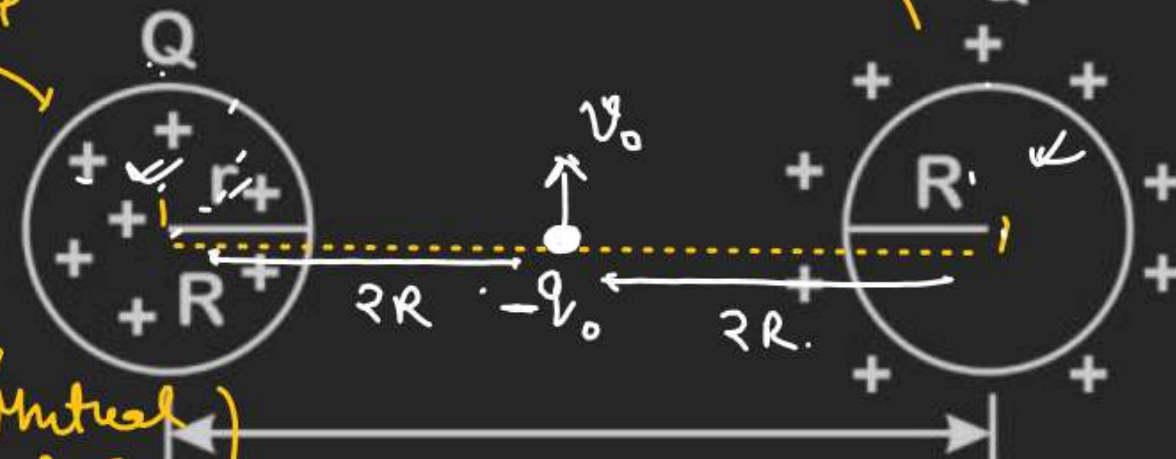
$$U_T = \left[\frac{kQ^2}{2R} + \frac{3}{5} \left(\frac{kQ^2}{R} \right) + \frac{kQ^2}{4R} \right]$$

$$= \left[\frac{3kQ^2}{4R} + \frac{3}{5} \frac{kQ^2}{R} \right] = \frac{3kQ^2}{R} \left(\frac{1}{4} + \frac{1}{5} \right) = \frac{3kQ^2}{R} \left[\frac{9}{20} \right] = \left[\frac{27kQ^2}{20R} \right]$$

$$\frac{\infty}{KE=0} \quad U=0 \quad U=qV_{\infty}^0$$

Uniformly Charged non-Conducting Sphere

Conducting Sphere



Find $(V_0)_{\text{min}}$ so that it can escape from the field of both spheres.

$$U_i + K.E_i = U_f + K.E_f$$

$$-\frac{kQq_0}{2R} \times 2 + \frac{1}{2} m V_0^2 = 0$$

$$V_0 = \sqrt{\frac{2kQq_0}{mR}}$$

POTENTIAL ENERGY

$$\text{Impulse} = \oint F dt = \Delta p$$

H.W.
Q. A charged particle of charge Q is held fixed and another charged particle of mass m and charge q (of the same sign) is released from a distance r . The impulse of the force exerted by the external agent on the fixed charge by the time distance between Q and q becomes $2r$ is:

(A) $\sqrt{\frac{Qq}{4\pi\epsilon_0 mr}}$

(B) $\sqrt{\frac{Qqm}{4\pi\epsilon_0 r}}$

(C) $\sqrt{\frac{Qqm}{\pi\epsilon_0 r}}$

(D) $\sqrt{\frac{Qqm}{2\pi\epsilon_0 r}}$

Diagram illustrating the initial state and final state of the system:

Initial State: Q (fixed), q (moving), distance r .
Final State: Q (fixed), q (moving), distance $2r$.
Forces: $F_{Q/q}$ and $F_{q/Q}$ are shown.
Impulse: $J_F = J_{\text{ext agent}}$

Energy Conservation:

$$\frac{kqQ}{r} + 0 = \frac{kqQ}{2r} + \frac{1}{2}mv^2$$

$$\frac{kQq}{2r} = \frac{1}{2}mv^2 \Rightarrow v = \sqrt{\frac{kQq}{mr}}$$

Impulse:

$$\Delta p = mv = m \sqrt{\frac{kQq}{mr}} = \sqrt{\frac{Qqm}{4\pi\epsilon_0 r}}$$

POTENTIAL ENERGY

H.W.

Q. A unit positive point charge of mass m is projected with a velocity v inside the tunnel as shown. The tunnel has been made inside a uniformly charged non-conducting sphere. The minimum velocity with which the point charge should be projected such it can reach the opposite end of the tunnel, is equal to:

(A) $[\sigma R^2 / 4m\epsilon_0]^{1/2}$

(B) $[\sigma R^2 / 24m\epsilon_0]^{1/2}$

(C) $[\sigma R^2 / 6m\epsilon_0]^{1/2}$

(D) ~~zero because the initial and the final points are at same potential~~

$$U = \frac{KQ}{2R^3} (3R^2 - r^2)$$

$$U_A \leftarrow r = R$$

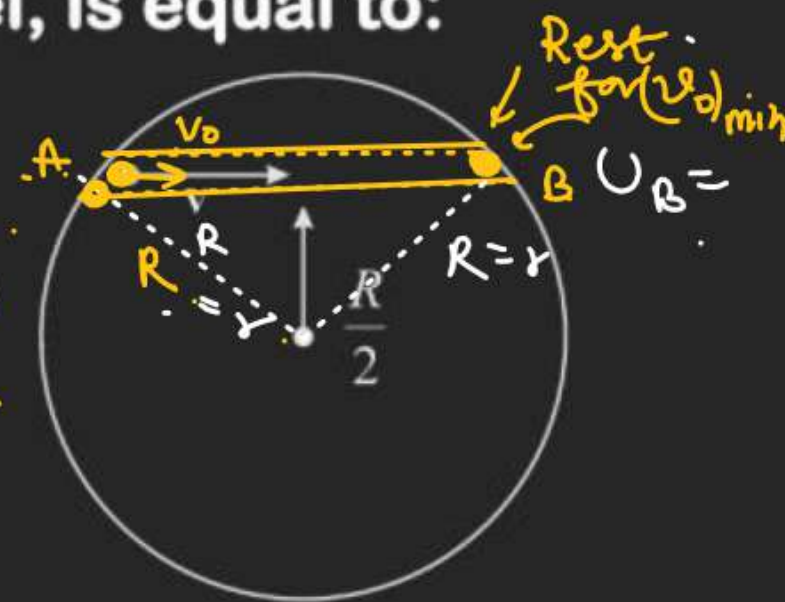
$$U_B \leftarrow r = R$$

$$U_A = U_B$$

$$U_A + (K \cdot E)_A = U_B + (K \cdot E)_B$$

$$(K \cdot E)_A = (U_B - U_A)$$

$$(K \cdot E)_A = 0 \Rightarrow$$



POTENTIAL ENERGY



H.W.
Q. The diagram shows a small bead of mass m carrying charge q . The bead can freely move on the smooth fixed ring placed on a smooth horizontal plane. In the same plane a charge $+Q$ has also been fixed as shown. The potential at the point P due to $+Q$ is V . The velocity with which the bead should be projected from the point P so that it can complete a circle should be greater than:

(A) $\sqrt{\frac{6qV}{m}}$

(C) $\sqrt{\frac{3qV}{m}}$

$\frac{+Q}{4a}$

$V = V_i = \left(\frac{kQ}{4a} \right)$

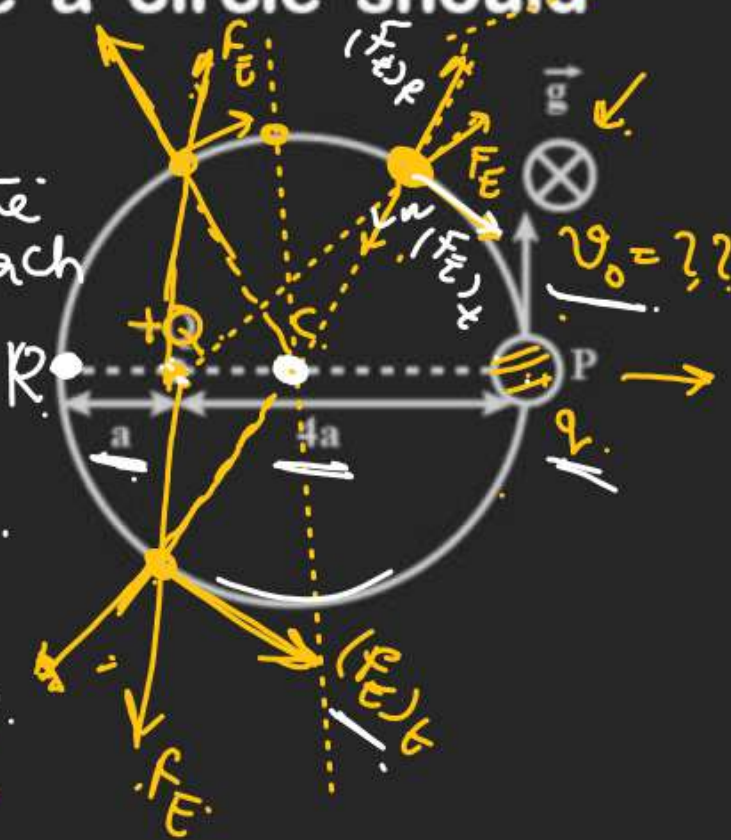
$V_f = \left(\frac{kQ}{a} \right) = 4V$

(B) $\sqrt{\frac{qV}{m}}$

(D) none of these $= (4V)q$

$\frac{1}{2} m v_0^2 = \sqrt{\frac{6qV}{m}} \frac{m v_0^2}{2} = 3qV$

$(V_{+Q})_P = V$
 For bead to complete the circle it just reach opposite to P.
 $(qV) + \frac{1}{2} m v_0^2 = (4V)q$



POTENTIAL ENERGY

H.W.

Q. A bullet of mass m and charge q is fired towards a solid uniformly charged sphere of radius R and total charge $+q$. If it strikes the surface of sphere with speed u , find the minimum speed u so that it can penetrate ~~the~~ (to the center.) the sphere. (Neglect all resistance forces or friction acting on bullet except electrostatic forces.):

(A) $\frac{q}{\sqrt{2\pi\epsilon_0 m R}}$

(B) $\frac{q}{\sqrt{4\pi\epsilon_0 m R}}$

(C) $\frac{q}{\sqrt{2\pi\epsilon_0 m R}}$

(D) $\frac{\sqrt{3}q}{\sqrt{4\pi\epsilon_0 m R}}$

$$u = \sqrt{\frac{Kq^2}{mR}}$$

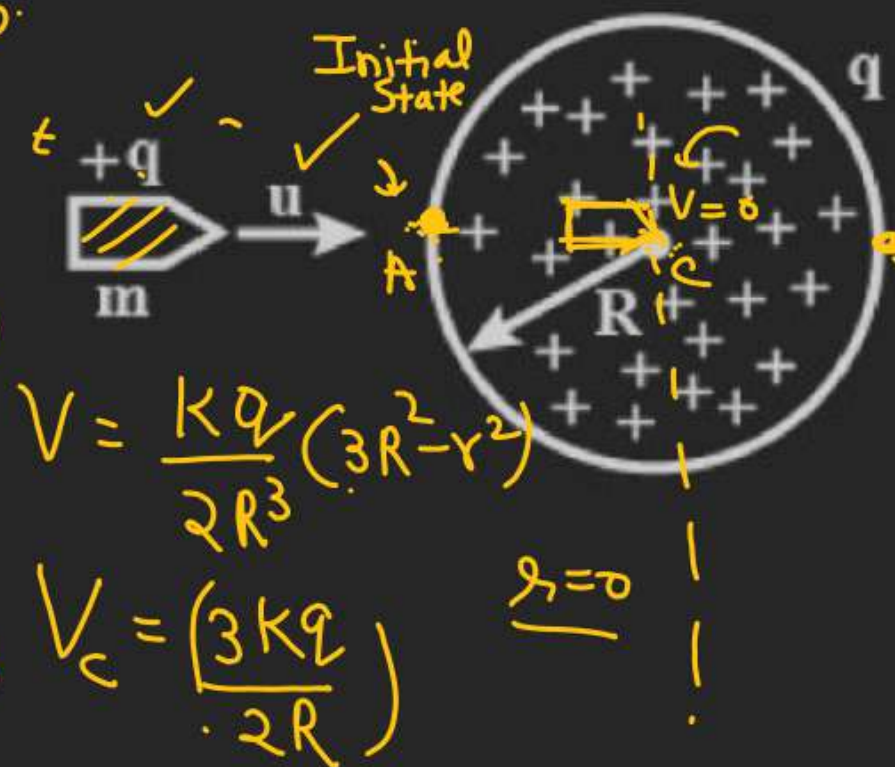
$$u = \frac{q}{\sqrt{4\pi\epsilon_0 m R}}$$

$$U_A + K \cdot E_A = U_C + (K \cdot E)_C$$

$$\frac{Kq^2}{R} + \frac{1}{2}mu^2 = \frac{3Kq^2}{2R} + 0$$

$$\frac{mu^2}{2} = \left(\frac{3Kq^2}{2R} - \frac{Kq^2}{R}\right)$$

$$\frac{mu^2}{2} = \frac{Kq^2}{R} \left(\frac{3}{2} - 1\right) = \frac{Kq^2}{2R}$$



POTENTIAL ENERGY

$$(K.E)_{\text{rotational}} = \left[\frac{1}{2} I \omega^2 \right]$$

$$v = R\omega$$

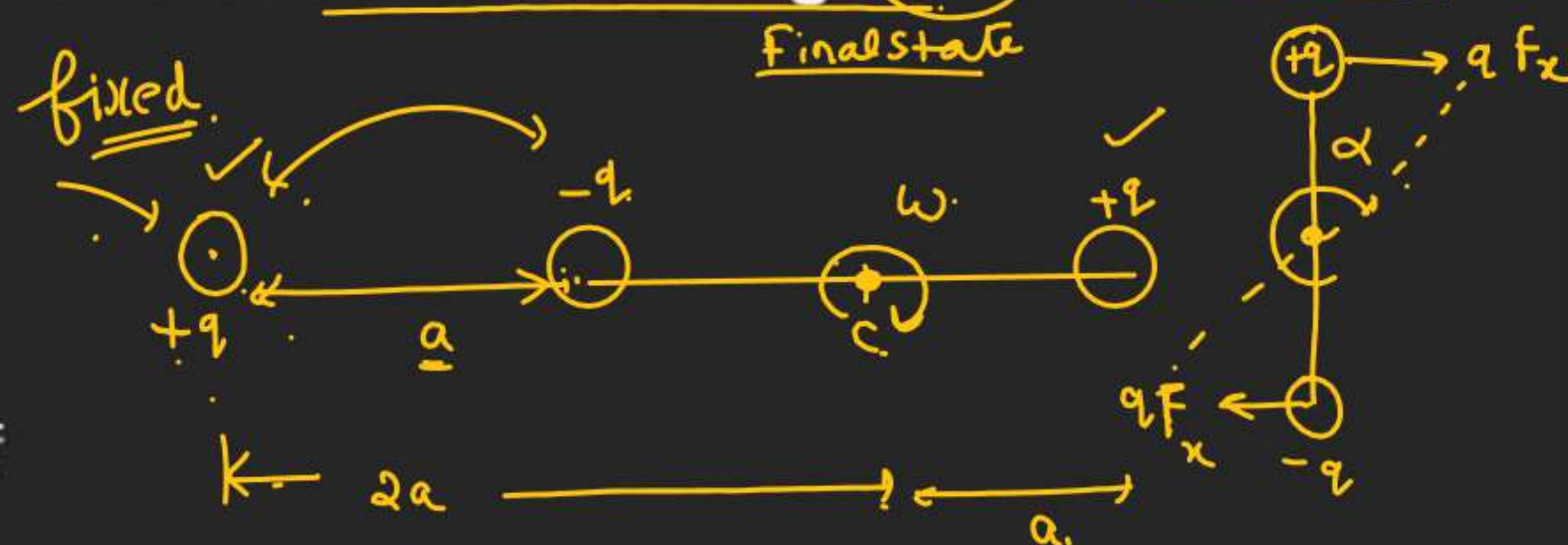
Q. Fig. shows a ball having a charge q fixed at a point A. Two identical balls of mass m having charge $+q$ and $-q$ are attached to the end of a light rod of length $2a$. The system is released from the situation shown in fig. Find the angular velocity of the rod when the rod turns through 90° :

(A) $\frac{\sqrt{2}q}{3\pi\epsilon_0 ma^3}$

(B) $\frac{q}{\sqrt{3\pi\epsilon_0 ma^3}}$

(C) $\frac{q}{\sqrt{6\pi\epsilon_0 ma^3}}$

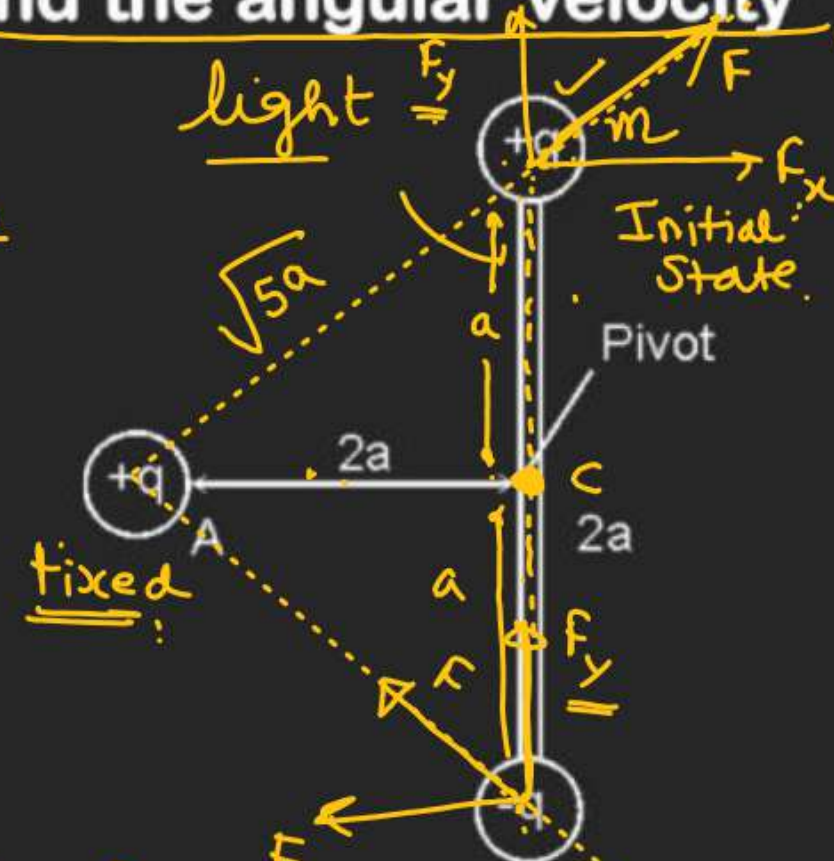
(D) $\frac{\sqrt{2}q}{4\pi\epsilon_0 ma^3}$



$$U_i + K.E_i = U_f + K.E_f$$

$$\left(\frac{kq^2}{\sqrt{5}a} - \frac{kq^2}{\sqrt{5}a} \right) + 0 = \left(\frac{kq^2}{a} + \frac{kq^2}{3a} \right) + \frac{1}{2} (ma^2) \omega^2 \times 2$$

$$\Rightarrow \omega = ??$$



$$+\frac{kq^2}{a} - \frac{kq^2}{3a} = ma^2\omega^2$$

$$\frac{kq^2}{a} \left(1 - \frac{1}{3}\right) = ma^2\omega^2.$$

$$\frac{2}{3} \frac{kq^2}{a} = ma^2\omega^2$$

$$\omega = \sqrt{\frac{2kq^2}{3ma^3}}$$

$$\omega = \sqrt{\frac{\frac{2}{3} \times \frac{1}{4\pi\epsilon_0} \times q^2}{ma^3}} = \sqrt{\frac{q^2}{ma^3 6\pi\epsilon_0}} = \frac{q}{\sqrt{ma^3 6\pi\epsilon_0}}$$

POTENTIAL ENERGY

$$\frac{mu^2}{2} = \frac{3kq^2}{20R} \Rightarrow u = \sqrt{\frac{3kq^2}{10R}}$$

H.W.

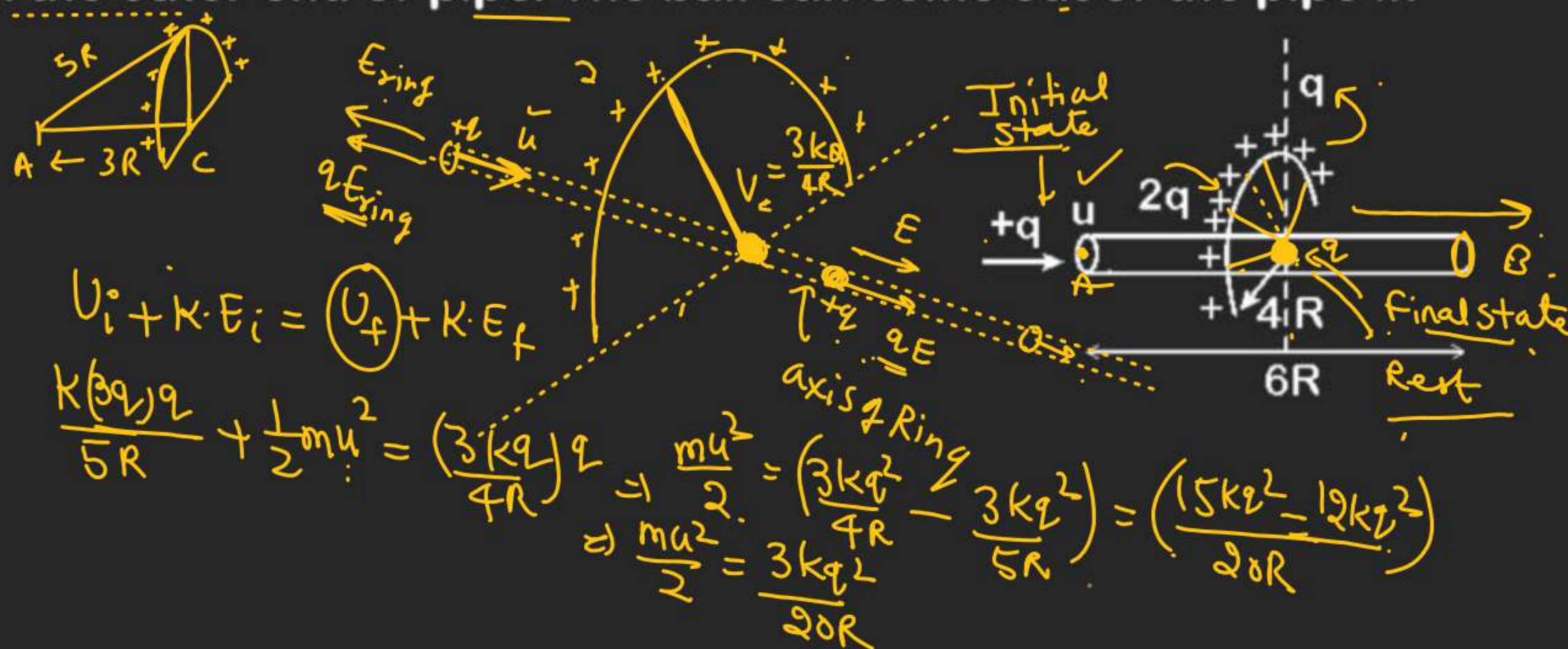
Q. On a semicircular ring of radius $= 4R$, charge $+3q$ is distributed in such a way that on one quarter $+q$ is uniformly distributed and on another quarter $+2q$ is uniformly distributed. Along its axis a smooth non-conducting and uncharged pipe of length $6R$ is fixed axially as shown. A small ball of mass m and charge $+q$ is thrown from the other end of pipe. The ball can come out of the pipe if:

(A) $u > \sqrt{\frac{7q^2}{40\pi\epsilon_0 Rm}}$

(B) $u > \sqrt{\frac{3q^2}{40\pi\epsilon_0 Rm}}$

(C) $u \geq \sqrt{\frac{3q^2}{40\pi\epsilon_0 Rm}}$

(D) $u > \sqrt{\frac{9q^2}{40\pi\epsilon_0 Rm}}$



ELECTRIC POTENTIAL

Q. Four ^{H.W.} equal point charges Q each are placed in the xy plane at $(0, 2)$, $(4, 2)$, $(4, -2)$ and $(0, -2)$. The work required to put a fifth charge Q at the origin of the coordinate system will be **[JEE (Main)-2019]**

(A) $\frac{Q^2}{2\sqrt{2}\pi\epsilon_0}$

(B) $\frac{Q^2}{4\pi\epsilon_0} \left(1 + \frac{1}{\sqrt{3}} \right)$

(C) $\frac{Q^2}{4\pi\epsilon_0}$

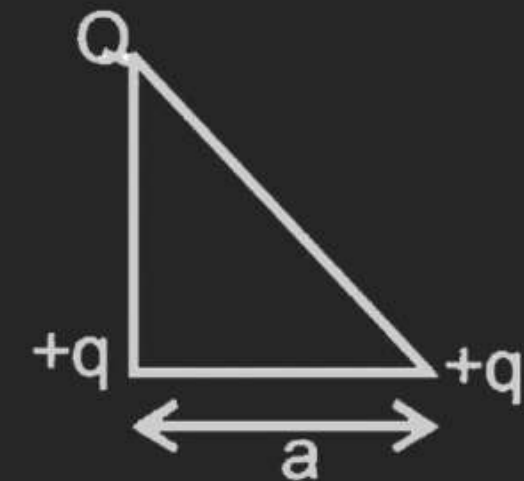
(D) $\frac{Q^2}{4\pi\epsilon_0} \left(1 + \frac{1}{\sqrt{5}} \right)$

ELECTRIC POTENTIAL

H.W.

Q. Three charges $Q, +q$ and $+q$ are placed at the vertices of a right-angle isosceles triangles as shown below. The net electrostatic energy of the configuration is zero, if the value of Q is

[JEE (Main)-2019]



(A) $\frac{-\sqrt{2}q}{\sqrt{2}+1}$

(B) $+q$

(C) $-2q$

(D) $\frac{-q}{1+\sqrt{2}}$

ELECTRIC POTENTIAL

H.W.

Q. The electric field in a region is given by $\vec{E} = (Ax + B)\hat{i}$, where E is in NC^{-1} and x is in meters. The values of constants are $A = 20\text{SI unit}$ and $B = 10\text{SI unit}$. If the potential at $x = 1$ is V_1 and that at $x = -5$ is V_2 , then $V_1 - V_2$ is :

[JEE (Main)-2019]

- (A) 180 V**
- (B) -520 V**
- (C) 320 V**
- (D) -48 V**

ELECTRIC POTENTIAL

H.W.

Q. A positive point charge is released from rest at a distance r_0 from a positive line charge with uniform density. The speed (v) of the point charge, as a function of instantaneous distance r from line charge is proportional to :

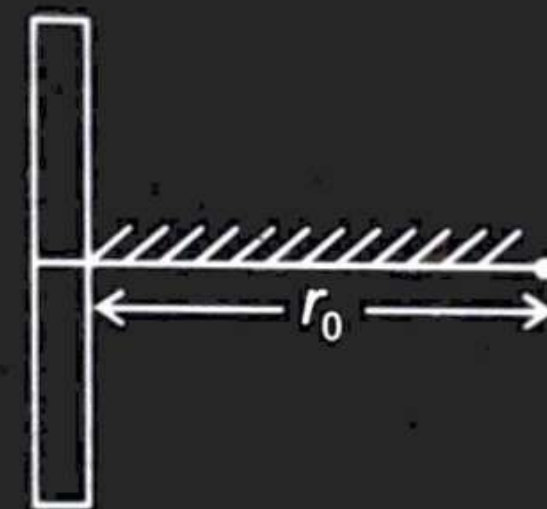
[JEE (Main)-2019]

(A) $v \propto \sqrt{\ln \left(\frac{r}{r_0} \right)}$

(B) $v \propto e^{+r/r_0}$

(C) $v \propto \ln \left(\frac{r}{r_0} \right)$

(D) $v \propto \left(\frac{r}{r_0} \right)$



ELECTRIC POTENTIAL*H.W.*

Q. A uniformly charged ring of radius $3a$ and total charge q is placed in xy -plane centred at origin. A point charge q is moving towards the ring along the z -axis and has speed v at $z = 4a$. The minimum value of v such that it crosses the origin is :

[JEE (Main)-2019]

(A) $\sqrt{\frac{2}{m} \left(\frac{1}{15} \frac{q^2}{4\pi\epsilon_0 a} \right)^{1/2}}$

(B) $\sqrt{\frac{2}{m} \left(\frac{1}{5} \frac{q^2}{4\pi\epsilon_0 a} \right)^{1/2}}$

(C) $\sqrt{\frac{2}{m} \left(\frac{4}{15} \frac{q^2}{4\pi\epsilon_0 a} \right)^{1/2}}$

(D) $\sqrt{\frac{2}{m} \left(\frac{2}{15} \frac{q^2}{4\pi\epsilon_0 a} \right)^{1/2}}$

ELECTRIC POTENTIAL

H.W.

Q. A two point charges $4q$ and $-q$ are fixed on the x -axis at $x = -\frac{d}{2}$ and $x = \frac{d}{2}$, respectively. If a third point charge ' q ' is taken from the origin to $x = d$ along the semicircle as shown in the figure the energy of the charge will

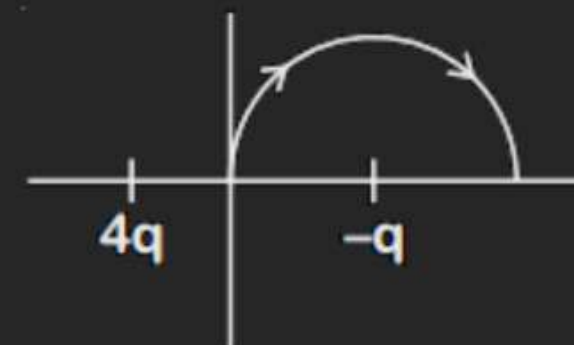
[JEE (Main)-2020]

(A) Decrease by $\frac{q^2}{4\pi\epsilon_0 d}$

(B) Decrease by $\frac{4q^2}{3\pi\epsilon_0 d}$

(C) Increase by $\frac{2q^2}{3\pi\epsilon_0 d}$

(D) Increase by $\frac{3q^2}{4\pi\epsilon_0 d}$



ELECTRIC POTENTIAL

H.W.

Q. A solid sphere of radius R carries a charge $Q + q$ distributed uniformly over its volume. A very small point like piece of it of mass m gets detached from the bottom of the sphere and falls down vertically under gravity. This piece carries charge q . If it acquires a speed v when it has fallen through a vertical height y (see figure), then (assume the remaining portion to be spherical).

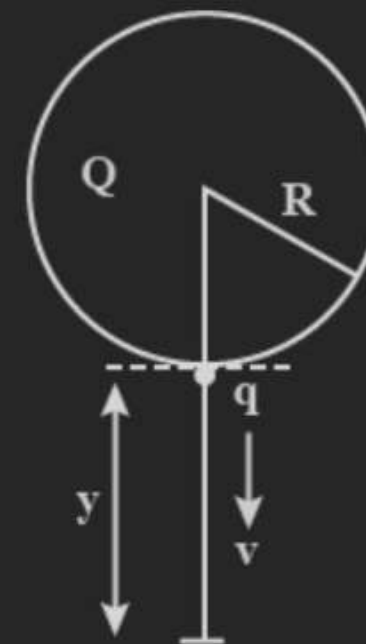
(A) $v^2 = y \left[\frac{qQ}{4\pi\epsilon_0 R(R+y)m} + g \right]$

(B) $v^2 = 2y \left[\frac{qQR}{4\pi\epsilon_0 (R+y)^3 m} + g \right]$

(C) $v^2 = y \left[\frac{qQ}{4\pi\epsilon_0 R^2 y m} + g \right]$

(D) $v^2 = 2y \left[\frac{qQ}{4\pi\epsilon_0 R(R+y)m} + g \right]$

[JEE (Main)-2020]



ELECTRIC POTENTIAL

H.W.

Q. Similar drops of mercury are maintained at 10 V each. All these spherical drops combine into a single big drop. The potential energy of the bigger drop is _____ times that of a smaller drop.

[JEE (Main)-2021]