Physicsaholics

DPP – 3 (Electrostatics)

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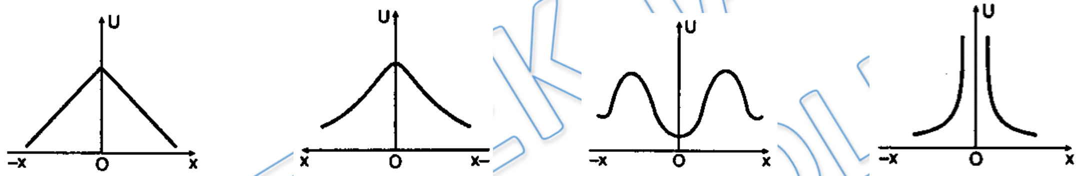
Q 1. Three point charges q, — 2q and —2q are placed at the vertices of an equilateral triangle of side a. The work done by some external force to increase their separation to 2a will be

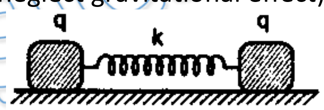
(a) $\frac{1}{4\pi\varepsilon_0}.\frac{2q^2}{a}$ (b) negative (c) zero (d) $\frac{1}{4\pi\varepsilon_0}.\frac{3q^2}{a}$

Q 2. Four equal charges of magnitude q each are placed at four corners of a square with its centre at origin and lying in y-z plane. A fifth charge +Q is moved along x-axis. The electrostatic potential energy (U) of system varies on shifting +Q on x-axis as:



(a) (b) (c) (d)

Q 3. Two identical particles of charge q each are connected by a massless spring of force constant k. They are placed over a smooth horizontal surface. They are released when the separation between them is r and spring is unstretched. If maximum extension of the spring is r, the value of square root of k is: (neglect gravitational effect)

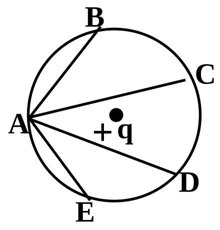


(a) $\frac{q}{4r}\sqrt{\frac{1}{\pi\varepsilon_0 r}}$ (b) $\frac{q}{2r}\sqrt{\frac{1}{\pi\varepsilon_0 r}}$ (c) $\frac{2q}{r}\sqrt{\frac{1}{\pi\varepsilon_0 r}}$ (d) $\frac{q}{r}\sqrt{\frac{1}{\pi\varepsilon_0 r}}$

Q 4. Two point positive charges q each are fixed at (a, 0) and (- a, 0). A third point positive charge Q is placed at origin. Electrostatic potential energy of the system will:

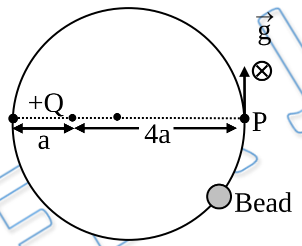
(a) increase if Q is slightly displaced along x-axis
(b) decrease if Q is slightly displaced along x-axis
(c) increase if Q is slightly displaced along y- axis
(d) decrease if Q is slightly displaced along y-axis

Q 5. In the electric field due to a point charge q, a test charge is carried from A to the points B, C, D and E lying on the same circle around q. The work done is



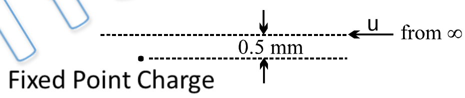
(a) the least along AB
(b) the least along AD
(c) zero along any of the paths AB, AD, AC and AE
(d) the least along AE

Q 6. 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 energy of system when bead is at the point P is U. The velocity with which the bead should projected from the point P so that it can complete a circle should be greater than



(a) $\sqrt{\frac{6U}{m}}$ (b) $\sqrt{\frac{U}{m}}$ (c) $\sqrt{\frac{3U}{m}}$ (d) None of these

Q 7. A particle of mass 1 kg & charge $\frac{1}{3}\mu C$ is projected towards a non-conducting fixed charge ($\frac{1}{3}\mu C$). Initially the point charge is far away from the sphere Impact parameter [Initial perpendicular distance of line of projection from Fixed charge] is 0.5 mm. Find the minimum initial velocity of projection required if minimum distance between two particles in subsequent motion is 1mm?



(a) $\sqrt{\frac{2}{3}}$m/s (b) $2\sqrt{\frac{2}{3}}$m/s (c) $\frac{2}{3}$m/s (d) $4\sqrt{\frac{2}{3}}$m/s

Q 8. Three Positive point charges 1μC, 2μC and 8μC are to be placed on a 9 cm long straight line. Minimum possible electrostatic potential energy of system is
(a) 1.6 J (b) 2.6 J
(c) 3.4J (d) None of these

Q 9. A particle of mass m charge q is projected from large distance with velocity v towards another particle of mass m and charge 2q along line joining them. Second particle was initially stationary. Velocity of second particle after long time will be
(a) v/4 (b) v/2 (c) v/3 (d) v

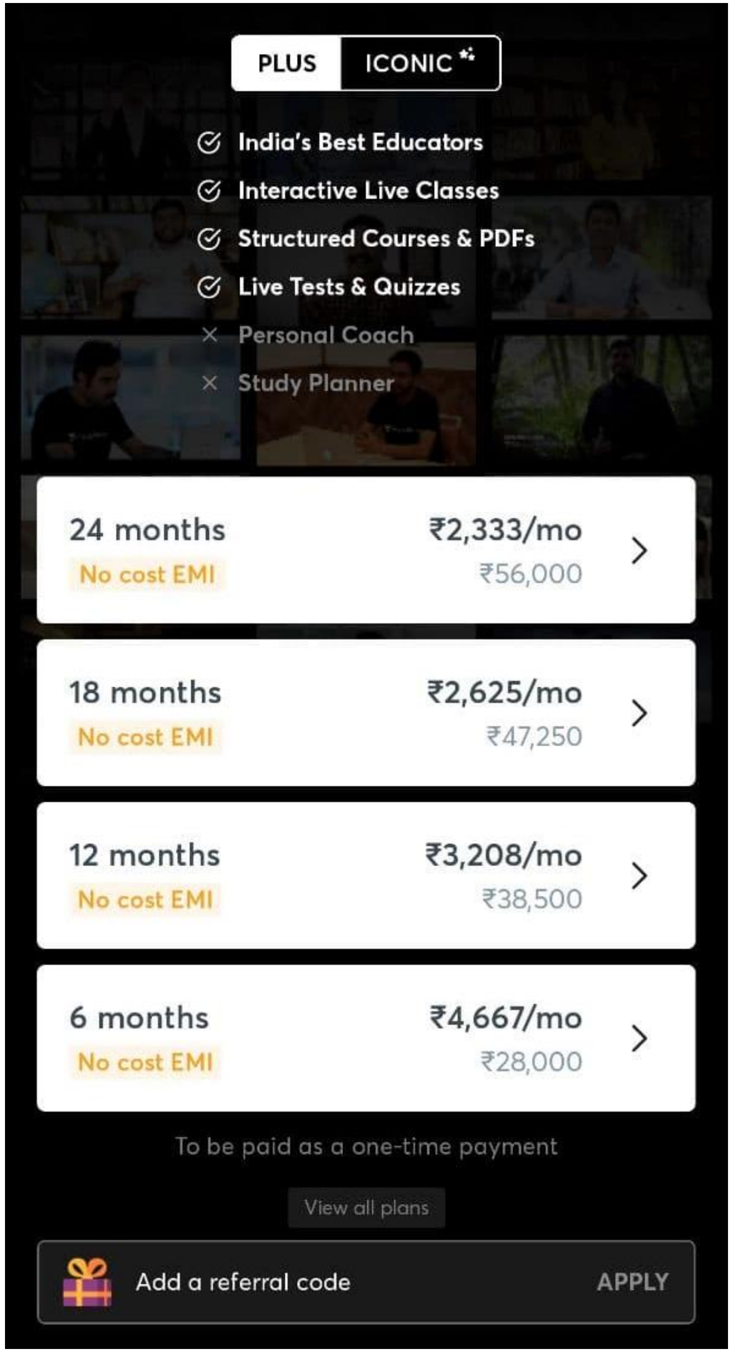
Q 10. Two paricles are released from infinte separation . First particle has mass m charge +q and second particle has mass 2m and charge – Q. Due to electrostatic force they move towards each other. There relative velocity at separation x is

(a) $\sqrt{\frac{2kQq}{mx}}$ (b) $\sqrt{\frac{3kQq}{mx}}$

(c) $\sqrt{\frac{kQq}{2mx}}$ (d) $\sqrt{\frac{2kQq}{3mx}}$

Answer Key

Q.1 c	**Q.2 b**	**Q.3 b**	**Q.4 a, d**	**Q.5 c**
Q.6 a	**Q.7 b**	**Q.8 c**	**Q.9 d**	**Q.10 b**



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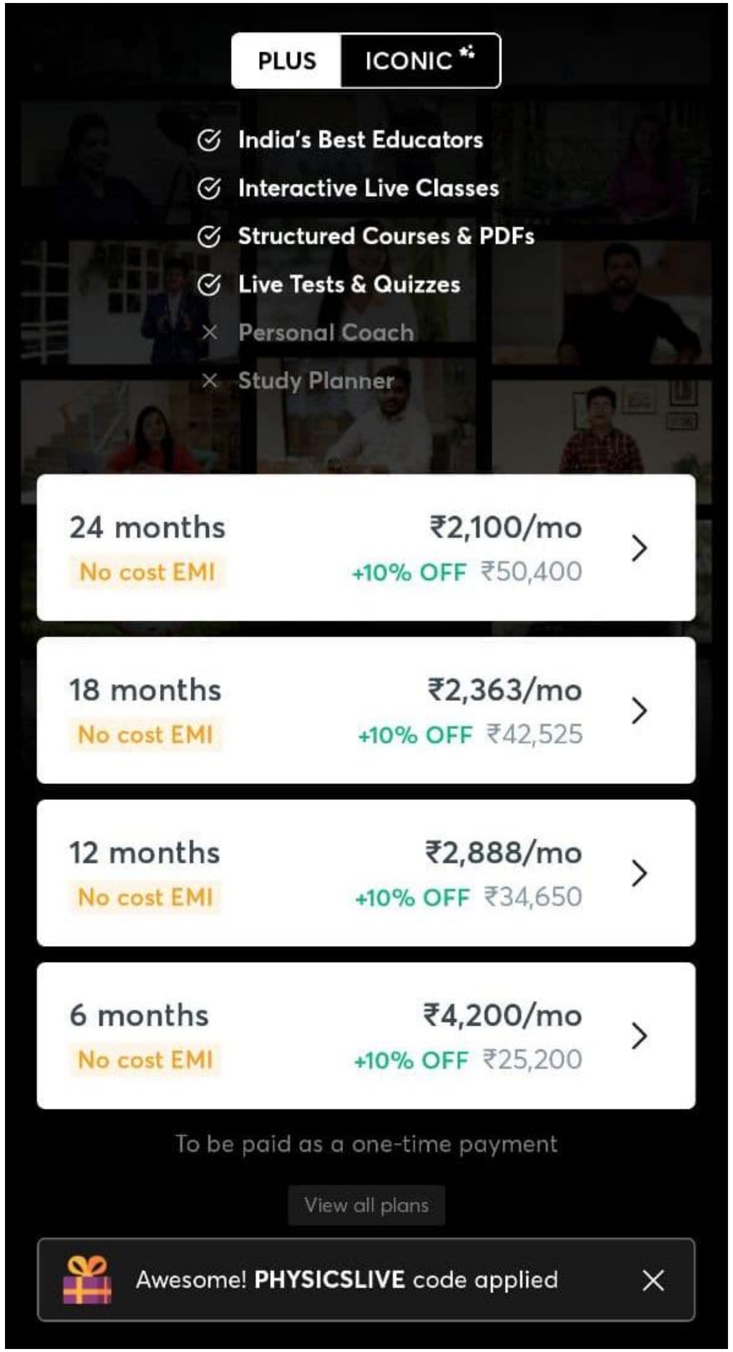

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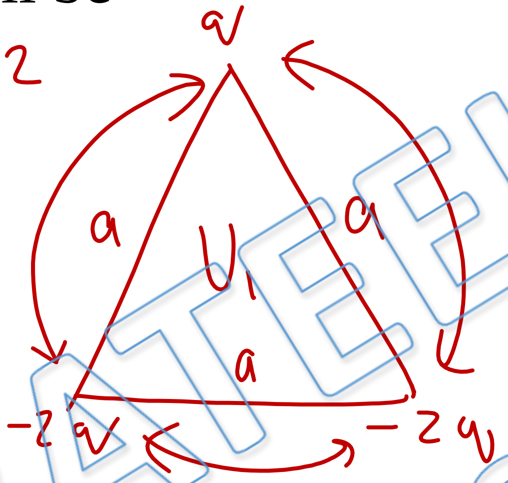
Written Solution

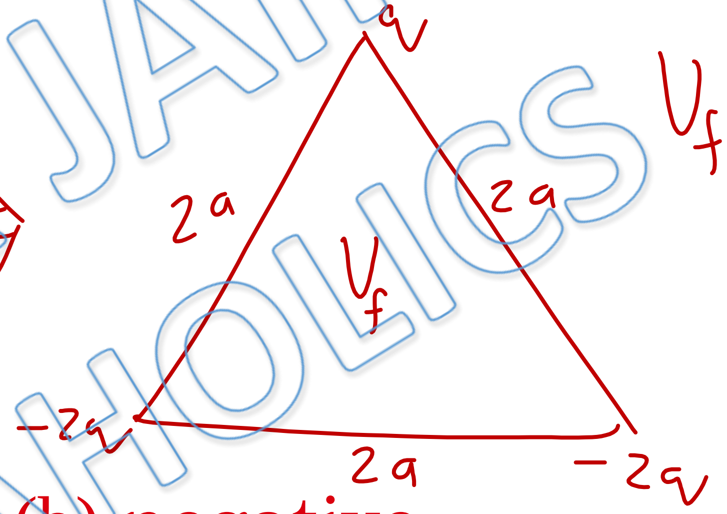
DPP-3 Electrostatics : Electrostatic Potential Energy

By Physicsaholics Team

Q1) Three point charges q, — 2q and —2q are placed at the vertices of an equilateral triangle of side a. The work done by some external force to increase their separation to 2a will be

$$U_i = -\frac{2Kq^2}{a} \times 2 + \frac{4Kq^2}{a} = 0$$





$U_f = 0$

(a) $\frac{1}{4\pi\varepsilon_0} \cdot \frac{2q^2}{a}$

(b) negative

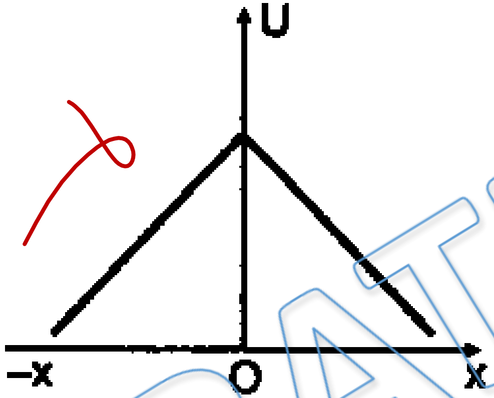
(c) zero

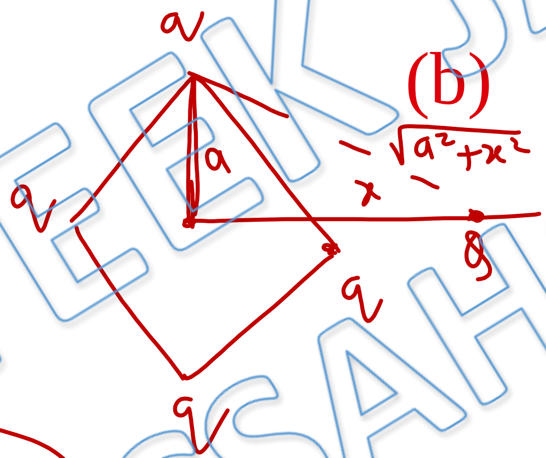
(d) $\frac{1}{4\pi\varepsilon_0} \cdot \frac{3q^2}{a}$

$$W = \Delta U = U_f - U_i = 0$$

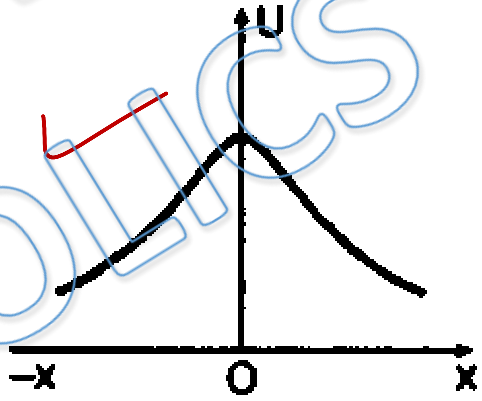
Q2) Four equal charges of magnitude q each are placed at four corners of a square with its centre at origin and lying in y-z plane. A fifth charge +Q is moved along x-axis. The electrostatic potential energy (U) of system varies on shifting +Q on x-axis as:

(a)





(b)



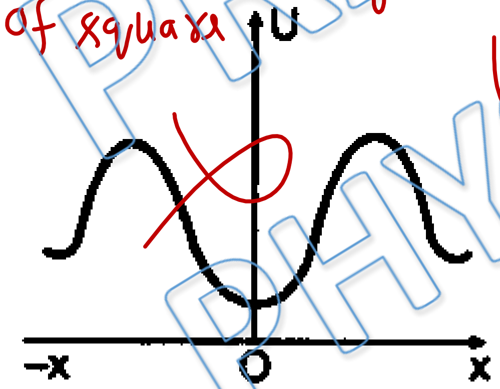
PE of pairs of charges of square

$$U = C + \frac{4KqQ}{\sqrt{a^2+x^2}}$$

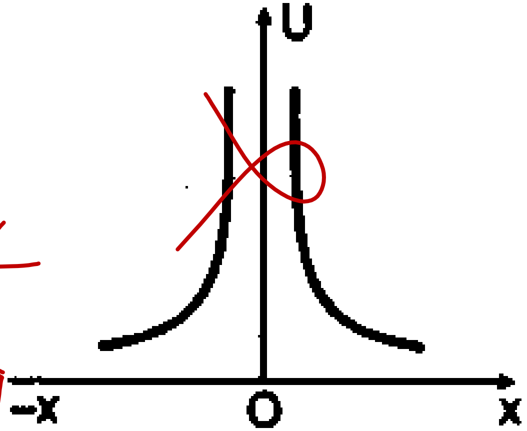
at $x = 0$, $U = C + \frac{4KqQ}{a}$

U decreases on increasing x

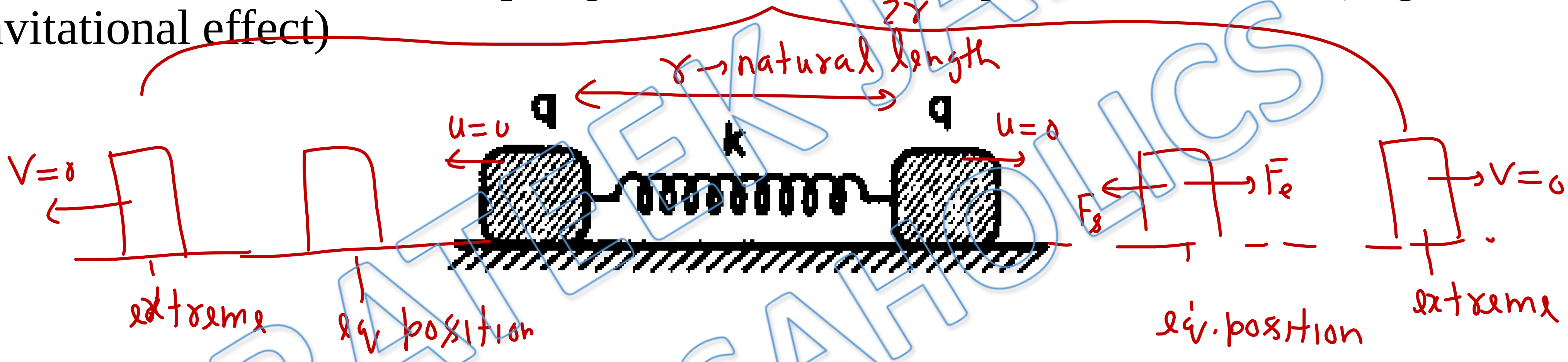
(c)



(d)



Q3) Two identical particles of charge q each are connected by a massless spring of force constant k. They are placed over a smooth horizontal surface. They are released when the separation between them is r and spring is unstretched. If maximum extension of the spring is r, the value of square root of k is: (neglect gravitational effect)



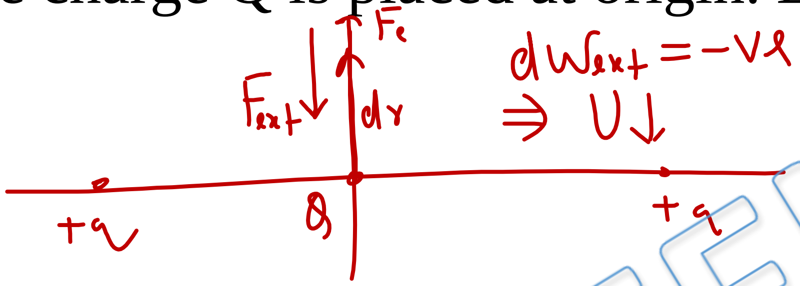
(a) $\frac{q}{4r}\sqrt{\frac{1}{\pi\varepsilon_0 r}}$ (b) $\frac{q}{2r}\sqrt{\frac{1}{\pi\varepsilon_0 r}}$ (c) $\frac{2q}{r}\sqrt{\frac{1}{\pi\varepsilon_0 r}}$ (d) $\frac{q}{r}\sqrt{\frac{1}{\pi\varepsilon_0 r}}$

by Conservation of M. Energy →

$$0 + 0 + \frac{q^2}{4\pi\epsilon_0 r} = 0 + \frac{1}{2}kr^2 + \frac{q^2}{4\pi\epsilon_0 \times 2r}$$

$$\frac{q^2}{2\times 4\pi\epsilon_0 r} = \frac{1}{2}kr^2 \qquad K = \frac{q^2}{4r^2 \times \pi\epsilon_0 r}$$

Q4) Two point positive charges q each are fixed at (a, 0) and (- a, 0). A third point positive charge Q is placed at origin. Electrostatic potential energy of the system will:



(a) increase if Q is slightly displaced along x-axis ✓

(b) decrease if Q is slightly displaced along x-axis

(c) increase if Q is slightly displaced along y- axis

(d) decrease if Q is slightly displaced along y-axis ✓

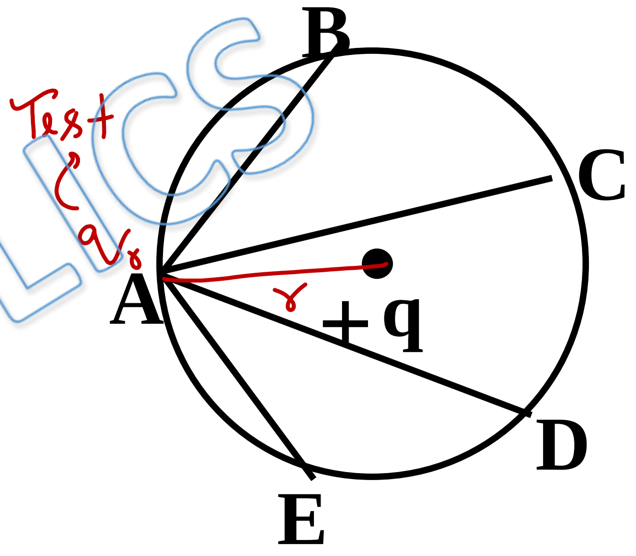
$dW_{ext} = +ve$

$\Rightarrow U \uparrow$

Q5) In the electric field due to a point charge q, a test charge is carried from A to the points B, C, D and E lying on the same circle around q. The work done is

$W = \Delta U = 0$ in all cases

$V_A = \frac{K q q_0}{r} = V_B = V_C = V_D = V_E$



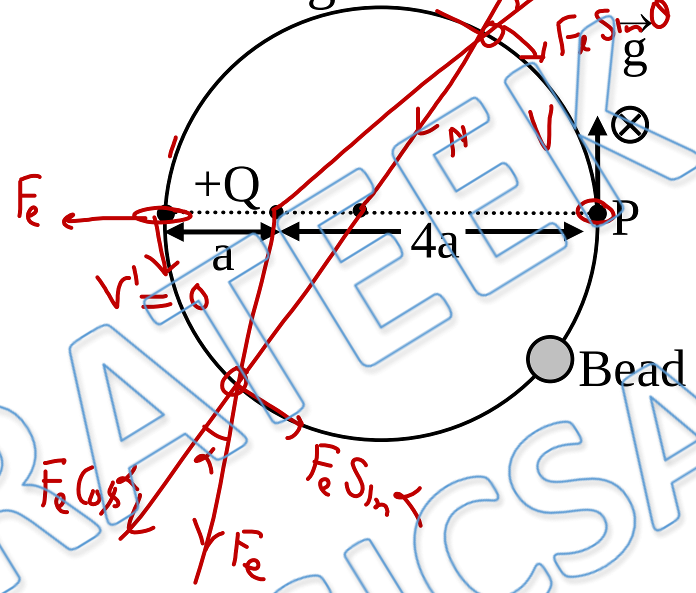
(a) the least along AB

(b) the least along AD

(c) zero along any of the paths AB, AD, AC and AE ✓

(d) the least along AE

Q6) 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 energy of system when bead is at the point P is U. The velocity with which the bead should projected from the point P so that it can complete a circle should be greater than



(a) $\sqrt{\frac{6U}{m}}$

(b) $\sqrt{\frac{U}{m}}$

(c) $\sqrt{\frac{3U}{m}}$

(d) None of these

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

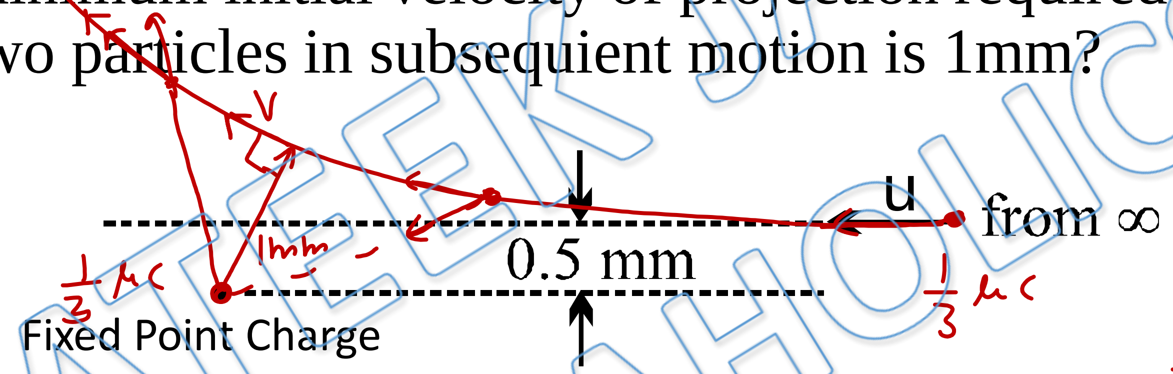
by Conservation of mechanical energy →

$U + \frac{1}{2}mv^2 = 4U + 0$

$\frac{1}{2}mv^2 = 3U$

$v = \sqrt{\frac{6U}{m}}$

Q7) A particle of mass 1 kg & charge $\frac{1}{3}\mu C$ is projected towards a non conducting fixed charge ($\frac{1}{3}\mu C$) .initially the point charge is far away from the sphere Impact parameter [Initial perpendicular distance of line of projection from Fixed charge] is 0.5 mm. Find the minimum initial velocity of projection required if minimum distance between two particles in subsequient motion is 1mm?



by Conservation of angular momentum →

$1 \times u \times 5\times10^{-3} = 1 \times v \times 10^{-3}$

$u = 2v$ —— (1)

(a) $\sqrt{\frac{2}{3}}$m/s (b) $2\sqrt{\frac{2}{3}}$m/s (c) $\frac{2}{3}$m/s (d) $4\sqrt{\frac{2}{3}}$m/s

by Conservation of M energy →

$0 + \frac{1}{2}\times1\,u^2 = \frac{9\times10^9 \times \frac{1}{9}\times10^{-12}}{10^{-3}} + \frac{1}{2}\times1\,v^2$

$\frac{u^2 - v^2}{2} = 1 \Rightarrow \frac{3u^2}{8} = 1 \Rightarrow u = \sqrt{8/3} = 2\sqrt{2/3}$

Q8) Three Positive point charges 1μC, 2μC and 8μC are to be placed on a 9 cm long straight line. Minimum possible electrostatic potential energy of system is

+8μC, F=0, +2μC
1μC
x cm = 6 cm, (9−x) cm = 3 cm

minimum PE ⇒ equilibrium position

$$F = 0 \Rightarrow \frac{K \times 8\mu \times 1\mu}{(x\ cm)^2} = \frac{K \times 2\mu \times 1\mu}{((9-x)\ cm)^2}$$

$$\frac{2}{x} = \frac{1}{(9-x)}$$

$$18 - 2x = x$$

$$3x = 18$$

$$x = 6$$

$$U_{min} = 9\times10^9\left[\frac{16\mu^2}{9\times10^{-2}} + \frac{8\mu^2}{6\times10^{-2}} + \frac{2\mu^2}{3\times10^{-2}}\right]$$

$$= \frac{9\times10^9\mu^2}{10^{-2}}\left[\frac{16+12+6}{9}\right]$$

$$= 10^{-1}\times 34$$

$$= 3.4\ J$$

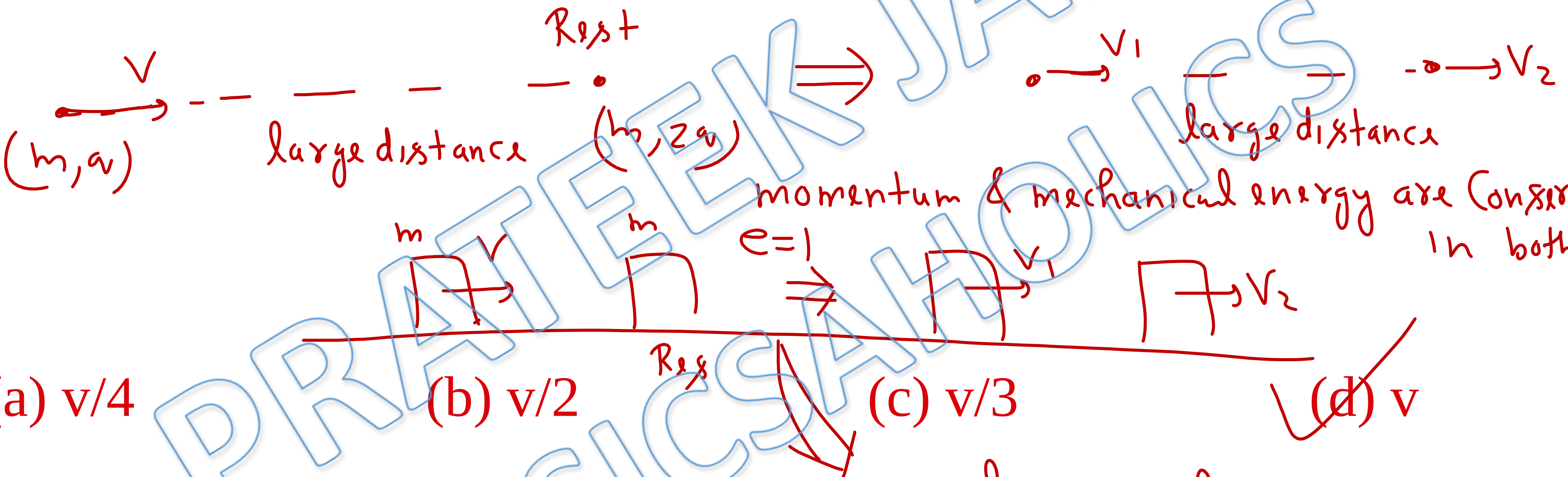
(a) 1.6 J

(b) 2.6 J

(c) 3.4J

(d) None of these

Q9) A particle of mass m charge q is projected from large distance with velocity v towards another particle of mass m and charge 2q along line joining them. Second particle was initially stationary. Velocity of second particle after long time will be



momentum & mechanical energy are conserved in both cases

(a) v/4 (b) v/2 (c) v/3 (d) v

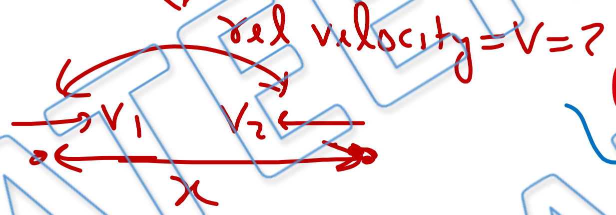
equal mass, elastic collision

$V_1 = 0, \; V_2 = V$

KE of two particle system from CM frame $= \frac{1}{2}\mu V_{rel}^2$ where $\mu = \frac{m_1 m_2}{m_1+m_2} = \frac{m \times 2m}{3m} = 2m/3$

Q10) Two paricles are released from infinte separation . First particle has mass m charge +q and second particle has mass 2m and charge – Q. Due to electrostatic force they move towards each other. There relative velocity at separation x is

(m, q) u = 0 large distance (2m, −Q) u = 0



(a) $\sqrt{\frac{2kQq}{mx}}$

(b) $\sqrt{\frac{3kQq}{mx}}$ ✓

(c) $\sqrt{\frac{kQq}{2mx}}$

(d) $\sqrt{\frac{2kQq}{3mx}}$

1st Method →

by Conservation of momentum

$0 + 0 = mV_1 - 2mV_2$

$V_1 = 2V_2$ --- (1)

by Conservation of M energy

$0 + 0 = \frac{1}{2}mV_1^2 + \frac{1}{2}\times 2mV_2^2 - \frac{KQq}{x}$ --- (II)

$V = V_1 + V_2 = ?$

2nd Method →

Here CM is inertial

by COME from CM frame →

$0 + 0 = \frac{1}{2}\mu V^2 - \frac{KQq}{x}$

$\frac{1}{2}\times\frac{2m}{3}V^2 = \frac{KQq}{x} \Rightarrow V = \sqrt{\frac{3KQq}{mx}}$

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