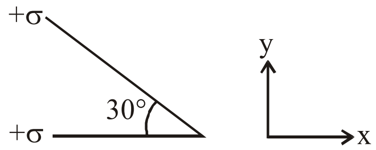
ELECTROSTATICS

1. Two infinite planes each with uniform surface charge density + σ are kept in such a way that the angle between them is 30°. The electric field in the region shown between them is given by:



(1) $\frac{\sigma}{\varepsilon_0}\left[\left(1+\frac{\sqrt{3}}{2}\right)\hat{y}+\frac{\hat{x}}{2}\right]$

(2) $\frac{\sigma}{2\varepsilon_0}\left[\left(1-\frac{\sqrt{3}}{2}\right)\hat{y}-\frac{\hat{x}}{2}\right]$

(3) $\frac{\sigma}{2\varepsilon_0}\left[\left(1+\sqrt{3}\right)\hat{y}+\frac{\hat{x}}{2}\right]$

(4) $\frac{\sigma}{2\varepsilon_0}\left[\left(1+\sqrt{3}\right)\hat{y}-\frac{\hat{x}}{2}\right]$

2. In finding the electric field using Gauss Law the formula $|\vec{E}|=\frac{q_{enc}}{\varepsilon_0 |A|}$ is applicable. In the formula ε_0 is permittivity of free space, A is the area of Gaussian surface and q_{enc} is charge enclosed by the Gaussian surface. The equation can be used in which of the following situation?

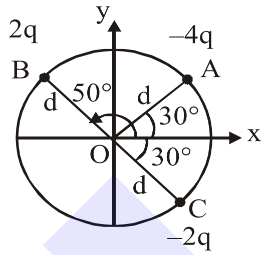
(1) Only when the Gaussian surface is an equipotential surface.

(2) Only when $|\vec{E}|$ = constant on the surface.

(3) For any choice of Gaussian surface.

(4) Only when the Gaussian surface is an equipotential surface and $|\vec{E}|$ is constant on the surface.

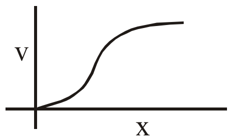
3. Three charged particle A, B and C with charges –4q, 2q and –2q are present on the circumference of a circle of radius d. the charged particles A, C and centre O of the circle formed an equilateral triangle as shown in figure. Electric field at O along x-direction is :



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

(3) $\frac{3\sqrt{3}\,q}{4\pi\varepsilon_0 d^2}$ (4) $\frac{\sqrt{3}\,q}{\pi\varepsilon_0 d^2}$

4. A particle of mass m and charge q is released from rest in a uniform electric field. If there is no other force on the particle, the dependence of its speed v on the distance x travelled by it is correctly given by (graphs are schematic and not drawn to scale)

(1)


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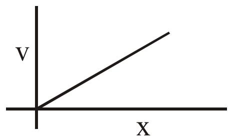
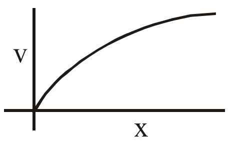


(3)


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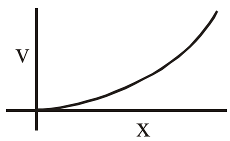
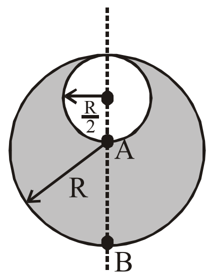


5. Consider two charged metallic spheres S_1 and S_2 of radii R_1 and R_2, respectively. The electric fields E_1 (on S_1) and E_2 (on S_2) on their surfaces are such that $E_1/E_2 = R_1/R_2$. Then the ratio V_1 (on S_1) / V_2 (on S_2) of the electrostatic potentials on each sphere is :

(1) (R_2/R_1) (2) $\left(\frac{R_1}{R_2}\right)^3$

(3) R_1/R_2 (4) $(R_1/R_2)^2$

6. Consider a sphere of radius R which carries a uniform charge density ρ. If a sphere of radius $\frac{R}{2}$ is carved out of it, as shown, the ratio $\frac{|\vec{E}_A|}{|\vec{E}_B|}$ of magnitude of electric field $\vec{E}_A$ and $\vec{E}_B$, respectively, at points A and B due to the remaining portion is :



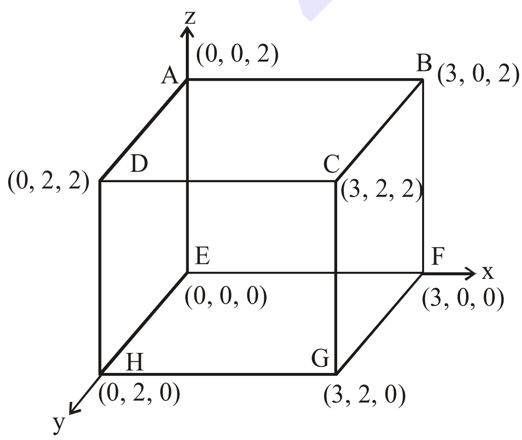
(1) $\frac{18}{54}$ (2) $\frac{21}{34}$ (3) $\frac{17}{54}$ (4) $\frac{18}{34}$

7. An electric dipole of moment $\vec{p} = (-\hat{i} - 3\hat{j} + 2\hat{k}) \times 10^{-29}$ C .m is at the origin (0, 0, 0). The electric field due to this dipole at $\vec{r} = +\hat{i} + 3\hat{j} + 5\hat{k}$ (note that $\vec{r}.\vec{p} = 0$) is parallel to :

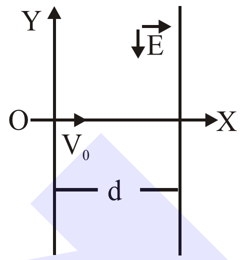
(1) $(-\hat{i} + 3\hat{j} - 2\hat{k})$ (2) $(+\hat{i} - 3\hat{j} - 2\hat{k})$

(3) $(+\hat{i} + 3\hat{j} - 2\hat{k})$ (4) $(-\hat{i} - 3\hat{j} + 2\hat{k})$

8. An electric field $\vec{E} = 4x\hat{i} - (y^2 + 1)\hat{j}$ N/C passes through the box shown in figure. The flux of the electric field through surfaces ABCD and BCGF are marked as ϕ_I and ϕ_{II} respectively. The difference between $(\phi_I - \phi_{II})$ is (in Nm^2/C) ___________.



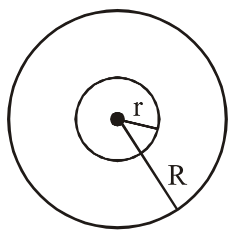
9. A charged particle (mass m and charge q) moves along X axis with velocity V_0. When it passes through the origin it enters a region having uniform electric field $\vec{E} = -E\hat{j}$ which extends upto x = d. Equation of path of electron in the region x > d is :



(1) $y = \frac{qEd}{mV_0^2}\left(\frac{d}{2} - x\right)$ (2) $y = \frac{qEd}{mV_0^2}(x - d)$

(3) $y = \frac{qEd}{mV_0^2}x$ (4) $y = \frac{qEd^2}{mV_0^2}x$

10. A charge Q is distributed over two concentric conducting thin spherical shells radii r and R (R > r). If the surface charge densities on the two shells are equal, the electric potential at the common centre is :



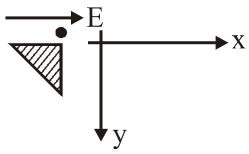
(1) $\frac{1}{4\pi\varepsilon_0}\frac{(R+2r)Q}{2(R^2+r^2)}$

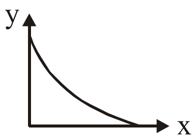
(2) $\frac{1}{4\pi\varepsilon_0}\frac{(R+r)}{2(R^2+r^2)}Q$

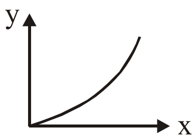
(3) $\frac{1}{4\pi\varepsilon_0}\frac{(R+r)}{(R^2+r^2)}Q$

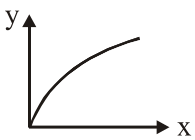
(4) $\frac{1}{4\pi\varepsilon_0}\frac{(2R+r)}{(R^2+r^2)}Q$

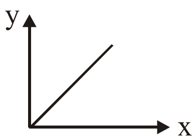
11. A small point mass carrying some positive charge on it, is released from the edge of a table. There is a uniform electric field in this region in the horizontal direction. Which of the following options then correctly describe the trajectory of the mass ? (Curves are drawn schematically and are not to scale).



(1) 

(2) 

(3) 

(4) 

12. Two isolated conducting spheres S_1 and S_2 of radius $\frac{2}{3}R$ and $\frac{1}{3}R$ have 12 μC and –3 μC charges, respectively, and are at a large distance from each other. They are now connected by a conducting wire. A long time after this is done the charges on S_1 and S_2 are respectively :

(1) 6 μC and 3 μC (2) +4.5 μC and –4.5 μC
(3) 3 μC and 6 μC (4) 4.5 μC on both

13. Concentric metallic hollow spheres of radii R and 4R hold charges Q_1 and Q_2 respectively. Given that surface charge densities of the concentric spheres are equal, the potential difference V(R) – V(4R) is:

(1) $\frac{3Q_1}{16\pi\varepsilon_0 R}$

(2) $\frac{Q_2}{4\pi\varepsilon_0 R}$

(3) $\frac{3Q_1}{4\pi\varepsilon_0 R}$

(4) $\frac{3Q_2}{4\pi\varepsilon_0 R}$

14. Which of the following will NOT be observed when a multimeter (operating in resistance measuring mode) probes connected across a component, are just reversed?

(1) Multimeter shows NO deflection in both cases i.e. before and after reversing the probes if the chosen component is capacitor.

(2) Multimeter shows a deflection,accompanied by a splash of light out of connected component in one direction and NO deflection on reversing the probes if the chosen component is LED.

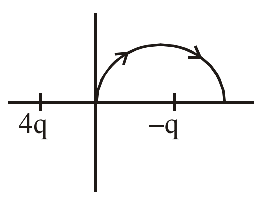
(3) Multimeter shows NO deflection in both cases i.e. before and after reversing the probes if the chosen compoenent is metal wire.

(4) Multimeter shows an equal deflection in both cases i.e. before and after reversing the probes if the chosen component is resistor.

15. Two resistors 400Ω and 800Ω are connected in series across a 6 V battery. The potential difference measured by a voltmeter of 10 kΩ across 400 Ω resistor is close to:

(1) 2 V (2) 1.95V (3) 2.05 V (4) 1.8 V

16. 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 :



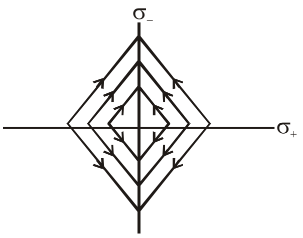
(1) increase by $\frac{2q^2}{3\pi\varepsilon_0 d}$

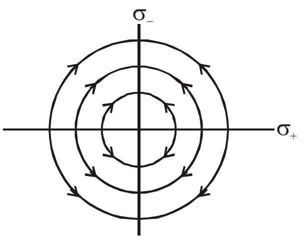
(2) increase by $\frac{3q^2}{4\pi\varepsilon_0 d}$

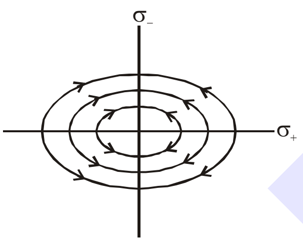
(3) decrease by $\frac{4q^2}{3\pi\varepsilon_0 d}$

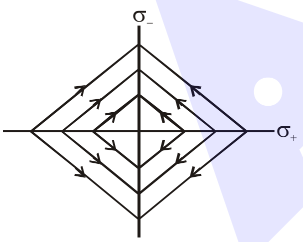
(4) decrease by $\frac{q^2}{4\pi\varepsilon_0 d}$

17. Two charged thin infinite plane sheets of uniform surface charge density σ_+ and σ_- where $|\sigma_+| > |\sigma_-|$ intersect at right angle. Which of the following best represents the electric field lines for this system :

(1)


(2)


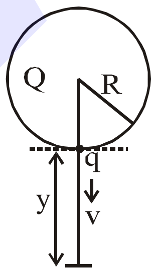
(3)


(4)


18. A particle of charge q and mass m is subjected to an electric field $E = E_0(1 - ax^2)$ in the x-direction, where a and E_0 are constants. Initially the particle was at rest at x = 0. Other than the initial position the kinetic energy of the particle becomes zero when the distance of the particle from the origin is :

(1) $\sqrt{\frac{2}{a}}$ (2) $\sqrt{\frac{1}{a}}$ (3) a (4) $\sqrt{\frac{3}{a}}$

19. 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).



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

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

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

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

20. Ten charges are placed on the circumference of a circle of radius R with constant angular separation between successive charges. Alternate charges 1, 3, 5, 7, 9 have charge (+q) each, while 2, 4, 6, 8, 10 have charge (–q) each. The potential V and the electric field E at the centre of the circle are respectively:
(Take V = 0 at infinity)

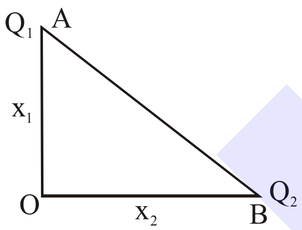
(1) $V = \frac{10q}{4\pi\epsilon_0 R}; E = \frac{10q}{4\pi\epsilon_0 R^2}$

(2) $V = 0, E = \frac{10q}{4\pi\epsilon_0 R^2}$

(3) V = 0, E = 0

(4) $V = \frac{10q}{4\pi\epsilon_0 R}; E = 0$

21. Charges Q_1 and Q_2 arc at points A and B of a right angle triangle OAB (see figure). The resultant electric field at point O is perpendicular to the hypotenuse, then Q_1/Q_2 is proportional to :



(1) $\frac{x_2^2}{x_1^2}$ (2) $\frac{x_1^3}{x_2^3}$ (3) $\frac{x_1}{x_2}$ (4) $\frac{x_2}{x_1}$

22. Consider the force F on a charge 'q' due to a uniformly charged spherical shell of radius R carrying charge Q distributed uniformly over it. Which one of the following statements is true for F, if 'q' is placed at distance r from the centre of the shell ?

(1) $F = \frac{1}{4\pi\varepsilon_0}\frac{Qq}{r^2}$ for r > R

(2) $\frac{1}{4\pi\varepsilon_0}\frac{qQ}{R^2} > F > 0$ for r < R

(3) $F = \frac{1}{4\pi\varepsilon_0}\frac{Qq}{r^2}$ for all r

(4) $F = \frac{1}{4\pi\varepsilon_0}\frac{Qq}{R^2}$ for r < R

23. Two identical electric point dipoles have dipole moments $\vec{p}_1 = p\hat{i}$ and $\vec{p}_2 = -p\hat{i}$ and are held on the x axis at distance 'a' from each other. When released, they move along the x-axis with the direction of their dipole moments remaining unchanged. If the mass of each dipole is'm', their speed when they arc infinitely far apart is:

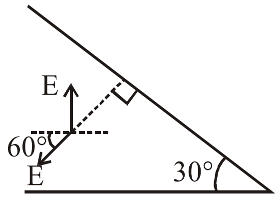
(1) $\frac{p}{a}\sqrt{\frac{1}{\pi\varepsilon_0 ma}}$ (2) $\frac{p}{a}\sqrt{\frac{3}{2\pi\varepsilon_0 ma}}$

(3) $\frac{p}{a}\sqrt{\frac{1}{2\pi\varepsilon_0 ma}}$ (4) $\frac{p}{a}\sqrt{\frac{2}{\pi\varepsilon_0 ma}}$

SOLUTION

1. NTA Ans. (2)

Sol. Electric field due to each sheet is uniform and equal to $E = \dfrac{\sigma}{2\varepsilon_0}$



Now net electric field between plates

$$\vec{E}_{net} = E\cos 60°(-\hat{x}) + (E - E\sin 60°)(\hat{y})$$

$$= \frac{\sigma}{2\varepsilon_0}\left[-\frac{\hat{x}}{2} + \left(1 - \frac{\sqrt{3}}{2}\right)\hat{y}\right].$$

2. NTA Ans. (4)

Sol. $|\vec{E}|$ should be constant on the surface and the surface should be equipotential.

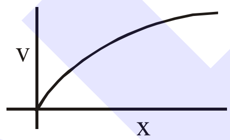
3. NTA Ans. (4)

Sol. $E_x = \dfrac{K(4q)}{R^2}\cos 30° + \dfrac{K(2q)}{R^2}\cos 30° + \dfrac{K(2q)}{R^2}\cos 30°$

4. NTA Ans. (3)

Sol. $v^2 = u^2 + 2as$

$v^2 = 0 + 2\left(\dfrac{qE}{m}\right)x$



$v^2 = \dfrac{2qE}{m}x$

5. NTA Ans. (4)

Sol. $E_1 = \dfrac{KQ_1}{R_1^2}$ $\qquad E_2 = \dfrac{KQ_2}{R_2^2}$

Given,

$$\frac{E_1}{E_2} = \frac{R_1}{R_2}$$

$$\frac{\frac{KQ_1}{R_1^2}}{\frac{KQ_2}{R_2^2}} = \frac{R_1}{R_2} \quad \Rightarrow \quad \boxed{\frac{Q_1}{Q_2} = \frac{R_1^3}{R_2^3}}$$

$$\frac{V_1}{V_2} = \frac{KQ_1/R_1}{KQ_2/R_2} = \frac{R_1^2}{R_2^2}$$

6. NTA Ans. (4)

Sol. Fill the empty space with $+\rho$ and $-\rho$ charge density.

$$|E_A| = 0 + \frac{k\rho.\frac{4}{3}\pi\left(\frac{R}{2}\right)^3}{\left(\frac{R}{2}\right)^2} = k\rho\frac{4}{3}\pi\left(\frac{R}{2}\right)$$

$$|E_B| = \frac{k\rho.\frac{4}{3}\pi R^3}{R^2} - \frac{k\rho.\frac{4}{3}\pi\left(\frac{R}{2}\right)^3}{\left(\frac{3R}{2}\right)^2}$$

$$= k\rho\frac{4}{3}\pi R - k\rho\frac{4}{3}\pi\frac{R}{18} = k\rho.\frac{4}{3}\pi\left(\frac{17R}{18}\right)$$

$$\frac{E_A}{E_B} = \frac{9}{17} = \frac{18}{34}$$

7. NTA Ans. (3)

Sol. Since $\vec{r}$ and $\vec{p}$ are perpendicular to each other therefore point lies on the equitorial plane. Therefore electric field at the point will be antiparallel to the dipole moment.

i.e. $\vec{E} \parallel -\vec{p}$

$$\vec{E} \parallel (\hat{i} + 3\hat{j} - 2\hat{k})$$

8. NTA Ans. (-48.00)

Sol. The flux passes through ABCD (x – y) plane is zero, because electric field parallel to surface.

Flux of the electric field through surface BCGF (y - z)

At BCGF (electric field) $\Rightarrow \vec{E} = 12\hat{i} - (y^2 + 1)\hat{j}$

(x = 3m)

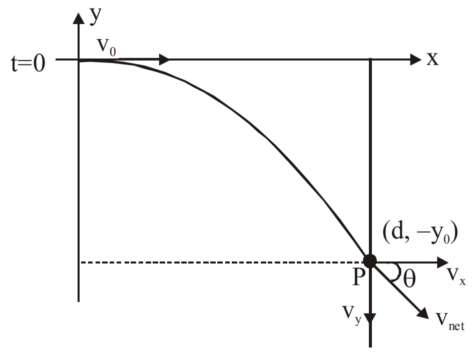
Flux $\phi_{II} = 12 \times 4 = 48$ Nm²/C

So $\phi_I - \phi_{II} = 0 - 48 = -48$ Nm²/C

∴ Correct answer –48

9. Official Ans. by NTA (1)

Sol.



Let particle have charge q and mass 'm'
Solve for (q,m) mathematically
$F_x = 0$, $a_x = 0$, $(v)_x$ = constant

time taken to reach at 'P' = $\frac{d}{v_0} = t_0$ (let) ...(1)

(Along –y), $y_0 = 0 + \frac{1}{2}.\frac{qE}{m}.t_0^2$ ....(2)

$v_x = v_0$

$v = u + at$ (along -ve 'y')

speed $v_{y0} = \frac{qE}{m}.t_0$

$\tan\theta = \frac{v_y}{v_x} = \frac{qEt_0}{m.v_0}, (t_0 = \frac{d}{v_0})$

$\tan\theta = \frac{qEd}{m.v_0^2}$

$$\boxed{\text{slope} = \frac{-qEd}{mv_0^2}}$$

Now we have to find eq^n of straight line whose slope is $\frac{-qEd}{mv_0^2}$ and it pass through point → $(d, -y_0)$

Because after x > d

No electric field ⇒ $F_{net} = 0$, $\vec{v}$ = const.

$y = mx + c$, $\left\{ \begin{matrix} m = \frac{qEd}{mv_0^2} \\ (d, -y_0) \end{matrix} \right\}$

$-y_0 = \frac{-qEd}{mv_0^2}.d + c \Rightarrow c = -y_0 + \frac{qEd^2}{mv_0^2}$

Put the value

$y = \frac{-qEd}{mv_0^2}x - y_0 + \frac{qEd^2}{mv_0^2}$

$y_0 = \frac{1}{2}.\frac{qE}{m}\left(\frac{d}{v_0}\right)^2 = \frac{1}{2}\frac{qEd^2}{mv_0^2}$

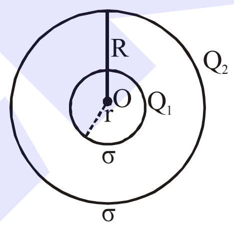
$y = \frac{-qEdx}{mv_0^2} - \frac{1}{2}\frac{qEd^2}{mv_0^2} + \frac{qEd^2}{mv_0^2}$

$y = \frac{-qEd}{mv_0^2}x + \frac{1}{2}\frac{qEd^2}{mv_0^2}$

$$\boxed{y = \frac{qEd}{mv_0^2}\left(\frac{d}{2} - x\right)}$$

10. Official Ans. by NTA (3)

Sol. Let the charges on inner and outer spheres are Q_1 and Q_2.



Since charge density 'σ' is same for both spheres, so

$\sigma = \frac{Q_1}{4\pi r^2} = \frac{Q_2}{4\pi R^2} \Rightarrow \frac{Q_1}{Q_2} = \frac{r^2}{R^2}$

$Q_1 + Q_2 = Q \Rightarrow \frac{Q_2 r^2}{R^2} + Q_2 = Q$

$\Rightarrow Q_2 = \frac{QR^2}{(r^2 + R^2)}$

$Q_1 = \frac{r^2}{R^2}.\frac{QR^2}{(R^2 + r^2)} = \frac{Qr^2}{(R^2 + r^2)}$

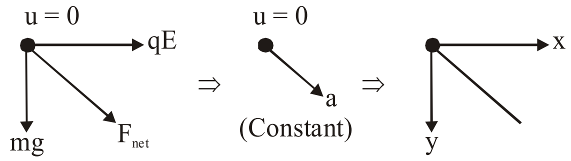
Potential at centre 'O' = $\frac{kQ_1}{r} + \frac{kQ_2}{R}$

$= k\left[\frac{Qr^2}{r(R^2 + r^2)} + \frac{QR^2}{R(R^2 + r^2)}\right]$

$= \frac{kQ(r + R)}{(R^2 + r^2)} = \frac{1}{4\pi\epsilon_0}\frac{(R + r)}{(R^2 + r^2)}Q$

11. Official Ans. by NTA (4)

Sol.



Since initial velocity is zero and acceleration of particle will be constant, so particle will travel on a straight line path.

12. Official Ans. by NTA (1)

Sol. Now

$Q_1 + Q_2 = Q'_1 + Q'_2 = 12\ \mu C - 3\ \mu C = 9\ \mu C$

$\&\ \ V_1 = V_2 \Rightarrow \dfrac{KQ'_1}{\frac{2R}{3}} = \dfrac{KQ'_2}{\frac{R}{3}}$

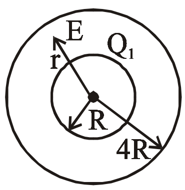
$Q'_1 = 2Q'_2 \Rightarrow 2Q'_2 + Q'_2 = 9\mu C$

$\Rightarrow Q'_2 = 3\ \mu C$

$\&\ \ Q'_1 = 6\ \mu C$

13. Official Ans. by NTA (1)

Sol.



$E = \dfrac{KQ_1}{r^2}$

$\Delta V = \int_R^{4R} E\,dr = \dfrac{3KQ_1}{4R}$

14. Official Ans. by NTA (1)

Sol. (1) Multimeter shows deflection when it connects with capacitor

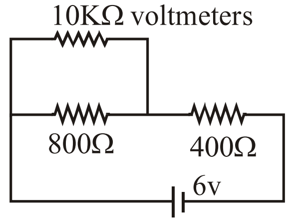
(2) If we assume that LED has negligiable resistance then multimeter shows no deflection for the forward blas but when it connects in reverse direction, it break down occurs so splash of light out.

(3) The resistance of metal wire may be taken zero, so no deflection in multimeter

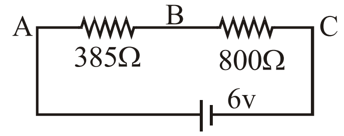
(4) No matter, how we connect the resistance across multimeter It shows same deflection.

15. Official Ans. by NTA (2)

Sol.



$\Rightarrow$



So the potential difference in voltmeter across the points A and B is $\dfrac{6}{1185} \times 385 = 1.949$ V

16. Official Ans. by NTA (3)

Sol. Potential of –q is same as initial and final point of the path therefore potential due to 4q will only change and as potential is decreasing the energy will decrease

Decrease in potential energy = q $(V_i - V_f)$

Decrease in potential energy

$$= q\left[\frac{k4q}{d/2} - \frac{k4q}{3d/2}\right] = \frac{4q^2}{3\pi\varepsilon_0 d}$$

Therefore correct answer is 3.

17. Official Ans. by NTA (1)

Sol. Thin infinite uniformly charged planes produces uniform electric field therefore option 2 and option 3 are obviously wrong.

And as positive charge density is bigger in magnitude so its field along Y direction will be bigger than field of negative charge in X direction and this is evident in option 1 so it is correct.

18. Official Ans. by NTA (4)

Sol. $E = E_0(1 - ax^2)$

$$W = \int qE\,dx = qE_0 \int_0^{x_0} (1 - ax^2)\,dx$$

$$= qE_0\left[x_0 - \frac{ax_0^3}{3}\right]$$

For $\Delta KE = 0$, $W = 0$

Hence $x_0 = \sqrt{\dfrac{3}{a}}$

19. Official Ans. by NTA (1)

Sol. $\frac{kQq}{R} + mgy$

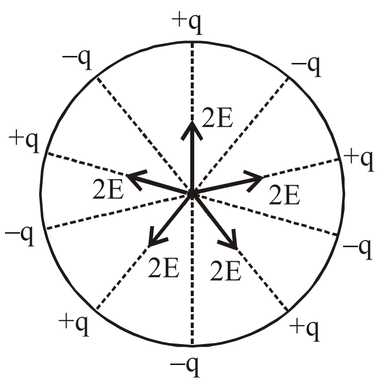
$= \frac{kQq}{R+y} + \frac{1}{2}mv^2$

$v^2 = 2gy + \frac{2kQqy}{mR(R+y)}$

20. Official Ans. by NTA (3)

Sol. Potential of centre = V = $\Sigma\left(\frac{kq}{R}\right)$

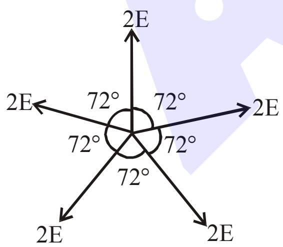
$V_C = \frac{K(\Sigma q)}{R}$



$V_C = \frac{K(0)}{R} = 0$

Electric field at centre $\vec{E}_B = \Sigma\vec{E}$

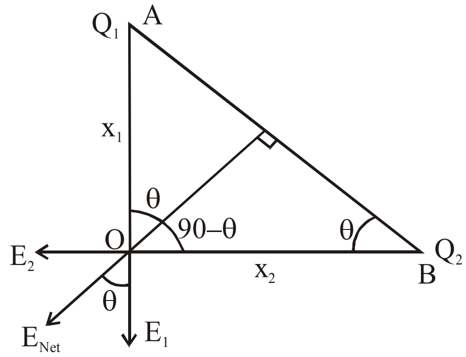
Let E be electric field produced by each charge at the centre, then resultant electric field will be



$E_C = 0$, Since equal electric field vectors are acting at equal angle so their resultant is equal to zero.

21. Official Ans. by NTA (3)

Sol.



E_2 = electric field due to Q_2

$= \frac{kQ_2}{x_2^2}$

$E_1 = \frac{kQ_1}{x_1^2}$

From diagram

$\tan\theta = \frac{E_2}{E_1} = \frac{x_1}{x_2}$

$\frac{kQ_2}{x_2^2 \times \frac{kQ_1}{x_1^2}} = \frac{x_1}{x_2}$

$\frac{Q_2 x_1^2}{Q_1 x_2^2} = \frac{x_1}{x_2}$

$\frac{Q_2}{Q_1} = \frac{x_2}{x_1}$

$\frac{Q_1}{Q_2} = \frac{x_1}{x_2}$

Ans. (3)

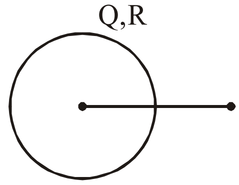
22. Official Ans. by NTA (1)

Sol. Inside the shell

E = 0

hence F = 0

Oustside the sheell



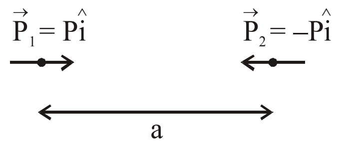
$E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$

hence $F = \frac{1}{4\pi\varepsilon_0}\frac{Qq}{r^2}$ for r > R

23. Official Ans. by NTA (3)

Sol. Using energy conservation:

$KE_i + PE_i = KE_f + PE_f$



$$O + \frac{2KP}{a^3} \times P = \frac{1}{2} mv^2 \times 2 + 0$$

$$V = \sqrt{\frac{2P^2}{4\pi\varepsilon_0 a^3 m}} = \frac{P}{a}\sqrt{\frac{1}{2\pi\varepsilon_0 am}}$$