Electric Charges and Fields

Question1

An electric charge 10^{-6}μC is placed at origin (0,0) m of X − Y co-ordinate system. Two points P and Q are situated at (√3, √3)m and (√6, 0)m respectively. The potential difference between the points P and Q will be :

[27-Jan-2024 Shift 1]

Options:

A.

√3V

B.

√6V

C.

0V

D.

3V

Answer: C

Solution:

Potential difference $= \frac{KQ}{r_1} - \frac{KQ}{r_2}$

$r_1 = \sqrt{(\sqrt{3})^2 + (\sqrt{3})^2}$

$r_2 = \sqrt{(\sqrt{6})^2 + 0}$

As $r_1 = r_2 = \sqrt{6}\mathrm{m}$

So potential difference $= 0$

Question2

A thin metallic wire having cross sectional area of $10^{-4}\mathrm{m}^2$ is used to make a ring of radius 30cm. A positive charge of 2πC is uniformly distributed over the ring, while another positive charge of 30 pC is kept at the centre of the ring. The tension in the ring is ____N ; provided that

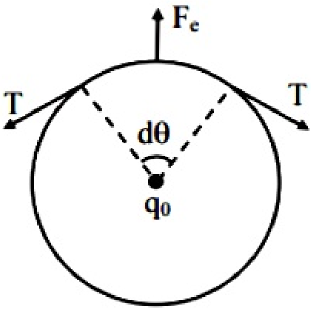
the ring does not get deformed (neglect the influence of gravity).

(given, $\frac{1}{4\pi E_0}$ = 9 × 10^9 SI units)

[27-Jan-2024 Shift 1]

Answer: 3

Solution:



$$2T\sin\frac{d\theta}{2} = \frac{kq_0}{R^2}\cdot\lambda R d\theta$$

$$\left[\lambda = \frac{Q}{2\pi R}\right]$$

$$\Rightarrow T = \frac{Kq_0Q}{(R^2)\times 2\pi}$$

$$= \frac{(9\times 10^9)(2\pi\times 30\times 10^{-12})}{(0.30)^2\times 2\pi}$$

$$= \frac{9\times 10^{-3}\times 30}{9\times 10^{-2}} = 3N$$

Question3

Given below are two statements : one is labelled a

Assertion (A) and the other is labelled as Reason(R)
Assertion (A) : Work done by electric field on moving a positive charge on an equipotential surface is always zero.
Reason (R) : Electric lines of forces are always perpendicular to equipotential surfaces.

In the light of the above statements, choose the most appropriate answer from the options given below :

[27-Jan-2024 Shift 2]

Options:

A.

Both (A) and (R) are correct but (R) is not the correct explanation of (A)

B.

((A) is correct but (R) is not correct

C.

(A) is not correct but (R) is correct

D.

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

Answer: D

Solution:

Electric line of force are always perpendicular to equipotential surface so angle between farce and displacement will always be 90∘. So work done equal to 0.

Question4

The electric potential at the surface of an atomic nucleus (z = 50) of radius 9×10^{-13}cm is ____ $\times 10^{6V}$

[27-Jan-2024 Shift 2]

Answer: 8

Solution:

$$\text{Potential} = \frac{kQ}{R} = \frac{k \cdot Ze}{R}$$

$$= \frac{9 \times 10^{9} \times 50 \times 1.6 \times 10^{-19}}{9 \times 10^{-13} \times 10^{-2}}$$

$$= 8 \times 10^{6}\text{V}$$

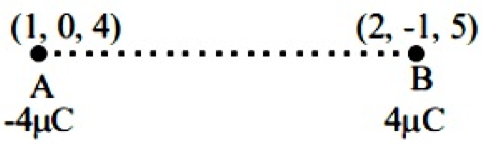
Question5

Two charges of $-4\mu C$ and $+4\mu C$ are placed at the points A(1, 0, 4)m and B(2, −1, 5)m located in an electric field $\vec{E} = 0.20\hat{i}\,\text{V/cm}$. The magnitude of the torque acting on the dipole is $8\sqrt{\alpha} \times 10^{-5}$ Nm, Where α = ____

[27-Jan-2024 Shift 2]

Answer: 2

Solution:



$$\vec{\tau} = \vec{p} \times \vec{E}$$

$$\vec{p} = q\vec{\ell}$$

$$\vec{E} = 0.2\,\frac{V}{cm} = 20\,\frac{V}{m}$$

$$\vec{p} = 4 \times (\hat{i} - \hat{j} + \hat{k})$$

$$= (4\hat{i} - 4\hat{j} + 4\hat{k})\mu C - m$$

$$\vec{\tau} = (4\hat{i} - 4\hat{j} + 4\hat{k}) \times (20\hat{i}) \times 10^{-6}\,Nm$$

$$= (8\hat{k} + 8\hat{j}) \times 10^{-5} = 8\sqrt{2} \times 10^{-5}$$

$$\alpha = 2$$

Question6

Two charges of 5Q and −2Q are situated at the points (3a,0) and (−5a, 0) respectively. The electric flux through a sphere of radius ' 4a ' having center at origin is :

[29-Jan-2024 Shift 1]

Options:

A.

$\frac{2Q}{\varepsilon_0}$

B.

$\frac{5Q}{\varepsilon_0}$

C.

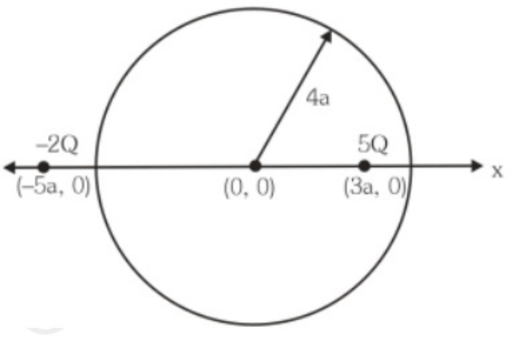
$\frac{7Q}{\varepsilon_0}$

D.

$\frac{3Q}{\varepsilon_0}$

Answer: B

Solution:



5Q charge is inside the spherical region flux through sphere = $5Q/\varepsilon_0$

Question7

Match List I with List II

	List I		List II
A.	$\oint \vec{B} \cdot \vec{dl} = \mu_0 i_c + \mu_0 \varepsilon_0 \frac{d\varphi_E}{dt}$	I.	Gauss law for electricity
B.	$\oint \vec{E} \cdot \vec{dl} = \frac{d\varphi_B}{dt}$	II.	Gauss law for magnetism
C.	$\oint \vec{E} \cdot \vec{dA} = \frac{Q}{\varepsilon_0}$	III.	Faraday law
D.	$\oint \vec{B} \cdot \vec{dA} = 0$	IV.	Ampere -Maxwell law

Choose the correct answer from the options given below

[29-Jan-2024 Shift 1]

Options:

A.

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

B.

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

C.

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

D.

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

Answer: C

Solution:

Ampere-Maxwell law

$\rightarrow \oint \vec{B} \cdot \vec{dl} = \mu_0 i_c + \mu_0 \varepsilon_0 \frac{d\phi_E}{dt}$

Faraday law $\rightarrow \oint \vec{E} \cdot \vec{dl} = \frac{d\phi_B}{dt}$

Gauss' law for electricity $\rightarrow \oint \vec{E} \cdot \vec{dA} = \frac{Q}{\varepsilon_0}$

Gauss ' law for magnetism $\rightarrow \oint \vec{B} \cdot \vec{dA} = 0$

Question8

An electron is moving under the influence of the electric field of a uniformly charged infinite plane sheet S having surface charge density +σ. The electron at t = 0 is at a distance of 1m from S and has a speed of 1m/ s. The maximum value of σ if the electron strikes S at t = 1 s is $\alpha\left[\frac{m\epsilon_0}{e}\right]\frac{C}{m^2}$ the value of α is___

[29-Jan-2024 Shift 1]

Answer: 8

Solution:

$u = 1m/s;\ a = -\frac{\sigma e}{2\varepsilon_0 m}$

$t = 1s$

$S = -1m$

Using $S = ut + \frac{1}{2}at^2$

$-1 = 1 \times 1 - \frac{1}{2} \times \frac{\sigma e}{2\varepsilon_0 m} \times (1)^2$

$\therefore \sigma = 8\frac{\varepsilon_0 m}{e}$

$\therefore \alpha = 8$

Question9

An electric field is given by $(6\hat{i}+5\hat{j}+3\hat{k})N/C$. The electric flux through a surface area $30\hat{i}m^2$ lying in YZ-plane (in SI unit) is :

[29-Jan-2024 Shift 2]

Options:

A.

90

B.

150

C.

180

D.

60

Answer: C

Solution:

$\overrightarrow{E}=6\hat{i}+5\hat{j}+3\hat{k}$

$\overrightarrow{A}=30\hat{i}$

$\phi=\overrightarrow{E}\cdot\overrightarrow{A}$

$\phi=(6\hat{i}+5\hat{j}+3\hat{k})\cdot(30\hat{i})$

$\phi=6\times30=180$

Question10

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

[30-Jan-2024 Shift 1]

Options:

A.

r

B.

$1/r^2$

C.

$1/r^3$

D.

$1/r$

Answer: B

Solution:

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

& can also checked dimensionally

Question11

A particle of charge ' −q' and mass ' m ' moves in a circle of radius ' r ' around an infinitely long line charge of linear density ' +λ '. Then time period will be given as:

(Consider k as Coulomb's constant)

[30-Jan-2024 Shift 2]

Options:

A.

$$T^2 = \frac{4\pi^2 m}{2k\lambda q} r^3$$

B.

$$T = 2\pi r\sqrt{\frac{m}{2k\lambda q}}$$

C.

$$T = \frac{1}{2\pi r}\sqrt{\frac{m}{2k\lambda q}}$$

D.

$$T = \frac{1}{2\pi}\sqrt{\frac{2k\lambda q}{m}}$$

Answer: B

Solution:

$$\frac{2k\lambda q}{r} = m\omega^2 r$$

$$\omega^2 = \frac{2k\lambda q}{mr^2}$$

$$\left(\frac{2\pi}{T}\right)^2 = \frac{2k\lambda q}{mr^2}$$

$$T = 2\pi r\sqrt{\frac{m}{2k\lambda q}}$$

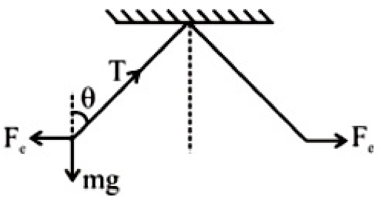
Question12

Two identical charged spheres are suspended by string of equal lengths. The string make an angle of 37° with each other. When suspended in a liquid of density 0.7g/cm^3, the angle remains same. If density of material of the sphere is 1.4g/cm3, the dielectric constant of the liquid is ______ (tan 37° = 3/4).

[30-Jan-2024 Shift 2]

Answer: 2

Solution:



$$T\cos\theta = mg$$

$$T\sin\theta = F_e$$

$$\tan\theta = \frac{F_e}{mg}$$

$$\tan\theta = \frac{F_e}{\rho_B V g} \quad \text{............(i)}$$

$$\tan\theta = \frac{F_e}{\frac{k}{(\rho_B - \rho_L)Vg}} \quad \text{............(ii)}$$

From Eq. (i) & (ii)

$$\rho_B Vg = (\rho_B - \rho_L)kVg$$

$$1.4 = 0.7k$$

$$k = 2$$

Question13

Two charges q and 3q are separated by a distance ' r ' in air. At a distance x from charge q, the resultant electric field is zero. The value of x is :

[31-Jan-2024 Shift 1]

Options:

A.

$$\frac{(1+\sqrt{3})}{r}$$

B.

$$\frac{r}{3(1+\sqrt{3})}$$

C.

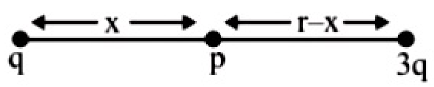
$$\frac{r}{(1+\sqrt{3})}$$

D.

$$r(1+\sqrt{3})$$

Answer: C

Solution:



$$\left(\vec{E}_{\text{net}}\right)_P = 0$$

$$\frac{kq}{x^2} = \frac{k \cdot 3q}{(r-x)^2}$$

$$(r-x)^2 = 3x^2$$

$$r - x = \sqrt{3}x$$

$$x = \frac{r}{\sqrt{3}+1}$$

Question14

Force between two point charges q_1 and q_2 placed in vacuum at ' r ' cm

apart is F. Force between them when placed in a medium having dielectric K = 5 at ' r/5 ' cm apart will be:

[31-Jan-2024 Shift 2]

Options:

A.

F/25

B.

5F

C.

F/5

D.

25F

Answer: B

Solution:

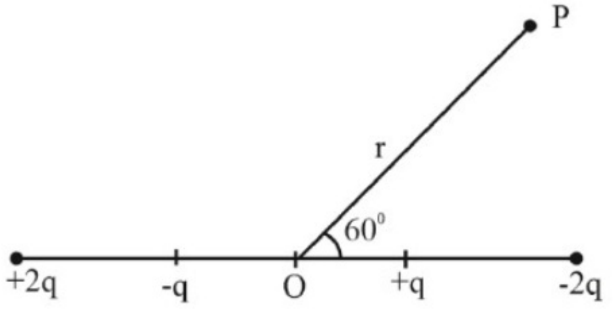
In air $F = \frac{1}{4\pi E_0} \frac{q_1 q_2}{r_2}$

In medium

$$F' = \frac{1}{4\pi(KE_0)} \frac{q_1 q_2}{(r')^2} = \frac{25}{4\pi(5E_0)} \frac{q_1 q_2}{(r)^2} = 5F$$

Question15

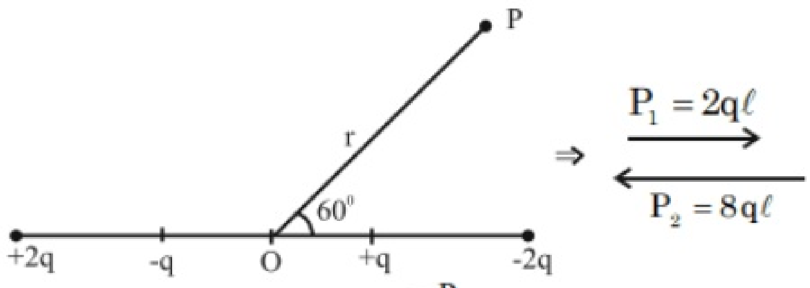
The distance between charges +q and −q is 2l and between +2q and −2q is 4l. The electrostatic potential at point P at a distance r from centre O is $-\alpha\left[\frac{ql}{r^2}\right] \times 10^9 V,$ **where the value of α is (Use $1/4\pi\varepsilon_0 = 9 \times 10^9 NM^2C^{-2}$)**

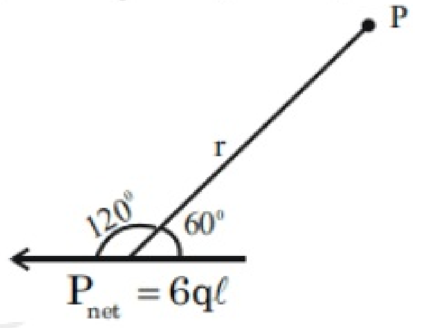


[31-Jan-2024 Shift 2]

Answer: 27

Solution:





$$V = \frac{K\vec{p}\cdot\vec{r}}{r^3} = \frac{9\times10^9(6q\ell)}{r^2}\cos(120^\circ)$$

$$= -(27)\left(\frac{q\ell}{r^2}\right)\times10^9 Nm^2c^{-2}$$

$$\Rightarrow \alpha = 27$$

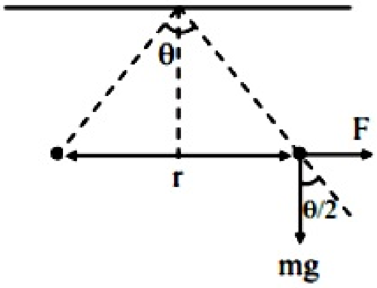
Question16

Two identical charged spheres are suspended by strings of equal lengths. The strings make an angle θ with each other. When suspended in water the angle remains the same. If density of the material of the sphere is 1.5g/cc, the dielectric constant of water will be ________(Take density of water = 1g/cc)

[1-Feb-2024 Shift 1]

Answer: 3

Solution:



In air $\tan\frac{\theta}{2} = \frac{F}{mg} = \frac{q^2}{4\pi\varepsilon_0 r^2 mg}$

In water $\tan\frac{\theta}{2} = \frac{F'}{mg'} = \frac{q^2}{4\pi\varepsilon_0\varepsilon_r r^2 mg_{eff}}$

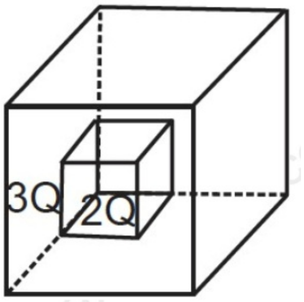
Equate both equations

$\varepsilon_0 g = \varepsilon_0\varepsilon_r g\left[1 - \frac{1}{1.5}\right]$

$\varepsilon_r = 3$

Question17

C_1 and C_2 are two hollow concentric cubes enclosing charges 2Q and 3Q respectively as shown in figure. The ratio of electric flux passing through C_1 and C_2 is :



[1-Feb-2024 Shift 2]

Options:

A.

2 : 5

B.

5 : 2

C.

2 : 3

D.

3 : 2

Answer: A

Solution:

$$\phi_{\text{smaller cube}} = \frac{2Q}{\epsilon_0}$$

$$\phi_{\text{bigger cube}} = \frac{5Q}{\epsilon_0}$$

$$\frac{\phi_{\text{smaller cube}}}{\phi_{\text{bigger cube}}} = \frac{2}{5}$$

Question18

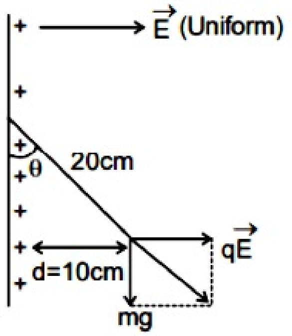
Suppose a uniformly charged wall provides a uniform electric field of 2 × 10^4N/C normally. A charged particle of mass 2g being suspended through a silk thread of length 20cm and remain stayed at a distance of 10cm from the wall. Then the charge on the particle will be $\frac{1}{\sqrt{x}}\mu C$ where x =....[. use g = 10m/ s^2]

[1-Feb-2024 Shift 2]

Options:

Answer: 3

Solution:



$$\sin\theta = \frac{10}{20} = \frac{1}{2}$$

$$\theta = 30^\circ$$

$$\tan\theta = \frac{qE}{mg}$$

$$\tan 30^\circ = \frac{q \times 2 \times 10^4}{1 \times 10^{-3} \times 10}$$

$$\frac{1}{\sqrt{3}} = q \times 10^6$$

$$q = \frac{1}{\sqrt{3}} \times 10^{-6}C$$

$$x = 3$$

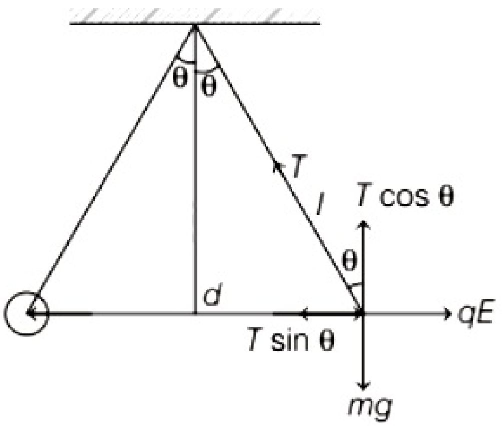
Question19

Two small spheres each of mass 10mg are suspended from a point by threads 0.5m long. They are equally charged and repel each other to a distance of 0.20m. The charge on each of the sphere is $\frac{a}{21} \times 10^{-8}$C. The value of a will be ....
[Given, g = 10ms^{-2}]
[25 Feb 2021 Shift 2]

Answer: 630

Solution:

Given, mass of each spheres, $m = 10mg = 10 \times 10^{-3} g$
Length of thread $(l) = 0.5m$
Separation between charges, $d = 0.2m$
Charge of each sphere, $q = \frac{a}{21} \times 10^{-8} C$
Acceleration due to gravity $(g) = 10 ms^{-2}$
The situation can be shown as below,



Taking component of tension (T)
$T \cos\theta = mg$ . . . (i)
$T \sin\theta = qE = \frac{k \mid q^2}{d^2}$ . . . (ii)

$\sin\theta = \frac{d / 2}{l} = \frac{0.1}{0.5} = \frac{1}{5}$

$\cos\theta = \sqrt{1 - \sin^2\theta} = \sqrt{1 - 1/25} = \frac{\sqrt{24}}{5}$

$\therefore \tan\theta = \frac{\sin\theta}{\cos\theta} = \frac{kq^2}{d^2 mg}$ [using Eqs. (i) and (ii)]

$\Rightarrow \frac{1/5}{\sqrt{24}/5} = \frac{kq^2}{d^2 mg}$

$\Rightarrow \frac{1}{\sqrt{24}} = \frac{9 \times 10^9 \times q^2}{(0.2)^2 \times 10 \times 10^{-3} \times 10}$

$\Rightarrow q = \sqrt{\frac{(0.2)^2 \times 10^{-1}}{\sqrt{24} \times 9 \times 10^9}} \Rightarrow q = 3 \times 10^{-7} C$

$\Rightarrow \frac{a}{21} \times 10^{-8} = 30 \times 10^{-8}$
$a = 630$

Question20

Two identical conducting spheres with negligible volume have 2.1nC and −0.1nC charges, respectively. They are brought into contact and then separated by a distance of 0.5m. The electrostatic force acting between the spheres is ____ $\times 10^{-9}$N .
[Given, $4\pi\varepsilon_0 = \frac{1}{9 \times 10^9}$ SI unit]
[25 Feb 2021 Shift 2]

Answer: 36

Solution:

According to Coulomb's law, the force of attraction or repulsion is directly proportional to the product of distance between them and inversely proportional to the square of the distance between them.

$F = K\frac{q_1 q_2}{r^2}$

Here we have, q_1 is the charge of the first mass, q_2 is the charge of the second mass, r is the distance and K is the proportionally constant.

Given: Charge of first sphere $q_1 = 2.1\,nc$

and Charge of second sphere $q_2 = -0.1\,NC$

when they connect with each other the charge becomes, $q = \frac{q_2 - q_1}{2}$

$\Rightarrow q = \frac{2.1 - 0.1}{2}$

$\Rightarrow q = 1\,nC$

σ

According to Coulomb's law, we have;

$F = \frac{1}{4\pi E_o}\frac{q_1 q_2}{r^2}$

Now, on putting the given values we have;

$F = 9 \times 10^9 \times \frac{1 \times 10^{-9} \times 1 \times 10^{-9}}{0.5^2}$

$F = 9 \times 10^9 \times \frac{10^{-18}}{0.25}$

$\Rightarrow F = 36 \times 10^{-9} N$

Hence, $F = 36 \times 10^{-9} N$

Question21

Two electrons each are fixed at a distance 2d . A third charge proton placed at the mid-point is displaced slightly by a distance x(x< < d) perpendicular to the line joining the two fixed charges. Proton will execute simple harmonic motion having angular frequency? (m = mass of charged particle)
[24 Feb 2021 Shift 2]

Options:

A. $\left(\frac{2q^2}{\pi\varepsilon_0 m d^3}\right)^{\frac{1}{2}}$

B. $\left(\frac{\pi\varepsilon_0 m d^3}{2q^2}\right)^{\frac{1}{2}}$

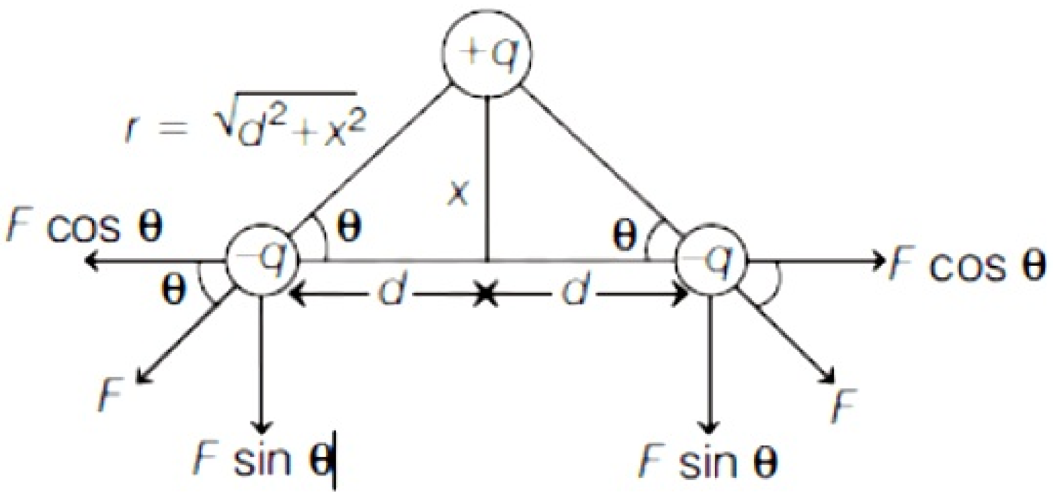
C. $\left(\frac{q^2}{2\pi\varepsilon_0 m d^3}\right)^{\frac{1}{2}}$

D. $\left(\frac{2\pi\varepsilon_0 m d^3}{q^2}\right)^{\frac{1}{2}}$

Answer: C

Solution:

The arrangement of charges is shown below



As we know that,
Coulomb's force between two charges. i.e. q_1 and q_2,

$$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{(d^2 + x^2)} \ldots \text{(i)}$$

Here, $q_1 = q_2 = q$
Force in SHM, $F = m\omega^2 x$ ...(ii)
Since, in order to have SHM $+q$ should move downwards and force responsible for this will be only
$F' = F\sin\theta + F\sin\theta = 2F\sin\theta \ldots$ (iii)
Using Eqs. (ii) and (iii), we get
$2F\sin\theta = m\omega^2 x$

$$\Rightarrow \frac{2}{4\pi\varepsilon_0}\frac{q^2}{(d^2 + x^2)}\sin\theta = m\omega^2 x$$

$$\Rightarrow \frac{2}{4\pi\varepsilon_0}\frac{q^2}{(d^2 + x^2)} \cdot \frac{x}{(d^2 + x^2)^{1/2}} = m\omega^2 x$$

$$\Rightarrow \omega = \left(\frac{1}{2\pi\varepsilon_0}\frac{q^2}{(d^2 + x^2)^{3/2} m}\right)^{1/2}$$

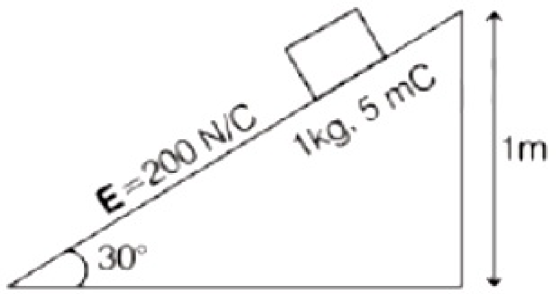
As, $x << d$

$$\therefore \omega = \left(\frac{1}{2\pi\varepsilon_0}\frac{q^2}{md^3}\right)^{1/2}$$

Question22

An inclined plane making an angle of 30° with the horizontal is placed in a uniform horizontal electric field $200N/C$ as shown in the figure. A body of mass 1kg and charge 5mC is allowed to slide down from rest at a height of 1m. If the coefficient of friction is 0.2, find the time taken by the body to reach the bottom.

[Take, $g = 9.8m/s^2$, $\sin 30^\circ = \frac{1}{2}$, $\cos 30^\circ = \frac{\sqrt{3}}{2}$]



[26 Feb 2021 Shift 2]

Options:

A. 0.92 s

B. 0.46 s

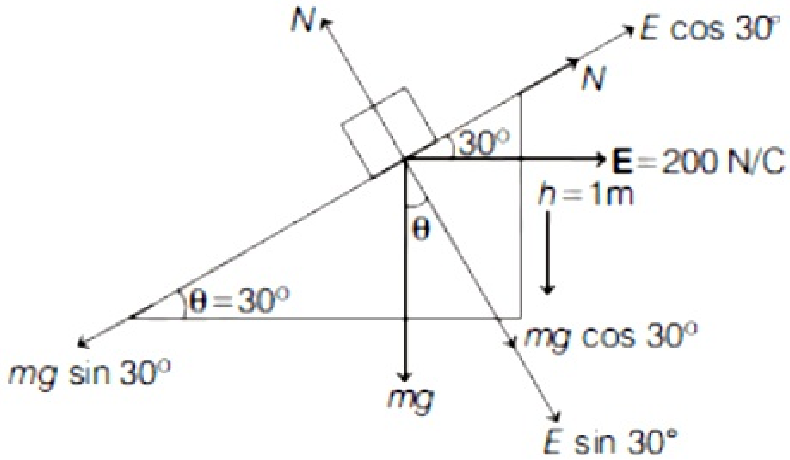
C. 2.3 s

D. 1.3 s

Answer: D

Solution:

Given, mass of block, $m = 1kg$
Acceleration due to gravity, $g = 9.8ms^{-2}$
Inclination, $\theta = 30^{\circ}$
Electric field, $E = 200N / C$
Coefficient of friction, $\mu = 0.2$
Charge, $q = 5mC = 5 \times 10^{-3}C$
Let friction force, $f = \mu N$
where, N be the normal reaction.
Since, net force is zero along the perpendicular direction of incline.

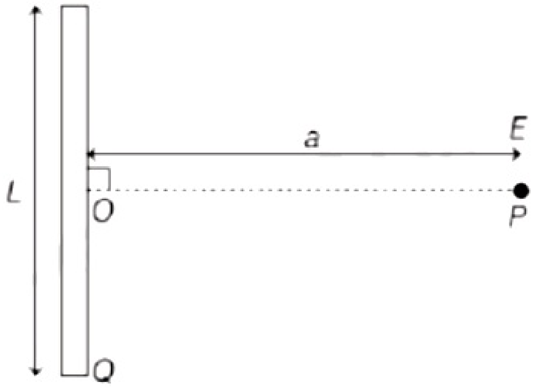


Therefore, force along Y-axis will be zero.
$\Rightarrow N = mg\cos 30^{\circ} + qE \sin 30^{\circ}$
$\Rightarrow N = 1 \times 9.8 \times \sqrt{3} / 2 + 5 \times 10^{-3} \times 200 \times 1 / 2$
$= 8.49 + 0.5$
$= 8.99N \sim eq9N$
$\therefore f = \mu N = \frac{2}{10} \times 9 = \frac{18}{10} = 1.8N$
Now, total force along the plane of incline,
$mg\sin 30^{\circ} - f - qE \cos 30^{\circ} = ma$
$\Rightarrow 1 \times 9.8 \times 1 / 2 - 1.8 - 5 \times 10^{-3} \times 200\sqrt{3} / 2 = a$
$\Rightarrow 5 - 1.8 - 1.732 / 2 = a$
$\Rightarrow a = 2.34ms^{-2}$
Since, initial velocity of body, $u = 0ms^{-1}$ and distance along incline, $s = h / \sin 30^{\circ} = 1 / \sin 30^{\circ} = 2$
By using second equation of motion,
$s = ut + 1 / 2at^2$
$\Rightarrow 2 = 0 + 1 / 2 \times 2.34 \times t^2$
$\Rightarrow t^2 = \frac{4}{2.34}$
$\Rightarrow t = \frac{2}{\sqrt{2.34}}$

Question23

Find the electric field at point P (as shown in figure) on the perpendicular bisector of a uniformly charged thin wire of length L carrying a charge Q. The distance of the point P from the centre of the rod is

a = $\frac{\sqrt{3}}{2}$**L**



[26 Feb 2021 Shift 1]

Options:

A. $\frac{\sqrt{3}Q}{4\pi\varepsilon_0 L^2}$

B. $\frac{Q}{3\pi\varepsilon_0 L^2}$

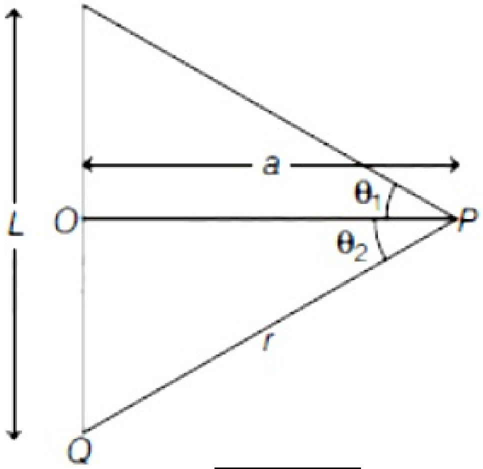
C. $\frac{Q}{2\sqrt{3}\pi\varepsilon_0 L^2}$

D. $\frac{Q}{4\pi\varepsilon_0 L^2}$

Answer: C

Solution:

Given, length of conductor $= L$
Charge on conductor $= Q$
According to figure, $OP = a = \frac{\sqrt{3}}{2}L$, $OQ = \frac{L}{2}$



Let $PQ = r = \sqrt{OP^2 + OQ^2}$

$\Rightarrow PQ = \sqrt{\left(\frac{\sqrt{3}}{2}L\right)^2 + \left(\frac{L}{2}\right)^2} = \sqrt{\frac{3}{4}L^2 + \frac{L}{4}} = L$ and E be the electric field at point P.

Since, E (due to finite wire) $= \frac{k\lambda}{a}(\sin\varphi_1 + \sin\varphi_2)$. . . (i) where, k = Coulomb's constant $= \frac{1}{4\pi\varepsilon_0}$

$\lambda =$ linear charge density $= \frac{Q}{L}$ and $\sin\varphi = \sin\varphi_2 = \frac{L/2}{L} = \frac{1}{2}$

Substituting the above value in Eq. (i), we get

$$E = \frac{k\lambda}{a} = \frac{1}{4\pi\varepsilon_0}\frac{Q}{L\cdot\frac{\sqrt{3}L}{2}} = \frac{1}{2\sqrt{3}\pi\varepsilon_0 L^2}$$

Question24

Given below are two statements:
Statement I An electric dipole is placed at the centre of a hollow sphere. The flux of electric field through the sphere is zero but the electric field is not zero anywhere in the sphere.
Statement II If R is the radius of a solid metallic sphere and Q be the total charge on it. The electric field at any point on the spherical surface of radius r(<R) is zero but the electric flux passing through this closed spherical surface of radius r is not zero.
In the light of the above statements, choose the correct answer from the options given below.
[26 Feb 2021 Shift 2]

Options:

A. Both Statement I and Statement II are true.

B. Statement I is true but Statement II is false.

C. Both Statement I and Statement II are false.

D. Statement I is false but Statement II is true.

Answer: B

Solution:

Net charge on electyric dipole $= +q - q = 0$
Hence, according to Gauss's law,

Electric flux, $\varphi = \frac{q_{net}}{\varepsilon_0} = \frac{0}{\varepsilon_0} = 0$

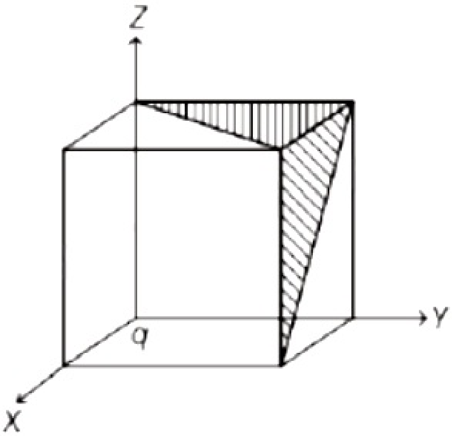
Electric field due to electric dipole is non-zero and varies at point to point.
Hence, statement I is true.
Electric field due to charged solid sphere at a distance r from centre.

$$E = \frac{1}{4\pi\varepsilon_0}\cdot\frac{Qr}{R^3}\left[\begin{array}{c}\text{when } r < R \\ R \rightarrow \text{ radius}\end{array}\right]$$

which is non-zero. Hence, statement II is false. Hence, option (b) is the correct.

Question25

A charge q is placed at one corner of a cube as shown in figure. The flux of electrostatic field E through the shaded area is



[25 Feb 2021 Shift 2]

Options:

A. $\frac{q}{48\varepsilon_0}$

B. $\frac{q}{4\varepsilon_0}$

C. $\frac{q}{8\varepsilon_0}$

D. $\frac{q}{24\varepsilon_0}$

Answer: D

Solution:

Given, charge q is at one of the corner of the cube.
∴ Contribution of q in cube will be $q_{\text{enclosed}} = q / 8$
As, only 3 faces of cube is allowing the flux lines to pass through it.
∴ Flux (φ) = $\frac{q_{\text{enclosed}}}{\varepsilon_0} = \frac{1}{3}\frac{q/8}{\varepsilon_0} = \frac{q}{24\varepsilon_0}$

Question26

The electric field in a region is given $E = \left(\frac{3}{5}E_0\hat{i} + \frac{4}{5}E_0\hat{j}\right)\frac{N}{C}$. The ratio of flux of reported field through the rectangular surface of area $0.2m^2$ (parallel to YZ-plane) to that of the surface of area $0.3m^2$ (parallel to XZ - plane) is a : b, where a = ...
[Here $\hat{i}$, $\hat{j}$ and $\hat{k}$ are unit vectors along X, Y and Z-axes, respectively]
[25 Feb 2021 Shift 1]

Answer: 1

Solution:

Given, $E = \frac{3E_0}{5}\hat{i} + \frac{4}{5}E_0\hat{j}$,

$A_1 = 0.2m^2\hat{i}$ and $A_2 = 0.3m^2\hat{j}$

Let φ_1 and φ_2 be the flux linked with area A_1 and A_2, respectively. As we know that,

$\varphi = \oint E \cdot dS = E \cdot A$

$\Rightarrow \varphi_1 = \left(3/5E_0\hat{i} + 4/5E_0\hat{j}\right) \cdot 0.2\hat{i} = 3/5E_0 \times 0.2$

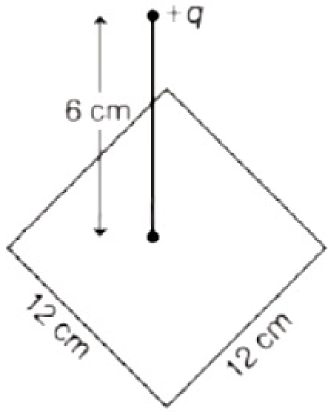
and similarly, $\varphi_2 = 4/5E_0 \times 0.3$

Now, $\frac{\varphi_1}{\varphi_2} = \frac{3/5E_0 \times 0.2}{4/5E_0 \times 0.3} = \frac{0.6}{1.2} = \frac{1}{2}$

$\therefore a = 1$

Question27

A point charge of $+12\mu C$ is at a distance 6cm vertically above the centre of a square of side 12cm as shown in figure. The magnitude of the electric flux through the square will be .... $\times 10^3 N - m^2/C$



[24 Feb 2021 Shift 2]

Answer: 226

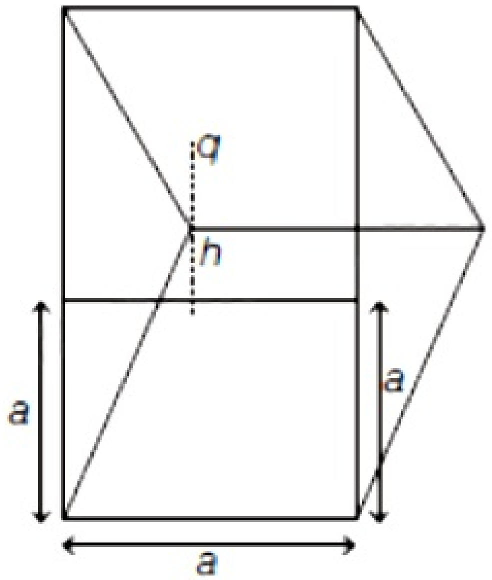
Solution:

Given, charge, $q = 12\mu C = 12 \times 10^{-6}C$

Height of charge from surface, $h = 6cm = 6 \times 10^{-2}m$

and side of square, $a = 12cm = 12 \times 10^{-2}m$

From figure, it is clear that the given square is one of the face of a cube of side $12cm$ and $+12\mu C$ charge is placed at its centre. Then, by Gauss's theorem,



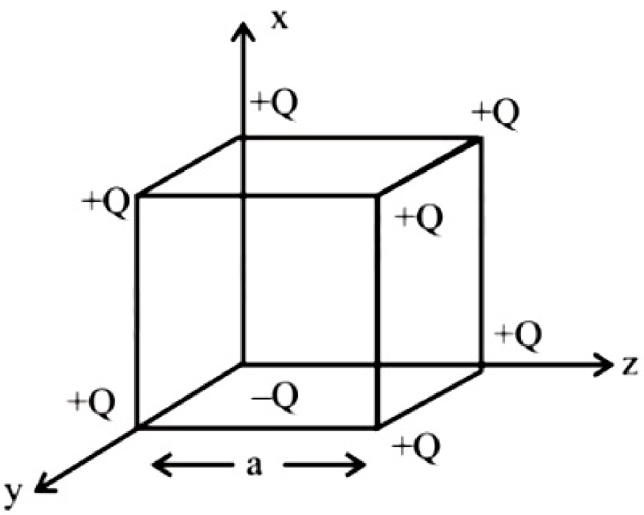
Flux through any face, $\varphi = \dfrac{q}{6\varepsilon_0}$

$$\Rightarrow \varphi = \frac{12 \times 10^{-6}}{6 \times 8.854 \times 10^{-12}} = 0.226 \times 10^{6} \mathrm{N} - \mathrm{m}^2 / \mathrm{C}$$

$$= 226 \times 10^{3} \mathrm{N} - \mathrm{m}^2 / \mathrm{C}$$

Question28

A cube of side ' a ' has point charges +Q located at each of its vertices except at the origin where the charge is −Q. The electric field at the centre of cube is :



{24Feb2021 Shift1}

Options:

A. $\dfrac{3Q}{3\sqrt{3}\pi\varepsilon_0 a^2}\left(\hat{x} + \hat{y} + \hat{z}\right)$

B. $\frac{-2Q}{3\sqrt{3}\pi\varepsilon_0 a^2}\left(\hat{x}+\hat{y}+\hat{z}\right)$

C. $\frac{2Q}{3\sqrt{3}\pi\varepsilon_0 a^2}\left(\hat{x}+\hat{y}+\hat{z}\right)$

D. $\frac{Q}{3\sqrt{3}\pi\varepsilon_0 a^2}\left(\hat{x}+\hat{y}+\hat{z}\right)$

Answer: B

Solution:

Electric field due to all charges will cancel out except two charges $+Q$ and $-Q$ placed along body diagonal.

$$\vec{E}_{-Q}=\frac{-Q}{4\pi\varepsilon_0\frac{3a^2}{4}}\frac{\left(\hat{x}+\hat{y}+\hat{z}\right)}{\sqrt{3}}$$

$$\vec{E}_{+Q}=\frac{-Q}{3\pi\varepsilon_0 a^2}\frac{\left(\hat{x}+\hat{y}+\hat{z}\right)}{\sqrt{3}}$$

Net electric field at the centre of cube is

$$\vec{E}_{net}=\vec{E}_{-Q}+\vec{E}_{+Q}$$
$$=\frac{-2Q}{3\sqrt{3}\pi\varepsilon_0 a^2}\left(\hat{x}+\hat{y}+\hat{z}\right)$$

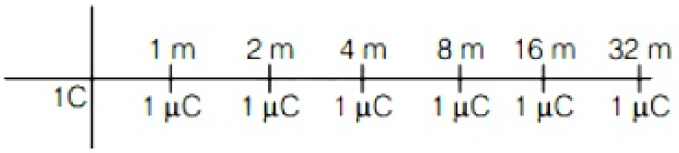
Question29

An infinite number of point charges, each carrying $1\mu C$ charge, are placed along the Y -axis at y = 1m, 2m, 4m, 8m. The total force on a 1C point charge, placed at the origin, is $x\times10^3N$. The value of x to the nearest integer, is ....
(Take, $\frac{1}{4\pi\varepsilon_0}=9\times10^9N-m^2/C^2$)
[18 Mar 2021 Shift 2]

Answer: 12

Solution:

The 1C charge present in the origin and other $1\mu C$ charge are placed at $1m$, $2m$, $4m$, $8m\ldots$



Using the Coulomb's law,

$$F = \frac{kq_1q_2}{r^2}$$

$$F = 9 \times 10^9 \times (1) \times 10^{-6} \left[1 + \frac{1}{2^2} + \frac{1}{4^2} + \frac{1}{8^2} + \cdots\right]$$

$$= 9 \times 10^3 \times \left[\frac{1}{1 - \frac{1}{4}}\right] = 12 \times 10^3 \mathrm{N}$$

The value of x to the nearest integer is 12 .

Question30

Find out the surface charge density at the intersection of point $X = 3m$ plane and X -axis, in the region of uniform line charge of 8nC / m lying along the Z -axis in free space
[16 Mar 2021 Shift 2]

Options:

A. $0.424 \mathrm{nCm}^{-2}$

B. $47.88 \mathrm{nCm}^{-2}$

C. $0.07 \mathrm{nCm}^{-2}$

D. $4.0 \mathrm{nCm}^{-2}$

Answer: A

Solution:

Solution:
Given,
Linear charge density, $\lambda = 8\mathrm{nC/m} = 8 \times 10^{-9} \mathrm{C/m}$
The relation between surface charge density and linear charge density can be given as
$\frac{2k\lambda}{r} = \frac{\sigma}{\varepsilon_0}$ .....(i)
where,
$k =$ Coulomb's constant,
$\lambda =$ linear charge density,
$\sigma =$ surface charge density,
$\varepsilon_0 =$ absolute electrical permittivity of free space
and $r =$ distance.
Substituting the values in Eq. (i), we get

$$\sigma = \frac{2k\lambda\varepsilon_0}{r}$$

$$= \frac{2 \times 9 \times 10^9 \times 8 \times 10^{-9} \times 8.85 \times 10^{-12}}{3}$$

$$= 0.424 \times 10^{-9} \mathrm{Cm}^{-2} = 0.424 \mathrm{nCm}^{-2}$$

Question31

An oil drop of radius 2mm with a density $3gcm^{-3}$ is held stationary under a constant electric field $3.55 \times 10^{5} V\,m^{-1}$ in the Millikan's oil drop experiment. What is the number of excess electrons that the oil drop will possess? (Take, $g = 9.81 m / s^{2}$)
[18 Mar 2021 Shift 1]

Options:

A. 48.8×10^{11}

B. 1.73×10^{10}

C. 17.3×10^{10}

D. 1.73×10^{12}

Answer: B

Solution:

Given, the radius of oil drop, $r = 2mm = 0.002m$
The density of oil drop, $\rho = 3g / cm^{3} = 3 \times 10^{3} kg / m^{3}$
The constant electric field, $E = 3.55 \times 10^{5} V\,m^{-1}$
The constant electric field, $E = 3.55 \times 10^{5} V\,m^{-1}$
Under stationary condition of oil drop,
$mg = qE$
$\Rightarrow \rho V g = qE \quad [\because m = \rho V]$
$\Rightarrow \rho \left(\frac{4}{3}\pi r^{3} \right) g = neE$
$\left[\because V = \frac{4}{3}\pi r^{3} \text{ and } q = ne \right]$
$$n = \frac{\rho \left(\frac{4}{3}\pi r^{3} \right) g}{eE}$$
$$\Rightarrow n = \frac{3 \times 10^{3} \times \left(\frac{4}{3}\pi (0.002)^{3} \right) 9.81}{1.6 \times 10^{-19} \times (3.55 \times 10^{5})}$$
$\Rightarrow n = 1.73 \times 10^{10}$

Question32

The electric field in a region is given by $E = \frac{2}{5} E_0 \hat{i} + \frac{3}{5} E_0 \hat{j}$ with $E_0 = 4.0 \times 10^{3} N / C$. The flux of this field through a rectangular surface area $0.4 m^{2}$ parallel to the yz-plane is .... $N - m^{2} C^{-1}$.
[17 Mar 2021 Shift 2]

Answer: 640

Solution:

Given,

The electric field in the region, $E = \frac{2}{5}E_0\hat{i} + \frac{3}{5}E_0\hat{j}$

Here, $E_0 = 4 \times 10^3 \frac{N}{C}$

Area of the rectangular surface, $A = 0.4m^2$

The direction of electric field vector and area vector is same, so the angle between the electric field vector and area vector is 0 .

As we know the expression of electric flux,

$\varphi = E \cdot A\cos\theta$...(i)

Here, E is the electric field vector, and A is the surface area of the surfaces.

Consider the surface parallel to the $Y - Z$ plane, so the area vector, A=0.4 i {m}^{2}

Substituting the values in Eq. (i), we get

$\varphi = E \cdot A\cos 0^\circ \Rightarrow \varphi = \frac{2}{5}E_0(0.4)$

$\Rightarrow \varphi = \frac{2}{5}(4 \times 10^3)(0.4) = 640N\,m^2C^{-1}$

Hence, the electric flux of the surface parallel to the $Y - Z$ plane is $640N\,m^2C^{-1}$.

Question33

Two identical tennis balls each having mass 'm' and charge ' q ' are suspended from a fixed point by threads of length ′l′. What is the equilibrium separation when each thread makes a small angle ′θ′ with the vertical ?
[27 Jul 2021 Shift 1]

Options:

A. $x = \left(\frac{q^2l}{2\pi\varepsilon_0 mg}\right)^{\frac{1}{2}}$

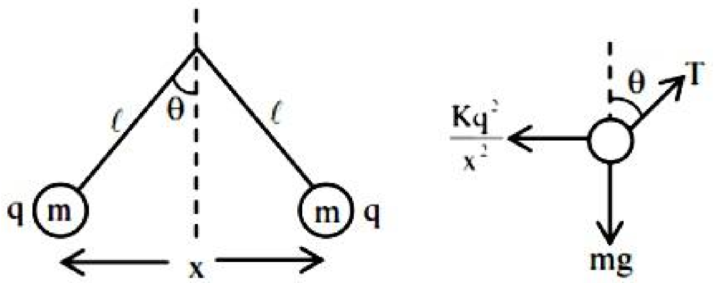
B. $x = \left(\frac{q^2l}{2\pi\varepsilon_0 mg}\right)^{\frac{1}{3}}$

C. $x = \left(\frac{q^2l^2}{2\pi\varepsilon_0 m^2g}\right)^{\frac{1}{2}}$

D. $x = \left(\frac{q^2l^2}{2\pi\varepsilon_0 m^2g^2}\right)^{\frac{1}{2}}$

Answer: B

Solution:



$T\cos\theta = mg$

$T\ \sin\theta = \frac{kq^2}{x^2}$

$\tan\theta = \frac{kq^2}{x^2 mg}$

as $\tan\theta \approx \sin\theta \approx \frac{x}{2L}$

$\frac{x}{2L} = \frac{Kq^2}{x^2 mg}$

$x = \left(\frac{q^2 L}{2\pi\varepsilon_0 mg}\right)^{1/3}$

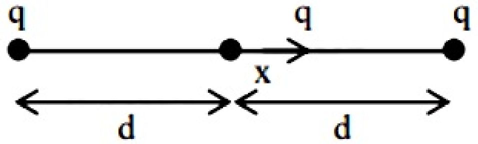
Question34

A particle of mass 1mg and charge q is lying at the mid-point of two stationary particles kept at a distance '2 m ' when each is carrying same charge 'q'. If the free charged particle is displaced from its equilibrium position through distance ' x′ (x< < 1m). The particle executes SHM. Its angular frequency of oscillation will be _____ $\times 10^5$ rad / s if $q^2 = 10C^2$ [25 Jul 2021 Shift 1]

Answer: 6

Solution:

Solution:



Net force on free charged particle

$F = \frac{kq^2}{(d+x)^2} - \frac{kq^2}{(d-x)^2}$

$F = -kq^2\left[\frac{4dx}{(d^2 - x^2)^2}\right]$

$a = -\frac{4kq^2 d}{m}\left(\frac{x}{d^4}\right)$

$a = -\left(\frac{4kq^2}{md^3}\right)x$

So, angular frequency

$\omega = \sqrt{\frac{4kq^2}{md^3}}$

$\omega = \sqrt{\frac{4\times 9\times 10^9\times 10}{1\times 10^{-6}\times 1^3}}$

$\omega = 6\times 10^8 \text{rad / sec}$

Question35

An electric dipole is placed on x-axis in proximity to a line charge of

linear charge density 3.0×10^{-6}C / m. Line charge is placed on z-axis and positive and negative charge of dipole is at a distance of 10mm and 12mm from the origin respectively. If total force of 4N is exerted on the dipole, find out the amount of positive or negative charge of the dipole.
[22 Jul 2021 Shift 2]

Options:

A. 815.1nC

B. 8.8μC

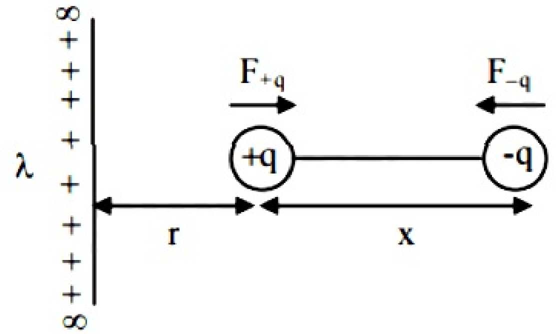
C. 0.485mC

D. 4.44μC

Answer: D

Solution:

Solution:



r = 10mm, x = 2,

$\left|\vec{F}_q\right| = \frac{2k\lambda}{r} \cdot q$

$\left|\vec{F}_{-q}\right| = \frac{2k\lambda}{r+x} \cdot q$

$\Rightarrow \left|\vec{F}_{net}\right| = \frac{2k\lambda q}{r} - \frac{2k\lambda q}{r+x}$

$\left|\vec{F}_{net}\right| = \frac{2k\lambda q \,.\, x}{r(r+x)}$

$4 = \frac{2 \times 9 \times 10^9 \times 3 \times 10^{-6} \times q \times 2mm}{10mm.12mm}$

$\Rightarrow q = 4.44\mu C$

Question36

A certain charge Q is divided into two parts q and$(Q - q)$. How should the charges Q and q be divided so that q and $(Q - q)$ placed at a certain distance apart experience maximum electrostatic repulsion?
[20 Jul 2021 Shift 1]

Options:

A. $Q = \frac{q}{2}$

B. $Q = 2q$

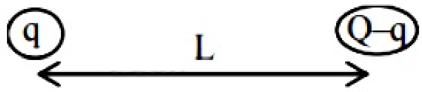
C. $Q = 4q$

D. $Q = 3q$

Answer: B

Solution:

Solution:



$F_q = \frac{kq(Q-q)}{L^2} = \frac{k}{L^2}(qQ - q^2)$

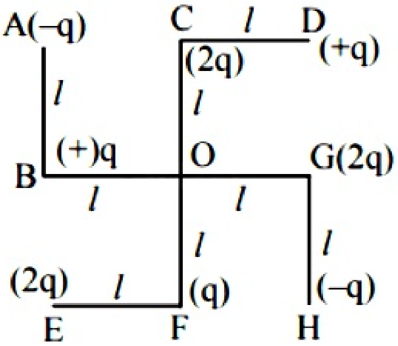
$\frac{dF}{dq} = 0$ when force is maximum

$\frac{dF}{dq} = \frac{k}{L^2}[Q - 2q] = 0$

$\Rightarrow Q - 2q = 0 \Rightarrow Q = 2q$

Question37

What will be the magnitude of electric field at point O as shown in figure? Each side of the figure is l and perpendicular to each other?



[27 Jul 2021 Shift 2]

Options:

A. $\frac{1}{4\pi\varepsilon_0}\frac{q}{l^2}$

B. $\frac{1}{4\pi\varepsilon_0}\frac{q}{(2l^2)}(2\sqrt{2} - 1)$

C. $\frac{q}{4\pi\varepsilon_0(2l)^2}$

D. $\frac{1}{4\pi\varepsilon_0}\frac{2q}{2l^2}(\sqrt{2})$

Answer: B

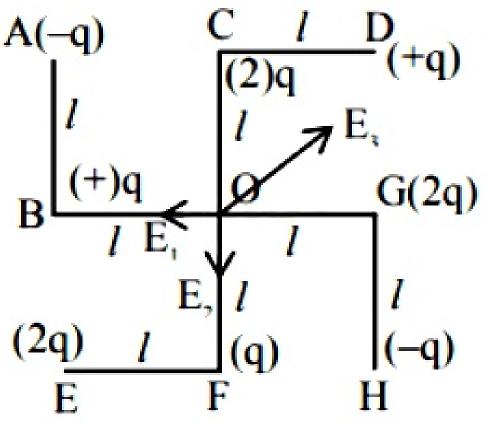
Solution:

Solution:

$E_1 = \frac{kq}{l^2} = E_2$

$$E_3 = \frac{kq}{(\sqrt{2}l)^2} = \frac{kq}{2l^2}$$

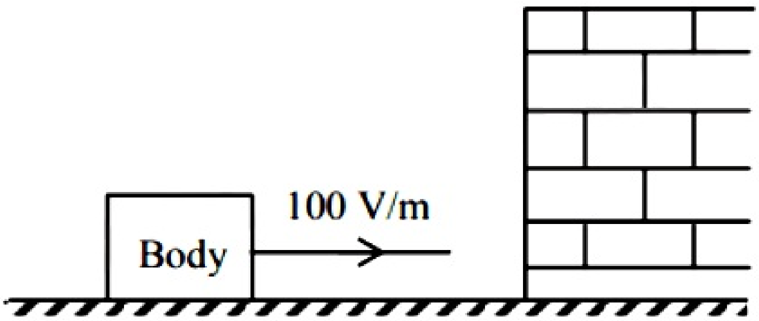
$$E = \frac{\sqrt{2}kq}{l^2} - \frac{kq}{2l^2} = \frac{kq}{2l^2}(2\sqrt{2} - 1)$$



Question38

A body having specific charge 8μC / g is resting on a frictionless plane at a distance 10cm from the wall (as shown in the figure). It starts moving towards the wall when a uniform electric field of100V / m is applied horizontally towards the wall.

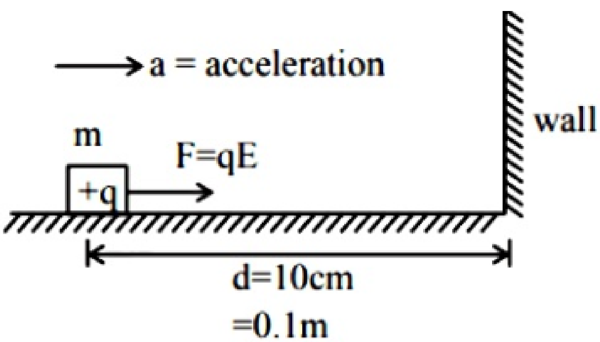
If the collision of the body with the wall is perfectly elastic, then the time period of the motion will be _____ s.



[20 Jul 2021 Shift 1]

Answer: 1

Solution:



$F = ma$
$qE = ma$
$a = \frac{qE}{m}$
Now $d = \frac{1}{2}at^2$
$t = \sqrt{\frac{2d}{a}}$
$t = \sqrt{\frac{2d}{\left(\frac{qE}{m}\right)}}$
$t = \sqrt{\frac{2 \times 0.1}{\left(\frac{8 \times 10^{-6}}{10^{-3}}\right) \times 100}} = \frac{1}{2}$
$\therefore$ Time period $= 2t = 1\text{sec}$

Question39

The total charge enclosed in an incremental volume of $2 \times 10^{-9} m^3$ located at the origin isnC, if electric flux density of its field is found as $D = e^{-x} \sin y \hat{i} - e^{-x} \cos y \hat{j} + 2z\hat{k} C / m^2$.
[22 Jul 2021 Shift 2]

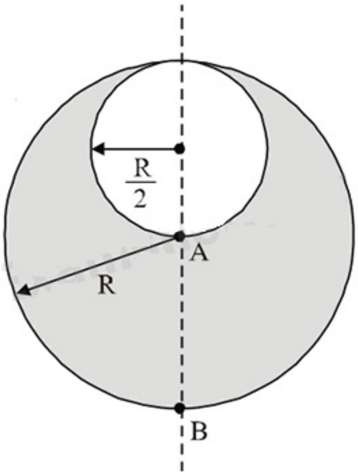
Answer: 4

Solution:

Electric flux density
$(D) = \frac{\text{charge}}{\text{Area}} \times \hat{r} = \frac{Q}{4\pi r^2}\hat{r} = \in_0 \left(\frac{Q}{4\pi \in_0 r^2}\hat{r}\right)$
$\Rightarrow \vec{E} = \frac{\vec{D}}{\in_0} = \frac{e^{-x} \sin y \hat{i} - e^{-x} \cos y \hat{j} + 2z\hat{k}}{\in_0}$
Also by Gauss's law
$\frac{\rho}{\in_0} = \left(\frac{}{x}\hat{i} + \frac{}{y}\hat{j} + \frac{}{z}\hat{k}\right) . \vec{E} = \left(\frac{}{x}\hat{i} + \frac{}{y}\hat{j} + \frac{}{z}\hat{k}\right) . \frac{\vec{D}}{\in_0}$
$\Rightarrow \rho = \frac{}{x}(e^{-x} \sin y) + \frac{}{y}(-e^{-x} \cos y) + \frac{}{z}(2z)$
$\rho = -e^{-x} \sin y + e^{-x} \sin y + 2$
At origin $\rho = -e^{-0} \sin 0 + e^{-0} \sin 0 + 2$
$\rho = 2C / m^3$
Charge $= \rho \times$ volume $= 2 \times 2 \times 10^{-9} = 4 \times 10^{-9} = 4nC$

Question40

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:



[9 Jan. 2020, I]

Options:

A. $\frac{21}{34}$

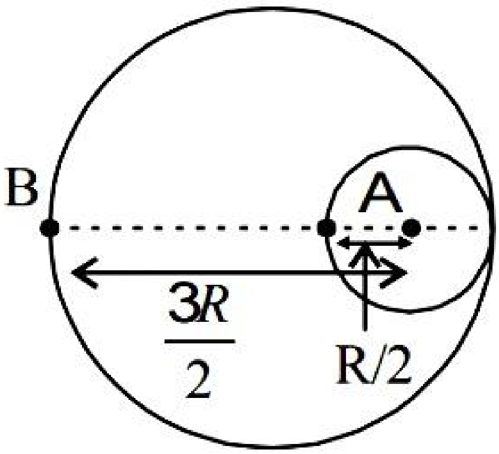
B. $\frac{18}{34}$

C. $\frac{17}{54}$

D. $\frac{18}{54}$

Answer: B

Solution:



Electric field at A $\left(R' = \frac{R}{2}\right)$

$E_A \cdot ds = \frac{q}{\varepsilon_0}$

$$\Rightarrow \vec{E}_A = \frac{\rho \times \frac{4}{3}\pi\left(\frac{R}{2}\right)^3}{\varepsilon_0 \cdot 4\pi\left(\frac{R}{2}\right)^2}$$

$$\Rightarrow \vec{E}_A = \frac{\sigma(R/2)}{3\varepsilon_0} = \left(\frac{\sigma R}{6\varepsilon_0}\right)$$

Electric fields at ‘B’

$$\vec{E}_B = \frac{k \times \rho \times \frac{4}{3}\pi R^3}{R^2} - \frac{k \times \rho \times \frac{4}{3}\pi\left(\frac{R}{2}\right)^3}{\left(\frac{3R}{2}\right)^2}$$

$$\Rightarrow \vec{E}_B = \frac{\sigma R}{3\varepsilon_0} - \left(\frac{1}{4\pi\varepsilon_0}\right)\frac{(\sigma)}{\frac{3R}{2}^{2}}\ \frac{4\pi}{3}\ \frac{R}{2}^{3}$$

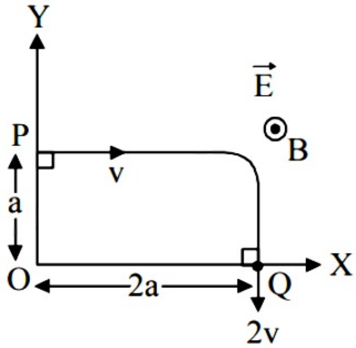
$$\Rightarrow \vec{E}_B = \frac{\sigma R}{3\varepsilon_0} - \frac{\sigma R}{54\varepsilon_0}$$

$$\Rightarrow E_B = \frac{17}{54}\ \frac{\sigma R}{\varepsilon_0}$$

$$\frac{E_A}{E_B} = \frac{1 \times 54}{6 \times 17} = \frac{9}{17} = \frac{9}{17} \times \frac{2}{2} = \frac{18}{34}$$

Question41

An electric dipole of moment $\vec{p} = \left(\hat{i} - 3\hat{j} + 2\hat{k}\right) \times 10^{-29}$C . mis 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 $\vec{r} \cdot \vec{p} = 0$) is parallel to:



[9 Jan. 2020, I]

Options:

A. $\left(+\hat{i} - 3\hat{j} - 2\hat{k}\right)$

B. $\left(-\hat{i} + 3\hat{j} - 2\hat{k}\right)$

C. $\left(+\hat{i} + 3\hat{j} - 2\hat{k}\right)$

D. $\left(-\hat{i} - 3\hat{j} + 2\hat{k}\right)$

Answer: C

Solution:

Since $\vec{r} \cdot \vec{p} = 0$

$\vec{E}$ must be antiparallel to $\vec{p}$
$\therefore \hat{E}$ is parallel to $\left(+\hat{i}+3\hat{j}-2\hat{k}\right)$

Question42

A charged particle of mass ' m ' and charge 'q' moving under the influence of uniform electric field E $\hat{i}$ and a uniform magnetic field B$\vec{k}$ follows a trajectory from point P to Q as shown in figure. The velocities at P and Q are respectively, v$\vec{i}$ and -2v$\vec{j}$. Then which of the following statements (A, B, C, D) are the correct? (Trajectory shown is schematic and not to scale)

(A) E $= \frac{3}{4}\left(\frac{mv^2}{qa}\right)$

(B) Rate of work done by the electric field at P is $\frac{3}{4}\left(\frac{mv^2}{a}\right)$
(C) Rate of work done by both the fields at Q is zero
(D) The difference between the magnitude of angular momentum of the particle at P and Q is 2 mav.
[9 Jan. 2020, I]

Options:

A. (A), (C), (D)

B. (B), (C), (D)

C. (A), (B), (C)

D. (A), (B), (C), (D)

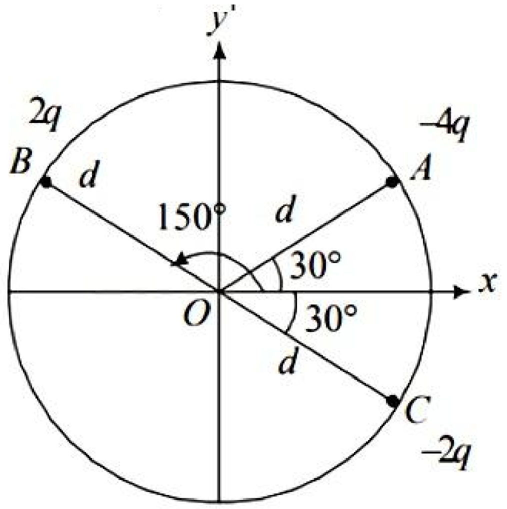
Answer: C

Solution:

Solution:
(A) By work energy theorem
$W_{mg} + W_{ele} = \frac{1}{2}m(2v)^2 - \frac{1}{2}m(v)^2$
$0 + qE_0 2a = \frac{3}{2}mv^2 \Rightarrow E_0 = \frac{3}{4}\frac{mv^2}{qa}$
(B) Rate of work done at P = power of electric force $= qE_0V = \frac{3}{4}\frac{mv^3}{a}$
(C) At, Q, $\frac{dw}{dt} = 0$ for both the fields
(D) The difference of magnitude of angular momentum of the particle at P and Q,
$\Delta\vec{L} = \left(-m2v2a\hat{k}\right) - \left(-mva\hat{k}\right)$
$\left|\Delta\vec{L}\right| = 3mva$

Question43

Three charged particles



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:
[8 Jan. 2020, I]

Options:

A. $\frac{\sqrt{3}q}{\pi \in_0 d^2}$

B. $\frac{2\sqrt{3}q}{\pi \in_0 d^2}$

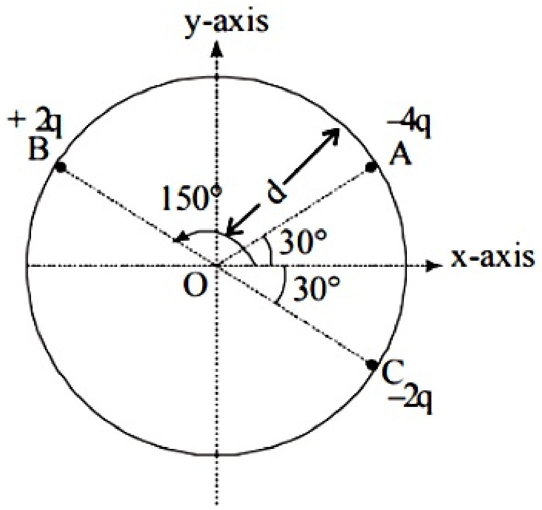
C. $\frac{\sqrt{3}q}{4\pi \in_0 d^2}$

D. $\frac{3\sqrt{3}q}{4\pi \in_0 d^2}$

Answer: A

Solution:

Solution:



Electric field due to charge $+2q$ at centre O

$\vec{E}_1 = \frac{1}{4\pi\varepsilon_0} \times \frac{2q}{d^2}\left[\frac{\sqrt{3}\hat{i} - \hat{j}}{2}\right]$

Electric field due to charge $-2q$ at centre O

$\vec{E}_2 = \frac{1}{4\pi\varepsilon_0} \times \frac{2q}{d^2}\left[\frac{\sqrt{3}\hat{i} - \hat{j}}{2}\right]$

Electric field due to charge $-4q$ at centre O

$\vec{E}_3 = \frac{1}{4\pi\varepsilon_0} \times \frac{4q}{d^2}\left[\frac{\sqrt{3}\hat{i} + \hat{j}}{2}\right]$

∴ Net electric field at point O

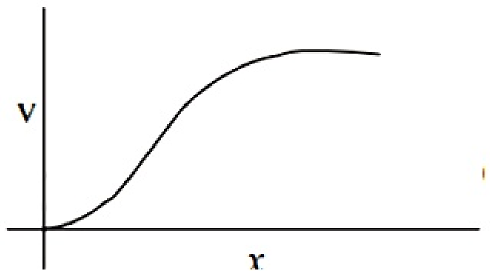
$\vec{E}_0 = \vec{E}_1 + \vec{E}_2 + \vec{E}_3 = \frac{\sqrt{3}q}{\pi\varepsilon_0 d^2}\hat{i}$

Question44

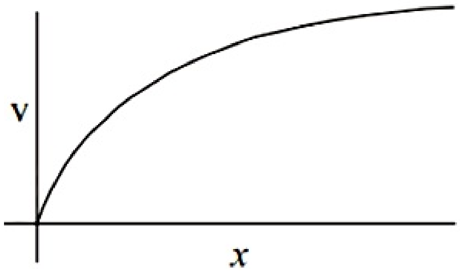
A particle of mass m and charge q is released from rest in a uniform electric field. If there is no other force on the particle, the dependence of its speed v on the distance x travelled by it is correctly given by (graphs are schematic and not drawn to scale)
[8 Jan. 2020, II]

Options:

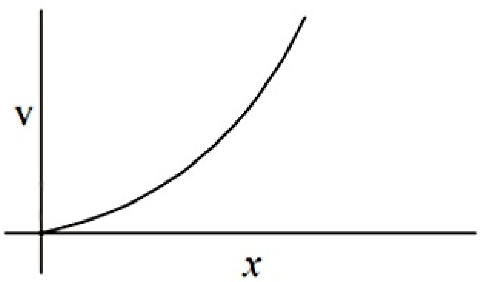
A.



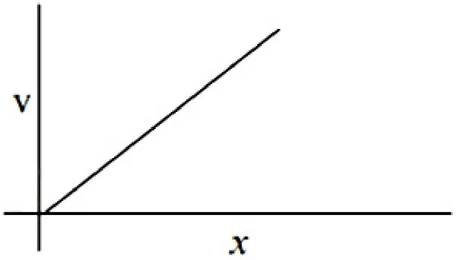
B.



C.



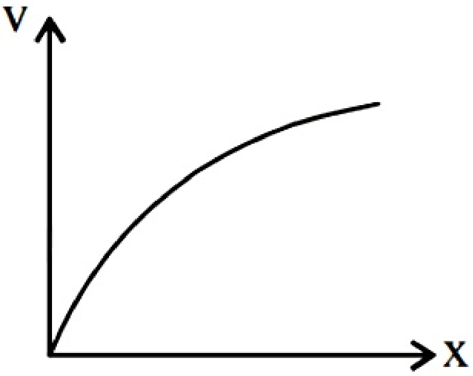
D.



Answer: B

Solution:

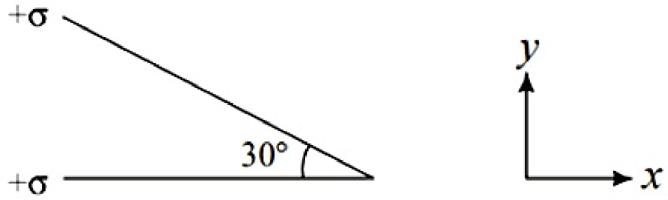
Solution:



Using
$v^2 - u^2 = 2aS$ ......(i)
Here, $u = 0$, $s = x$
Also, $F_{electric} = ma$
$\Rightarrow qE = ma \Rightarrow a = \frac{qE}{m} \Rightarrow a = \frac{qE}{m}$
Substituting the values in (i) we get
$v^2 = \frac{2qE}{m}x$

Question45

Two infinite planes each with uniform surface charge density $+\sigma$ 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:



[7 Jan. 2020, I]

Options:

A. $\frac{\sigma}{2\epsilon_0}\left[(1+\sqrt{3})\hat{y} - \frac{\hat{x}}{2}\right]$

B. $\frac{\sigma}{\epsilon_0}\left[\left(1+\frac{\sqrt{3}}{2}\right)\hat{y} + \frac{\hat{x}}{2}\right]$

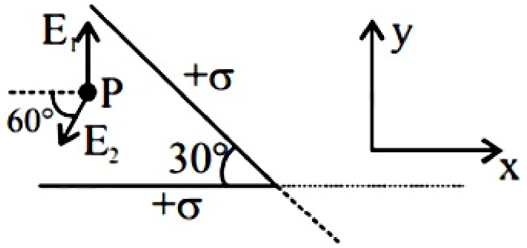
C. $\frac{\sigma}{2\in_0}\left[(1+\sqrt{3})\hat{y}+\frac{\hat{x}}{2}\right]$

D. $\frac{\sigma}{2\in_0}\left[\left(1-\frac{\sqrt{3}}{2}\right)\hat{y}-\frac{\hat{x}}{2}\right]$

Answer: D

Solution:

Solution:



From figure,

$\vec{E}_1=\frac{\sigma}{2\varepsilon_0}\hat{y}$ and $\vec{E}_2=\frac{\sigma}{2\varepsilon_0}(-\cos 60°\,\hat{x}-\sin 60°\,\hat{y})$

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

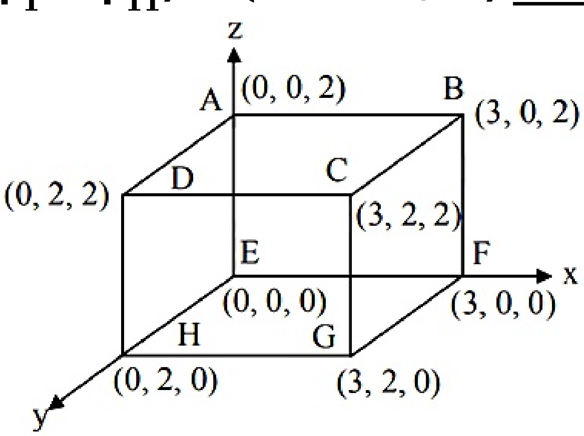
Electric field in the region shown in figure (P)

$\vec{E}_P=\vec{E}_1+\vec{E}_2=\frac{\sigma}{2\varepsilon_0}\left[-\frac{1}{2}\hat{x}+\left(1-\frac{\sqrt{3}}{2}\right)\hat{y}\right]$

or, $\vec{E}_P=\frac{\sigma}{2\varepsilon_0}\left[\left(1-\frac{\sqrt{3}}{2}\right)\hat{y}-\frac{\hat{x}}{2}\right]$

Question46

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_1 and ϕ_{11} respectively. The difference between $(\phi_1-\phi_{11})$ is (in $N\,m^2/C$) ________.



[9 Jan 2020, II]

Answer: -48

Solution:

Flux of electric field $\vec{E}$ through any area $\vec{A}$ is defined as
$\phi = \int E\ . A \cos\theta$
Here, $\theta =$ angle between electric field and area vector of a surface
For surface ABCD Angle, $\theta = 90°$
$\therefore \phi_1 = \int E\ . A \cos 90° = 0$
For surface BCGF $\phi_n = \int \vec{E}\ . d\vec{A}$
$\therefore \phi_{11} = \left[4 \times \hat{i} - (y^2 + 1)\hat{j}\right].4\hat{i} = 16x$
$\phi_{11} = 48\frac{N\,m^2}{C}$
$\phi_1 - \phi_{11} = -48$

Question47

In finding the electric field using Gauss law the formula $\left|\vec{E}\right| = \frac{q_{enc}}{\epsilon_0 |A|}$ 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. This equation can be used in which of the following situation? [8 Jan 2020, I]

Options:

A. Only when the Gaussian surface is an equipotential surface and $\left|\vec{E}\right|$ is constant on the surface.

B. equipotential surface and $\left|\vec{E}\right|$ is constant on the surface.

C. Only when $\left|\vec{E}\right| =$ constant on the surface.

D. For any choice of Gaussian surface.

Answer: A

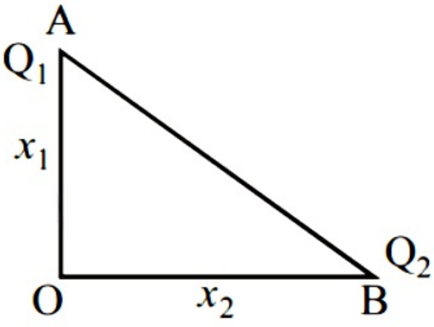
Solution:

According to Gauss' Law,
$\oint \vec{E}_i d\vec{A} = \frac{q_{ene}}{E_0}$
Where $\vec{E}_1$ is the electric field and $d\vec{A}$ is the elemental. areal vector for any small elemental area on the gaussian surface.
$\left|\vec{E}_1\right|\left|d\vec{A}\right|\cos\theta = \frac{q_{ene}}{E_0}$
Given that the formula $\left|\vec{E}\right| = \frac{q_{ene}}{\epsilon_0 |A|}$ is applicable.
$\therefore \left|\vec{E}\right|\left|A\right| = \frac{q_{ene}}{E_0}$
$\therefore \left|\vec{E}\right|\left|A\right| = \oint\left|\vec{E}_1\right|\left|d\vec{A}\right|\cos\theta$
This relation will be valid when $\vec{E}_1$ is a consatnt and $\left|\vec{E}_1\right| = \left|\vec{E}\right|$ and also when $\theta = 0^\circ$

$\oint|\vec{E}_1||d\vec{A}|\cos\theta$ becomes $|\vec{E}|\oint|d\vec{A}|=|\vec{E}||A|$
The condition $\theta = 0$ means that the components of electric field parallel to the elemental surface $araE_1 \sin\theta = 0$.
This means that the potential gradient over the surface is zero. Hence the surface is equipotential.

Question48

Charges Q_1 and Q_2 are 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 :



[Sep. 06,2020 (I)]

Options:

A. $\frac{x_1^3}{x_2^3}$

B. $\frac{x_2}{x_1}$

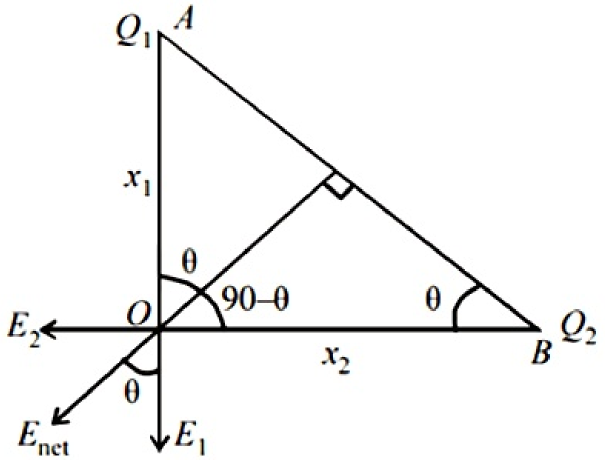
C. $\frac{x_1}{x_2}$

D. $\frac{x_2^2}{x_1^2}$

Answer: C

Solution:

Solution:
Electric field due charge Q_2, $E_2 = \frac{kQ_2}{x_2^2}$
Electric field due charge Q_1, $E_1 = \frac{kQ_1}{x_1^2}$



From figure,

$\tan\theta = \frac{E_2}{E_1} = \frac{x_1}{x_2} \Rightarrow \frac{kQ_2}{x_2^2 \times \frac{kQ_1}{x_1^2}} = \frac{x_1}{x_2}$

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

Question49

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? [Sep. 06, 2020 (II)]

Options:

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

B. $F = \frac{1}{4\pi\varepsilon_0}\frac{Qq}{R^2} > F > 0$ for $r < R$

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

D. $F = \frac{1}{4\pi\varepsilon_0}\frac{Qq}{R^2}$ for all r

Answer: C

Solution:

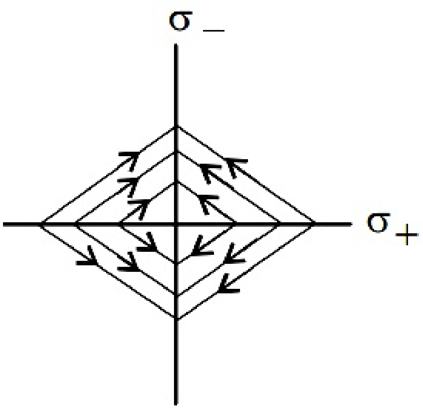
Solution:
For spherical shell
$E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}(\text{ if } r \geq R)$
$= 0(\text{ if } r < R)$
Force on charge in electried field, $F = qE$
$\therefore F = 0(\text{For } r < R)$
$F = \frac{1}{4\pi\varepsilon_0}\frac{Qq}{r^2}(\text{ For } r > R)$

Question50

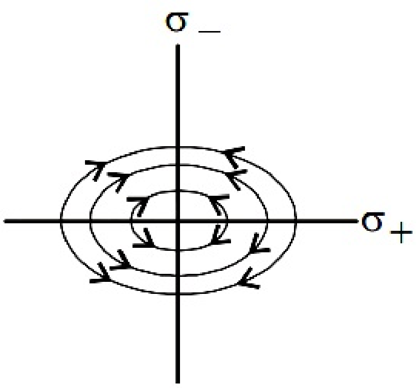
Two charged thin infinite plane sheets of uniform surface charge density σ_+ and σ_-, where $|\sigma_+| > |\sigma_-|$, intersect at right angle. Which of the following best represents the electric field lines for this system? [Sep. 04, 2020 (I)]

Options:

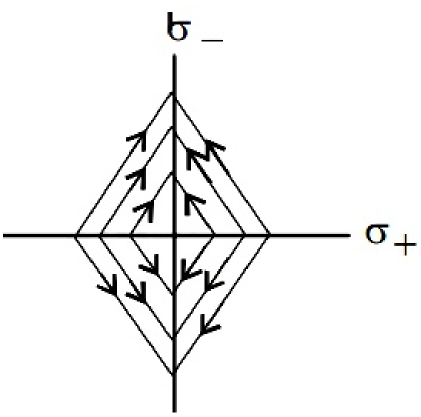
A.



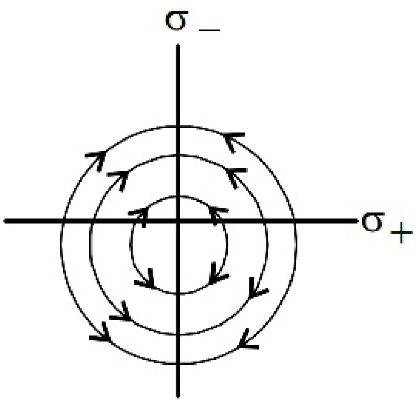
B.



C.



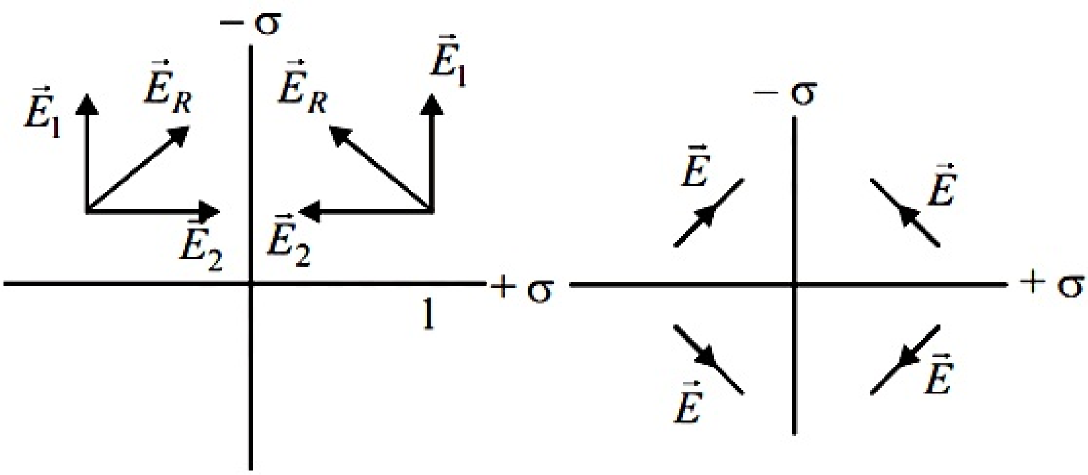
D.



Answer: C

Solution:

Solution:
The electric field produced due to uniformly charged infinite plane is uniform. So option (b) and (d) are wrong. And +ve charge density σ_+ is bigger in magnitude so its field along Y direction will be bigger than field of - ve charge density σ_- in X direction. Hence option (c) is correct.



Question51

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 :
[Sep. 04,2020 (II)]

Options:

A. a

B. $\sqrt{\frac{2}{a}}$

C. $\sqrt{\frac{3}{a}}$

D. $\sqrt{\frac{1}{a}}$

Answer: C

Solution:

Solution:

$f = qE = qE_0(1 - ax^2)$

$\Rightarrow mv\frac{dv}{dx} = qE_0(1 - ax^2)$

$vdv = \frac{qE_0(1 - ax^2)}{m}dx$

$\int$ both sides;

$\int_0^v vdv = \frac{qE_0}{m}\int_0^x (1 - ax^2)dx$

$\frac{v^2}{2} = \frac{qE_0}{m}\left(x - \frac{ax^3}{3}\right)$

K.E of particle becomes zero

$\frac{1}{2}mv^2 = qe_0 \cdot \left(x - \frac{ax^3}{3}\right) = 0$

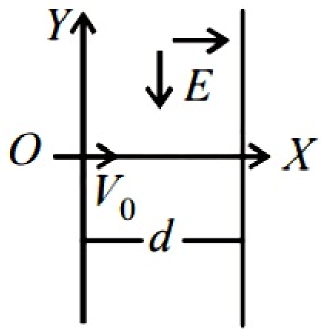
$x = \frac{ax^3}{3}$

$\frac{3}{a} = x^2$

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

Question52

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 :



[Sep. 02, 2020 (I)]

Options:

A. $y = \frac{qEd}{mV_0^2}(x - d)$

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

C. $y = \frac{qEd}{mV_0^2}x$

D. $y = \frac{qEd^2}{mV_0^2}x$

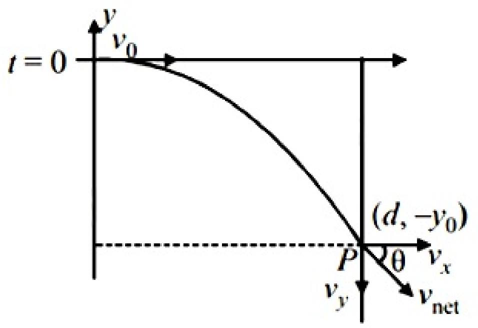
Answer: B

Solution:

Solution:
$F_x = 0$, $a_x = 0$, $(v)_x =$ constant

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

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



$\tan\theta = \frac{v_y}{v_x} = \frac{qE\,t_0}{m \cdot v_0}$, $\left(t = \frac{d}{v_0}\right)$

$\tan\theta = \frac{qE\,d}{m \cdot v_0^2}$, Slope $= \frac{-qE\,d}{mv_0^2}$

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

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

$-y_0 = \frac{-qE\,d}{mv_0^2}, d + c \Rightarrow c = -y_0 + \frac{qE\,d^2}{mv_0^2}$

$y = \frac{-qE\,d}{mv_0^2}x - y_0 + \frac{qE\,d^2}{mv_0^2}$

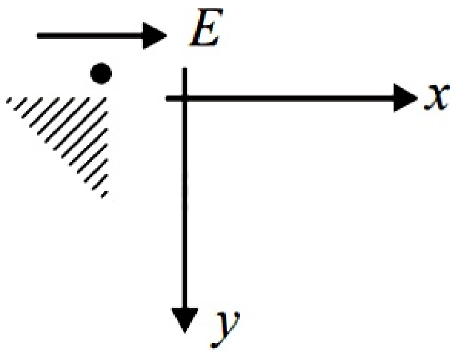
$y_0 = \frac{1}{2} \cdot \frac{qE}{m}\left(\frac{d}{v_0}\right)^2 = \frac{1}{2}\frac{qE\,d^2}{mv_0^2}$

$y = \frac{-qE\,d\,x}{mv_0^2} - \frac{1}{2}\frac{qE\,d^2}{mv_0^2} + \frac{qE\,d^2}{mv_0^2}$

$y = \frac{-qE\,d}{mv_0^2} + \frac{1}{2}\frac{qE\,d^2}{mv_0^2} \Rightarrow y = \frac{qE\,d}{mv_0^2}\left(\frac{d}{2} - x\right)$

Question53

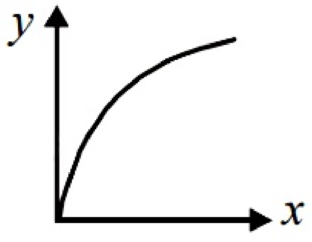
A small point mass carrying some positive charge on it, is released from the edge of a table. There is a uniform electric field in this region in the horizontal direction. Which of the following options then correctly describe the trajectory of the mass ? (Curves are drawn schematically and are not to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



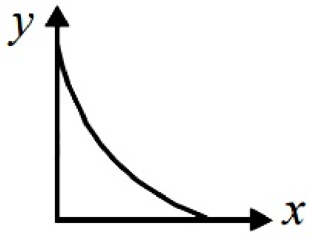
[Sep. 02, 2020 (I)]

Options:

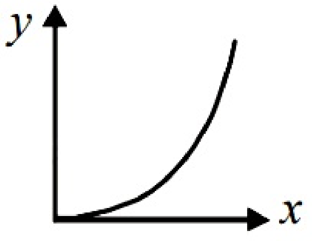
A.



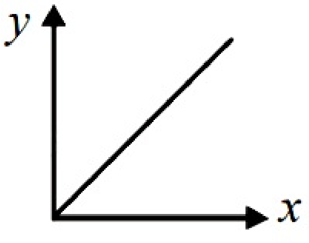
B.



C.



D.

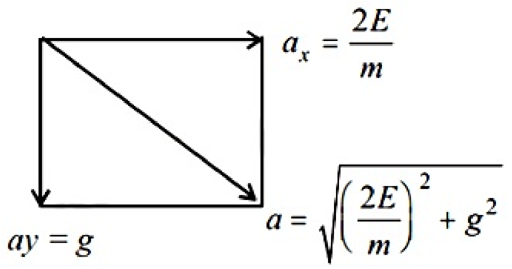


Answer: D

Solution:

Solution:
Net force acting on the particle,
$\vec{F} = qE\hat{i} + mg\hat{j}$

Net acceleration of particle is constant, initial velocity is zero therefore path is straight line.



Question54

A particle of mass m and charge q has an initial velocity $\vec{v} = v_0\hat{j}$. If an electric field $\vec{E} = E_0\hat{i}$ and magnetic field $\vec{B} = B_0\hat{i}$ act on the particle, its speed will double after a time:
[2020, I]

Options:

A. $\frac{2mv_0}{qE_0}$

B. $\frac{3mv_0}{qE_0}$

C. $\frac{\sqrt{3}mv_0}{qE_0}$

D. $\frac{\sqrt{2}mv_0}{qE_0}$

Answer: C

Solution:

Solution:
Electric field will increase the speed of particle in x direction.
$F_X = qE$
$\therefore a = \frac{qE}{m}$
Also $V_X = at = \frac{qE}{m}t$
$v_x^2 + v_y^2 = v^2$
$\Rightarrow v_x^2 + v_0^2 = (2v_0)^2$
$\Rightarrow V_x = \sqrt{3}v_0$
$\therefore \frac{qE}{m}t = \sqrt{3}v_0$
$\Rightarrow t = \frac{\sqrt{3}mv_0}{qE_0}$

Question55

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 x axis with the direction of their dipole moments remaining unchanged. If the mass of each dipole is ' m ', their speed when they are infinitely far apart is :
[Sep. 06, 2020 (II)]

Options:

A. $\frac{P}{a}\sqrt{\frac{1}{\pi\varepsilon_0 ma}}$

B. $\frac{P}{a}\sqrt{\frac{1}{2\pi\varepsilon_0 ma}}$

C. $\frac{P}{a}\sqrt{\frac{2}{\pi\varepsilon_0 ma}}$

D. $\frac{P}{a}\sqrt{\frac{2}{2\pi\varepsilon_0 ma}}$

Answer: B

Solution:

Solution:
Let v be the speed of dipole.
Using energy conservation
$K_i + U_i = K_f + U_f$
$\Rightarrow 0 - \frac{2k \cdot p_1}{r^3} p_2 \cos(180°) = \frac{1}{2}mv^2 + \frac{1}{2}mv^2 + 0$
($\because$ Potential energy of interaction between dipole = $\frac{-2p_1p_2\cos\theta}{4\pi \in_0 r^3}$)
$\Rightarrow mv^2 = \frac{2kp_1p_2}{r^3} \Rightarrow v = \sqrt{\frac{2kp_1p_2}{mr^3}}$
When $p_1 = p_2 = p$ and $r = a$
$v = \frac{p}{a}\sqrt{\frac{1}{2\pi \in_0 ma}}$

Question56

Three charges +Q, q, +Q are placed respectively, at distance, $\frac{d}{2}$ and d from the origin, on the x -axis. If the net force experienced by +Q, placed at x = 0, is zero, then value of q is:
[9 Jan. 2019 I]

Options:

A. $-Q / 4$

B. $+Q / 2$

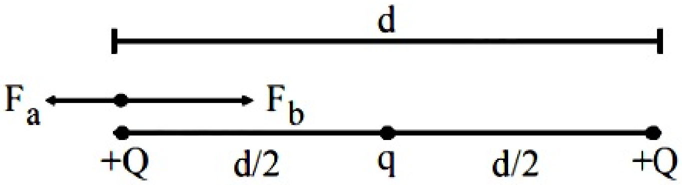
C. $+Q / 4$

D. $-Q / 2$

Answer: A

Solution:

Solution:



Force due to charge +Q

$F_a = \frac{KQQ}{d^2}$

Force due to charge q

$F_b = \frac{KQq}{\left(\frac{d}{2}\right)^2}$

For equilibrium,

$\vec{F}_a + \vec{F}_b = 0$

$\Rightarrow \frac{kQQ}{d^2} + \frac{kQq}{(d/2)^2} = 0 \therefore q = -\frac{Q}{4}$

Question57

Charge is distributed within a sphere of radius R with a volume charge density p(r) = $\frac{A}{r^2}e^{-2r/a}$ where A and aare constants. If Q is the total charge of this charge distribution, the radius R is:
[9 Jan. 2019, II]

Options:

A. $a \log\left(1 - \frac{Q}{2\pi aA}\right)$

B. $\frac{a}{2}\log\left(\frac{1}{1 - \frac{Q}{2\pi aA}}\right)$

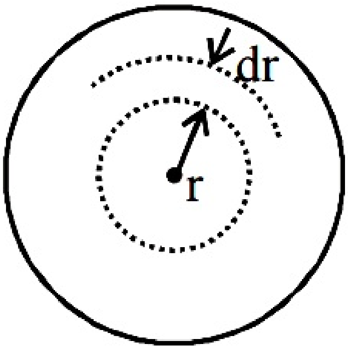
C. $a \log\left(\frac{1}{1 - \frac{Q}{2\pi aA}}\right)$

D. $\frac{a}{2}\log\left(1 - \frac{Q}{2\pi aA}\right)$

Answer: B

Solution:

Solution:



$Q = \int \rho d v = \int_0^R \frac{A}{r^2} e^{-2r/a}(4\pi r^2 d r)$

$= 4\pi A \int_0^R e^{-2r/a} d r = 4\pi A \left(\frac{e^{-2r/a}}{-\frac{2}{a}} \right)_0^R$

$= 4\pi A \left(-\frac{a}{2}\right)(e^{-2R/a} - 1)$

$Q = 2\pi a A(1 - e^{-2R/a})$

$R = \frac{a}{2} \log \left(\frac{1}{1 - \frac{Q}{2\pi a A}} \right)$

Question58

For a uniformly charged ring of radius R, the electric field on its axis has the largest magnitude at a distance h from its centre. Then value of h is:
[9 Jan. 2019 I]

Options:

A. $\frac{R}{\sqrt{5}}$

B. $\frac{R}{\sqrt{2}}$

C. R

D. $R\sqrt{2}$

Answer: B

Solution:

Solution:
Electric field on the axis of a ring of radius R at a distance h from the centre,

$E = \frac{kQh}{(h^2 + R^2)^{3/2}}$

Condition: for maximum electric field $\frac{dE}{dh} = 0$

$\Rightarrow \frac{d}{dh}\left[\frac{kQh}{(R^2 + h^2)^{3/2}} \right] = 0$

By using the concept of maxima and minima we get,

$h = \frac{R}{\sqrt{2}}$

Question59

Two point charges $q_1(\sqrt{10}\mu C)$ and $q_2(-25\mu C)$ are placed on the x -axis at x = 1m and x = 4m respectively. The electric field (in V / m) at a point y = 3m on y -axis is

$\left[\text{take } \frac{1}{4\pi\epsilon_0} = 9 \times 10^9 N\, m^2 C^{-2}\right]$

[9 Jan 2019, II]

Options:

A. $\left(63\hat{i} - 27\hat{j}\right) \times 10^2$

B. $\left(-63\hat{i} + 27\hat{j}\right) \times 10^2$

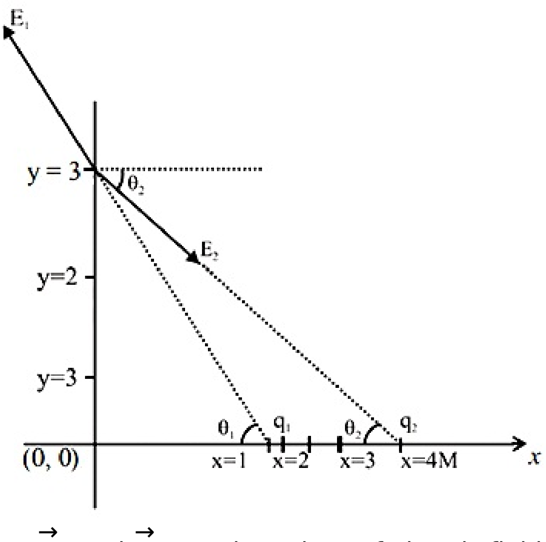
C. $\left(81\hat{i} - 81\hat{j}\right) \times 10^2$

D. $\left(-81\hat{i} + 81\hat{j}\right) \times 10^2$

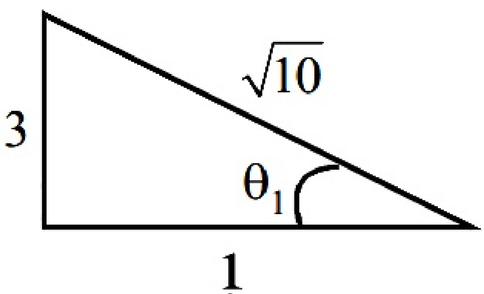
Answer: A

Solution:

Solution:



Let $\vec{E}_1$ and $\vec{E}_2$ are the values of electric field due to charge, q_1 and q_2 respectively magnitude of $E_1 = \frac{1}{4\pi\epsilon_0}\frac{q_1}{{r_1}^2}$



$= \frac{1}{4\pi\epsilon_0}\frac{\sqrt{10} \times 10^{-6}}{(1^2 + 3^2)}$

$= (9 \times 10^9) \times \sqrt{10} \times 10^{-7}$

$= 9\sqrt{10} \times 10^2$

$\therefore \vec{E}_1 = 9\sqrt{10} \times 10^2 \left[\cos\theta_1\left(-\vec{i}\right) + \sin\theta_1 \vec{j}\right]$

$\Rightarrow E_1 = 9 \times \sqrt{10} \times 10^2 \left[\frac{1}{\sqrt{10}}\left(-\hat{i}\right) + \frac{3}{\sqrt{10}}\hat{j}\right]$

$\Rightarrow E_1 = 9 \times 10^2[-\hat{i} + 3\hat{j}] = [-9\hat{i} + 27\hat{j}]10^2$

Similarly, $E_2 = \frac{1}{4\pi\epsilon_0}\frac{q_2}{r^2}$

$E_2 = \frac{9 \times 10^9 \times (25) \times 10^{-6}}{(4^2 + 3^2)}$ $E_2 = 9 \times 10^3 V/m$

$\therefore \vec{E}_2 = 9 \times 10^3(\cos\theta_2\hat{i} - \sin\theta_2\hat{j})$ $\because \tan\theta_2 = \frac{3}{4}$

$\therefore \vec{E}_2 = 9 \times 10^3\left(\frac{4}{5}\hat{i} - \frac{3}{5}\hat{j}\right) = (72\hat{i} - 54\hat{j}) \times 10^2$

$\therefore \vec{E} = \vec{E}_1 + \vec{E}_2 = (63\hat{i} - 27\hat{j}) \times 10^2 V/m$

Question60

An electric field of 1000V / m is applied to an electric dipole at angle of 45°. The value of electric dipole moment is 10^{-29}C . m. What is the potential energy of the electric dipole? [11 Jan 2019, II]

Options:

A. -20×10^{-18}J

B. -7×10^{-27}J

C. -10×10^{-29}J

D. -9×10^{-20}J

Answer: B

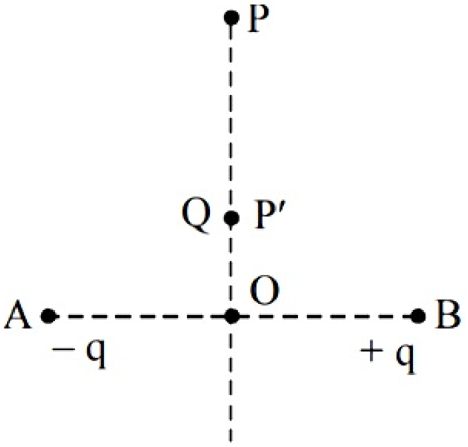
Solution:

Solution:
Potential energy of a dipole is given by

$U = -\vec{P} \cdot \vec{E}$
$= -PE\cos\theta$
[Where $\theta =$ angle between dipole and perpendicular to the field]
$= -(10 - 29)(10^3)\cos 45°$
$= -0.707 \times 10^{-26}J = -7 \times 10^{-27}J$

Question61

Charges $-q$ and $+q$ located at A and B, respectively constitute an electric dipole. Distance AB = 2a, O is the mid point of the dipole and OP is perpendicular to AB. A charge Q is placed at P where OP = y and y> > 2a. The charge Q experiences an electrostatic force F . If Q is now moved along the equatorial line to P′ such that OP′ $= \left(\frac{y}{3}\right)$, the force on Q will be close to: $\left(\frac{y}{3} >> 2a\right)$



[10 Jan 2019, II]

Options:

A. 3F

B. $\frac{F}{3}$

C. 9F

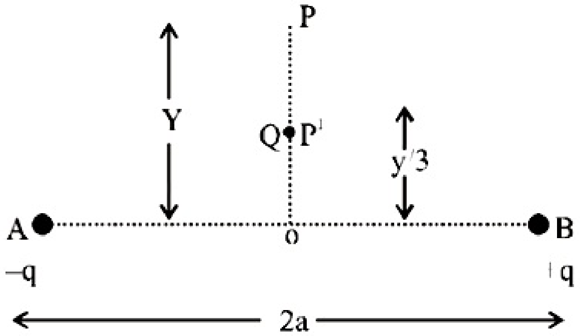
D. 27F

Answer: D

Solution:

Solution:

Electric field of equatorial plane of dipole $= -\frac{K\vec{P}}{r^3}$

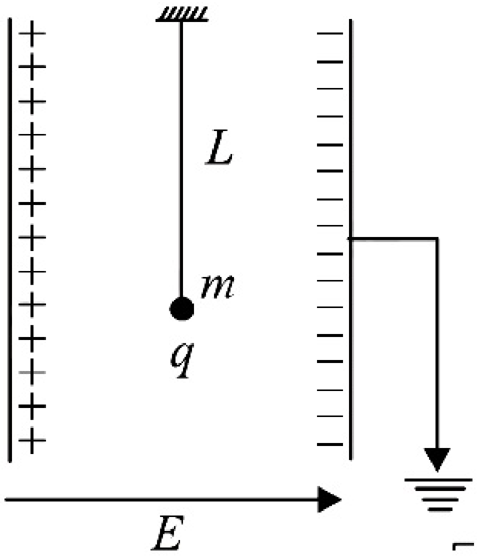


$\therefore$ At point P, $= +\frac{K\,P}{y^3}Q$

At Point P^1, $F^1 = +\frac{K\,PQ}{(y/3)^3} = 27F$.

Question62

A simple pendulum of length L is placed between the plates of a parallel plate capacitor having electric field E as shown in figure. Its bob has mass m and charge q. The time period of the pendulum is given by:



[10 April 2019, II]

Options:

A. $2\pi\sqrt{\dfrac{L}{\left(g+\dfrac{qE}{m}\right)}}$

B. $2\pi\sqrt{\dfrac{L}{\sqrt{\left(g^2-\dfrac{q^2E^2}{m^2}\right)}}}$

C. $2\pi\sqrt{\dfrac{L}{\left(g-\dfrac{qE}{m}\right)}}$

D. $2\pi\sqrt{\dfrac{L}{\sqrt{\left(g^2+\dfrac{q^2E^2}{m^2}\right)}}}$

Answer: D

Solution:

Solution:
Time period of the pendulum (T) is given by

$T = 2\pi\sqrt{\dfrac{L}{g_{eff}}}$

$g_{eff} = \dfrac{\sqrt{(mg)^2+(qE)^2}}{m}$

$\Rightarrow g_{eff} = \sqrt{g^2+\left(\dfrac{qE}{m}\right)^2} \Rightarrow T = 2\pi\sqrt{\dfrac{L}{\sqrt{g^2+\left(\dfrac{qE}{m}\right)^2}}}$

Question63

Four point charges $-q$, $+q$, $+q$ and $-q$ are placed on y -axis at $y=-2d$, $y=-d$, $y=+d$ and $y=+2d$, respectively. The magnitude of

the electric field E at a point on the x -axis at x = D, with D> > d , will behave as:
[9 April 2019, II]

Options:

A. $E \propto \frac{1}{D^3}$

B. $E \propto \frac{1}{D}$

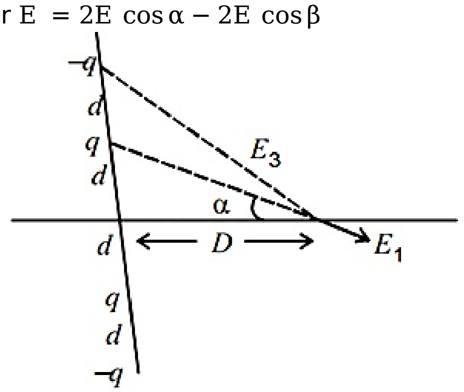
C. $E \propto \frac{1}{D^4}$

D. $E \propto \frac{1}{D^2}$

Answer: D

Solution:

Solution:
$\vec{E} = \left(\vec{E}_1 + \vec{E}_2\right) + \left(\vec{E}_3 + \vec{E}_4\right)$
or $E = 2E \cos\alpha - 2E \cos\beta$



$= \frac{2kq}{(D^2 + d^2)} \times \frac{D}{\sqrt{D^2 + d^2}} - \frac{2kq}{(D^2 + (2d)^2.} \times \frac{D}{\sqrt{D^2 + (2d)^2}}$
$= \frac{2kqD}{(D^2 + d^2)^{3/2}} - \frac{2kqD}{[D^2 + (2d)^2]^{3/2}}$
For $d < < D$
$E \propto \frac{D}{D^3} \propto \frac{1}{D^2}$

Question64

The bob of a simple pendulum has mass 2g and a charge of $5.0\frac{1}{4}$C. It is at rest in a uniform horizontal electric field of intensity 2000V / m. At equilibrium, the angle that the pendulum makes with the vertical is : (take $g = 10m / s^2$)
[8 April 2019 I]

Options:

A. $\tan^{-1}(2.0)$

B. $\tan^{-1}(0.2)$

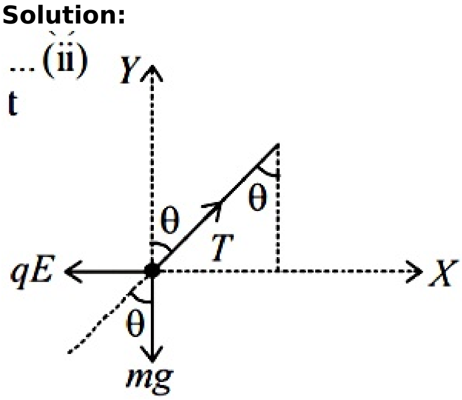
C. $\tan^{-1}(5.0)$

D. $\tan^{-1}(0.5)$

Answer: D

Solution:

Solution:



At equilibrium resultant force on bob must be zero, soT $\cos\theta = mg$ ....(i)
$T \sin\theta = qE$ ....(ii)
Solving (i) and (ii) we get

$\tan\theta = \frac{qE}{mg}$

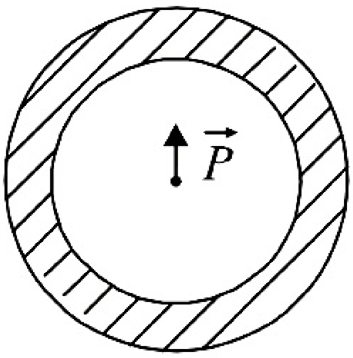
$\tan\theta = \frac{5 \times 10^{-6} \times 2000}{2 \times 10^{-3} \times 10} = \frac{1}{2}$

[Here, $q = 5 \times 10^{-6}C, E = 2000v/m, m = 2 \times 10^{-3}kg$]

$\Rightarrow \tan^{-1}\left(\frac{1}{2}\right)$

Question65

Shown in the figure is a shell made of a conductor. It has inner radius a and outer radius b, and carries charge Q. At its centre is a dipole $\vec{p}$ as shown. In this case :



[12 April 2019, I]

Options:

A. surface change density on the inner surface is uniform and equal to $\frac{Q/2}{4\pi a^2}$

B. electric field outside the shell is the same as that of a point charge at the centre of the shell.

C. surface charge density on the outer surface depends on $\left|\vec{P}\right|$

D. surface charge density on the inner surface of the shell is zero everywhere.-

Answer: B

Solution:

Solution:
Surface charge density depends only due to Q. Also

$\oint \vec{E} \cdot d\vec{A} = \frac{q_1 \lambda}{\varepsilon_0}$

or $E \times 4\pi r^2 = \frac{Q}{\varepsilon_0} \Rightarrow E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}, r \geq R$

Question66

Let a total charge 2Q be distributed in a sphere of radius R, with the charge density given by ρ(r) = kr, where r is the distance from the centre. Two charges A and B, of −Q each, are placed on diametrically opposite points, at equal distance, a, from the centre. If A and B do not experience any force, then. [12 April 2019, II]

Options:

A. $a = 8^{-1/4}R$

B. $a = \frac{3R}{2^{1/4}}$

C. $a = 2^{-1/4}R$

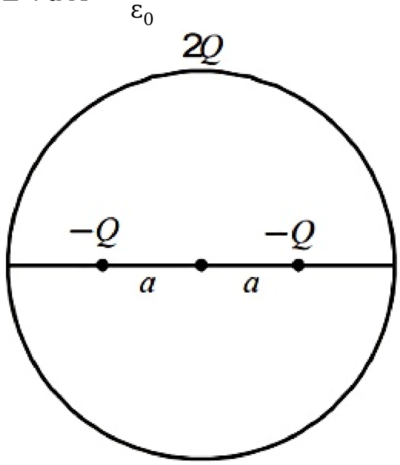
D. $a = R/\sqrt{3}$

Answer: A

Solution:

Solution:

$\oint \vec{E} \cdot d\vec{A} = \frac{q_{in}}{\varepsilon_0}$



or $E \times 4\pi r^2 = \frac{1}{\varepsilon_0}\int S(4\pi r^2) d r$

or $E \times 4\pi r^2 = \frac{1}{\varepsilon_0}\int_0^r (kr)(4\pi r^2)dr$

or $E \times 4\pi r^2 = \frac{4\pi k}{\varepsilon_0}\left(\frac{r^4}{4}\right)$

$\therefore E = \frac{k}{4\varepsilon_0}r^2$ ....(i)

Also $2Q = \int_0^R (kr)(4\pi r^2)dr = 4\pi k\left|\frac{r^4}{4}\right|_0^R$

$Q = \frac{\pi k R^4}{2}$ ....(ii)

From above equations,

$E = \frac{Qr^2}{2\pi\varepsilon_0 R^4}$ ....(iii)

According to given condition

$= E\,Q\frac{Q^4}{4\pi\varepsilon_0(20)^2}$ ....(iv)

From equations (iii) and (iv), we have

$a = 8^{-1/4}R$.

Question67

An electric dipole is formed by two equal and opposite charges q with separation d . The charges have same mass m. It is kept in a uniform electric field E . If it is slightly rotated from its equilibrium orientation, then its angular frequency ω is : [8 April 2019, II]

Options:

A. $\sqrt{\frac{qE}{md}}$

B. $\sqrt{\frac{2qE}{md}}$

C. $2\sqrt{\frac{qE}{md}}$

D. $\sqrt{\frac{qE}{2md}}$

Answer: B

Solution:

Solution:

$\tau = -PE\sin\theta$

or $I\alpha = -PE(\theta)$

$\alpha = \frac{PE}{I}(-\theta)$

On comparing with

$\alpha = -\omega^2\theta$

$\omega = \sqrt{\frac{PE}{I}} = \sqrt{\frac{qdE}{2m\left(\frac{d}{2}\right)^2}} = \sqrt{\frac{2qE}{md}}$

Question68

Two identical conducting spheres A and B, carry equal charge. They are separated by a distance much larger than their diameter, and the force between them is F . A third identical conducting sphere, C, is uncharged. Sphere C is first touched to A, then to B, and then removed. As a result, the force between A and B would be equal to [Online April 16,2018]

Options:

A. $\frac{3F}{4}$

B. $\frac{F}{2}$

C. F

D. $\frac{3F}{8}$

Answer: D

Solution:

Solution:
Spheres A and B carry equal charge say 'q'

$\therefore$ Force between them, $F = \frac{kqq}{r^2}$

When A and C are touched, charge on both $q_A = q_C = \frac{q}{2}$

Then when B and C are touched, charge on B

$q_B = \frac{\frac{q}{2} + q}{2} = \frac{3q}{4}$

Now, the force between charge q_A and q_B

$F' = \frac{kq_Aq_B}{r^2} = \frac{k \times \frac{q}{2} \times \frac{3q}{4}}{r^2} = \frac{3}{8}\frac{kq^2}{r^2} = \frac{3}{8}F$

Question69

A body of mass M and charge q is connected to a spring of spring constant k. It is oscillating along x - direction about its equilibrium position, taken to be at x = 0, with an amplitude A. An electric field E is applied along the X-direction. Which of the following statements is correct? [Online April 15, 2018]

Options:

A. The total energy of the system is $\frac{1}{2}m\omega^2A^2 + \frac{1}{2}\frac{q^2E^2}{k}$

B. The new equilibrium position is at a distance: $\frac{2qE}{k}$ from x = 0

C. The new equilibrium position is at a distance: $\frac{qE}{2k}$ from x = 0

D. The total energy of the system is $\frac{1}{2}m\omega^2A^2 - \frac{1}{2}\frac{q^2E^2}{k}$

Answer: A

Solution:

Solution:
Equilibrium position will shift to point where resultant force = 0

$kx_{eq} = qE \Rightarrow x_{eq} = \frac{qE}{k}$

Total energy $= \frac{1}{2}m\omega^2A^2 + \frac{1}{2}kx_{eq}^2$

Total energy $= \frac{1}{2}m\omega^2A^2 + \frac{1}{2}\frac{q^2E^2}{k}$

Question70

A solid ball of radius R has a charge density ρ given by$\rho = \rho_0\left(1 - \frac{r}{R}\right)$ for $0 \leq r \leq R$. The electric field outside the ball is: [Online April 15, 2018]

Options:

A. $\frac{\rho_0R^3}{\varepsilon_0r^2}$

B. $\frac{4\rho_0R^3}{3\varepsilon_0r^2}$

C. $\frac{3\rho_0R^3}{4\varepsilon_0r^2}$

D. $\frac{\rho_0R^3}{12\varepsilon_0r^2}$

Answer: D

Solution:

Charge density, $\rho = \rho_0\left(1 - \frac{r}{R}\right)$

$dq = \rho dv$

$q_{in} = \int dq = \rho dv$

$= \rho_0\left(1 - \frac{r}{R}\right)4\pi r^2 dr (\because dv = 4\pi r^2 dr)$

$= 4\pi\rho_0\int_0^R\left(1 - \frac{r}{R}\right)r^2 dr$

$= 4\pi\rho_0\int_0^R r^2 dr - \frac{r^2}{R}dr$

$= 4\pi\rho_0\left[\left[\frac{r^3}{3}\right]_0^R - \left[\frac{r^4}{4R}\right]_0^R\right] = 4\pi\rho_0\left[\frac{R^3}{3} - \frac{R^4}{4R}\right]$

$= 4\pi\rho_0\left[\frac{R^3}{3} - \frac{R^3}{4}\right] = 4\pi\rho_0\left[\frac{R^3}{12}\right]$

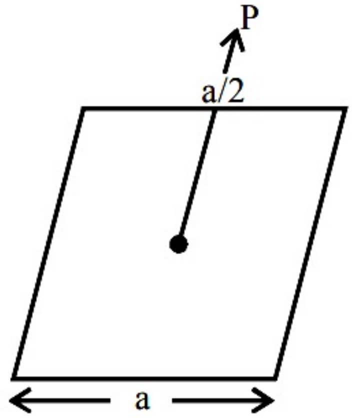
$q = \frac{\pi\rho_0 R^3}{3}$

$E.4\pi r^2 = \left(\frac{\pi\rho_0 R^3}{3\in_0}\right)$

∴ Electric field outside the ball, $E = \frac{\rho_0 R^3}{12 \in_0 r^2}$

Question71

A charge Q is placed at a distance a / 2 above the centre of the square surface of edge a as shown in the figure. The electric flux through the square surface is:



[Online April 15, 2018]

Options:

A. $\frac{Q}{3\varepsilon_0}$

B. $\frac{Q}{6\varepsilon_0}$

C. $\frac{Q}{2\varepsilon_0}$

D. $\frac{Q}{\varepsilon_0}$

Answer: B

Solution:

Solution:
When cube is of side a and point charge Q is at the center of the cube then the total electric flux due to this charge will pass evenly through the six faces of the cube.
So, the electric flux through one face will be equal to 1/6 of the total electric flux due to this charge.
Flux through 6 faces $= \frac{Q}{\in_0}$

∴ Flux through 1 face , $= \frac{Q}{6\in_0}$

Question72

An electric dipole has a fixed dipole moment $\vec{p}$, which makes angle θ with respect to x-axis. When subjected to an electric field $\vec{E}_1 = E\hat{i}$, it experiences a torque $\vec{T}_1 = \tau\hat{i}$ When subjected to another electric field $\vec{E}_2 = \sqrt{3E_1}\hat{j}$ it experiences torque $\vec{T}_2 = -\vec{T}_1$. The angle θ is:
[2017]

Options:

A. 60°

B. 90°

C. 30°

D. 45°

Answer: A

Solution:

Solution:

$T = PE\ \sin\text{theta}$ Torque experienced by the dipole in an electric field, $\vec{T} = \vec{P} \times \vec{E}$

$\vec{p} = p\cos\theta\,\hat{i} + p\sin\theta\,\hat{j}$

$\vec{E}_1 = E\,\vec{i}$

$\vec{T}_1 = \vec{p} \times \vec{E}_1 = \left(p\cos\theta\,\hat{i} + p\sin\theta\,\hat{j}\right) \times E\left(\hat{i}\right)$

$\tau\hat{k} = pE\ \sin\theta\left(-\hat{k}\right)$ ....(i)

$\vec{E}_2 = \sqrt{3}E_1\hat{j}$

$\vec{T}_2 = p\cos\theta\,\hat{i} + p\sin\theta\,\hat{j} \times \sqrt{3}E_1\hat{j}$

$\tau\hat{k} = \sqrt{3}pE_1\cos\theta\,\hat{k}$ ....(ii)

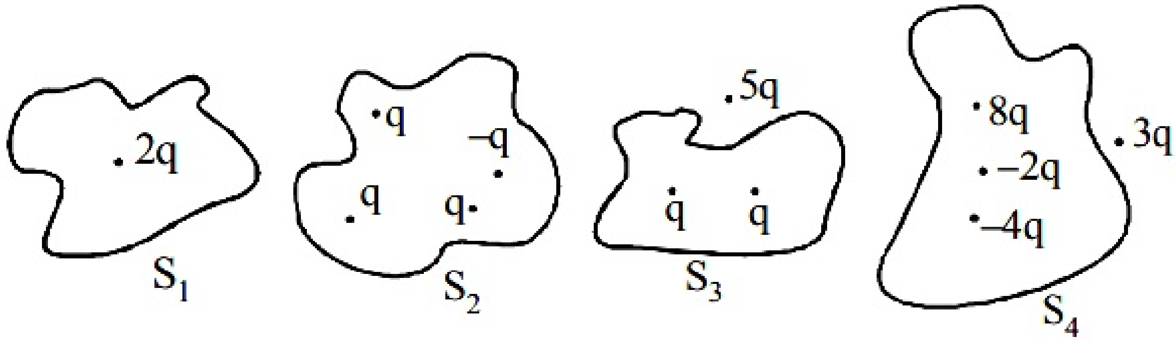
From eqns. (i) and (ii)

$pE\ \sin\theta = \sqrt{3}pE\ \cos\theta$

$\tan\theta = \sqrt{3} \quad \therefore \theta = 60°$

Question73

Four closed surfaces and corresponding charge distributions are shown below.



Let the respective electric fluxes through the surfaces be Φ_1, Φ_2, Φ_3, and Φ_4. Then :
[Online April 9, 2017]

Options:

A. $\Phi_1 < \Phi_2 = \Phi_3 > \Phi_4$

B. $\Phi_1 > \Phi_2 > \Phi_3 > \Phi_4$

C. $\Phi_1 = \Phi_2 = \Phi_3 = \Phi_4$

D. $\Phi_1 > \Phi_3$; $\Phi_2 < \Phi_4$

Answer: C

Solution:

Solution:
The net flux linked with closed surfaces S_1, S_2, S_3 & S_4 are

For surface S_1, $\phi_1 = \frac{1}{\phi_0}(2q)$

For surface S_2, $\phi_2 = \frac{1}{\varepsilon_0}(q + q + q - q) = \frac{1}{\varepsilon_0}2q$

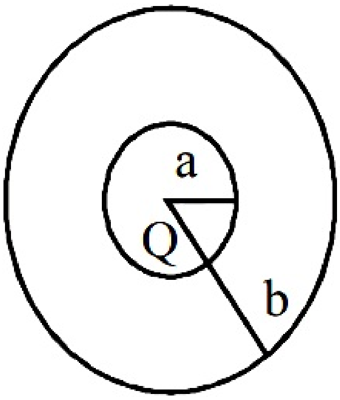
For surface S_3, $\phi_3 = \frac{1}{\varepsilon_0}(q + q) = \frac{1}{\varepsilon_0}(2q)$

For surface S_4, $\phi_4 = \frac{1}{\varepsilon_0}(8q - 2q - 4q) = \frac{1}{\varepsilon_0}(2q)$

Hence, $\phi_1 = \phi_2 = \phi_3 = \phi_4$ i.e. net electric flux is same for all surfaces.
Keep in mind, the electric field due to a charge outside (S_3 and S_4), the Gaussian surface contributes zero net flux through the surface, because as many lines due to that charge enter the surface as leave it.

Question74

The region between two concentric spheres of radii 'a' and 'b', respectively (see figure), have volume charge density $\rho = \frac{A}{r}$, where A is a constant and r is the distance from the centre. At the centre of the spheres is a point charge Q. The value of A such that the electric field in the region between the spheres will be constant, is:



[2016]

Options:

A. $\frac{2Q}{\pi(a^2 - b^2)}$

B. $\frac{2Q}{\pi a^2}$

C. $\frac{Q}{2\pi a^2}$

D. $\frac{Q}{2\pi(b^2 - a^2)}$

Answer: C

Solution:

Solution:
Applying Gauss's law

$\oint_S \vec{E} \cdot d\vec{s} = \frac{Q}{\in_0}$

$\therefore E \times 4\pi r^2 = \frac{Q + 2\pi A r^2 - 2\pi A a^2}{\in_0}$

$\rho = \frac{dr}{dV}$

$Q = \rho 4\pi r^2$

$Q = \int_a^r \frac{A}{r} 4\pi r^2 dr = 2\pi A[r^2 - a^2]$

$E = \frac{1}{4\pi\in_0}\left[\frac{Q - 2\pi A a^2}{r^2} + 2\pi A\right]$

For E to be independent of ' r '

$Q - 2\pi A a^2 = 0$

$\therefore A = \frac{Q}{2\pi a^2}$

Question75

Shown in the figure are two point charges +Q and −Q inside the cavity of a spherical shell. The charges are kept near the surface of the cavity on opposite sides of the centre of the shell. If sigma$_1$ is the surface charge on the inner surface and Q_1 net charge on it and σ_2 the surface charge on the outer surface and Q_2 net charge on it then :

[Online April 10, 2015]

Options:

A. $\sigma_1 \neq 0, Q_1 = 0$
$\sigma_2 = 0, Q_2 = 0$

B. $\sigma_1 \neq 0, Q_1 = 0$
$\sigma_2 \neq 0, Q_2 = 0$

C. $\sigma_1 = 0, Q_1 = 0$
$\sigma_2 = 0, Q_2 = 0$

D. $\sigma_1 \neq 0, Q_1 \neq 0$
$\sigma_2 \neq 0, Q_2 \neq 0$

Answer: C

Solution:

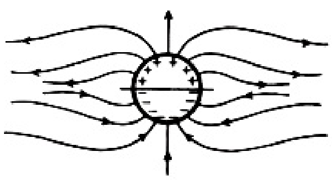
Solution:
Inside the cavity net charge is zero.
$\therefore Q_1 = 0$ and $\sigma_1 = 0$
There is no effect of point charges $+Q$, $-Q$ and induced charge on inner surface on the outer surface.
$\therefore Q_2 = 0$ and $\sigma_2 = 0$

Question76

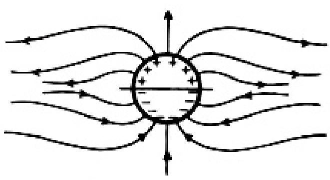
A long cylindrical shell carries positive surface charge σ in the upper half and negative surface charge −σ in the lower half. The electric field lines around the cylinder will look like figure given in : (figures are schematic and not drawn to scale)
[2015]

Options:

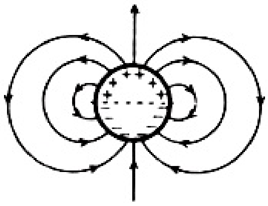
A.



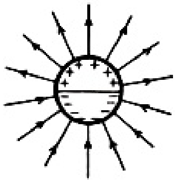
B.



C.



D.



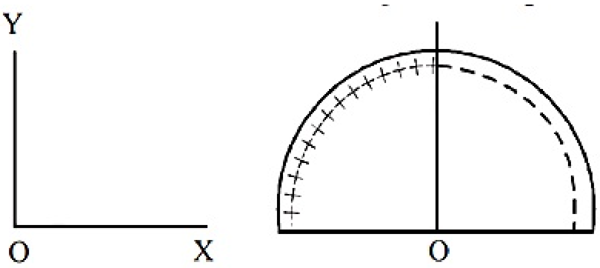
Answer: C

Solution:

Solution:
Field lines originate perpendicular from positive charge and terminate perpendicular at negative charge.
Further this system can be treated as an electric dipole.

Question77

A wire of length L(= 20cm), is bent into a semicircular arc. If the two equal halves of the arc were each to be uniformly charged with charges ±Q, [|Q| = $10^3 \varepsilon_0$. Coulomb where ε_0 is the permittivity (in SI units) of free space] the net electric field at the centre O of the semicircular arc would be :



[Online April 11, 2015]

Options:

A. $(50 \times 10^3 N / C)\hat{j}$

B. $(50 \times 10^3 N / C)\hat{i}$

C. $(25 \times 10^3 N / C)\hat{j}$

D. $(25 \times 10^3 N / C)\hat{i}$

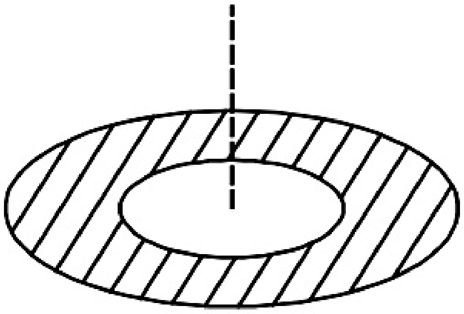
Answer: D

Solution:

Given: Length of wire L = 20cm
charge $Q = 10^3\varepsilon_0$
We know, electric field at the centre of the semicircular arc
$E = \frac{2K\lambda}{r}$
or, $E = 2K\left(\frac{2Q}{\pi r}\right)r\left[\text{As}\,\lambda = \frac{2Q}{\pi r}\right]$
$= \frac{4KQ}{\pi r^2} = \frac{4KQ\pi^2}{\pi L^2} = \frac{4\pi KQ}{L^2} = 25 \times 10^3 N / C\,\hat{i}$

Question78

A thin disc of radius b = 2a has a concentric hole of radius ' a ' in it (see figure). It carries uniform surface charge ' σ ' on it. If the electric field on its axis at height ' h ' (h< < a) from its centre is given as ' Ch ' then value of ' C ' is :



[Online April 10, 2015]

Options:

A. $\frac{\sigma}{4a\epsilon_0}$

B. $\frac{\sigma}{8a\epsilon_0}$

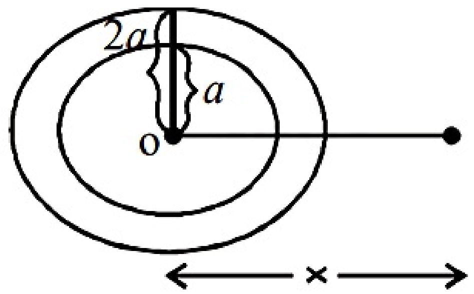
C. $\frac{\sigma}{a\epsilon_0}$

D. $\frac{\sigma}{2a\epsilon_0}$

Answer: A

Solution:

Electric field due to complete disc(R = 2a) at a distance x and on its axis
$E_1 = \frac{\sigma}{2\varepsilon_0}\left[1 - \frac{x}{\sqrt{R^2 + x^2}}\right]$ $E_1 = \frac{\sigma}{2\varepsilon_0}\left[1 - \frac{h}{\sqrt{4a^2 + h^2}}\right]$
$= \frac{\sigma}{2\varepsilon_0}\left[1 - \frac{h}{2a}\right]$[here x = h and, R = 2a]



Similarly, electric field due to disc $(R = a)$

$E_2 = \frac{\sigma}{2\varepsilon_0}\left(1 - \frac{h}{a}\right)$

Electric field due to given disc

$E = E_1 - E_2$

$\frac{\sigma}{2\varepsilon_0}\left[1 - \frac{h}{2a}\right] - \frac{\sigma}{2\varepsilon_0}\left[1 - \frac{h}{a}\right] = \frac{\sigma h}{4\varepsilon_0 a}$

Hence, $c = \frac{\sigma}{4a\varepsilon_0}$

Question79

The electric field in a region of space is given by, $\vec{E} = E_o\hat{i} + 2E_o\hat{j}$ where $E_o = 100N / C$. The flux of the field through a circular surface of radius 0.02 m parallel to the YZ plane is nearly: [Online April 19, 2014]

Options:

A. $0.125N\,m^2 / C$

B. $0.02N\,m^2 / C$

C. $0.005N\,m^2 / C$

D. $3.14N\,m^2 / C$

Answer: A

Solution:

$\vec{E} = E_o\hat{i} + 2E_o\hat{j}$

Given, $E_0 = 100N / c$

So, $\vec{E} = 100\hat{i} + 200\hat{i}$

Radius of circular surface $= 0.02m$

Area $= \pi r^2 = \frac{22}{7} \times 0.02 \times 0.02$

$= 1.25 \times 10^{-3}\hat{i}\,m^2$ [Loop is parallel to Y-Z plane]

Now, flux $(\phi) = E\,A\cos\theta$

$= \left(100\hat{i} + 200\hat{j}\right) . 1.25 \times 10^{-3}\hat{i}\ \cos\theta°[\theta = 0°]$

$= 125 \times 10^{-3}N\,m^2 / c$

$= 0.125N\,m^2 / c$

Question80

A spherically symmetric charge distribution is characterised by a charge density having the following variations:

$$\rho(r) = \rho_o\left(1 - \frac{r}{R}\right) \text{ for } r < R$$

$$\rho(r) = 0 \text{ for } r \geq R$$

Where r is the distance from the centre of the charge distribution ρ_0 is a constant. The electric field at an internal point (r < R) is:
[Online April 12,2014]

Options:

A. $\frac{\rho_o}{4\varepsilon_o}\left(\frac{r}{3} - \frac{r^2}{4R}\right)$

B. $\frac{\rho_o}{\varepsilon_o}\left(\frac{r}{3} - \frac{r^2}{4R}\right)$

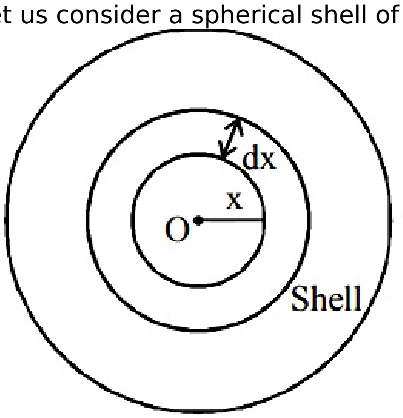
C. $\frac{\rho_o}{3\varepsilon_o}\left(\frac{r}{3} - \frac{r^2}{4R}\right)$

D. $\frac{\rho_o}{12\varepsilon_o}\left(\frac{r}{3} - \frac{r^2}{4R}\right)$

Answer: B

Solution:

Solution:
Let us consider a spherical shell of radius x and thickness dx.



Charge on this shell

$d\,q = \rho.4\pi x^2 d\,x = \rho_0\left(1 - \frac{x}{R}\right).\,4\pi x^2 d\,x$

∴ Total charge in the spherical region from centre to $r(r q = \int d\,q = 4\pi\rho_0\int_0^r \left(1 - \frac{x}{R}\right)x^2 d\,x$

$= 4\pi\rho_0\left[\frac{x^3}{3} - \frac{x^4}{4R}\right]_0^r = 4\pi\rho_0\left[\frac{r^3}{3} - \frac{r^4}{4R}\right] = 4\pi\rho_0 r^3\left[\frac{1}{3} - \frac{r}{4R}\right]$

∴ Electric field at r, $E = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{r^2}$

$= \frac{1}{4\pi\varepsilon_0}\cdot\frac{4\pi\rho_0 r^3}{r^2}\left[\frac{1}{3} - \frac{r}{4R}\right] = \frac{\rho_0}{\varepsilon_0}\left[\frac{r}{3} - \frac{r^2}{4R}\right]$

Question81

The magnitude of the average electric field normally present in the

atmosphere just above the surface of the Earth is about 150N / C , directed inward towards the center of the Earth. This gives the total net surface charge carried by the Earth to be:
[Given $\varepsilon_0 = 8.85 \times 10^{-12} C^2 / N - m^2$, $R_E = 6.37 \times 10^6 m$]
[Online April 9, 2014]

Options:

A. $+670 kC$

B. $-670 kC$

C. $-680 kC$

D. $+680 kC$

Answer: C

Solution:

Solution:
Given,
Electric field E = 150 N/C
Total surface charge carried by earth q = ?
or, $q = \in_0 E A$
$= \in_0 E \pi r^2$
$= 8.85 \times 10^{-12} \times 150 \times (6.37 \times 10^6)^2$.
$\simeq 680 K c$
As electric field directed inward hence
$q = -680 K c$

Question82

Two charges, each equal to q, are kept at x = −a and x = a on the x -axis. A particle of mass m and charge $q_0 = \frac{q}{2}$ is placed at the origin. If charge q_0 is given a small displacement (y< < a) along the y-axis, the net force acting on the particle is proportional to
[2013]

Options:

A. y

B. $-y$

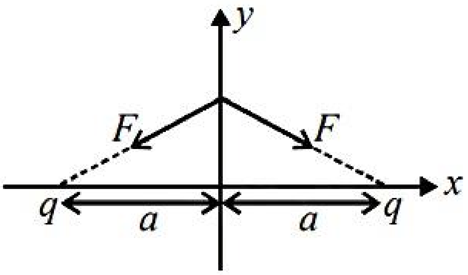
C. $\frac{1}{y}$

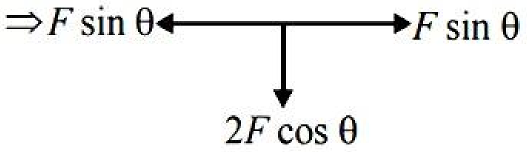
D. $-\frac{1}{y}$

Answer: A

Solution:

(a)





$\Rightarrow F_{net} = 2F\cos\theta$

$F_{net} = \dfrac{2kq\left(\frac{q}{2}\right)}{\left(\sqrt{y^2+a^2}\right)^2} \cdot \dfrac{y}{\sqrt{y^2+a^2}}$

$F_{net} = \dfrac{2kq\left(\frac{q}{2}\right)y}{(y^2+a^2)^{3/2}} (\because y << a)$

$\Rightarrow \dfrac{kq^2 y}{a^3}$ So, $F \propto y$

Question83

Two balls of same mass and carrying equal charge are hung from a fixed support of length l . At electrostatic equilibrium, assuming that angles made by each thread is small, the separation, x between the balls is proportional to:
[Online April 9, 2013]

Options:

A. l

B. l^2

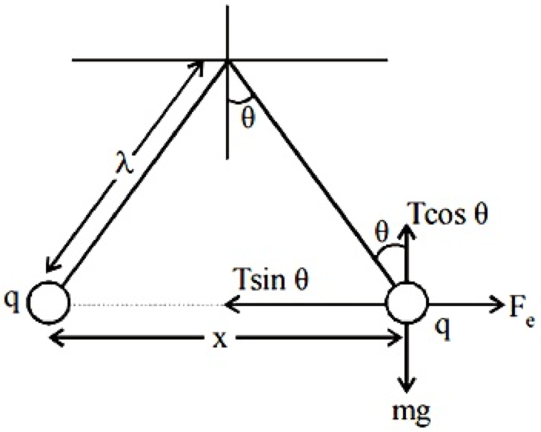
C. $l^{2/3}$

D. $l^{1/3}$

Answer: D

Solution:

Solution:



In equilibrium, $F_e = T \sin\theta$

$mg = T \cos\theta$

$\tan\theta = \frac{F_e}{mg} = \frac{q^2}{4\pi \in_0 x^2 \times mg}$

also $\tan\theta \approx \sin = \frac{x/2}{l}$

Hence, $\frac{x}{2l} = \frac{q^2}{4\pi \in_0 x^2 \times mg}$

$\Rightarrow x^3 = \frac{2q^2 l}{4\pi \in_0 mg}$

$\therefore x = \left(\frac{q^2 l}{2\pi \in_0 mg}\right)^{1/3}$

Therefore $x \propto l^{1/3}$

Question84

The surface charge density of a thin charged disc of radius R is σ. The value of the electric field at the centre of the disc is $\frac{\sigma}{2\in_0}$. With respect to the field at the centre, the electric field along the axis at a distance R from the centre of the disc : [Online April 25, 2013]

Options:

A. reduces by 70.7%

B. reduces by 29.3%

C. reduces by 9.7%

D. reduces by 14.6%

Answer: A

Solution:

Solution:

Electric field intensity at the centre of the disc.

$E = \frac{\sigma}{2\in_0}\left(\text{ given }\right)$

Electric field along the axis at any distance x from the centre of the disc

$E' = \frac{\sigma}{2\in_0}\left(1 - \frac{x}{\sqrt{x^2 + R^2}}\right)$

From question, x = R (radius of disc)

$\therefore E' = \frac{\sigma}{2\epsilon_0}\left(1 - \frac{R}{\sqrt{R^2 + R^2}}\right)$

$= \frac{\sigma}{2\epsilon_0}\left(\frac{\sqrt{2}R - R}{\sqrt{2}R}\right)$

$= \frac{4}{14}E$

∴ % reduction in the value of electric field

$= \frac{\left(E - \frac{4}{14}E\right) \times 100}{E} = \frac{1000}{14}\% \simeq 70.7\%$

Question85

A liquid drop having 6 excess electrons is kept stationary under a uniform electric field of $25.5 \mathrm{kV\,m^{-1}}$. The density of liquid is $1.26 \times 10^3 \mathrm{kg\ m^{-3}}$. The radius of the drop is (neglect buoyancy). [Online April 23, 2013]

Options:

A. $4.3 \times 10^{-7}\mathrm{m}$

B. $7.8 \times 10^{-7}\mathrm{m}$

C. $0.078 \times 10^{-7}\mathrm{m}$

D. $3.4 \times 10^{-7}\mathrm{m}$

Answer: B

Solution:

Solution:

$F = qE = mg(q = 6e = 6 \times 1.6 \times 10^{-19})$

Density $(d) = \frac{\text{mass}}{\text{volume}} = \frac{m}{\frac{4}{3}\pi r^3}$

or $r^3 = \frac{m}{\frac{4}{3}\pi d}$

Putting the value of d and $m\left(= \frac{qE}{g}\right)$ and solving we get $r = 7.8 \times 10^{-7}\mathrm{m}$

Question86

Two point dipoles of dipole moment $\vec{p}_1$ and $\vec{p}_2$ are at a distance x from each other and $\vec{p}_1 \parallel \vec{p}_2$. The force between the dipoles is: [Online April 9, 2013]

Options:

A. $\frac{1}{4\pi\varepsilon_0}\frac{4p_1p_2}{x^4}$

B. $\frac{1}{4\pi\varepsilon_0}\frac{3p_1p_2}{x^3}$

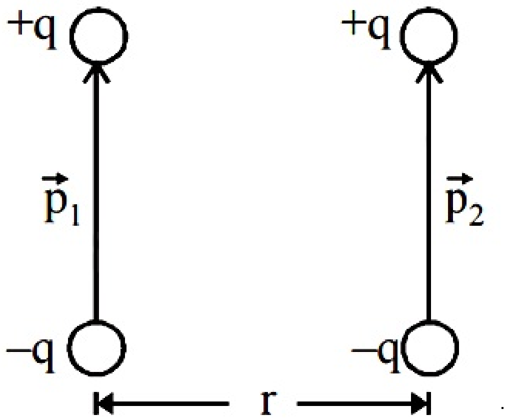
C. $\frac{1}{4\pi\varepsilon_0}\frac{6p_1p_2}{x^4}$

D. $\frac{1}{4\pi\varepsilon_0}\frac{8p_1p_2}{x^4}$

Answer: C

Solution:

Solution:
Force of interaction
$F = \frac{1}{4\pi\epsilon_0}\cdot\frac{6p_1p_2}{r^4}$

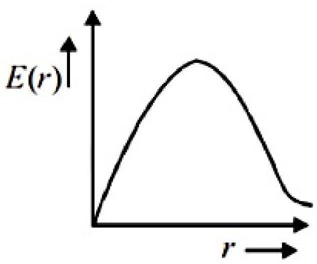


Question87

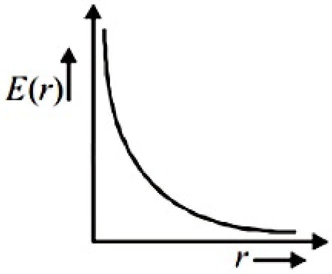
In a uniformly charged sphere of total charge Q and radius R, the electric field E is plotted as function of distance from the centre, The graph which would correspond to the above will be: [2012]

Options:

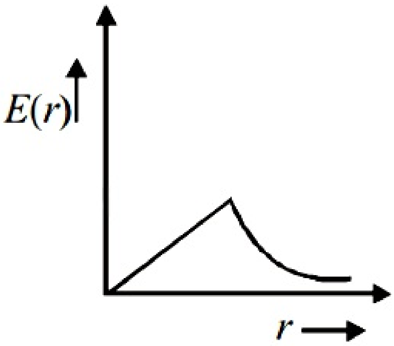
A.



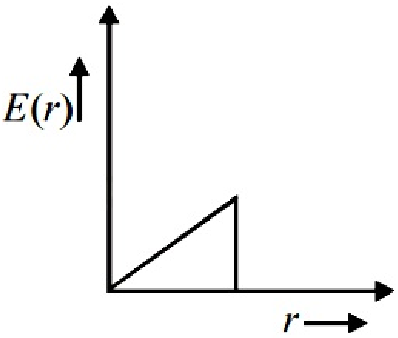
B.



C.



D.



Answer: C

Solution:

Solution:

$E_{in} \propto r$

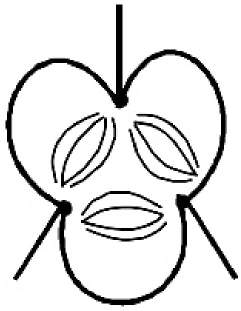
$E_{out} \propto \frac{1}{r^2}$

Question88

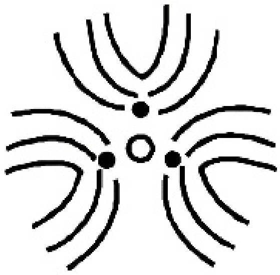
Three positive charges of equal value q are placed at vertices of an equilateral triangle. The resulting lines of force should be sketched as in
[Online May 26, 2012]

Options:

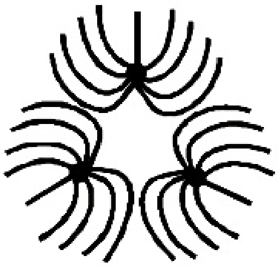
A.



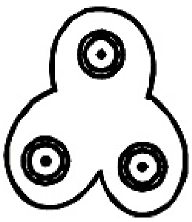
B.



C.



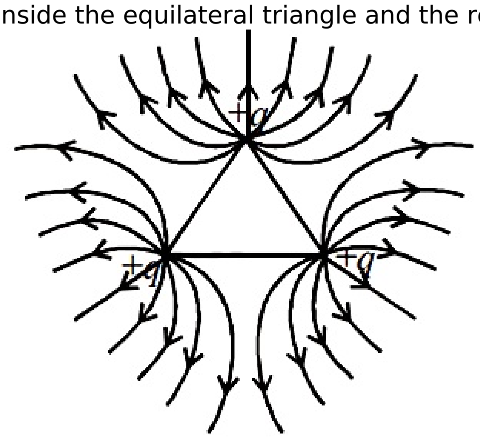
D.



Answer: C

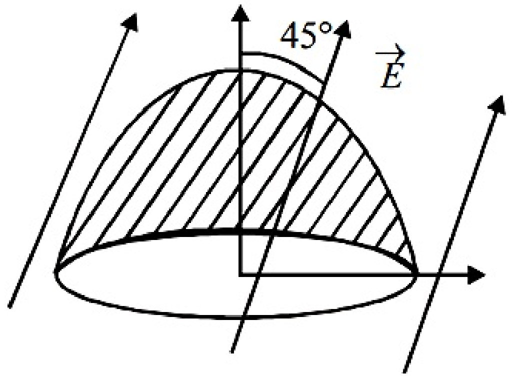
Solution:

Solution:
Electric lines of force due to a positive charge is spherically symmetric.
All the charges are positive and equal in magnitude. So repulsion takes place. Due to which no lines of force are present inside the equilateral triangle and the resulting lines of force obtained as shown:



Question89

The flat base of a hemisphere of radius a with no charge inside it lies in a horizontal plane. A uniform electric field $\vec{E}$ is applied at an angle $\frac{\pi}{4}$ with the vertical direction. The electric flux through the curved surface of the hemisphere is



[Online May 19, 2012]

Options:

A. $\pi a^2 E$

B. $\frac{\pi a^2 E}{\sqrt{2}}$

C. $\frac{\pi a^2 E}{2\sqrt{2}}$

D. $\frac{(\pi + 2)\pi a^2 E}{(2\sqrt{2})^2}$

Answer: B

Solution:

Solution:
We know that,
$\phi = \oint \vec{E} \cdot d\vec{S} = E \oint dS \cos 45°$
In case of hemisphere
$\phi_{curved} = \phi_{circular}$
Therefore, $\phi_{curved} = E \pi a^2 \cdot \frac{1}{\sqrt{2}} = \frac{E \pi a^2}{\sqrt{2}}$

Question90

Two identical charged spheres suspended from a common point by two massless strings of length l are initially a distance d $(d << l)$ apart because of their mutual repulsion. The charge begins to leak from both the spheres at a constant rate. As a result charges approach each other with a velocity v. Then as a function of distance x between them, [2011]

Options:

A. $v \propto x^{-1}$

B. $v \propto x^{1/2}$

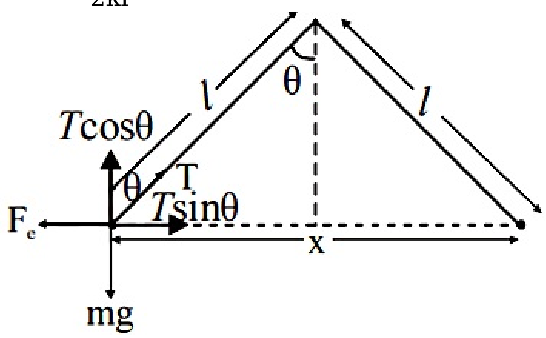
C. $v \propto x$

D. $v \propto x^{-1/2}$

Answer: D

Solution:

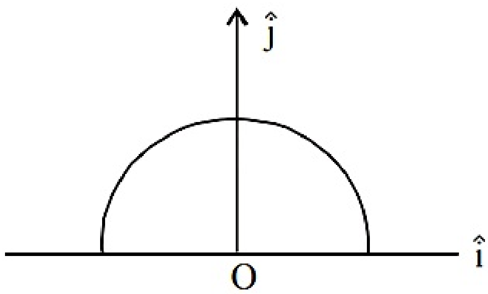
Solution:
From figure
$T \cos\theta = mg$ ......(i)
$T \sin\theta = F_e$ ....(ii)
Dividing equation (ii) by (i), we get
$\Rightarrow \frac{\sin\theta}{\cos\theta} = \frac{F_e}{mg} \Rightarrow F_e = mg\tan\theta$
$\Rightarrow \frac{kq^2}{x^2} = mg\tan\theta \Rightarrow q^2 = \frac{x^2 mg\tan\theta}{k}$
Since θ is small
$\therefore \tan\theta \approx \sin\theta = \frac{x}{2l}$
$\therefore q^2 = \frac{x^3 mg}{2kl} \Rightarrow q^2 \propto x^{3/2}$



$\Rightarrow \frac{dq}{dt} \alpha \frac{3}{2}\sqrt{x}\frac{dx}{dt} = \frac{3}{2}\sqrt{x}V$
Since $\frac{dq}{dt} = \text{const.}$
$\Rightarrow v \propto x^{-1/2}$ $[\because q^2 \propto x^3]$

Question91

A thin semi-circular ring of radius r has a positive charge q distributed uniformly over it. The net field $\vec{E}$ at the centre O is



[2010]

Options:

A. $\frac{q}{4\pi^2\varepsilon_0 r^2}\hat{j}$

B. $-\frac{q}{4\pi^2\varepsilon_0 r^2}\hat{j}$

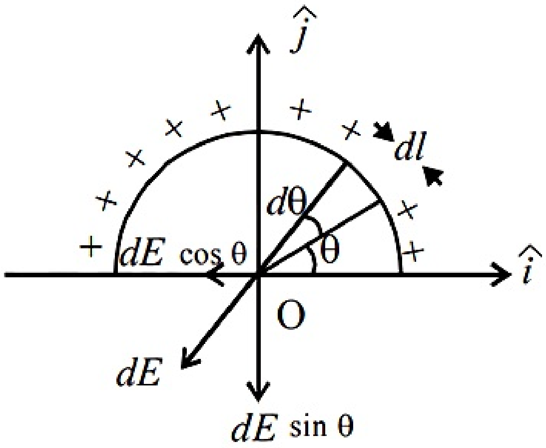
C. $-\frac{q}{2\pi^2\varepsilon_0 r^2}\hat{j}$

D. $\frac{q}{2\pi^2\varepsilon_0 r^2}\hat{j}$

Answer: C

Solution:

Solution:
Letus consider a differential element dl subtending at angle dQ at the centre Q as shown in the figure. Linear charge density
$\lambda = \frac{q}{Qr}$



Charge on the element, $dq = \left(\frac{q}{\pi r}\right)dl$

$= \frac{q}{\pi r}(rd\theta)\ (\because dl = rd\theta)$

$= \left(\frac{q}{\pi}\right)d\theta$

Electric field at the center O due to dq is

$dE = \frac{1}{4\pi\in_0} \cdot \frac{dq}{r^2} = \frac{1}{4\pi\in_0} \cdot \frac{q}{\pi r^2}d\theta$

Resolving dE into two rectangular component, we find the component $dE\cos\theta$ will be counter balanced by another element on left portion. Hence resultant field at O is the resultant of the component $dE\sin\theta$ only.

$\therefore E = \int dE\sin\theta = \int_0^{\pi} \frac{q}{4\pi^2 r^2\in_0}\sin\theta\, d\theta$

$= \frac{q}{4\pi^2 r^2\in_0}[-\cos\theta]_0^{\pi}$

$= \frac{q}{4\pi^2 r^2\in_0}(+1+1) = \frac{q}{2\pi^2 r^2\in_0}$

The direction of E is towards negative y -axis.

$\therefore \vec{E} = -\frac{q}{2\pi^2 r^2\in_0}\hat{j}$

Question92

Let there be a spherically symmetric charge distribution with charge

density varying as $\rho(r) = \rho_0\left(\frac{5}{4} - \frac{r}{R}\right)$ upto r = R, and $\rho(r) = 0$ for r > R, where r is the distance from the origin. The electric field at a distance r(r < R) from the origin is given by
[2010]

Options:

A. $\frac{\rho_0 r}{4\varepsilon_0}\left(\frac{5}{3} - \frac{r}{R}\right)$

B. $\frac{4\rho_0 r}{3\varepsilon_0}\left(\frac{5}{3} - \frac{r}{R}\right)$

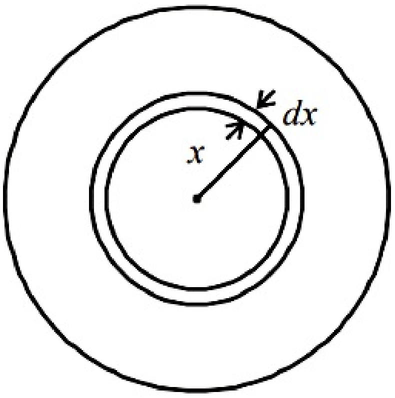
C. $\frac{\rho_0 r}{4\varepsilon_0}\left(\frac{5}{4} - \frac{r}{R}\right)$

D. $\frac{\rho_0 r}{3\varepsilon_0}\left(\frac{5}{4} - \frac{r}{R}\right)$

Answer: A

Solution:

Solution:
Let us consider a spherical shell of radius x and thickness dx.
Due to shpherically symmetric charge distribution, the chrge on the spherical surface of radius x is
$dq = dV\rho \,.\, 4\pi x^2 dx = \rho_0\left(\frac{5}{4} - \frac{x}{R}\right) . 4\pi x^2 dx$
∴ Total charge in the spherical region from centre to $r(r < R)$ is
$q = \int dq = 4\pi\rho_0 \int_0^r \left(\frac{5}{4} - \frac{x}{R}\right) x^2 dx$



$= 4\pi\rho_0\left[\frac{5}{4} \cdot \frac{r^3}{3} - \frac{1}{R} \cdot \frac{r^4}{4}\right] = \pi\rho_0 r^3\left(\frac{5}{3} - \frac{r}{R}\right)$
∴ Electric field intensity at a point on this spherical surface
$E = \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{r^2}$
$= \frac{1}{4\pi\epsilon_0} \cdot \frac{\pi\rho_0 r^3}{r^2}\left(\frac{5}{3} - \frac{r}{R}\right) = \frac{\rho_0 r}{4\epsilon_0}\left(\frac{5}{3} - \frac{r}{R}\right)$

Question93

A charge Q is placed at each of the opposite corners of a square. A charge q is placed at each of the other two corners. If the net electrical force on Q is zero, then Q / q equals:

[2009]

Options:

A. -1

B. 1

C. $-\frac{1}{\sqrt{2}}$

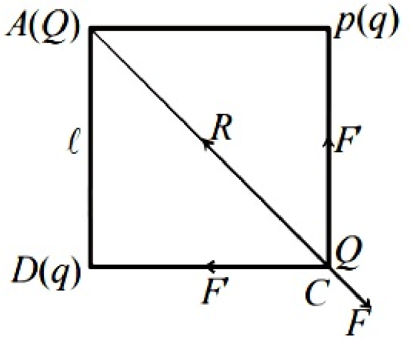
D. $-2\sqrt{2}$

Answer: D

Solution:

Solution:

Let F be the force between Q and Q. The force between q and Q should be attractive for net force on Q to be zero. Let F' be the force between Q and q. The resultant of F' and F is R. For equilibrium



Net force on Q at C is zero

$\therefore \vec{R} + \vec{F} = 0 \Rightarrow \sqrt{2}F' = -F$

$\Rightarrow \sqrt{2} \times k\frac{Qq}{l^2} = -k\frac{Q^2}{(\sqrt{2}l)^2}$

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

Question94

This question contains Statement- 1 and Statement- 2 . Of the four choices given after the statements, choose the one that best describes the two statements.
Statement-1: For a charged particle moving from point P to point Q, the net work done by an electrostatic field on the particle is independent of the path connecting point P to point Q.
Statement- 2 : The net work done by a conservative force on an object moving along a closed loop is zero.
[2009]

Options:

A. Statement- 1 is true, Statement- 2 is true; Statement-2 is the correct explanation of Statement- 1 .

B. Statement- 1 is true, Statement- 2 is true; Statement-2 is not the correct explanation of Statement- 1 .

C. Statement- 1 is false, Statement- 2 is true.

D. Statement- 1 is true, Statement- 2 is false.

Answer: A

Question95

Let $\rho(r) = \frac{Q}{\pi R^4} r$ be the charge density distribution for a solid sphere of radius R and total charge Q. For a point ′P ' inside the sphere at distance r_1 from the centre of the sphere, the magnitude of electric field is : [2009]

Options:

A. $\frac{Q}{4\pi \in 0 r_1{}^2}$

B. $\frac{Q r_1{}^2}{4\pi \in_0 R^4}$

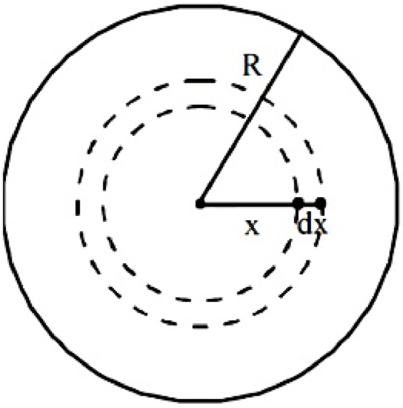
C. $\frac{Q r_1{}^2}{3\pi \in_0 R^4}$

D. 0

Answer: B

Solution:

Solution:



Let us consider a spherical shell of thickness dx and radius x. The area of this spherical shell $= 4\pi x^2$.
The volume of this spherical shell $= 4\pi x^2 dx$. The charge enclosed within shell
$dq = \left[\frac{Q \cdot x}{\pi R^4}\right][4\pi x^2 dx] = \frac{4Q}{R^4} x^3 dx$
The charge enclosed in a sphere of radius r_1 can be calculated by

$Q = \int dq = \frac{4Q}{R^4}\int_0^{r_1} x^3 dx = \frac{4Q}{R^4}\left[\frac{x^4}{4}\right]_0^1 = \frac{Q}{R^4} r_1{}^4$

∴ The electric field at point P inside the sphere at a distance r_1 from the centre of the sphere is

$E = \frac{1}{4\pi E}\frac{Q}{r_1{}^2}$

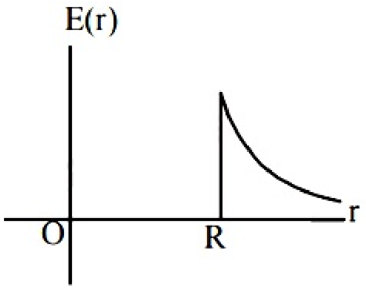
$\Rightarrow E = \frac{1}{4\pi\epsilon_0}\frac{\left[\frac{Q}{R^4} r_1{}^4\right]}{r_1{}^2} = \frac{1}{4\pi\epsilon_0}\frac{Q}{R^4} r_1{}^2$

Question96

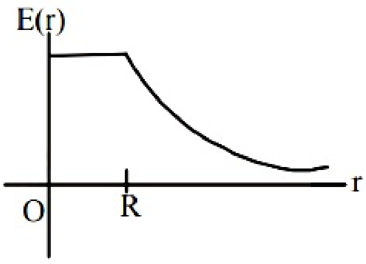
A thin spherical shell of radus R has charge Q spread uniformly over its surface. Which of the following graphs most closely represents the electric field E (r) produced by the shell in the range $0 \le r < \infty$, where r is the distance from the centre of the shell? [2008]

Options:

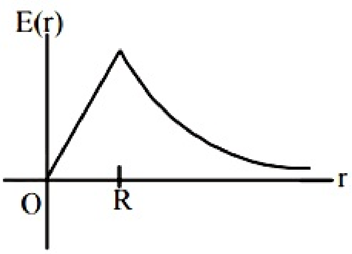
A.



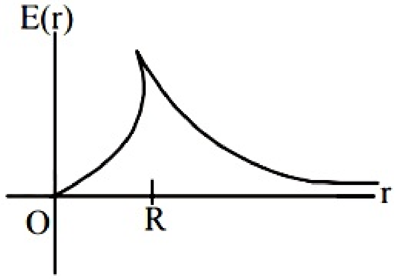
B.



C.



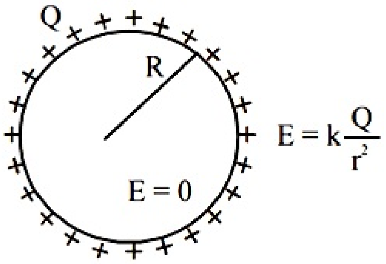
D.



Answer: A

Solution:

Solution:
The electric field inside a thin spherical shell of radius R has charge Q spread uniformly over its surface is zero.



Outside the shell the electric field is $E = k\frac{Q}{r^2}$. These characteristics are represented by graph (a).

Question97

If g_E and g_M are the accelerations due to gravity on the surfaces of the earth and the moon respectively and if Millikan's oil drop experiment could be performed on the two surfaces, one will find the ratio $\frac{\text{electronic charge on the moon}}{\text{electronic charge on the earth}}$ to be [2007]

Options:

A. g_M / g_E

B. 1

C. 0

D. g_E / g_M

Answer: B

Solution:

Solution:
It is obvious that by charge conservaiton law, electronic charge does not depend on acceleration due to gravity as it is a universal constant.
So, electronic charge on earth = electronic charge on moon
∴ Required ratio = 1.

Question98

Two spherical conductors A and B of radii 1mm and 2mm are separated by a distance of 5cm 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
[2006]

Options:

A. 4: 1

B. 1: 2

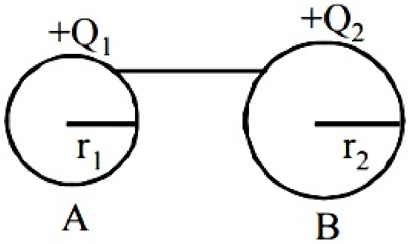
C. 2: 1

D. 1: 4

Answer: C

Solution:

Solution:



When the two conducting spheres are connected by a conducting wire, charge will flow from one to other till both acquire same potential.

∴ After connection, $V_1 = V_2$

$\Rightarrow k\frac{Q_1}{r_1} = k\frac{Q_2}{r_2} \Rightarrow \frac{Q_1}{r_1} = \frac{Q_2}{r_2}$

The ratio of electric fields $\frac{E_1}{E_2} = \frac{k\frac{Q_1}{r_1^2}}{k\frac{Q_2}{r_2^2}} \Rightarrow \frac{E_1}{E_2} = \frac{Q_1}{r_1^2} \times \frac{r_2^2}{Q_2}$

$\Rightarrow \frac{E_1}{E_2} = \frac{r_1 \times r_2^2}{r_1^2 \times r_2} \Rightarrow \frac{E_1}{E_2} = \frac{r_2}{r_1} = \frac{2}{1}$

Question99

An electric dipole is placed at an angle of 30° to a nonuniform electric field. The dipole will experience
[2006]

Options:

A. a translational force only in the direction of the field

B. a translational force only in a direction normal to the direction of the field

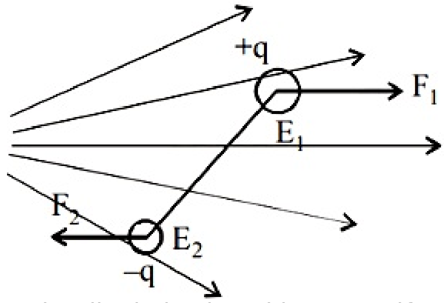
C. a torque as well as a translational force

D. a torque only

Answer: C

Solution:

Solution:



As the dipole is placed in non-uniform field, so the force acting on the dipole will not cancel each other. This will result in a force as well as torque.

Question100

Two point charges +8q and −2q are located at x = 0 and x = L respectively. The location of a point on the x axis at which the net electric field due to these two point charges is zero is [2005]

Options:

A. $\frac{L}{4}$

B. 2L

C. 4L

D. 8L

Answer: B

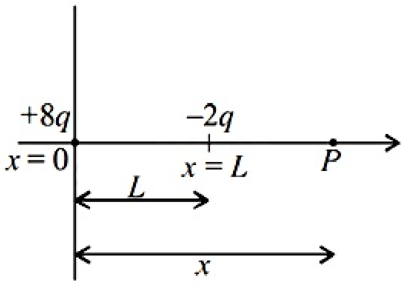
Solution:

At P $\frac{-K\,2q}{(x-L)^2} + \frac{K\,8q}{x^2} = 0$

$\Rightarrow \frac{1}{(x-L)^2} = \frac{4}{x^2}$

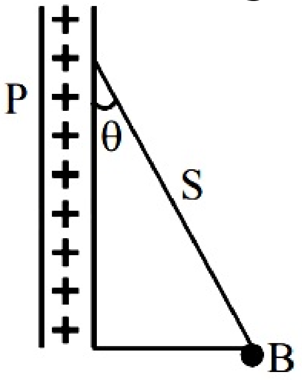
or $\frac{1}{x-L} = \frac{2}{x}$

$\Rightarrow x = 2x - 2L$ or $x = 2L$



Question101

A charged ball B hangs from a silk thread S, which makes an angle θ with a large charged conducting sheet P, as shown in the figure. The surface charge density σ of the sheet is proportional to



[2005]

Options:

A. $\cot\theta$

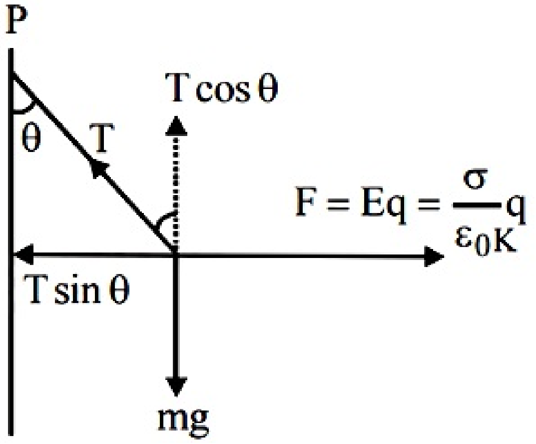
B. $\cos\theta$

C. $\tan\theta$

D. $\sin\theta$

Answer: C

Solution:



$T\ \sin\theta = qE$ ....(i)
$T\ \cos\theta = mg$ ....(ii)
Dividing (i) by (ii),

$\tan\theta = \frac{qE}{mg} = \frac{q}{mg}\left(\frac{\sigma}{\varepsilon_0 K}\right)\frac{\sigma q}{\varepsilon_0 K\ .mg}$

$\therefore \sigma \propto \tan\theta$

Question102

Two spherical conductors B and C having equal radii and carrying equal charges on them repel each other with a force F when kept apart at some distance. A third spherical conductor having same radius as that B but uncharged is brought in contact with B, then brought in contact with C and finally removed away from both. The new force of repulsion between B and C is
[2004]

Options:

A. F/8

B. 3F/4

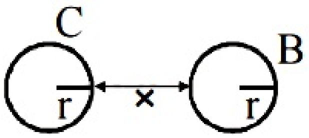
C. F/4

D. 3F/8

Answer: D

Solution:

Solution:



Initial force, $F = K\frac{Q_B Q_C}{x^2}$x is distance between the spheres. When third spherical conductor comes in contact with B charge on B is halved i.e., $\frac{Q}{2}$ and charge on third sphere becomes $\frac{Q}{2}$. Now it is touched to C, charge then equally distributes themselves to make potential same, hence charge on C becomes $\left(Q + \frac{Q}{2}\right)\frac{1}{2} = \frac{3Q}{4}$.

$\therefore F_{new} = k\frac{Q_C' Q_B'}{x^2} = k\frac{\left(\frac{3Q}{4}\right)\left(\frac{Q}{2}\right)}{x^2} = k\frac{3}{8}\frac{Q^2}{x^2}$

or $F_{new} = \frac{3}{8}F$

Question103

Four charges equal to −Q are placed at the four corners of a square and a charge q is at its centre. If the system is in equilibrium the value of q is
[2004]

Options:

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

B. $\frac{Q}{4}(1+2\sqrt{2})$

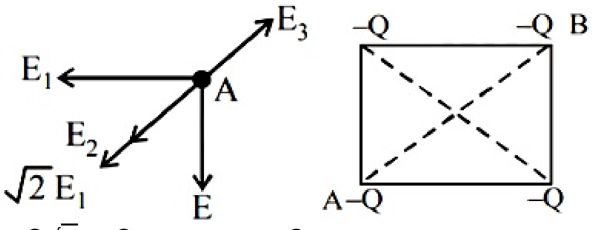
C. $-\frac{Q}{4}(1+2\sqrt{2})$

D. $\frac{Q}{2}(1+2\sqrt{2})$

Answer: B

Solution:

Solution:
For the system to be equilibrium, net field at A should be zero
$\sqrt{2}E_1 + E_2 = E_3$
$\therefore \frac{kQ \times \sqrt{2}}{a^2} + \frac{kQ}{(\sqrt{2}a)^2} = \frac{kq}{\left(\frac{a}{\sqrt{2}}\right)^2}$



$\Rightarrow \frac{Q\sqrt{2}}{1} + \frac{Q}{2} = 2q \Rightarrow q = \frac{Q}{4}(2\sqrt{2}+1)$

Question104

A charged oil drop is suspended in a uniform field of 3×10^4 v / m so that it neither falls nor rises. The charge on the drop will be (Take the mass of the charge $= 9.9 \times 10^{-15}$kg and $g = 10m / s^2$) [2004]

Options:

A. $1.6 \times 10^{-18}C$

B. $3.2 \times 10^{-18}C$

C. $3.3 \times 10^{-18}C$

D. $4.8 \times 10^{-18}C$

Answer: C

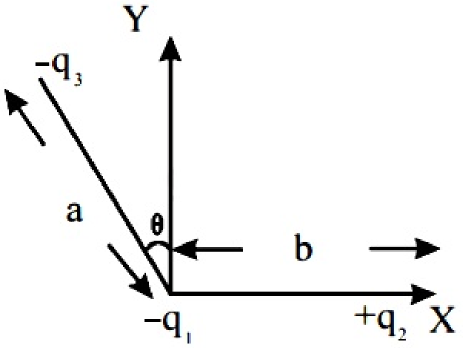
Solution:

Solution:
Given, Electric field, $E = 3 \times 10^4$
Mass of the drop, $m = 9.9 \times 10^{-15}kg$
At equilibrium, coulomb force on drop balances weight of drop.
$qE = mg$

$\Rightarrow q = \frac{mg}{E} \Rightarrow q = \frac{9.9 \times 10^{-15} \times 10}{3 \times 10^{4}} = 3.3 \times 10^{-18} C$

Question105

Three charges $-q_1$, $+q_2$ and $-q_3$ are place as shown in the figure. The x - component of the force on $-q_1$ is proportional to



[2003]

Options:

A. $\frac{q_2}{b^2} - \frac{q_3}{a^2}\cos\theta$

B. $\frac{q_2}{b^2} + \frac{q_3}{a^2}\sin\theta$

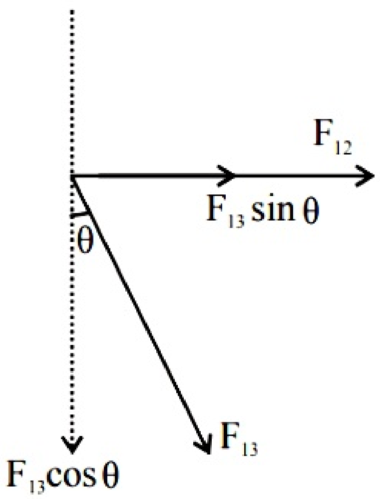
C. $\frac{q_2}{b^2} + \frac{q_3}{a^2}\cos\theta$

D. $\frac{q_2}{b^2} - \frac{q_3}{a^2}\sin\theta$

Answer: B

Solution:

Solution:



Force applied by charge q_2 on q_1

$F_{12} = k\frac{q_1 q_2}{b^2}$

Force applied by charge q_3 on q_1 $F_{13} = k\frac{q_1q_3}{a^2}$

The X -component of net force (F_x) on

q_1 is $F_{12} + F_{13}\sin\theta$

$\therefore F_x = k\frac{q_1q_2}{b^2} + k\frac{q_1q_2}{a^2}\sin\theta$

$\therefore F_x \propto \frac{q_2}{b^2} + \frac{q_3}{a^2}\sin\theta$

Question106

If the electric flux entering and leaving an enclosed surface respectively is ϕ_1 and ϕ_2, the electric charge inside the surface will be [2003]

Options:

A. $(\phi_2 - \phi_1)\varepsilon_0$

B. $(\phi_1 - \phi_2) / \varepsilon_0$

C. $(\phi_2 - \phi_1) / \varepsilon_0$

D. $(\phi_1 - \phi_2)\varepsilon_0$

Answer: A

Solution:

Solution:
The electric flux ϕ_1 entering an enclosed surface is taken as negative and the electric flux ϕ_2 leaving the surface is taken as positive, by convention. Therefore the net flux leaving the enclosed surface,
$\phi = \phi_2 - \phi_1$
According to Gauss theorem
$\phi = \frac{q}{\in_0} \Rightarrow q = \in_0 \phi = \in_0 (\phi_2 - \phi_1)$

Question107

If a charge q is placed at the centre of the line joining two equal charges Q such that the system is in equilibrium then the value of q is [2002]

Options:

A. $\frac{Q}{2}$

B. $-\frac{Q}{2}$

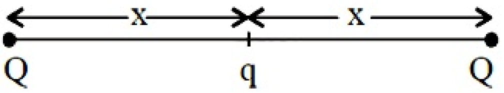
C. $\frac{Q}{4}$

D. $-\frac{Q}{4}$

Answer: D

Solution:

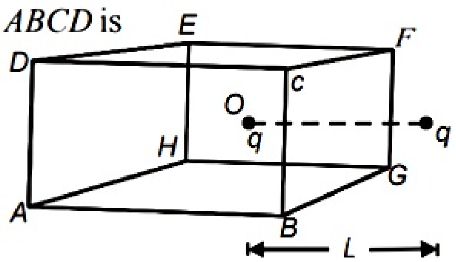
Solution:
At equilibrium net force is zero,
$\therefore k\frac{Q \times Q}{(2x)^2} + k\frac{Qq}{x^2} = 0$



$\Rightarrow q = -\frac{Q}{4}$

Question108

A charged particle q is placed at the centre O of cube of length L(ABCDE F GH). Another same charge q is placed at a distance L from O. Then the electric flux through ABCD is



[2002]

Options:

A. $q / 4\pi \in_0 L$

B. zero

C. $q / 2\pi \in_0 L$

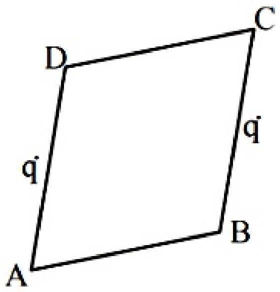
D. $q / 3\pi \in_0 L$

E. (None)

Answer: E

Solution:

Solution:
Electric flux due to charge placed outside is zero. But for the charge inside the cube, flux due to each face is $\frac{1}{6}\left[\frac{q}{\in_0}\right]$ which is not in option.


D
C
q
q
A
B