JEE Main 2021

Chapter wise Solution

Electrostatics

PHYSICS

MCQ

Q.1. 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]

(1) 0.424 nCm^{-2}

(2) 47.88 C/m

(3) 0.07 nCm^{-2}

(4) 4.0 nCm^{-2}

MCQ

Q.2. A plane electromagnetic wave of frequency 100MHz is travelling in vacuum along the x-direction. At a particular point in space and time, $\vec{B} = 2.0 \times 10^{-8}\hat{k}T$. (where, $\hat{k}$ is unit vector along z-direction) What is $\vec{E}$ at this point?

[18 Mar 2021 Shift -1]

(1) $0.6\hat{j}V/m$

(2) $6.0\hat{k}V/m$

(3) $6.0\hat{j}V/m$

(4) $0.6\hat{k}V/m$

MCQ

Q.3. 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:

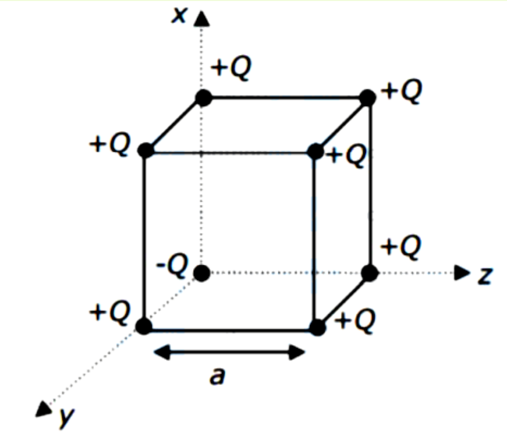
[24 Feb 2021 Shift -1]

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

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

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

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



MCQ

Q.4. Two electrons each are fixed at a distance ‘2d’. A third charge proton placed at the midpoint 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]**

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

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

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

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

MCQ

Q.5. A charge 'q' is placed at one comer of a cube as shown in figure. The flux of electrostatic field E through the shaded area is:

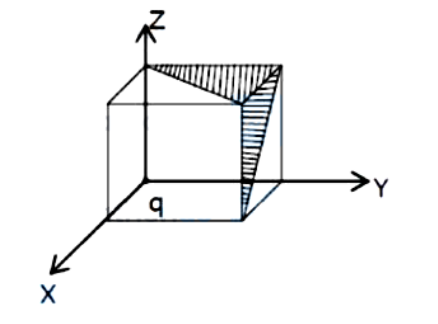
[25 Feb 2021 Shift -2]

(1) $\frac{q}{48\varepsilon_0}$

(2) $\frac{q}{8\varepsilon_0}$

(3) $\frac{q}{24\varepsilon_0}$

(4) $\frac{q}{4\varepsilon_0}$




1,2,3

MCQ

Q.6. 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 July 2021 Shift -1]

(1) $Q = \frac{q}{2}$

(2) $Q = 2q$

(3) $Q = 4q$

(4) $Q = 3q$

MCQ

Q.7. 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 12 mm 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 July 2021 Shift -1]

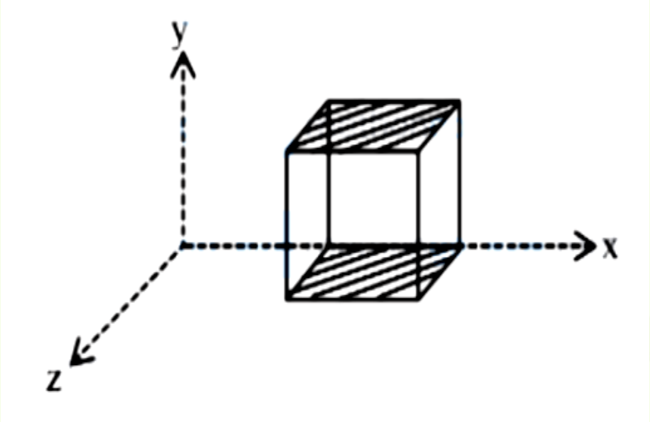
(1) 815.1nC
(2) 8.8μC
(3) 0.485mC
(4) 4.44μC

MCQ

Q.8. A cube is placed inside an electric field, $\vec{E} = 150y^2\hat{j}$. The side of the cube is 0.5m and is placed in the field as shown in the given figure. The charge inside the cube is:

[01 Sep 2021 Shift -2]

(1) 3.8×10^{-11}C
(2) 8.3×10^{-11}C
(3) 3.8×10^{-12}C
(4) 8.3×10^{-12}C



MCQ

Q.9. Choose the incorrect statement:

(a) The electric lines of force entering into a Gaussian surface provide negative flux.

(b) A charge ‘q’ is placed at the centre of a cube. The flux through all the faces will be the same.

(c) In a uniform electric field net flux through a closed Gaussian surface containing nonet charge, is zero.

(d) When electric field is parallel to a Gaussian surface, it provides a finite non-zero flux.

Choose the most appropriate answer from the option given below **[31 Aug 2021 Shift -2]**

(1) (c) and (d) only

(2) (b) and (d) only

(3) (d) only

(4) (a) and (c) only

Integer

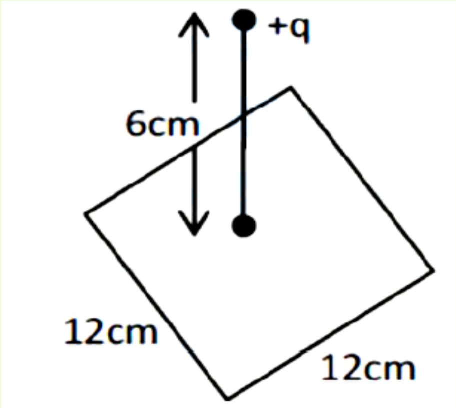
Q.10. The electric field in a region is given by $\vec{E} = \frac{2}{5}E_0\hat{i} + \frac{3}{5}E_0\hat{j}$ with $E_0 = 4.0 \times 10^3 \frac{N}{C}$. The flux of this field through a rectangular surface area $0.4m^2$ parallel to the Y-Z plane is ______ Nm^2C^{-1}

[17 Mar 2021 Shift -2]

Integer

Q.11. A point charge of +12μC 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 ___ $\times 10^3 Nm^2/C$

[24 Feb 2021 Shift -2]



Integer

Q.12. 512 identical drops of mercury are charged to a potential of 2V each. The drops are joined to form a single drop. The potential of this drop is ___ V.

[25 Feb 2021 Shift -1]

Integer

Q.13. 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. Then charge on each of the sphere is $\frac{a}{21} \times 10^{-8}$C. The value of ‘a’ will be

[25 Feb 2021 Shift -2]

Integer

Q.14. The total charge enclosed in an incremental volume of 2×10^{-9} m^3 located at the origin is ____ nC, 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 July 2021 Shift -1]

Integer

Q.15. A particle of mass 1mg and charge q is lying at the mid-point of two stationary particles kept at a distance '2m' when each is carrying same charge 'q'. If the free charged particle is displaced from its equilibrium

[25 July 2021 Shift -1]

1,2,3

Electrostatics – Solution

Q. 1 **(1)**

$$\frac{2\,K\lambda}{r}=\frac{\sigma}{\varepsilon_0}\quad(x=3\text{ m})$$

$$\sigma=0.424\times10^{-9}\,\frac{C}{m^2}$$

Q. 2 **(3)**

$$E=BC=6$$

$$(\text{Dir. of wave})\,\|(\vec{E}\times\vec{B})$$

$$\hat{i}=\hat{j}\times\hat{k}$$

$$\vec{E}=6\hat{j}\,V/m$$

Q. 3 Here electric field at centre $=2(E.f.)_4$

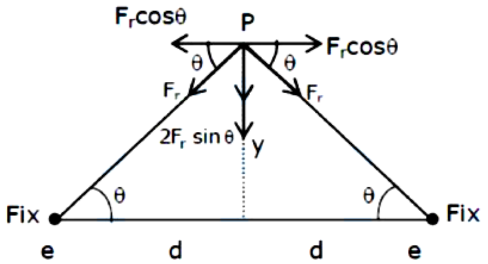
As, $|E_4|=|E_7|$

$$(E.F)_C=\frac{2kQ}{\left(\frac{\sqrt{3}a}{2}\right)^2}=\frac{8\,KQ}{3a^2}\quad\left\{\because K=\frac{1}{4\pi\varepsilon_0}\right\}$$

$$(E\cdot F)_C=\frac{2Q}{3a^2\pi\varepsilon_0}$$

In vector form $\Rightarrow\vec{E}=\frac{-2Q}{3a^2\pi\varepsilon_0}\times\left(\frac{x+y+z}{\sqrt{3}}\right)$

Q. 4 **(1)**



Restoring force on proton :-

$$F_r=\frac{2Kq^2y}{[d^2+y^2]^{\frac{3}{2}}}$$

$$Y<<<d$$

$$F_r=\frac{2kq^2y}{d^3}=\frac{q^2y}{2\pi\varepsilon_0d^3}=ky$$

$$K=\frac{q^2}{2\pi\varepsilon_0\,d^3}$$

Angular Frequency : $\omega=\sqrt{\frac{k}{m}}$

$$\omega=\sqrt{\frac{q^2}{2\pi\varepsilon_0md^3}}$$

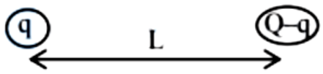
Q. 5 **(3)**

$$\phi=\frac{q}{24\varepsilon_0}$$

$$\phi_T=\left(\frac{q}{24\varepsilon_0}+\frac{q}{24\varepsilon_0}\right)\times\frac{1}{2}$$

$$\phi_T=\frac{q}{24\varepsilon_0}$$

Q. 6



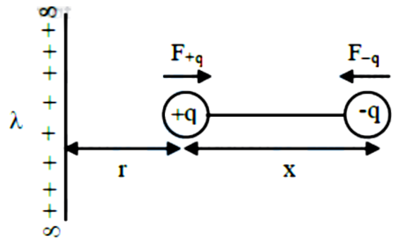
$$F_q=\frac{kq(Q-q)}{L^2}=\frac{k}{L^2}(qQ-q^2)$$

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

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

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

Q. 7



$r=10$ mm, $x=2$,

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

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

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

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

$$4=\frac{2\times9\times10^9\times3\times10^{-6}\times q\times2\text{ mm}}{10\text{ mm}.12\text{ mm}}$$

$$\Rightarrow\quad q=4.44\mu C$$

Q. 8 As electric field is in y-direction so electric flux is only due to top and bottom surface

Bottom surface $y=0$

$$\Rightarrow E=0\Rightarrow\phi=0$$

Top surface $y=0.5$ m

$$\Rightarrow E=150(.5)^2=\frac{150}{4}$$

Now flux $\phi=EA=\frac{150}{4}(.5)^2=\frac{150}{16}$

By Gauss's law $\phi=\frac{Q_{in}}{\epsilon_0}$

$$\frac{150}{16}=\frac{Q_{in}}{\epsilon_0}$$

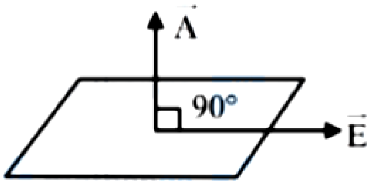
$$Q_{in}=\frac{150}{16}\times8.85\times10^{-12}=8.3\times10^{-11}C$$

Option (2)

Electrostatics – Solution

Q. 9 (3)

Since $\phi = \vec{E} \cdot \vec{A} = EA\cos\theta$



$\theta = 90^{\circ}$

$\therefore \phi = 0$

Q. 10

(640)

$$\phi = E_x A \Rightarrow \frac{2}{5} \times 4 \times 10^3 \times 0.4 = 640$$

Q. 11

(226)

Using Gauss law, it is a part of cube of side 12 cm and charge at centre so;

$\phi = \frac{Q}{6\varepsilon_0} = \frac{12\mu c}{6\varepsilon_0} = 2 \times 4\pi \times 9 \times 10^9 \times 10^{-6}$

$= 226 \times 10^3 \mathrm{Nm^2/C}$

Q. 12 (128)

Let charge on each drop $= q$

radius $= r$

$v = \frac{kq}{r}$

$2 = \frac{kq}{r}$

radius of bigger

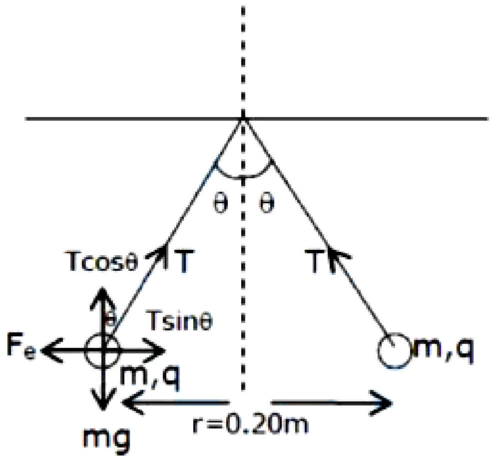
$\frac{4}{3}\pi R^3 = 512 \times \frac{4}{3}\pi r^3$

$R = 8r$

$v = \frac{k(512)q}{R} = \frac{512}{8}\frac{kq}{r} = \frac{512}{8} \times 2$

$= 128$ V

Q. 13 (20)



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

$T\cos\theta = mg$

$\tan\theta = \frac{kq^2}{mgr^2}$

$q^2 = \frac{\tan\theta mgr^2}{k}$

$\because \tan\theta = \frac{0.1}{0.5} = \frac{1}{5}$

$q^2 = \frac{1}{5} \times \frac{10\times10^{-6}\times10\times0.2\times0.2}{9\times10^9}$

$q = \frac{2\sqrt{2}}{3} \times 10^{-8}$

after comparison from the given equation a $= 20$

Q. 14

Electric flux density

$(\vec{D}) = \frac{\text{charge}}{\text{Area}} \times \hat{r} = \frac{Q}{4\pi r^2}\hat{r} = \epsilon_0\left(\frac{Q}{4\pi\epsilon_0 r^2}\hat{r}\right)$

$\Rightarrow \vec{E} = \frac{\vec{D}}{\epsilon_0} = \frac{e^{-x}\sin y\hat{i} - e^{-x}\cos\hat{y} + 2z\hat{k}}{\epsilon_0}$

Also by Gauss's law

$\frac{\rho}{\epsilon_0} = \left(\frac{\partial}{\partial x}\hat{i} + \frac{\partial}{\partial y}\hat{j} + \frac{\partial}{\partial z}\hat{k}\right) \cdot \vec{E} = \left(\frac{\partial}{\partial x}\hat{i} + \frac{\partial}{\partial y}\hat{j} + \frac{\partial}{\partial z}\hat{k}\right) \cdot \frac{\vec{D}}{\epsilon_0}$

$\Rightarrow \rho = \frac{\partial}{\partial x}(e^{-x}\sin y) + \frac{\partial}{\partial y}(-e^{-x}\cos y) + \frac{\partial}{\partial z}(2z)$

$\rho = -e^{-x}\sin y + e^{-x}\sin y + 2$

At origin $\rho = -e^{-0}\sin 0 + e^{-0}\sin 0 + 2$

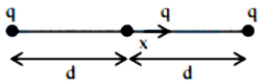
$\rho = 2\mathrm{C/m^3}$

Charge $= \rho\times$ volume $= 2 \times 2 \times 10^{-9} = 4 \times 10^{-9} =$

$4nC$

Electrostatics – Solution

Q. 15



Net force on free charged particle $\mathbf{F} = \frac{kq^2}{(d+x)^2} - \frac{kq^2}{(d-x)^2}$

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

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

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

So, angular frequency $\omega = \sqrt{\frac{4kq^2}{md^3}}$

$\omega = \sqrt{\frac{4\times9\times10^9\times10}{1\times10^{-6}\times1^3}}$

$\omega = 6\times10^8\,\mathrm{rad/sec}$