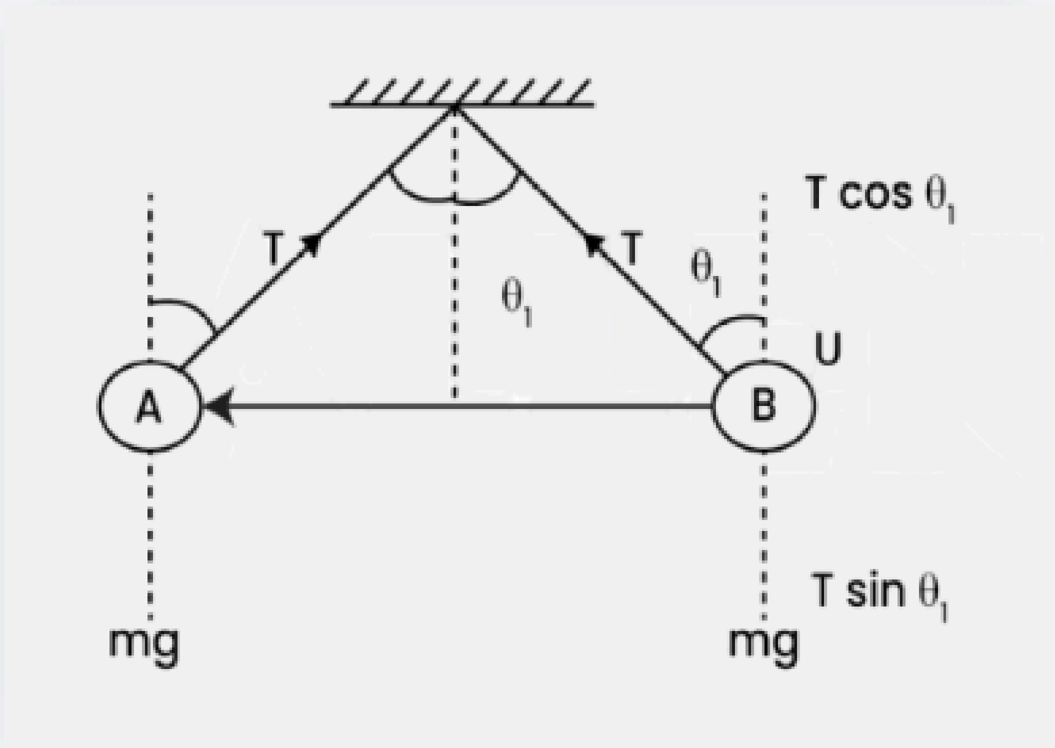
Electrostatics: JEE Main Past Year Solved Questions

Q-1. Two identical charged spheres are suspended by strings of equal lengths. The strings make an angle with each other. When suspended in water the angle remains the same. If density of the material of the sphere is 1.5 g/cc , the dielectric constant of water will be_____

(Take density of water=1g/cc)

Solution:



Case-1 When suspended in water

$T\cos\theta 1 = mg$
$T\sin\theta 1 = F$
Dividing both equations, we get,
$\tan\theta 1 = \frac{F}{mg}$...........(1)

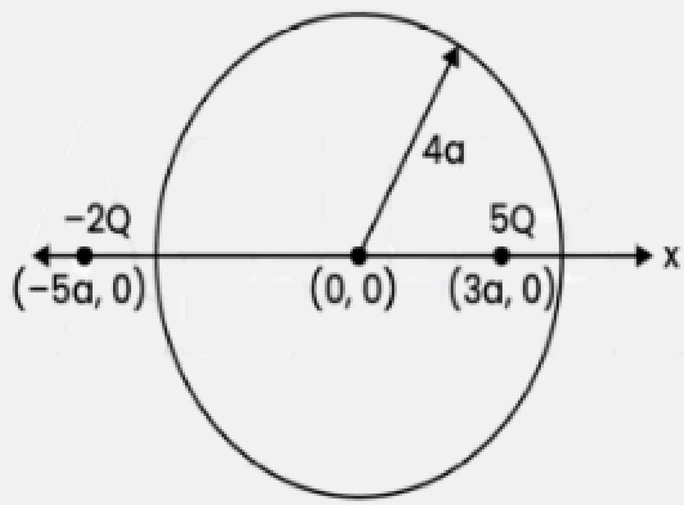
Case-2 When suspense in water,value of electrostatic force may changes,

$F' = \frac{F}{K}$
$F' = T\sin\theta 1$.......(2)
$mg - U = T\cos\theta 1 \quad (\text{where} U = \text{Upthrust})$
$\sigma Vg - \rho Vg = T\cos\theta 1$
$(\sigma-\rho)Vg = T\cos\theta 1$:........(3)
Dividing (2) by (3):
$\tan\theta 1 = \frac{F'}{(\sigma-\rho)Vg}$
Dividing (1) by (4):
$1 = \frac{F}{mg} \times \frac{(\sigma-\rho)Vg}{F} = \frac{F}{\sigma Vg} \times \frac{(\sigma-\rho)Vg}{F}$
$\Rightarrow 1 = K \times \frac{(\sigma-\rho)}{\sigma} \times \frac{1.5-1}{1.5} = K \times \frac{0.5}{1.5} = K \times \frac{1}{3} \Rightarrow K = 3$
$K = 3$

Q-2. 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 :

(1) $\frac{2Q}{\varepsilon 0}$
(2) $\frac{5Q}{\varepsilon 0}$
(3) $\frac{7Q}{\varepsilon 0}$
(4) $\frac{3Q}{\varepsilon 0}$

Solution: (2) $\frac{5Q}{\varepsilon 0}$



5Q charge is inside the spherical region

$\phi\text{net} = \frac{q\text{enclosed}}{\varepsilon 0} = \frac{5Q}{\varepsilon 0}$

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

(1) 90

(2)150

(3)180

(4)60

Solution:

$$\vec{E} = \left(6\hat{i} + 5\hat{j} + 3\hat{k}\right) \mathrm{N/C}$$
$$A = 30\,\hat{i}\,\mathrm{m}^2$$
$$\phi = \vec{E} \cdot \vec{A} = (6\hat{i} + 5\hat{j} + 3\hat{k}) \cdot (30\hat{i}) = 6 \times 30 = 180$$

Q-4. Two identical charged spheres are suspended by a string of equal lengths. The string makes an angle of 30° with each other. When suspended in a liquid of density 0.8 gcm^{-3}, the angle remains the same. If density of material of the sphere is 1.6 gcm^{-3}, the dielectric constant of the liquid is_____

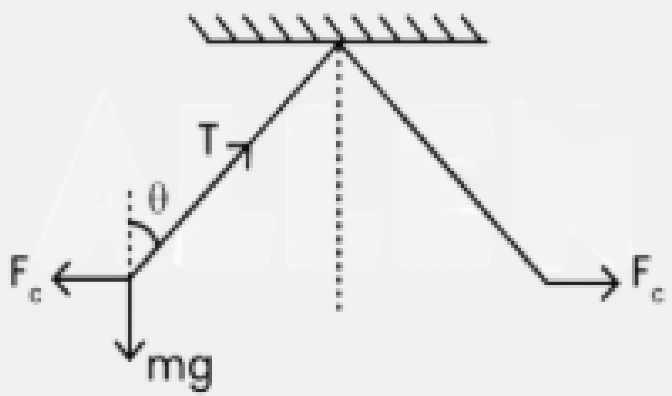
1) 1

2) 4

3) 3

4) 2

Solution: 42



$T\cos\theta = mg$
$T\sin\theta = F_e$
$\tan\theta = \frac{Fe}{mg}$
$\tan\theta = \frac{Fe}{\rho bVg}$........(1)
$\tan\theta = \frac{Fe}{(\rho b-\rho l)Vg}$......(2)
$From equations (1) and (2):$
$\rho_b Vg = (\rho_b - \rho_l)kVg$
$1.4 = 0.7k \Rightarrow k = 2$

Q-5. A particle of charge '-q' and mass 'm' moves in a circle a of radius 'r' around an infinitely long line charge of linear charge density '+'.Then time period will be given as Consider k as Coulomb's Constant

$(1) T^2 = \frac{4\pi^2 mr^3}{2k\lambda q}$

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

$(3) T = \frac{1}{2\pi}\sqrt{\frac{m}{2k\lambda q}}$

$(4) T = \frac{1}{2\pi}\sqrt{\frac{2k\lambda q}{m}}$

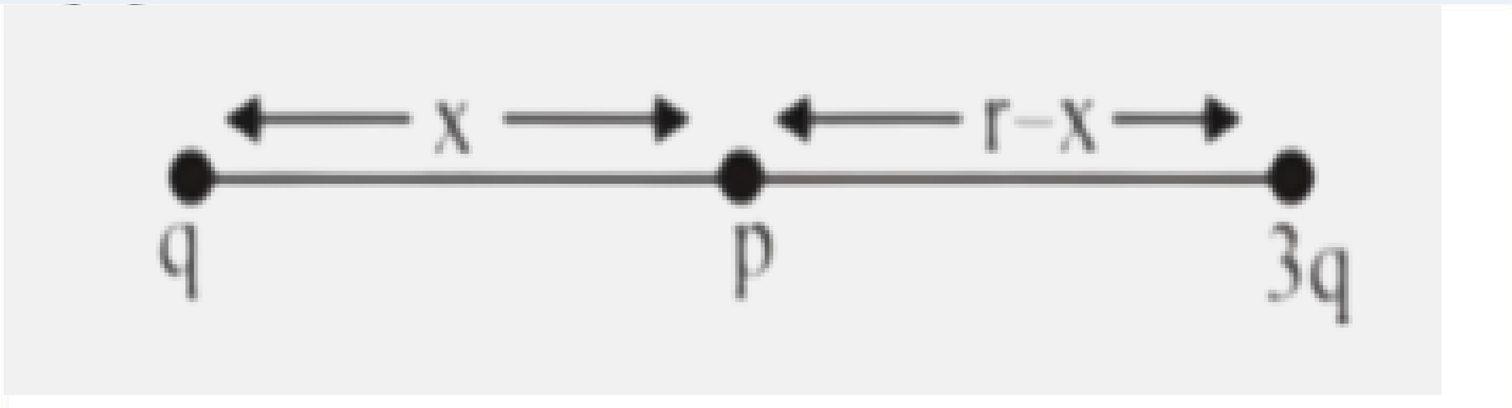
Solution: $T = 2\pi r\sqrt{\frac{m}{2k\lambda q}}$

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

Q-6. Two charges q and 3q are separated by a distance 'r' in the air. At a distance x from charge q the resultant electric field is zero. The value of x is

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

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



$\left(\vec{E}\text{net}\right)p = 0$
$\frac{kq}{x^2} = \frac{k \cdot 3q}{(r-x)^2}$
$\frac{1}{x^2} = \frac{3}{(r-x)^2} \Rightarrow (r-x)^2 = 3x^2$
$r - x = \sqrt{3}x$
$r = x(1+\sqrt{3})$
$x = \frac{r}{1+\sqrt{3}}$

Q-7. Force between two point charges $q1$ and $q2$ placed in vacuum at 'r' cm apart is F. Force between them when placed in a medium having dielectric K=5 at 'r5'cm apart will be

$(1) F = \frac{25}{3}$
$(2) 5F$
$(3) \frac{F}{5}$
$(4) 25F$

Solution:(2) 5F

In air, $F = \frac{1}{4\pi\varepsilon 0} \cdot \frac{q1q2}{r^2}$

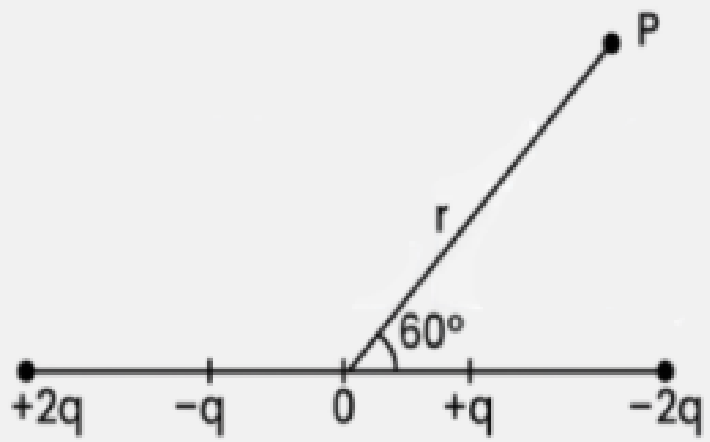
In medium, $F = \frac{1}{4\pi(k\varepsilon 0)} \cdot \frac{q1q2}{r^2}$

$= \frac{q1q2}{4\pi\varepsilon 0 r^2} \cdot \frac{1}{k}$
$= \frac{25}{4\pi\varepsilon 0} \cdot \frac{q1q2}{r^2} \Rightarrow 5F$

Q-8. 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

Solution:

Solution:



Due to q:

$V_q = \frac{kq\cos\theta}{r} = \frac{kq(2\theta)}{r}$

$V_q = \frac{kql}{r^2}$ ....(1)

Due to 2q:

$V_{2q} = \frac{k \cdot 2q \cdot \cos(120^\circ) \cdot l}{r^2}$

$= \frac{8kql}{r^2} \cdot \left(-\frac{1}{2}\right)$

$= \frac{-4kql}{r^2}$ ......(2)

Using equations (1) and (2):

$V_{net} = \frac{kql}{r^2} - \frac{4kql}{r^2} = \frac{-3kql}{r^2}$

$V_{net} = -3\left(\frac{ql}{r^2}\right) \times 9 \times 10^9$

$V_{net} = -27\left(\frac{ql}{r^2}\right) \times 10^9$ V

$\alpha = 27$

Q-9. If two charges q_1 *and* q_2 are separated with distance 'd' and placed in a medium of dielectric constant K. What will be the equivalent distance between charges in air for the same electrostatic force?

(1) $\frac{a}{\sqrt{k}}$

(2) $k\sqrt{a}$

(3) $1.5a/k$

(4) $2a/\sqrt{k}$

Solution: (1) $\frac{a}{\sqrt{k}}$

$F = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{kd^2}$ (in medium)

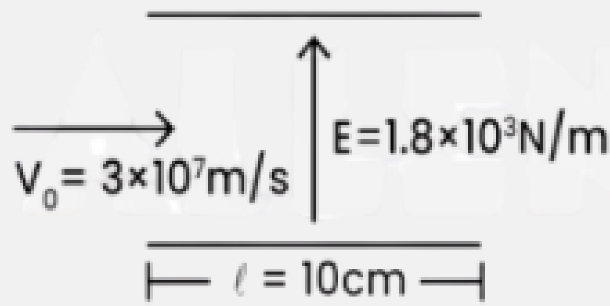
$F_{air} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{d^2}$

$F = F_{air} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{kd^2} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{d'^2}$

$d' = \frac{d}{\sqrt{k}}$

Q-10. A stream of a positively charged particles having $\frac{q}{m} = 2 \times 10^{11}, \frac{c}{kg}$ and velocity $\vec{v}o = 3 \times 10^7\,\hat{i}\,\mathrm{m/s}$ is deflected by an electric field 1.8 k V/m. The electric field exists in a region of 10 cm along x direction. Due to the electric field, the deflection of the charge particles in the y direction is __________mm.

Solution: 2 mm



$a = \frac{F}{m} = \frac{qE}{m} = (2 \times 10^{11})(1.8 \times 10^3) = 3.6 \times 10^{14}\,\mathrm{m/s}^2$

Time to cross plates:

$t = \frac{d}{v0} = \frac{0.10}{3\times10^7} = \frac{1}{3\times10^8}\ \mathrm{s}$

$y = \frac{1}{2}at^2 = \frac{1}{2}(3.6 \times 10^{14})\left(\frac{1}{3\times10^8}\right)^2 = \frac{1.8}{9\times10^2} = 0.002\,\mathrm{m} = 2\mathrm{mm}$

Q-11. The electric potential at the centre of two concentric half rings of radii R1 and R2, having same linear charge density is

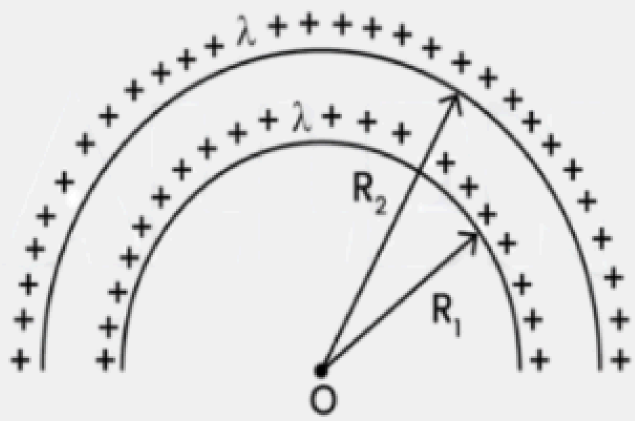
(1) $\frac{2\lambda}{\varepsilon 0}$

(2) $\frac{\lambda}{2\varepsilon 0}$

(3) $\frac{\lambda}{4\varepsilon 0}$

(4) $\frac{\lambda}{\varepsilon 0}$

Solution: $\frac{\lambda}{2\varepsilon 0}$

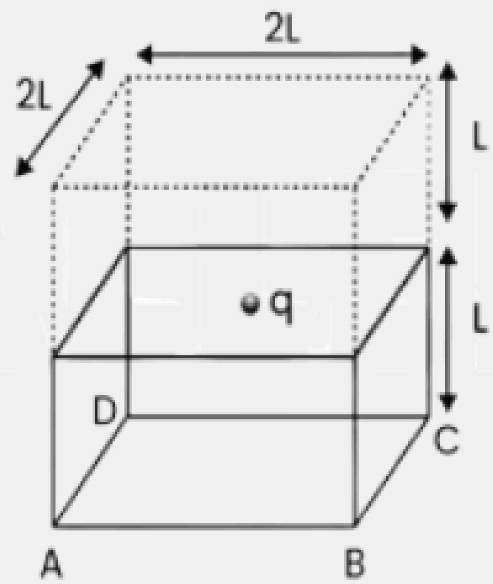


Potential at the centre

$$V = \frac{(\lambda \pi R1)}{4\pi\varepsilon 0 R2} + \frac{(\lambda \pi R2)}{4\pi\varepsilon 0 R1} = \frac{\lambda}{2\varepsilon 0}$$

Q-12. In a cuboid of dimension 2L × 2L × 2L ,a charge q is placed at the centre of the surface 'S' having area of $4L^2$. The flux through the opposite surface to 'S' is given by

(1) $\frac{q}{12\varepsilon 0}$
(2) $\frac{q}{3\varepsilon 0}$
(3) $\frac{q}{4\varepsilon 0}$
(4) $\frac{q}{6\varepsilon 0}$



Flux through whole cube $= \frac{q}{\varepsilon 0}$
As total faces are 6 so flux through ABCD is $\phi = \frac{q}{6\varepsilon 0}$

Q-13. A long cylindrical volume contains a uniformly distributed charge of density .The radius of cylindrical volume is R.A charge particle q revolves around the cylinder in a circular path. The Kinetic of the particle is

(1) $\frac{\rho q R^2}{\varepsilon 0}$
(2) $\frac{\rho q R^2}{2\varepsilon 0}$
(3) $\frac{q\rho}{4\varepsilon 0 R^2}$
(4) $\frac{4\varepsilon 0 k R^2}{q\rho}$

Solution: $\frac{\rho q R^2}{\varepsilon 0}$

$q_{enc} = \rho\pi r^2 l$

$E \cdot 2\pi Rl = \frac{q_{enc}}{\varepsilon 0} = \frac{\rho\pi R^2 l}{\varepsilon 0}$

$\Rightarrow E = \frac{\rho R}{\varepsilon 0}$

For a particle of charge q revolving at radius R, the centripetal force is provided by electric field:

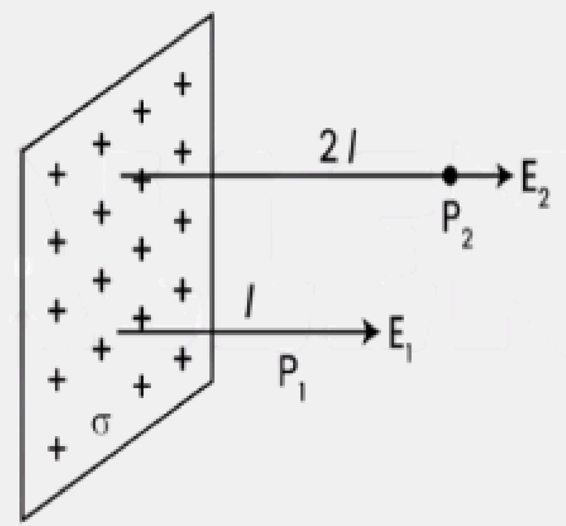
$qE = \frac{mv^2}{R}$

$q \cdot \frac{\rho R}{\varepsilon 0} = \frac{mv^2}{R}$

$\Rightarrow \frac{1}{2}mv^2 = \frac{q\rho R^2}{2\varepsilon 0}$

$K.E = \frac{q\rho R^2}{4\varepsilon 0}$

Q-14. In the figure a very large plane sheet of positive charge is shown P_1 and P_2 are two points at distance l and 2l from the charge distribution. If σ is the surface charge density, then the magnitude of electric Fields E_1 and E_2 at P_1 and P_2 respectively are :



$(a) E_1 = \frac{\sigma}{\varepsilon 0}, \quad E_2 = \frac{\sigma}{2\varepsilon 0}$

$(b) E_1 = \frac{2\sigma}{\varepsilon 0}, \quad E_2 = \frac{\sigma}{\varepsilon 0}$

$(c) E_1 = E_2 = \frac{\sigma}{2\varepsilon 0}$

$(d) E_1 = E_2 = \frac{\sigma}{\varepsilon 0}$

Solution:$(c) \quad E_1 = E_2 = \frac{\sigma}{2\varepsilon 0}$ From a uniformly charged infinite sheet:

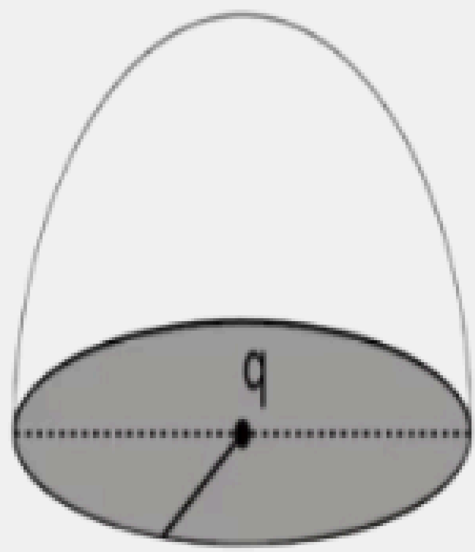
$E = \frac{\sigma}{2\varepsilon 0}$.......(1)

From the above equation it is clear that the electric field due to a uniformly charged surface is independent of distance from the surface.It c

Here in both the cases electric field will be the same

$(A) E_1 = E_2 = \frac{\sigma}{2\varepsilon 0}$

Q-15. If a charge q is placed at the centre of a closed hemispherical non-conducting surface, the total flux passing through the flat surface would be



(1) $\frac{q}{\varepsilon 0}$

(2) $\frac{q}{2\varepsilon 0}$

(3) $\frac{q}{4\varepsilon 0}$

(4) $\frac{2q}{\pi\varepsilon 0}$

Solution:(2) $\frac{q}{2\varepsilon 0}$

Total flux through complete spherical surface is $\frac{q}{\varepsilon 0}$

So the flux through curved surface is $\frac{q}{2\varepsilon 0}$

The flux through flat surface is zero