ELECTROSTATICS

(AIPMT)

2012

1. An electric dipole of moment p is placed in an electric field of intensity E. The dipole acquires a position such that the axis of the dipole makes an angle θ with the direction of the field. Assuming that the potential energy of the dipole to be zero when $\theta = 90^0$, the torque and the potential energy of the dipole will respectively be

a) $pE\sin\theta, -pE\cos\theta$ b) $pE\sin\theta, -2pE\cos\theta$

c) $pE\sin\theta, 2pE\cos\theta$ d) $pE\cos\theta, -pE\sin\theta$

2. What is the flux through a cube of side a if a point charge of q is at one of its corner?

a) $\frac{2q}{\varepsilon_0}$ b) $\frac{q}{8\varepsilon_0}$ c) $\frac{q}{\varepsilon_0}$ d) $\frac{q}{2\varepsilon_0}6a^2$

3. A parallel plate capacitor has a uniform electric field E in the space between the plates. If the distance between the plates is d and area of each plate is A, the energy stored in the capacitor is

a) $\frac{1}{2}\varepsilon_0 E^2$ b) $\frac{E^2 Ad}{\varepsilon_0}$ c) $\frac{1}{2}\varepsilon_0 E^2 Ad$ d) $\varepsilon_0 EAd$

4. Two metallic spheres of radii 1cm and 3 cm are given charges of -1 x 10^{-2} C and 5 x 10^{-2} C, respectively. If these are connected by a conducting wire, the final charge on the bigger sphere is

a) 2 x 10^{-2} C b) 3 x 10^{-2} C c) 4 x 10^{-2} C d) 1 x 10^{-2} C

2011

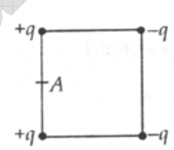
5 A charge Q is enclosed by a Gaussian spherical surface of radius R. If the radius is doubled, then the outward electric flux will

a) increase four times b) be reduced to half c) remain the same d) be doubled

6. A parallel plate condenser has a uniform electric field E (V/m) in the space between the plates. If the distance between the plates is d (m) and area of each plate is A (m^2) the energy (joules) stored in the condenser is

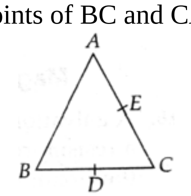
a) $E^2 Ad/\varepsilon_0$ b) $\frac{1}{2}\varepsilon_0 E^2$ c) $\varepsilon_0 EAd$ d) $\frac{1}{2}\varepsilon_0 E^2 Ad$

7. Four electric charges +q, +q, -q and –q are placed at the corners of a square of side 2L (see figure). The electric potential at point A, midway between the two charges +q and +q, is



a) $\frac{1}{4\pi\varepsilon_0}\frac{2q}{L}\left(1+\sqrt{5}\right)$ b) $\frac{1}{4\pi\varepsilon_0}\frac{2q}{L}\left(1+\frac{1}{\sqrt{5}}\right)$ c) $\frac{1}{4\pi\varepsilon_0}\frac{2q}{L}\left(1-\frac{1}{\sqrt{5}}\right)$ d) zero

8. Three charges, each +q are placed at the corners of an isosceles triangle ABC of sides BC and AC, 2a. D and E are the mid points of BC and CA. The work done in taking a charge Q from D to E is



a) $\frac{3pQ}{4\pi\varepsilon_0 a}$ b) $\frac{3pQ}{8\pi\varepsilon_0 a}$ c) $\frac{qQ}{4\pi\varepsilon_0 a}$ d) zero

9. The electric potential V at any point (x, y, z), all in metres in space is given by $V = 4x^2$ volt. The electric field at the point (1, 0, 2) in volt/meter, is

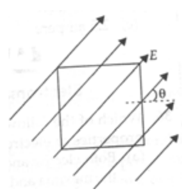
a) 8 along negative X –axis
b) 8 along positive X –axis
c) 16 along negative X –axis
d) 16 along positive X –axis

2010

10. Two positive ions, each carrying a charge q, are separated by a distance d. If F is the force of repulsion between the ions, the number of electrons missing from each ion will be
(e being the charge on an electron)

a) $\frac{4\pi\varepsilon_0 Fd^2}{e^2}$
b) $\sqrt{\frac{4\pi\varepsilon_0 Fe^2}{a^2}}$
c) $\sqrt{\frac{4\pi\varepsilon_0 Fd^2}{e^2}}$
d) $\frac{4\pi\varepsilon_0 Fd^2}{q^2}$

11. A square surface of side L meter in the plane of the paper is placed in a uniform electric field E (volt/m) acting along the same plane at an angle θ with the horizontal side of the square as shown in figure. The electric flux linked to the surface, in units of is



a) EL^2
b) $EL^2 \cos\theta$
c) $EL^2 \sin\theta$
d) zero

12. A series combination of n_1 capacitors, each of value C_1, is charged by a source of potential difference 4V. When another parallel combination of n_2 capacitors, each of value C_2, is charged by a source of potential difference V, it has the same (total) energy stored in it, as the first combination has. The value of C_2, in terms of C_1, is then

a) $\frac{2C_1}{n_1 n_2}$
b) $16\frac{n_2}{n_1}C_1$
c) $2\frac{n_2}{n_1}C_1$
d) $\frac{16C_1}{n_1 n_2}$

13. Two parallel metal plates having charges +Q and –Q face each other at a certain distance between them. If the plates are now dipped in kerosene oil tank, the electric field between the plates will

a) Become zero
b) increase
c) decrease
d) remain same

14. The electric field at a distance $\frac{3R}{2}$ from the centre of a charged conducting spherical shell of radius R is E. The electric field at a distance $\frac{R}{2}$ from the centre of the sphere is

a) Zero
b) E
c) $\frac{E}{2}$
d) $\frac{E}{3}$

KEY

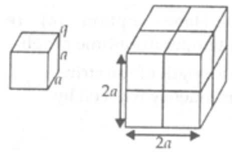
1. a	2. b	3.c	4.b	5.c.	6.d	7.c
8. d	9.a	10.c	11.d	12.d	13.c	14.a

SOLUTIONS

1. (a) Torque, τ = pE $\sin\theta$

Potential energy, U = -pE cos θ

2. (b)



Eight identical cubes are required so that the given charge q appears at the centre of the bigger cube.

From Gauss law, the electric flux passing through the given cube is $\phi = \frac{1}{8}\left(\frac{q}{\varepsilon_0}\right) = \frac{q}{8\varepsilon_0}$

3. (c)

Capacitance of a parallel plate capacitor is

$C = \frac{\varepsilon_0 A}{d}$ ….. (i)

Potential difference between the plates is

V = Ed

The energy stored in the capacitor is …..(ii)

$U = \frac{1}{2}CV^2 = \frac{1}{2}\left(\frac{\varepsilon_0 A}{d}\right)(Ed)^2$ (Using (i) and (ii))

$= \frac{1}{2}\varepsilon_0 E^2 Ad$

4. (b)

When the given metallic spheres are connected by a conducting wire, charge will flow till both the spheres acquire a common potential which is given by Common potential,

$V = \frac{q_1 + q_2}{C_1 + C_2} = \frac{-1\times10^{-2} + 5\times10^{-2}}{4\pi\varepsilon_0 R_1 + 4\pi\varepsilon_0 R_2}$

$= \frac{4\times10^{-2}}{4\pi\varepsilon_0 \times 4\times10^{-2}}$

$\therefore$ Final charge on the bigger sphere is

$q_2' = C_2 V = 4\pi\varepsilon_0 R_2 V$

$= 3\times10^{-2}$ C

5. (c) According to Gauss's law

$\phi_E = \frac{Q_{enclosed}}{\varepsilon_0}$

If the radius of the Gaussian surface is doubled, the outward electric flux will remain the same. This is because electric flux depends only on the charge enclosed by the surface.

6. (d) Capacitance of a parallel plate condenser is

$C = \frac{\varepsilon_0 A}{d}$ …………… (i)

Potential difference across the plates is

V = Ed …………… (ii)

Energy stored in the condenser is

$$U = \frac{1}{2}CV^2$$

$$= \frac{1}{2}\left(\frac{\varepsilon_0 A}{d}\right)(Ed)^2 \qquad \text{(Using (i) and (ii))}$$

$$= \frac{1}{2}\varepsilon_0 E^2 Ad$$

7. (c)

A is the midpoint of PS

$\therefore$ PA = As = L

AR = AQ = $\sqrt{(SR)^2 + (AS)^2} = \sqrt{(2L)^2 + (L)^2} = L\sqrt{5}$

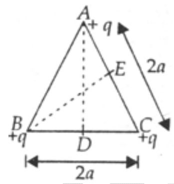
Electric potential at point A due to the given charge configuration is

$$V_A = \frac{1}{4\pi\varepsilon_0}\left[\frac{q}{PA} + \frac{q}{AS} + \frac{(-q)}{AQ} + \frac{(-q)}{AR}\right]$$

$$= \frac{1}{4\pi\varepsilon_0}\left[\frac{q}{L} + \frac{q}{L} + \frac{(-q)}{L\sqrt{5}} + \frac{(-q)}{L\sqrt{5}}\right]$$

$$= \frac{1}{4\pi\varepsilon_0}\left[\frac{2q}{L} - \frac{2q}{L\sqrt{5}}\right] = \frac{1}{4\pi\varepsilon_0}\frac{2q}{L}\left[1 - \frac{1}{\sqrt{5}}\right]$$

8. (d)



Given, AC = BC = 2a

D and E are the midpoints of BC and AC

$\therefore$ AE = EC = a and BD = DC = a

In ΔADC, $(AD)^2 = (AC)^2 - (DC)^2$

= $(21)^2 - (1)^2 = 4a^2 - a^2 = 3a^2$

AD = $a\sqrt{3}$

Similarly, BE = $a\sqrt{3}$

Potential at point D due to the given charge configuration is

$$V_D = \frac{1}{4\pi\varepsilon_0}\left[\frac{q}{BC} + \frac{q}{DC} + \frac{q}{AD}\right]$$

$$= \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{a} + \frac{1}{a} + \frac{1}{\sqrt{3}a}\right] = \frac{q}{4\pi\varepsilon_0 a}\left[2 + \frac{1}{\sqrt{3}}\right] \qquad \text{.....(i)}$$

Potential at point E due to the given charge configuration is

$$V_E = \frac{1}{4\pi\varepsilon_0}\left[\frac{q}{AE} + \frac{q}{EC} + \frac{q}{BE}\right]$$

$$= \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{a} + \frac{1}{a} + \frac{1}{a\sqrt{3}}\right] = \frac{q}{4\pi\varepsilon_0 a}\left[2 + \frac{1}{\sqrt{3}}\right] \qquad \text{.....(ii)}$$

From the (i) and (ii), it is clear that

$V_D = V_E$

The work done in taking a charge Q and D to E is

$$W = Q(V_E = V_D) = 0 \qquad (\therefore V_D = V_E)$$

9. (1) $\vec{E} = -\vec{\nabla} V$

Where $\vec{\nabla} = \hat{i}\frac{\partial}{\partial x} + \hat{j}\frac{\partial}{\partial y} + \hat{k}\frac{\partial}{\partial z}$

$$\therefore \quad \vec{E} = -\left[\hat{i}\frac{\partial V}{\partial x} + \hat{j}\frac{\partial V}{\partial y} + \hat{k}\frac{\partial V}{\partial z}\right]$$

Here, $V = 4x^2$

$\therefore \quad \vec{E} = -8x\hat{i}$

The electric field at point (1, 0, 2) is

$$\vec{E}_{(1,0,2)} = -8\hat{i}Vm^{-1}$$

So electric field is along the negative X-axis

10: (c) According to Coulomb's law, the force of repulsion between the two positive ions each of charge q, separated by a distance d is given by

$$F = \frac{1}{4\pi\varepsilon_0}\frac{(q)(q)}{d^2}$$

$$F = \frac{q^2}{4\pi\varepsilon_0 d^2}$$

$$q^2 = 4\pi\varepsilon_0 F d^2$$

$$q = \sqrt{4\pi\varepsilon_0 F d^2}$$

Since, q = ne

Where,

n = number of electrons missing from each ion

e = magnitude of charge on electron

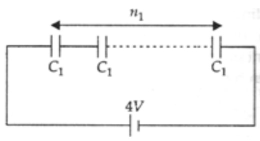
$$\therefore \quad n = \frac{q}{e}$$

$$n = \frac{\sqrt{4\pi\varepsilon_0 F d^2}}{e}$$

$$= \frac{\sqrt{4\pi\varepsilon_0 F d^2}}{e^2}$$

11: (d) Electric flux $\phi = \overline{E}.\overline{A} = 0$. The lines are parallel to the surface

12: d) A series combination of n_1 capacitors each of capacitance C_1 are connected to 4V source as shown in the figure



Total capacitance of the series combination of the capacitors is

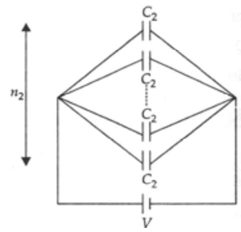
$$\frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_1} + \frac{1}{C_1} + \ldots\ldots \text{up to } n_1 \text{ terms} = \frac{n_1}{C_1}$$

Or $C_s = \frac{C_1}{n_1}$

Total energy stored in a series combination of the capacitors is

$$U_s = \frac{1}{2}C_s(4V)^2 = \frac{1}{2}\left(\frac{C_1}{n_1}\right)(4V)^2$$

A parallel combination of n_2 capacitors each of capacitance C_2 are connected to V source as shown in the figure.



Total capacitance of the parallel combination of capacitors is

$C_p = C_2 + C_2$ +….. Upto n_2 terms

$\Rightarrow C_p = n_2C_2$

Total energy stored in a parallel combination of capacitors is

$$U_p = \frac{1}{2}C_PV^2 = \frac{1}{2}(n_2C_2)(V)^2$$

According to the given problem,

$U_s = U_p$

Equating the values of U_s and U_p

$$\frac{1}{2}\frac{C_1}{n_1}(4V)^2 = \frac{1}{2}(n_2C_2)(V)^2$$

Or $\frac{C_1 16}{n_1} = (n_2C_2)$ or $C_2 = \frac{16C_1}{n_1n_2}$

13. (c) in vaccum electric field between two parallel plates

$$E = \frac{\sigma}{\varepsilon_0}$$

In medium of dielectric constant K

$$E^1 = \frac{\sigma}{\varepsilon_0 k}$$

For kerosene oil k>1 => E^1<E

14: (a) Electric field inside charged conductor is always zero