SELF ASSESSMENT PAPER - 1

SOLUTIONS

I. Multiple Choice Questions [1 × 4 = 4]

1. **Option (A) is correct.**

Explanation: Charge of 1 electron = – 1.6×10^{-19}C

So, Charge of 10×10^{18} electrons = – $10 \times 10^{18} \times 1.6 \times 10^{-19}$ C = – 1.6C

Already existing charge = 2C

So, net charge at present = 2 – 1.6 = 0.4 C

2. **Option (D) is correct.**

Explanation: The area is 20 cm^2 or 20×10^{-4}m^2 .

Substituting $E = 20$ N/C, $A = 20 \times 10^{-4}$ m^2 and $\theta = 30°$

$\varphi = EA \cos\theta$

$= 20 \times 20 \times 10^{-4} \cos 30°$

= 0.0346 Vm

3. **Option (A) is correct.**

Explanation: The electric potential at any point due to a charge Q is given by

$$V = \frac{W}{Q} = \frac{1}{10} = 0.1\text{V}$$

4. **Option (A) is correct.**

II. Assertion and Reason [1 × 2 = 2]

1. **Option (D) is correct.**

Explanation: Considering suitable Gaussian surfaces, we can easily find the electric field at any point. So, the assertion is false. But it is very difficult to apply Gauss law if the charge distribution is so that the Gaussian surface is complicated in shape. So, the reason is true.

2. **Option (D) is correct.**

Explanation: Electric potential and electric potential energy are two different quantities. Hence the assertion is false. Electric potential is defined as the potential energy per unit charge. So, the reason is true.

III. Competency Based Questions [1 × 4 = 4]

1. **Option (C) is correct.**

Explanation: A Faraday cage or Faraday shield is an enclosure made of a conducting material.

Since copper is the only metal given in the list of options, copper is the correct answer.

2. **Option (A) is correct.**

Explanation: Cars are example of Faraday Cages in the real world. Cars can help keep us safe from lightning. Its metal body acts as a Faraday Cage.

3. **Option (C) is correct.**

Explanation: The field within a conductor cancel out with any external fields, so the electric field within the enclosure is zero.

4. **Option (C) is correct.**

Explanation: If a charge is placed inside an ungrounded Faraday shield without touching the walls of the internal face of the shield becomes charged with – q, and + q accumulates on the outer face of the shield. If the cage is grounded, the excess charges will be neutralized by the ground connection.

5. **Option (C) is correct.**

Explanation: The number of electric field lines passing through the cube normally and leaving the surface $= Q/\varepsilon_0$

$Q = 2\ \mu\text{C} = 2 \times 10^{-6}$ C

$\varepsilon_0 = 8.85 \times 10^{-12}$ C^2/Nm^2

$\therefore Q/\varepsilon_0 = 2.2 \times 10^5$ Nm^2/C

IV. Very Short Answer Type Questions [1 × 3 = 3]

1. Electrostatic force. [Coulomb force acts between two charges at rest. Coulomb force is also known as electrostatic force since the force is acting between two static charges.]

2. In a cubic surface, the net electric charge will be zero since dipole carries equal and opposite charges. The net electric flux through a closed cubic surface is $\frac{\text{charge enclosed}}{\varepsilon_0}$ and because the charge enclosed is zero, electric flux is also zero.

3. The electric potential is a scalar quantity and the distance of the point from each charge is same. So, the net potential at the point will be zero because of the same magnitude and the opposite sign.

V. Short Answer Type Questions-I [3 × 2 = 6]

1. $\tau = p E \sin\theta,\ 4 = pE\frac{1}{2}$, so $pE = 8$

Potential energy $U = -pE \cos\theta$

$U = -8 \times \cos 30°$

$U = -6.928$ J

2. $q_A = 2 \times 10^{-6}\text{C} = q_B$

$r = 0.2$ m

$q_c = -4 \times 10^{-6}$ C

$W = W_{AB} + W_{BC} + W_{AC}$

$$W = \frac{1}{4\pi\varepsilon_0 r}[q_A q_B + q_B q_C + q_C q_A]$$

$$W = 9\times10^9 \times \frac{1}{0.2}[2\times2 - 4\times2 - 2\times4]\times10^{-12}\text{ J}$$

$W = -0.54$ J

3. When a battery remains connected to a parallel plate capacitor and if a dielectric slab is inserted between the plates of the capacitor, then (i) there will be no change in the potential difference as the capacitor remained connected with the battery. (ii) capacity or capacitance will increase with the introduction of the dielectric slab, resulting an increase in C. (iii) Electric field will be the same as there will be no change in potential difference and distance between the plates. (iv) Energy stored will be increased, since C increases.

VI. Short Answer Type Questions-II [2 × 3 = 6]

1. Definition: Electric Flux is the dot product of electric field and area vector.

$$\varphi = \int E \cdot ds$$

SI Unit: Nm^2/C

For a given case

$$\phi = \phi_1 + \phi_2 = \left[E_x(\text{at } x = 2a) - E_x(\text{at } x = a)\right]a^2$$
$$= [\alpha(2a) - \alpha(a)]a^2$$
$$= \alpha a^3$$
$$\phi = 50 \times (0.01)^3$$
$$\phi = 5 \times 10^{-5} \frac{\text{Nm}^2}{\text{C}}$$
$$\phi = \frac{q}{\varepsilon_0}$$
$$q = \phi\varepsilon_0 = 5 \times 10^{-5} \times 8.854 \times 10^{-12}$$
$$= 44.27 \times 10^{-17} \text{ C}$$

2. (i) Work done by the source of potential, in storing an additional charge (dq), is

$$dW = V.dq$$

But

$$\Rightarrow \quad dW = \frac{q}{C}dq$$

Total work done in storing the charge q,

$$\int dW = \int_0^q \frac{q}{C}\, dq$$

$$W = \frac{1}{C}\left(\frac{q^2}{2}\right)_0^q = \frac{q^2}{2C}$$

This work is stored as electrostatic energy in the capacitor.

$$U = \frac{1}{2}CV^2 \qquad (\because q = CV)$$

Energy stored per unit volume $= \dfrac{\frac{1}{2}CV^2}{Ad}$

$$u = \frac{\frac{1}{2}\left(\frac{\varepsilon_0 A}{d}\right)(Ed)^2}{Ad}$$

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

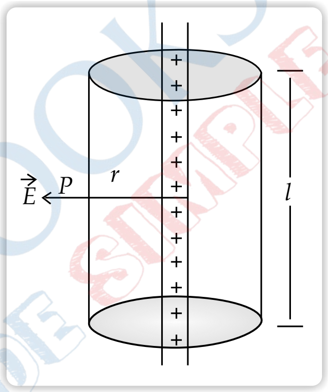
(ii) Work done in moving the charge q from a to b, and from c to d is zero because electric field is perpendicular to the displacement.

Work done from b to c = – Work done from d to a.

So, the net work done is zero.

VII. Long Answer Type Questions [5 × 1 = 5]

1. (i)



To calculate the electric field, imagine a cylindrical Gaussian surface around the current carrying wire, since the field is every where radial, flux through two ends of the cylindrical Gaussian surface is zero.

At cylindrical part of the surface electric field E is normal to the surface at every point and its magnitude is constant.

Therefore flux through the Gaussian surface = Flux through the curved cylindrical part of the surface,

$= E \times 2\pi rl$ ...(i)

Applying Gauss' Law

$$\text{Flux, } \phi = \frac{q_{\text{enclosed}}}{\varepsilon_0}$$

Total charge enclosed = Linear charge density × l

$$= \lambda l$$

$$\phi = \frac{\lambda l}{\varepsilon_0} \qquad \text{...(ii)}$$

Using Equations (i) & (ii),

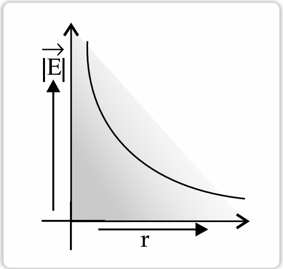
$$E \times 2\pi rl = \frac{\lambda l}{\varepsilon_0}$$

$$\Rightarrow \quad E = \frac{\lambda}{2\pi\varepsilon_0 r}$$

In vector notation, $\vec{E} = \dfrac{\lambda}{2\pi\varepsilon_0 r}\hat{n}$

(where $\hat{n}$ is a unit vector normal to the line charge)

(ii) The required graph is as shown:



(iii) Work done in moving the charge of through a displacement 'dr'

$$dW = \vec{F} \cdot d\vec{r}$$

$$dW = q\vec{E} \cdot d\vec{r}$$

$$= qE\,dr\cos 0°$$

$$dW = q \times \frac{\lambda}{2\pi\varepsilon_0 r} dr$$

Work done in moving the given charge from r_1 to r_2 $(r_2 > r_1)$

$$W = \int_{r_1}^{r_2} dW = \int_{r_1}^{r_2} \frac{\lambda q dr}{2\pi\varepsilon_0 r}$$

$$W = \frac{\lambda q}{2\pi\varepsilon_0}[\log_e r_2 - \log_e r_1]$$

$$W = \frac{\lambda q}{2\pi\varepsilon_0}\left[\log_e \frac{r_2}{r_1}\right]$$

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