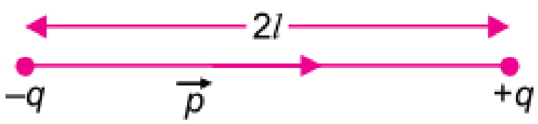
Short Answer Questions – I (PYQ)

Q. 1. Define electric dipole moment. Is it a scalar or a vector quantity? What are its SI unit? [CBSE (AI) 2011, 2013, (F) 2009, 2012, 2013]

Ans.



The electric dipole moment is defined as the product of either charge and the distance between the two charges. Its direction is from negative to positive charge.

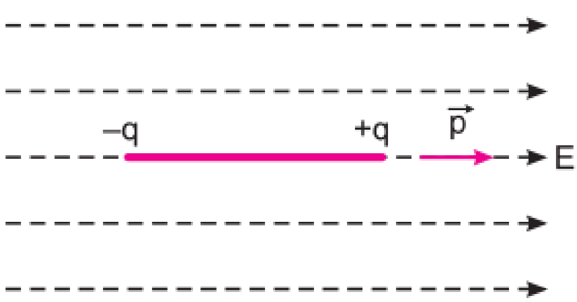
i.e., |p| = q(2l)

Electric dipole moment is a vector quantity.

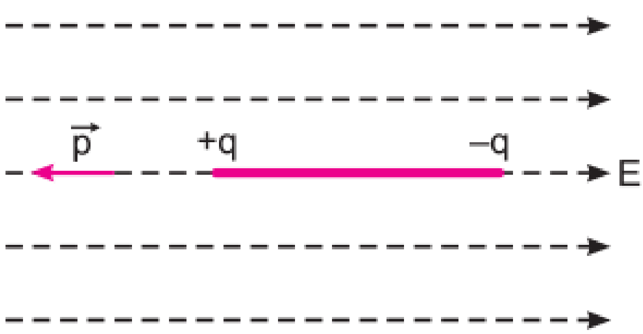
Its SI unit is coulomb-metre.

Q. 2. Depict the orientation of the dipole in (a) stable, (b) unstable equilibrium in a uniform electric field. [CBSE Delhi 2017]

Ans. (a) Stable equilibrium, θ = 0° $\vec{P}$ is parallel to $\vec{E}$



(b) Unstable equilibrium, θ = 180° $\vec{P}$ is anti parallel to $\vec{E}$



Q. 3. Two equal balls having equal positive charge 'q' coulombs are suspended by two insulating strings of equal length. What would be the effect on the force when a plastic sheet is inserted between the two? [CBSE AI 2014]

Ans. Force will decrease.

Reason: Force between two charges each 'q' in vacuum is $F_0 = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q^2}{r^2}$

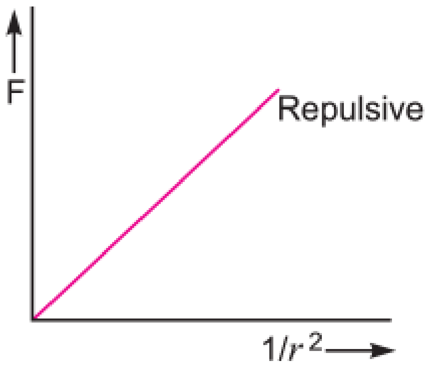
On inserting a plastic sheet (a dielectric K > 1)

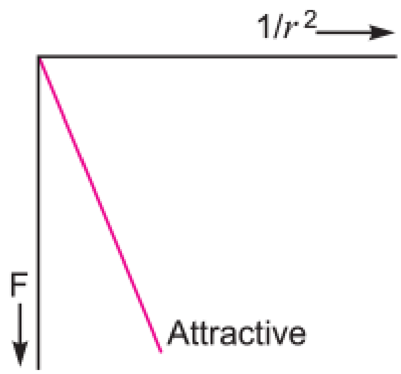
Then $F = \frac{1}{4\pi\varepsilon_0 K} \cdot \frac{q^2}{r^2}$ i.e., Force $F = \frac{F_0}{K}$

Q. 4. Plot a graph showing the variation of coulomb force (F) versus $\left(\frac{1}{r^2}\right)$, where r is the distance between the two charges of each pair of charges: (1 μC, 2 μC) and (2 μC, – 3 μC). Interpret the graphs obtained. [CBSE (AI) 2011]

Ans. $F = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r^2}$

The graph between F and $\frac{1}{r^2}$ is a straight line of slope $\frac{1}{4\pi\varepsilon_0} q_1 q_2$ passing through origin in both the cases.





Since, magnitude of the slope is more for attraction, therefore, attractive force is greater than repulsive force.

Q. 5. Answer the following questions:

(a) Define electric flux. Write its SI unit.

(b) "Gauss's law in electrostatics is true for any closed surface, no matter what its shape or size is." Justify this statement with the help of a suitable example. [CBSE Allahabad 2015]

Ans. (a) Refer to above question.

(b) According to Gauss theorem, the electric flux through a closed surface depends only on the net charge enclosed by the surface and not upon the shape or size of the surface.

For any closed arbitrary shape of the surface enclosing a charge the outward flux is the same as that due to a spherical Gaussian surface enclosing the same charge.

Justification: This is due to the fact that

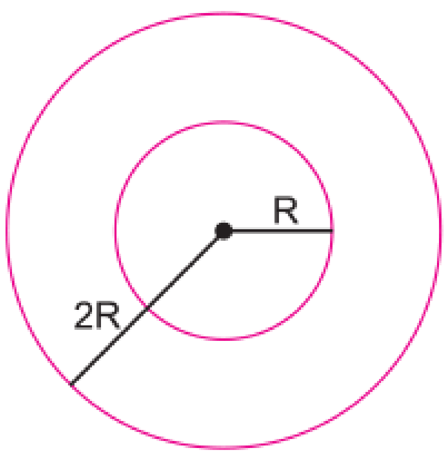
(i) Electric field is radial and

(ii) The electric field $E \propto \frac{1}{R^2}$

Thus, **electric field at each point inside a charged thin spherical shell is zero.**

Q. 6. Two concentric metallic spherical shells of radii R and 2R are given charges Q1 and Q2 respectively. The surface charge densities on the outer surfaces of the shells are equal. Determine the ratio Q1 : Q2. [CBSE (F) 2013]

Ans.



Surface charge density σ is same.

$\therefore$ Charge $\quad Q_1 = 4\pi R^2 \sigma$

and Charge $\quad Q_2 = 4\pi (2R)^2 \sigma$

$$\therefore \quad \frac{Q_1}{Q_2} = \frac{4\pi R^2 \sigma}{4\pi (2R)^2 \sigma} = \frac{1}{4}$$

Q. 7. The sum of two point charges is 7μ C. They repel each other with a force of 1 N when kept 30cm apart in free space. Calculate the value of each charge. [CBSE (F) 2009]

Ans.

$$q_1 + q_2 = 7 \times 10^{-6} \text{ C} \quad \dots (1)$$

$$\frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{(0.30)^2} = 1 \quad \Rightarrow \quad q_1 q_2 = (4\pi\varepsilon_0)(0.30)^2$$

$$\text{or} \quad q_1 q_2 = \frac{1}{9\times10^9} \times 9 \times 10^{-2} = 10^{-11} \quad \dots (2)$$

$$(q_1 - q_2)^2 = (q_1 + q_2)^2 - 4q_1 q_2$$

$$= (7\times10^{-6})^2 - 4\times10^{-11}$$

$$= 49 \times 10^{-12} - 40 \times 10^{-12} = 9 \times 10^{-12}$$

$$q_1 - q_2 = 3 \times 10^{-6} \text{ C} \quad \dots (3)$$

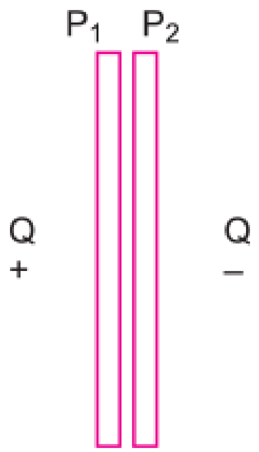
Solving (1) and (3), we get

$$q_1 = 5\times10^{-6} \text{ C}, \; q_2 = 2\times10^{-6} \text{ C}$$

$$\Rightarrow \quad q_1 = 5\mu\text{C}, \; q_2 = 2\mu\text{C}$$

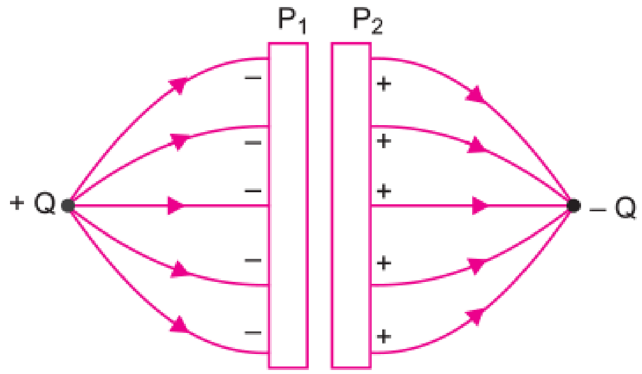
Q. 8. Figure shows two large metal plates P1 and P2, tightly held against each other and placed between two equal and unlike point charges perpendicular to the line joining them.

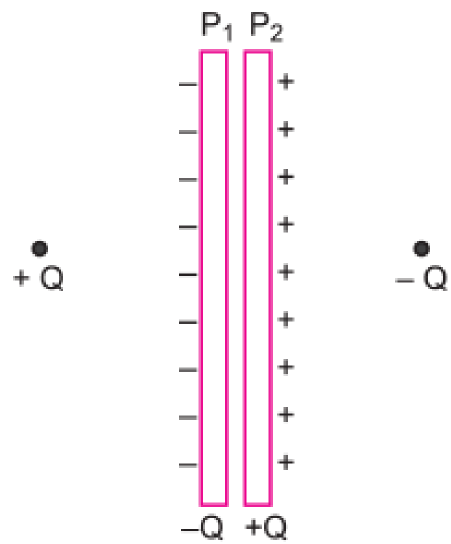
(i) What will happen to the plates when they are released?
(ii) Draw the pattern of the electric field lines for the system. [CBSE (F) 2009]



Ans. (i) Charges induced on outer surfaces of P_1 and P_2 are – Q and + Q respectively. When plates are released, they will tend to move away from one another; plate P_1 moving towards + Q and P_2 towards – Q due to attraction.

(ii) The field pattern is shown in fig.





Q. 9. Calculate the amount of work done in rotating a dipole, of dipole moment 3 × 10^{-8} Cm, from its position of stable equilibrium to the position of unstable equilibrium, in a uniform electric field of intensity 10^4 N/C. [CBSE (F) 2011]

Ans.

$P = 3 \times 10^{-8}$ Cm; $E = 10^4$ N/C

At stable equilibrium $(\theta_1) = 0°$

At unstable equilibrium $(\theta_2) = 180°$

Work done in a rotating dipole is given by:

$W = PE(\cos\theta_1 - \cos\theta_2) = (3 \times 10^{-8})(10^4)[\cos 0° - \cos 180°] = 3 \times 10^{-4}[1 - (-1)]$

$W = 6 \times 10^{-4}$ J

Q. 10. Given a uniform electric field $\vec{E} = 5 \times 10^3\ \hat{i}$ N/C, find the flux of this field through a square of 10 cm on a side whose plane is parallel to the Y-Z plane. What would be the flux through the same square if the plane makes a 30° angle with the X-axis? [CBSE Delhi 2014]

Ans.

Here, $\vec{E} = 5 \times 10^3\ \hat{i}$ N/C, *i.e.*, field is along positive direction of X-axis.

Surface area, A = 10 cm × 10 cm = 0.10 m × 0.10 m = 10^{-2} m^2

(i) When plane is parallel to Y-Z plane, the normal to plane is along X-axis. Hence

$$\theta = 0°$$

$$\varphi = EA\cos\theta = 5 \times 10^3 \times 10^{-2}\cos 0° = 50\ NC^{-1}\ m^2$$

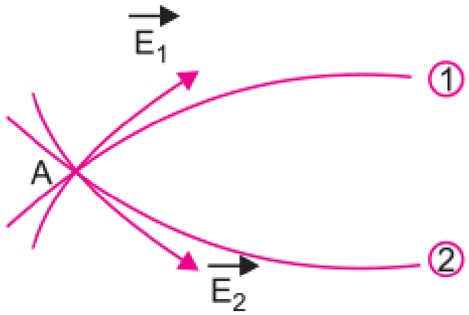
(ii) When the plane makes a 30° angle with the X-axis, the normal to its plane makes 60° angle with X-axis. Hence $\theta = 60°$

$$\varphi = EA\ \cos\theta = 5 \times 10^3 \times 10^{-2}\cos 60° = 25\ NC^{-1}\ m^2$$

Q. 11. Answer the following questions.

(i) An electrostatic field line is a continuous curve. That is, a field line cannot have sudden breaks. Why is it so?

(ii) Explain why two field lines never cross each other at any point.



Ans. (i) An electrostatic field line is the path of movement of a positive test charge (q0 → 0)

A moving charge experiences a continuous force in an electrostatic field, so an electrostatic field line is always a continuous curve.

(ii) Two electric lines of force can never cross each other because if they cross, there will be two directions of electric field at the point of intersection (say A); which is impossible.

Q. 12. An electric dipole is held in a uniform electric field.

(i) Show that the net force acting on it is zero.

(ii) The dipole is aligned parallel to the field. Find the work done in rotating it through the angle of 180°. [CBSE (AI) 2012]

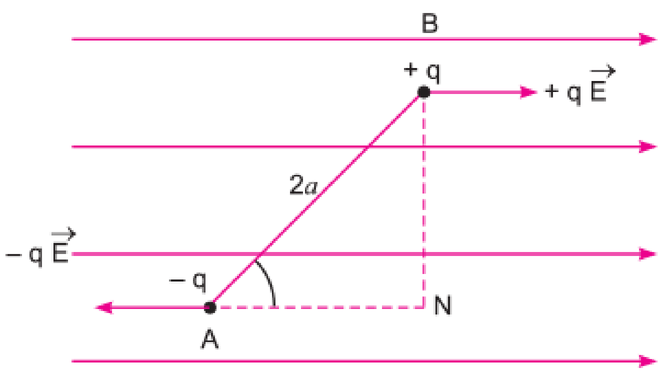
Ans. (i)

(i) The dipole moment of dipole is $|\vec{p}| = q \times (2a)$

$$\text{Force on } -q \text{ at } A = -q\vec{E}$$

$$\text{Force on } +q \text{ at } B = +q\vec{E}$$

$$\text{Net force on the dipole} = q\vec{E} - q\vec{E} = 0$$



Q. 13. Answer the Following Questions.

(i) Define electric flux. Write its SI unit.

(ii) A spherical rubber balloon carries a charge that is uniformly distributed over its surface. As the balloon is blown up and increases in size, how does the total electric flux coming out of the surface change? Give reason. [CBSE (F) 2016]

Ans. (i) Total number of electric field lines crossing a surface normally is called electric flux. Its SI unit is Nm^2C^{-1} or Vm.

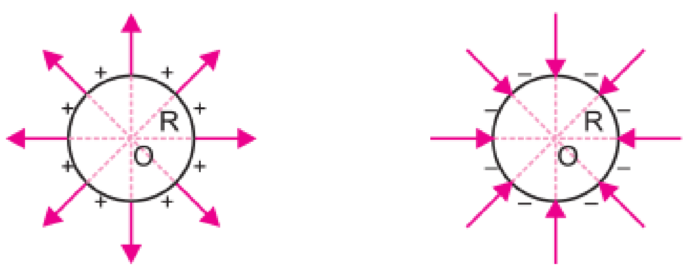
(ii) Total electric flux through the surface = $\frac{q}{\varepsilon_0}$

As charge remains unchanged when size of balloon increases, electric flux through the surface remains unchanged.

Short Answer Questions-I (OIQ)

Q. 1. Draw the electric field lines due to a uniformly charged thin spherical shell when charge on the shell is (i) positive and (ii) negative.

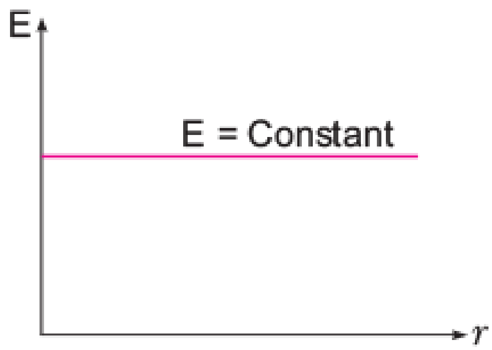
Ans. The electric field lines are shown in the figure. For a positively charged shell, the field lines are directed in radially outward direction and for negatively charged shell, these are directed in radially inward direction.



(a) Positively charged shell (b) Negatively charged shell

Q. 2. Represent graphically the variation of electric field with distance, for a uniformly charged plane sheet. [CBSE Sample Paper 2017]

Ans.



Electric field due to a uniformly charged plane sheet.

$$E = \frac{\sigma}{2\varepsilon_0}$$

Which is independent of distance.

So, it represents a straight line parallel to distance axis.

Q. 3. The force between two point charges kept at a distance r apart in air is F. If the same charges are kept in water at the same distance, how does the force between them change?

Ans.

The force in air $F_a = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$

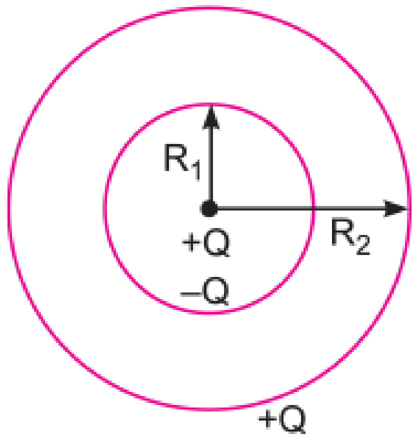
The force in water $F_w = \frac{1}{4\pi\varepsilon_0 K}\frac{q_1 q_2}{r^2}$

$\therefore \qquad \frac{F_w}{F_a} = \frac{1}{K}$

Dielectric constant of water is 81, so the force in water reduces to $\frac{1}{81}$ times.

Q. 4. A metallic spherical shell has an inner radius R_1 and outer radius R_2. A charge Q is placed at the centre of the spherical cavity. What will be surface charge density on (i) the inner surface, and (ii) the outer surface? [NCERT Exemplar]

Ans.



When a charge + Q is placed at the centre of spherical cavity,

The charge induced on the inner surface = – Q

The charge induced on the outer surface = + Q

∴ Surface charge density on the inner surface = $\frac{-Q}{4\pi R_1^2}$

Surface charge density on the outer surface = $\frac{+Q}{4\pi R_2^2}$

Q. 5. Two point electric charges of unknown magnitude and sign are placed at some distance‘d’ apart. The electric field intensity is zero at a point, not between the charges but on the line joining them.

Write two essential conditions for this to happen.

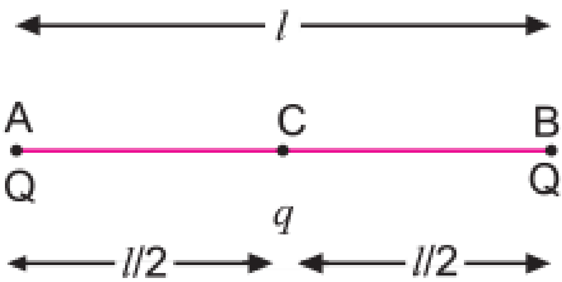
Ans. (i) The two charges must be of opposite kind.

(ii) The magnitude of two charges must be unequal. The charge closer to the point of observation should be of smaller magnitude.

Q. 6. A charge q is placed at the centre of the line joining two equal charges Q.

Show that the system of three charges will be in equilibrium if q = – $\frac{Q}{4}$.

Ans.



Charge q is in equilibrium since charges A and B exert equal and opposite forces on it.

For equilibrium of charge Q at B;

$F_{BC} + F_{AB} = 0$

$$\Rightarrow \quad \frac{1}{4\pi\varepsilon_0}\frac{qQ}{(l/2)^2} + \frac{1}{4\pi\varepsilon_0}\frac{Q.Q}{l^2} = 0$$

$$\Rightarrow \quad \frac{1}{4\pi\varepsilon_0}\frac{Q}{l^2}(4q+Q) = 0 \quad \Rightarrow \quad q = -\frac{Q}{4}$$

Q. 7. A point charge is placed at the centre of a closed Gaussian spherical surface of radius r. Electric flux passing through the surface is φ How is the electric flux φ through the surface affected when the following changes are made in turn:

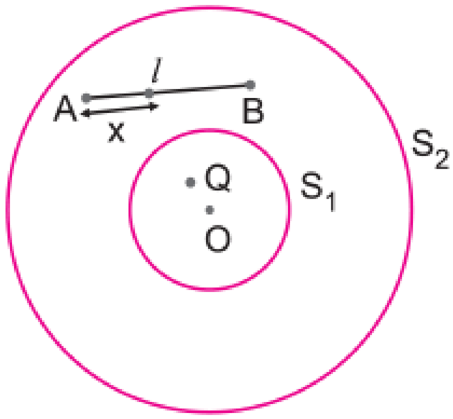
(i) The spherical surface is replaced by a cylindrical surface of the same radius?
(ii) The point charge is replaced by an electric dipole?

Justify your answer in each case.

Ans. (i) Since the charge inside the Gaussian surface remains the same, the electric flux through it remains unchanged.

(ii) Since the net charge inside the surface is zero, the electric flux passing through the surface also becomes zero.

Q. 8. In the figure shown, calculate the total flux of the electrostatic field through the spheres S1 and S2. The wire AB shown here has a linear charge density λ given by λ = kx where x is distance measured along the wire, from the end A. [HOTS]



Ans. Total charge on wire AB

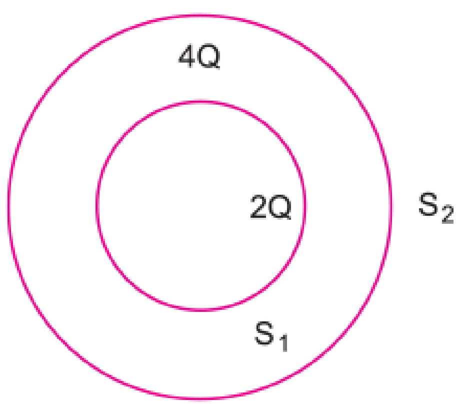
$$Q_{AB} = \int_0^l \lambda dx = \int_0^l kx \ dx = k\left[\frac{x^2}{2}\right]_0^l = \frac{1}{2}kl^2$$

By Gauss theorem,

$$\text{Total flu through } S_1 = \frac{Q}{\varepsilon_0}$$

$$\text{Total flux through } S_2 = \frac{Q+Q_{AB}}{\varepsilon_0} = \left(\frac{Q+\frac{1}{2}kl^2}{\varepsilon_0}\right)$$

Q. 9. Consider two hollow concentric spheres, S_1 and S_2, enclosing charges 2Q and 4Q respectively as shown in the figure. (i) Find out the ratio of the electric flux through them. (ii) How will the electric flux through the sphere S1 change if a medium of dielectric constant 'ε_r' is introduced in the space inside S1 in place of air? Deduce the necessary expression. [HOTS]



Ans.

Using Gauss's Theorem $\oint \overrightarrow{E} \cdot \overrightarrow{dS} = \frac{q(T)}{\varepsilon_0}$

Electric flux through sphere S_1, $\varphi_1 = \frac{2(Q)}{\varepsilon_0}$

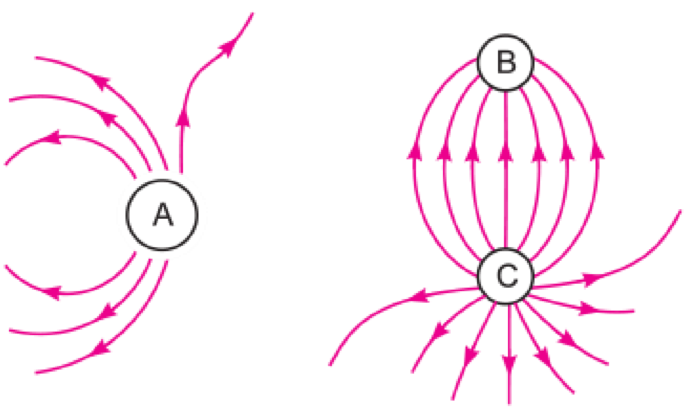
Electric flux through sphere S_2, $\varphi = \frac{(2Q+4Q)}{\varepsilon_0} = \frac{6Q}{\varepsilon_0}$

$$\text{Ratio} = \frac{\varphi_1}{\varphi} = \frac{\frac{2Q}{\varepsilon_0}}{\frac{6Q}{\varepsilon_0}} = \frac{1}{3}$$

If a medium of dielectric constant K(= ε_r) is filled in the sphere S_1, electric flux through sphere,

$$\varphi'_1 = \frac{2Q}{\varepsilon_r \varepsilon_0} = \frac{2Q}{K\varepsilon_0}.$$

Q. 10.



The given figure shows the electric field lines around three point charges A, B and C.

(i) Which charges are positive?

(ii) Which charge has the largest magnitude? Why?

(iii) In which region or regions of the picture could the electric field be zero? Justify your answer.

(i) near A (ii) near B (iii) near C (iv) nowhere. [NCERT Exemplar] [HOTS]

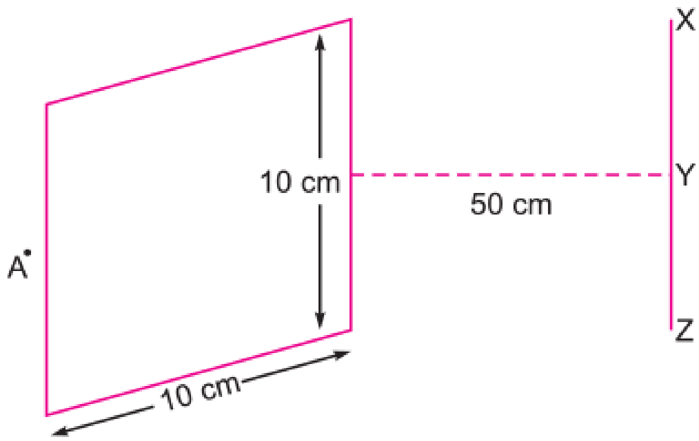
Ans. (i) Charges A and C are positive since lines of force emanate from them.

(ii) Charge C has the largest magnitude since maximum number of field lines are associated with it.

(iii) (i) near A.

Justification: There is no neutral point between a positive and a negative charge. A neutral point may exist between two like charges. From the figure we see that a neutral point exists between charges A and C. Also between two like charges the neutral point is closer to the charge with smaller magnitude. Thus, electric field is zero near charge A.

Q. 11. Given a uniformly charged plane/sheet of surface charge density, σ = 2 × 10^{17} C/m^2.



(i) Find the electric field intensity at a point A, 5 mm away from the sheet on the left side.

(ii) Given a straight line with three points X, Y and Z placed 50 cm away from the charged sheet on the right side. At which of these points, the field due to the sheet remain the same as that of point A and why? [CBSE Sample Paper 2016]

Ans.

$$(i)\ \text{At } A,\ E = \frac{\sigma}{2\varepsilon_0} = \frac{2\times10^{17}\ \text{Cm}^{-2}}{2\times8.854\times10^{-12}C^2N^{-1}m^{-2}}$$

E = 1.1×1028 N/C

Directed away from the sheet

(ii) Point Y

Because at 50 cm, the charge sheet acts as a finite sheet and thus the magnitude remains same towards the middle region of the planar sheet.

Q. 12. Two isolated metal spheres A and B have radii R and 2R respectively, and same charge q. Find which of the two spheres have greater energy density just outside the surface of the spheres. [CBSE Sample Paper 2016]

Ans. Energy density,

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

But, $E = \frac{\sigma}{\varepsilon_0} = \frac{Q}{A\varepsilon_0}$

$$\therefore \quad U = \frac{1}{2}\ \frac{\varepsilon_0 Q^2}{A^2 \varepsilon_0} \quad \Rightarrow \quad U = \frac{Q^2}{2A^2}$$

$$\Rightarrow \quad U \propto \frac{1}{A^2} \quad \Rightarrow \quad U_A > U_B$$