ELECTRIC CHARGES AND FIELD

1 MARK QUESTIONS

1) Two identical metallic spheres of exactly equal masses are taken. One is given a positive charge *q* coulombs and other an equal negative charge. Are their masses after charging equal?
2) Ordinary rubber is an insulator. But the special rubber tyres of aircrafts are made slightly conducting. Why is this necessary?
3) Two charges q_1 and q_2 separated by a small distance satisfy the equation $q_1+q_2 = 0$. What does it tell about the charges?
4) Name the experiment which established the quantum nature of electric charges?
5) Can a body have a charge of 0.8×10^{-19} C? Justify your answer by comment.
6) 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?
7) Force between two-point charges kept at a distant d apart in air F. If these charges are kept at the same distance in water how does the electric force between them change?
8) Why is electric field zero inside a charged conductor?
9) Why do the electrostatic field lines not form closed loops?
10) Draw lines of force to represent a uniform electric field?

2 MARK QUESTIONS

1) A force F is acting between two charges placed some distance apart in vacuum. If a brass rod is placed between these two charges how does the force change?
2) Two dipoles made charges + q and + Q respectively have equal dipole moments. Give the (i) ratio between the separation of these two pairs of charges (ii) angle between the dipole axes of these two dipoles.
3) A metallic spherical shell has an inner radius R1 and outer radius R2. A charge Q is placed at the center of the spherical cavity. What will be the surface charge density on (i) the inner surface and (ii) the outer surface?
4) A thin metallic spherical shell of radius R carries a charge Q on its surface. A point charge Q/2 is placed at its center C and another charge +2Q is placed outside the shell at a distance x from the center as shown.

Find (i) the force on the charge at the center of the shell and at the point A .
(ii) the electric flux through the shell.

5) Explain the meaning of the statement 'electric charge of a body is 'quantized'.

6) Why can one ignore quantization of electric charge when dealing with macroscopic i.e., large scale charges?

7) When a glass rod is rubbed with a silk cloth, charges appear on both. A similar phenomenon is observed with many other pairs of bodies. Explain how this observation is consistent with the law of conservation of charge.

8) Four-point charges $q_A = 2$ μC, $q_B = -5$ μC, $q_C = 2$ μC, and $q_D = -5$ μC are located at the corners of a square ABCD of side 10 cm. What is the force on a charge of 1 μC placed at the center of the square?

9) A system has two charges $q_A = 2.5 \times 10^{-7}$ C and $q_B = -2.5 \times 10^{-7}$ C located at points A: (0, 0, –15 cm) and B: (0, 0, +15 cm), respectively. What are the total charge and electric dipole moment of the system?

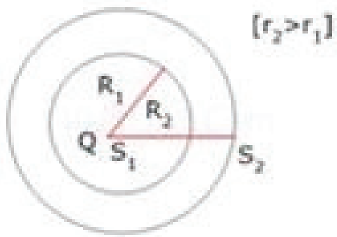
10) **(*a*)** An electrostatic field line is a continuous curve. That is, a field line cannot have sudden breaks. Why not?

(*b*) Explain why two field lines never cross each other at any point?

3 MARK QUESTIONS

1) Define the term dipole moment $\vec{P}$ of an electric dipole indicating its direction. Write its S.I unit. An electric dipole is placed in a uniform electric field $\vec{E}$. Deduce the expression for the Torque acting on it.

2) Electric charge is uniformly distributed on the surface of a spherical balloon. Show how electric intensity and electric potential vary (a) on the surface (b) inside and (c) outside.



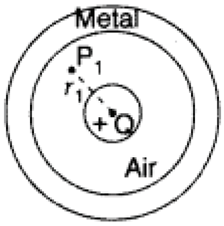
3) Two point charges +q and +9q are separated by a distance of 10 a. Find the point on the line joining the two changes where electric field is zero?

4) Consider a uniform electric field $E = 3 \times 10^3\ \hat{i}\ N/C$. (a) What is the flux of this field through a square of 10 cm on a side whose plane is parallel to the *yz* plane? (b) What is the flux through the same square if the normal to its plane makes a $60°$ angle with the *x*-axis?

5) A conducting sphere of radius 10 cm has an unknown charge. If the electric field 20 cm from the centre of the sphere is $1.5 \times 10^3\ N/C$ and points radially inward, what is the net charge on the sphere?

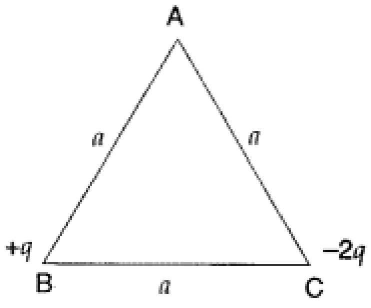
6) A system has two charges $q_A = 2.5 \times 10^{-7}$ C and $q_B = -2.5 \times 10^{-7}$ C located at points A: $(0, 0, -15 \text{ cm})$ and B: $(0, 0, +15 \text{ cm})$, respectively. What are the total charge and electric dipole moment of the system?

7) A small metal sphere carrying charge +Q is located at the centre of a spherical cavity in a large uncharged metallic spherical shell. Write the charges on the inner and outer surfaces of the shell. Write the expression for the electric field at the point P_1 .

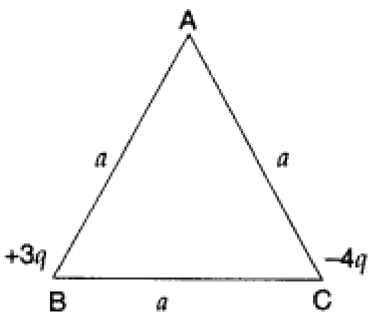


8) A thin conducting spherical shell of radius R has charge Q spread uniformly over its surface. Using Gauss's law, derive an expression for an electric field at a point outside the shell.
Draw a graph of electric field E(r) with distance r from the centre of the shell for $0 \leq r \leq \infty$

9) Two point charges + q and -2q are placed at the vertices 'B' and 'C' of an equilateral triangle ABC of side as given in the figure. Obtain the expression for (i) the magnitude and (ii) the direction of the resultant electric field at the vertex A due to these two charges.



10) Two point charges + 3q and – 4q are placed at the vertices 'B' and 'C' of an equilateral triangle ABC of side 'a' as given in the figure. Obtain the expression for

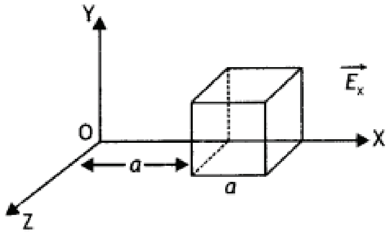


(i) the magnitude and
(ii) the direction of the resultant electric field at the vertex A due to these two charges.

11) Two spherical conductors of radii Ra and R2 ($R_2 > R_1$) are charged. If they are connected by a conducting wire, find out the ratio of the surface charge densities on them.

LONG ANSWER QUESTIONS

1. (a) State Gauss theorem in electrostatics. Using it, prove that the electric field at a point due to a uniformly charged infinite plane sheet is independent of the distance.
   (b) How is the field directed if (i) the sheet is positively charged, (ii) negatively charged?
2. Use Gauss's law to derive the expression for the electric field ($\vec{E}$) due to a straight uniformly charged infinite line of charge λ Cm^{-1}.
3. Define electric flux and write its SI unit. The electric field components in the figure shown are : $E_x = \alpha x$, $E_y = 0$, $E_z = 0$ where $\alpha = 100N/cm$. Calculate the charge within the cube, assuming $a = 0.1m$.



MCQ

1. Three-point charges Q_1, $Q_2$and Q_3 are placed equally spaced in order along a straight line. Q_2 and Q_3 are equal in magnitude but opposite in sign . If the net force on Q_3 is zero, the value of Q_1 is
   (a) $Q_1 = 4Q_3$ (b) $Q_1 = 2(Q_3)$ (c) $Q_1= \sqrt{2}\, Q_3$ (d) $Q_1 = |Q_3|$
2. Two-point charges are placed at a distance d apart. If a copper plate is placed between the charges the effective force will be
   (a) F (b) 2F (c) $\sqrt{F}$ (d) zero
3. The charges on two spheres are +7μC and -5 μC respectively. They experience a force F. If an additional charge of-2 μC is given to each of them the force between them is
   (a) F (b) F/2 (c) F/$\sqrt{3}$ (d)2F
4. What is the flux through a cube if q is at one corner of the cube?
   (a) q/ϵ_0 (b)$2q/\epsilon_0$ (c) $q/8\epsilon_0$ (d) $q/4\epsilon_0$
5. 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
   (a) $\frac{4\pi\epsilon_0 F d^2}{e^2}$ (b) $\sqrt{\frac{4\pi\epsilon_0 F e^2}{d^2}}$ (c) $\sqrt{\frac{4\pi\epsilon_0 F d^2}{e^2}}$ (d) $\frac{4\pi\epsilon_0 F e^2}{d^2}$
6. A plane square sheet of charge of side 0.5m has uniform surface charge density. An electron at 1cm from the center of the sheet experiences a force of 1.6×10^{-19} N directed away from the sheet. The total charge on the plane square sheet is
   (a) 16.25 μC (b) -22.15 μC (C) -44.27 μC (d) 144.27 μC
7. Seven charges of equal magnitude q are placed at the corners of a cube of side b. The force experienced by another charge Q placed at the center of the cube is
   (a) Zero (b) KQq/ 3b (c) 7KQq/3b (d) 2KQq/3b

8. Electric charge is uniformly distributed along a long straight wire of radius 1mm. The charge per cm of the wire is Q coulomb. Another cylindrical surface of length L meter encloses the wire symmetrically, The total flux through the surface is

   (a) Q/ε_0 (b) LQ/ε_0 (c) $QL/10^{-3}\varepsilon_0$ (d) $Q/L\ 10^{-3}\varepsilon_0$

9. The total electric flux emanating from an alpha particle is

   (a) $2e/\varepsilon_0$ (b)e/ε_0 (c) $4e/\varepsilon_0$ (d) e^2/ε_0

10. A positive charge Q is placed at the center of a neutral conducting metal sphere and an electric field E is applied outside the sphere. Then

    (a) force on Q is due to E is zero (b) Net force on Q is zero (c) Net force on Q and conducting shell as a single system is zero (d) Net force on the shell due to E is zero

Assertions & Reasons

1. Given below are two statements labelled as Assertion(A) and Reason(R).

Assertion(A) Insulators do not allow flow current through themselves.

Reason(R) They have no free charge carriers.

Select the most appropriate answer from the options given below.

(i) Both A and R are true, and R is the correct explanation of A.
(ii) Both A and R are true, and R is not the correct explanation of A.
(iii) A is true but R is false
(iv) A is false and R is also false.

2. Given below are two statements labelled as Assertion(A) and Reason(R).

Assertion(A) During charging by rubbing, the insulating material with lower work function becomes positively charged.

Reason(R) Electrons are negatively charged.

Select the most appropriate answer from the options given below.

(i) Both A and R are true, and R is the correct explanation of A.
(ii) Both A and R are true, and R is not the correct explanation of A.
(iii) A is true but R is false
(iv) A is false and R is also false.

3. Given below are two statements labelled as Assertion(A) and Reason(R).

Assertion(A) A metallic shield in the form of a hollow shell, can be built to block an electric field.

Reason(R) In a hollow spherical shell, electric field inside is not zero at every point.

Select the most appropriate answer from the options given below.

(i) Both A and R are true and, R is the correct explanation of A.
(ii) Both A and R are true and, R is not the correct explanation of A.
(iii) A is true but R is false
(iv) A is false and R is also false.

4. Given below are two statements labelled as Assertion(A) and Reason(R).
Assertion (A). A charge is quantized because only integral number of electrons can be transferred.

Reason (R) There is no possibility of transfer of some fraction of electron.

Select the most appropriate answer from the options given below.

(i) Both A and R are true and, R is the correct explanation of A.
(ii) Both A and R are true and, R is not the correct explanation of A.
(iii) A is true but R is false
(iv) A is false and R is also false

5. Given below are two statements labelled as Assertion(A) and Reason(R).
Assertion (A): The Coulomb force is dominating force in the universe.

Reason(R): The Coulomb force is weaker than the gravitational force.

Select the most appropriate answer from the options given below.

(i) Both A and R are true and, R is the correct explanation of A.
(ii) Both A and R are true and, R is not the correct explanation of A.
(iii) A is true but R is false
(iv) A is false and R is also false

6. Given below are two statements labelled as Assertion(A) and Reason(R) Assertion (A): Gauss theorem can used to find the electric field at any point.
Reason (R): Gauss theorem can be applied to any type of charge distribution.
(i) Both A and R are true and R is the correct explanation of A
(ii) Both A and R are true but R is not the correct explanation of A.
(iii) A is true but R is false.
(iv) A is false and R is also false.

7. Given below are two statements labelled as Assertion(A) and Reason(R) Assertion (A): If a dipole is enclosed by a surface, then according to the gauss theorem, electric flux linked with it is zero
Reason (R): The charge enclosed by the surface is zero.
(i) Both A and R are true and R is the correct explanation of A
(ii) Both A and R are true but R is not the correct explanation of A.
(iii) A is true but R is false.
(iv) A is false and R is also false.

8. Given below are two statements labelled as Assertion(A) and Reason(R) Assertion (A): positive electric flux indicates that electric lines of force are directed outwards
Reason (R): Positive electric flux is due to a positive charge
(i) Both A and R are true and R is the correct explanation of A
(ii) Both A and R are true but R is not the correct explanation of A.
(iii) A is true but R is false.
(iv) A is false and R is also false.

9. Given below are two statements labelled as Assertion(A) and Reason(R) Assertion (A): Coulombs law is useful for calculation of electric field intensity due to point charges
Reason (R): Gauss law is used for calculating electric field intensity due to symmetric charge distributions
(i) Both A and R are true and R is the correct explanation of A
(ii) Both A and R are true but R is not the correct explanation of A.
(iii) A is true but R is false.
(iv) A is false and R is also false.

10. Given below are two statements labelled as Assertion(A) and Reason(R) Assertion (A): A graph showing the variation of electric field at a point with distance due to an infinite plane sheet of charge is a straight line parallel to the distance axis
Reason (R): The electric field at a point due to an infinite plane sheet of charge is independent of the distance to the point.
(i) Both A and R are true and R is the correct explanation of A
(ii) Both A and R are true but R is not the correct explanation of A.
(iii) A is true but R is false.
(iv) A is false and R is also false

ASSERTION REASON

1. Ans. *Option (i)*
2. Ans. *Option (ii)*
3. Ans. *Option(iii)*
4. Ans. *Option (i)*
5. Ans. *Option (iv)*
6. Ans. *Option(iii)*
7. Ans. *Option(i)*
8. Ans. *Option(ii)*
9. Ans. *Option(ii)*
10. Ans. *Option(i)*

CASE STUDY QUESTIONS

1. Lightning is an electric current. Within a thundercloud way up in the sky, many small bits of ice (frozen raindrops) bump into each other as they move around in the air. All of those collisions create an electric charge. After a while, the whole cloud fills up with electrical charges. The positive charges or protons form at the top of the cloud and the negative charges or electrons form at the bottom of the cloud. Since opposites attract, that causes a positive charge to build up on the ground beneath the cloud. The grounds electrical charge concentrates around anything that sticks up, such as mountains, people, or single trees. The charge coming up from these points eventually connects with a charge reaching down from the clouds and lightning strikes.

(i) Charge is the property associated with matter due to which it produces and experiences

(a) electric effects only

(b) magnetic effects only

(c) both electric and magnetic effects

(d) None of these

(ii) When some charge is transferred to ...*A*... it readily gets distributed over the entire surface of ... *A*... If some charge is put on ... *B*..., it stays at the same place. Here, A and B refer to

(a) insulator, conductor

(b) conductor, insulator

(c) insulator, insulator

(d) conductor, conductor

(iii) On charging by conduction, mass of a body may

(a) increase

(b) decreases

(c) increase or decrease

(d) None of these

(iv) If one penetrates a uniformly charged spherical cloud, electric field strength

(a) decreases directly as the distance from the centre

(b) increases directly as the distance from the centre

(c) remains constant

(d) None of these

(v) The law, governing the force between electric charges in the cloud is known as

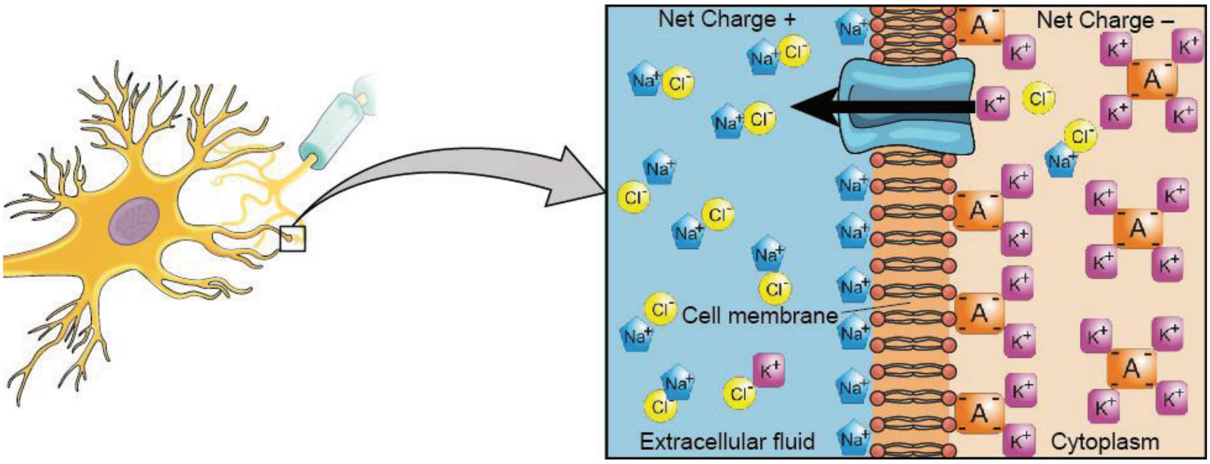
(a) Ampere's law

(b) Ohm's law

(c) Faraday's law

(d) Coulomb's law

2.Neurons maintain different concentrations of certain ions across their cell membranes. Imagine the case of a boat with a small leak below the water line. In order to keep the boat afloat, the small amount of water entering through the leak has to be pumped out, which maintains a lower water level relative to the open sea. Neurons do the same thing, but they pump out positively charged sodium ions. In addition, they pump in positively charged potassium ions. Thus there is a high concentration of sodium ions present outside the neuron, and a high concentration of potassium ions inside. Thus sodium channels allow sodium ions through the membrane while potassium channels allow potassium ions through.



(i) When neuron pump out and in the positive sodium and positive potassium ions respectively which property of charge is to be followed

(a) Quantisation of charge

(b) Additivity of charges

(c) Conservation of charges

(d) Associativity of charge

(ii) Coulomb's law is true for

(a) atomic distances (= 10^{-11} m)

(b) nuclear distances (= 10^{-15} m)

(c) charged as well as uncharged particles

(d) all the distances

(iii) Electric lines of force about a positive sodium or potassium ions are

(a) circular anticlockwise

(b) circular clockwise

(c) radial, inwards

(d) radial, outwards

(iv) Electric flux produced by positive Potassium ions indicates that electric lines are directed

(a) outwards

(b) inwards

(c) either (a) or (b)

(d) None of these

(v) Electric flux over a surface of neuron in an electric field may be

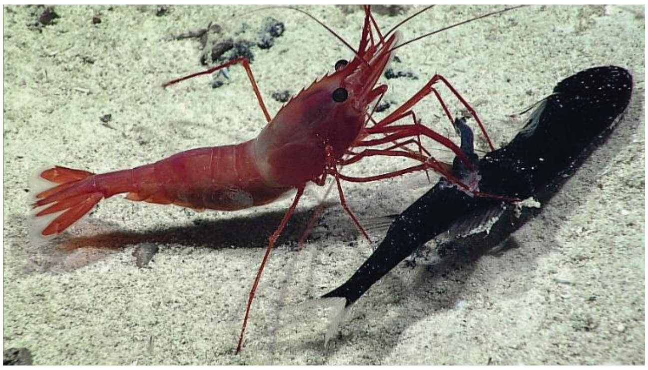
(a) positive

(b) negative

(c) zero

(d) All of the above

3. Animals emit low frequency electric fields due to a process known as osmoregulation. This process allows the concentration of ions (charged atoms or molecules) to flow between the inside of our bodies and the outside. In order for our cells to stay intact, the flow of ions needs to be balanced. But balanced doesn't necessarily mean equal. The concentration of ions within a shrimp's body is much lower than that of the sea water it swims in. Their voltage, or potential difference generated between the two concentrations across "leaky" surfaces, can then be measured.



(i) The Gaussian surface for ions in the body of animals

(a) can pass through a continuous charge distribution.

(b) cannot pass through a continuous charge distribution.

(c) can pass through any system of discrete charges.

(d) can pass through a continuous charge distribution as well as any system of discrete charges.

(ii) Gauss's law is valid for

(a) any closed surface

(b) only regular close surfaces

(c) any open surface

(d) only irregular open surfaces

(iii) The electric field inside a shrimp's body of uniform charge density is

(a) zero

(b) constant different from zero

(c) proportional to the distance from the curve

(d) None of the above

(iv) If a small piece of linear isotropic dielectric is swallowed by a shrimp and inside the body it is influenced by an electric field of strength E, then the polarization P is

(a) independent of E

(b) inversely proportional to E

(c) directly proportional to $\sqrt{E}$

(d) directly proportional to E

(v) Field due to multiple charges/ions inside Shrimp's body at a point is found by using

I. superposition principle.

II. Coulomb's law.

III. law of conservation of charges.

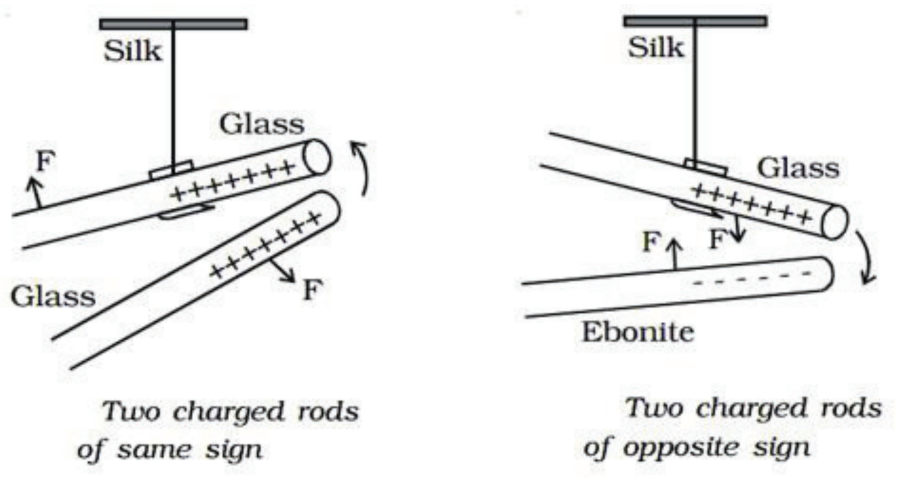
(a) I and II

(b) II and III

(c) I and III

(d) I, II and III

4. **Electric Charge**: When a glass rod is rubbed with silk, the rod acquires one kind of charge and the silk acquires the second kind of charge. This is true for any pair of objects that are rubbed to be electrified. Now if the electrified glass rod is brought in contact with silk, with which it was rubbed, they no longer attract each other. They also do not attract or repel other light objects as they did on being electrified. Thus, the charges acquired after rubbing are lost when the charged bodies are brought in contact. What can you conclude from these observations? It just tells us that unlike charges acquired by the objects neutralise or nullify each other's effect. Therefore, the charges were named as positive and negative by the American scientist Benjamin Franklin. We know that when we add a positive number to a negative number of the same magnitude, the sum is zero. This might have been the philosophy in naming the charges as positive and negative. By convention, the charge on glass rod or cat's fur is called positive and that on plastic rod or silk is termed negative. If an object possesses an electric charge, it is said to be electrified or charged. When it has no charge it is said to be electrically neutral



(i) When you charge a balloon by rubbing it on your hair this is an example of what method of charging?

(a)Friction (b)Conduction (c)Grounding (d)Induction

(ii) Neutral atoms contain equal numbers of positive __ and negative __.

(a)Electrons and Protons (b)Protons and Electrons (c)Neutrons and Electrons (d)Protons and Neutrons

(iii) During charging by rubbing which of the following is not true?

(a) Mass is conserved (b)charge is conserved (c)mass of each object is conserved (d)Net charge before and after rubbing is zero

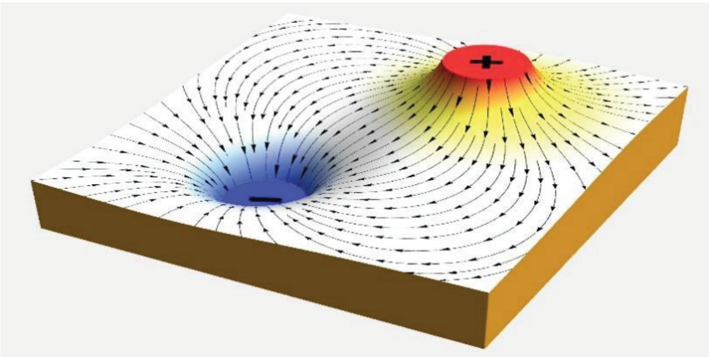
(iv) If a negatively charged rod touches a conductor, the conductor will be charged by what method?

(a) Friction (b) Conduction (c) Induction (d) Convection

(v) If we bring charged plastic rod near-neutral aluminium rod, then rods will

(a)Repel each other (b)Attract each other (c)Remain their position (d)Exchange charges

5. Electric Dipole: The electric field due to a charge configuration with total charge zero is not zero, but for distances large compared to the size of the configuration, its field falls off faster than $1/r^2$, typical of the field due to a single charge. An electric dipole is the simplest example of this fact. An electric dipole is a pair of equal and opposite charges +q and -q separated by some distance 2a. Its dipole moment vector p has magnitude 2qa and is in the direction of the dipole axis from -q to +q. The electric field of the pair of charges can be found out from Coulomb's law and the superposition principle. The magnitude and the direction of the dipole field depend not only on the distance r but also on the angle between the position vector r and the dipole moment p. In some molecules, like H_2O, the centers of -ve charges and of +ve charges do not coincide. So they have permanent dipole moment. Such molecules are called polar molecules.



(i)What will be the value of electric field at the centre of the electric dipole?

(a) Zero (b) Equal to the electric field due to one charge at Centre

(c) Twice the electric field due to one charge at Centre

(d) Half the value of electric field due to one charge at Centre

(ii) If r is the distance of a point from the Centre of a short dipole, then the electric field intensity due to the short dipole remains proportional to

(a)r^2 (b) r^3

(c) r^{-2} (d) r^{-3}

(iii) An electric dipole coincides on Z-axis and its midpoint is on origin of the coordinate system. The electric field at an axial point at a distance z from origin is Ez and electric field at an equatorial point at a distance y from origin is Ey. Here z=y>>a, so |Ez|/|Ey| is equal to…

(a)1 (b)4 (c) 3 (d) 2

(iv) An electric dipole of moment p is placed in a uniform electric field E. The maximum torque experienced by the dipole is…

(a) pE (b) p/E (c) E/p (d) p . E

(v) An electric dipole is placed in a uniform electric field parallel to the field

(a) It experiences a force and moves parallel to the field

(b) It experiences a torque and moves in a circular path

(c) It experiences no force and no torque and remains at rest

(d) It experiences force as well as torque and has translatory and rotational motion

Answers (Electric Charges and Fields very short answers)

1) No. the positive charge of the body is due to deficit of electron while the negative charge is due to surplus of electrons. Hence the mass of negatively charged sphere will be slightly more than that of the positively charged sphere

2) During landing the tyres of aircrafts may get highly charged due to friction between tyres and the air strip. If the tyres are made slightly conducting they will lose the charge to the earth otherwise too much of static electricity accumulated may produce spark and result in fire.

3) The equation signifies that the electric charges are algebraically addictive and here q1 and q2 are equal and opposite.

4) Millikan's oil drop experiment for determining electronic charge.

5) The charge on anybody is always an integral multiple of e here ,

$$N = q/e = \frac{0.8\times10^{-19}\ C}{1.6\times10^{-19}\ C}$$

This is not an integer .so a body cannot have a charge of 0.8×10^{-19} C

6) The force between the two balls decrease because K(plastic) > 1 and F =1/K

7) Dielectric constant for water K = 80

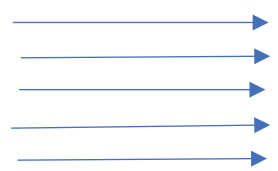
$$F_{WATER} = F_{AIR} / K = F/80$$

Thus the force in water is 1/80 times the original force in air .

8) This is because charges reside on the surface of a conductor and not inside it.

9) Electrostatic field lines start from positive charge and end on a negative charge or they fade out at infinity in case of isolated charges without forming any closed loop.

10) The lines of force of a uniform electric field are equidistant parallel lines



Answers (short answer questions)

1) For any metal ,K=∞

   $F_{brass} = f_{vac} / K = F/\infty = 0$

   i ,e in the presence of brass rod the force between the two charges becomes zero

2) As the two dipoles have equal dipoles moments so

   (i) qa = Qa' = a'/a = q/Q

   (ii) their dipoles axes must have same direction.

3) Change -Q is induced on the inner surface and charge +Q is induced on the surface of the cavity .

   Therefore surface charge density on the inner surface = $-Q/4\pi R^2$

   Surface charge density on the outer surface = $Q/4\pi R^2$

4) Net force on the charge Q/2placed at the center of the shell is zero .

   Force on the charge 2Q kept at point A at distance r from the center is

$$F = E \times 2Q = \frac{1}{4\pi\varepsilon_0}\frac{(+Q/2+Q)2Q}{R^2}$$

ii) electric flux through the shell ,

$$\Phi_E = \frac{Q/2}{\varepsilon_0} = Q/2\varepsilon_0$$

5) Electric charge of a body is quantized. This means that only integral (1, 2, ..., n) number of electrons can be transferred from one body to the other. Charges are not transferred in fraction. Hence, a body possesses total charge only in integral multiples of electric charge

6) In macroscopic or large-scale charges, the charges used are huge as compared to the magnitude of electric charge. Hence, quantization of electric charge is of no use on macroscopic scale. Therefore, it is ignored and it is considered that electric charge is continuous.

7) When two bodies are rubbed with each other transfer of charge takes place. One body receives charge and other loses, becoming negatively and positively charged respectively. In the whole process no new charge is created or destroyed. This implies that in an isolated system the total charge is always conserved.

8) The charges of equal magnitude and same sign are at the corners of same diagonal. So they will exhibit equal and opposite forces at the charge situated at center, cancelling out each other. So, the force is zero Newton.

9) Total charge of electric dipole = zero coulomb

   Magnitude of Dipole moment,

$|p|$ = (Magnitude of either charge) × (Distance between 2 charges) = $q.2a$

Given, $2a$ = 30 cm, $q = 2.5 \times 10^{-7}$ C

$= (2.5 \times 10^{-7}) \times (30)$

$= 7.5 \times 10^{-8}$ C-m

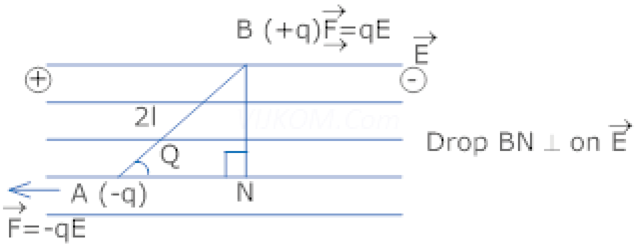
10) **(a)** The direction of electric field is given by tangent at each point on the curve. At sudden breaks, the field will have more than one direction which is not possible. That's why electrostatic field line is a continuous curve.

(b) At the crossing point there will be two directions of electric field at that point given by the two tangents. This cannot happen, and so two field lines never cross each other at any point

Answers (3 mark questions)

1) Electric dipole moment is defined as the product of the magnitude of either charge and the length of dipole. Its direction is from –ve to +ve charge.

$\vec{P} = q(\vec{2l})$ Its S.I. unit is coulomb meter (Cm)



Consider a dipole placed in uniform electric field and makes an angle (θ) with the electric field $(\vec{E})$ Since two forces acts on the charges constituting an electric dipole which are equal and opposite in direction, thus a torque acts on the dipole which makes the dipole rotate.

And Torque $\tau = Ethier\ force \times \perp distance$

Here force (F) = qE

$And\ \frac{BN}{AB} = \sin\theta \Rightarrow BN = AB \sin\theta = 2\ell \sin\theta$

$(\tau) = qE \times 2sin$

(τ) = PE Sin θ $(\because \vec{P} = q(\vec{2l}))$

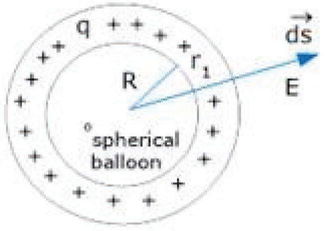
$\vec{\tau} = \vec{P} \times \vec{E}$

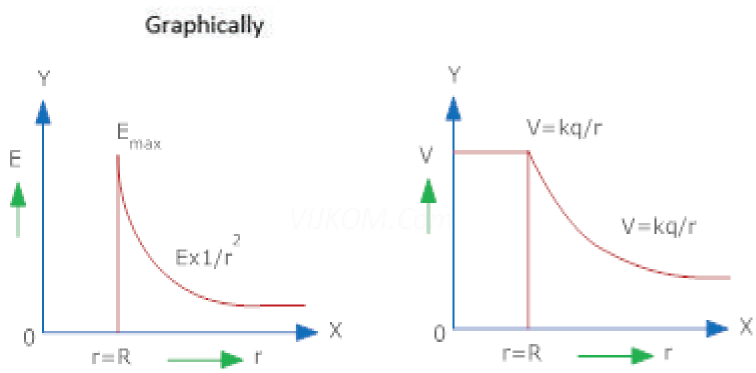
2) Electric field intensity on the surface of a shell

E = σ / ϵo& V = Kq/R

Inside E = o& V = Kq/R

Outside $E = \frac{\sigma}{\in o} \frac{R^2}{r^2}$ & V = Kq/r





3) Let P be the pt where test charge ($+q_o$) is present then electric field at pt. P will be zero if Field at pt. P due to +q = field at p+. P due to + 9q————1

$\Rightarrow E\vec{A} = \frac{K(+q)}{x^2} E\vec{B} = \frac{K(+9q)}{(10a-x)^2}$

Substituting in eq. 1

$\frac{K(+q)}{x^2} = \frac{K(+9q)}{(10a-x)^2}$

$(10a-x)^2 = 9x^2 \Rightarrow 10a - x = 3x$

$10a = 4x \Rightarrow x = \frac{10}{4}9$

$x = 2.5$ a from change (+q)

Or

10 a - x = 10a - 2.5a = 7.5 a from change (+9q)

4)(a) Electric field intensity, $\vec{E} = 3 \times 10^3 \text{ i} N/C$

Φ)

Magnitude of electric field intensity, $|\vec{E}| = 3 \times 10^3 N/C$

Side of the square, *s* = 10 cm = 0.1 m

Area of the square, $A = s^2 = 0.01 m2$

The plane of the square is parallel to the *y*-*z* plane. Hence, angle between the unit vector normal to the plane and electric field, $\theta = 0°$

Flux (through the plane is given by the relation,

$\Phi = |\overline{E}| A \cos\theta$

$= 3\times 10^{3} \times 0.01 \times cos 0°$

$= 30\ N\ m^{2} / C$

(b) Plane makes an angle of 60° with the *x*-axis. Hence, $\theta = 60°$

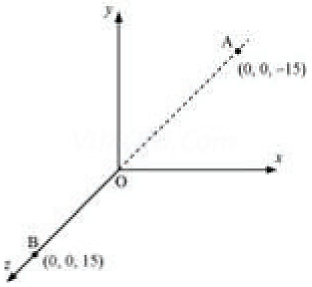
Flux, $\Phi = |\overline{E}| A \cos\theta$

$= 3 \times 10^{3} \times 0.01 \times cos 60°$

$= 30 \times \frac{1}{2}$

$= 15\ N\ m^{2} / C$

5) The both the charges can be located in a coordinate frame of reference as shown in the given figure.



At A, amount of charge, $q_A = 2.5 \times 10^{-7} C$

At B, amount of charge, $q_B = -2.5 \times 10^{-7}\ C$

Total charge of the system,

$q = q_A + q_B$

$= 2.510^{7}\ C - 2.510^{-7}\ C = 0$

Distance between two charges at points A and B,

$d = 15 + 15 = 30\ cm = 0.3\ m$

Electric dipole moment of the system is given by,

$p = q_A \times d = q_B \times d$

$= 2.5\times 10^{-7} \times 0.3$

$= 7.5\times 10^{-8}\ Cm$ along positive *z*-axis

Therefore, the electric dipole moment of the system is $7.5\times 10^{-8} C$ m along positive *z*-axis.. Therefore, the net charge on the sphere is 6.67 nC.

6)

1. Charge on inner surface : – Q
2. Charge on outer surface : + Q
3. Electric field at point P1 (E) = (1/4πε0)Q/r²1

$(i)\ W = \int_{\theta_1}^{\theta_2} \tau\, d\theta \quad \Rightarrow \int_{0}^{\pi} pE\sin\theta\, d\theta$

$\Rightarrow pE[-\cos\theta]_0^{\pi} \quad \Rightarrow pE[\cos\pi - \cos 0]$

$\Rightarrow pE[(-1) - (1)]\ . \quad \Rightarrow \mathbf{-2pE}$

(ii) τ = p→ ×E→ = pE sin θ

For θ = π/2, sin θ = 1 and τ is maximum

7) Electric field at a point outside the shell :
(a) (i) To find out electric field at a point outside a spherical charged shell we imagine a symmetrical Gaussian surface in such a way that the point lies on it.

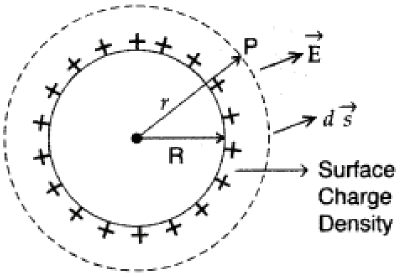
From Gauss's theorem, $\phi = \oint_S \vec{E}.d\vec{S} = \frac{q_m}{\varepsilon_0}$

Flux ϕ through S′

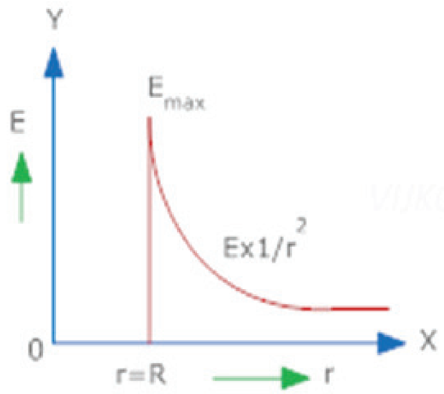
$$\phi = \oint_{S'} \vec{E}.d\vec{S} = \oint_{S'} EdS = E.4\pi r^2$$

$$\Rightarrow E.4\pi r^2 = \frac{q_m}{\varepsilon_0}$$

$$\Rightarrow E = \frac{1}{4\pi\varepsilon_0}.\frac{q_m}{r^2}$$



Graph of electric field E(r) :



8)

(i) **Magnitude,**

$$|\vec{E}_{AB}| = \frac{1}{4\pi\epsilon_0}\frac{q}{a^2} = E$$

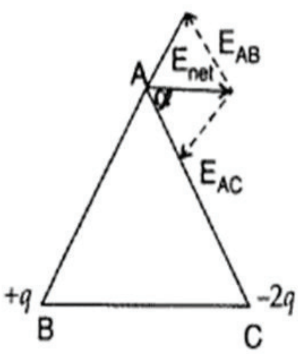
$$|\vec{E}_{AC}| = \frac{1}{4\pi\epsilon_0}\frac{2q}{a^2} = 2E$$

$$E_{net} = \sqrt{(2E)^2 + E^2 + 2\times 2E\times E\times\left(-\frac{1}{2}\right)}$$

$$\left[\because \cos 120° = -\frac{1}{2}\right.$$

$$= \sqrt{4E^2 + E^2 - 2E^2}$$

$$= \sqrt{3E^2} = E\sqrt{3} = \frac{1}{4\pi\epsilon_0}\frac{q\sqrt{3}}{a^2}$$



(*ii*) **Direction** of resultant electric field at vertex A,

$$\tan\alpha = \frac{E_{AB}\sin 120°}{E_{AC}+E_{AB}\cos 120°}$$

$$= \frac{E\times\frac{\sqrt{3}}{2}}{2E+E\times\left(\frac{-1}{2}\right)} = \frac{\frac{E\times\sqrt{3}}{2}}{\frac{3E}{2}} = \frac{\sqrt{3}}{3}$$

$$= \frac{1}{\sqrt{3}} = \tan 30°$$

$\therefore$ $\alpha = 30°$ **(with side AC)**

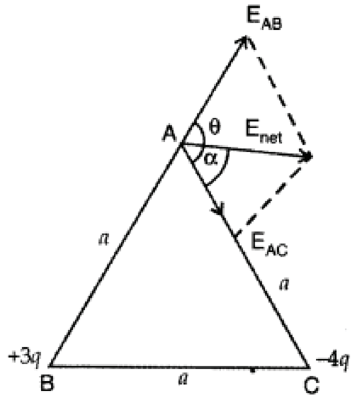
9) (*i*) **Magnitude,**

$$|\vec{E}_{AB}| = \frac{1}{4\pi\epsilon_0}\frac{3q}{a^2} = 3E, \quad \textbf{where} \left[E = \frac{1}{4\pi\epsilon_0}\frac{q}{a^2}\right]$$

$$|\vec{E}_{AC}| = \frac{1}{4\pi\epsilon_0}\frac{4q}{a^2} = 4E$$

$$E_{net} = \sqrt{(3E)^2+(4E)^2+2(3E)\times(4E)\times\left(-\frac{1}{2}\right)}$$

$$\left\{\because \theta = 120°, \ \cos\theta = -\frac{1}{2}\right\}$$



$$= \sqrt{9E^2+16E^2-12E^2}$$

$$= \sqrt{13E^2} = E\sqrt{13} = \frac{1}{4\pi\epsilon_0}\frac{q\sqrt{13}}{a^2}$$

(*ii*) **Direction,**

$$\tan\alpha = \frac{|E_{AB}|\sin 120°}{|E_{AC}|+|E_{AB}|\cos 120°} = \frac{3E\times\frac{\sqrt{3}}{2}}{4E+3E\times-\left(\frac{1}{2}\right)}$$

$$\tan\alpha = \frac{3E\sqrt{3}\times 2}{2\times 5E} = \frac{3\sqrt{3}}{5} \quad \therefore \alpha = \tan^{-1}\left(\frac{3\sqrt{3}}{5}\right)$$

10) When two charged spherical conductors of Radii R_1 and R_2 respectively ($R_2 > R_1$) are connected by a conducting wire, we know that the common potential (V) is given by,

$$V = \frac{q_1}{c_1} = \frac{q_2}{c_2}$$

$\because$ C for a spherical conductor, $C = 4\pi\epsilon_0 R$,

We have, $\frac{q_1}{4\pi\varepsilon_0 R_1} = \frac{q_2}{4\pi\varepsilon_0 R_1} \Rightarrow \frac{q_1}{R_1} = \frac{q_2}{R_2}$

$$\Rightarrow \frac{q_1}{q_2} = \frac{R_1}{R_2}$$

$$\frac{\sigma_1}{\sigma_2} = \frac{q_1}{4\pi\varepsilon_0 R_1^2} \times \frac{4\pi\varepsilon_0 R_2^2}{q_2} \quad \because \sigma = \frac{q}{4\pi\varepsilon_0 R^2}$$

$$= \frac{q_1}{q_2} \times \frac{R_2^2}{R_1^2} = \frac{R_1}{R_2} \times \frac{R_2^2}{R_1^2} = \frac{R_2}{R_1}$$

$$\therefore \frac{\sigma_1}{\sigma_2} = \frac{R_2}{R_1}$$

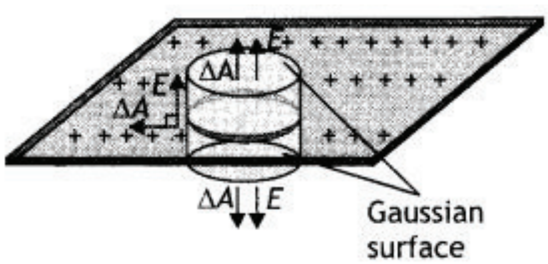
ANSWERS OF LONG ANSWER QUESTIONS

1. It states, "The net electric flux through any Gaussian surface is equal to 1ε0 times the net electric charge enclosed by the surface.

Mathematically, $\Phi = \int \vec{E}.\overrightarrow{dS} = q/\varepsilon_0$

Consider an infinite plane sheet of charge. Let a be the uniform surface charge density, i.e. the charge per unit surface area. From symmetry, we find that the electric field must be perpendicular to the plane of the sheet and that the direction of E on one side of the plane must be opposite to its direction on the other side as shown in the figure below. In such a case let us choose a Gaussian surface in the form of a cylinder with its axis perpendicular to the sheet of charge, with ends of area A.

The charged sheet passes through the middle of the cylinder's length so that the cylinder's ends are equidistant from the sheet. The electric field has a normal component at each end of the cylinder and no normal component along the curved surface of the cylinder. As a result, the electric flux is linked with only the ends and not the curved surface.



Therefore by the definition of electric flux, the flux Linked with the Gaussian surface is given by

$\Phi = \oint_A \vec{E} \cdot \Delta\vec{A}$

$\Phi = E_A + E_A = 2E_A$ … (1)

But by Gauss's Law

$\Phi = q/\varepsilon_0 = \sigma A/\varepsilon_0$ [$\because q = \sigma A$] … (2)

From equations (1) and (2), we have

$2E_A = \sigma A/\varepsilon 0$ … (3)

$E = \sigma/2\varepsilon 0$ …. (4)

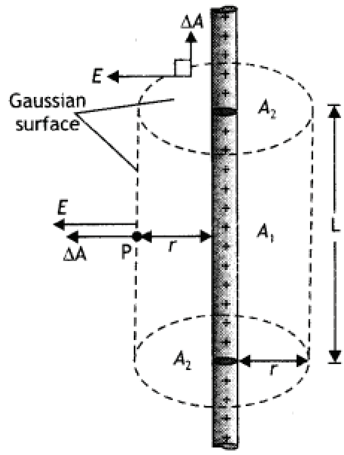
This gives the electric field due to an infinite plane sheet of charge which is independent of the distance from the sheet.

(b) (i) directed outwards

(ii) directed inwards.

2.

Consider an infinitely Long, thin wire charged positively and having uniform Linear charge density λ. The symmetry of the charge distribution shows that must be perpendicular to the tine charge and directed outwards. As a result of this symmetry, we consider a Gaussian surface in the form of a cylinder with arbitrary radius r and arbitrary Length L. with its ends perpendicular to the wire as shown in the figure. Applying Gauss's theorem to curved surface ΔA_1 and circular surface ΔA_2.



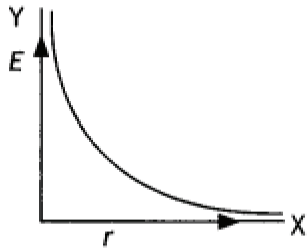
$\Phi\ E\Delta A_1 \cos 0° + E\Delta A_2 \cos 90° = q\varepsilon_0 = \lambda l\varepsilon_0$ [∵ λ = q/l]

Or

$E \cdot 2\pi rl = \lambda l\varepsilon 0 \Rightarrow E = 1/2\pi\varepsilon 0\lambda r$

This is the expression for the electric field due to an infinitely long thin wire.

The graph is as shown.



3.Electric Flux is the dot product of the electric field and area vector.

$\Phi = \oint \vec{E} \cdot \vec{ds}$

SI Unit: Nm^2/C or Vm

For a given case

$\Phi = \Phi_1 - \Phi_2 = [Ex(atx= 2a) - Ex\ (atx = a)]a^2$

$= [\alpha(2a)-\alpha(a)]a^2 = \alpha a^3$

$= 10^4 \times (0.1\ )^3 = 10\ Nm^2/C$

But

$\Phi = q\varepsilon_0$

$\therefore q = \varepsilon_0\Phi = 8.854 \times 10^{-12} \times 10\ C = 8.54\ pC$

Answers-MCQ

1.Ans (a) Given $Q_2 = Q_3 = Q$;

Net force on $Q_3 = -KQ^2/x^2 + KQ_1Q/4x^2 = 0$

$Q_1 = 4Q$; $Q_1 = 4Q_3$

2.Ans (d) K for metals is infinity. $F_m = F_0/K = 0$

3.Ans (a) When -2μC is given to +7μC and -5μC they become +5C and -7μC. Force remains same

4. Ans (c)

5. Ans (c) $F = Kq^2/d^2$; q = ne ; $F = Kn^2e^2/d2$; $n = \sqrt{\frac{4\pi\epsilon_0 F d^2}{e^2}}$

6. Ans (c) qE = 1.6 x 10-19 $E = \sigma/\varepsilon 0$; $Q = \sigma A$; Q = -44.27μC

7 (d) 8. (b) 9. (a) 10. .(a)

Case Study ANSWERS

1. (i). (c) both electric and magnetic effects

(ii). (b) conductor, insulator

(iii). (c) increase or decrease

(iv). (a) decreases directly as the distance from the centre

(v). (d) Coulomb's law

2. (i). (c) Conservation of charges

(ii). (d) all the distances

(iii). (d) radial, outwards

(iv). (a) outwards

(v). (d) All of the above

3. (i). (d) can pass through a continuous charge distribution as well as any system of discrete charges.

(ii). (a) any closed surface

(iii). (a) zero

(iv). (d) directly proportional to E

(v). (a) I and II

4 Electric charge

(i) a (ii) b (iii) c (iv) b (v) b

5.Electric dipole

(i)c (ii) d (iii) d (iv) a (v) c