Explore the World with a New Vision....

G.C.E. ADVANCED LEVEL EXAMINATION

PHYSICS

Unit - 06
Part - I

Electric Field

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Types of electric charges

In the past, man observed that certain objects have the ability to attract certain small objects when they were taken apart after rubbing against each other. This ability was given to objects because they were "charged". Furthermore, objects that have been rubbed were described as being charged oppositely because they did not show the above capability when they were brought back together. These opposite charges are named as (+) and (-).

Standard (+) charge

The charge on a glass rod rubbed with a silk cloth and its like charges were named as (+).

Standard (–) charge

The charge on an ebonite rod rubbed with a wool cloth and its like charges were named as (–).

Electrostatic charges

Electric charges which are not moving (not flowing) are known as electrostatic charges. Under electric fields, we study the electrical results of such charges.

Charged bodies

If the amount of positive charge on an object is greater than the amount of negative charge on that object, it’s known as a positively charged object.

If the amount of negative charge on an object is greater than the amount of negative charge on that object, it's known as a negatively charged object.

If the amount of positive and negative charge on an object is equal, it’s known as an electrically neutral object.

Quantity of charges and it's units

Coulomb (C) is the SI unit measuring the charge.

The smallest amount of charge that has been experimentally discovered so far is -1.6×10^{-19}C, which is known as the charge of an electron (e).

$$e = -1.6\times10^{-19}\text{C}$$

If Q is any other amount of charge, it's made up of a whole number multiplication of the charge of an electron.

$$\boxed{Q = \pm n\,|e|} \qquad n = 1, 2, 3 \,..... \qquad \{|e| \text{ - magnitude of the charge of an electron}\}$$

Electric field

The region where a force can be applied to a charge is known as an electric field. There is such an area around any charge (Electric fields also occur in association with changing magnetic fields).

- To examine whether an electric field exists at a certain point, we must place a small charge at the point and test whether an electrical force acts on it.
- Homogeneous charges have an electric repulsive force and a heterogeneous charges have an electric attractive forces.

Electric field intensity - (E)

The electric field intensity at a certain point of an electric field is the electric force acting on a charge + 1C.
This is a vector quantity.

If the electric force acting on a charge Q is F,

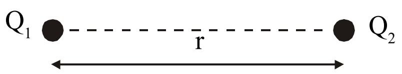
$$Q \longrightarrow F$$

$$1 \longrightarrow \frac{F}{Q} = E \Rightarrow \boxed{F = EQ} \quad ; \text{ Units of E: } NC^{-1} / Vm^{-1}$$

- The force on the (+) charges is in the direction of E and the force on the (-) charges is in the opposite direction to E.

Coulomb's law

"The electrical force acting between two point charges is directly proportional to the product of magnitudes of their charges and inversely proportional to the square of the distance between them."

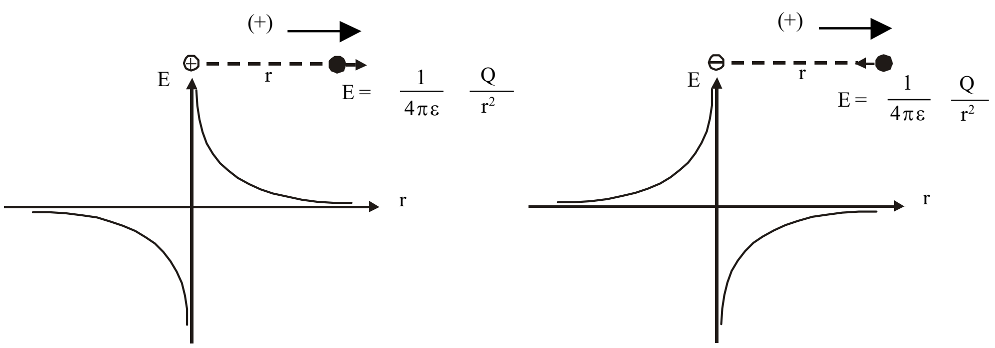


$$\left.\begin{array}{l} F \propto Q_1 Q_2 \\ F \propto \dfrac{1}{r^2} \end{array}\right\} \quad F \propto \frac{Q_1 Q_2}{r^2} \Rightarrow \boxed{F = \frac{1}{4\pi\varepsilon}\frac{Q_1 Q_2}{r^2}}$$

- Proportionality constant "ε" is a constant that depends on the electrical properties of the medium in which charges were kept, and it is called permittivity.
- Vacuum permittivity $\varepsilon_0 = 8.85 \times 10^{-12}\ C^2\ N^{-1}\ m^{-2}$
- $\dfrac{1}{4\pi\varepsilon_0} \approx 9 \times 10^9\ Nm^2\ C^{-2}$
- Relative permittivity (ε_r) (dielectric constant - k) $= \dfrac{\text{Permittivity of the medium } (\varepsilon)}{\text{Vaccum permittivity } (\varepsilon_0)}$

$$\varepsilon = \varepsilon_0\ \varepsilon_r$$

Variation of the electric field intensity around a point charge



Resultant electric field intensity

In a region containing multiple charges, we can find the resultant electric field intensity at a point by obtaining the vector addition of the individual field intensities caused at the point by the charges, separately.

Neutral points

Points at which the resultant electrical field intensity is zero are called neutral points. There will be no electric force acting on charges kept at these points.

Electric field lines

Electric field lines are a concept developed to understand the invisible electric field better. According to this concept, the electric field is considered to be full of electric field lines.

An electric field line is a hypothetical line drawn at a certain point where the direction of the tangent is the same as the direction of the electric field intensity at that point.

- In addition to the fact that the electric field lines represent the direction of the field intensity at any point, the gap between the electric field lines gives an idea of the magnitude of the field intensity at the relevant point. At a place where the field intensity is strong, the gap between the field lines decreases and at a place where field intensity is weak, the gap between the field lines increases.
- The concept of field lines was introduced by Michael Faraday. Although he called these ' lines of forces', the name 'field lines' is more appropriate.

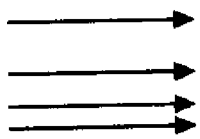
Characteristics of electric field lines

There are two ways in which electric fields can be caused.

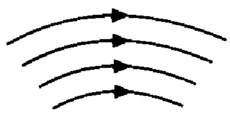
1. By charges 2. By changing magnetic fields

- Field lines representing the electric fields caused by the charges, travel away from the positive charges and also towards the negative charges. (This feature does not apply to field lines that represent electric fields generated by changing magnetic fields.)
- Field lines representing the electric fields caused by charges begin with positive charges and end with negative charges. (This feature does not apply to field lines that represent electric fields generated by changing magnetic fields.)
- Field lines representing electric fields caused by charges cannot form closed loops. This is because a field line that starts with a certain charge cannot end with that same charge. (Field lines representing electric fields caused by changing magnetic fields can form closed loops.)
- The direction of the field intensity at a certain point is obtained from the direction of the tangent of the field line at that point.
- Electric field lines never intersect each other.
- Electric field lines do not pass through neutral points.
- Electric field lines are perpendicular to equipotential surfaces.
- Field lines do not exist in the conductive matter under electrostatic conditions. For such a conductor, the field lines start or end at its surface , perpendicularly to the surface.
- The quantity of field lines associated with a charge is proportional to the magnitude of that charge.

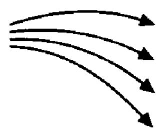
1. A field where magnitude is not a constant (Direction is a constant)



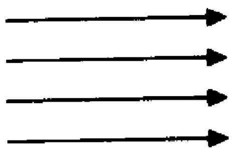
2. A field where direction is not a constant (Magnitude is a constant)



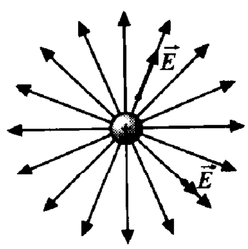
3. A field where magnitude and direction both are not constants



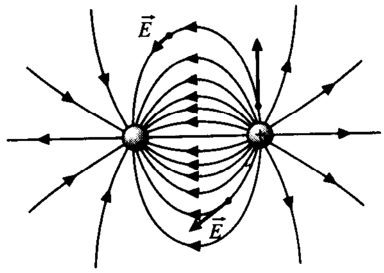
4. A field where magnitude and direction both are constants



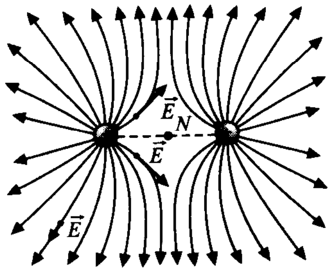
5. A positive point charge



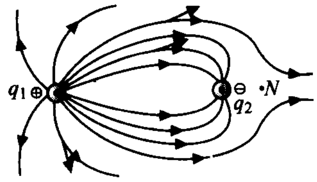
6. Two heterogeneous point charges of equal magnitudes



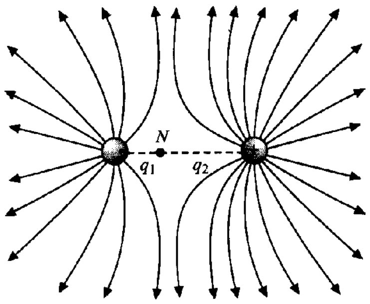
7. Two positive point charges of equal magnitudes



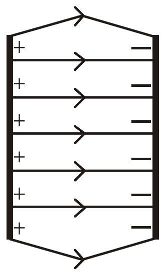
8. A Large positive charge and a small negative charge



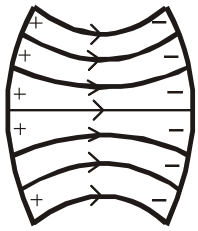
9. Two point charges of different magnitudes



10. Two heterogeneously charged parallel planar conductor plates

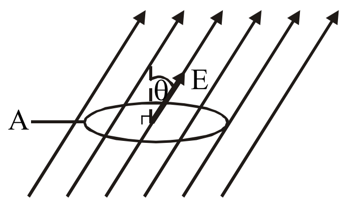


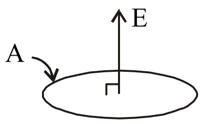
11. Two heterogeneously charged curved conductor plates



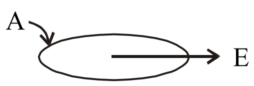
Electric flux

The electric flux across a given area is defined as the product of the area and the field intensity component perpendicular to the area.



- 

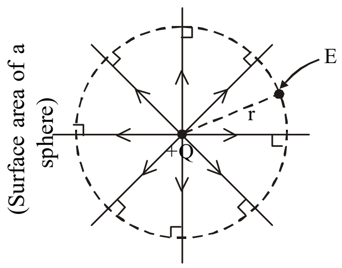
$\phi = A \times E$



$\phi = 0$

$\phi = A \times E \cos\theta$

Electric flux associated with a charge



By Coulomb's law,

$$E = \frac{1}{4\pi\varepsilon}\frac{Q}{r^2}$$

$$E \times 4\pi r^2 = Q/\varepsilon \;----(1)$$

If the product of the area and the field intensity component perpendicular to that area is called as the electric flux, then $E \times 4\pi r^2$ represents a certain electric flux. Furthermore it must be the total electric flux (ϕ). released by the Q charge.

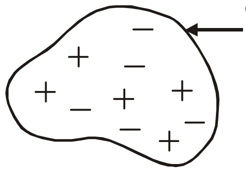
Then, $\phi = Q/\varepsilon$

- This shows that if the electric flux across a certain area is given by the product of that area and the field intensity component perpendicular to that area, then the electric flux associated with a charge Q is Q/ε.

Gauss's theorem

" If the net charge in a closed surface (Gaussian surface) of any shape selected in an electric field is Q, then the effective electric flux across that surface is Q / ε."

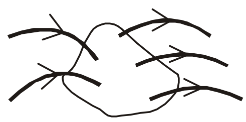
If the net charge in the Gaussian surface is Q,



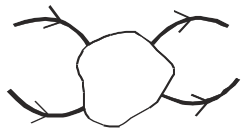
$$\phi = Q / \varepsilon$$

- A Gaussian surface is not something that truly exists. It's a hypothetical surface.
- Depending on whether the charge is (+) or (–), the flux is either (+) or (–). (+) flux moves away from the considered surface and the (–) flux is towards the surface.
- The nature of an object can be determined by considering the field line distribution near that object.

E.g : i. - A non-conductive object because it has field lines internally.
- An object with net (+) charge because the effective field lines move outwardly.



ii. - A conductive object because there are no field lines internally.
- An object that does not have net charge because it does not have effective field lines.



Finding the field intensity around charge distributions by using Gauss's theorem

It's easier to find field intensity at a certain point using the Gauss's theorem instead of finding field intensities by the Coulomb's theorem. But for that, there must be symmetrical features in the relevant charge distribution.

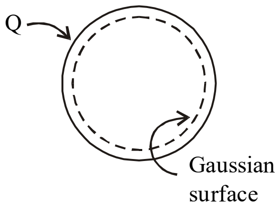
1. Identify the charge distribution.
   - Can be linear, surface or solid (volume).
   - No excess charge is present in the material of a conductor under electrostatic conditions. They are on the surface.
2. Identify the field line distribution.
   - Understand the symmetrical, three-dimensional nature.
   - Field lines do not exist in a conductive matter under electrostatic conditions. They are perpendicular to their surface.
3. Select the Gaussian surface.
   - The point where the field intensity is sought must be on this surface.
   - Field lines must be perpendicular to the surface at the point where the field intensity is sought.
   - Must be closed.

4. Find the net charge (Q) in the Gaussian surface.

5. Use $E \times A = Q/\varepsilon$
   - A is the area perpendicular to the field lines of the Gaussian surface.
   - Q is the net charge in the Gaussian surface.

- Charges that are kept so far away from the earth as to cause no change in the field line distribution due to the earth are known as "isolated" charges.

Showing the absence of excess charges inside a conducting material with electrostatic conditions



The excess charge applied to a conductive object is present in the conductor at the beginning but then they spread rapidly to positions where the field intensity is zero, as they obtain "electrostatic stability". Thus there are movable charges in a conductor that can change position instantly.

Consider a Gaussian surface covering an entire conductor , that is positioned inside the conductive surface by an infinitesimal value.

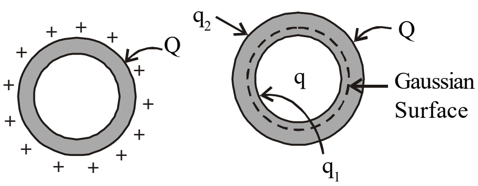
$$E \times A = Q/\varepsilon$$

Since E = 0 in the conductor, $0 \times A = Q/\varepsilon$

$$\therefore Q = 0$$

There is no excess charge in the conductor. They spread to their outer surface.

Finding an unknown charge distribution



(Figure 1) (Figure 2)

As shown in Figure 1, all excess charge applied to a hollow conductor distribute only on its outer surface. But as shown in Figure 2, if a certain charge is retained in the cavity and charges are applied to the conductor, they will split between the inner surface and the outer surface. Let's find out what are the amounts of charge thus divided

Consider a Gaussian surface in the conductive medium as the type shown in the figure, that covers the entire cavity,

$E \times A = Q/\varepsilon$ E = 0 in the conductor,

$$0 \times A = \frac{q_1 + q_2}{q}$$

$q_1 = -q$ Since

$$q_1 + q_2 = Q$$
$$-q + q_2 = Q$$
$$q_2 = Q + q$$

Exercises

$$\varepsilon_0 = 8.85 \times 10^{-12}\ C^2\ N^{-1}\ m^{-2}, \quad \frac{1}{4\pi\varepsilon_0} = 9 \times 10^9\ N\ m^2\ C^{-2},\ e = 1.6 \times 10^{-19}\ C,\ m_e = 9.1 \times 10^{-31}\ kg$$

01. Calculate the number of electrons contained in a neutral silver ($^{107}_{47}Ag$) nail with a mass of 10g. If electrons were added to that silver nail until it gets a total charge of – 1 mC, how much electrons have been added for each 10^9 electrons in the neutral nail? ($N_A = 6.022\times10^{23}\ mol^{-1}$)

02. A sphere of mass 5 g has hung by a thread of length 2 m. The sphere was displaced by 2 cm horizontally when a horizontal field 0.5 NC^{-1} was established near that sphere. Find the charge of the sphere.

03. Consider that a mass of 1.00g of hydrogen was separated into electrons and protons, and all those protons were placed on north pole while all those electrons were placed on south pole. Find the compressive force applied on the earth by this. Gram atomic weight of hydrogen is 1.00 in grams. The Avogadro constant is 6.022×10^{23} and the radius of the earth is 6400 km.

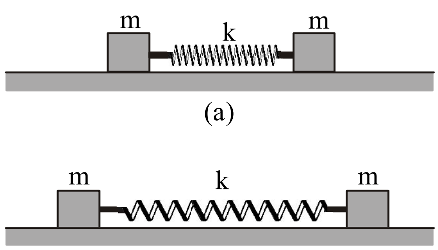
04. Show that the gravitational force produced between two electrons can be neglected when compared to electric repulsive force between them.

05. Two small equivalent water drops contain an extra electron each while the electric repulsive force between them is balanced by the gravitational force between them. Find the radius of a sphere if the density of water is 1000 kg m^{-3}.

06. Assuming that the electron contained in the hydrogen atom is going on a circular path around its' nucleus, determine its' speed. The radius of the circle is 0.5×10^{-10} m.

07. Two small identical metal spheres are placed with a 0.300 m distance between their centers of gravity. Then a charge of +12.0 nC is given to one sphere while a charge of – 18.0 nC is given to the other.
    - i. Find the electric force between the two spheres.
    - ii. The two spheres were connected by a very thin conductive wire. Find the electric force between them after they reach to equilibrium.
    - iii. Would the real electric forces be less than or greater than to the values calculated in (i) and (ii)?

08. Two identical metal cubes have been kept on a smooth horizontal plane with a light metal spring of spring constant k connecting them as shown in the diagram. Its' length is L_1 when it is in the natural length as shown in the diagram (a). Now the spring again comes to the equilibrium at a length of L_2 when a charge of Q is given to the system. Find the value of Q.

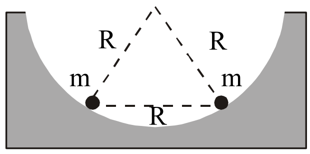


09. Two charges of +5μC and –5μC have been kept 8 cm apart from each other. A charge of +5μC is kept 3 cm away on the perpendicular bisector of the line which connects the two charges. Find the resultant force acting on this third charge.

10. Two small identical spheres with equal charges were hung at the same point by the ends of two threads of similar lengths. What should be the density of the sphere material for the two spheres to repel each other by the same distance in air, as well as in kerosene of density 0.8 gcm^{-3}? Relative permittivity if kerosene is 2.

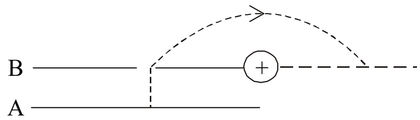
11. When two small identical metal spheres of the same charges attached to the ends of two long threads of similar lengths were hung from single point, they came to equilibrium with a distance of 5 cm between them. Describe the situation if one sphere discharges its' total charge instantaneously. Find the distance at which they come to equilibrium afterwards.

12. A smooth hemispherical hole of radius R made in a cube is shown in the diagram. If two identical spheres of mass m each which contain equal charges are at equilibrium as shown in the diagram, find the charge of one sphere?

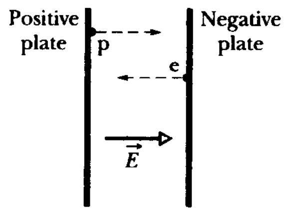


13. Two stationary particles with equivalent charges are released from rest keeping a 3.2×10^{-3} m distance between them. The initial acceleration of the first particle is 7 ms^{-2} while its' mass is 6.3×10^{-7} kg. If the initial acceleration of the second particle is 9 ms^{-2}, find the mass of the second particle and the common charge of those two particles.

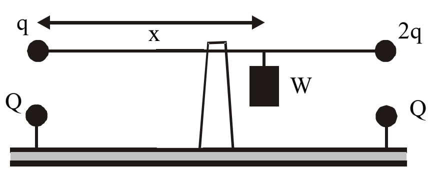
14. A uniform electric field of 12×10^{-4} NC^{-1} is applied vertically downwards between two plates A and B with a distance of 6mm between them. An electron released by the plate A exits through the hole in the plate B and moves along a circular path with the radius 1 cm. There is a nucleus of atomic number of 100 at the center of the circle. Calculate the charge of the electron.



15. There is a uniform electric field between two parallel copper plates which is kept 5 cm apart as shown in the diagram. An electron from the negatively charged plate is released at the same time when a proton is released from the positively charged plate. Neglect the electric force between the electron and the proton. Find the distance where the electron and the proton pass each other measured from the positively charged plate, considering that the mass of the proton is 1836 times that of the electron.



16. The diagram shows how a light, uniform rod with the length of L is pivoted at its' midpoint. A weight of W is hung at a distance x from the left end. Two light particles with charges of q and 2q are kept on the left and right ends of the rod respectively. There are two small spheres just below the above two particles, Q charge each. The vertical height between a sphere and a particle is h while the rod is horizontal. What should be the value of x to keep the rod at equilibrium horizontally? What should be the value of h for there to be no vertical reaction at the point of pivioting? (h << L)



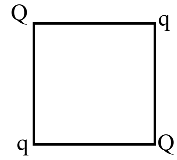
17. Three charges of +Q, – Q and +q are placed on the vertices of an equilateral triangle of side length of a. Find the force acting on q.

18. Equal charges of charge q each are placed on the vertices of an equilateral triangle. Find where we should place another charge and the amount of its' charge to make the resultant force acting upon every charge to be zero.

19. Four equal charges of charge q each have been placed on the vertices of a square. Find where we should place another charge and the amount of its' charge to maintain the system at equilibrium. Is that equilibrium stable?

20. Three equal, small spheres with the same mass of 10g each are charged equally and hung to the same point by 3 threads of length 1m each. If those spheres reach equilibrium such that each sphere lies on a vertex of an equilateral triangle, find the charge of a sphere.

21. Build up the relationships that should be satisfied for the resultant force acting on each Q charge on the square shown in the diagram to be zero.

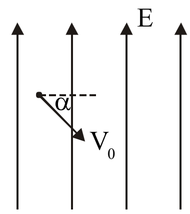


22. Two small objects with masses m and M have charges of – q and + Q respectively. What is the distance that should be maintained between the two masses for them to accelerate keeping a constant distance between them when a uniform electric field is applied parallelly to the line which connects the two masses (Neglect gravitational forces)?

23. A + Q charge has been placed at the midpoint of each side of a square with the side length 2a. Find the resultant electric field intensity at a point situated r distance from the center on the line through the center perpendicular to the plane of the square.

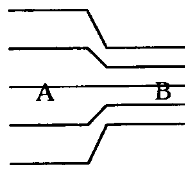
24. A circularly bent wire with the radius of r is uniformly charged to get the linear density of σ. Find the magnitude of field intensity and its' direction at the center of the circularly bent wire and at a point situated d distance away from the center on the axis of the wire.

25. A proton (charge e) is projected with a velocity of V_0 at an angle α downward from the horizontal into an electric field of field intensity E acting vertically upwards. Consider the mass of a proton as m.



   i. Find the maximum distance (h_{max}) that is travelled by the proton vertically downwards.
   ii. What is the horizontal displacement (d) made by the proton when it reaches to the initial level again?
   iii. Plot the path of the proton on a graph.
   iv. Find the values for h_{max} and d when $E = 500\ NC^{-1}$, $V_0 = 4 \times 10^5\ ms^{-1}$ and $\alpha = 30^0$. ($m = 1.67 \times 10^{-27}$ kg)

26. The distance between subsequent force lines of the electric field on the left side is twice than that on the right side as seen in the diagram. If the magnitude of the electric field at A is 40 NC^{-1}, how much is the electro static force acting on an electron placed at B?



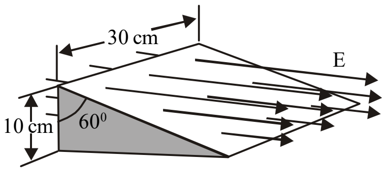
27. You were supplied with 4-point charges of +2q, +q, – q and – 2q. If we can select Gaussian surfaces such that the net flux (i) 0 (ii) $+3q/\varepsilon_0$ (iii) $-2q/\varepsilon_0$, describe how to do so. There should be at least the + 2q charge inside each surface.

28. There is an electric field with the strength of $7.80 \times 10^4 NC^{-1}$ acting horizontally across a neutral object as shown in the diagram.

i. Find the electric flux across the rectangular vertical surface of the object.

ii. Find the electric flux across the inclined rectangular surface of the object.

iii. Find the net flux across the object.



29. There is a vertical electric field with the strength of 52 NC^{-1} near a pyramid of 4m height which has a square shaped horizontal base of side length of 6m. Find the electric flux across the four inclined surfaces of the pyramid. Consider the pyramid as chargeless object.

30. A region in space in the shape of a spherical shell with the internal radius a and the external radius b is uniformly charged with the charge density σ. Considering the charges as negative,

(i) $r < a$ (ii) $a < r < b$ (iii) $r > b$

Find magnitudes and directions of the field intensity at points situated r distance away from the center of the shell for above instances.

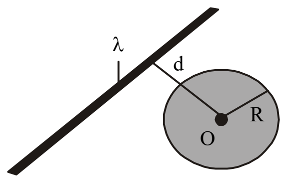
31. There is a uniform distribution of charges with density σ very long cylindrical shell with shaped region in space, internal radius a and external radius b.

(i) $r < a$ (ii) $a < r < b$ (iii) $r > b$

Find the field intensity of points situated r distance measured away from the axis of the shell for above instances.

32. There is a spherical surface with radius R near a thin, straight, conductive, charged rod of infinite length having a linear density of λ as shown in the figure. Find the net flux across the spherical surface for, the following instances.

(i) $R < d$ (ii) $R > d$



33. Find the field intensity on the surface of a $^{208}_{82}Pb$ nucleus. Consider the volume of the $^{208}_{82}Pb$ nucleus is 216 times the volume of a proton. Consider that a proton is spherical and its' radius is 1.20×10^{-15} m.

34. Two metal cylindrical shells with infinite length having radii of 3.0 cm and 6.0 cm are kept co-axially. The charge per unit length of internal cylinder is $+ 5.0 \times 10^{-6} Cm^{-1}$ and that value of external cylinder is $- 7.0 \times 10^{-6} Cm^{-1}$. Find the electric field intensities at,

(i) A point 4.0cm away from the axis,

(ii) A point 8.0cm away from the axis.

35. A thin, spherical metal shell with radius 'a' has a charge of $+q_1$ and another thin spherical metal shell with radius **b** having a charge of $+q_2$ are kept concentrically ($b > a$) . If the distance measured from the common center of two spheres is r, find the field intensity and the distribution of charges between the inner and outer surfaces of each shell using the Gauss theorem for the following instances.

(i) $r < a$ (ii) $a < r < b$ (iii) $r > b$

36. Two infinitely large, thin metal plates kept parallelly to each other are charged so as to get charge densities of $+\sigma$ and $-\sigma$. Find the magnitude of the field intensity at a point between the metal plates. What is the magnitude of the field intensity at a point situated externally to two plates in above question?

37. A particle of mass 20 mg hung by a silk thread was given a 1nC charge and an infinitely large, charged vertical metal plate was brought near that particle. The thread was inclined an angle of 30^0 to the vertical at that time. How much is the surface charge density of the plate?

Afterwards, a large vertical, negatively charged, metal plate which has a similar surface charge density to the above plate is kept parallelly to the first plate with the particle locating in-between them. What is the inclination shown to the vertical by the thread?

If the negatively charged plate is kept between the first plate and the particle, parallelly to the first plate, what is the inclination of the thread to the vertical ?

38. A thin insulate rod with infinite length is uniformly charged as to have the linear density of 2×10^{-9} Cm^{-1}. The rod was placed along the axis of a long, neutral, hollow, conductive cylinder (internal radius = 5cm, external radius = 10cm). Find the field intensity 15 cm distance away from the axis of the cylinder and the surface charge density of internal and external surfaces of the cylinder.

39. An atom is created by a positive point charge of value Ze and a spherical negative charge distribution of –Ze, that is located centered around the positive point charge with radius R, according to a certain model. Here Z is the atomic number while e is the charge of an electron. Show that the electric field intensity (E) of a point situated r (<R) distance from the center of the atom is given by the following equation.

$$E = \frac{Ze}{4\pi\varepsilon_0}\left(\frac{1}{r^2} - \frac{r}{R^3}\right)$$

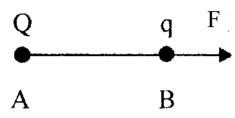
40. A q point charge is placed on a vertex of a cube with the side length of a. Find the electric flux travel across each surface of the cube. (Hint: Use the Gauss theorem and logic of symmetry)

MCQ

Time target : 20 minutes

01. Two point-charges placed 3m away from each other have values of +100C and -1C. What is the correct statement from the following,
1. There is no neutral point around charges.
2. There is a neutral point between the charges 1/3m distance away from the positive charge.
3. There is a neutral point between the charges 1/3m distance away from the negative charge.
4. There is a neutral point on the line connecting the two charges situated outwardly 1/3m distance away from the negative charge.
5. There is a neutral point on the line connecting the two charges situated outwardly 1/3m distance away from the positive charge.

02. The point charges of Q and q are placed on A and B respectively. If the electrostatic force upon q is F, the magnitude and the direction of the electric field at A are,



1. F/Q, to direction AB
2. F/Q, to direction BA
3. F/q, to direction AB
4. F/q, to direction BA
5. None of the above.

03. Five small spheres named as 1, 2, 3, 4, 5 are hung separately by threads. If the spheres pairs of (1,2) , (2,4) and (4,1) show electrostatic attractions while the spheres pairs of (2,3) and (4,5) show electrostatic repulsions, sphere 1 is,

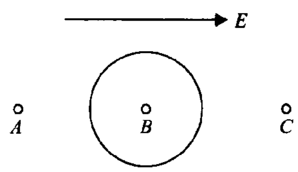
1. negatively charged.
2. positively charged
3. electrically neutral.
4. metal sphere.
5. wooden sphere.

04. Two particles having the ratio of 1 : 2 between masses and the ratio of 1 : 1 between charges are released from rest in a uniform electric field at t = 0. The ratio between the kinetic energies of two particles when t = t is,
(Neglect the mutual electric forces between the charges)

1. 1 : 1
2. 2 : 1
3. 4 : 1
4. 8 : 1
5. 16 : 1

05. A dielectric neutral sphere is placed in a uniform electric field with field intensity of E. What are the correct statements regarding the changing of field intensities at the points A, B and C?

1. Field intensity at A increases while that at B and C decrease.
2. Field intensities at A and B decrease while it increases at C.
3. Field intensities at A and C increase while it decreases at B.
4. Field intensities of all three points increase.
5. Field intensities of all three points decrease.



06. Two identical particles are given equal charges and hung up by the middle of a thread that is attached to the two particles at its ends. The distance between the two particles is same in both vacuum and in a medium with the relative permittivity k and density d. The density of the material used to make particles is,

1. d/(k–1)
2. k/(k–1)
3. (k–1)/kd
4. kd/(k–1)
5. d

07. A q charge is placed on each vertex of an equilateral triangle and unlike charge of Q is placed at its' center. For the resultant force acting upon any charge to be zero, the value of Q/q should be,

1. 1/3
2. $1/\sqrt{3}$
3. 1
4. $\sqrt{3}$
5. 3

08. A Q charge is uniformly distributed in a dielectric sphere with the radius R. A particle with mass m and charge – q does a simple harmonic motion along a diameter. If the amplitude of it is less than R, the frequency of the simple harmonic motion is,

1. $\sqrt{\dfrac{Qq}{4\pi\varepsilon mR}}$
2. $\sqrt{\dfrac{Qq}{4\pi\varepsilon mR^2}}$
3. $\sqrt{\dfrac{Qq}{4\pi\varepsilon mR^3}}$
4. $\sqrt{\dfrac{m}{4\pi\varepsilon qQ}}$
5. $\sqrt{\dfrac{mR}{4\pi\varepsilon qQ}}$

09. A uniform electric field with magnitude of E is generated near the ground due to positively charged lightning cloud moving above the ground. The horizontal range of an object with the mass of m and the charge of +Q which is projected with an inclination of θ , and velocity of U from the ground level is,

1. $\dfrac{2\,u\,\text{Sin}\,\theta}{g}$
2. $\dfrac{2\,u^2 \sin\theta\cos\theta}{g}$
3. $\dfrac{u\,\text{Sin}\,\theta}{EQ+g}$
4. $\dfrac{2\,u^2 \sin\theta\cos\theta}{mg+EQ}$
5. $\dfrac{2\,mu^2 \sin\theta\cos\theta}{mg+EQ}$

10. A Q charge is placed on each vertex of a square with the side length of a. The field intensity of a distance $a/\sqrt{2}$ away from the center on the line perpendicular to the plane goes across the center of the square is

1. $\dfrac{Q}{2\sqrt{2}\,\pi\varepsilon_0 a^2}$
2. $\dfrac{Q}{\sqrt{2}\,\pi\varepsilon_0 a^2}$
3. $\dfrac{2\sqrt{2}Q}{\pi\varepsilon_0 a^2}$
4. $\dfrac{\sqrt{2}\,Q}{\pi\varepsilon_0 a^2}$
5. $\dfrac{2Q}{\pi\varepsilon_0 a^2}$

Answer

01. 2.6×10^{24}, 2.4 **02.** 1mC **03.** 2×10^{6} N

05. 0.076 mm

06. $2.25 \times 10^{6}\ ms^{-1}$ **07.** i. 2.16×10^{-5} N ii. 9×10^{-7} N iii. (i) Increasing (ii) Decreasing

08. $4 L_2 \sqrt{[\, k (L_2 - L_1) \pi\varepsilon_0 \,]}$ **09.** 144 N **10.** 1.6 g cm^{-3}

11. $\frac{5}{4^{1/3}}$ Cm **12.** $2R \left(\frac{\pi\varepsilon_0 mg}{\sqrt{3}} \right)^{\frac{1}{2}}$ **13.** 4.9×10^{-7} kg, 7.1×10^{-11} C

14. 1.6×10^{-19} C **15.** 2.72×10^{-3} cm **16.** $\frac{L}{2}\left(1 + \frac{1}{4\pi\varepsilon_0}\frac{qQ}{Wh^2}\right), \sqrt{\frac{3}{4\pi\varepsilon_0}\frac{qQ}{W}}$

17. $\frac{1}{4\pi\varepsilon_0} \frac{Qq}{a^2}$ **18.** At center $-q / \sqrt{3}$ **19.** At center 0.957 q

20. 6×10^{-8} C **21.** $Q = -2\sqrt{2}\, q$ **22.** $\sqrt{\frac{q\, Q\, (M + m)}{4\pi\varepsilon_0 E\, (Qm + qM)}}$

23. $\frac{Qr}{\pi\varepsilon_0\, (a^2 + r^2)^{3/2}}$ **24.** 0, $\frac{\sigma\, dr}{2\varepsilon_0\, (r^2 + d^2)^{3/2}}$

25. i. $\frac{mV_0^{\,2} \sin^2 \alpha}{2Ee}$ ii. $\frac{2mV_0^{\,2} \sin \alpha \cos \alpha}{Ee}$ iv. $h_{max} = 0.418$ m , d = 2.89 m

26. 2.56×10^{-17} N

27. i. 2q & –2q ii. 2q & q iii. Cannot

28. i. 2340 Nm^2C^{-1} ii. 2340 Nm^2C^{-1} iii. 0

29. 1872 $Nm^2\ C^{-1}$

30. i. 0 ii. $\frac{\sigma\, (r^3 - a^3)}{3\varepsilon_0 r^2}$ iii. $\frac{\sigma\, (b^3 - a^3)}{3\varepsilon_0 r^2}$

31. i. 0 ii. $\frac{\rho\, (r^2 - a^2)}{2\varepsilon_0 r}$ iii. $\frac{(b^2 - a^2)}{2\varepsilon_0 r}$

32. i. 0 ii. $\frac{2\lambda}{\varepsilon_0} \sqrt{R^2 - d^2}$ **33.** $2.28 \times 10^{21}\ NC^{-1}$

34. i. $2.3 \times 10^{6}\ NC^{-1}$ ii. $4.5 \times 10^{5}\ NC^{-1}$

35. i. 0 ii. $\frac{q_1}{4\pi\varepsilon_0 r^2}$ iii. $\frac{q_1 + q_2}{4\pi\varepsilon_0 r^2}$

36. $\frac{\sigma}{\varepsilon_0}$, 0 **37.** $1.02 \times 10^{-6}\ Cm^{-2}$, 49.5^0 , 0^0 **38.** 240 NC^{-1}, 6.37 nCm^{-2}, 3.18 nCm^{-2}

40. 0 & $q / 24\varepsilon_0$

Answer - MCQ

01. 4	02. 2	03. 3	04. 2	05. 3
06. 4	07. 2	08. 3	09. 5	10. 2

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