FOCUS NCERT CBSE MODULE

CLASS XII

NCERT CHAPTER 1

ELECTROSTATICS- I

ELECTRIC CHARGES AND FIELDS

SALIENT FEATURES OF THIS BOOKLET

1. FULL CHAPTER WITH ALL NCERT TOPICS
2. NCERT EXAMPLES AND BACK EXERCISES
3. A SOLVED QUESTION BANK FOR TERMINAL AND FINAL EXAMS
4. TOPIC WISE QUESTIONS AND NCERT TEXT WITH INTERESTING FACTS
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MASS PHYSICS

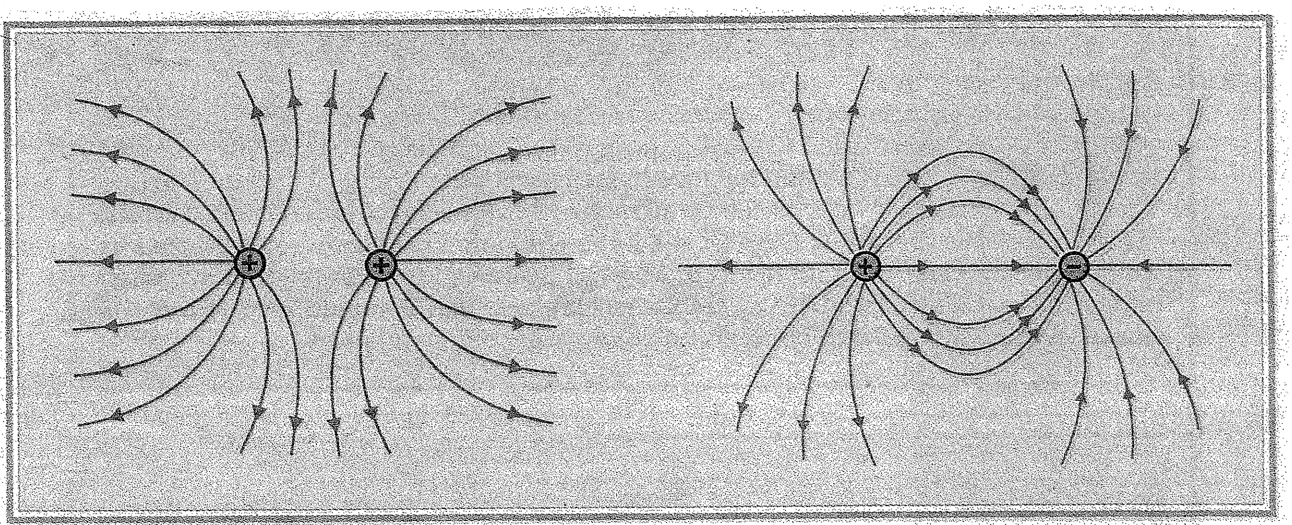
FOCUS NCERT/CBSE MODULE

Chapter 1

ELECTROSTATICS

ELECTRIC CHARGES AND FIELDS

INTRODUCTION



1.1 INTRODUCTION

The science of electricity and magnetism is basic to the modern technological civilisation. Electric power, telecommunication, radio and television, and so many of the practical appliances that we use in daily life are based on the principles of this science. Yet only two hundred years ago, electric and magnetic phenomena seemed unusual and curious, unrelated to the ordinary phenomena that we see around us. However, our understanding of nature has vastly improved in the last two centuries. We now know that the electric force is as pervasive as the gravitational force and that these two fundamental forces underlie nearly all natural phenomena (Chapter 1, Class XI). This is so because any piece of matter, even if electrically neutral as a whole, actually consists of elementary charged constituents. It is, therefore, not surprising that any microscopic understanding of the properties of matter requires the study of electric and magnetic phenomena.

Electric and magnetic phenomena are generally bracketed together, since both derive from charged particles. Magnetism, as you will learn in Chapter 5, arises from charges in motion. Charged particles in motion exert both electric and magnetic types of forces on each other. Because of this inseparable nature, electricity and magnetism are regarded as two aspects of the general subject called *electromagnetism*. However, in the frame of reference where all charges are at rest, the forces are purely electrical. The subject of Electrostatics, as the name suggests, deals with the physics of charges at rest. *Electrostatics* forms the content of this and the next chapter.

TOPIC-2 ELECTRIC CHARGE

Q.1 What is electric charge? Write a short note on its history [origin]?

A. According to William Gilbert, charge is something possessed by material objects that makes

It possible for them to exert electrical forces and to respond to electrical forces.

But : charge can be defined as:

When two substances are rubbed against each other, there can be exchange of electric charge. The process by ch a substance or an object acquires electric charge is called **electrification.**

The electric charge on an object can be measured and hence electric charge is a **physical quantity**.

Electric charge is a ***scalar*** quantity.

SI derived unit of charge is **coulomb** and denoted by C.

Note:- [c.g.s unit- stat coulomb.]

Dimensional formula **of charge** :

Electric charge, q = It, where I is electric current and t is time.

∴ Dimensional formula of electric charge = [AT],

where A = ampere, symbol of SI unit of electric current.

History of charge:

1. Around 6OOBC In Greece Thales of Miletus discovers that Amber rubbed with wool or silk attracts light objects

2. The name electricity is coined from the Greek word electron meaning Amber.

3. Static charge can be developed on a body or two by rubbing them with each other.

4. The positive and negative form of charges was given by Benjamin Franklin.

5. The bodies like glass, plastic rod, silk, fur or pith balls suggested that on rubbing they get electrified, or they acquire an electric charge on rubbing.

6. Various experiments shows that a) like charge repel & b) unlike charge attracts.

7. NOTE. The charges acquired after rubbing are lost when the charged bodies are brought in contact (when the body has no charge it is said to be neutral.

NCERT IN TEXT FOR FRICTIONAL ELECTRICITY

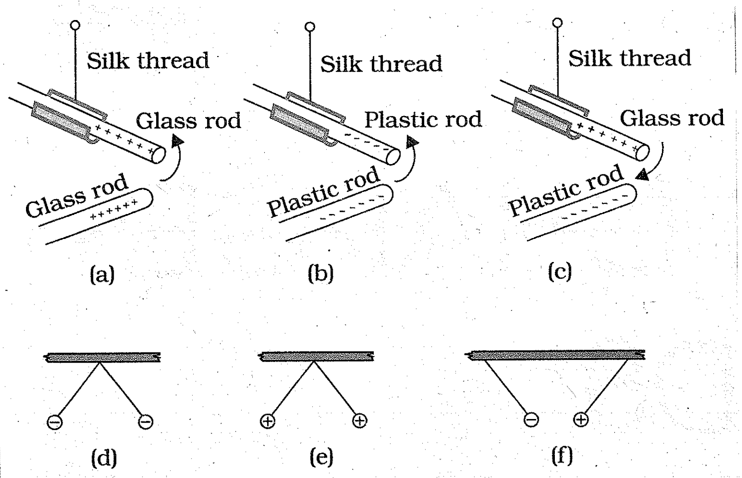


FIGURE 1.1 Rods and pith balls: like charges repel and unlike charges attract each other.

It was observed that if two glass rods rubbed with wool or silk cloth are brought close to each other, they repel each other [Fig. 1.1(a)]. The two strands of wool or two pieces of silk cloth, with which the rods were rubbed, also repel each other. However, the glass rod and wool attracted each other. Similarly, two plastic rods rubbed with cat's fur repelled each other [Fig. 1.1(b)] but attracted the fur. On the other hand, the plastic rod attracts the glass rod [Fig. 1.1(c)] and repel the silk or wool with which the glass rod is rubbed. The glass rod repels the fur.

If a plastic rod rubbed with fur is made to touch two small pith balls (now-a-days we can use polystyrene balls) suspended by silk or nylon thread, then the balls repel each other [Fig. 1.1(d)] and are also repelled by the rod. A similar effect is found if the pith balls are touched with a glass rod rubbed with silk [Fig. 1.1(e)]. A dramatic observation is that a pith ball touched with glass rod attracts another pith ball touched with plastic rod [Fig. 1.1(f)].

These seemingly simple facts were established from years of efforts and careful experiments and their analyses. It was concluded, after many careful studies by different scientists, that there were only two kinds of an entity which is called the *electric charge*. We say that the bodies like glass or plastic rods, silk, fur and pith balls are electrified. They acquire an electric charge on rubbing. The experiments on pith balls suggested that there are two kinds of electrification and we find that (i) *like charges repel* and (ii) *unlike charges attract* each other. The experiments also demonstrated that the charges are transferred from the rods to the pith balls on contact. It is said that the pith balls are electrified or are charged by contact. The property which differentiates the two kinds of charges is called the *polarity* of charge.

Types of Polarity of 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.

ELECTROSCOPE

Q.1 Explain 2 experiments (electroscopes) for studying repulsive behavior of static charge?

A. The **GOLD LEAF ELECTROSCOPE** (G.L.E) & **PAPER STRIP EXPERIMENT**.

A simple apparatus to detect charge on a body is the *gold-leaf electroscope* [Fig. 1.2(a)]. It consists of a vertical metal rod housed in a box, with two thin gold leaves attached to its bottom end. When a charged object touches the metal knob at the top of the rod, charge flows on to the leaves and they diverge. The degree of divergance is an indicator of the amount of charge.

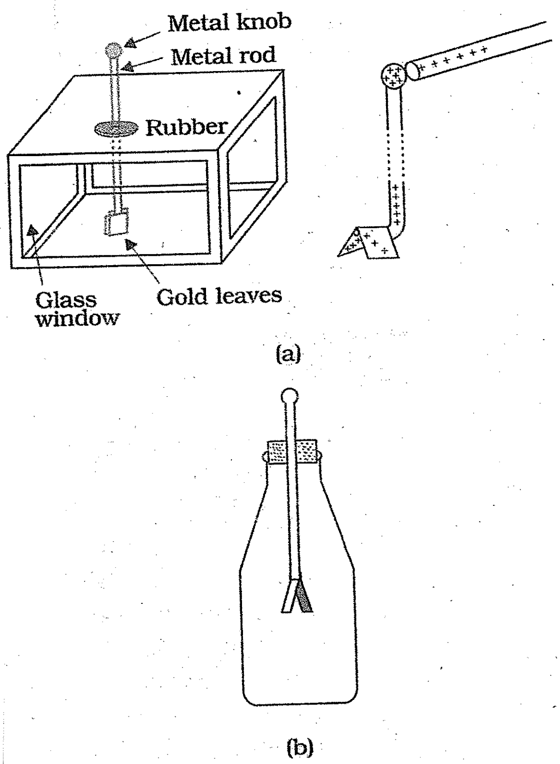


FIGURE 1.2 Electroscopes: (a) The gold leaf electroscope, (b) Schematics of a simple electroscope.

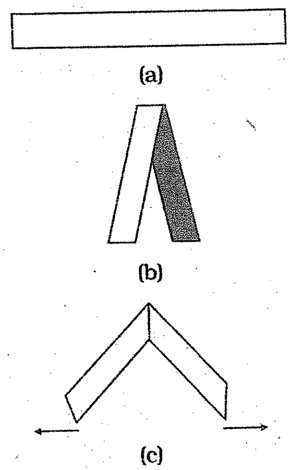


FIGURE 1.3 Paper strip experiment.

Paper Strip Experiment :- → To understand how the electroscope works, use the white paper strips we used for seeing the attraction of charged bodies. Fold the strips into half so that you make a mark of fold. Open the strip and iron it lightly with the mountain fold up, as shown in Fig. 1.3. Hold the strip by pinching it at the fold. You would notice that the two halves move apart. This shows that the strip has acquired charge on ironing. When you fold it into half, both the halves have the same charge. Hence they repel each other. The same effect is seen in the leaf electroscope.

PROPERTIES OF CHARGES

Q.1 What are the five Important properties of electric charge?

A. While studying charges we treat them as point charges and they posses five important properties:

1. **Charge is additive in nature:**

⟶ If a system contains two point charges q_1 and q_2, the total charge of the system is obtained simply by adding algebraically q_1 and q_2, i.e., charges add up like real numbers or they are scalars like the mass of a body. If a system contains n charges $q_1, q_2, q_3, ..., q_n$, then the total charge of the system is $q_1 + q_2 + q_3 + ... + q_n$. Charge has magnitude but no direction, similar to mass.

2. Conservation of charge:

3. Charge of a body is independent on its velocity:

4. Like charges repel and unlike charges attracts each other due to Coulombs force of electrostatics.

Special case:

PROPERTIES OF CHARGES

5. **QUANTISATION OF CHARGE :**

Experimentally it is established that all free charges are integral multiples of a basic unit of charge denoted by *e*. Thus charge *q* on a body is always given by

$$q = ne$$

where *n* is any integer, positive or negative. This basic unit of charge is the charge that an electron or proton carries. By convention, the charge on an electron is taken to be negative; therefore charge on an electron is written as $-e$ and that on a proton as $+e$. ⇒ $q = \pm ne$

The fact that electric charge is always an integral multiple of *e* is termed as *quantisation of charge*. There are a large number of situations in physics where certain physical quantities are quantised. The quantisation of charge was first suggested by the experimental laws of electrolysis discovered by English experimentalist Faraday. It was experimentally demonstrated by Millikan in 1912.

In the International System (SI) of Units, a unit of charge is called a *coulomb* and is denoted by the symbol C. A coulomb is defined in terms the unit of the electric current which you are going to learn in a subsequent chapter. In terms of this definition, one coulomb is the charge flowing through a wire in 1 s if the current is 1 A (ampere), (see Chapter 2 of Class XI, Physics Textbook , Part I). In this system, the value of the basic unit of charge is

$$e = 1.602192 \times 10^{-19}\ \text{C}$$

UNIFICATION OF ELECTRICITY AND MAGNETISM

UNIFICATION OF ELECTRICITY AND MAGNETISM

In olden days, electricity and magnetism were treated as separate subjects. Electricity dealt with charges on glass rods, cat's fur, batteries, lightning, etc., while magnetism described interactions of magnets, iron filings, compass needles, etc. In 1820 Danish scientist Oersted found that a compass needle is deflected by passing an electric current through a wire placed near the needle. Ampere and Faraday supported this observation by saying that electric charges in motion produce magnetic fields and moving magnets generate electricity. The unification was achieved when the Scottish physicist Maxwell and the Dutch physicist Lorentz put forward a theory where they showed the interdependence of these two subjects. This field is called *electromagnetism*. Most of the phenomena occurring around us can be described under electromagnetism. Virtually every force that we can think of like friction, chemical force between atoms holding the matter together, and even the forces describing processes occurring in cells of living organisms, have its origin in electromagnetic force. Electromagnetic force is one of the fundamental forces of nature.

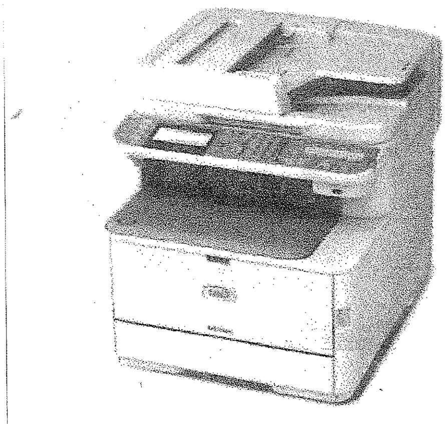
Maxwell put forth four equations that play the same role in classical electromagnetism as Newton's equations of motion and gravitation law play in mechanics. He also argued that light is electromagnetic in nature and its speed can be found by making purely electric and magnetic measurements. He claimed that the science of optics is intimately related to that of electricity and magnetism.

The science of electricity and magnetism is the foundation for the modern technological civilisation. Electric power, telecommunication, radio and television, and a wide variety of the practical appliances used in daily life are based on the principles of this science. Although charged particles in motion exert both electric and magnetic forces, in the frame of reference where all the charges are at rest, the forces are purely electrical. You know that gravitational force is a long-range force. Its effect is felt even when the distance between the interacting particles is very large because the force decreases inversely as the square of the distance between the interacting bodies. We will learn in this chapter that electric force is also as pervasive and is in fact stronger than the gravitational force by several orders of magnitude (refer to Chapter 1 of Class XI Physics Textbook).

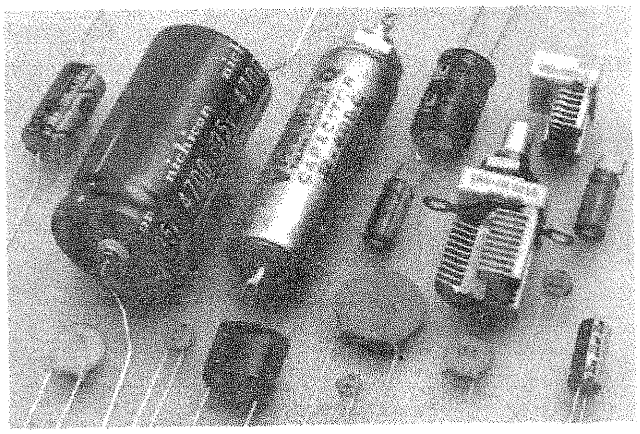
APPLICATIONS OF ELECTROSTATICS

Applications of Electrostatics

(i) A ***photocopier*** is mainly based on the principle of electrostatics.



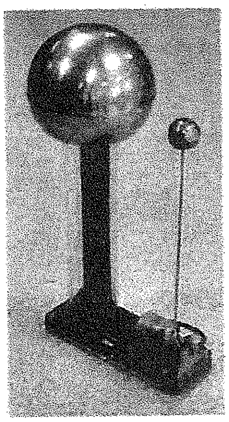
Photocopier



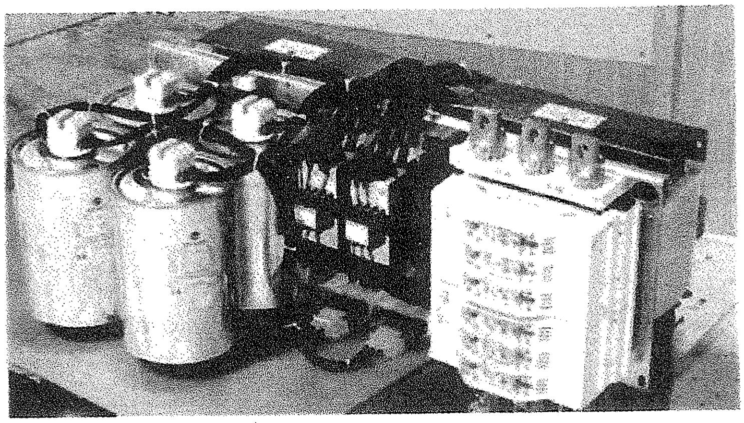
Capacitors

(ii) ***Electric capacitors*** or condensers work on the principle of electrostatics.

(iii) High electric potential source, ***van de Graaff generator*** works on the principle of electrostatics.



van de Graaff generator

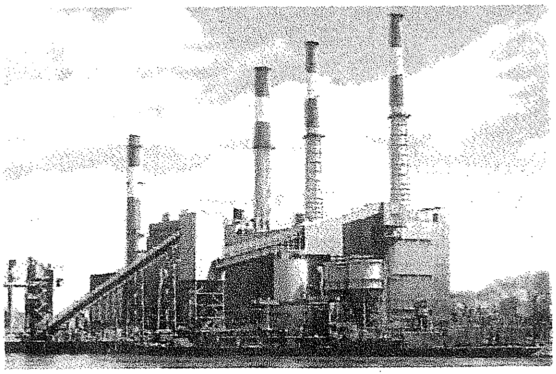


Power factor corrector

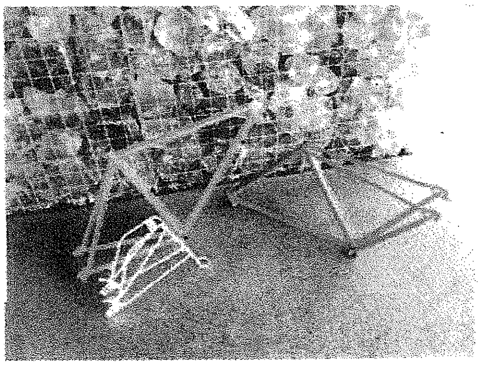
(iv) Energy losses can be reduced with the help of ***power factor correctors*** which work on the principle of electrostatics.

APPLICATIONS OF ELECTROSTATICS

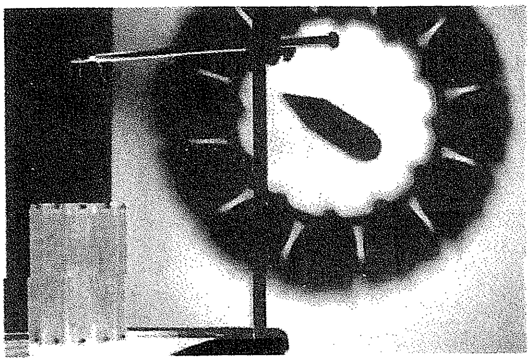
(v) Pollution can be controlled with the help of ***electrostatic precipitator of fly ash.***



Electrostatic precipitator



Powder coatings



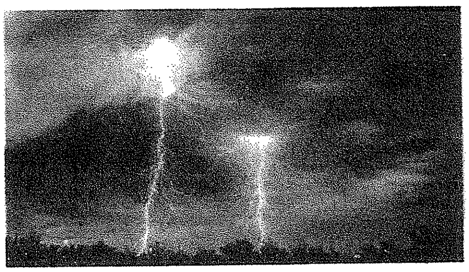
Electrostatic shielding

(vi) ***Spray painting*** and ***powder coatings*** are done with the help of principle of electrostatics.

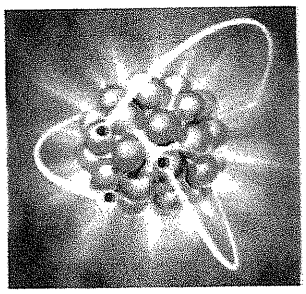
(vii) Sensitive instruments are protected from external electric fields with the help of ***electrostatic shielding***.

(viii) Path of charges can be changed and the charges can be accelerated by using the principle of electrostatics.

(ix) Natural phenomena like ***lightning and thunder*** can be explained by using the knowledge of electrostatics.



Lightning and Thunder



Atomic Structure

(x) ***Atomic structure*** can be explained by using the principles of electrostatics.

NCERT EXAMPLE

Example 1.2 If 10^9 electrons move out of a body to another body every second, how much time is required to get a total charge of 1 C on the other body?

Solution

EXAMPLE 1.2

Interactive animation on simple electrostatic experiments:
http://demoweb.physics.ucla.edu/content/100-simple-electrostatic-experiments

PHYSICS

NCERT EXAMPLE

EXAMPLE 1.3

Example 1.3 How much positive and negative charge is there in a cup of water?

Solution

let the mass of water in cup is:

$m = 250\,gm$

NCERT BACK EXERCISES

NCERT. 1.4. **(a) Explain the meaning of the statement 'electric charge of a body is quantised.'**

(b) Why can one ignore quantisation of electric charge when dealing with macroscopic *i.e.*, large scale charges ?

Ans. (a) Total charge on a body is equal to integral multiple of charge on an electron (e).

i.e. $q = \pm ne$, where $n = 0, 1, 2, 3, ...$

(b) At macroscopic level, the quantisation of charge has no practical importance because the charge at macroscopic level is very large as compared to elementary charge e *i.e.* $1{\cdot}6 \times 10^{-19}$ C. For example, a small charge of 1 μC has about 10^{13} electronic charges. In such cases the charge may be treated as ***continuous*** and ***not quantised.***

NCERT. 1.5. **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.**

Ans. On rubbing, the electrons are transferred from one body to the other. For example, when glass rod is rubbed with a piece of silk cloth, electrons from the glass rod are transferred to the piece of silk cloth. The glass rod acquires (+) charge whereas the silk cloth gets (–) charge. Silk and glass are neutral before rubbing and after rubbing the total charges on glass as well as silk taken together are once again zero. Similar phenomenon is observed with other pairs of bodies. *Thus, in an isolated system the total charge is neither created nor destroyed, the charge is simply transferred from one body to the other.* This observation is consistent with the law of *conservation of charges.*

ELECTRIC CHARGE & MASS

Q.1 Compare Electric charge and Mass?

Ans. Electric charge and mass, both are the intrinsic charcteristics of a particle. However, they possess different properties. The comparison of the properties of electric charge and mass are given in **Table 1.**

Table 1. Comparison of the properties of Electric Charge and Mass

Electric Charge	Mass
1. Electric charge may be *positive* or *negative physical quantity*.	1. Mass of a body is always a *positive physical quantity*.
2. Charges can be added like real numbers, so they can be treated as scalars or scalar quantities.	2. Masses are also added like real numbers and are scalars or scalar quantities.
3. Charge is quantized.	3. Mass of a body is not considered to be quantized.
4. Charge is always conserved.	4. Mass is not conserved as mass can be changed into energy and vice-versa according to the relation, $E = mc^2$.
5. Charge on a body is not affected by the velocity of the body *i.e.* charge is *invariant* $q_{\text{(at rest)}} = q_{\text{(in motion)}}$	5. Mass of a body changes with velocity of the body. as per relation, $m = m_0 / \left[\sqrt{1-(v^2/c^2)}\right]$ where, m = mass of the moving body, m_0 = rest mass of the body; v = velocity of the body and c = velocity of light in vacuum = 3×10^8 m s^{-1}. Clearly, when $v = c$, mass of moving body becomes infinite.
6. Force between charges may be *attractive* (in case of unlike charges) or *repulsive* (in case of like charges).	6. Force between masses is always attractive in nature.
7. It plays an important role in electricity.	7. It has an important role in gravitation.
8. The electric charge is a derived physical quantity.	8. The mass is a fundamental physical quantity.
9. Charge may not exist without mass.	9. Mass exists without net charge also.
10. Transfer of charge brings change in microscopic mass.	10. Transfer of mass may not bring change in charge.

CONDUCTORS AND INSULATORS

Q.1 What are conductors and insulators, distinguish them on the basic of charge theory?

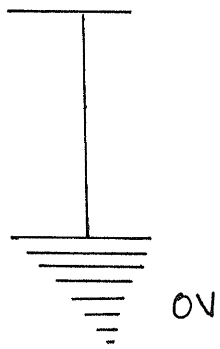
Also explain the process of earthing or grounding ?

Ans. Some substances readily allow passage of electricity through them, others do not. Those which allow electricity to pass through them easily are called *conductors*. They have electric charges (electrons) that are comparatively free to move inside the material. Metals, human and animal bodies and earth are conductors. Most of the non-metals like glass, porcelain, plastic, nylon, wood offer high resistance to the passage of electricity through them. They are called *insulators*. Most substances fall into one of the two classes stated above*.

When some charge is transferred to a conductor, it readily gets distributed over the entire surface of the conductor. In contrast, if some charge is put on an insulator, it stays at the same place. You will learn why this happens in the next chapter.

EARTHING:—

When we bring a charged body in contact with the earth, all the excess charge on the body disappears by causing a momentary current to pass to the ground through the connecting conductor (such as our body). This process of sharing the charges with the earth is called *grounding or earthing*. Earthing provides a safety measure for electrical circuits and appliances. A thick metal plate is buried deep into the earth and thick wires are drawn from this plate; these are used in buildings for the purpose of earthing near the mains supply. The electric wiring in our houses has three wires: live, neutral and earth.



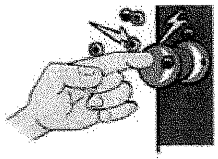
* There is a third category called *semiconductors*, which offer resistance to the movement of charges which is intermediate between the conductors and insulators.

INTERESTING FACTS

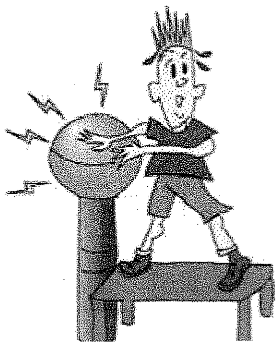
Electrostatics

(electricity + at rest)

Study of charges at rest

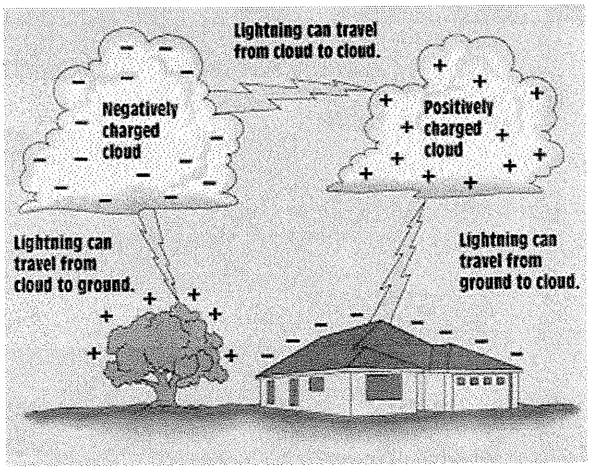


- **Electrostatic Force**
  - Opposites attract
  - Like repel
- All materials are *neutral* ($p^+=e^-$)
- Charging- process of removing or adding electrons
  - Conduction- direct contact
  - Induction- indirect contact



- Grounding- Connection with free flow of electrons to or from the Earth

Static Electricity



Lightning travels from negative to positive areas.

CHARGING BY INDUCTION

Q.1 ***What are the two modes of transferring charge to a conducting body ?***

A. Two modes of transferring charge are:

1. CONDUCTION:

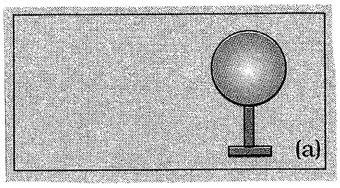
2. INDUCTION:

To understand them refer to following questions:

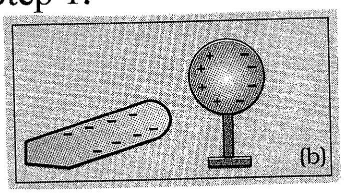
Example 1.1 How can you charge a metal sphere positively without touching it? ***N.C.E.R.T***

Ans. This can be done by the means of induction and earthing in following steps:

Consider an uncharged metallic sphere on an insulating metal stand.



Step 1.



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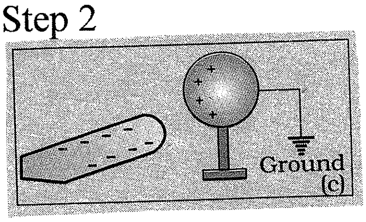

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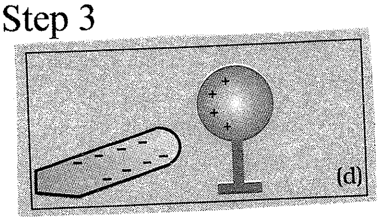
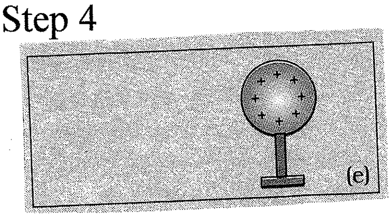


Step 4



CHARGING BY INDUCTION

NCERT IN TEXT QUESTION:

How to provide equal and opposite charge to identical metal spheres by the process of induction?

Ans. Let us consider two metal spheres on insulated stand , to provide them charge by induction we must follow these steps:

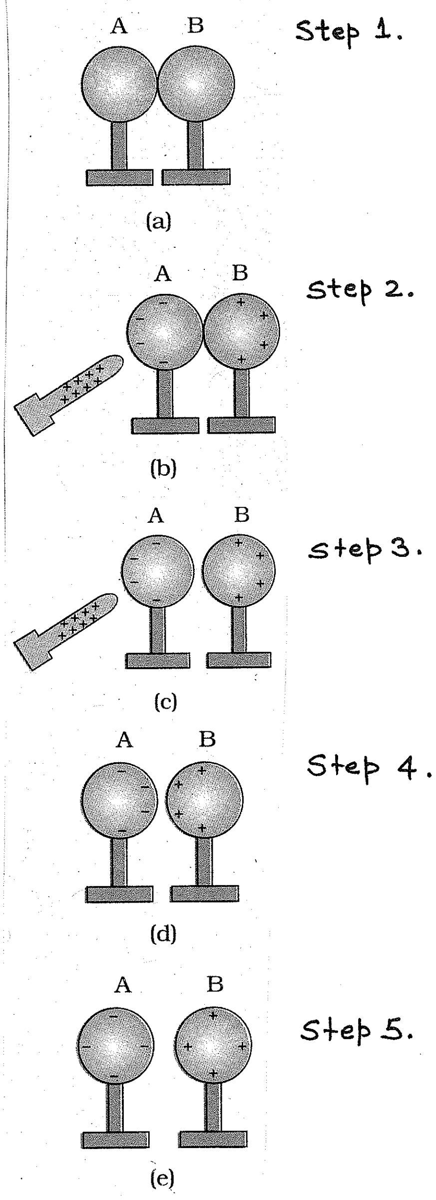


FIGURE 1.4 Charging by induction.

PHYSICS

Interactive animation on charging a two-sphere system by induction:
http://www.physicsclassroom.com/mmedia/estatics/itsn.cfm

IMPORTANT MCQS BASED ON CHARGES

MCQ MULTIPLE CHOICE QUESTIONS

(Only One Option Correct)

1. When a glass rod is rubbed with a piece of silk cloth, the charge acquired by glass rod is

(a) positive

(b) negative

(c) both positive and negative

(d) none of these.

Ans. (a).

2. Minimum value of charge a charged body can have is

(a) 10^{-19}C (b) 1.6×10^{-19}C

(c) 1.6×10^{19}C (d) 0.8×10^{-19}C. *(J & K 2012)*

Ans. (b).

3. Number of electrons forming 1 coulomb charge is equal to

(a) 6·25 (b) 6.25×10^{-18}

(c) 6.25×10^{18} (d) 6.25×10^{-19}. *(H.P.S.E.B. 2019)*

Ans. (c) $n = \frac{q}{e}$.

4. When a body becomes negatively charged, its mass

(a) decreases

(b) increases

(c) remains the same

(d) first increases then decreases *(H.P.S.E.B. 2016)*

Ans. (b).

5. If q be the charge on a body at rest, then the charge on the body, when it is moving with speed υ is

(a) q (b) $\frac{q}{2}$

(c) $2q$ (d) $\frac{q}{\sqrt{1-\frac{\upsilon^2}{c^2}}}$

Ans. (a). Invariance of electric charge.

6. The cause of charging of a body is

(a) transfer of neutrons

(b) transfer of protons

(c) transfer of electrons

(d) transfer of both protons and neutrons

Ans. (c).

7. What is the charge on a metal when one electron is removed from it

(a) 1.6×10^{-19} C (b) 8×10^{-19} C

(c) 16×10^{-19} C (d) zero. *(Haryana 2015)*

Ans. (a). $q = ne = 1 \times 1.6 \times 10^{-19}$ C $= 1.6 \times 10^{-19}$ C

8. The charge on the neutron is

(a) 0 C (b) 1.6×10^{-19}C

(c) -1.6×10^{-19}C (d) 1C *(H.S.E.B. 2018)*

Ans. (a). Neutron is a neutral particle. It has no electric charge.

9. The number of electrons present is -1.6×10^{-6} Coulomb charge is

(a) 10^1 (b) 10^{12}

(c) 10^{13} (d) 10^{14}. *(H.S.E.B. 2018)*

Ans. (c). $q = ne$ or $n = \frac{q}{e} = \frac{-1.6 \times 10^{-6}\text{C}}{-1.6 \times 10^{-19}\text{C}} = 10^{13}$.

10. The charge on an electron is

(a) 0 C (b) 1 C

(c) -1.6×10^{-19}C (d) 1.6×10^{-19}C. *(H.S.E.B. 2018)*

Ans. (c).

11. The charge on a proton is

(a) 0 C (b) 1 C

(c) 1.6×10^{-19}C (d) -1.6×10^{-19}C. *(H.S.E.B. 2018)*

Ans. (c).

12. The existence of a negative charge on a body implies that it has :

(a) lost some of its electrons

(b) lost some of its protons

(c) acquired some electrons from outside

(d) acquired some protons from outside. *(C.P.M.T.)*

Ans. (c) acquired some electrons from outside

When body acquires electrons, it becomes negatively charged.

ELECTROSTATICS

Q.1 What is Electrostatics and frictional electricity?

A. The branch of physics, which deals with the study of charges at rest, the forces between static charges, fields and potentials due to these charges, is called electrostatics. It is also known as **static electricity**

Static electricity is produced by friction between two surfaces in contact and hence called as **frictional electricity**

Q.2 What are the various physical quantities which describes electrostatics? Write a brief note?

Ans. There are 5 major quantities in electrostatics :

1. $\vec{F}$ (forces between charges)

2. $\vec{E}$ (Electric field intensity)

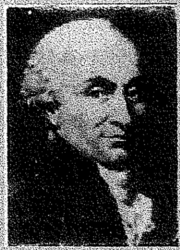
3. ϕ (Electric field Flux)

4. V (Electric field potential)

5. C (Capacitance)

Note: This chapter deals with first 3 physical quantities (F, E & ϕ) while last 2 quantities (V & C) are in NCERT chapter 2

ABOUT COULOMB & CAVENDISH



Charles Augustin de Coulomb (1736–1806)

Coulomb, a French physicist, began his career as a military engineer in the West-Indies. In 1776, he returned to Paris and retired to a small estate to do his scientific research. He invented a torsion balance to measure the quantity of a force and used it for determination of forces of electric attraction or repulsion between small charged spheres. He thus arrived in 1785 at the inverse square law relation, now known as Coulomb's law. The law had been anticipated by Priestley and also by Cavendish earlier, though Cavendish never published his results. Coulomb also found the inverse square law of force between unlike and like magnetic poles.

Henry Cavendish (1731-1810)

Outstanding physicist and chemist. He became wealthy by inheritance at age 40, but remained a recluse all his life. His results on electricity were unpublished and remained unknown till Maxwell edited and published them around 1875. Apart from the law of electrostatic attraction and repulsion, he invented the torsion balance to measure the Newtonian gravitational constant by a laboratory experiment, and thus weighed the earth! He also did experiments on the composition of air, and properties of hydrogen. The Cavendish laboratory of Cambridge University was set up in his honour in 1871.

FORCE BETWEEN CHARGES [F]

Four form of coulombs law:

Q.1 Explain Coulombs law for force between point charges in free space? (SCALAR form)

Ans. Coulomb's law is a quantitative statement about the force between two point charges. When the linear size of charged bodies are much smaller than the distance separating them, the size may be ignored and the charged bodies are treated as *point charges*. Coulomb measured the force between two point charges and found that *it varied inversely as the square of the distance between the charges and was directly proportional to the product of the magnitude of the two charges and acted along the line joining the two charges*. Thus, if two point charges q_1, q_2 are separated by a distance r in vacuum, the magnitude of the force (**F**) between them is given by

$$F = k\frac{|q_1 \ q_2|}{r^2} \quad (1.1)$$

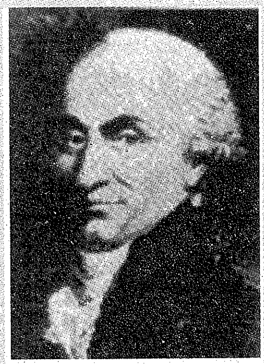
How did Coulomb arrive at this law from his experiments? Coulomb used a torsion balance* for measuring the force between two charged metallic sphere.

* A torsion balance is a sensitive device to measure force. It was also used later by Cavendish to measure the very feeble gravitational force between two objects, to verify Newton's Law of Gravitation.

FORCE BETWEEN CHARGES [F]

Coulombs law:

CHARLES AUGUSTIN DE COULOMB (1736–1806)



Charles Augustin de Coulomb (1736 – 1806) Coulomb, a French physicist, began his career as a military engineer in the West Indies. In 1776, he returned to Paris and retired to a small estate to do his scientific research. He invented a torsion balance to measure the quantity of a force and used it for determination of forces of electric attraction or repulsion between small charged spheres. He thus arrived in 1785 at the inverse square law relation, now known as Coulomb's law. The law had been anticipated by Priestley and also by Cavendish earlier, though Cavendish never published his results. Coulomb also found the inverse square law of force between unlike and like magnetic poles.

That is, 1 C is the charge that when placed at a distance of 1 m from another charge of the same magnitude *in vacuum* experiences an electrical force of repulsion of magnitude 9×10^9 N. One coulomb is evidently too big a unit to be used. In practice, in electrostatics, one uses smaller units like 1 mC or 1 μC.

The constant k in Eq. (1.1) is usually put as $k = 1/4\pi\varepsilon_0$ for later convenience, so that Coulomb's law is written as

$$F = \frac{1}{4\pi\varepsilon_0}\frac{|q_1 q_2|}{r^2} \qquad (1.2)$$

ε_0 is called the *permittivity of free space*. The value of ε_0 in SI units is

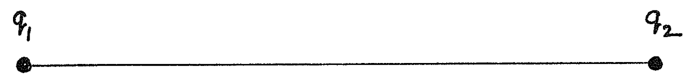
$\varepsilon_0 = 8.854 \times 10^{-12}\ C^2 N^{-1} m^{-2}$

FORCE BETWEEN CHARGES [F]

Q.2 Explain Coulombs law in vector form for two point charge system?

Ans. Consider two point charges q_1 & q_2 kept in vacuum (free space) at distance r then two case arises:

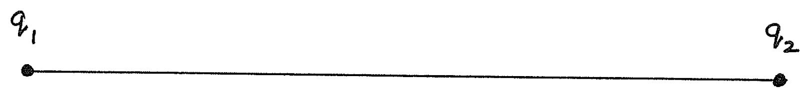
CASE 1. ATTRACTION:



$\vec{F}_{12} =$

$\vec{F}_{21} =$

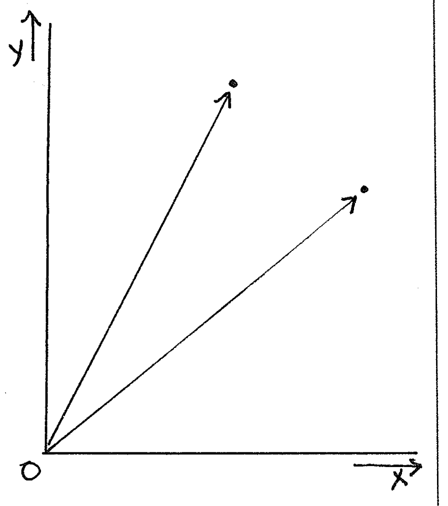
CASE 2. REPULSION:



FORCE BETWEEN CHARGES [F]

Q.3 Explain Coulombs law in position vector form?

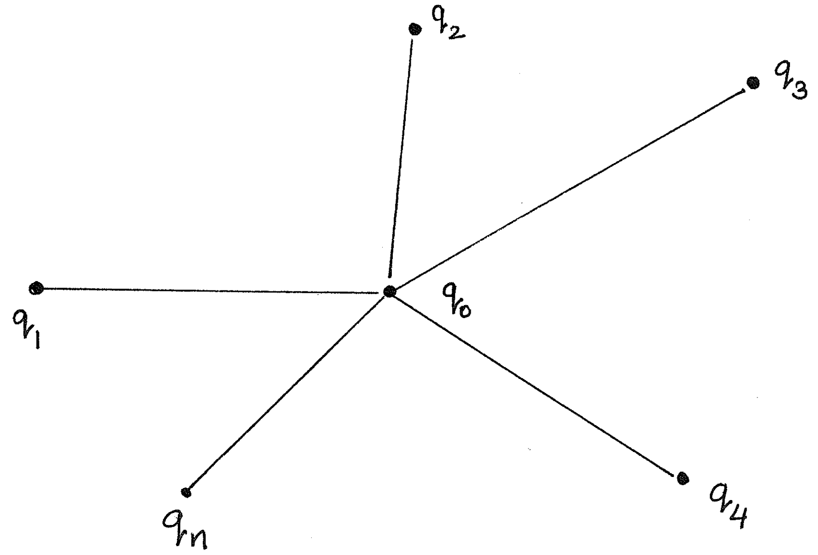
Ans. As we know we can split a displacement vector to position vectors..



FORCE BETWEEN CHARGES [F]

Q.4 Explain Coulombs law in superposition form? Or forces between multiple charges?

Ans. Let us consider a unit test positive charge q_0 surrounded by n number of charges around it as shown below:



Net force experience by q_0 due to n-charges around it:-

$\vec{F_0}$ =

ELECTROSTATIC FORCE & GRAVITATIONAL FORCE

Q.1 Compare Electrostatic and Gravitational forces?

Ans. The comparative study of electrostatic and gravitational forces is given in Table 4. They have many similarities but some very important differences also.

Table 4. Comparison between electrostatic and gravitational forces

Electrostatic Force	*Gravitational Force*
1. It may be an *attractive* or a *repulsive* force.	1. It is *always an attractive* force.
2. It is the *force between two charges*.	2. It is the *force between two masses*.
3. Electrostatic force is *very large* as compared to the gravitational forces (*i.e.* $F_e = 10^{36} F_g$).	3. It is the *weakest fundamental force in nature*. It is almost negligible as compared to the electrostatic force.
4. This force depends upon the *medium* in which the charges are kept.	4. This force does not depend upon the medium in which the masses are kept.
5. It is *long range* force.	5. It is *also long range force*.
6. It varies inversely as the square of distance between interacting charges *i.e.* $F_e \propto \frac{1}{r^2}$. In other words, it obeys *inverse square* law.	6. It also varies inversely as the square of distance between interacting masses *i.e.* $F_g \propto \frac{1}{r^2}$. In other words, it obeys *inverse square law*.
7. It is a *central force i.e.* it acts along the line joining the centres of two charges.	7. It is also a *central force i.e.* it acts along the line joining the centres of two masses.
8. It is a *conservative force*. If work done by a force on a particle does not depend upon the actual path followed by the particle but depends on the initial and final positions of the particle, then the force is called ***conservative force.***	8. It is also a *conservative* force.
9. It obeys Newton's third law.	9. It also obeys Newton's third law.

NCERT EXAMPLE

NCERT. **Example 1.4** Coulomb's law for electrostatic force between two point charges and Newton's law for gravitational force between two stationary point masses, both have inverse-square dependence on the distance between the charges and masses respectively. (a) Compare the strength of these forces by determining the ratio of their magnitudes (i) for an electron and a proton and (ii) for two protons. (b) Estimate the accelerations of electron and proton due to the electrical force of their mutual attraction when they are 1 Å (= 10^{-10} m) apart? ($m_p = 1.67 \times 10^{-27}$ kg, $m_e = 9.11 \times 10^{-31}$ kg)

Solution

PHYSICS

Interactive animation on Coulomb's law:
http://webphysics.davidson.edu/physlet_resources/bu_semester2/menu_semester2.html

EXAMPLE 1.4

NCERT BACK EXERCISES

NCERT. 1.3. Check that the ratio $ke^2/G\, m_e m_p$ is dimensionless. Look up a Table of Physical Constants and determine the value of this ratio. What does the ratio signify ?

Ans.

NCERT EXAMPLE

Example 1.6 Consider three charges q_1, q_2, q_3 each equal to q at the vertices of an equilateral triangle of side l. What is the force on a charge Q (with the same sign as q) placed at the centroid of the triangle, as shown in Fig. 1.9?

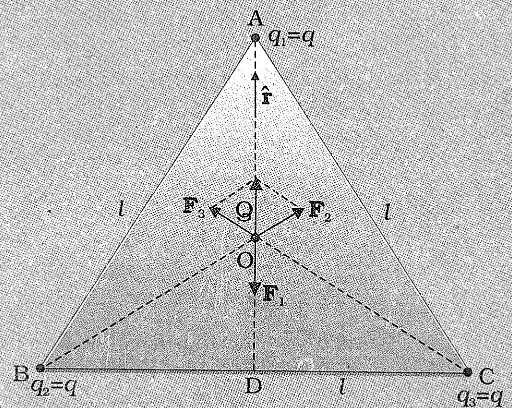


FIGURE 1.9

Solution

EXAMPLE 1.6

NCERT EXAMPLE

Example 1.7 Consider the charges q, q, and $-q$ placed at the vertices of an equilateral triangle, as shown in Fig. 1.10. What is the force on each charge?

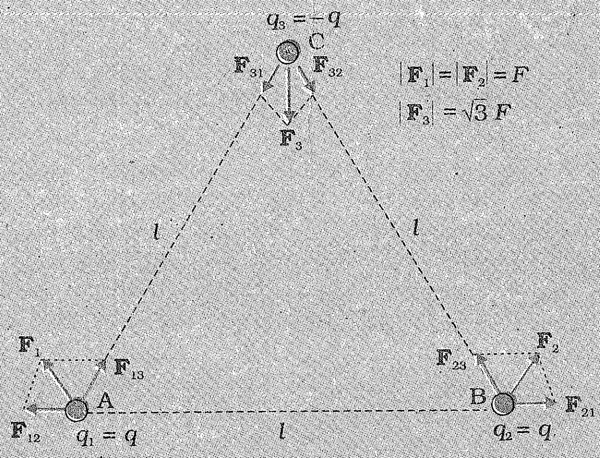


FIGURE 1.10

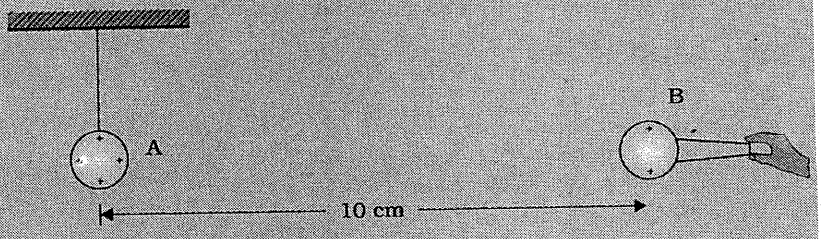
Solution

EXAMPLE 1.7

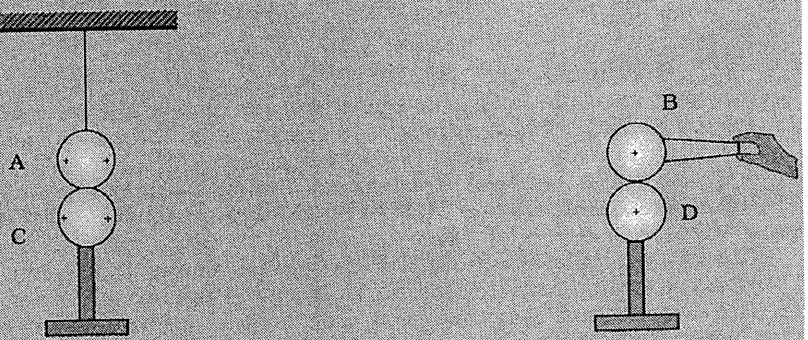
NCERT

Example 1.5 A charged metallic sphere A is suspended by a nylon thread. Another charged metallic sphere B held by an insulating handle is brought close to A such that the distance between their centres is 10 cm, as shown in Fig. 1.7(a). The resulting repulsion of A is noted (for example, by shining a beam of light and measuring the deflection of its shadow on a screen). Spheres A and B are touched by uncharged spheres C and D respectively, as shown in Fig. 1.7(b). C and D are then removed and B is brought closer to A to a distance of 5.0 cm between their centres, as shown in Fig. 1.7(c). What is the expected repulsion of A on the basis of Coulomb's law? Spheres A and C and spheres B and D have identical sizes. Ignore the sizes of A and B in comparison to the separation between their centres.

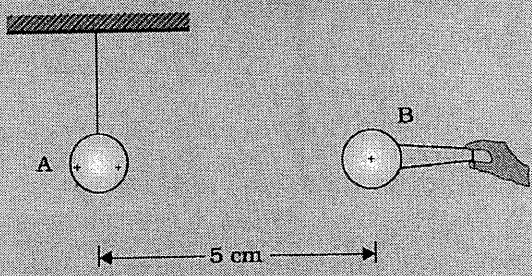
Ans:-



(a)



(b)



(c)

NCERT BACK EXERCISES

NCERT. **1.1. What is the force between two small charged spheres having charges of 2×10^{-7} C and 3×10^{-7} C placed 30 cm apart in air ?**

Ans. Using $F = 9 \times 10^9 \frac{q_1 q_2}{r^2}$, we get

$$F = \frac{9 \times 10^9 \times 0{\cdot}2 \times 10^{-6} \times (0{\cdot}3 \times 10^{-6})}{0{\cdot}3 \times 0{\cdot}3}$$

$= 6 \times 10^{-3}$ N (repulsive).

NCERT. **1.2. The electrostatic force on a small sphere of charge 0·4 μC due to another small sphere of charge –0·8 μC in air is 0·2 N.**

(a) What is the distance between the two spheres ?

(b) What is the force on the second sphere due to the first ?

Ans. (a) Force on charge 1 due to charge 2 is given by the relation

NCERT BACK EXERCISES

NCERT. 1.12. (*a*) Two insulated charged copper spheres A and B have their centres separated by a distance of 50 cm. What is the mutual force of electrostatic repulsion if the charge on each is $6{\cdot}5 \times 10^{-7}$ C ? The radii of A and B are negligible compared to the distance of separation.

(*b*) What is the force of repulsion if each sphere is charged double the above amount, and the distance between them is halved ?

Ans. (a)

EQUILIBRIUM OF CHARGES

Q.1 What is equilibrium of charges ? Explain its two types?

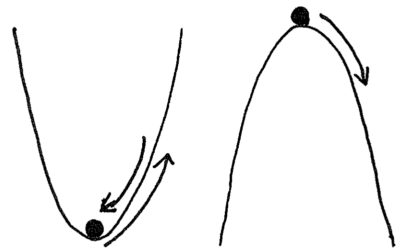
Ans. *A system of charges is said to be in equilibrium if each charge experience a zero net force due all of the charges in its vicinity.*

Types of equilibrium:

1. STABLE EQUILIBRIUM

Example:

2. UNSTABLE EQUILIBRIUM



Example:

Important Q.2 A Charge q is placed at the center of the line joining two equal two equal charges Q. Show that the system of three charges will be in equilibrium if q= -Q/4. NEET-2016: CBSE 2015

Ans. Q-----------------q------------------Q

IMPORTANT QUESTION ON EQUILIBRIUM OF CHARGES

Important

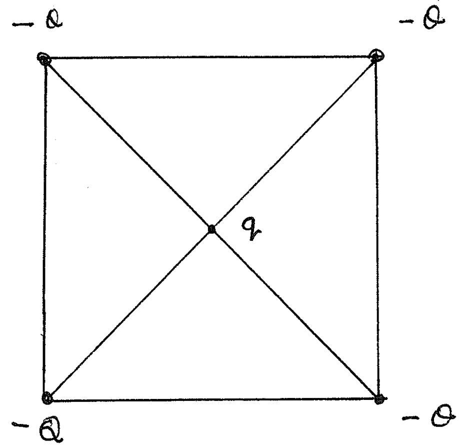
Four charges of – Q each are placed at 4 corners of a square and a charge q is at its centre. For equilibrium, value of q should be :

(a) $-\frac{Q}{4}(1+2\sqrt{2})$ (b) $\frac{Q}{4}(1+2\sqrt{2})$

(c) $-\frac{Q}{2}(1+2\sqrt{2})$ (d) $\frac{Q}{2}(1+2\sqrt{2})$.

(A.I.E.E.E. 2004) CBSE-2015, NEET – 2014

Ans:-

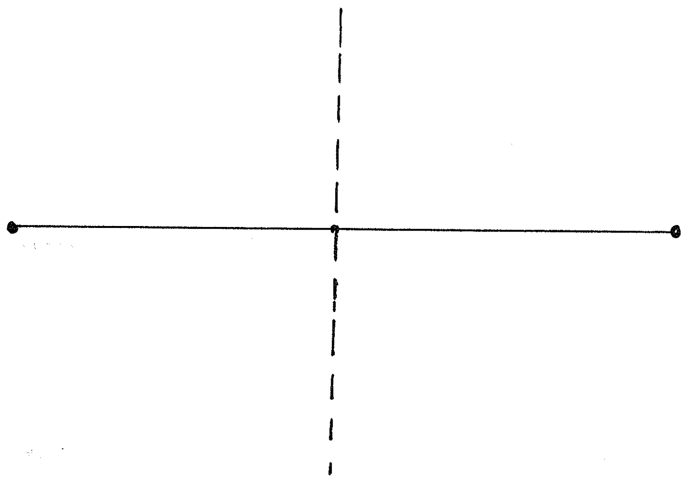


NCERT BACK EXERCISES

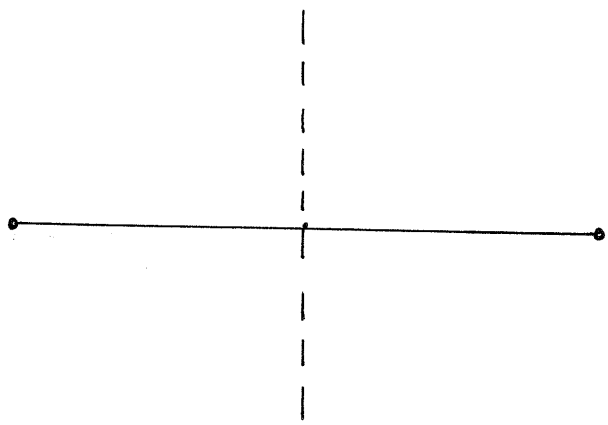
NCERT. 1.32. (*a*) Consider an arbitrary electrostatic field configuration. A small test charge is placed at a null point (*i.e.*, where E = 0) of the configuration. Show that the equilibrium of the test charge is necessarily unstable.

(*b*) Verify this result for the simple configuration of two charges of the same magnitude and sign placed a certain distance apart.

Ans (a)



Ans (b)

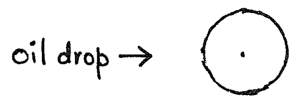


NCERT BACK EXERCISES

NCERT. **1.25.** **An oil drop of 12 excess electrons is held stationary under a constant electric field of $2{\cdot}55 \times 10^4$ NC^{-1} in Millikan's oil drop experiment. The density of the oil is $1{\cdot}26$ g cm^{-3}. Estimate the radius of the drop. ($g = 9{\cdot}81$ ms^{-2} ; $e = 1{\cdot}60 \times 10^{-19}$ C.)**

Ans. Charge on drop,

$q = ne$



EQUILIBRIUM OF CHARGES

NCERT. **1.13. Suppose the spheres A and B in Q 1.12 have identical sizes. A third sphere of the same size but uncharged is brought in contact with the first, then brought in contact with the second, and finally removed from both. What is the new force of repulsion between A and B ?**

Ans. Charge on sphere A on contact with third sphere (say C) having no charge is given by

$$q'_A = \frac{q_A + q_C}{2} = \frac{6{\cdot}5 \times 10^{-7} + 0}{2}$$

$$= 3{\cdot}25 \times 10^{-7}\ \text{C}$$

When third sphere, now having charge $3{\cdot}25 \times 10^{-7}$ C is brought in contact with sphere B, the charge left on sphere B is given by,

$$q'_B = \frac{q_B + q'_C}{2}$$

$$= \frac{6{\cdot}5 \times 10^{-7} + 3{\cdot}25 \times 10^{-7}}{2} = 4{\cdot}875 \times 10^{-7}\ \text{C}$$

$\therefore$ New Coulomb's force $= \dfrac{1}{4\pi\varepsilon_0}\dfrac{q'_A q'_B}{r^2}$

$$= \frac{9 \times 10^9 \times 3{\cdot}25 \times 10^{-7} \times 4{\cdot}875 \times 10^{-7}}{(50 \times 10^{-2})^2}$$

$$= 5{\cdot}7 \times 10^{-3}\ \text{N}.$$

MASS PHYSICS

FOCUS NCERT/CBSE MODULE

MCQS BASED ON FORCE BETWEEN CHARGES [COULOMB LAW]

Q. 1. The value of absolute electrical permittivity of free space is

(a) $8{\cdot}85 \times 10^{-12}\ C^2 N^{-1} m^{-2}$
(b) $8{\cdot}85 \times 10^{-12}\ C^2 N m^{-2}$
(c) $9 \times 10^{-9}\ N m^2 C^{-2}$
(d) $9 \times 10^{9}\ N m^2 C^{-2}$

ANS. (a).

Q. 2. The dimensional formula of permittivity ($\in_0$) of free space is

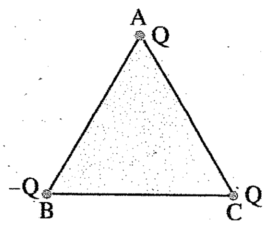
(a) $[M^{-1}L^3T^4A^2]$ (b) $[M^{-1}L^{-2}T^2A]$
(c) $[M^{-1}L^{-2}T^{-2}A]$ (d) $[M^{-1}L^{-2}T^{-2}A^2]$

(H.P.S.E.B. 2018)

ANS. (a). $F = \frac{1}{4\pi\in_0}\frac{q^2}{r^2}$

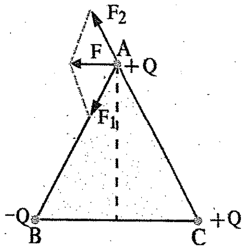
Q. 3. Three charges are placed at the vertices of an equilateral triangle of side a. The force experienced by the charge placed at vertex A in direction normal to BC is :

(a) $Q^2/4\pi\in_0 a^2$ (b) $-Q^2/4\pi\in_0 a^2$
(c) zero (d) $Q^2/2\pi\in_0 a^2$.



(A.I.I.M.S. 2003)

ANS. (c), The figure clearly indicates that the net electrostatic force on charge at A is acting horizontally *i.e.*, along CB. No force is acting along a direction normal to BC.



Q. 4. An electron is moving around a nucleus of a hydrogen atom in a circular orbit of radius r. The coulomb's force $\vec{F}$ between the two is :

(a) $k\frac{e^2}{r^3}\vec{r}$ (b) $\frac{-ke^2}{r^3}\vec{r}$
(c) $\frac{ke^2}{r^2}\hat{r}$ (d) $-\frac{ke^2}{r^3}\hat{r}$

(where, $k = \frac{1}{4\pi\varepsilon_0}$) *(C.B.S.E. PMT 2003)*

ANS. (b), Charge on the hydrogen nucleus is $+e$ and charge on electron is $-e$. Coulomb's force between them is attractive.

$\vec{F} = \frac{-1}{4\pi\in_0}\frac{e.e}{r^2}\hat{r}$ (–ve sign shows that $\vec{F}$ is attractive)

Since $\hat{r} = \frac{\vec{r}}{r}$

$\therefore\ \vec{F} = \frac{-1}{4\pi\in_0}\frac{e^2}{r^3}\vec{r} = -\frac{ke^2}{r^3}\vec{r}$.

Q5. Two point charges separated by a distance d repel each other with a force of 9 N. If the separation between them becomes $3d$, the force of repulsion will be :

(a) 1 N (b) 3 N
(c) 6 N (d) 27 N. *(C.P.M.T.)*

ANS. (a). $F \propto \frac{1}{r^2}$

Q6. The dielectric constant of metals is :

(a) 1 (b) greater than 1
(c) zero (d) infinite.

(M.P.C.E.E. ; C.P.M.T., COMED–H 2009)

ANS. (d)

$K = \infty$ for metals.

Q7. Electrons remain bound to the nucleus due to which of the following forces :

(a) Electrostatic (b) van der Waal
(c) Gravitation (d) Nuclear. *(A.F.M.C. 2001)*

ANS. (a)

Electrostatic force between nucleus and electron.

Q8. What are the units of $K = \frac{1}{4\pi\in_0}$?

(a) $C^2 N^{-1} m^{-2}$ (b) $N m^2 C^{-2}$
(c) $N m^2 C^2$ (d) unitless. *(A.F.M.C. 2004)*

ANS. (b). $K = \frac{Fr^2}{q^2}$

Q9. In a hydrogen atom, the distance between the electron and proton is $2{\cdot}5 \times 10^{-11}$ m. The electrical force of attraction between them will be

(a) $2{\cdot}8 \times 10^{-7}$ N (b) $6{\cdot}2 \times 10^{-7}$ N
(c) $3{\cdot}7 \times 10^{-7}$ N (d) $9{\cdot}1 \times 10^{-7}$ N. *(Delhi PMT)*

ADDITIONAL MCQS ON COULOMBS LAW

26. **When a soap bubble is charged,**
    (a) **it contracts**
    (b) **it expands**
    (c) **it bursts**
    (d) **it neither contracts nor expands.**

EXPLANATION.

Size of soap bubble increases, when charged.

27. **Which of the following is the unit of electric charge ?**
    (a) **coulomb** *(b)* **newton**
    (c) **volt** *(d)* **ampere.**

EXPLANATION.

coulomb

28. **A comb runs through one's dry hair, attracts small bits of paper. This is due to :**
    (a) **comb is a good conductor**
    (b) **paper is a good conductor**
    (c) **the atoms in the paper get polarised by the charged comb**
    (d) **the comb possesses magnetic properties.**
    (Karnataka C.E.T. 2006)

EXPLANATION.

Paper is a dielectric. It gets polarised due to frictionally charged comb.

29. **Five balls numbered 1 to 5 are suspended using separate threads. Pairs (1, 2), (2, 4), (4, 1) show electrostatic attraction, while pairs (2, 3) and (4, 5) show repulsion. Therefore, ball 1 must be :**
    (a) **positively charged**
    (b) **negatively charged**
    (c) **neutral**
    (d) **made of metal.** *(N.C.E.R.T.)*

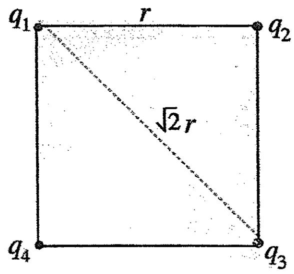
EXPLANATION

Ball (1) is not charged.

30. **Three equal charges are placed on three corners of a square. If the force between q_1 and q_2 is F_{12} and that between q_1 and q_3 is F_{13}, the ratio of magnitude F_{12}/F_{13} is :**
    (a) **1/2** *(b)* **2**
    (c) $\frac{1}{\sqrt{2}}$ *(d)* $\sqrt{2}$. *(M.P.P.E.T.)*

EXPLANATION.

$$F_{12} = \frac{1}{4\pi\epsilon_0}\frac{q_1q_2}{r^2}$$



$$F_{13} = \frac{1}{4\pi\epsilon_0}\frac{q_1q_3}{2r^2}$$

$$\therefore \quad \frac{F_{12}}{F_{13}} = 2.$$

31. **Two spherical conductors B and C having equal radii and carrying equal charges repel with a force F. A third uncharged similar sphere is brought in contact with B, then brought in contact with C and finally removed away. The new force between B and C is :**
    (a) **F/4** *(b)* **3F/4**
    (c) **F/8** *(d)* **3F/8.**
    (A.I.E.E.E. 2004)

EXPLANATION

Let q be initial charge on each sphere B and C

then, $F = \frac{1}{4\pi\epsilon_0}\frac{q^2}{d^2}$

After contact, charge on uncharged conductor $= \frac{q}{2}$

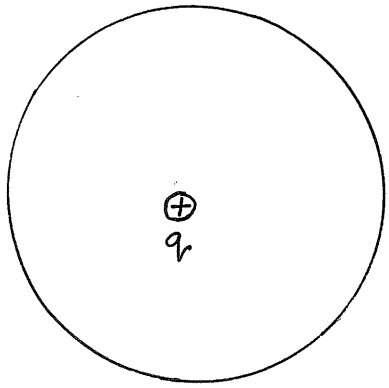
and charge on B $= \frac{q}{2}$. On its contact with C the charge on each conductor becomes $= \frac{\frac{q}{2}+q}{2} = \frac{3}{4}q$

Thus, new force between B and C is given by

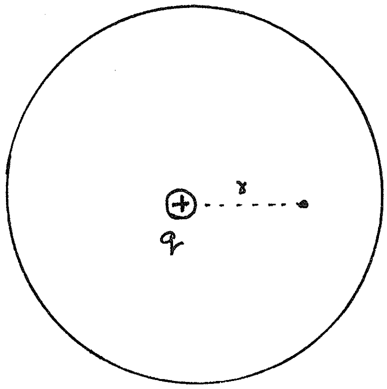
$$F' = \frac{1}{4\pi\epsilon_0}\frac{\left(\frac{q}{2}\right)\left(\frac{3}{4}q\right)}{d^2} = \frac{3}{8}F.$$

ELECTRIC FIELD

ELECTRIC FIELD



ELECTRIC FIELD INTENSITY $\vec{E}$



Note :-

q_0 = Unit test positive charge
(It is $q_0 \xrightarrow{\text{limit}} 0$)
∴ Its electric field is so small w.r.t q & can be neglected.

ELECTRIC FIELD DUE TO A SYSTEM OF CHARGES

NCERT TEXT: Consider a system of charges q_1, q_2, ..., q_n with position vectors $\mathbf{r}_1$, $\mathbf{r}_2$, ..., $\mathbf{r}_n$ relative to some origin O. Like the electric field at a point in space due to a single charge, electric field at a point in space due to the system of charges is defined to be the force experienced by a unit test charge placed at that point, without disturbing the original positions of charges q_1, q_2, ..., q_n. We can use Coulomb's law and the superposition principle to determine this field at a point P denoted by position vector $\mathbf{r}$.

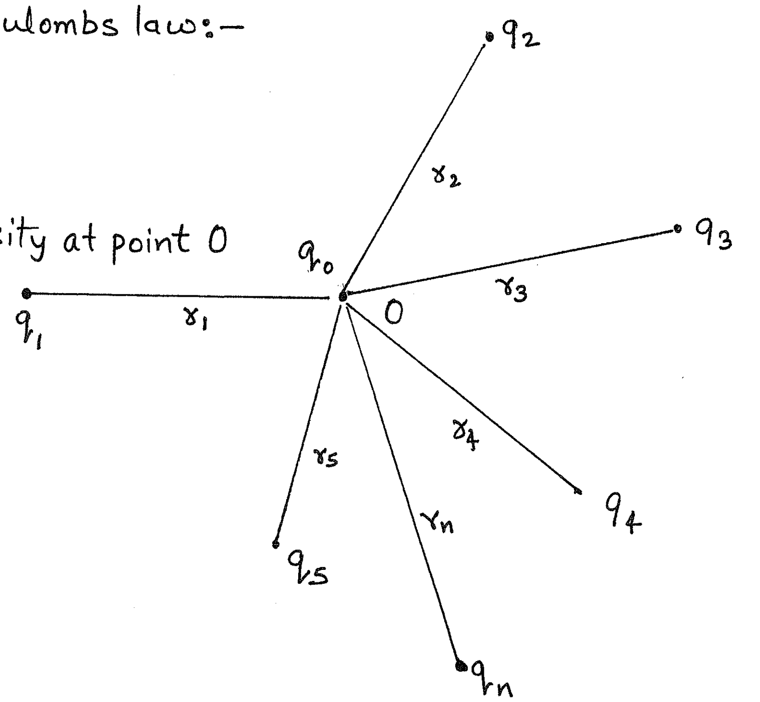
From superposition form of Coulombs law:—

$$\vec{F_o} = \frac{q_o}{4\pi\epsilon_o} \sum_{i=1}^{n} \frac{q_i}{r_{io}^2} \hat{r}_{io}$$

to calculate Electric field Intensity at point O due to system of n-charges.

$$\vec{E_o} = \frac{\vec{F_o}}{q_o}$$

$\therefore$



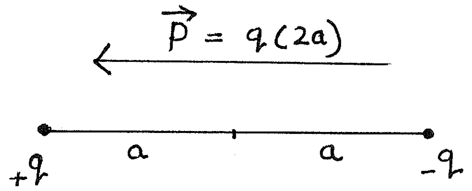
Very Important note for numericals:— Electric field Intensity is a vector quantity !
$\therefore$ always consider its direction along with Magnitude while solving Numericals.

ELECTRIC DIPOLE

Q.1 What is electric dipole, give some examples?

Ans. An electric dipole is a pair of equal and opposite point charges q and $-q$, separated by a distance $2a$. The line connecting the two charges defines a direction in space. By convention, the direction from $-q$ to q is said to be the direction of the dipole. The mid-point of locations of $-q$ and q is called the centre of the dipole.

The total charge of the electric dipole is obviously zero. This does not mean that the field of the electric dipole is zero. Since the charge q and $-q$ are separated by some distance, the electric fields due to them, when added, do not exactly cancel out. However, at distances much larger than the separation of the two charges forming a dipole ($r >> 2a$), the fields due to q and $-q$ nearly cancel out.



Q.2 What is electric dipole moment $\vec{P}$?

Ans.

ELECTRIC DIPOLE

Q.3 Find net dipole moment of given electrostatic systems?

(For water Molecule) H_2O

Ans:-

Note: there are 4 important topics in electric dipole :

1. Electric field on axial line of dipole

2.Electric field on equatorial line of dipole

3. Torque on dipole due to external electric field

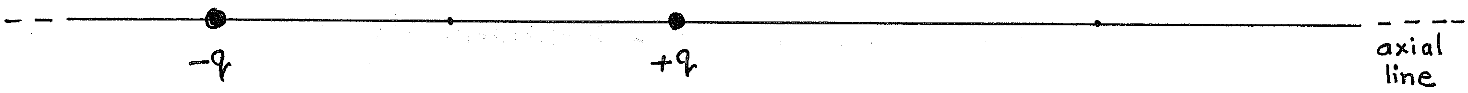
4. Potential energy stored in dipole when kept in external electric field

THE FIELD OF AN ELECTRIC DIPOLE

FOR POINTS ON THE AXIAL LINE

Q.1 Find electric field at a point on the axial line passing through electric dipole? Also explain the case of short dipole?

Ans .Consider an electric dipole having dipole moment p and a point A on its axial line , to find electric field intensity of this point we must place a test charge q_o on it as shown in the diagram below:



THE FIELD OF AN ELECTRIC DIPOLE

FOR POINTS ON THE AXIAL LINE

Condition for short dipole:

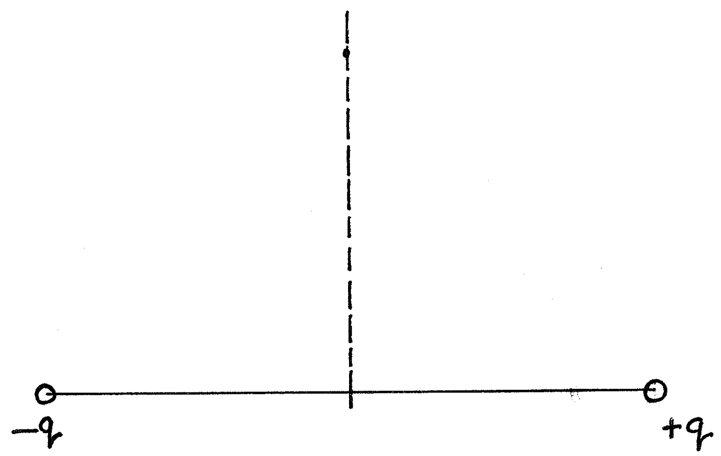
Angle between $\vec{E}$ & $\vec{P}$ =

THE FIELD OF AN ELECTRIC DIPOLE

FOR POINTS ON THE EQUATORIAL LINE {PLANE}

Q.2 Find electric field at a point on the equatorial line passing through electric dipole? Also explain the case of short dipole?

Ans .Consider an electric dipole having dipole moment p and a point A on its equatorial line , to find electric field intensity of this point we must place a test charge q_o on it as shown in the diagram below:



THE FIELD OF AN ELECTRIC DIPOLE

FOR POINTS ON THE EQUATORIAL LINE {PLANE}

Condition for short dipole.

Angle between $\vec{E}$ & $\vec{P}$ at equatorial line:-

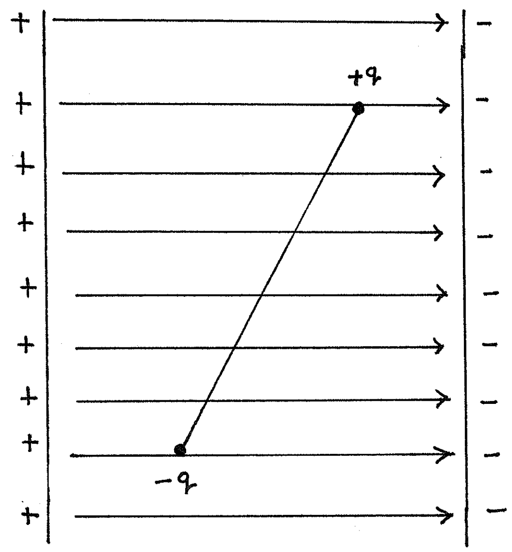
DIPOLE IN A UNIFORM EXTERNAL FIELD

Q.1 Explain the motion of dipole in a uniform electric field?

Or

Find the torque experienced by electric dipole inside external uniform electric field?

Ans. Consider an electric dipole placed by any angle inside external uniform electric field due to this field the dipole will experience two equal and opposite forces and these forces will result in a turning effect called torque as shown in diagram.



DIPOLE IN A UNIFORM EXTERNAL FIELD

SPECIAL CASES:

1. MAXIMUM TORQUE:

2. MINIMUM TORQUE:

3. TWO TYPES OF EQUILIBRIUM FOR DIPOLE:

4. IF THE EXTERNAL FIELD IS NON-UNIFORM :

P.E OF DIPOLE IN A UNIFORM EXTERNAL FIELD

Q.1 Find the potential energy stored in a dipole when kept inside external uniform electric field?

Ans. The torque acting on dipole results in a work done to provide an angular motion from unstable state to stable state, this work done is equivalent to potential energy stored in dipole.

Small work done by the torque to turn the dipole:

PHYSICAL SIGNIFICANCE OF ELECTRIC DIPOLE

NCERT Text.

In most molecules, the centres of positive charges and of negative charges* lie at the same place. Therefore, their dipole moment is zero. CO_2 and CH_4 are of this type of molecules. However, they develop a dipole moment when an electric field is applied. But in some molecules, the centres of negative charges and of positive charges do not coincide. Therefore they have a permanent electric dipole moment, even in the absence of an electric field. Such molecules are called polar molecules. Water molecules, H_2O, is an example of this type. Various materials give rise to interesting properties and important applications in the presence or absence of electric field.

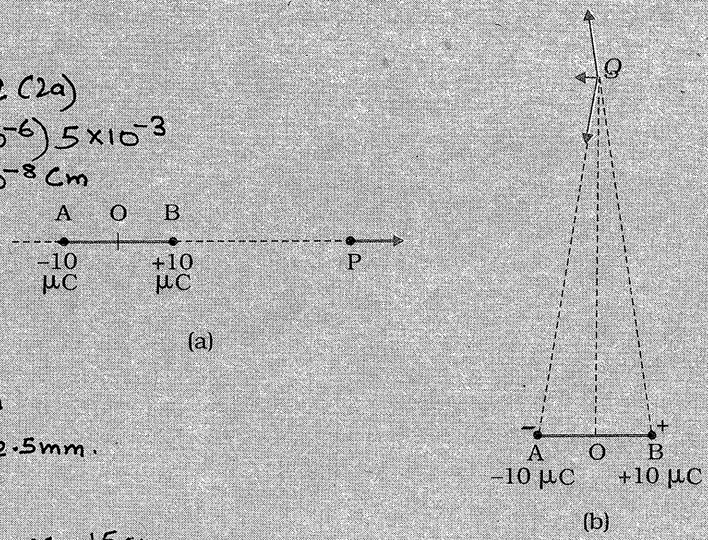
NCERT EXAMPLE

NCERT. **Example 1.10** Two charges ±10 μC are placed 5.0 mm apart. Determine the electric field at (a) a point P on the axis of the dipole 15 cm away from its centre O on the side of the positive charge, as shown in Fig. 1.21(a), and (b) a point Q, 15 cm away from O on a line passing through O and normal to the axis of the dipole, as shown in Fig. 1.21(b).

dipole Moment $p = q(2a)$

$= (10\times10^{-6})\,5\times10^{-3}$

$p = 5\times10^{-8}$ Cm



Note:- $2a = 5$ mm

$a = \frac{5}{2} = 2.5$ mm.

distance of point P $= r = 15$ cm.

FIGURE 1.21

EXAMPLE 1.10

Ans. $\therefore\ r >> a$ hence it is a case of short dipole:-

(a) P point is axial point for short dipole.

$E_P =$

(b) Q point is equatorial point for short dipole:

$E_Q =$

NCERT EXAMPLE

NCERT. **Example 1.9** Two point charges q_1 and q_2, of magnitude $+10^{-8}$ C and -10^{-8} C, respectively, are placed 0.1 m apart. Calculate the electric fields at points A, B and C shown in Fig. 1.14.

Note:- $2a = 0.1m \Rightarrow a = \frac{0.1}{2} = 0.05m.$

$P = q\,(2a) = 10^{-8} \times 0.1 = 10^{-9}\,Cm$

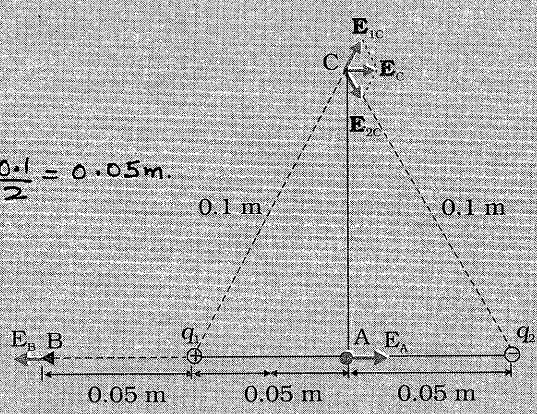


FIGURE 1.14

Ans:-

$$E_A = \frac{Kq}{r^2} + \frac{Kq}{r^2} = \frac{2Kq}{r^2} = \frac{2 \times 9\times10^9 \times 10^{-8}}{(0.05)^2}\ N\ (\hat{i})$$

B point is axial point for dipole:-

$\therefore\ E_B =$

C Point is equatorial point:-

$\therefore\ E_C =$

NCERT BACK EXERCISES

NCERT. **1.10.** An electric dipole with dipole moment 4×10^{-9} Cm is aligned at 30° with the direction of a uniform electric field of magnitude 5×10^{4} NC^{-1}. Calculate the magnitude of the torque acting on the dipole.

Ans.

NCERT. **1.11.** A polythene piece rubbed with wool is found to have a negative charge of $3{\cdot}2 \times 10^{-7}$ C.

(*a*) Estimate the number of electrons transferred (from which to which ?)

(*b*) Is there a transfer of mass from wool to polythene?

Ans.

NCERT BACK EXERCISES

NCERT. **1.8.** Two point charges $q_A = 3\ \mu C$ and $q_B = -3\ \mu C$ are located 20 cm apart in vacuum.

(*a*) What is the electric field at the midpoint O of the line AB joining the two charges ?

(*b*) If a negative test charge of magnitude $1{\cdot}5 \times 10^{-9}$ C is placed at this point, what is the force experienced by the test charge ? *(C.B.S.E. 2003)*

Ans.

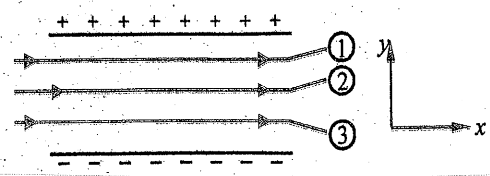
a)

b) as we know $\vec{E} = \dfrac{\vec{F}}{q_0}$

$\therefore\ \vec{F} = q_0 \vec{E}$

NCERT BACK EXERCISES

NCERT. **1.14.** **Figure shows tracks of three charged particles in a uniform electrostatic field. Give the signs of the three charges. Which particle has the highest charge to mass ratio ?**



Ans.

NCERT BACK EXERCISES

NCERT. 1.21. **A conducting sphere of radius 10 cm has an unknown charge. If the electric field 20 cm from the centre of the sphere is $1{\cdot}5 \times 10^3$ N/C and points radially inward, what is the net charge on the sphere ?**

Ans. Using $E = \frac{9 \times 10^9 (q)}{r^2}$, we get

Since electric field points radially inward, so E is taken as –ve.

$$q = -\frac{Er^2}{9 \times 10^9}$$

$$= -\frac{(1{\cdot}5 \times 10^3)[(20 \times 10^{-2})]^2}{9 \times 10^9}$$

$$= -\frac{(1{\cdot}5 \times 10^3)(0{\cdot}2)^2}{9 \times 10^9}$$

$= -6{\cdot}67$ nC.

NCERT EXAMPLE

NCERT. **Example 1.8** An electron falls through a distance of 1.5 cm in a uniform electric field of magnitude 2.0×10^4 N C^{-1} [Fig. 1.13(a)]. The direction of the field is reversed keeping its magnitude unchanged and a proton falls through the same distance [Fig. 1.13(b)]. Compute the time of fall in each case. Contrast the situation with that of 'free fall under gravity'.

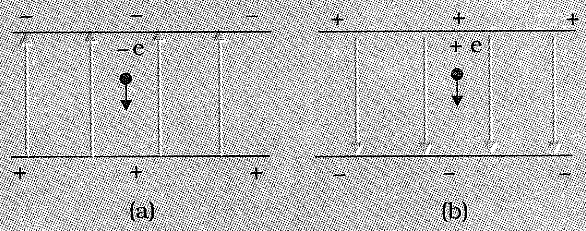


FIGURE 1.13

Solution

EXAMPLE 1.8

ELECTRIC FIELD LINES

Q.1 What are electric field lines? Write their important properties, also explain their mapping?

A. Definition:

The picture of field lines was invented by Faraday to develop an intuitive non-mathematical way of visualising electric fields around charged configurations. Faraday called them *lines of force*. *This term is somewhat misleading, especially in case of magnetic fields. The more appropriate term is field lines (electric or magnetic) that we have adopted in this book.*

Electric field lines are thus a way of pictorially mapping the electric field around a configuration of charges. An electric field line is, in general,

we place a small planar element of area ΔS normal to $\mathbf{E}$ at a point, the number of field lines crossing it is proportional* to $E\ \Delta S$. Now suppose we tilt the area element by angle θ. Clearly, the number of field lines crossing the area element will be smaller. The projection of the area element normal to E is $\Delta S \cos\theta$. Thus, the number of field lines crossing ΔS is proportional to $E\,\Delta S \cos\theta$. When $\theta = 90°$, field lines will be parallel to ΔS and will not cross it at all (Fig. 1.18).

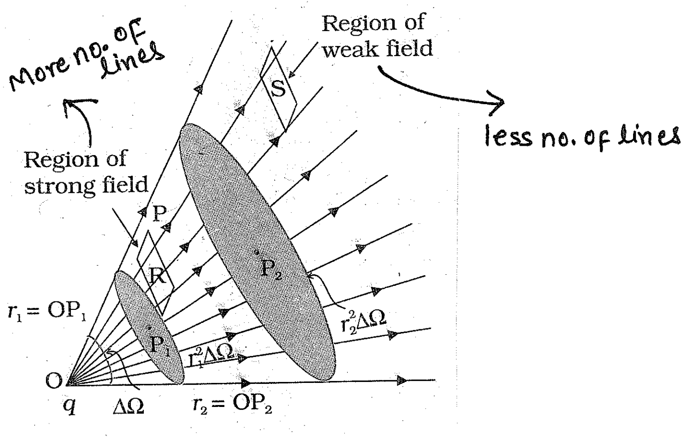


FIGURE 1.16 Dependence of electric field strength on the distance and its relation to the number of field lines.

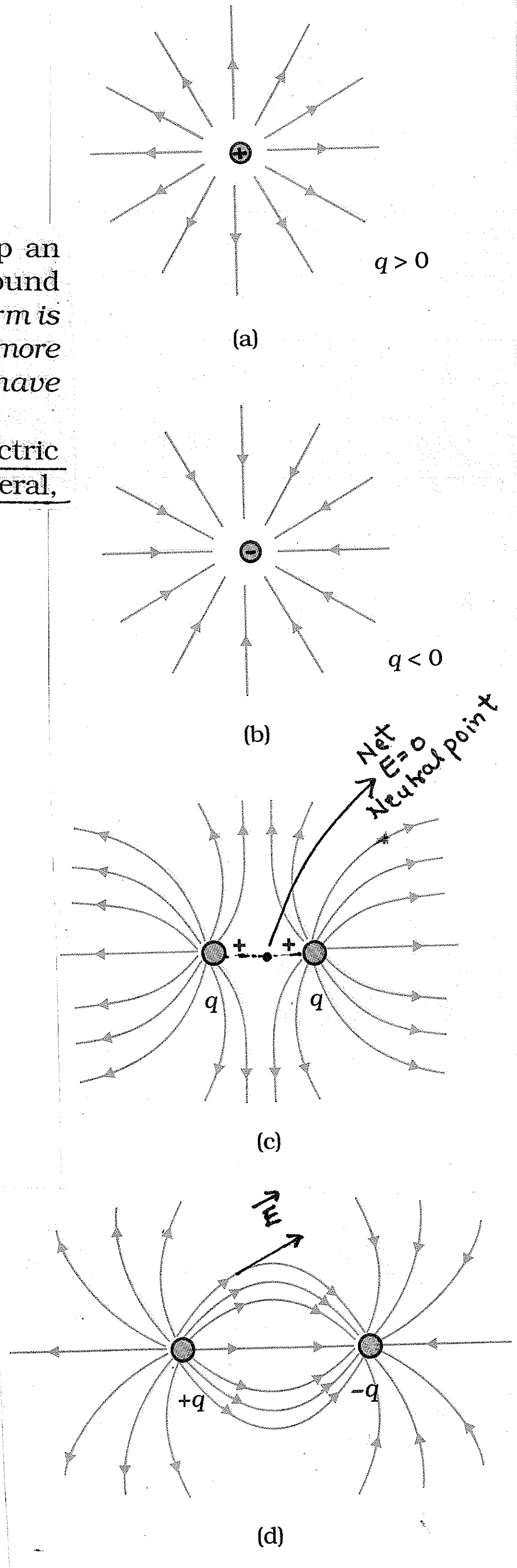


FIGURE 1.17 Field lines due to some simple charge configurations.

ELECTRIC FIELD LINES

Properties of electric field lines:

1. hypothetical property:

2. tangent:

3. No. of field lines:

4. Loop property:

5.Intersection property:

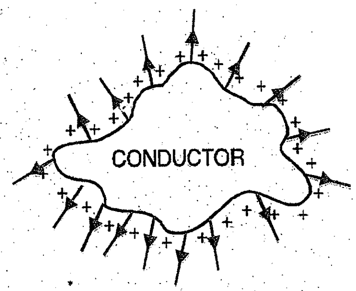
6. Perpendicular property:

MAPING OF FIELD LINES:

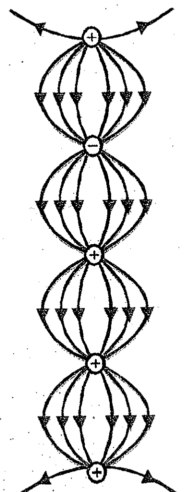
NCERT BACK EXERCISES

NCERT. **1.26. Which among the curves shown in figure cannot possibly represent electrostatic field lines ?**

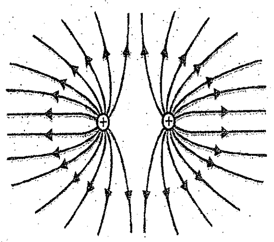
Ans:-



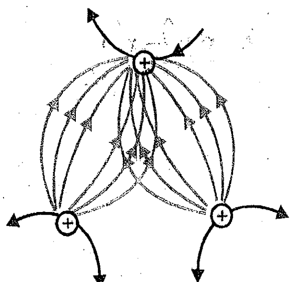
(a)



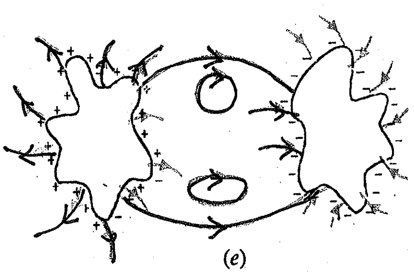
(b)



(c)



(d)

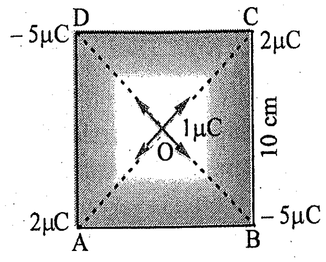


(e)

NCERT BACK EXERCISES

NCERT **1.6. Four point charges $q_A = 2\ \mu C$, $q_B = -5\ \mu C$, or $q_C = -2\ \mu C$ and $q_D = -5\ \mu C$ 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 centre of the Square?**

Ans. The symmetry of the figure clearly indicates that 1 μC charge will experience equal and opposite forces due to equal charges of 2 μC placed at A and C. Similarly, 1 μC charge will experience equal and opposite forces due to -5 μC charges placed at D and B.



NCERT **1.7.** (*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 ?**

Ans. (*a*) An electrostatic field line starts from a positive charge and ends at a negative charge. The tangent to this line at any point represents the direction of the field at that point. Since electric field is continuous so the field line has to be continuous.

(*b*) If two field lines cross each other, then at the point of intersection, there will be two tangents showing that at the point of intersection, there are two directions of a given electric field. This is not possible. Hence, two field lines cannot cross each other.

PHYSICAL SIGNIFICANCE OF ELECTRIC FIELD

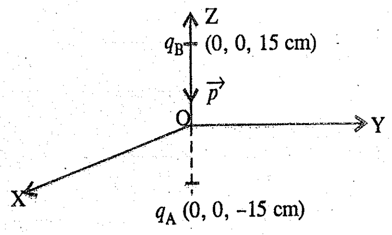
The true physical significance of the concept of electric field, however, emerges only when we go beyond electrostatics and deal with time-dependent electromagnetic phenomena. Suppose we consider the force between two distant charges q_1, q_2 in accelerated motion. Now the greatest speed with which a signal or information can go from one point to another is c, the speed of light. Thus, the effect of any motion of q_1 on q_2 cannot arise instantaneously. There will be some time delay between the effect (force on q_2) and the cause (motion of q_1). It is precisely here that the notion of electric field (strictly, electromagnetic field) is natural and very useful. *The field picture is this: the accelerated motion of charge q_1 produces electromagnetic waves, which then propagate with the speed c, reach q_2 and cause a force on q_2.* The notion of field elegantly accounts for the time delay. Thus, even though electric and magnetic fields can be detected only by their effects (forces) on charges, they are regarded as physical entities, not merely mathematical constructs. They have an *independent dynamics* of their own, i.e., they evolve according to laws of their *own*. They can also transport energy. Thus, a source of time-dependent electromagnetic fields, turned on for a short interval of time and then switched off, leaves behind propagating electromagnetic fields transporting energy. The concept of field was first introduced by Faraday and is now among the central concepts in physics.

NCERT BACK EXERCISES

NCERT. **1.9.** **A system has two charges $q_A = 2\cdot5 \times 10^{-7}$ C and $q_B = -2\cdot5 \times 10^{-7}$ C located at points A : (0, 0, –15 cm) and B : (0, 0, + 15 cm), respectively. What are the total charge and electic dipole moment of the system?**

Ans. Clearly, the given points are lying on z-axis.

Distance between charges, $2l$



$= 15 + 15 = 30$ cm $= 0\cdot3$ m

Total charge

$= (2\cdot5 \times 10^{-7}) - (2\cdot5 \times 10^{-7}) = 0$

Dipole moment

$= q \times 2l = 2\cdot5 \times 10^{-7} \times 0\cdot3$

$= 7\cdot5 \times 10^{-8}$ C m along negative z-axis.

NCERT BACK EXERCISES

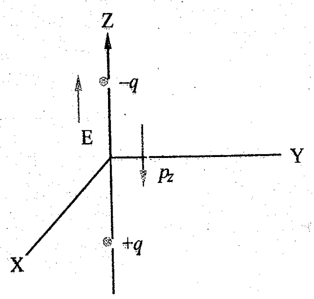
NCERT. 1.31. It is now believed that protons and neutrons (which constitute nuclei of ordinary matter) are themselves build out of more elementary units called quarks. A proton and a neutron consist of three quarks each. Two types of quarks, the so called 'up' quark (denoted by u) of charge + (2/3)e, and the 'down' quark (denoted by d) of charge (–1/3)e, together with electrons build up ordinary matter. (Quarks of other types have also been found which give rise to different unusual varieties of matter.) Suggest a possible quark composition of a proton and neutron.)

Ans:-

NCERT BACK EXERCISES

NCERT. **1.27. In a certain region of space, electric field is along the z-direction throughout. The magnitude of electric field is, however, not constant but increases uniformly along the positive z-direction, at the rate of 10^5 N C^{-1} per metre. What are the force and torque experienced by a system having a total dipole moment equal to 10^{-7} C m in the negative z-direction ?**

Ans. Suppose the dipole is along z-axis.



Then dipole moment, $p_z = -10^{-7}$ m

$$\frac{\partial E}{\partial z} = 10^5 \text{ NC}^{-1} \text{ m}^{-1}$$

$$\text{Here F} = p_x \frac{\partial E}{\partial x} + p_y \frac{\partial E}{\partial y} + p_z \frac{\partial E}{\partial z}$$

$$= 0 + 0 - 10^{-7} \times 10^5$$

$$= -10^{-2} \text{ N.}$$

Torque, $\tau = pE \sin\theta = pE \sin 180° = 0$

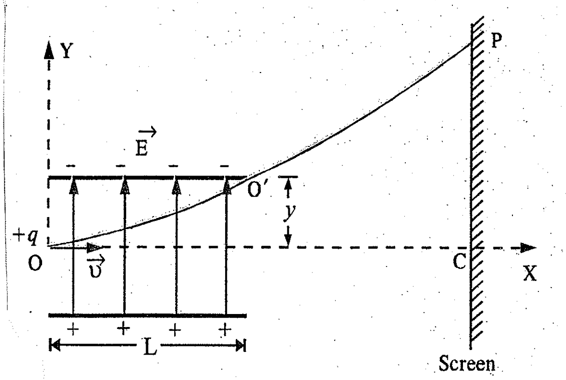
[$\because$ p and E are opposite to each other]

NCERT BACK EXERCISES

NCERT. 1.33. A particle of mass m and charge $(-q)$ enters the region between the two charged plates initially moving along x-axis with speed σ_x, (like particle 1 in figure.) The length of plate is L and an uniform electric field E is maintained between the plates. Show that the vertical deflection of the particle at the far edge of the plate is $qEL^2/(2m\,\upsilon_x^2)$.

Compare this motion with motion of a projectile in gravitational field discussed in Section 4.10. of Class XI Textbook of Physics.

Ans:-



NCERT ADDITIONAL EXERCISES & NCERT TEXT

NCERT. **1.34. Suppose that the particle in Q 1.33 is an electron projected with velocity $\upsilon_x = 2{\cdot}0 \times 10^6$ ms^{-1}. If E between the plates separated by 0·5 cm is $9{\cdot}1 \times 10^2$ N/C, where will the electron strike the upper plate ? ($|e| = 1{\cdot}6 \times 10^{-19}$ C, $m_e = 9{\cdot}1 \times 10^{-31}$ kg.)**

Ans. Using $y = \dfrac{qEL^2}{2mv_x^2}$, we get

$$\frac{0\cdot5\times10^{-2}}{2} = \frac{(1\cdot6\times10^{-19})(9\cdot1\times10^{2})(L^2)}{2\times9\cdot1\times10^{-31}\times2\times10^{6}\times2\times10^{6}}$$

i.e. $L^2 = \dfrac{2}{1\cdot6}\times10^{-4}$

i.e. $L = 1{\cdot}12 \times 10^{-2} = 1{\cdot}12$ cm.

Important NCERT TEXT !

You know that all matter is made up of atoms and/or molecules. Although normally the materials are electrically neutral, they do contain charges; but their charges are exactly balanced. Forces that hold the molecules together, forces that hold atoms together in a solid, the adhesive force of glue, forces associated with surface tension, all are basically electrical in nature, arising from the forces between charged particles. Thus the electric force is all pervasive and it encompasses almost each and every field associated with our life. It is therefore essential that we learn more about such a force.

To electrify a neutral body, we need to add or remove one kind of charge. When we say that a body is charged, we always refer to this excess charge or deficit of charge. In solids, some of the electrons, being less tightly bound in the atom, are the charges which are transferred from one body to the other. A body can thus be charged positively by losing some of its electrons. Similarly, a body can be charged negatively by gaining of electrons.

MASS PHYSICS

FOCUS NCERT/CBSE MODULE

MCQS BASED ON ELECTRIC FIELD

MULTIPLE CHOICE QUESTIONS

(Only One Option Correct)

1. S.I. unit of electric field intensity is

(*a*) N C (*b*) N C^2

(*c*) N C^{-1} (*d*) N^{-1} C.

(Bihar 2013, Uttarkhand 2018)

ANS. (*c*). $E = \frac{F}{q}$.

2. Force acting on a stationary point charge q in an electric field $\vec{E}$ is

(*a*) $\frac{\vec{E}}{q}$ (*b*) $q\vec{E}$

(*c*) $q^2\vec{E}$ (*d*) $\frac{\vec{E}}{q^2}$. *(Jharkhand 2013)*

ANS. (*b*).

3. Electric field due to a source charge Q at the location of test charge q_0 is $\vec{E}$. What is the electric field due to this source charge if test charge is replaced by $-q_0$?

(*a*) $-q_0\vec{E}$ (*b*) $\frac{\vec{E}}{-q_0}$

(*c*) Zero (*d*) $\vec{E}$.

ANS. (*d*). Electric field of a source charge is independent of test charge.

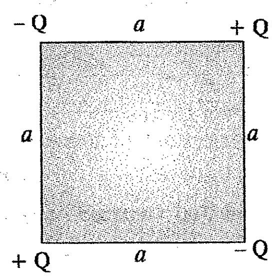
4. Electric field intensity due to a source charge Q at a distance *r* varies as

(*a*) r (*b*) r^2

(*c*) r^{-1} (*d*) r^{-2}. *(M.P. Board 2013)*

ANS. (*d*). $E = \frac{1}{4\pi \epsilon_0}\frac{Q}{r^2}$.

5. What is the electric field intensity at the centre of a square having charges at its corners as shown in figure ?

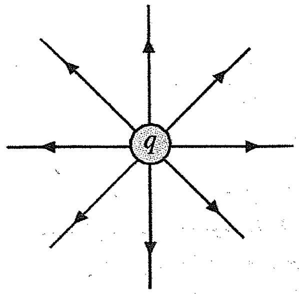


(*a*) $\frac{1}{4\pi \epsilon_0}\frac{4Q}{a^2}$ (*b*) $\frac{1}{4\pi \epsilon_0}\frac{Q}{a^2}$

(*c*) $\frac{1}{4\pi \epsilon_0}\frac{Q}{2a^2}$ (*d*) zero.

ANS. (*d*).

6. Electric field lines emanating from a charge q are shown in figure. What is the sign of the charge q ?



(*a*) positive

(*b*) negative

(*c*) neither positive nor negative

(*d*) may be positive or negative.

ANS. (*a*). Electric field lines start from positive charge and end on negative charge.

7. Dimensional formula of electric field is

(*a*) $[M L T^{-3} A^{-1}]$

(*b*) $[M L^2 T A^{-1}]$

(*c*) $[M L T^2 A^{-1}]$

(*d*) $[M L T A^2]$.

ANS. (*a*). $E = F/q = \frac{F}{It}$

8. A stationary charge produces

(*a*) an electric field only

(*b*) a magnetic field only

(*c*) both (*a*) and (*b*)

(*d*) none of these. *(H.P.S.E.B. 2014)*

ANS. (*a*). A stationary electric charge produces an electric field only.

ELECTRIC FLUX

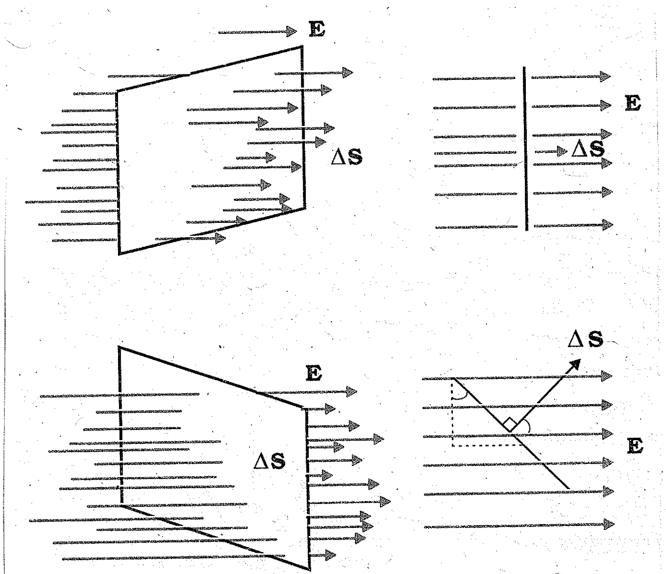


FIGURE 1.18 Dependence of flux on the inclination θ between $\mathbf{E}$ and $\hat{\mathbf{n}}$.

Def No. 1:-

Def. No. 2:-

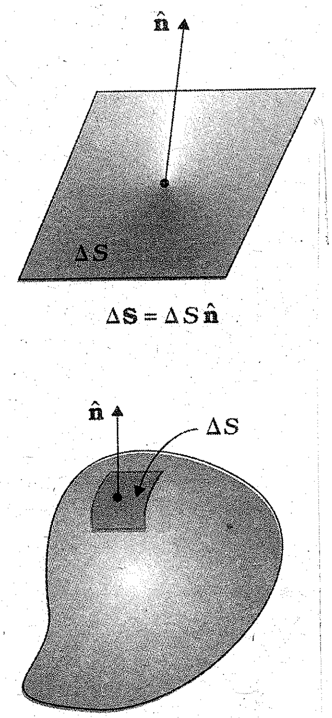


FIGURE 1.19 Convention for defining normal $\hat{\mathbf{n}}$ and ΔS.

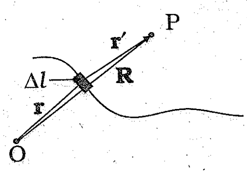
S.I units of flux:-

Area Vector $\hat{n}$

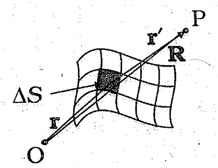
CONTINUOUS CHARGE DISTRIBUTION

Q.1 What is continuous charge distribution C.C.D , explain its various forms?

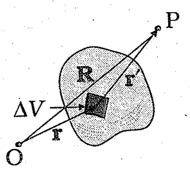
Ans.



Line charge $\Delta Q = \lambda \Delta l$



Surface charge $\Delta Q = \sigma \Delta S$



Volume charge $\Delta Q = \rho \Delta V$

FIGURE 1.24 Definition of linear, surface and volume charge densities. In each case, the element (Δl, ΔS, ΔV) chosen is small on the macroscopic scale but contains a very large number of microscopic constituents.

We have so far dealt with charge configurations involving discrete charges $q_1, q_2, \ldots, q_n$. One reason why we restricted to discrete charges is that the mathematical treatment is simpler and does not involve calculus. For many purposes, however, it is impractical to work in terms of discrete charges and we need to work with continuous charge distributions. For example, on the surface of a charged conductor, it is impractical to specify the charge distribution in terms of the locations of the microscopic charged constituents. It is more feasible to consider an area element ΔS (Fig. 1.24) on the surface of the conductor (which is very small on the macroscopic scale but big enough to include a very large number of electrons) and specify the charge ΔQ on that element. We then define a *surface charge density* σ at the area element by

$$\sigma = \frac{\Delta Q}{\Delta S} \rightarrow \sigma = \frac{dq}{ds} \quad \text{Units} \rightarrow C\,m^{-2} \tag{1.23}$$

We can do this at different points on the conductor and thus arrive at a continuous function σ, called the surface charge density. The surface charge density σ so defined ignores the quantisation of charge and the discontinuity in charge distribution at the microscopic level*. σ represents macroscopic surface charge density, which in a sense, is a smoothed out average of the microscopic charge density over an area element ΔS which, as said before, is large microscopically but small macroscopically. The units for σ are C/m^2.

Similar considerations apply for a line charge distribution and a volume charge distribution. The *linear charge density* λ of a wire is defined by

$$\lambda = \frac{\Delta Q}{\Delta l} \rightarrow \lambda = \frac{dq}{dl} \quad \text{Units} \rightarrow C\,m^{-1} \tag{1.24}$$

where Δl is a small line element of wire on the macroscopic scale that, however, includes a large number of microscopic charged constituents, and ΔQ is the charge contained in that line element. The units for λ are C/m. The *volume charge density* (sometimes simply called charge density) is defined in a similar manner:

$$\rho = \frac{\Delta Q}{\Delta V} \rightarrow \rho = \frac{dq}{dV} \quad \text{Units} \rightarrow C\,m^{-3} \tag{1.25}$$

where ΔQ is the charge included in the macroscopically small volume element ΔV that includes a large number of microscopic charged constituents. The units for ρ are C/m^3.

MASS PHYSICS

FOCUS NCERT/CBSE MODULE

GAUSS'S THEORM

John Carl Friedrich Gauss, a German scientist gave a relationship between flux through a closed surface and the charge enclosed by the surface. This relationship is known as Gauss's Law

USE OF <u>ELECTRIC FLUX AND AREA VECTORS</u>

Q. 1 State and explain Gauss theorem for electrostatic?

Ans.

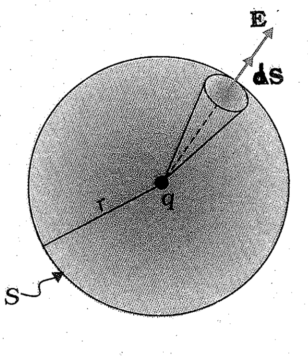
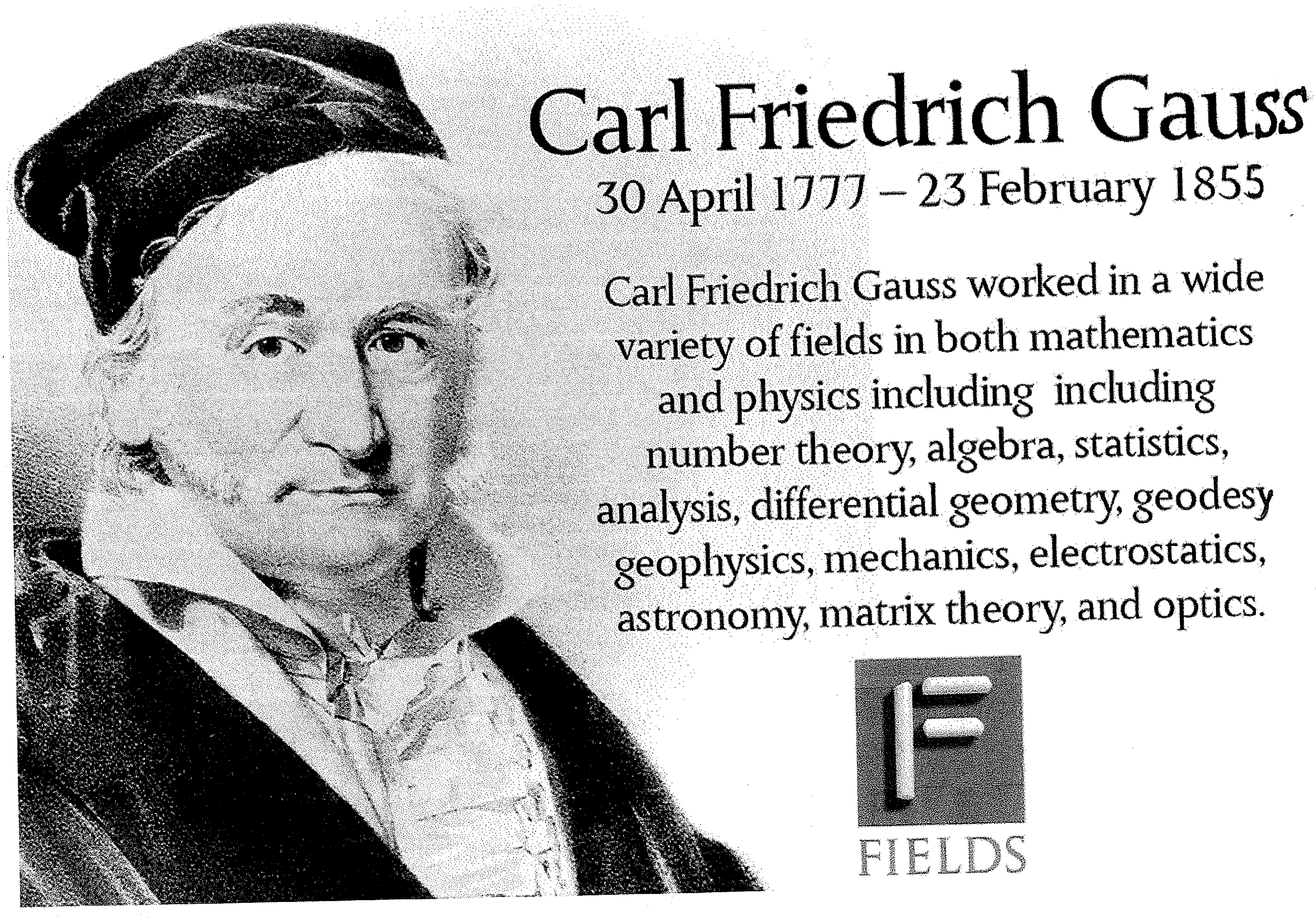


FIGURE 1.25 Flux through a sphere enclosing a point charge q at its centre.

GAUSS'S LAW


Carl Friedrich Gauss
30 April 1777 – 23 February 1855
Carl Friedrich Gauss worked in a wide variety of fields in both mathematics and physics including including number theory, algebra, statistics, analysis, differential geometry, geodesy geophysics, mechanics, electrostatics, astronomy, matrix theory, and optics.
FIELDS

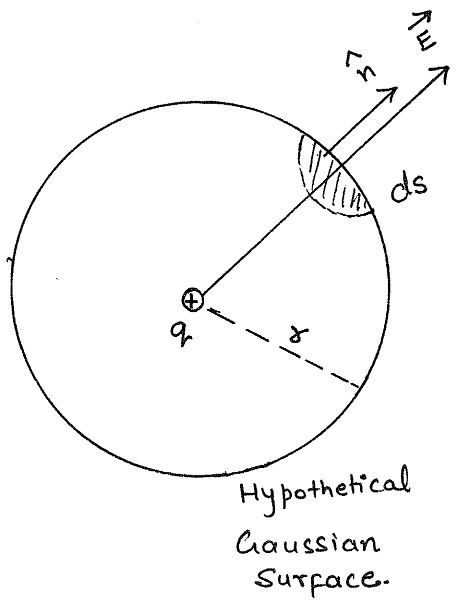
RELATION BETWEEN GAUSS'S LAW & COULOMB'S LAW

Important Q.1 Deduce Coulomb's law from Gauss's law

Or

Deduce Gauss's law from Coulomb's law

Ans:- Coulomb's law from Gauss's law :-



RELATION BETWEEN GAUSS'S LAW & COULOMB'S LAW

NCERT IN TEXT POINTS ABOUT GAUSS'S LAW

note some important points regarding this law:

(i) Gauss's law is true for any closed surface, no matter what its shape or size.

(ii) The term q on the right side of Gauss's law, Eq. (1.31), includes the sum of all charges enclosed by the surface. The charges may be located anywhere inside the surface.

(iii) In the situation when the surface is so chosen that there are some charges inside and some outside, the electric field [whose flux appears on the left side of Eq. (1.31)] is due to all the charges, both inside and outside S. The term q on the right side of Gauss's law, however, represents only the total charge inside S.

(iv) The surface that we choose for the application of Gauss's law is called the Gaussian surface. You may choose any Gaussian surface and apply Gauss's law. However, take care not to let the Gaussian surface pass through any discrete charge. This is because electric field due to a system of discrete charges is not well defined at the location of any charge. (As you go close to the charge, the field grows without any bound.) However, the Gaussian surface can pass through a continuous charge distribution.

(v) Gauss's law is often useful towards a much easier calculation of the electrostatic field *when the system has some symmetry*. This is facilitated by the choice of a suitable Gaussian surface.

(vi) Finally, Gauss's law is based on the inverse square dependence on distance contained in the Coulomb's law. Any violation of Gauss's law will indicate departure from the inverse square law.

NCERT EXAMPLE

NCERT. **Example 1.11** The electric field components in Fig. 1.27 are $E_x = \alpha x^{1/2}$, $E_y = E_z = 0$, in which α = 800 N/C $m^{1/2}$. Calculate (a) the flux through the cube, and (b) the charge within the cube. Assume that a = 0.1 m.

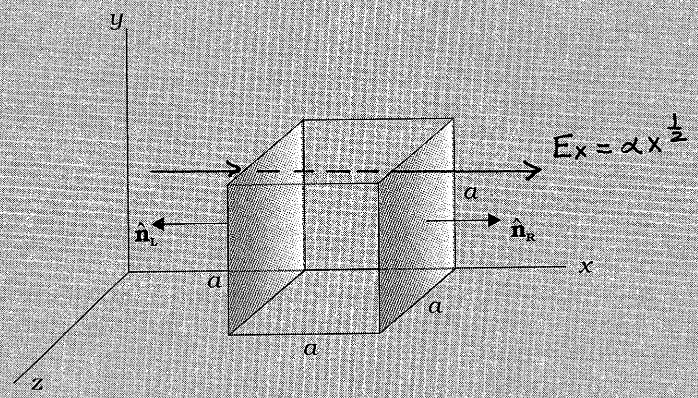


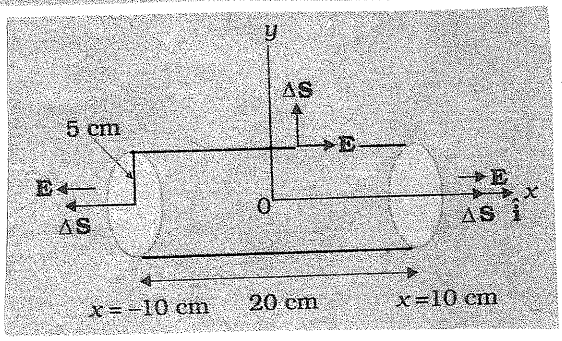
FIGURE 1.27

ution

NCERT EXAMPLE

Example 1.12 An electric field is uniform, and in the positive x direction for positive x, and uniform with the same magnitude but in the negative x direction for negative x. It is given that $\mathbf{E} = 200\ \hat{\mathbf{i}}$ N/C for $x > 0$ and $\mathbf{E} = -200\ \hat{\mathbf{i}}$ N/C for $x < 0$. A right circular cylinder of length 20 cm and radius 5 cm has its centre at the origin and its axis along the x-axis so that one face is at $x = +10$ cm and the other is at $x = -10$ cm (Fig. 1.28). (a) What is the net outward flux through each flat face? (b) What is the flux through the side of the cylinder? (c) What is the net outward flux through the cylinder? (d) What is the net charge inside the cylinder?

Solution



Ans.

(a).

(b).

(c).

(d).

NCERT BACK EXERCISES

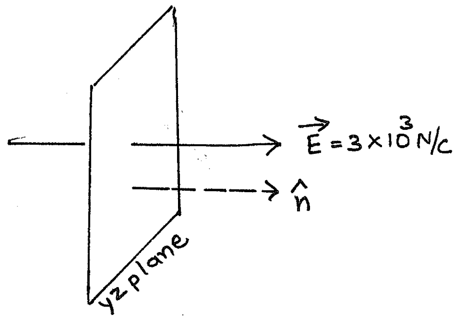
NCERT. **1.15.** Consider a uniform electric field $\vec{E} = 3 \times 10^3\ \hat{i}$ N/C.

(*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 ?

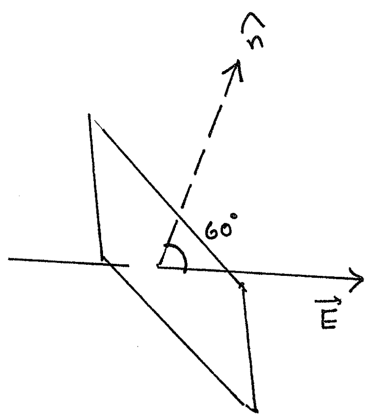
(*b*) What is the flux through the same square if the normal to its plane makes a 60° angle with the *x*-axis ?

Ans.

(a)



(b)



NCERT BACK EXERCISES

NCERT. **1.16. What is the net flux of the uniform electric field of Problem 1.15 through a cube of side 20 cm oriented so that its faces are parallel to the co-ordinate planes ?**

Ans. Zero, because number of field lines entering the cube is equal to the number of field lines coming out of the cube.

NCERT. **1.17. Careful measurement of the electric field at the surface of a black box indicates that the net outward flux through the surface of the box is $8{\cdot}0 \times 10^3$ Nm^2/C.**

(a) What is the net charge inside the box ?

(b) If the net outward flux through the surface of the box were zero, could you conclude that there were no charges inside the box ? Why or why not ?

Ans. (a) Using $\phi = q/\varepsilon_0$, we get $q = \phi\, \varepsilon_0$

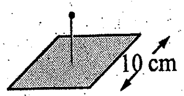
$$= (8 \times 10^3)(8{\cdot}854 \times 10^{-12})$$
$$= 70{\cdot}8 \times 10^{-9}\ C = 0{\cdot}07\ \mu C$$

(b) No, it cannot be said so because there may be equal number of positive and negative elementary chages inside the box. It can only be said that *net charge* inside the box is zero.

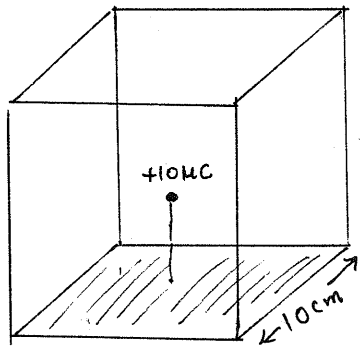
NCERT BACK EXERCISES

NCERT. 1.18. A point charge + 10 μC is a distance 5 cm directly above the centre of a square of side 10 cm, as shown in the given figure. What is the magnitude of the electric flux through the square ?

[Hint. Think of the square as one fact of a cube with edge 10 cm.]



Ans.



NCERT BACK EXERCISES

NCERT. 1.19. A point charge of 2·0 μC is at the centre of a cubic Gaussian surface 9·0 cm on edge. What is the net electric flux through the surface ?

Ans.

NCERT. 1.20. A point charge causes an electric flux of $-1\cdot0 \times 10^3$ Nm^2/C to pass through a spherical Gaussian surface of 10·0 cm radius centred on the charge.

(*a*) If the radius of the Gaussian surface were doubled, how much flux would pass through the surface ?

(*b*) What is the value of the point charge ?

Ans.

NCERT BACK EXERCISES

NCERT. **1.22.** **A uniformly charged conducting sphere of 2·4 m diameter has a surface charge density of 80·4 μC/m².**

(*a*) Find the charge on the sphere.

(*b*) What is the total electric flux leaving the surface of the sphere ? ***(C.B.S.E. 2009 C)***

Ans. (*a*) ***Charge on the sphere*** is given by

$$q = \sigma \times 4\pi R^2$$

MASS PHYSICS

FOCUS NCERT/CBSE MODULE

APPLICATIONS OF GAUSS'S LAW

By using Gauss's law we can find electric field due to continuous charge distribution.

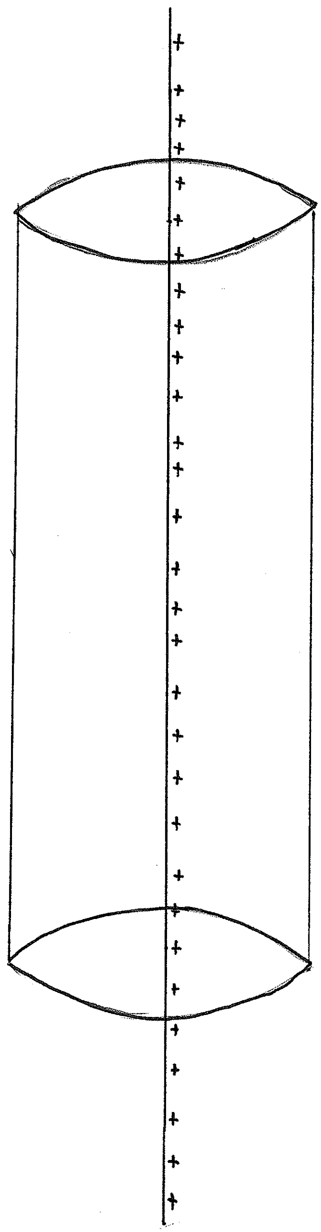
According to the shape and distribution of charge we have 4 Applications of Gauss's law

APPLICATION NO.1 **E DUE TO AN INFINITELY LONG STRAIGHT UNIFORMLY CHARGED THIN WIRE**

Q. 1 Find electric field due to an infinitely long straight uniformly charged wire by using Gauss's law?

Ans. Consider an infinite and very thin straight uniformly charged wire having linear charge density λ

To calculate the electric field intensity E at a point P, distance r from the line, draw hypothetical cylindrical Gaussian surface of radius r and length l around the charged line as shown in the diagram



ELECTRIC FIELD DUE TO UNIFORMLY CHARGED INFINITE STRAIGHT WIRE

SPECIAL CASES

NCERT BACK EXERCISES

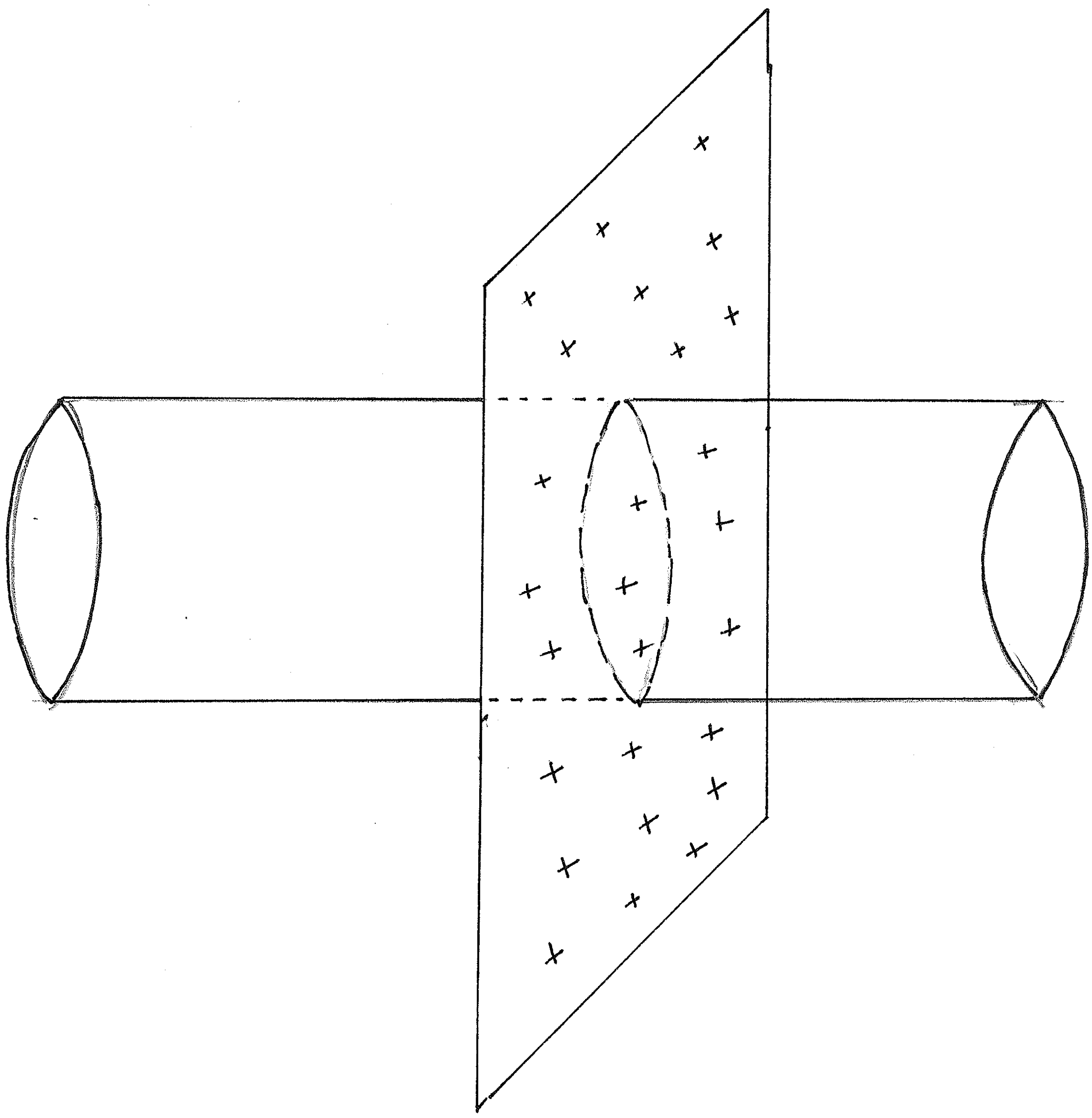
NCERT. **1.23. An infinite line charge produces a field of 9×10^4 N/C at a distance of 2 cm. Calculate the linear charge density.**

Ans.

APPLICATION NO.2 **E DUE TO UNIFORMLY CHARGED INFINITE PLANE SHEET**

Q.1 Find Electric field due to a uniformly charged infinite plane sheet by using Gauss's law?

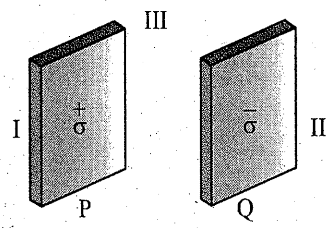
Ans.



ELECTRIC FIELD DUE TO UNIFORMLY CHARGED INFINITE PLANE SHEET

NCERT BACK EXERCISES

NCERT. **1.24.** **Two large, thin metal plates are parallel and close to each other. On their inner faces, the plates have surface charge densities of opposite signs and of magnitude $17{\cdot}0 \times 10^{-22}$ C/m^2. What is E :**



Note:- If the plates are close to each other then neglect the distance between them.

(*a*) in the outer region of the first plate,

(*b*) in the outer region of the second plate, and

(*c*) between the plates ?

Ans:-

(a)

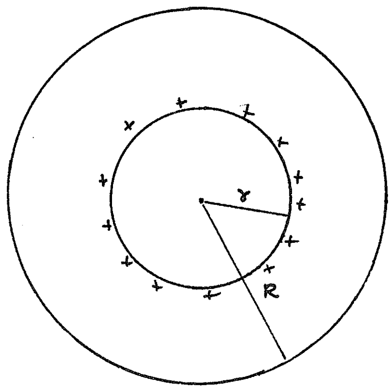
(b)

(c)

APPLICATION NO.3 **E DUE TO UNIFORMLY CHARGED HOLLOW SPHERE**

Q.1 Find Electric field due to a uniformly charged thin spherical shell by using Gauss's law?

Ans. Consider a positive charge q distributed uniformly on the surface of a spherical shell of radius r. let us consider a point outside the shell at a distance R from the center of the shell (R>r), where Electric field is to be calculated. Draw a hypothetical Gaussian surface in the form of a sphere of radius R with O as the center as shown in the diagram



ELECTRIC FIELD DUE TO UNIFORMLY CHARGED HOLLOW SPHERE

SPECIAL CASES:-

a) When Gaussian surface is outside the sphere: $R > r$

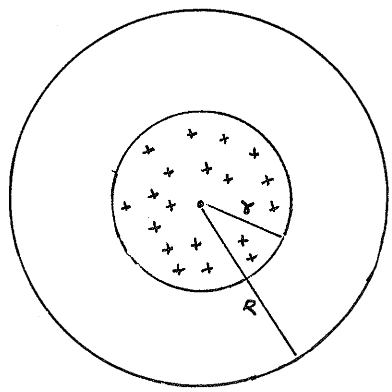
b) When Gaussian Surface is on the surface of charged sphere $R = r$

c) When Gaussian surface is Inside the charged hollow sphere $R < r$

APPLICATION NO.4 **E DUE TO UNIFORMLY CHARGED DENSE SPHERE**

Q.1 Find Electric field due to a uniformly charged solid(dense) sphere by using Gauss's law?

Ans. Consider a positive charge q distributed uniformly inside a spherical dense sphere of radius r. let us consider a point outside the shell at a distance R from the center of the shell (R>r), where Electric field is to be calculated. Draw a hypothetical Gaussian surface in the form of a sphere of radius R with O as the center as shown in the diagram



E DUE TO UNIFORMLY CHARGED DENSE SPHERE

SPECIAL CASES:-

a) When Gaussian surface is outside the charged sphere $R > r$

$E =$

b) When Gaussian surface is on the surface of dense charged sphere $R = r$

$E =$

c) When Gaussian surface is inside the dense charged sphere $R < r$

$E =$

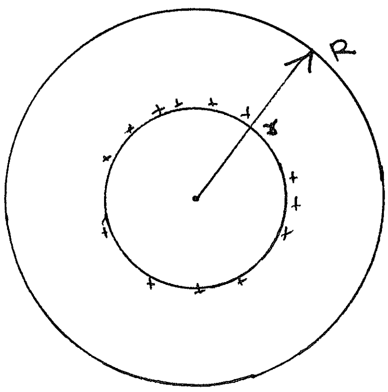
ELECTRIC FIELD DUE TO HOLLOW & DENSE CHARGED SPHERE

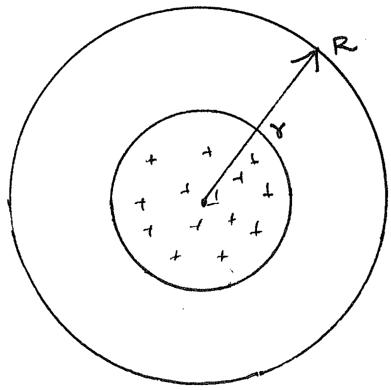
IMPORTANT QUESTION:

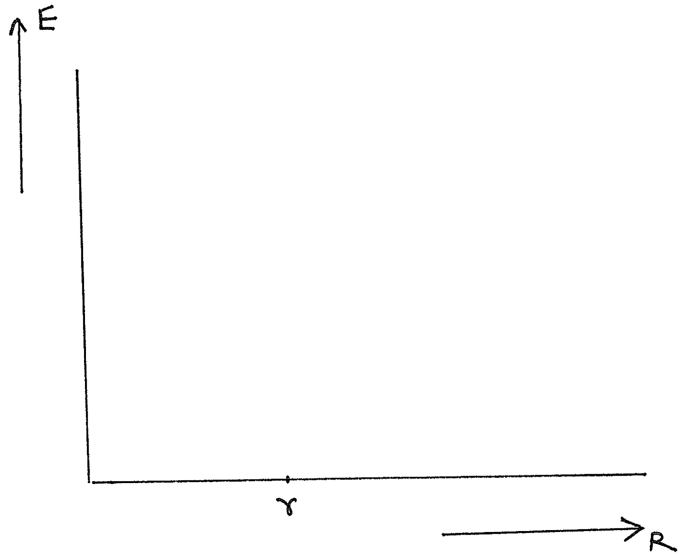
Q.1 Plot the graph showing the variations of electric field w.r.t distance R from the center of:

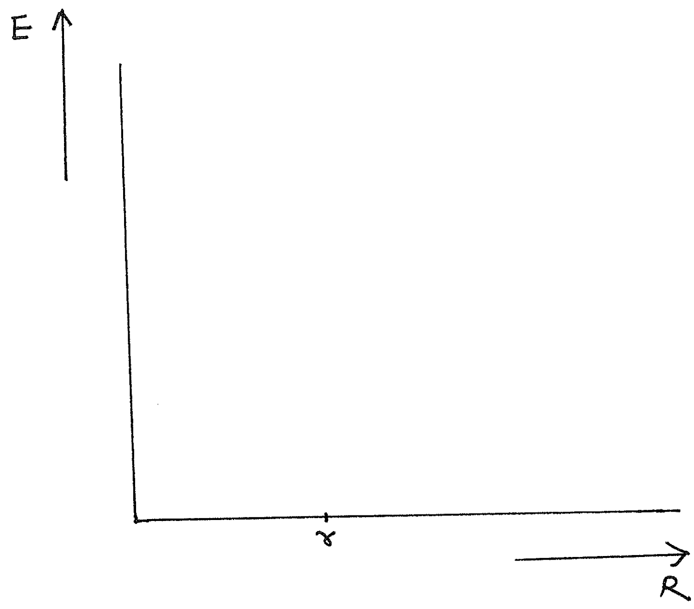
1. Hollow charged sphere.
2. Dense charged sphere.

Ans.





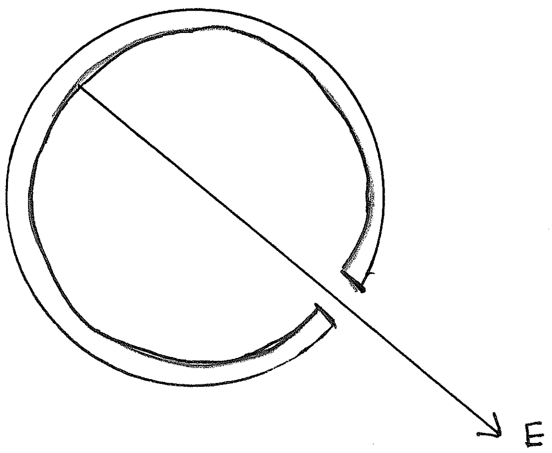




NCERT BACK EXERCISES

NCERT **1.29.** **A hollow charged conductor has a tiny hole cut into its surface. Show that the electric field in the hole is $(\sigma/2\varepsilon_0)\,\hat{n}$, where $\hat{n}$ is the unit vector in the outward normal direction, and σ is the surface charge density near the hole.**

Ans.

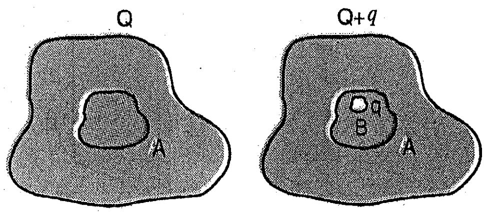


NCERT BACK EXERCISES

NCERT 1.28. **(a) A conductor A with a cavity as shown in figure (a) is given a charge Q. Show that the entire charge must appear on the outer surface of the conductor.**

(b) Another conductor B with charge q is inserted into the cavity keeping B insulated from A. Show that the total charge on the outside surface of A is Q + q [Figure (b)].

(c) A sensitive instrument is to be shielded from the strong electrostatic fields in its environment. Suggest a possible way.



(a) (b)

Ans. Select a Gaussian surface lying wholly inside the conductor but very near to the surface of the conductor.

(a) There is no electric field inside the conductor so electric flux through Gaussian surface is zero or in other words, net charge inside the Gaussian surface is zero. Then it can be said that the charge lies outside the Gaussian surface *i.e.* on the outer surface of the conductor.

(b) Charge q inside the cavity will induce a charge $-q$ on the inner side of cavity and thus $+q$ will appear on outer surface. Thus total charge will be $(q + Q)$.

(c) The instrument should be enclosed in a metallic shell so that the effect of electrostatic field is cancelled out.

NCERT BACK EXERCISES

NCERT. **1.30.** **Obtain the formula for the electric field due to a long thin wire of uniform linear charge density λ without using Gauss's law.**

[Hint. Use Coulomb's law directly and evaluate the necessary integral.]

Ans.

NCERT ADDITIONAL EXERCISES

NCERT EXAMPLE

NCERT.

Example 1.13 An early model for an atom considered it to have a positively charged point nucleus of charge Ze, surrounded by a uniform density of negative charge up to a radius R. The atom as a whole is neutral. For this model, what is the electric field at a distance r from the nucleus?

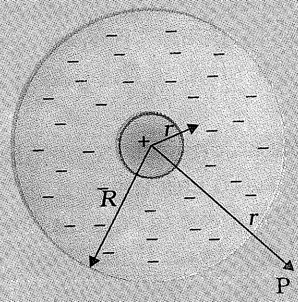


FIGURE 1.32

Ans.

MCQS BASED ON GAUSS LAW

Note: Electric flux is independent of the size of the closed surface.

1. Electric field intensity due to an infinitely long straight uniformly charged wire at a distance r from the wire varies as

(a) r (b) r^{-1}
(c) r^2 (d) r^{-2}.

Ans. (b). $E = \frac{1}{4\pi \epsilon_0} \frac{2\lambda}{r}$.

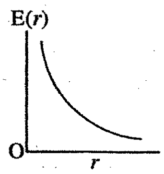
2. Electric field intensity due to uniformly charged thin infinite non-conducting plane sheet of surface charge density σ at a distance r is

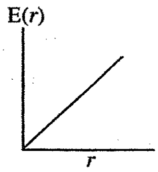
(a) $\frac{\sigma}{\epsilon_0}$ (b) $\frac{\sigma}{2\epsilon_0}$

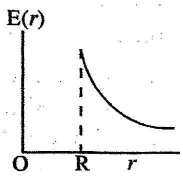
(c) $\frac{\sigma}{2r}$ (d) $\frac{\sigma}{2\epsilon_0 r}$.

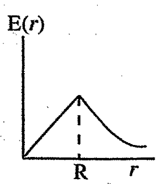
Ans. (b).

3. Which of the following graphs represent the variation of electric field intensity E(r) due to a charged spherical shell of radius R with distance r from its centre ?

(a) 

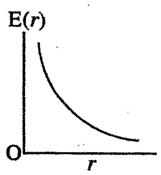
(b) 

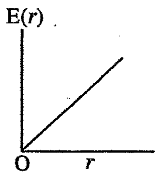
(c) 

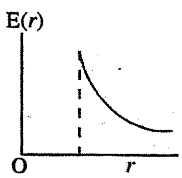
(d) 

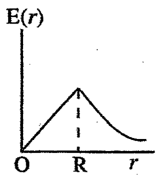
Ans. (c).

4. Which of the following graphs represent the variation of electric field intensity E(r) due to a charged insulating solid sphere of radius R with distance r from its centre.

(a) 

(b) 

(c) 

(d) 

Ans. (d).

5. The electric flux over the surface of a sphere if it is charged with 10 μC is

(a) $36\pi \times 10^4$ Nm^2/C (b) $36\pi \times 10^{-4}$ Nm^2/C
(c) $36\pi \times 10^6$ Nm^2/C (d) $36\pi \times 10^{-6}$ Nm^2/C.

(Bihar 2013)

Ans. (a). $\phi = \frac{q}{\epsilon_o} = 4\pi \times 9 \times 10^9 \times 10 \times 10^{-6}$

$$\left(\because \frac{1}{\epsilon_0} = 4\pi \times 9 \times 10^9 \text{ SI Unit}\right)$$

$= 36\pi \times 10^4$ Nm^2/C.

6. Dimensions of electric flux are

(a) $M^1L^3T^{-3}A^{-1}$ (b) $ML^2T^2A^{-1}$
(c) $ML^3T^2A^{-2}$ (d) $ML^2T^3A^{-1}$

(H.S.E.B. 2018)

Ans. (a).

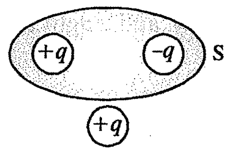
7. Eight dipoles of charges of magnitude $\pm e$ are placed inside a cube. What will be the total flux coming out of the cube ?

(a) 0 (b) ∞
(c) e (d) $-e$ (M.P.P.M.T.)

Ans. (a) Total flux coming out of the cube,

$$\phi = \frac{\Sigma q}{\epsilon_0} = \frac{+8e - 8e}{\epsilon_0} = \text{zero}$$

8. Shown below is distribution of charges :



The flux of electric field to these charges through the surface S is :

(a) $\frac{3q}{\epsilon_0}$ (b) $\frac{2q}{\epsilon_0}$

(c) $\frac{q}{\epsilon_0}$ (d) zero. (AIIMS 2003)

Ans. (d) Flux through a closed surface $= \frac{q_{net}}{\epsilon_0}$

Since $q_{net} = +q - q = 0$ and and the charge outside the surface does not contribute to the electric flux, therefore flux through the surface = 0.

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

(a) be reduced to half
(b) remain the same
(c) be doubled
(d) increase four times. (C.B.S.E. 2011)

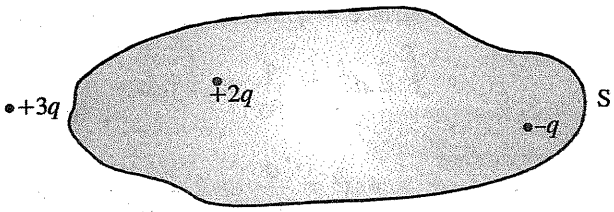
Ans. (b) Electric flux is independent of the size of the Gaussian surface.

QUESTIONS FROM CBSE BOARD EXAMS

10. Does the charge given to a metallic sphere depend on whether it is hollow or solid ? Give reason for your answer. ***(C.B.S.E. 2017)***

Ans. No, because charge resides on the surface of a metallic conductor.

11. Figure shows three charges $+2q$, $-q$ and $+3q$. Two charges $+2q$ and $-q$ are enclosed within a surface S. What is the electric flux due to this configuration through the surface S ?



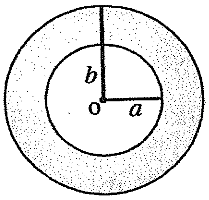
(C.B.S.E. 2010)

Ans. According to Gauss's law,

electric flux through the surface,

$$\phi = \frac{q_{net}}{\epsilon_0} = \frac{+2q - q}{\epsilon_0} = \frac{q}{\epsilon_0}$$

12. A point charge $+Q$ is placed at the centre O of an uncharged hollow spherical conductor of inner radius 'a' and outer radius 'b'.



Find the following :

(*a*) The magnitude and sign of the charge induced on the inner and outer surfaces of conducting shell.

(*b*) The magnitude of electric field vector at a distance (*i*) $r = \frac{a}{2}$, and (*ii*) $r = 2b$, from the shell. ***(C.B.S.E. 2018)***

Ans:-

MASS PHYSICS

FOCUS NCERT/CBSE MODULE

IMPORTANT TOPICS WITH FORMULAS FOR NUMERICALS

TOPIC 1 FORCE [COULOMBS LAW]

1. $F = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r^2}$ (Scalar form)
2. $\vec{F}_{12} = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r_{12}^2}\hat{r}_{12}$ (Vector form)
3. $\vec{F}_{12} = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2(\vec{r}_2 - \vec{r}_1)}{|\vec{r}_2 - \vec{r}_1|^3}$ (Position Vector Form)
4. $\vec{F}_0 = \frac{q_0}{4\pi\epsilon_0}\sum \frac{q_i \hat{r}_{i0}}{r_{i0}^2}$ (Superposition form.
5. K = Force constant $= \frac{1}{4\pi\epsilon_0}$

   $K = 9 \times 10^9\ Nm^2C^{-2}$

   ϵ_0 = absolute permittivity of Free space $= 8.85 \times 10^{-12}$

TOPIC-2 CHARGE AND CONTINUOUS CHARGE DISTRIBUTION

1. Charge $q = \pm ne$
2. L.C.D $\lambda = q/l$
3. S.C.D $\sigma = q/A$
4. VCD $\rho = q/V$
5. Dipole Moment $\vec{P} = q(2a)$

TOPIC-3 FLUX AND GAUSS'S LAW

1. Area Vector $\vec{ds} = ds\,\hat{n}$
2. Electric flux (ϕ_E)

   $\oint \vec{E}\cdot\vec{ds} = EA\cos\theta$
3. Gauss's Law.

   $\phi_E = \oint \vec{E}\cdot\vec{ds} = \frac{q}{\epsilon_0}$

   q = net charged enclosed.

   Unit of $\phi_E = NC^{-1}m^2$.

TOPIC 4 ELECTRIC FIELD [E]

1. due to single charge

   E =
2. due to system of charges.

   E =
3.
4.
5.
6.
7.
8.
9.
10.
11. Relation between E & V

    E =
12. Relation between $\vec{E}$ & $\vec{B}$

    E =

IMPORTANT SELF PRACTICE TEST FOR BOARD EXAM

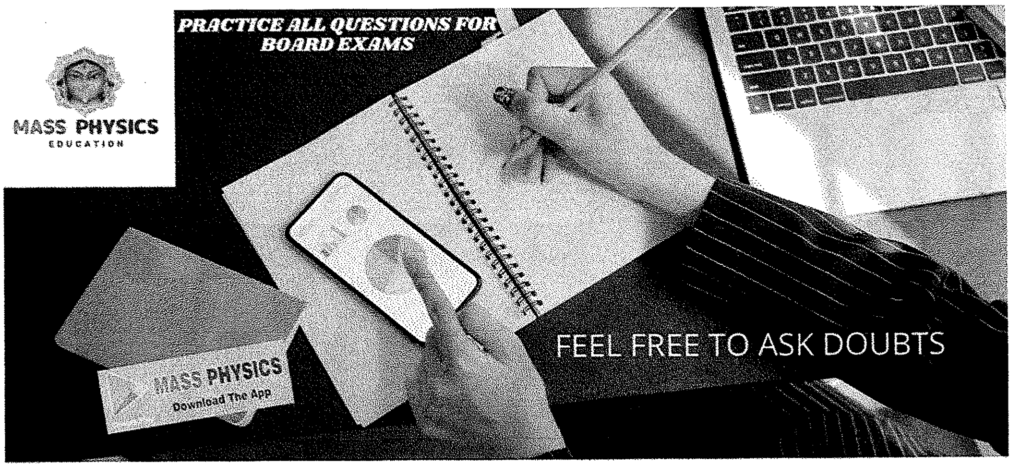
SELF ASSESSMENT TEST

Total Marks : 50

1. Two point charges q_1 and q_2 are such that $q_1 q_2 < 0$. What is the nature of force between two charges ? 1
2. State conservation of charge. 1
3. Define 1 coulomb of charge. 1
4. What is the least possible value of electric charge ? 1
5. Define SI unit of electric intensity. 1
6. What is the force acting on a charge Q placed in electric field $\vec{E}$? 1
7. Sketch electric lines due to a $+q$ charge. 1
8. Can electric lines appear as closed loops ? 1
9. What does $q_1 + q_2 = 0$ signify ? 1
10. State Gauss' law in electrostatics. 1
11. Is Coulomb's law a universal law ? Why ? 2
12. Why is repulsion a surer test for electrification ? 2
13. Explain superposition theorem for multiple charges. 2
14. Plastic is rubbed with wool. Which of these will acquire negative charge and why ? 2
15. What is an ideal dipole ? What is the physical significance of a dipole ? 2
16. Why do two electric lines not cross each other ? 2
17. Define electric dipole moment, give its direction and S.I. unit. 2
18. Give an electric field sketch for a dipole. 2
19. What is electric flux ? Write its S.I. unit. 2
20. A balloon of radius r has inward electric flux ϕ. What will be the electric flux if radius of the balloon is doubled ? Explain. 2
21. Calculate the force of electrostatic attraction between a proton and an electron separated by a distance of 8×10^{-14} m. What would be the nature and magnitude of the electric force if proton is replaced with an electron? 3
22. Compare charge and mass as well as electrical force and gravitational force. What is the magnitude of electric field intensity that will balance the weight of an electron ? Given, $e = 1{\cdot}6 \times 10^{-19}$ C and $m_e = 9 \times 10^{-31}$ kg. 3
23. **(a)** Calculate torque acting on a dipole having dipole moments 4×10^{-9} C m aligned at 30° with electric field of 5×10^4 N C^{-1}.

    (b) An electric dipole consisting of a pair of equal and opposite charges each of magnitude 5μC has dipole moment of 5×10^{-7} C m. Find the length of the dipole. 3
24. Two charges of $+25 \times 10^{-9}$ C and -25×10^{-9} C are placed 6 m apart. Find electric field at a point 4 m on axial line from the centre of the dipole. 3
25. Specific charges (*i.e.*, *e*/*m* ratio) of a sprayed fundamental particle is to be found out. Length l of the oppositely charged plates producing uniform electric field E between them is given along with velocity υ of the particle. Is this data sufficient to calculate the specific charge ? 3
26. **(a)** Using Gauss' theorem, derive an expression for the electric field of an infinitely long line of charge having a uniform charge density λ.

    (b) A point charge of 10^{-7}C is situated at the centre of a cube of 1 m side. Calculate the electric flux through its surface. 5



Objective question bank

Focus NCERT CBSE MODULE FOR CLASS XII EXAMS

Focus NCERT CBSE MODULE FOR CLASS XII EXAMS

MCQ'S (SINGLE & MULTIPLE RESPONSE TYPE), FILL IN THE BLANKS, TRUE/FALSE, MATCHING TYPE QUESTIONS, ASSERTION-REASON TYPE QUESTIONS & CASE- BASED INTEGRATED QUESTIONS

CHARGES & FIELDS
CHAPTER 1
FOCUS NCERT

ELECTRIC CHARGES AND ELECTRIC FIELD 1

OBJECTIVE QUESTION BANK

TYPE–A MULTIPLE CHOICE QUESTIONS
(Only one option correct)

Based on Quantization of charge, coulomb's force, dipole moment and electric field

1. The law of force that governs the force between two electric charges was discovered by :
   (*a*) Ampere (*b*) Faraday (*c*) Ohm (*d*) Coulomb.
2. The electrostatic force between the electrons separated by a distance r varies as :
   (*a*) r^2 (*b*) r^{-1} (*c*) r (*d*) r^{-2}.
3. The existence of a negative charge on a body implies that it has :
   (*a*) lost some of its electrons (*b*) lost some of its neutrons
   (*c*) acquired some electrons from outside (*d*) acquired some protons from outside.
4. Two point charges separated by a distance d repel each other with a force of 9N. If the separation between them becomes $3d$, the force of repulsion will be :
   (*a*) 1 N (*b*) 3 N (*c*) 6 N (*d*) 27 N.
5. The dielectric constant K of a metal is :
   (*a*) 1 (*b*) finite and greater than 1
   (*c*) zero (*d*) infinite.
6. Electrons remain bound to the nucleus due to which of the following forces :
   (*a*) Electrostatic (*b*) van der Waal (*c*) Gravitation (*d*) Nuclear.
7. The S.I. units of $k = \dfrac{1}{4\pi \epsilon_0}$ are
   (*a*) $C^2 N^{-1} m^{-2}$ (*b*) $N m^2 C^{-2}$ (*c*) $N m^2 C^2$ (*d*) none of these.
8. The unit of permittivity of free space, ϵ_0 is
   (*a*) coulomb/newton metre (*b*) newton metre^2/coulomb^2
   (*c*) coulomb^2/newton metre^2 (*d*) coulomb^2/(newton metre)^2.

9. Two positive ions, each carrying a charge q, are separated by a distance d. If F is the force of repulsion between the ions, the number of electrons missing from each ion will be (e is the charge on an electron and ϵ_0 is the absolute permittivity.

(a) $\frac{4\pi \epsilon_0 Fd^2}{e^2}$ (b) $\sqrt{\frac{4\pi \epsilon_0 Fe^2}{d^2}}$ (c) $\sqrt{\frac{4\pi \epsilon_0 Fd^2}{e^2}}$ (d) $\frac{4\pi \epsilon_0 Fd^2}{q^2}$.

10. How many electrons must be removed from an electrically neutral plate to give it a positive charge of 1×10^{-7}C ?

(a) $6{\cdot}25 \times 10^{11}$ (b) $6{\cdot}45 \times 10^{13}$ (c) $6{\cdot}25 \times 10^{-11}$ (d) $6{\cdot}45 \times 10^{-13}$.

11. In a hydrogen atom, the distance between the electron and proton is $2{\cdot}5 \times 10^{-11}$ m. The electrical force of attraction between them will be

(a) $2{\cdot}8 \times 10^{-7}$ N (b) $6{\cdot}2 \times 10^{-7}$ N (c) $3{\cdot}7 \times 10^{-7}$ N (d) $9{\cdot}1 \times 10^{-7}$ N.

12. Two charged spheres separated by a distance d exert some force F on each other. If they are immersed in a liquid of dielectric constant 2, then the force exerted by them, when all other conditions remain same is :

(a) 4F (b) 2F (c) F (d) F/2.

13. A charge q is placed at the centre of the line joining two exactly equal positive charges each having charge Q. The system of three charges will be in equilibrium if q is equal to

(a) –Q/4 (b) + Q (c) – Q (d) Q/2.

14. Dimensions of electric field intensity when mass is (M), time is (T) (a) length is (L) and charge is (Q) can be given as

(a) $ML^2T^{-2}Q^{-1}$ (b) $MLT^{-2}Q^{-1}$ (c) $M^2LT^{-2}Q^{-1}$ (d) $ML^2T^{-2}Q$.

15. If a glass rod is rubbed with silk, the glass rod acquires a positive charge because :

(a) protons are added to it (b) protons are removed from it

(c) electrons are added to it (d) electrons are removed from it.

16. A comb when run through dry hair attracts small bits of paper. This is due to :

(a) comb is a good conductor

(b) paper is a good conductor

(c) the paper get polarised by the charged comb

(d) the comb possesses magnetic properties.

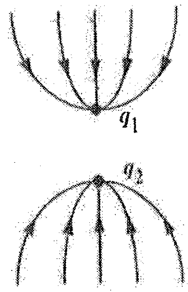
17. Two charges of equal magnitudes kept at a distance r from each other exert a force F on each other. If the charges are halved and distance between them is doubled, then the new force acting on each charge is :

(a) $\frac{F}{8}$ (b) $\frac{F}{4}$ (c) 4F (d) $\frac{F}{16}$.

18. An infinite number of charges, each of charge 1 μC are placed at different points on the x-axis with coordinates $x = 1, 2, 4, 8, \ldots\ldots \infty$. If a charge of 1C is kept at the origin, then the net force acting on 1C charge is,

(a) 9000 N (b) 12000 N (c) 24000 N (d) 3600 N.

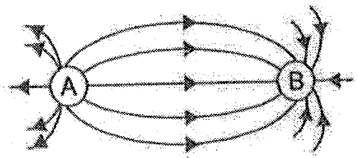
19. Figure shows electric field lines due to two charges q_1 and q_2. Find out sign of charges.



(a) both negative
(b) upper positive and lower negative
(c) both positive
(d) upper negative and lower positive.

20. The insulation property of air breakdown is $E = 3 \times 10^6$ volt per metre. The maximum charge in coulomb that can be given to a sphere of diameter 5 metre is approximately :
(a) 2×10^{-2} C (b) 2×10^{-3} C (c) 2×10^{-4} C (d) 2×10^{-5} C.

21. The spatial distribution of the electric field due to two charges (A, B) is shown in figure. Which one of the following statements is correct ?



(a) A is +ve and B is –ve and $|A| = |B|$
(b) A is –ve and B is +ve and $|A| = |B|$
(c) Both are +ve but A > B
(d) Both are negative but A > B.

22. The point charges Q and –2Q are placed some distance apart. If the electric field at the location of Q is E, then electric field at the location of –2Q will be
(a) $-\frac{E}{2}$ (b) $-\frac{3E}{2}$ (c) –E (d) –2E.

23. The electric field required to keep a water drop of mass *m* just to remain suspended, when charged with one electron of charge *e* (take *g* as acceleration due to gravity) is :
(a) mg (b) $\frac{mg}{e}$ (c) emg (d) $\frac{em}{g}$.

24. Two small charged spheres A and B have charges 10 μC and 40 μC respectively and are held at a separation of 90 cm from each other. At what distance from A, electric field intensity would be zero ?
(a) 22·5 cm (b) 18 cm (c) 30 cm (d) 36 cm

25. What is the angle between the electric dipole moment and the electric field strength due to it on the equatorial line ?
(a) 0° (b) 90° (c) 180° (d) None of these.

26. An electric dipole of moment p is lying along a uniform electric field E. The work done in rotating the dipole by 90° is :
(a) pE (b) $\sqrt{2}pE$ (c) $\frac{pE}{2}$ (d) $2pE$.

27. Three point charges $+q$, $-2q$ and $+q$ are placed at point $(x = 0, y = a, z = 0)$, $(x = 0, y = 0, z = 0)$ and $(x = a, y = 0, z = 0)$ respectively. The magnitude and direction of the dipole moment vector of this assembly are :
(a) $\sqrt{2}qa$ along $+x$ direction
(b) $\sqrt{2}qa$ along $+y$ direction
(c) $\sqrt{2}qa$ along the line joining points $(x = 0, y = 0, z = 0)$ and $(x = a, y = a, z = 0)$
(d) qa along the line joining points $(x = 0, y = 0, z = 0)$ and $(x = 0, y = 0, z = 0)$.

28. A dipole of dipole moment $\vec{P}$ is placed in uniform electric field $\vec{E}$, then torque acting on it is given by :

(a) $\tau = \vec{P} . \vec{E}$ (b) $\tau = \vec{P} \times \vec{E}$ (c) $\tau = \vec{P} + \vec{E}$ (d) $\tau = \vec{P} - \vec{E}$.

29. Two equal and opposite charges of 2×10^{-10} C are placed at a distance of 1 cm forming a dipole and are placed in an electric field of 2×10^5 N C^{-1}. The maximum torque on dipole is :

(a) $2\sqrt{2} \times 10^{-6}$ N m (b) 8×10^8 N m (c) 4×10^{-9} N m (d) 4×10^{-7} N m

30. Which one out of the following is not a property of electric field lines :

(a) Field lines are continuous curves without any breaks.
(b) Two field lines cannot cross each other.
(c) Field lines start at a positive charge and end at a negative charge.
(d) Field lines form closed loops.

31. An electric dipole is placed at an angle of 30° to a non-uniform electric field. The dipole will experience :

(a) a torque only
(b) a translational force only in the direction of field
(c) a translational force only in a direction normal to the direction of field
(d) a torque as well as a translational force.

32. Eight dipoles of charges of magnitude $\pm$ e are placed inside a cube. The total flux coming out of the cube is,

(a) 0 (b) ∞ (c) e (d) $-e$.

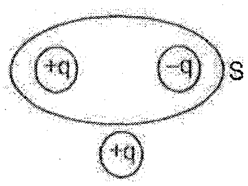
33. If Q is situated at the centre of a cube, then the electric flux through one of the faces of the cube is :

(a) $\frac{Q}{\epsilon_0}$ (b) $\frac{Q}{2\epsilon_0}$ (c) $\frac{Q}{4\epsilon_0}$ (d) $\frac{Q}{6\epsilon_0}$.

34. A charge q is placed at the centre of a cube with side L. The electric flux linked with cubical surface is :

(a) $\frac{q}{6L^2 \epsilon_0}$ (b) $\frac{q}{L^2 \epsilon_0}$ (c) $\frac{q}{\epsilon_0}$ (d) zero.

35. The given figure shows distribution of charges. The flux of electric field due to these charges through the surface S is :



(a) $\frac{3q}{\epsilon_0}$ (b) $\frac{2q}{\epsilon_0}$

(c) $\frac{q}{\epsilon_0}$ (d) zero.

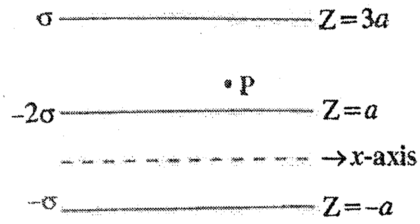
36. In case of infinite long wire, electric field is proportional to :

(a) r^3 (b) $\frac{1}{r^3}$ (c) $\frac{1}{r^2}$ (d) $\frac{1}{r}$.

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

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

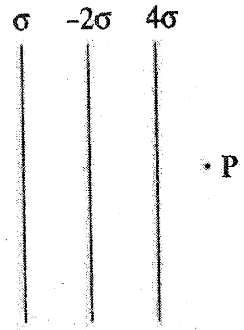
38. Three infinitely long charged sheets having charge densities $-\sigma$, -2σ, and σ are placed as shown. The electric field at point P is



(a) $\frac{2\sigma}{\epsilon_0}\hat{k}$ (b) $\frac{4\sigma}{\epsilon_0}\hat{k}$

(c) $-\frac{2\sigma}{\epsilon_0}\hat{k}$ (d) $-\frac{4\sigma}{\epsilon_0}\hat{k}$.

39. Three nonconducting large parallel plates have surface charge densities σ, -2σ and 4σ respectively as shown in figure. The electric field at the point P is :



(a) $\frac{3\sigma}{2\epsilon_0}$ (b) $\frac{3\sigma}{\epsilon_0}$

(c) $\frac{\sigma}{\epsilon_0}$ (d) $\frac{\sigma}{2\epsilon_0}$

40. An imaginary, closed spherical surface S of radius R is centered on the origin. A positive charge $+q$ is originally at the origin and electric flux through the surface is ϕ_E. Three additional charges are now added along the x axis : $-3q$ at $x = -\frac{R}{2}$, $+5q$ at $x = \frac{R}{2}$ and $4q$ at $x = \frac{3R}{2}$ The flux through S is now :

(a) $3\phi_E$ (b) $4\phi_E$ (c) $6\phi_E$ (d) $7\phi_E$

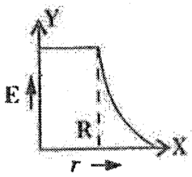
41. A sphere of radius R has a uniform distribution of electric charge in its volume. At a distance x from its centre for $x < R$, the electric field is directly proportional to :

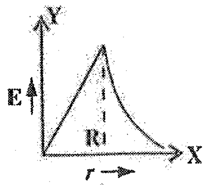
(a) $\frac{1}{x^2}$ (b) $\frac{1}{x}$ (c) x (d) x^2

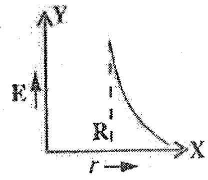
42. The charged spherical shell of radius 1m does not produce an electric field at any :

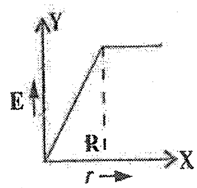
(a) interior point (b) point beyond 2 m (c) point beyond 10 m (d) none of these

43. The electric field E due to a uniformly charged non-conducting sphere of radius R as a function of distance r from its centre is represented by :

(a) 

(b) 

(c) 

(d) 

ANSWERS

1. (d)	2. (d)	3. (c)	4. (a)	5. (d)	6. (a)	7. (b)	8. (c)	9. (c)
10. (a)	11. (c)	12. (d)	13. (a)	14. (b)	15. (d)	16. (c)	17. (d)	18. (b)
19. (a)	20. (b)	21. (a)	22. (a)	23. (b)	24. (c)	25. (c)	26. (a)	27. (c)
28. (b)	29. (d)	30. (d)	31. (d)	32. (a)	33. (d)	34. (c)	35. (d)	36. (d)
37. (b)	38. (c)	39. (a)	40. (a)	41. (c)	42. (a)	43. (b)		

2. $F \propto \frac{1}{r^2}$.

3. When body acquires electrons, it becomes negatively charged.

4. $F \propto \frac{1}{r^2}$.

5. $k = \infty$ for metals.

6. Electrostatic force between nucleus and electron.

7. $K = \frac{Fr^2}{q^2}$.

8. $F = \frac{1}{4\pi \epsilon_0}\frac{q^2}{r^2}$; $\therefore$ $\epsilon_0 = \frac{q^2}{4\pi F r^2}$ $\Rightarrow$ unit of ϵ_0 = coulomb^2/newton metre^2.

9. $F = \frac{1}{4\pi \epsilon_0}\frac{q^2}{d^2}$

   Since $q = ne$; $\therefore$ $F = \frac{1}{4\pi \epsilon_0}\frac{n^2e^2}{d^2}$ or $n = \sqrt{\frac{4\pi \epsilon_0 Fd^2}{e^2}}$.

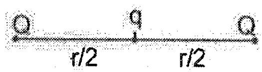
10. $q = ne$; $\therefore$ $n = \frac{q}{e} = \frac{1\times10^{-7}}{1{\cdot}6\times10^{-19}} = 6{\cdot}25 \times 10^{11}$.

11. $F = \frac{1}{4\pi \epsilon_0}\frac{e^2}{r^2} = \frac{9\times10^9\times(1{\cdot}6\times10^{-19})^2}{(2{\cdot}5\times10^{-11})^2} = 3{\cdot}7 \times 10^{-7}$ N

12. $F_m = \frac{F}{K} = \frac{F}{2}$.

13. The system of charges will be in equilibrium if net force acting on charge Q is zero.

   i.e. $\frac{1}{4\pi \epsilon_0}\frac{Qq}{(r/2)^2} + \frac{1}{4\pi \epsilon_0}\frac{Q^2}{r^2} = 0$ or $4Qq = -Q^2$ or $q = -\frac{Q}{4}$.



14. $F = qE$

   or $E = \frac{F}{q}$

   $[E] = \frac{[MLT^{-2}]}{[Q]} = [MLT^{-2}Q^{-1}]$

15. A body becomes positively charged by losing electrons (*i.e.*, negative charges).

16. Paper is a dielectric. It gets polarised due to frictionally charged comb.

17. $F \propto \frac{q^2}{r^2}$; $\therefore$ $\frac{F'}{F} = \frac{(q')^2}{(r')^2}\times\frac{r^2}{q^2}$ where $q' = \frac{q}{2}$ and $r' = 2r$ *i.e.* $\frac{F'}{F} = \frac{q^2}{4\times4r^2}\times\frac{r^2}{q^2} = \frac{1}{16}$; $F' = \frac{F}{16}$.

18. $F = \frac{1\times1\times10^{-6}}{4\pi\epsilon_0}\left[\frac{1}{1^2}+\frac{1}{2^2}+\frac{1}{4^2}+\ldots\right] = 9\times10^9\times1\times10^{-6}\left[1+\frac{1}{4}+\frac{1}{16}+\ldots\right]$

using sum of G.P. $= \frac{a}{1-r}$

$$F = 9\times10^3\left[\frac{1}{1-\frac{1}{4}}\right] = 9\times10^3\times\frac{4}{3} = 12000\text{ N.}$$

19. Electric field lines terminate on negative charge.

20. Electric field on the surface of the sphere is given by, $E = \frac{1}{4\pi\epsilon_0}\frac{q}{R^2}$

Using the given data,

$(3\times10^6) = (9\times10^9)\frac{q}{(2{\cdot}5)^2}$ *i.e.* $q = \frac{18{\cdot}75}{9\times10^3} = 2{\cdot}08\times10^{-3} \simeq 2\times10^{-3}$ C

21. Field lines start from +ve charge and end on –ve charge and number of field lines are directly proportional to the magnitude of charge.

22. Electric field at the location of Q is due to the charge –2Q

$\therefore \quad E = \frac{1}{4\pi\epsilon_0}\frac{-2Q}{r^2}$ ...(*i*)

Electric field at the location of –2Q is due to the charge Q $\therefore E' = \frac{1}{4\pi\epsilon_0}\frac{Q}{r^2}$ ...(*ii*)

$\therefore$ Using equations (*i*) and (*ii*), we get $\frac{E'}{E} = -\frac{1}{2}$ or $E' = -\frac{E}{2}$.

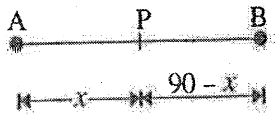
23. Drop will remain suspended if force on drop due to electric field = weight of drop

i.e. $eE = mg \quad \therefore \quad E = \frac{mg}{e}$.

24. Let at a distance x from A, electric field E = 0

$\frac{1}{4\pi\epsilon_0}\frac{q_1}{x^2} = \frac{1}{4\pi\epsilon_0}\frac{q_2}{(90-x)^2}$ or $\frac{10}{x^2} = \frac{40}{(90-x)^2}$

or $90 - x = 2x$ or $x = 30$ cm



25. $\vec{E} = \frac{(-\vec{p})}{4\pi\epsilon_0(r^2+l^2)^{3/2}}$

In this case, directions of electric dipole moment and the electric field strength are opposite to each other.

26. Work done, $W = -pE(\cos\theta_2 - \cos\theta_1) = -pE(\cos 90° - \cos 0°) = pE$.

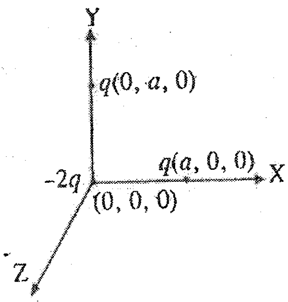
27. The system can be considered as consisting of two dipoles one along + x axis and another along + y axis.

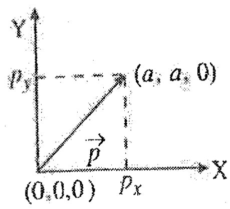
Dipole moment along x–axis, $p_x = qa$

Dipole moment along y–axis, $p_y = qa$

$\therefore$ Resultant dipole moment $p = \sqrt{p_x^2 + p_y^2}$

$= \sqrt{2}\,qa$.





28. $\tau = PE \sin\theta$, where θ is angle between $\vec{P}$ and $\vec{E}$ or $\vec{\tau} = \vec{P} \times \vec{E}$

29. $\tau_{max} = pE = (q \times 2l)E = 2 \times 10^{-10} \times 10^{-2} \times 2 \times 10^{5} = 4 \times 10^{-7}$ N m

31. In this case, non-uniform electric field will tend to rotate as well as translate the dipole.

32. Net flux due to a dipole inside a cube is zero. Therefore, total flux coming out of the cube due to 8 dipoles is zero.

33. Electric flux through a cube, $\phi = \frac{Q}{\epsilon_0}$; Electric flux through one face of cube $= \frac{\phi}{6} = \frac{Q}{6\epsilon_0}$.

34. $\phi = \frac{q}{\epsilon_0}$. (Gauss's theorem)

35. Flux through a closed surface $= \frac{q_{net}}{\epsilon_0}$.

Since $q_{net} = +q - q = 0$ and the charge outside the surface does not contribute to the electric flux, therefore net flux through the surface = 0.

36. $E = \frac{\lambda}{2\pi\epsilon_0 r}$.

37. Electric flux is independent of the size of the Gaussian surface.

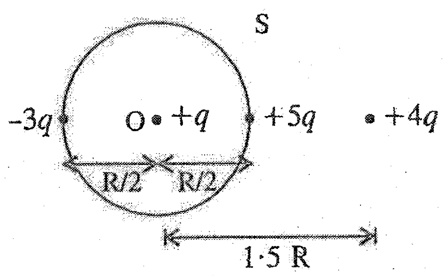
38. Net electric field $= \frac{\sigma}{2\epsilon_0}(-\hat{k}) + \left(\frac{-2\sigma}{2\epsilon_0}\right)\hat{k} + \left(\frac{-\sigma}{2\epsilon_0}\right)\hat{k} = \frac{4\sigma}{2\epsilon_0}(-\hat{k}) = \frac{-2\sigma}{\epsilon_0}(\hat{k})$.

39. $E = \frac{\sigma}{2\epsilon_0} + \frac{(-2\sigma)}{2\epsilon_0} + \frac{4\sigma}{2\epsilon_0} = \frac{3\sigma}{2\epsilon_0}$.

40. Initial electric flux, $\phi_E = \frac{q}{\epsilon_0}$

Final electric flux, $\phi'_E = \frac{q - 3q + 5q}{\epsilon_0}$

$= \frac{3q}{\epsilon_0} = 3\phi_E$.



41. Electric field at a point inside a solid sphere at a distance x from the centre of the sphere is given by,

$$E = \frac{1}{4\pi\epsilon_0}\frac{qx}{R^3}.$$

42. Electric field inside a spherical shell = zero.

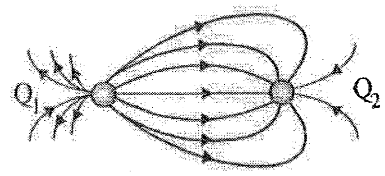
43. For a point inside a non-conducting charged sphere the electric field $E \propto r$ whereas at any point outside the sphere it is given by, $E \propto \frac{1}{r^2}$.

TYPE-B

MULTIPLE RESPONSE QUESTIONS

(More than one correct option)

44. A few electric field lines for a system of two charges Q_1 and Q_2 fixed at two different points on the X-axis are shown in the Fig. These lines suggest that : [IIT, 2010]



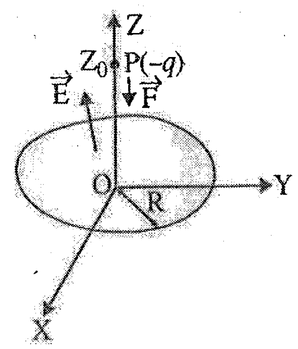
(a) $|Q_1| > |Q_2|$

(b) $|Q_1| < |Q_2|$

(c) at a finite distance to the left of Q_1, the electric field is zero

(d) at a finite distance to the right of Q_2, the electric field is zero.

45. A positively charged thin metal ring of radius R is fixed in the XY-plane with its centre at the origin O. A negatively charged particle P is released from rest at the point $(0, 0, z_0)$ where $z_0 > 0$. Then, the motion of P is :



(a) periodic for all the values of z_0 satisfying $0 < z_0 < \infty$

(b) simple harmonic for all the values of z_0 satisfying $0 < z_0 \leq R$

(c) approximately simple harmonic provided $z_0 << R$

(d) such that P crosses O and continues to move along the negative Z-axis towards $z = -\infty$.

46. A non-conducting solid sphere of radius R is uniformly charged. The magnitude of the electric field due to the sphere at a distance r from its centre :

(a) increases as r increases, for $r < R$

(b) decreases as r increases, for $0 < r < \infty$

(c) decreases as r increases, for $R < r < \infty$

(d) is discontinuous at $r = R$.

47. Under the influence of the Coulomb field of charge $+q$, a charge $-q$ is moving around it in an elliptical orbit. Find out the correct statement(s). [IIT, 2009]

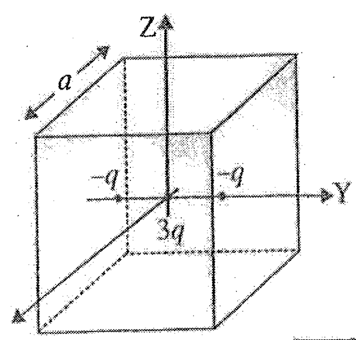
(a) The angular momentum of the charge $-q$ is constant

(b) The linear momentum of the charge $-q$ is constant

(c) The angular velocity of the charge $-q$ is constant

(d) The linear speed of the charge $-q$ is constant.

48. A cubical region of side a has its centre at the origin. It encloses three fixed point charges $-q$ at $(0, +a/4, 0)$ [Fig.]. Choose the correct option(s). [IIT, 2012]



(a) The net electric flux crossing the plane $x = +a/2$ is equal to the net electric flux crossing the plane $x = -a/2$.

(b) The net electric flux crossing the plane $y = +a/2$ is more than the net electric flux crosing the plane $y = -a/2$.

(c) The net electric flux crossing the entire region is q/ϵ_0.

(d) The net electric flux crossing the plane $z = +a/2$ is equal to the net electric flux crossing the plane $x = +a/2$.

ANSWERS

44. (*a, d*) **45.** (*a, c*) **46.** (*a, c*) **47.** (*a*) **48.** (*a, c, d*)

HINTS AND EXPLANATIONS

44. Number of electric field lines is directly proportional to the magnitude of charge. Therefore, $|Q_1| > |Q_2|$, $E \propto \frac{1}{r^2}$. Charge Q_1 is positive and charge Q_2 is negative. At any point to the right side of Q_2, $\vec{E}_1 + \vec{E}_2 = \frac{1}{4\pi\varepsilon_0}\frac{Q_1}{r_1^2}\hat{i} - \frac{1}{4\pi\varepsilon_0}\frac{Q_2}{r_2^2}\hat{i}$.

45. Electric field due to charged ring at Z_0 is given by $\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{Qz_0}{(R^2+z_0^2)^{\frac{3}{2}}}\hat{k}$

$\therefore$ Force on charge $(-q)$ at P, $\vec{F} = -q\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{qQz_0}{(R^2+z_0^2)^{\frac{3}{2}}}\hat{k}$

The force acts towards the centre of the ring.

Thus, motion of particle is periodic for $0 < Z_0 < \infty$

For $Z_0 << R$, $\vec{F} \propto -Z_0\hat{k}$. So motion of particle is S.H.M.

46. For a charged solid sphere of radius R,

$E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{R^3}r$ for $r < R$ or $E \propto r$; For $r > R$, $E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$ or $E \propto \frac{1}{r^2}$.

47. When charge $-q$ moves in a central force field, no torque (τ) acts on the particle.

Now $\frac{d\vec{L}}{dt} = \vec{\tau} = 0$ or $\vec{\tau}$ = constant. or Iw = constant.

When particle is near to $+q$, its M.I. decreases and hence angular velocity increases.

The direction of motion of charge $-q$ changes continuously, so its linear velocity and hence linear momentum charges.

48. (*a*) Since charges are symmetrically placed about $x = +\frac{a}{2}$ and $x = -\frac{a}{2}$ planes, so electric flux crossing these planes is same.

(*c*) Net enclosed charge, $q = -q - q + 3q = q$; $\therefore \phi = \frac{q}{\varepsilon_0}$ (Gauss's law).

(*d*) Since charges are symmetrically placed about $z = +\frac{a}{2}$, and $z_2 = -\frac{a}{2}$ planes so electric flux crossing these planes is same.

TYPE-C FILL IN THE BLANKS WITH APPROPRIATE ANSWERS

49. Like charges .... each other and unlike charges .... each other.
50. Lightning in the sky is an example of .... through air.
51. Charges were named as positive and negative by ....
52. A device used to detect charge on a body is known as ....
53. The process of sharing the charges with earth is called ....
54. The process of charging a metal sphere positively without touching it with a negatively charged body is called ....
55. Insulators are also called ....
56. The total charge on a body having n_1 electrons and n_2 protons is equal to ....
57. The value of electrostatic force constant in free space (in S.I.) is ....
58. The value of permittivity of free space is ....
59. Force experiened by a charge q in electric field $\vec{E}$ is ....
60. S.I. unit of electric field is ....
61. Electric field due to charge Q at a point is .... of test charge at that point.
62. Electric field due to a charge at a point in the space is the .... experienced by a .... at that point.
63. The concept of electric field was introduced by ....
64. Electrostatic field line do not form any closed ....
65. Electric flux through a closed surface enclosing electric charge q is ....
66. Electric flux through a Gaussian surface is .... of the size of the surface.
67. S.I. unit of electric dipole moment is ....
68. The electric field intensity due to an electric dipole varies inversely as .... of the distance of the point.
69. The net electric charge of an electric dipole is ....
70. When an electric dipole is placed in an uniform electric field, the net force acting on the electric dipole is ....
71. An electric dipole experiences no ...., when the electric dipole moment of the electric dipole is in the direction of the applied electric field.
72. Electric field due to a uniformly charged infinite plane sheet having charge density σ at a distance r is ....

ANSWERS

49. repel, attract
50. electric discharge
51. Franklin Benjamin
52. Electroscope
53. earthing or grounding
54. induction
55. dielectrics
56. $(n_2 - n_1)e$
57. $9 \times 10^9 Nm^2C^{-2}$.
58. $8{\cdot}854 \times 10^{-12} C^2N^{-1}m^{-2}$.
59. $q\vec{E}$
60. NC^{-1}
61. independent
62. force, unit positive charge

63. Faraday 64. loops 65. $\frac{q}{\varepsilon_0}$ 66. independent

67. Coulomb-metre (Cm). 68. cube 69. zero 70. zero

71. torque 72. $\frac{\sigma}{2\varepsilon_0}$

TYPE-D STATE, WHETHER THE STATEMENT IS TRUE OR FALSE

73. In the phenomenon of electrification by friction, the law of conservation of charge is violated.

74. The electric force experienced by a charge moving in an electric field depends on its velocity.

75. Two electric lines of force do not intersect with each other.

76. An electric charge $+1\mu C$ experiences a force of magnitude F due to the electric charge $+5\mu C$ placed at a distance r. The magnitude of the force experienced by $+5\mu C$ charge due to $+1\mu C$ charged placed at the same position is 5F.

77. The value of Coulomb's force constant in SI is $9 \times 10^9\ Nm^2C^{-2}$.

78. The electric field due to a charge configuration with total charge zero is zero.

79. The electric field due to a charge is independent of the space coordinate $\vec{r}$.

80. The electric field due to a positive charge at a point is radially inwards towards the charge.

81. The electric field lines start from a positive charge and end on negative charge.

82. The force experienced by a charge q placed inside a uniformly charged spherica' ·hell is zero.

83. Surface charge density is directly proportional to the surface area of the body.

84. The electric field lines form closed loops.

85. The electric field intensity due to a charged shell varies inversely as the square of the distance outside the shell.

ANSWERS

73. False (charge is conserved) 74. False 75. True 76. False $(\vec{F_1} = -\vec{F_2})$

77. True

78. False (Electric field due to an electric dipole (net charge = 0) is non-zero) 79. False $(E \propto \frac{1}{r^2})$

80. False (radially outwards) 81. True

82. True ($F = qE = 0$, because $E = 0$ inside the charged shell) 83. False ($\sigma = q/A$)

84. False 85. True

TYPE-E MATCHING TYPE QUESTIONS

86. Column I gives the objects and column II gives the dependence of electric field (E) due to these objects on the distance (r) from these objects. Match the entries in column I with the enteries in column II.

Column I	Column II
(A) Point charge	(p) r^0
(B) Electric dipole	(q) r^{-1}
(C) Infinitely long straight uniformly charged wire	(r) r^{-2}
(D) Uniformly charge inifinite plane sheet	(s) r^{-3}

(a) A → p; B → q; C → r; D → s
(b) A → r; B → s; C → q; D → p
(c) A → r; B → s; C → p; D → q
(d) A → p; B → p; C → r; D → s.

87. Column I gives the physical quantities and column II gives the values of these physical quantities. Match the physical quantities given in column I with their values in column II.

Column I	Column II
(A) Electric charge on an electron	(p) $8{\cdot}854 \times 10^{-12} C^2N^{-1}m^{-2}$
(B) Dielectric constant of water	(q) $9 \times 10^9\ Nm^2c^{-2}$
(C) Electrostatic force constant in SI	(r) $-1{\cdot}6 \times 10^{-19}C$
(D) Permittivity of free space	(s) 81

(a) A → r; B → s; C → q; D → p
(b) A → s; B → r; C → q; D → p
(c) A → r; B → s; C → p; D → q
(d) A → p; B → q; C → r; D → s.

88. Match the physical quantities given in Column I with their respective expressions given in Column II.

Column I	Column II
(A) Electrostatic force between two charges q_1 and q_2 separated by a distance r in free space	(p) $\frac{\rho r}{3 \epsilon_0}$
(B) Electric flux through a closed surface enclosing a charge q	(q) zero
(C) Electric field due to a uniformly charged shell at a point inside the shell	(r) $\frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r^2}$
(D) Electric field due to a uniformly charged solid sphere at a point inside the sphere	(s) $\frac{q}{\epsilon_0}$

(a) A → s; B → r; C → q; D → p
(b) A → r; B → s; C → q; D → p
(c) A → r; B → s; C → p; D → q
(d) A → s; B → r; C → p; D → q.

89. Match items in column I with that of column II

Column I	Column II
(A) SI unit of electric field	(*p*) $C^2N^{-1}m^{-2}$
(B) SI unit of electric dipole moment	(*q*) Cm^{-3}
(C) SI unit of volumne charge density	(*r*) NC^{-1}
(D) SI unit of electro static force constant	(*s*) Cm

(*a*) A → *p*; B → *q*; C → *r*; D → *s*
(*b*) A → *r*; B → *s*; C → *q*; D → *p*
(*c*) A → *s*; B → *r*; C → *p*; D → *q*
(*d*) A → *q*; B → *p*; C → *s*; D → *r*.

ANSWERS

86. (*b*) 87. (*a*) 88. (*b*) 89. (*b*)

TYPE-F ASSERTION-REASON TYPE QUESTIONS

Each question has two statements I (Assertion) and II (reason). of the following statements, choose the correct code if.

(A) Both statements are true and statement II is the correct explanation of statement I.
(B) Both statements are true but statement II is not the correct explanation of statement I.
(C) Statement I is true but statement II is false.
(D) Statement I is false but statement II is true.

90. **Statement I** : During charging by rubbing, the insulating material with lower work function becomes positively charged.

Statement II : Electrons are negatively charged particles.

(*a*) A (*b*) B (*c*) C (*d*) D.

91. **Statement I** : The Coulomb's force is the dominating force in the universe.

Statement II : Coulomb's force is stronger than the gravitational force.

(*a*) A (*b*) B (*c*) C (*d*) D. **(AIIMS 2003)**

92. **Statement I** : The lightning conductor at the top of a high building has sharp pointed ends.

Statement II : The surface density of charge at sharp points is very high resulting in setting up electric winds.

(*a*) A (*b*) B (*c*) C (*d*) D. **(AIIMS 2007)**

93. **Statement I** : If a metal is placed between two electric charges, the electric force between them becomes zero.

Statement II : Dielectric constant of metal is infinite.

(*a*) A (*b*) B (*c*) C (*d*) D.

94. **Statement I** : The whole charge of a body can be transferred to another body.

Statement II : Electric charge cannot be transferred partially.

(*a*) A (*b*) B (*c*) C (*d*) D

95. **Statement I** : Electric flux through a closed surface enclosing an electric dipole is zero.

Statement II : The net charge of electric dipole is zero.

(*a*) A (*b*) B (*c*) C (*d*) D

96. **Statement I** : A charged particle free to move in an electric field always follows the electric field line.

Statement II : The electric field lines start from a positive charge and end on a negative charge.

(*a*) A (*b*) B (*c*) C (*d*) D

ANSWERS

90. (*b*) **91.** (*d*) **92.** (*a*) **93.** (*a*) **94.** (*c*) **95.** (*a*) **96.** (*d*)

HINTS AND EXPLANATIONS

90. Material having lower work function easily loose electrons.

91. Although Coulomb's force is very strong than the gravitational force but the dominating force in the universe is gravitational force.

92. Surface charge density, $\sigma = \frac{q}{A}$, where A is area. Charged sharp points creates a very strong electric field around it.

93. $F_n = \frac{F}{K} = \frac{F}{\infty} = 0$

94. When a charged body placed inside a hollow conductor is connected with it, entire charge of charged body is transferred to the hollow conductor.

95. $\phi = \frac{q_{en}}{\varepsilon_0} = 0$, because q_{en} = net charge on electric dipole = 0.

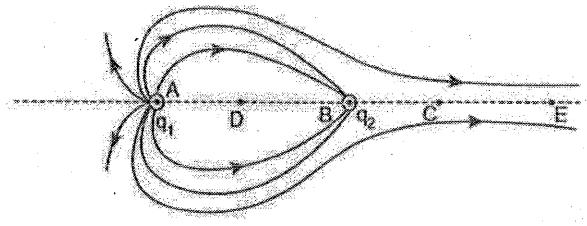
96. Only charged particle initially at rest follows electric field line.

Case-based/Passage-based Integrated Questions

1 ELECTRIC CHARGES AND FIELDS

CASE-BASED/PASSAGE-BASED INTEGRATED QUESTIONS

Q 1. Two point charges q_1 and q_2 of unequal magnitude are placed as shown below.



(i) Determine the ratio $q_1:q_2$

(ii) If one null point is at infinity, then where is another null point?

(iii) If q_1 and q_2 are separated by a distance of 10 cm, then find the position of a null point.

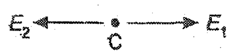
(iv) Will a positive charge follow the electric lines of force if free to move?

Ans. (i) $\frac{q_1}{q_2} = \frac{8}{4} = \frac{2}{1}$ [Count the Number of field lines associated with each charge]

(ii) $\because$ $q_2 < q_1$ and q_1 is positive and q_2 is negative,

$\therefore$ Null point will lie at point C to the right side of point B

Reason: Electric field at C is in opposite direction as shown.



Here, E_1 and E_2 are electric fields due to electric charges q_1 and q_2.

(iii) $\because$ Net electric field at C = 0

$$\therefore \quad |\vec{E}_1| = |\vec{E}_2|$$

$$\frac{k|q_1|}{(AC)^2} = \frac{k|q_2|}{(BC)^2},$$

Here AB = 10 cm = 0.1 m

Let BC = x

$$\therefore \quad \frac{q_1}{q_2} = \left(\frac{AC}{BC}\right)^2 \Rightarrow \frac{2}{1} = \left(\frac{0.1+x}{x}\right)^2$$

Taking square root

$$\sqrt{2} = \frac{0.1+x}{x} \qquad \left[\because \sqrt{\frac{q_1}{q_2}} = \sqrt{\frac{2}{1}}\right]$$

$$(\sqrt{2}-1)x = 0.1$$

$$x = \frac{0.1}{(\sqrt{2}-1)} = \frac{0.1}{\sqrt{2}-1} \times \frac{(\sqrt{2}+1)}{\sqrt{2}+1}$$

$$x = 0.141 + 0.1 = 0.241 \text{ m}$$

or x = 24.1 cm from point B.

(iv) No.

As the electric field lines are curved, and at any point on it a test charge (+ve) will experience acceleration but direction of acceleration and velocity may not be same.

Q 2. An electric dipole is a system consisting of the two equal and opposite point charges seperated by a small and finite distance. If dipole moment of this system is $\vec{p}$ and it is placed in a uniform electric field $\vec{E}$.

(i) Write the expression of torque experienced by a dipole.

(ii) Identify two pairs of perpendicular vectors in the expression.

(iii) Show diagrammatically the orientation of the dipole in the field for which the torque is

(a) Maximum.

(b) Half the maximum value.

(c) Zero.

Ans. (i) $\vec{\tau} = \vec{p} \times \vec{E}$

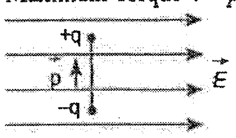
or $\tau = pE \sin\theta$

here $p = 2aq$

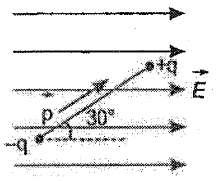
(If point charges are q and $-q$ separated by a distance $2a$.)

(ii) Torque is perpendicular to dipole moment and electric field. $\vec{\tau} \perp \vec{p}$ and $\vec{\tau} \perp \vec{E}$

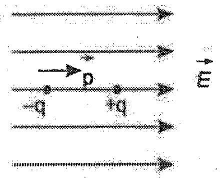
(*iii*) (*a*) Maximum Torque $\tau = pE$ when $\theta = 90°$



(*b*) $\tau = \frac{pE}{2}$ when, $\sin\theta = \frac{1}{2}$ *i.e.*, $\theta = 30°$ or $150°$



(*c*)



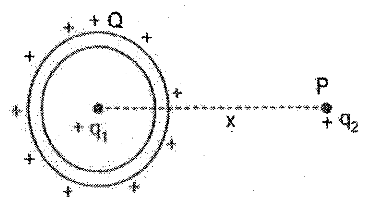
$\because \theta = 0°$ or $180°$

$\therefore \tau = pE \sin 0° = 0$

$\therefore \tau =$ minimum

3. **A thin conducting shell contains a charge +Q distributed uniformly all over it. Now a point charge $+q_1$ is placed at the centre of the shell, and another charge $+q_2$ is placed outside the shell. What is the net force on**
   (*i*) **charge q_1**
   (*ii*) **charge q_2**
   (*iii*) **spherical shell**
   (*iv*) **also determine charge density on the shell if radius of shell is R.**
   (*v*) **What is the net electric flux through the sphere?**

Ans. (*i*)



Net force on charge q_1 is zero as electric field inside a charged conducting shell is zero.

(*ii*) Due to induction charge inside the shell is $-q_1$ and outside the shell net charge will be $(Q + q_1)$

$\because$ Electric field due to charged sphere at point P is $E_P = \frac{k(Q+q_1)}{x^2}$

$\therefore$ Force on charge $q_2 = q_2 E = \frac{k(Q+q_1) \cdot q_2}{x^2}$

(*iii*) Force on spherical shell has same magnitude

$= \frac{k(Q+q_1)q_2}{x^2}$

(*iv*) Charge density $= \frac{\text{Total charge on the sphere}}{\text{Surface area of sphere}}$

$\therefore \quad \sigma = \frac{(Q+q_1)}{4\pi R^2}$

(*v*) Net electric flux through the sphere is given

$\phi = \frac{q_1}{\varepsilon_0^2}$ [by Gauss's Theorem]

SELF EVALUATION TEST FOR CBSE BOARD EXAMS

Self Evaluation Test - 1

Electric Charges and Field

Maximum Marks : 30 | *Duration : 75 minutes*

1 Mark Questions

1. How is the force between two charges affected when dielectric constant of the medium in which they are placed increases ?
2. Name the physical quantity whose SI unit is NC^{-1}.
3. What do electric lines of force represent ?
4. Define electric flux.
5. Is electric field intensity a scalar or a vector quantity ?
6. Define dielectric constant of a medium.
7. What is an ideal electric dipole ?
8. Write the S.I unit of electric dipole moment.

2 Marks Questions

9. A charge of $\sqrt{2}$ C is placed on top of your school building and another equal charge is placed on top of your house. If the distance between the two locations is 2 km, how many kilo-newton force is exerted by the charges on each other ?
10. Vehicles carrying inflammable materials usually have metallic ropes touching the ground during movement. Why ?
11. Derive an expression for the electric field intensity at a distance 'r' from a point charge 'q'.
12. Two point charges 4 μC and 2 μC are separated by a distance 1m in air. At what point on the line joining the charges is the electric field intensity zero ?

3 Marks Questions

13. (a) An electrostatic field line of force is a continuous curve. That is, a field line of force cannot have sudden breaks. Why not?
    (b) Explain why two field lines of force never cross each other at any point.
14. Show that in a uniform electric field, a dipole experiences only a torque but no net force. Derive an expression for the torque.
15. An electric dipole of length 2 cm is placed with its axis making an angle of 60° with respect to a uniform electric field of 10^5 N/C. If it experiences a torque of $8\sqrt{3}$ Nm, calculate the
    (i) magnitude of the charge on the dipole, and
    (ii) potential energy of the dipole.

5 Marks Question

16. Derive the expressions for electric field intensity due to a uniformly charged non-conducting solid sphere at :
    (i) a point outside the solid sphere
    (ii) a point on the surface of the solid sphere
    (iii) a point inside the solid sphere

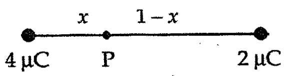
SELF EVALUATION TEST FOR CBSE BOARD EXAMS

Hints / Answers

1. Force between two charges when placed in the dielectric medium

   $F' = \frac{1}{4\pi\varepsilon_0 K}\frac{q_1 q_2}{r^2} = \frac{F}{K}$, where F is the force in vacuum.

   If dielectric constant of the medium increases, then force decreases.
2. Electric field intensity.
3. Direction and strength of electric field intensity.
4. Electric flux over an area in an electric field represents the total number of electric lines of force crossing the area in a direction normal to the plane of the area.
5. Vector quantity.
6. Dielectric constant or relative permittivity of the medium is the ratio of the electrostatic force between two charges separated by certain distance in vacuum to the electrostatic force between the same two charges separated by the same distance in that medium.
7. Two equal and opposite (in nature) electric point charges separated by an infinitesimally small distance constitute an ideal dipole.
8. Cm.
9. $F = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q_1 q_2}{r^2} = 9 \times 10^9 \times \frac{\sqrt{2}\times\sqrt{2}}{(2\times10^3)^2} = 4.5 \times 10^3 N$.
10. Rubber tyres are insulators, hence the metallic body of the vehicles and tanks are not earthed. Metallic chains touching the ground make them earthed, hence any frictional electricity if gets developed does not let any sparks produced to let the inflammable liquid catch fire.

12. 

   $\Rightarrow \frac{1}{4\pi\varepsilon_0}\cdot\frac{4}{x^2} = \frac{1}{4\pi\varepsilon_0}\cdot\frac{2}{(1-x)^2}$

   $\Rightarrow x^2 = 2(1-x)^2 = 2(1-2x+x^2)$

   $\Rightarrow x^2 - 4x + 2 = 0$

   $\Rightarrow x = 2\pm\sqrt{2}$ *i.e.* $2-\sqrt{2}$ m from 4μC because $2+\sqrt{2}$ is not possible

15. Given length of dipole, $2a = 0.02$ m

   $\theta = 60°$

   $E = 10^5 N/C, \quad \tau = 8\sqrt{3}$ Nm

   (i) $\tau = pE\sin\theta = (q.2a)E\sin\theta$

   $\therefore 8\sqrt{3} = (q)\cdot(0.02)\,10^5 \sin 60°$

   On solving, $q = 8 \times 10^{-3}$ C = **8 mC.**

   (ii) Potential Energy $= -pE\cos\theta = -8 \times 10^{-3} \times 0.02 \times 10^5 \times \frac{1}{2} J = -0.08 \times 10^2 J = \mathbf{-8\,J}$.

DEAR STUDENTS ELECTROSTATICS COVERS 7 MAJOR TOPICS

1. **CHARGES AND THEIR PROPERTIES**
2. **FORCE BETWEEN CHARGES [COULOMBS LAW]**
3. **ELECTRIC FIELD DUE TO CHARGES AND DIPOLE**
4. **ELECTRIC FLUX [GAUSS LAW]** (ncert chapter 1)

5. **ELECTRIC POTENTIAL**
6. **ELECTROSTATIC POTENTIAL ENERGY**
7. **CAPACITANCE** (ncert chapter 2)

We cover first four topics in this chapter while next three topics are in NCERT chapter 2