According to the Latest NCERT Syllabus

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PHYSICS

Class-12 (Part-I)

For the Students of Rajasthan Board of Secondary Education

By

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Preface

We are extremely pleased to present this book according to latest syllabus of NCERT. The book has been written in easy and simple language so that students may assimilate the subject easily. We hope that students will get benefitted from it and teachers will appreciate our efforts. In comparison to other books available in market, this book has many such features which make it a unique book :

1. Theoretical subject-material is given in adequate and accurate description along with pictures.
2. The latest syllabus of NCERT is followed thoroughly.
3. Complete solutions of all the questions given at the end of the chapter in the textbook are given in easy language.
4. Topic wise summary is also given in each chapter for the revision of the chapter.
5. In every chapter, all types of questions that can be asked in the exam (Objective, Fill in the blanks, Very short, Short, Numerical and Long answer type questions) are given.
6. At the end of every chapter, multiple choice questions asked in various competitive exams are also given with solutions.

Valuable suggestions received from subject experts, teachers and students have also been given appropriate place in the book.

We wholeheartedly bow to the Almighty God, whose continuous inspiration and blessings have made the writing of this book possible.

We express our heartfelt gratitude to the publisher – Mr. Pradeep Mittal and Manoj Mittal of Sanjiv Prakashan, all their staff, laser type center and printer for publishing this book in an attractive format on time and making it reach the hands of the students.

Although utmost care has been taken in publishing the book, human errors are still possible, hence, valuable suggestions are always welcome to make the book more useful.

In anticipation of cooperation!

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CHAPTER 1

ELECTRIC CHARGES AND FIELDS

Chapter Overview

1.1 Introduction

Static electricity is that branch of physics in which the interaction between stationary charges and the fields generated by charges is studied. In this chapter, we will discuss charge and its properties, electric field, electric force and electric potential and in addition to it, we will study about the concept of electric dipole and its applications in detail.

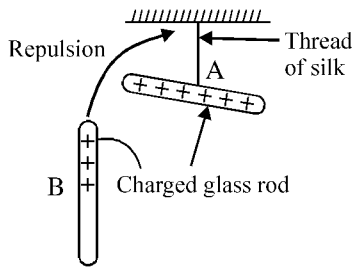
1.2 Electric Charge

About 600 years before Christ, Thales, a famous Greek philosopher, observed that when a substance called amber was rubbed with flannel, silk or cat's skin, it develops an ability to attract light particles like small pieces of paper, towards itself. After Thales, scientists did not pay any attention to this discovery for about 2000 years. In 1600 AD, Queen Elizabeth's physician Dr. Gilbert proved this through his experiments that like amber, glass, leather, ebonite, sulphur, lac etc. are also such substances which when rubbed have the power to attract light objects towards themselves. It is clear that this special quality of attraction in these substances is due to friction. This charge generated due to friction is called Frictional Electricity. After friction, when objects acquire the property of attracting lighter objects, the rubbed objects are called electrified. In daily experience also, we can see that after combing the dry hair, hair-comb starts attracting small pieces of paper. In fact, in this process the hair-comb becomes electrified. This characteristic property of an electrical substance is called electric charge. Electric substance is also called charged substance.

1.2.1 Positive and Negative Charges

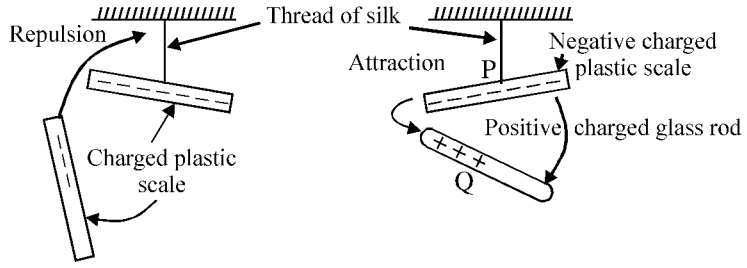
After a few years of experiments, scientists observed that different types of charges are obtained by rubbing. These charges attract and repel each other under particular cirumstances. To demonstration this phenomenon we do the following experiments :

For this, a glass rod is rubbed with a silk cloth and attached to a stable base with a thread as shown in the Fig. I. Now we take another glass rod. If we rub it with a silk cloth and bring it near the suspended rod, we see that it repels.



Repulsion occurs between like (positive) charges

Fig. I



(a) Repulsion between like (negative) charges

(b) Attraction between unlike charges

Fig. II

Similarly, if we repeat the above experiment with the help of two plastic scales and a woollen cloth, we see that there is repulsion in the charged plastic scales also. As shown in Fig. II (a). Now we bring a charged glass rod near the charged plastic scale and we see that there is an attraction between the plastic scale and the glass rod. As shown in Fig. II (b).

It is clear from the above experiments that the electricity generated on rubbing a glass rod with a silk cloth is of different nature from the electricity generated when a plastic is rubbed with a woollen cloth. Therefore, charged objects are divided into two parts :

(1) The first type is those charged objects in which electricity is generated like a glass rod rubbed with silk cloth. In this way charged objects are said to be charged with positive charge.

(2) The second type includes those objects in which electrical properties similar to plastic scale rubbed with woollen cloth or fur are produced. Such charged objects are said to be charged with negative electricity.

It is clear from the above experiments that :

(i) There is repulsion between similar charges.

(ii) There is attraction between dissimilar charges.

The experiment here concludes that the objects to be rubbed and the object with which it is rubbed simultaneously have equal and opposite charges.

We will further study that in the atoms of each substance there are equal amounts of positive charge and negative charge. Basically negative charge is present in electrons and positive charge is present in protons. Due to this, every atom is electrically neutral. When we rub a glass rod with a silk cloth, some electrons (negative charge) from the glass rod get transferred to the silk cloth. Due to this, there is an abundance of positive charges in the glass rod and there is an abundance of negative charges in the silk cloth.

1.2.2 Electron Theory of Electric Charge

According to this theory, every substance is made up of small particles, which we call atoms. The entire weight of an atom is concentrated in its central part, which is called nucleus. There are two types of physical particles in the nucleus—(1) Proton (2) Neutron. The proton has a positive charge while the neutron is neutral. The electrons around the nucleus have a negative charge. The negative charge on each electron is equal in magnitude to the positive charge on each proton. Apart from this, the number of protons in each atom is equal to the number of electrons. Therefore, despite the presence of two oppositely charged particles in the atom, the atom is electrically neutral.

If one or more electrons are somehow removed from an atom, then the amount of positive charge on it increases and it is called positively charged. When an atom somehow acquires one or more electrons from outside, then the amount of negative charge on it increases and it is called negatively charged because every object has innumerable atoms. "Therefore, the positive charge of an object reflects the lack of electrons in its atoms and its negative charge reflects the dominance of electrons."

Because the process of an object becoming positively or negatively charged can be explained only by the transfer of electron and the electron can also be easily separated from the atom, not the proton. Therefore, for an object to be charged, only electrons are responsible, not protons.

Important facts : (1) An object being positively charged means that there is a lack of electrons on the object in its normal state and the objects being negatively charged means that there is an excess of electrons on the object in its normal state.

(2) Electrons are responsible for electrification of any object, not protons, because electrons remain outside the nucleus, it is easy to separate them, whereas protons remain held inside the nucleus by strong forces, hence it is difficult to remove protons from the nucleus.

1.2.3 Explanation of Frictional Electricity

Generally we experience that a substance called amber when rubbed with wool, it acquires the property of attracting light objects (like small pieces of paper, light straws, etc.). Similarly, when a glass rod is rubbed with a silk cloth and ebonite is rubbed with a cat's skin, similar properties develop in them. It is clear that this special quality of attraction in these substances arises only as a result of friction. This effect caused by friction is called friction electricity. When a glass rod is rubbed with silk, some electrons are released from the glass atoms and go to the silk. Due to lack of electrons on the glass, there is an excess of positive charge and on the silk, there is an excess of negative charge. Hence the glass rod becomes positively charged and the silk negatively charged. Similarly, when an ebonite rod is rubbed with the skin of a cat, some electrons from the skin come into the ebonite, hence the ebonite rod becomes negatively charged due to excess of electrons and the cat's skin becomes positively charged due to lack of electrons. We know that the mass of the electron is $m_e = 9.1 \times 10^{-31}$ kg and as the electron is removed from the object, its mass will decrease. Although this decrease or increase is in very small quantity *i.e.*, very little. But this is correct in principle. In the table given below, due to friction, the objects in the first column acquire a positve charge and the objects in the second column acquire a negative charge.

Positive Charge	Negative Charge
1. Glass rod	Silk cloth
2. Cat's skin	(i) Ebonite rod (ii) Any rod of plastic
3. Woollen cloth	(i) Ebonite (ii) Rubber (iii) Plastic

The mass of a particle does not behave like charge because at very high velocity $v \sim c$ the mass of the particle is $m = \dfrac{m_o}{\sqrt{1-\dfrac{v^2}{c^2}}}$.

Here, m_o is the value of mass in the steady state of the particle whereas this is not the case of charge. The main reason for this is that charge is positive and negative but mass is only positive. Charge is always associated with mass, *i.e.*, charge cannot exist without mass, whereas mass can exist without charge. Particles whose rest mass is zero cannot be charged. Like photon or neutrino.

Differences between Mass and Charge

	Mass	Charge
1.	Mass is possible without charge.	Charge is not possible without mass.
2.	Mass is based on the reference frame. $m = \frac{m_o}{\sqrt{1-\left(\frac{v^2}{c^2}\right)}}$	Charge does not depend on the reference frame.
3.	Mass is always positive.	Charge may be positive or negative. The negatively charged object has more mass and the positively charged object has less mass.
4.	There is always a force of attraction between two masses : $F = -\frac{G\, m_1 m_2}{r^2}$ This force does not depend on the medium.	There can be attraction or repulsion between two charges : $F = \frac{k\, q_1 q_2}{r^2}$ This force depends on the medium : $F = \frac{k}{\text{Medium } \varepsilon_r}\frac{q_1 q_2}{r^2}$
5.	Accelerated mass does not emit energy.	Accelerated charge releases energy.

1.3 Conductors and Insulators

All the substances found in nature can be divided mainly into two parts :

(1) Conductors and

(2) Insulators.

(1) Conductors : Those substances which are used to flow electric charges from one place to another are called conducting substances. For example, iron, copper, silver, aluminium, mercury, acid, alkali, salt solution etc. are materials that conduct electricity. Silver is the best conductor of electricity. When a charge is given to a conductor then this charge spreads on the outer surface of the conductor and the charge at every point inside the conductor is zero.

(2) Insulators : The substances through which charge (or electricity) cannot flow is called a bad conductor or insulator. For example, glass, rubber, plastic, ebonite etc. are insulating substances. These are also called dielectric substances.

Free and Bound Charges : Generally, electricity is conducted in substances by electrons (negatively charged particles). The electrons in the atom revolve in different orbits around the nucleus.

In some substances, due to the strong attraction of the nucleus on the valence electrons of atoms, it is generally not possible for their valence electrons to move freely in the substance. Such electrons are called bound electrons and such material is called dielectric material. When dielectric materials are placed in an external electric field, the centre of positive charges and the centre of negative charges in their atoms get displaced from each other. As a result, induced charge appears on their surface.

1.4 Basic Properties of Electric Charge

We saw that there are two types of charges—positive and negative. Like charges repel each other, while unlike charges attract each other. Here we will describe some other important properties of electric charges.

1.4.1 Additivity of Charges

"Additivity of charges is the property by which the total charge is obtained from the algebraic sum of its various charges in a system." *i.e.*, charges can be added like real numbers or charge is a scalar quantity like mass.

If n charges in system are q_1, q_2, q_3, ..., q_n, then the total charge of the system is $q_1 + q_2 + q_3 + ... + q_n$. Like mass, charge has magnitude, not direction. The mass of an object is always positive whereas a charge can be