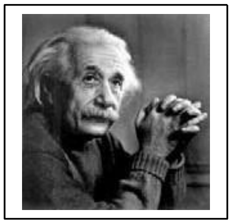
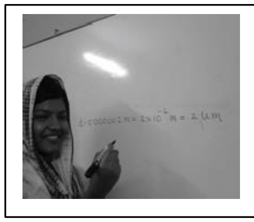
Chapter one

PHYSICAL QUANTITIES AND MEASUREMENT





[Science is the companion of our everyday life. It is inextricably related to each and every activities of our daily life .Starting from the toothpaste used in the morning to the day long using of internet, mobile and watching of television all are the fruits of scientific discovery. Science has made human life beautiful and prosperous. It has increased comfort and happiness. However, this development of science was not possible in a day. Science has reached this stage due to untiring efforts of innumerable scientist from ancient time. In this chapter we will try to introduce the contribution of those dedicated scientists by giving a description of a brief but continuous history of development of physical science especially of physics from ancient times.

Measurement is related to most of our daily activities. The act of measuring some thing is called measurement. In this chapter, we will discuss Measurement, Unit of Measurement, International system of units, some measuring instruments and their uses. In almost all the experiments in physics it is necessary to measure deferent quantities.]

By the end of this chapter we will be able to-

1. Explain the scope and gradual development of physics.
2. Describe the objectives of physics.
3. Explain the concept of space and time.
4. Explain the physical quantities [with units and magnitude] as the origin of physics.
5. Explain the measurement and necessity of units.
6. Explain the difference between fundamental and derived quantities.
7. Explain the international system of units.
8. Calculate the dimension of quantities.
9. Calculate the transformation of prefixes of multiple and sub-multiple units.
10. Express the concept of physics and its theories by using scientific names, symbols and notations.
11. Measure the physical quantities by using apparatus.
12. Explain the mechanism of exactness, accuracy and close approximation of measurement.
13. Determine the area and volume of objects by using simple instruments.
14. Determine the length, mass, area and volume of the objects used in our daily life.

1.1 Physics

The branch of science which deals with matter and energy is called physics. The main objectives of physics are to establish the relation between matter and energy and to express it quantitatively on the basis of observation, experimentation and analysis.

Scope of Physics :

Physics is the key of all science. It is the fundamental branch of science because the foundation of other subjects is based on the principles of physics. For example, the principle of conservation of energy is a basic principle of physics used to explain the wide range of science starting from the structure of atom to weather forecasting. Starting from Engineering to Medical Science, Astronomy to Oceanology, Biology to Psychology the instruments of Physics are used.

For the systematic study of physics, we can divide it into the following branches : (1) Mechanics (2) Heat and thermodynamics (3) Sound (4) Optics (5) Electricity and Magnetism (6) Solid State Physics (7) Atomic Physics (8) Nuclear Physics (9) Quantum Physics and (10) Electronics

Development of physics:

Modern civilization is the product of science. Behind this development of science there are untiring efforts, discoveries and innovation of scientists. Science has no national or political boundaries. The growth, development and benefit of science are enjoyed by all people of all nations. From ancient time scientist have been contributing for the development of science. In this lesson we will try to mention the contributions of physicists. Thales (624-569 B.C) is famous for his predictions regarding solar eclipse. He also knew about the magnetic properties of loadstone. Pythagoras (527-497 B.C) is a memorable name in the history of science. Beside the invention of several Geometric theorem, he made longer lasting contribution through his works on vibrating string. He was given several Geometric theorem .Moreover, he made long lasting contributions through his works on vibrating strings. The present scales of musical instruments and music are partially the contributions of his research on the vibration of strings.

Greek philosopher Democritus (460-370 B.C) gave the idea that the matter consists of indivisible units. He called it atom. His concept about atom was significant even though it is completely different from the present concept. Greek scientist Archimedes (287-212 B.C) discovered the principles of lever and the law of upward force acting on bodies immersed in liquid and was able to determine the impurity in metals. He also knew the technique of setting fire by concentrating sun rays with the help of spherical mirrors.

After Archimedes, scientific discoveries advanced rather slowly for a few centuries. In fact scientific discoveries did not revive in Europe before the thirteenth century. During this time West European civilization particularly adopted the trends of the Byzantine and Muslim civilization in the pursuit of knowledge. The Arabs were also particularly advanced in Science, Mathematics, Astronomy, Chemistry and Medical Science. During this time the contribution of Ibne-Al-Haithan (965-1039 A.D) and Al-Hazen (965-1038 A.D) may be particularly mentioned for their theories of light, a branch of physics. Ptolemy (127-151 A.D) and other earlier scientists believed that the eyes itself sends light rays to see an object. Al-Hazen contradicted this view and asserted that we see an object because light rays from the object fall on our eyes. Experiments with magnifying glass brought him near to the modern theory of convex lens. Al-Masudi (896-956 A.D) wrote an encyclopedia on the History of Nature in which the name of Windmill was first mentioned. At present many countries of the world produce electricity by using this windmill.

Roger Bacon (1214-1294 A.D) was the pioneer of the experimental scientific methods. According to him all scientific truths should be verified through observations and experiments. At the end of the fifteenth century, Leonardo de Vinci (1452-1519 A.D) made a model of aero plane by observing the act of flying of birds. Although he was a painter, he had considerable knowledge about mechanics. As a result, he was able to invent efficiently some common instruments. During the Galileo-Newtonian age and even before that time a few of very important scientists, although small in number were born. They contributed a lot to the advancement of science too. Dr. Gilbert (1540-1603 A.D) is unforgettable for his extensive research and theory on magnetism. Snell (1591-1626 A.D) of Germany discovered the laws of refraction of light. Huygen (1626-1695 A.D) reviewed the motion of pendulum, developed the mechanical device of clocks and invented the wave theory of light. Robert Hook (1635-1703 A.D) strove to find out the elastic properties of bodies. Robert Boyle (1627-1691 A.D) conducted experiments to find out the properties of gases at different pressures. Von Guerick (1602-1686 A.D) invented air pump. Romer (1644-1710 A.D) measured the velocity of light by studying the eclipse of a satellite of Jupiter, but none of his contemporary scientist believed that velocity of light could be so high.

Kepler (1571-1630 A.D) presented three laws for a general mathematical explanation of concept of solar-centered theory of Copernicus. Kepler’s success was based on his assumption of an elliptical orbit opposed to the conventional circular orbit. He verified the validity of his mathematical laws about the orbits of the planets with the data collected through observation by his teacher Tychobrahe (1546-1601 A.D).

The inception of modern scientific method was made by a famous Italian scientist Galileo (1564-1642 A.D). He showed for the first time that the observations, experimentations and definitions of physical quantities systematically and the determination of relations among them are the basic foundation of scientific works. Galileo introduced the scientific trends of developing mathematical theory and verifying its authenticity through experiment. Later, Newton (1642-1727 A.D) gave it a complete shape. Galileo defined displacement, motion, acceleration, time etc. and determined relations among them. Consequently he discovered the laws of falling bodies and established the foundation of statics. Newton by his versatile genius discovered mechanics and the three famous laws of mechanics and law of universal gravitation. He also made contribution for optics, heat and sound. He invented calculus, a new branch of mathematics.

The discovery and inventions of the eighteenth and nineteenth century paved the way for Europe to industrial revolution. The steam engine of James Watt (1736-1819 A.D) played a vital role for industrial revolution. Hans Christian Oersted (1777-1851 A.D) demonstrated the magnetic effect of current. This discovery led Michael Faraday (1791-1867 A.D), Henry (1797-1879 A.D) and Lenz (1804-1865 A.D) towards discovering the fact that magnetic effect produces electric current. In fact, this was a discovery of the process of converting mechanical energy into electrical energy.

In 1864 James Clark Maxwell (1831-1879 A.D) demonstrated that light is one kind of electromagnetic wave. He established the electromagnetic theory by combining electric and magnetic field. Similar kind of radiation was also discovered and produced in 1888 by Heinrich Hertz (1857-1894 A.D). Using the same kind of waves in 1896, Marconi (1874-1937 A.D) discovered the method of sending signal through ″Morse code″ to far off distance. Before him Sir Jagadish Chandra Basu (1858-1937 A.D) was able to send energy from one place to another through electromagnetic wave. In this way radio communication was developed. By the end of nineteenth century Roentgen (1845-1923 A.D) discovered x-rays and Becquerel (1852-1908 A.D) discovered the radio activity of uranium.

In the twentieth century surprising advancement took place in the field of physics. Max Planck (1858-1947 A.D) discovered quantum theory of radiation. Albert Einstein (1879-1955 A.D) invented theory of relativity. These two theories not only explained the previous experimental result but also made some predictions which were experimentally verified. Ernest Rutherford's (1871-1937 A.D) nuclear theory regarding atoms and Neill Bohr's (1885-1962 A.D) concept of electron layers in the hydrogen atoms were very important step of atomic physics.

The next important discovery was made in 1938. At this time Otto Hann (1879-1968 A.D) and Stresemann (1902-1980 A.D) found out that nucleus was fissionable. Due to fission a nucleus of large mass number splits up into two nuclei of approximately equal mass number and a part of its mass is converted into energy as a result of which atom bomb and nuclear reactor are invented. The amount of energy we are getting at present from the nucleus is huge compared to the energy obtained from all the sources in the past. Day by day nuclear energy is becoming the principal source of energy. In this century quantum theory of the relativity etc. was developed in the field of theoretical physics. Satyendranath Basu (1894-1974 A.D) professor of physics, University of Dhaka made important contribution on theoretical physics. He demonstrated a comparatively correct form of Planck's quantum theory. His theory is known as Bose-Einstein's statistics. As recognition of his contribution one kind of elementary particle is named after him and is called Boson. Three nobel laureate physicist Prof. Abdus Salam (1926-1996 A.D) of Pakistan, Sheldon Glasso (1932-) and Stevan Wienberg (1933-) of United States made outstanding contribution by discovering weak electric force in unifying the elementary particles in unified field theory. Prior to that nobel laureate physicist Chandra Shekhar Ramon (1888-1970 A.D) discovered Ramon effect. Physics has made significant contribution in the progress of medical science in twentieth century. By using radio isotopes along with the discovery of numerous equipments physics has contributed to medical science. Another advancement of physics in twentieth century is exploration in the space. The contribution of physics lies in landing human footprint on the moon along with the staying of months after months in space station and exploration on the Mars.

Artificial satellite has contributed to forecast weather and made communication easy. Moreover electronics has already brought about revolution in our daily life and changed our life style. Now a days radio, television, digital camera, mobile phone, i-pad and computer are used almost in every house. Various electronics instruments have developed human's work ability to a great extent.

In nineteenth century physics played a vital role for the advancement of medical science. Outstanding contribution of physics in the field of medical science lies in inventing different instrument along with radio isotope for the prevention of diseases. Another advancement of physics in the twentieth century is the exploration in the space.

1.2 Objectives of Physics :

Physics unearths the mystery of nature: Physics is the fundamental branch of science because its principles are the basis of other branches of science. For example, the principle of conservation of energy is a principle of physics used to explain the wide range of science starting from the structure of atom to weather forecasting.

Although the main function of physics is to study matter and energy, the main objective of physics is to realize the rules of nature as well as unearthing the mystery of nature. In the beginning of twentieth century physicist discovered that electrons revolves around the positively charged nucleus of atom. Subsequent experiments proved that nucleus consists of protons and neutrons. Now the physicists have discovered that proton and neutron are formed of more smaller particles.

The study of physics helps not only to understand and explain the natural events but also its application plays a vital role in other branches of science. At present physics is at the centre probably because of its application in other branches of science. The discovery of electron at the end of ninetieth century made possible to invent electron microscope which has brought about a revolution in material science and Cytology.

In physics there is development of theories and application mathematics at the same time it has practical application and engineering application too. Physics is very essential to give fundamental explanation and form idea about Chemistry, Geology, Astronomy, Meteorology etc. In addition, there is wide application of methodology and instruments of physics in Biology, Oceanology, Psychology and Medical Science.

Physics describes the laws of nature: The natural world that we live in follows some certain laws e.g. Newton's law of gravitation, law of conservation of energy etc. Since our childhood we have been acquiring these laws through our personal experiences which are very essential for our life. We cannot change the function and laws of nature but can utilize them. For their proper utilization we need sufficient knowledge about them. Moreover physics is the science that studies on this earth for innovation.

Development of technology results from the proper application of fundamental laws of physics :

We have to have knowledge about the fundamental laws of physics if want to know how television works, rocket flies in the space, artificial satellite revolves around the earth, , mobile phone functions, submarine remain submerged into water and how by using internet the whole world can be explored in a moment . The discovered laws of physics pave the way to invent these technologies.

Study of physics is a perfect human training :

We can achieve new idea by the study of physics. Physics instructs on how to think, show cause, how to put argument, how to utilize logic and mathematics. It stimulates our imagination and develops the power of thinking.

Physics teaches how to carry out observation:

We can develop our capability of observation. We can also learn how to carry out systematic observations by studying physics properly

1.3 Space and time

In science particularly in physics the concept of space and time is very important. We need the concept of space and time to describe any event, because without it we cannot get clear idea about space and time of the event. The concept of space is in vogue from ancient time to locate the position of an object and space occupied by it. Similarly the concept of time is necessary to understand sequence and duration of the event.

Euclid's concept: Euclid was fast to present the geometric concept of space.

Galileo's concept: Galileo in his book, *Statics* used space and time in the law of motion and acceleration. Thus space and time have become very important quantities in mathematical equations.

Newton's concept: The concept of space and time has become more clear and taken quantitative form through Newtonian mechanics. Space is a three dimensional extension in Newtonian or classical physics. Space has no beginning or end. It has limitless extension. Space can be divided into infinite small parts i.e. space is continuous. Space is homogenous as regions of any space are identical. Space is independent. Though all the events take place and spread within the space; space is never influenced by any object or event. Like space, time is also independent. So, passage of time cannot change space.

1.4 Physical Quantities

Any thing that is measurable in this physical world is called a physical quantity. For example, the length of a table can be measured. Here, length is a physical quantity. The mass of your body can be measured, mass is a physical quantity. The time during which you are reading this book can be measured, time is a physical quantity. If you apply force to lift some thing, that force can be measured. So force is a physical quantity. There are many such quantities in this physical world. Among these, it is seen that there are a few quantities which can be measured without any help from any other quantities. These quantities are `fundamental quantities'. For instance, to measure the length of a table, you need to measure only the length. To measure this length, there is no need of measuring any other quantity. So, length is a fundamental quantity. On the other hand, measurement of some quantities need the help of other quantities. For example, to measure the density of copper bar it is necessary to measure the mass and volume of a piece of copper bar and then mass is to be divided by the volume. Again, to measure the volume, the length, the breadth and the height are to be measured, that is, lengths are to be measured three times in three directions. So, it is seen that, there are certain quantities which are fundamental. They do not depend on other quantities. These are called fundamental quantities.

So, the physical quantities which are independent or neutral that is, they do not depend on other quantity, rather other quantities depend on them, are called fundamental quantities. Scientists have identified seven such quantities as fundamental quantities which are used in all branches of science for measurement. These are (1) length (2) mass (3) time (4) temperature (5) electric current (6) luminous intensity and (7) amount of substance.

All other quantities may be derived from fundamental quantities that means, these are obtained from the product or quotient of one or more fundamental quantities. These are called derived quantities or compound quantities.

So, the quantities depend on fundamental quantities or obtain from fundamental quantities are called derived quantities. Velocity, acceleration, force, work, heat, electric current etc. are derived quantities since these are obtain from fundamental quantities.

For instance,

force = mass x acceleration

$$= \text{mass} \times \frac{\text{velocity}}{\text{time}} \qquad [\because \text{acceleration} = \frac{\text{velocity}}{\text{time}}]$$

$$= \text{mass} \times \frac{\text{distance}}{\text{time}} \times \frac{1}{\text{time}} \qquad [\because \text{velocity} = \frac{\text{distance}}{\text{time}}]$$

$$= \text{mass} \times \frac{\text{distance}}{\text{time}^2}$$

Hence, force is a derived quantity.

1.5 Units of measurements

Measurement is related to most of our daily activities. Moreover, we need accurate measurement for various research works. The act of measuring something in our daily life is called measurement. In general, measurement means the act of determining the quantity of something. For example, the distance of the school from Rizu's home is 700 meters. Sohel has bought 5 Kilograms of rice from the shop. Rina takes 50 seconds to go to the school's office room. Here, 700 meters is the distance, 5 kilograms is the mass of rice and 50 seconds is the amount of time spent. We need two things to measure anything. One is number and another is unit.

A standard is essential, comparing with which any measurement is done. These standard quantities are called the unit of measurement. Say, the length of a rod is 4 meters. Here, meter is a unit of length and 1 meter is a specific measurement. Therefore, length of the rod 4 meters means length of the rod is 4 times of this 1 meter's unit. There are different units for measurement of time, volume, velocity, mass, force, energy, temperature, electric current etc. These units have been designed in such way that they can be convenient and can be easily and accurately reproduced. Except some units all these units are interrelated with one another.

Fundamental unit in SI

We can select fundamental units according to your liking, since the units of fundamental quantities do not depend on other units. But our selection must have international recognition. It should have some characteristics as well. For example, it should be unchangeable, that is, independent of place, time and person. It will not change due to passage of time or any other natural change. It could be reproduced easily. The standard of fundamental units that were accepted in 1960, while introducing the SI system of units, were changed later on in some cases in order to attain suitable characteristics. But no change was brought in values of the units. For example, at present, meter is defined in terms of distance traveled by light. Earlier, meter was defined using wavelength of a kind of light. Prior to it, the length of a rod kept at Sevres near Paris in France was taken as the standard of meter. The latest accepted standard of fundamental units in International System are described below

Unit of length : Meter : The distance traveled by light in vacuum (air-free space) in $\frac{1}{299792458}$ second is defined as one meter (m).

Unit of mass : Kilogram : The kilogram is the mass equal to that of a cylinder made of platinum-iridium alloy (International prototype kilogram) kept at the International Bureau of Weights and Measures at Severs, France. The diameter of this cylinder is 3.9 cm ; its height is also 3.9 cm.

Unit of time : Second : The time required to complete 9 192 631 770 vibrations by a caesium-133 atom is called one second (s).

Unit of temperature : Kelvin : The temperature which equals to $\frac{1}{273.16}$ of the thermodynamic temperature of the triple point of water is called one Kelvin (k).

Unit of electric current : Ampere : The ampere is that current which produces a force of $2\text{x}10^{-7}$ Newton per meter in vacuum between two parallel infinitely long conductors of negligible cross-sectional area 1 meter apart when each conductor carries the same current.

Unit of luminous intensity: Candela : Candela is the quantity of luminous intensity of any source of light which radiates monochromatic radiation at a particular direction with a frequency of $540\text{x}10^{12}$ Hz and emissive power of $\frac{1}{683}$ watt per steredian solid angle.

Unit of amount of substance : Mole : The mole is defined as the amount of substance which contains elementary entities (e.g atoms, molecules, ions, electrons etc. or any specified group of these particles) equal to the number of atoms in 0.012 kilogram of Carbon-12.

Fundamental quantities and their units

SL No	Name of Physical Quantities	Symbol of quantities	SI Unit	Symbol for unit
1	Length	L	meter	m
2	Mass	m	kilogram	kg
3	Time	T	second	s
4	Temperature	θ, T	Kelvin	k
5	Electric current	I	ampere	A
6	Luminous intensity	I_V	candela	cd
7	Amount of substance	n	mole	mol

Multiple and sub-multiple of units :

Sometimes it is beneficial to use the fractions or multiples of fundamental units. When the value of a quantity is very big or small, the prefixes mentioned in the following table is very essential. For example, if we consider the distance of two molecules of air, we can see the distance is very small and it is 0.00000001 m. If we use this number frequently, we have to be careful about the number of zero's every time to see weather it is mentioned accurately or not. But if we mentioned the number by a prefix we will write 0.01μm instead of 0.00000001m. Here the symbol μ refers to the prefix 10^{-6}. Similarly if we mentioned the power of newly built electricity production center is 2000 x 10^6 w = 2000mw instead of 2000000000w, it will be more convenient. The use of indices of 10 before the unit of the following prefixes is approved to be use in SI system.

	Multiple/Sub-multiple	Factor	Symbol	Example
Multiple	exa	10^{18}	E	1 exa meter = 1 E.M = 10^{18}m
	peta	10^{15}	P	1 peta meter = 1 pm = 10^{15}m
	tera	10^{12}	T	1 tera gram = 1 tg = 10^{12}g
	giga	10^{9}	G	1 giga bite = 1 GB = 10^{9}B
	mega	10^{6}	M	1 mega watt = 1 MW = 10^{9}W
	kilo	10^{3}	K	1 kilo volt = 1 kV = 10^{3}V
	hecto	10^{2}	h	1 hecto joule = 1 hj = 10^{2}j
Su	deca	10^{1}	da	1 deca newton = 1 da N =10^{1}N

	desi	10^{-1}	d	1 deci ohm = 1 dΩ = 10^{-1}Ω
	centi	10^{-2}	c	1 centimeter = 1 cm = 10^{-2}m
	milli	10^{-3}	m	1 mili ampere = 1 mA = 10^{-3}A
	micro	10^{-6}	μ	1 micro volt = 1 μV = 10^{-6}V
	nano	10^{-9}	n	1 nano second = 1ns = 10^{-9}s
	pico	10^{-12}	p	1 pico farad = 1 pf = 10^{-12}f
	femto	10^{-15}	f	1 femto meter = 1 fm = 10^{-15}m
	atto	10^{-18}	a	1 atto watt = 1 aW = 10^{-18}W

when a number is expressed as the product of any power of 10 and another number between 1 and 10, it is called a scientific notation. As for example, 6733000000 are 6.733×10^9 and 0.00000846 is 8.46×10^{-6}. So it is seen that the original number is obtained from a number expressed in notation by placing the decimal point to the right by the number of digits equal to the power of 10 if the power is positive and to the left if the power is negative.

In the case of numbers expressed in scientific notation the following general rule of multiplication is applicable :

$10^m \times 10^n = 10^{m+n}$

Here, m and n may be any positive or negative number. For example, $10^6 \times 10^7 = 10^{13}$, $10^7 \times 10^{-20} = 10^{-13}$

In case of division the following rule is applicable :

$$= \frac{10^n}{10^m} = 10^n \div 10^m = 10^{n-m}$$

For example, $10^6 \div 10^4 = 10^2$ or $10^3 \div 10^{-7} = 10^{3-(-7)} = 10^{10}$

1.6 Dimensions :

By now, we know that a physical quantity is a combination of one or more fundamental quantities. So, any physical quantities may be expressed as the product of one or more fundamental quantities of different powers. The power of fundamental quantities in a physical quantity is called its dimension.

For example, Force $= \text{mass} \times \text{acceleration} = \text{mass} \times \dfrac{\text{velocity}}{\text{time}}$

$$= \text{mass} \times \frac{\text{distance}}{\text{time}} \times \frac{1}{\text{time}}$$

$$= \text{mass} \times \frac{\text{distance}}{\text{time}^2}$$

Now, if we take that the dimension of length as L, the dimension of mass as M and the dimension of time as T, then the dimension of force is ML/T^2 or MLT^{-2} , that is, force has the dimension of mass (1) dimension of length (1) dimension of time (-2). (The equation to express the dimension of physical quantity is called the dimensional equation). Third bracket [ ] is used to indicate dimensions in any quantity. As for example, the dimensional equation of force is [F] = [MLT^{-2}]

Except these above mentioned three physical quantities of length, mass and time others dimension of physical quantities are :

The dimension of temperature as θ (Capital alphabet of Greek letter θ), the dimension of electric current as I, the dimension of luminous intensity as J and the dimension of amount of substance as N.

We can verify the validity of any equation or formula by analyzing dimension. For example, the following equation may be considered:

$$S = ut + \frac{1}{2} at^2$$

We know that addition, subtraction or equivalence are possible for any same kind of quantities. Hence every term of an equation must indicate the same kind of quantity, that is, the dimension of every term must be the same. Now there are three terms in the above equation, one to the left and two to the right.

In this equation, s is displacement : its dimension is L, u is initial velocity; its dimension is $^{L}/_{T} = LT^{-1}$, a is acceleration ; its dimension is $^{L}/_{T^2} = LT^{-2}$, t is time ; its dimension is T.

$\therefore$ The dimension is ut = $LT^{-1} \times T = L$

The dimension of $at^2 = LT^{-2} \times T^2 = L$

Thus it is seen that the dimension of each of the term on both sides of the above equation is the same L. Therefore, the equation is valid.

1.7 Scientific symbols and notations :

Mathematics is said to be the language of physics. We usually express the laws of physics in the form of mathematical equation and physicists solved many problems by applying these laws or equations. Various symbols and notations are used according to the SI system for different quantities and units. This SI system of units is not only used in physics but also used in other branches of science now a days for measurement.

The following methods are followed for expressing symbol of units of different quantities.

1. The symbol of units are to be expressed by writing a number and a space after it (actually expresses multiplication) for expressing the value of a quality. For example "2.21 Kg'', "7.3 x 10^2 m^2'', "22 k''. The sign of % also follows the same rule. However

space after number is not used to express the unit of angle i.e. degree, minute, and second (° , ` and ").

2. Derived unit produced by multiplication is expressed using a space between two units e.g. N m.

3. Derived unit produced by division is expressed as negative power e.g. meter/second is expressed as ms^{-1} .

4. No punctuation mark or full stop is used with the notations as – they are not the abbreviated from any thing but the form of mathematical expression.

5. The symbol of unit is written in Roman type font, for example m for meter, s for second but the symbol of quantities are written in italic type font, for example, m for mass, s for displacement etc. It does not matter what kind of language or font is used after of before of these symbols and units to express.

6. The symbols of unit are expressed in small letters, for example “m’’, “s’’, “mol’’, but capital letters are used to write the unit which is derived from name of a person, for example, the unit N is derived from the name of Newton and Pa from Pascal. However, while expressing full form of unit small letters are used. For example, newton or pascal.

7. As prefix of a unit is the part of it, no space is used to express its symbol. For example, km for kilometer (k), MW for megawatt (M) GHz for giga Hertz (G). More than one prefix is not allowed to use such as μμF, but pF.

8. Prefixes more than kilo (10^3) must be in capital letter.

9. The symbols of units are always singular. Such as ``25 kg’’ instead of ``25 kgs’’.

10. Line-break should be avoided for expressing any number or compound unit or number and unit. Only for important purposes line-break may be acceptable.

1.8 Measuring Instruments :

Meter Scale :

This simplest instrument to measure length in the laboratory is a meter scale. It’s length is 1 meter or 100 centimeters. This is why, it is called a meter scale. One side of this scale is graduated in centimeter and the other side in inches. Each centimeter is divided into ten equal parts. Each of this parts is called 1 millimeter or 0.1 centimeter. Each inch is divided into eight, ten or sixteen equal parts.

Measure with a meter scale : To measure the length of a rod or a stick by the meter scale, it’s one end is so placed that is coincides with the 0 mark or some other convenient mark of the scale. The reading of the mark that coincides with the other end of the rod is taken. The difference between the readings at the two ends of the rod gives the length of the rod. In general if the reading of the mark that coincides with the left end of the rod is x and that of the mark coinciding with the right end is y. Then the length of the rod is L = y – x. With this scale length may be measured to an accuracy of 1 millimeter. For more accurate measurement vernier scales are used.

Vernier scale :

In the ordinary meter scale we can measured length up to 1 millimeter. To measure fractions of millimeter like 0.2mm, 0.6mm, 0.8mm etc. we have to use vernier scale. This scale was invented by a mathematician Pierea Vernier and is called vernier scale according to his name.

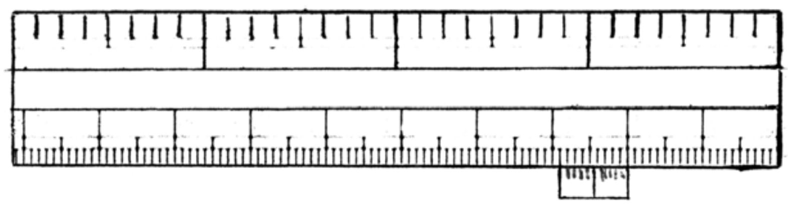


Fig.1.1 Vernier Scale

A small scale is used by the side of the main scale for accurate measurement of fractions of the smallest division of the main scale. By using vernier scale along with meter scale fractions of millimeter may be measured accurately.

Vernier scale can be moved forward or backward along the side of the main scale. Say, a vernier scale has ten divisions, this ten division is equal to nine smallest divisions of the main scale (fig 1.1). Nine smallest divisions of main scale is 9 millimeter or 0.9 centimeter. As 10 vernier scale divisions is equal to nine smallest divisions of the main scale. So, a vernier scale division is slightly smaller than the smallest division of the main scale. The difference between the smallest main scale division and the vernier scale division is called vernier constant. It is generally written by VC. A simple equation may be used to determine the vernier constant, that is vernier constant = s/n, where s is the length of 1 smallest division of the main scale and n the number of vernier divisions.

As mentioned above, s = 1 mm and n = 10 divisions

$\therefore$ Vernier constant = s / n = 1mm / 10 = 0.1mm = 0.01cm.

Sometimes 20 vernier scale divisions are equal to 19 smallest main scale divisions and the smallest main scale division is less than 1mm. Then the vernier constant becomes difference. The vernier constant depends on the characteristics of marking the main scale and the vernier scale.

Slide Calipers :

The other name of slide calipers is venire calipers. Because the Venire's method is used for the measurement with this instrument. The main scale of the slide calipers is made of a graduated rectangular still plate. A metal jaw is fixed at the starting end of the main scale, that is, at the end marked 0 of the main scale. A Jawed small scale is put over the body of the main scale, to measure fraction of the small division of the main scale accurately. It is called venire scale.

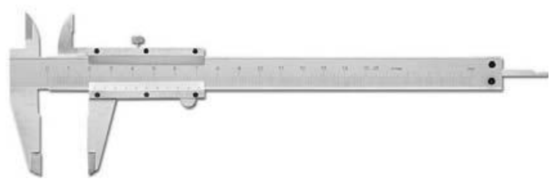


Fig 1.2 Slide Calipers

This Jawed vernier scale can be moved forward or backward along with the main scale. There is screw in it. It can be fixed at any point on the body of the main scale with this screw. When the Jaw of the vernier scale touches the Jaw of the main scale then the zero of the main scale should coincide with the zero of the vernier scale.

By using vernier scale fraction of millimeter may be measured accurately.

Vernier constant of the slide calipers can determine from the above mentioned vernier scale chapter.

Measurement of slide calipers : Suppose, the length of rod is to be measured. The rod is to be placed between the two jaws of the slide calipers. The jaw connected with the vernier scale is to be pushed forward so that the jaws of the main scale and the vernier scale touch the opposite ends of the object. The rod is placed such that it's left end coincides with zero (0) mark of the main scale. The vernier scale is moved forward and backward to make it coincide with the right side of the rod. Suppose the right end of the rod has crossed M mm mark of the scale and is between M and (M + 1) mm. This extra distance beyond M mm is to be determined by using the vernier scale. This length will be the vernier reading.

Now it is to be noted which vernier scale mark coincides with which of the main scale mark. If no vernier mark coincide with a main scale mark then find out the nearest vernier mark. The reading of this mark that is the number of vernier scale divisions from the left to this mark, is the vernier scale reading.

Suppose the V^{th} vernier mark coincides with or nearest with any main scale mark. Hence the vernier constant of the instrument is *VC*.

The length of the rod = main scale reading + vernier scale reading = main scale reading + vernier scale reding x vernier scale constant.

Thus, $L = M + V \times VC$, where VC is the vernier constant.

Example : Suppose, the end B of the rod has crossed 12mm mark of the main scale and 7th vernier mark has coincide with a main scale mark. Then the length of the rod will be
L = 12mm + 7 x 0.1mm (here vernier constant is 0.1mm)
= 12.7mm = 1.27cm.

The jaw connected with the vernier scale is to be pushed forward so that the jaws of the main scale and the vernier scale touch the opposite ends of the object. In some instrument reading not be coincided. Then have to understand there are some errors in the instruments and have to rectify it.

The Screw Gauge

This is device for the measurement of radius of wire of this cylinders and small length. It consists of a u-shaped still frame F (1.3).

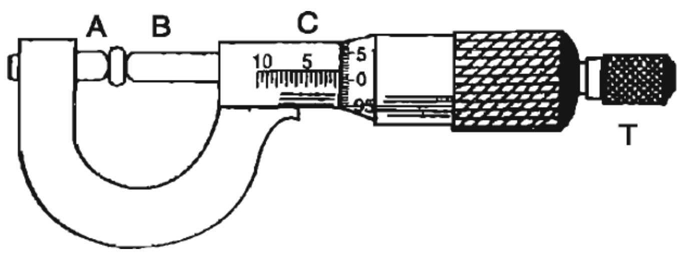


Fig 1.3 Screw Gauge

The rod with plane end is permanently fixed with the plane surface A of one arm. The other arm has a hollow cylinder C. A linear scale graduated in millimeter is marked on the cylinder and a screw with a cylindrical cap T is fitted with it. The screw can moved through the hollow cylinder C. The end of the cylindrical cap T is graduated 0 to 50 or 100. When the Jaws are closed, that is, then the head of the screw B touches the plane end of the fixed rod A, the zero of the circular scale coincides with the zero of the linear scale. If the zero marks of the two scales do not coincide, then there is instrumental error.

The distance through which the screw advances along the linear scale when the cap T is rotated once is called the Pitch of the screw gauge. The distance through which the screw advances when the circular scale is rotated through only 1 division is called the least count. The least count is obtained by dividing the pitch by the number of divisions in the circular scale.

Therefore, Least count = $\dfrac{\text{Pitch}}{\text{no. of division of the circular scale.}}$

Usually the circular scale has 100 divisions and the pitch is 1mm.

Least count = $\dfrac{1}{100\text{mm}}$ = 0.01mm.

Measurement by Screw Gauge :

The wire whose diameter is to be measured or the plate whose thickness is to be determined is placed between A and B. The wire or the plate should be so placed that it’s one side touches A and the other side touches B. Now the reading of the linear and circular scales is to be taken. Suppose the reading of the linear scale 1mm, and the number of divisions of the circular scale is C. Then the diameter of the wire or the thickness of the plate will be :

Diameter or thickness = Linear scale reading + no. of divisions of the circular scale x Least count.

That is, $D = L + C \times LC$

Example : Suppose the linear scale is 3mm and the no. of divisions of the circular scale is 20, then the diameter of the wire = 3mm + 20 x 0.01mm = 3mm + 0.2mm = 3.2mm

When the head of the screw touches the plane end of the fixed rod A, then the zero of the circular scale should coincide with the zero of the linear scale, then it means there is an error. For this reading should be corrected.

Balance :

Sometimes in physics and chemistry the mass of a small quantity of a substance needs to be measured very accurately, this is not possible with a common balance. The less quantity of the substance, the more accurate the balance should be. The balance is such an accurate weighting machine. This instrument is used in physics and chemistry laboratories for accurate measurement of small masses. Because, if the measurement of the mass in the laboratory is not accurate, the result will be wrong and the objective of the experiment will not be fulfilled.

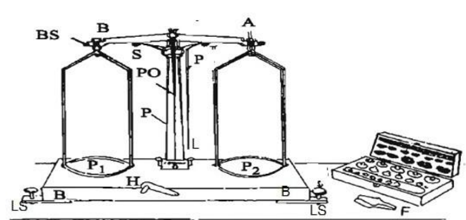


Fig 1.4

The balance has two scales pans P_1 and P_2 of equal weight at the two ends like an ordinary balance. The scale pans are hanged from the ends of a metal beam AB with the help of two frames of equal weight. The frames are placed on two inverted knife edges in two grooves at the end.

A knife with its edges downward, is fixed in the middle of the beam AB. It is placed on a hollow vertical pillar. The pillar is firmly fixed at the middle of a wooden floor CC. Three leveling screws LS are fixed with this floor (the third has not been shown in the fig.). These are used to level the instrument. A solid metal rod inside the hollow pillar can be raised or lowered with the help of a level H connected with the floor. The base of triangular shaped agate is fixed exactly in the middle of the beam AB. The sharp age is kept on an agate plate placed on the solid rod of the beam. When the solid rod is lifted, the beam AB swings about the narrow edge of the agate as the fulcrum.

The broad side of a long pointer (PO) is fixed at the middle of the balance. It's lower narrow end is free to move over a scale. When the beam is horizontal, the pointed end of the pointer rests on the zero of the scale. The beam is made horizontal with the help of a plumb-line (PL) and the leveling screws. The entire instrument is kept in a glass box.

Measurement by Balance : To use the balance, the handle H is rotated to left the pillar and hence the beam AB .The beam will then start swing freely about the knife edge. Along with the beam the scale pans will also keep in swinging up and down, with the backward rotation of the handle H. The pillar will be lowered and the swinging of the beam and scale pans will stop.

When the beam AB swings, the lower end of the pointer keeps oscillating right and left over the scale. If there is nothing on the scale pan, the oscillation of the pointer should be equal on the two sides of the zero of the scale. If it is not, the two adjusted screws (BS) at the two ends of the beam AB are to be so adjusted that the oscillation of the pointer on the two sides of the zero of the scale becomes equal. Whether the pillar P is vertical or not is seen with the plumb-line PL.

To measure the mass of an object it is placed on the left-hand pan. Known weights are placed slowly on the right-hand pan one by one, till the pointer oscillates equally to the two sides of the zero of the scale. Thus the mass of an object is determined with the help of known weights.

Stopwatch

Stopwatch is used to measure small time interval. Stopwatches are of two kinds digital stopwatch and analog stopwatch. Digital stopwatch can give more accurate reading than that of analog stopwatch. A analog stopwatch can give an accurate reading up to $\pm$ 0.15 while a digital stopwatch can read accurately up to $\pm$0.015. Now a days digital stopwatch is found in mobile phone also.

A stopwatch has to start and stop by the hands to measure a time. An error of about a large fraction of a second takes place in the reading of time interval though it may vary from person to person. The degree of error is more to the old than the young. For most of the people the error is about 0.3seconds.

1.9 Error and accuracy in measurement

All measurements have some limitations of accuracy. Accuracy of measurement depend on the skill of observer and the instruments used. Suppose a meter scale is graduated in centimeter and millimeter. If we want to measure the length of this book we will get the result probably up to 0.1cm accurately. In Accuracy may be reduced in case of measuring the length of a house because the scale is to be used several time for measuring the full length. Every time the position of the front edge of the scale has to be marker on the floor. This increases the source of error thus increasing the probability of errors.

The accuracy of measurement is as important as measurement itself. So, the observer should mention the degree of accuracy of result with the result of the experiment. Let the length of this book be 26.0cm ± 0.1cm. Here the symbol ± means that the real length of the book is between 25.9cm and 26.1cm. Here 0.1cm is the uncertainty or error of measurement.

Generally there are three types of error in measurement. There are :

a) Random error

b) Instrumental error

c) Personal error

a) Random error : The error for which irrelevant occur in measured results by measuring a constant quantities. Several times is random error. The word random itself implies that the error cannot be guessed earlier and expected value will be zero. This is because measured values moves around the accurate value and average value of the errors should be zero if the value of the quantity is measured by the same instrument. The random error will be included as much as many time the scale is used to measure the floor. Each time the front edge marking on the floor falls a little back and forth of the accurate mark. Another random error takes place with the measurement when the meter scale is placed at the previous marking (slightly error position) as back edge starts from back and forth position. The final result may be very much high or low due to random error. It is impossible to avoid random error but this error can be reduced by precautionary measurement. In order to minimize the random error average of the frequent measurement is to be taken.

b) Instrumental error : We need instruments for experimental measurement in physics. The error with the instrument is called instrumental error. For example, if the zero marking of main scale is not super-imposition with the zero marking vernier then the result of measurement will not be accurate. This kind of error is known as instrumental error . Similarly if the indicator needle of ammeter or voltmeter is not super-imposition with the zero marking then there remains error with the instrument. The instrumental error has to be determined before starting the experiment. Finally the actual reading has to be obtained by subtracting this error from the reading.

c) Personal error : We have to take various readings during experiment. The error that an experimenter makes during experiment is called personal error. The error with the position of the observer, observing any mark or any calculation is also said to be personal error. For example there will be an error while measuring the length of a rod if the super-imposition of the edge of a rod with a definite mark of the scale is observed obliquely instead of perpendicular position. There will be error in reading when we cannot observe which division of circular scale is in super-imposition with the linear scale of a time per screw gauge. Similarly we cannot find accurate if there is mistake in counting oscillation number while determining time period of a pendulum. All these are known as personal errors. We have to take the reading properly and carefully with a view to avoiding these errors.

Investigation:1.1

Determination of area and volume of a rectangular substance.

Objective : By using slide calipers determining the length of a substance.

Theory : Area of a substance is the surface of that substance. And the substance occupy some space is called volume of the substance if area of a substance is A and volume of the substance V.

$A = L$ x B, where L = Length of the substance ....(i)

B = Breadth of the substance

and $V = L$ x B x H where, L = Length of the substance.............(ii)

B = Breadth of the substance

H = Height of the substance

For taking the reading of any length by slide calipers.

Length = Main scale reading (M) + Vernier super imposition (V) x vernier constant (VC)

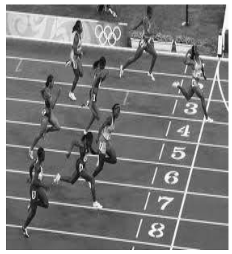
that is, L or B or $H = M + V$ x VC

Apparatus : Slide calipers, Rectangular substance

Procedure :

1) The value of the smallest division of the main scale of the slide calipers and the total number of divisions of the vernier scale are observed and from that the vernier constant (VC) of the instrument is determined.
2) The length of the rectangular substance be measured with the help of the slide calipers by placing the two surface of the body between the two jaws of the calipers.

Chapter Two
MOTION

[The object, that we see around us either are stationery or in motion. What do we actually understand by the words ``rest'' and ``motion''. We need different quantities regarding motion to express the characteristics of motion of a moving object. In this chapter we will discuss different quantities regarding motion, their dimensions, units, the relations among them etc.]

By the end of this chapter we will be able to-

1. Explain the rest and motion

2. Find out the difference among different types of motion.

3. Explain the scalar and vector quantities

4. Analyze the relation among the quantities regarding motion

5. Explain the motion of freely falling bodies

6. Analyze the relations among the quantities regarding motion with the help of graph

7. Realize the effect of motion in our life

2.1 Rest and motion

Position : Where is your school ? In answer to this question we will know the position of your school. If you say your school is in Jheeltuli it is absolutely true but we cannot know the exact position of your school from this information. We can know the exact position only when you mention the position, direction and distance of your school with respect to a particulars place. At first we have to consider a known point or an object with respect to that the position of another point or object is to be determined. For example, if said your school is one kilometer apart in the east from the gate of your residence, its position can be told certainly. We have to consider a particular point to find out the position of our village or town, country or the world or the universe around us. This point is called reference point or origin and fixed object with respect to which we find out the position, rest and motion of another object is known as reference frame. Any point can be considered as reference point for our convenience. In the above example we could consider any other point as reference point.

Rest and motion : We see many object around us of them some are rest and some are in motion. What do we actually mean by rest and moving object.

Do by yourself : Hold a pen in your hand**.**

What is there around the pen ? Does the position of the pen get changed with respect to other objects around ? It does not. The pen in your has a particulars distance and direction with respect to the objects around you such as your chair, table, book, copy, house, door, window and to all other things. So the position of your pen is fixed with respect to other objects around you. The position of the pen is not changing with the change of time. We can say the pen is in rest to the surroundings. The act of remain rest of the pen is called rest. Therefore, a body is said to be static or at rest with respect to its surroundings when it does not change its position with time.

Ani is standing by the side of the road. He said that, houses, plants and trees, electric poles etc are standing at rest. Why does he say so ? According to Ani those objects are not changing their positions with respect to time.

Do by yourself : Keep the pen in your hand moving to and fro**.**

Does the position of the pen change with respect to the objects around, the position and direction of the pen is gradually changing with respects to each object of its surrounding. The position of the pen is changing with time. We say the pen is in motion with respect to the surroundings. A body is said to be in motion with respect to its surroundings when it changes its position with time. And this change of position with time is called motion.

We discussed earlier that to understand whether an object is in rest or in motion it is necessary to chose a reference object or reference frame. If the relative positions of this considered object and the reference object remain unchanged with time, the considered object is said to be in rest with respect to reference object. If the considered object and the reference object move along the same direction with same velocity even though the distance between the objects, remain unchanged despite the object, being in motion. If two friends remain seated face to face in a running train, then the relative position of one with respect to other does not change. So one is said to have in rest with respect to other. When a person observes these two friends standing by the side of the train line he will see their position is changing with respect to him. That is both the two friends are in motion with respect to the person standing by the side of the train line.

So we see that an object is actually in rest or not depends on the reference object. If the reference frame is actually in rest, object in rest will be : actually in rest with respect to that frame. This type of rest is called absolute rest. A body is said to be in absolutely rest when it is in rest with respect to an absolutely rest object.

Similarly absolute motion of a body is its motion with respect to a reference object absolutely at rest. But in this universe it is not possible to get a reference object which is at absolute rest. Since the earth is continuously moving round the sun, while the sun itself is moving along the galaxy with its planets and satellites. Thus when we say that a body is at rest or in motion, we mean it is to be so with respect to a body apparently at rest. So we can say that in this universe all rest and all motion are relative. No rest or no motion is absolute.

Mitu is waiting for a bus at the bus stand to go somewhere. She notices her friend Roni crossing her by rickshaw. She says that the rickshaw is in motion because it is changing its position continuously with respect to time.

The change of position of a body may take place in two ways.

Let us consider the following example :

a) Mou is standing under a tree and sees that her friend Awishi is running away from her. So the distance between Mou and Awishi is increasing with time.

b) A large circular tract is made in the school field of Raju for race of annual sports. He notices his friend Shihab practicing to running along that track standing at the centre of the trac (Fig 2.1 (b)). Raju says Shihab is in motion but the distance between them is not changing with time. How it can be said that Shihab is in motion with respect to Raju.

Fig-2.1(a)

Fig-2.1(b)

In the first example, the position of Awishi is changing with respect to Mou with the change of distance and time. In the second example, the position of Shihab is changing with respect to Raju with time but the distance is not changing. What is changing then ? The direction of position of Shihab is changing with respect to Raju. The position of a moving body with respect to an observer can be taken place either indirection or in distance or by both.

2.2 Types of motion

Linear motion : If a body is in motion along a straight line, that is, if the motion of a body is restricted on a straight line its motion is called linear motion. The motion of a car in a straight street is linear motion.

Rotational motion : When a body rotates around a particular point or an axis keeping the distance of the particles of the body unchanged is called rotational motion. For example, motion of an electric fan, motion of the heads of a clock.

Rectilinear motion : When a body moves along a straight line in such a way that each particle of the body travels the same distance at the same time in the same direction.

If a book is pushed to shift from one end to the other of a table without rotation, the motion will be rectilinear because all the particles of the book travel the equal distance, at equal time in the same direction.

Periodic motion : If the motion of a moving particle is such that it passes through a definite point along the path of its motion in the same direction in a definite interval of time, this type of motion is called periodic motion. This motion can be circular, elliptical or rectilinear. The motion of the hands of a clock, the motion of earth round the sun, the motion of piston in the cylinder of a steam or petrol engine etc.

The time interval at which a particle of periodic motion passes through a definite point from the same direction repeatedly is called its time period.

Vibratory motion : If a body executing periodic motion moves in a definite direction for one half of its time period and exactly for the other half in the opposite direction then this motion is called vibratory motion. Motion of a simple pendulum, motion of vibrating tuning fork and the motion of string of guitar.

2.3 Scalar and vector quantities :

Anything that can be measured in this physical world is called a physical quantity. When a physical quantity is measured, it has got a magnitude. We express this magnitude in terms of a number and a unit. For example, if we say that the height of the bench is 1.5 meter, we mean that the unit of length is meter and height of the bench is 1.5 times this unit. But all physical quantities cannot be completely expressed by its magnitude only. To express not only magnitude of some quantities is needed but also the direction.

For example, if we say that a car is running at the speed of 40 km per hour, it is understood that the car moves a distance 40 km in one hour, but the direction of motion of the car cannot be known from this statement. To know the actual position of the car, the direction of the motion should also be stated. So, we can see, to express some of the quantities completely direction is needed with the magnitude of the quantities. In consideration of direction all quantities of the world we can divide into two category. Such as

1. In-directional quantity or Scalar quantity
2. Directional quantity or Vector quantity

Scalar quantity : Physical quantities which can be fully expressed by magnitude only are called scalar quantities. Length, mass, speed, work, energy, time, temperature etc are the examples of scalar quantities.

Vector quantity : Physical quantity which need both magnitude and direction to be fully expressed are called vector quantities. Displacement, velocity, acceleration, force, electric intensity etc are the examples of vector quantities.

Table 2.1 Shows that vectors are expressed by magnitude and direction whereas scalars are expressed by magnitude only.

Table 2.1

Examples of scalar and vector quantities

Scalar Quantity			**Vector quantity**		
Distance	*d*	40m	Displacement	**s**	40m east direction
Speed	*v*	$30ms^{-1}$	Velocity	**v**	$30\ ms^{-1}$ north direction
Time	*t*	15s	Force	**F**	100N upward direction
Energy	*E*	2000j	Acceleration	**a**	$98ms^{-2}$ downward direction

Representation of a vector :

A vector quality is represented by an arrow over the symbol of the physical quantity. For example, $\vec{A}$ or $|\vec{A}|$, where $|\vec{A}|$ represents, the magnitude of the vector quantity $\vec{A}$. Sometimes bold **A** instead of $\vec{A}$ is used to represent a vector and an ordinary A to represent its magnitude. The vector quantities in the table 2.1 are represented by bold letter.

In figure, a vector quantity represented by an arrow headed straight line. The length of the straight line represents the magnitude and the arrow head indicates the direction of the vector. For example, in figure 2.2 displacement of 50km has been represented by 1cm. Hence the vector A in this figure, whose length is 3cm represents a displacement of 150km towards west. The vector B represents a displacement of 100km towards north at an angle of 30^0 with the east.

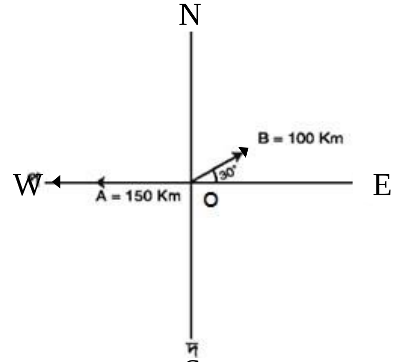


Fig-2.2

2.4 Different quantities related to motion

Distance and Displacement:

Suppose, Ovi ran 100m from his school gate. It is true that Ovi is 100m away from the gate, but it does not tell the exact position of Ovi. Because Ovi can be 100m away to the east, to the west, to the north, to the south or any other directions. To know exactly the change of position of Ovi, the direction towards which he moved 100m should also be known. If it is stated that Ovi ran 100m from the gate to the east then his exact position will be known definitely. If you go straight to the east from the gate you will find Ovi at a distance of 100m. The physical quantity which was first used to indicate the change of position of Ovi is distance. This is a scalar quantity. In the second case, direction has also been mentioned along with distance, this is called displacement. This is a vector quantity. Change of position or distance in a definite direction is displacement. So, the change of position of an object with respect to its surrounding in a definite direction is called displacement.

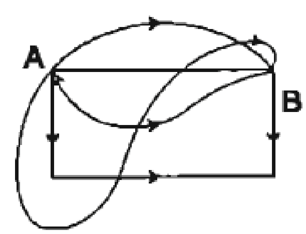


Fig-2.3

The minimum distance, that is, the linear distance between the initial and final position of a body is the magnitude of its displacement at its direction is towards final position from the initial position.

The displacement does not depend on the path of the object. An object can move from position A to position B following different paths. But its displacement will be from A towards B. The minimum distance between A and B, that is, in this case the linear distance AB is the magnitude of displacements. AB and its direction is towards B from A. Here, it is a vector quantity, since displacement has both magnitude and direction.

The dimension of displacement is the same as that of distance.

Therefore, $[\ s\ ] = L$

The unit of displacement is the same as that of distance that is meter (m). The displacement of a body is 50m towards north means that the body has moved 50m from its initial position towards north direction.

Speed : Suppose in the previous example, Ovi takes 50 seconds, to travel 100m distance. If Mitu covers the same distance in 40 seconds, who goes faster ? Ovi or Mitu, definitely Mitu goes faster because she takes less time.

Suppose, Ovi travels 100m in 50 seconds, Mitu travels 75m in 30 seconds can we say Ovi goes slower than Mitu ? Does not Ovi travel more distance than Mitu ? The distance of a particular time Ovi and Mitu travels has to be compared to know who goes faster. Let the particular time be 1 second therefore,

In 1 second Ovi travels $\frac{100}{50} = 2$ meter

In 1 second Mitu travels $\frac{75}{30} = 2.5$ meter

So, Mitu goes faster than Ovi because in 1 second Mitu travels more distance than Ovi.

From the above discussion we can understand time and distance determines who goes faster.

The quantity by which we can measure how fast a body moves or distance traveled, is called speed. Speed expresses the rate of change position of a body. The rate of change of position of a body with time is called the speed.

Speed of a body is measured by the distance traveled per unit time. i.e

$$\text{Speed} = \frac{\text{distance}}{\text{time}}$$

If a moving body travels a distance `d' in time `t' then the speed v is

$$v = \frac{d}{t}$$

The direction of rate of change of position of the body cannot be known by the speed. So it has no direction. Therefore, speed is a scalar quantity.

The dimension of speed is the dimension of = $\frac{\text{distance}}{\text{time}}$

$\therefore$ [V] = [$^{L}/_{T}$] = [LT^{-1}]

As speed is obtained by the division of distance and time, unit of speed is obtained, by the division of units of distance and time.

Since the unit of distance is meter (m) and unit of time is second (s), unit of speed is meter/second (ms^{-1}).

The speed of a body is $4ms^{-1}$ means that the body moves a distance of 4m in 1second.

Though the unit of speed is meter/second, for our convenience sometimes we consider the unit of speed is kilometer/hour where the unit of distance is kilometer and of time is hour. The speedometer of car measures the speed in kmh^{-1} .

Average Speed : If the magnitude of speed does not change during the motion of the body, that is if the body travels equal distance in equal interval of time, then the speed of the body is called uniform speed. And if the body does not travel equal distance in equal interval of time then the speed is called non uniform speed.

If a body does not move with uniform speed, then the speed obtained by dividing the total distance traveled by time is called average speed.

So, average speed = $\frac{\text{total distance}}{\text{time}}$

If a car runs 300 km in 6 hours since 7 in the morning on the way from Dhaka to Dinajpur, the average speed of the car is 300km/6h = $50kmh^{-1}$. Here, average speed $50kmh^{-1}$ does not mean the car travels 50km in every hour rather it might travel sometimes faster or sometimes slower than the average speed.

Instantaneous speed : If we want to know the instantaneous speed of any body at any instant, for example what was the speed of the car just the moment its 33miniutes travel is over, the speed of that moment will be the instantaneous speed. To find the instantaneous speed at any instant, the distance traveled at during a small interval, has to be known and then the distance has to be divided by the time interval.

If any one wants to the speed of the car at 10 : 32 : 43 am (10 hours 32 minute 43 second) or at the time of cross over a speed breaker on the highway beside any school, he has to see the reading of the speedometer at the moment. Similarly with the help of Rudder or Laser gun we can know whether a car is violating the highest limit on the highway or the speed every ball of Mashrafi Bin Murtaja, the fastest bowler of Bangladesh national team.

Velocity : Sometimes during usual conversation many people use the word velocity to mean speed. But in science the two words do not mean the same thing speed indicates only the rate of change of position with time, it does not indicate the direction of change of position. The velocity states the rate of change of position along with its direction that is, velocity means the rate of change of position in a definite direction or in other words the rate of change of displacement. Hence velocity of a body is its rate of change of displacement with time, that is the distance traveled by a moving body in unit time in a definite direction is called the velocity of the body.

If a body travels a distance *s* in a definite direction in time *t* the velocity is $v = \frac{3}{t}$

The dimension of velocity is the same as that of speed, i.e $[LT^{-1}]$

The unit of velocity is ms^{-1} the same as that of speed. Velocity has both magnitude and direction. So, velocity is a vector quantity. A road may be taken as an example at some place the road has made a 30^0 angle with east and has gone straight towards north (Fig 2.4). On this road, if a car moves with a uniform speed of $20kmh^{-1}$ then we will be able to state correctly that the velocity of the car is 20 kmh^{-1} towards north at an angle 30^0 with east. But if the same car moves in a circular road with uniform speed of $20kmh^{-1}$ than the direction of its motion will be continuously changed. So its velocity will also be changed continuously, although its speed will always remain the same. The magnitude of the velocity of a body is its speed. The specific directional speed is its velocity.

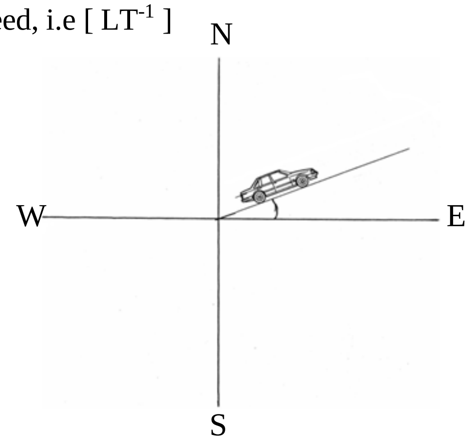


Fig-2.4

If the magnitude and direction of the velocity of a moving body remains unchanged, then the velocity of the body as called uniform or equal velocity. The velocity of sound is a good example of natural phenomenon of uniform velocity. Sound travels in a definite direction over equal distances in equal intervals of time and it is $332ms^{-1}$ in Air at 0^0c. Sound travels in a definite direction through a distance of 332m in the 1^{st} second, 332m in the 2^{nd} second and so on for every second. Here the magnitude and the direction of the velocity of sound remains the same. So the velocity of sound $332ms^{-1}$ is a uniform velocity.

If the magnitude or direction or both of the velocity of a moving body changes during its motion, then its velocity is called variable or uniform velocity. In other words if the body does not move through equal distance in equal intervals of time or changes its direction of motion while moving then its velocity will be variable. Usually we moving, car runs on the road etc. are the uniform velocity.

Acceleration and Retardation : If a body does not move with uniform velocity then the magnitude or direction or both of the velocity may change. We say that there is acceleration of a body if its velocity changes. Suppose a car is moving along a straight road. Mitu sitting in the car recorded the readings of speedometer of the car after every 8 seconds. The velocity of the car at different time in the units kmh^{-1} and ms^{-1} are shown in the following table.

Table 2.2

Velocity-Time table

Serial No	**Time (s)**	**Velocity (kmh^{-1})**	**Velocity (ms^{-1})**
1.	0	0	0
2.	8	14.4	4
3.	16	28.8	8
4.	24	43.2	12
5.	32	57.6	16
6.	40	72.0	20

From this table we can see that the velocity of the car increases from 0 to $4ms^{-1}$ in first 8 second. In the next 8 seconds the velocity of the car increases by $4ms^{-1}$. In the way the velocity of the car increases by $4ms^{-1}$ in every 8 seconds. In other words the change of velocity of the car is $0.5ms^{-1}$. So, the rate of change of velocity of the car with time is $0.5ms^{-1}$.

The rate of change of velocity with time that is the change of velocity in unit time is known as acceleration. The rate of increase of velocity with time of a body moving in a straight line is called positive acceleration and the rate of decrease of velocity of a body with time is called negative acceleration. Sometimes negative acceleration is called retardation or deceleration.

The rate of change of non-uniform velocity of a body with time is called its acceleration.

If the initial velocity of a body is u and its final velocity after time t is v.

then change of velocity in time $t = v - u$

Hence, change of velocity in unit time = $\frac{v-u}{t}$

$\therefore$ rate of change of velocity, i.e.

acceleration, a = $\frac{v-u}{t}$

Therefore, acceleration = $\frac{\text{change of velocity}}{\text{time}}$

Acceleration is a vector quantity. It has direction. Its direction is along the change of velocity. Since we are considering the motion along a straight line, change of direction of velocity will be either along the direction of velocity or opposite to the velocity. If the velocity increases than the change of velocity takes place along the velocity. In this case acceleration will be positive. If the velocity decreases then the change of velocity takes place opposite to the velocity. In this case acceleration will be negative and is called retardation or deceleration.

Dimension : The dimension of acceleration is the dimension of $^{velocity}/_{time}$

$$\text{That is, acceleration} = \frac{\text{velocity}}{\text{time}}$$

$$= \frac{\text{displacement}}{\text{time}} \times \frac{1}{\text{time}}$$

$$= \frac{\text{displacement}}{\text{time}^2}$$

$$\text{Therefore, } [\,a\,] = \frac{L}{T^2} = LT^{-2}$$

Unit : The unit of acceleration is the unit of $^{velocity}/_{time}$, that is, $^{ms^{-1}}/_{s} = ms^{-2}$

The acceleration of a body is $5ms^{-2}$ towards south means that the velocity of the body increases by $5ms^{-1}$ in 1 second towards south.

Uniform acceleration and non-uniform acceleration :

Acceleration may be two types. Such as- uniform acceleration and non-uniform acceleration. If the rate of increase of velocity of a moving body in a particular direction is maintained constant all the time, then the acceleration is said to be uniform. Conversely, if the rate of increase of velocity changes with time, the acceleration is said to be non-uniform or variable.

An example of uniform acceleration is the acceleration of a freely falling, body due to gravity the acceleration of a freely falling body is $9.8ms^{-2}$, that is, its velocity increases by $9.8ms^{-1}$ for each successive seconds. That is, generally we see these moving body- car, cycle, rickshaw, etc are the example of non-uniform acceleration.

Mathematical Example 2.1 : Velocity of a car increases uniformly at the rate of $5ms^{-1}$ and after 10s becomes $45ms^{-1}$. Find the acceleration of the car.

Solution :

Here,

initial velocity u = $5ms^{-1}$
final velocity v = $45ms^{-1}$
time t = 5s
$\therefore$ acceleration a = ?

We know,

$$a = \frac{v-u}{t}$$

$$\text{or, } a = \frac{45ms^{-1} - 5ms^{-1}}{5s}$$

$$= \frac{40ms^{-1}}{5s}$$

$$= 8ms^{-2}$$

Ans : $8ms^{-2}$

Mathematical Example 2.2 : The Velocity of a car decreases uniformly from $20ms^{-1}$ and after 4s it becomes $4ms^{-1}$. Find the acceleration of the car.

Solution :

We know,

$$a = \frac{v-u}{t}$$

$$\text{or, } a = \frac{4ms^{-1} - 20ms^{-1}}{4s}$$

$$= -16ms^{-1}$$

$$= 45$$

$$= -4ms^{-2}$$

Ans : $-4ms^{-2}$

Here,

initial velocity u = $20ms^{-1}$

final velocity v = $4ms^{-1}$

time t = 4s

$\therefore$ acceleration a = ?

2.5 Equations of motion :

We can solve the problems regarding motion of any moving bodies by using only four equations. These equations are called equation of motion. These equation are applicable when the object moves along straight line with uniform acceleration. Let a body with initial velocity *u* move with uniform acceleration *a*. Let the final velocity be *v* after traveling *a* distance *s* at time *t*.

Let the initial velocity of a body be *u* moving with uniform acceleration *a*. After traveling a distance *s* in time *t* its final velocity becomes *v*. We express the equations of motion by the following symbols. These symbols are :

u = initial velocity

a = uniform acceleration

t = traveled time

s = displacement i.e. distance traveled in time t

v = final velocity i.e. velocity after time t

There are five quantities ``Suvat'' are related in such a way that if we know the value of three, we can find the value of other two. So there are four equations and every equations has four quantities we can find the value of unknown quantities using the values known quantities by this equation.

In lesson 2.4 we see

Acceleration, $a = \frac{v-u}{t}$

$$\therefore v = u + at \qquad (2.1)$$

We also find there

average speed = $\frac{\text{distance traveled}}{\text{time}}$

or, $\frac{u+v}{2} = \frac{s}{t}$

$$\therefore s = \frac{(u+v)t}{2} \qquad (2.2)$$

Calculate : Put the value of v of eq (2.1) into equation (2.2)

$$\therefore s = ut + \frac{1}{2} at^2 \qquad (2.3)$$

Calculate : Find the value of t from equation (2.1) and put it in eqn (2.2) and by cross multiplication arrange the terms.

$$\therefore v^2 = u^2 + 2as \qquad (2.4)$$

If it is said in a problem the body starts its motion from rest, the initial velocity will be u = 0

Mathematical Example 2.3 : A car starting from rest moves with acceleration of $2ms^{-2}$ its velocity reach at $20ms^{-1}$. How long time does the car take part in acceleration activity?

Solution :

Here,

initial velocity u = 0

final velocity v = $20ms^{-1}$

acceleration a = $2ms^{-2}$

$\therefore$ time = ?

We know,

$$v = u + at$$

$$\text{or, } at = v - u$$

$$t = \frac{v-u}{a}$$

$$= \frac{20ms^{-1} - 0}{2ms\text{-}2}$$

10s

Ans : 10s

Mathematical Example 2.4 : A car is moving with a velocity, of $54kmh^{-1}$. It is accelerated by $4ms^{-2}$ for 5s. What is the final velocity of the car and how far will it travel during the period of acceleration ?

Solution :

Here,

initial velocity $u = 54kms^{-1}$

$= 54 \frac{km}{h} = \frac{54 \times 1000m}{3600s}$

$= 3 \times 5ms^{-1}$

$= 15ms^{-1}$

acceleration $a = 4ms^{-2}$

time, $s = 5s$

final velocity $v = ?$

traveled distance $s = ?$

We know,

$$v = u + at$$

$$= 15ms^{-1} + 4ms^{-2} \times 5s$$
$$= 15ms^{-1} + 20ms^{-1}$$
$$= 35ms^{-1}$$

Again,
We know

$$s = ut + \frac{1}{2}at^2$$

$$= 15ms^{-1} \times 5s + \frac{1}{2} \times \frac{4ms^{-2}}{(5s)^2}$$

$$= 75m + 50m$$
$$= 125m$$

Ans : Final velocity v = 35ms-1

Traveled distance s = 125m

Mathematical Example 2.5 : A car starting from rest in straight moves with uniform acceleration of $10ms^{-2}$. What will be the velocity while crossing a person at a distance 80m ?

Solution :

Here,
Initial velocity $u = 0$
Acceleration $a = 10ms^{-2}$
Traveled distance $s = 80m$
Final velocity $v = ?$

We know

$$v^2 = u^2 + 2as$$
$$= 0 + 2 \times 10ms^{-2} \times 80m$$
$$= 1600m^2s^{-2}$$

taking root both the sides,

$$v = 40ms^{-1}$$

$\therefore$ Ans : $40ms^{-1}$

2.6 Motion of falling bodies

Gravity : Every particle of this universe attracts towards each other. The force of attraction between any two bodies or particles in this universe is called ``Gravitation''. If earth is one of the two bodies, then the force of attractions is called gravity, that is, the attraction of the earth on any other body is called gravity. There is a law of Newton about this attraction between any two bodies of the universe is known as Newton's law of gravitation.

We know from the Newton's second law of motion that when a force acts on a body, it acts acceleration. So, acceleration of a body is produced due to the force of gravity as well. This acceleration is called acceleration due to gravity.

The rate of increase of velocity of a freely falling body on earth due to force of gravity is called the acceleration due to gravity. The acceleration due to gravity is represented by the letter g.

The quantities of magnitude of `g' any place on earth is

$$g = \frac{GM}{R^2}$$

Here, M = mass of the earth

G = a universal constant, which is called gravitational constant

R = Radius of the earth

As the earth is not perfectly round, the polar regions are a bit compressed, therefore the radius of the earth R is not constant. Hence the values of `g'' is not the same at all places on earth. The polar radius `R' is the shortest and so the value of `g' at the pole is the maximum. And the value of R is the longest at the equator. So the value of `g' at the equation is the minimum.

Since the value of `g' is different at different places on the surface of the earth, its value at sea level altitude 45° is accepted as the standard value. This standard value of `g' is $9.80665ms^{-2}$. For convenience the standard value of `g' is taken to be $9.8ms^{-2}$ or $9.81ms^{-2}$.

Falling Bodies : If a body is dropped from a certain height, it falls on earth due to the influence of gravity. If a heavy and a light object are dropped from the same height simultaneously, will they reach the ground at the same time ?

In fact, if a piece of stone and a piece of paper are dropped from the same height, it is seen that the stone reaches the ground first. Since the acceleration due to gravity does not dropped on the mass of the body, the acceleration of the stone and that of the paper would be the same. So they should reach at the same time on the earth, but due to the resistance of air two bodies reach at different time on the earth. If there is no resistance of the air, they would fall at the same time.

Laws of falling bodies :

Galilio discovered three laws relating to falling bodies : These are called laws of falling bodies. These laws are applicable only for bodies falling from rest without any resistance. At the time of falling, the body will ``fall from rest, it will have no initial velocity. The body will fall freely without any resistance, that is, no force other than the gravitational force will act on the body. For example, the resistance due to air will not act on it.

Laws of falling bodies are :

First Law : All bodies falling from rest and from the same height without any resistance traverse equal distance in equal time.

Second Law : The velocity *(v)*, acquired by a freely falling body from rest in a given time *(t)* is directly proportional to time that is, $v \propto t$

Third Law : The distance *(h)* traversed by a freely falling body from rest in a given time *(t)* is directly proportional to the square of the time, that is, $h \propto t^2$.

Equation of falling Body : Let a body be falling freely due to gravity with initial velocity u. The body attains a velocity v after time t. If the body falls through a distance h in that time and distance s is replaced by h and acceleration a is replaced by accelerate on due to gravity g then the equations of falling body will be as following.

$$v = u+gt$$

$$h = \frac{(u+v)t}{2}$$

$$h = ut + \frac{1}{2}gt^2$$

$$v^2 = u^2 + 2gh$$

Mathematical Example : 2.6 : A body drops from the roof of a building 50m high. With what velocity will it strike the ground.

$g = 9.8ms^{-2}$

We know, in case of falling bodies

$$\begin{aligned} v^2 &= u^2 + 2gh \\ \text{or } v^2 &= 0 + 2 \times 9.8\ ms^{-2} \times 50m \\ &= 980m^2s^{-2} \\ \therefore v &= 31.3ms^{-1} \end{aligned}$$

Ans : $31.3ms^{-1}$

2.7 Motion and Graph

1. Distance-Time Graph : A moving object changes its position with the change of time. The distance traveled by the body depends on time. This relation can be represented graphically. In this case axis `X' in the graph represents time (t) and axis Y represent distance (s). This graph is called distance-time graph. We can find velocity easily by this graph. The methods of determining velocity from the distance-time graph for uniform and non-uniform velocities are discussed below. We will discuss the motion of an object moving only along straight line to avoid the complexities. So the velocity changes only for its magnitude.

(A) In case of uniform Velocity:

Suppose a pollution free CNG run auto-rickshaw is moving along plane straight road. The table below shows the distances traveled after every 12 minutes.

Distance – Time table

Time, *t* (min)	Distance *s* km
0	0
12	6
24	12
36	18
48	24
60	30

Table 2.3

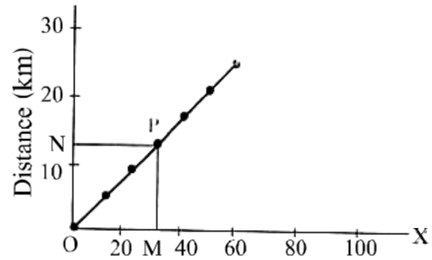


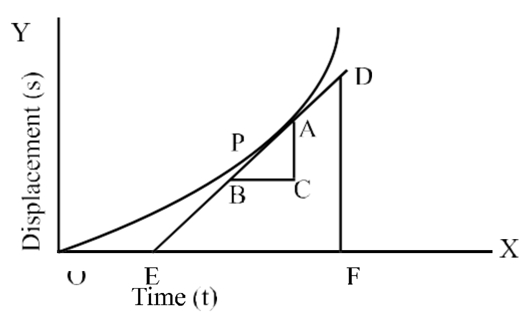
Figure 2.5

For above mentioned motion in the table a distance-time graph shown in fig 2.5. Suppose from the graph we have to find the traveled distance in 32 minute by the auto-rickshaw; we have to mark a point (M) to indicate time, 32 minute on X-axis. Then we have to draw a line parallel to Y-axis from that point on the graph. Let the line at point P. Now draw a perpendicular on Y-axis from P. This perpendicular meets at point N on Y-axis. Therefore, ON is the distance traveled in 32 minutes. The graph shows that the auto-rickshaw travels 16km in this time. Therefore, from graph we find any traveled distance S = PM for any time t = OM.

$\therefore$ Velocity = $\dfrac{\text{distance}}{\text{time}} = \dfrac{PM}{OM} = \dfrac{ON}{OM}$, Here, $\dfrac{PM}{OM}$ is the slope of the OP.

> **Do by yourself :** Take a graph paper. Draw the distance-time graph on the graph paper using any convenient unit mentioned in the table above. Find the distance traveled and velocity of the auto-rickshaw in 32 minutes from the graph. What will be the distance traveled and velocity in 44 minutes.

(B) In case of Non-uniform velocity : Fig 2.6 represents a distance-time graph of a body moving with non-uniform velocity. In this case the body does not move over equal distance in equal intervals of time, so the graph will not be a straight line. It will be a curved line. Since, the body is not moving with uniform velocity, its velocity will not be the same at all instants during its motion.



Suppose, the velocity of the body at a particular instant indicated by the point P in the curved line, is to be determined. To determine the velocity at the point P, we will have to consider a very small right angled triangle ABC. Its hypotenuse AB is so small that it virtually consider with the curved line adjacent to point P. In other words we are considering a part of the curved line which is so small that it may be considered a straight line.

Then the velocity at the point P = $\dfrac{\text{distant represented by AC}}{\text{time interval represented by BC}}$

or $v = \dfrac{AC}{BC}$

But it is difficult to get correct result by measuring such a small triangle. So we draw a tangent ED at the point P and draw a greater triangle DEF similar to ABC.

Now from the triangles ABC and DEF We get, $\dfrac{AC}{BC} = \dfrac{DF}{EF}$

$\therefore v = \dfrac{DF}{EF}$

But, $\dfrac{DF}{EF}$ is the slope of ED

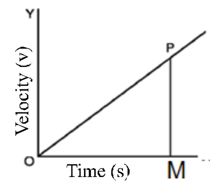
Therefore, the velocity at the point P is the slope or gradient of the tangent drawn at that point. Thus it may be said that the gradient of the tangent at any point on the distance-time graph represents the velocity at that point.

2. Velocity – time graph

The velocity of an object moving with non-uniform velocity depends on time. This relation can be expressed by a graph. In this case time (t) is plotted along X-axis and velocity (v) along Y-axis. This graph is called velocity-time graph. We can find velocity and acceleration i.e. the rate of change of velocity with time from the graph easily. The method of finding acceleration from velocity-time graph in case uniform acceleration is discussed below.

In case of uniform acceleration : When a body moves with uniform acceleration, its velocity increases equally for equal intervals of time. Hence the velocity-time graph will be a straight line (fig 2.7). Now let us take a point P on this graph and draw a normal PM on the X-axis from P. Then the change of velocity PM for any time interval of OM is obtained.

$\therefore$ Acceleration, $a = \dfrac{\text{change of velocity}}{\text{time interval}} = \dfrac{PM}{OM}$



But, $\dfrac{PM}{OM}$ is the slope or gradient of OP

So it is said that the slope of tangent drawn at any point on velocity-time graph represents the acceleration of that point.

Do by yourself : The velocity of a car after every five seconds is given in the table below.

Table : 2.4

Time (s)	**Velocity (kmh^{-1})**	**Velocity (ms^{-1})**
0	0	0
5	9	2.5
10	18	5.0
15	27	7.5
20	36	10.0
25	45	12.5
30	54	15.0

Take a graph paper. Draw the velocity-time graph on the graph paper using any convenient unit mentioned in the table above. Find the velocity and acceleration of the car in 12 seconds from the graph.

Investigation: 2.1

Determination of the average speed of a marble rolling over slanting plank.

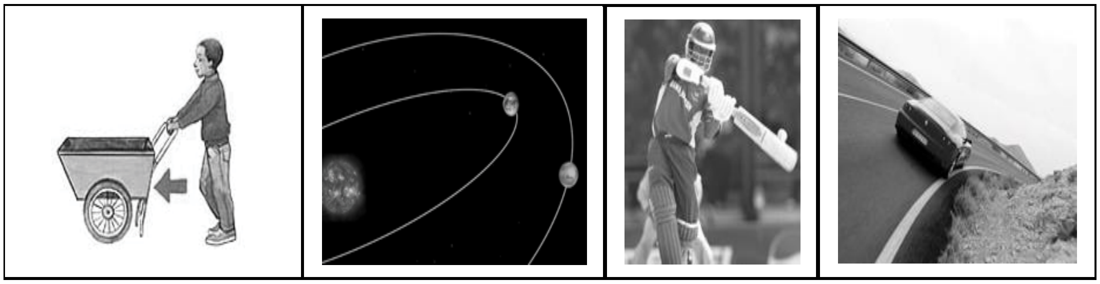
Objective : To determine the average speed in every case finding time of equal distance traveled in different acceleration.

Apparatus : Plank, meter scale, marble, stopwatch.

Working Procedure :

1. Take a plank long as possible
2. Place brick or book under one end to make it high. So the plank will be inclined with the horizontal
3. Hold a marble at the upper end of the plank and then start the stopwatch the moment you release the marble. Stop the stopwatch the moment it strikes the ground
4. Find the average speed dividing the distance i.e. the length of the plank the marble travels by this time
5. Place more bricks or books at the upper end to make it higher i.e. to make it more sloppy
6. Again find the average speed measuring the time the marble requires to strike the ground.
7. Similarly measure the average speed for different slope of the plank.

Chapter three
FORCE



[Sir Isaac Newton has done a lot of research about the motion of an object. He expressed the fundamental principles of motion by three laws. In this chapter we shall discuss about these laws of motion. In addition, the inertia of a object, force, nature of force, momentum, friction and safe journey will also be discussed.]

By the end of this chapter we will be able to-

1. Explain the inertia of an object and qualitative concept of force applying Newton's first law of motion.
2. Explain the nature of different types of forces.
3. Explain the influence of balanced and unbalanced forces.
4. Explain the momentum and collision of objects.
5. Analyze the influence of force on motion and shape of an object.
6. Measure the force by applying Newton's second law of motion.
7. Explain the action and reaction force by applying Newton's third law of motion.
8. Analyze the influence of motion and force on safe travelling.
9. Explain different types of friction and frictional forces.
10. Analyze the influence of friction on the motion of an object.
11. Describe the means to increase or decrease friction.
12. Explain the positive impact of friction in our daily life.

3.1 Inertia and qualitative concept of force- Newton's first law

We have already known about rest, motion, displacement, velocity, acceleration etc. We can see different types of objects around us. Some of them are in rest and some of them are in motion. Among the bodies in rest, there are chair, table, houses, log of wood etc. Can a body in rest move itself? Tonight your reading table is in a certain place. Will it be in the same place in the next morning? What do we observe from these practical experiences? It is observed that the bodies at rest are still at rest. These bodies can't move by themselves. Suppose that one of your friends is riding a bi-cycle on a plane road. At any moment he stopped paddling the cycle. Will the cycle stop at once? We find that the cycle will stop slowly after crossing a small distance. Would the cycle move continuously if there is no air resistance and friction?

From this evidence we can understand that everybody has the tendency to remain in the same state as it is. If the body is at rest it continues to be at rest. On the other hand if the body is in motion it continues to be in motion. This tendency or property of a body to maintain its own state is called inertia. Thus the tendency of a body to maintain its own state for ever in which the body is at present or the property of a body to preserve that state is defined as inertia.

The inertia of a body depends on its mass. That is, mass is the measure of its inertia. The more the mass, the more the inertia of a body. In other words, it is difficult to move, increase or decrease velocity or change the direction of velocity of a body whose inertia is large.

Do yourself

- Keep a pen and a book on a table. Now strike the pen with finger. What do you observe? The pen moved a small distance on the table.
- Now repeat this procedure for the book. The book won't move. Now push the book with your hand. The book will be displaced from its original position.

Between the pen and the book, it needs more effort to move the book as the mass i.e. the inertia of the book is greater.

Example of inertia

If a bus at rest suddenly starts moving the passengers lean backwards. The reason behind this is inertia. When the bus is at rest, the bodies of the passengers are also at rest. When the bus starts moving, the part of the passenger's body attached to the bus also moves with it. But the upper part of the body tends to remain stationary due to inertia of rest. Thus the upper part of the body lags behind with respect to the lower part. As a result the passenger inclines backwards. On the other hand, when a sudden brake is applied in a moving bus the passengers lean forwards. When a bus is in motion, the passenger of the bus is also in the same speed of the bus. When the bus stops suddenly, the lower part of the body also becomes stationary with the bus. But the upper part of the passenger's body moves forward due to inertia of motion.

During car driving the drivers wear seat belt for safety. What is the reason? The reason behind this is inertia. If he doesn't use seat belt, he would lean forward due to inertia of motion for applying fast brake. For this reason he would hit the steering and other bodies in front of him, for this a serious accident may happen. Not only have the drivers, the passengers also had to wear the seat belt if there is an arrangement of seat belt in the car.

We have a general concept about force from our daily life experiences. When we pull or push a body, then we say a force is applied upon the body. This applied force can create or tends to create motion in a stationary body. If the body is in motion, then the applied force can cease the motion of the body or tries to increase its velocity. In both cases to apply force, it needs direct contact between the force applier and the body. These types of force are known as contact force. If the two bodies are not in direct contact, still they can apply force on each other. Such a well-known force is the force of gravitation, whose practical example is the weight of a body. When a body falls from your hand, then it quickly touches the ground. What is the reason? It happens due to the weight or attraction of the earth on the body. We define this force as the force of gravitation. In this way we feel the existence of different type of forces in different events of nature.

For example- the magnetic force between two poles of a magnet, the electrical force between two charged bodies, nuclear force within the nucleus.

Now we will see how we can get concept about inertia and force from Newton's first law of motion. Newton's first law of motion is-

'Every object will continue in its state of rest or of uniform motion in a straight line unless an external force is applied to it.'

Newton's first law expresses the property of inertia of matter.

From Newton's first law of motion we observe that a body cannot change its state on its own. If the body is at rest, it tends to remain at rest forever and if it is in motion it tends to keep on motion with uniform speed for all time. This property of a body is termed as inertia. Thus from the Newton's first law of motion we get the concept of inertia.

Again from Newton's first law we see that to change the state of a body something external must be applied. That is, the external cause which changes or tends to change the state of an object is called force. Thus from Newton's first law we get qualitative definition of force. According to Newton's first law, a force is that which acting on a body at rest produces or tends to produce motion or acting on a moving body changes or tends to change its state of motion.

3.2 Nature of force

Contact force:

We are familiar with different types of force in our daily lives. Nature of them is of different types. Some of them are produced due to direct contact between two bodies. In addition, there are some forces which do not need direct contact between two bodies. The force which needs direct contact between two bodies to be created is defined as contact force. When we push or pull a body with hand our hand exerts a force on the body at that time. This push or pull force is contact force. Since this force is the consequence of the direct contact between the hand and the body. The examples of contact forces are- frictional force, pulling force and the force created during collision.

When a body tends to move or move over another body, then a resistive frictional force is produced against the motion between the contact surfaces of two bodies. Here the frictional force is produced due to direct contact between the surfaces of the two bodies. We apply pulling force on a box when we pull it over the floor. At that time frictional force is produced opposite to the motion of the box.

Non-Contact force:

The force which acts without direct contact between two bodies is called non-contact force. The attractive gravitational force between two bodies, the attractive or repulsive electric force between two charged bodies, the attractive or repulsive force between two poles of two magnets, the force of attraction acting between a magnet and a magnetic material are the examples of non-contact force or distant force.

Do yourself: Release a pen or pencil or any object from your hand.

The body will fall down. Something is pulling the body downward certainly. Who is pulling? Here, the earth is pulling the body towards it, though there is no direct connection between the body and the earth i.e. the earth is not in contact with the body. Here the earth is applying force of gravitation on the body. The force of gravitation is a non-contact force. Any two body of the universe exert force of gravitation on each other. When the earth exerts force of gravitation on another body, then this force is called gravity.

Though we observe different kinds of force in nature, fundamental force are of four types. Rest of them is some forms of these fundamental forces. The forces which are root or independent i.e. the forces which are not produced from some other forces or not any forms of some other forces are called fundamental forces. Instead, other forces are some forms of these fundamental forces.

The four fundamental forces which exist in nature are:

1. Force of gravitation
2. Electromagnetic force
3. Weak nuclear force
4. Strong nuclear force

Force of Gravitation:

In this universe every body attracts each other by a force towards them. The mutual attraction between any two bodies of the universe is called gravitation. This attraction occurs due to mass of the bodies. The force of gravitation is comparatively weak among the fundamental forces. Weight of us is the consequence of gravitation. The planets of the solar system are revolving round the Sun due to force of gravitation. The range of gravitation extends to infinity.

Electromagnetic force:

The electromagnetic force is defined as the force exerted by two charged particles or bodies on each other due to their charges. This force may be of both types- attractive or repulsive. When the charged particles are at rest, only electric force works between them. The magnetic force is created simultaneously in addition to the electric force between the particles when the charged particles are mobile. The force of attraction or repulsion between two magnetic poles is also electromagnetic force. The electric force acting between two charged fundamental particles is more powerful than the force of gravitation between them. Nevertheless, electric force is of medium type considering strength. Frictional force, spring force etc. are produced due to electric forces between the charged particles.

Weak nuclear force

The short range and small magnitude force that exists between the fundamental particles within the nucleus is called weak nuclear force. Due to this force the nucleus becomes unstable and beta decay occurs. Most of the radioactive disintegration occurs due to weak nuclear force. The range of this force is less than 10^{-16} m.

Strong nuclear force

It is known that there are two particles namely proton and neutron within the nucleus of an atom. These particles are called nucleon. The strong force that exists between two nucleons within the nucleus of an atom is called strong nuclear force. This force bounds the nucleons together. The strong nuclear force is responsible for the stability of the nucleus. This force is very short range and attractive. The range of this force is 10^{-15} m which is the radius of the nucleus. This force is the strongest among the fundamental forces.

3.3 Balanced and unbalanced forces

When two or more forces acting on an object produce zero resultant force, i.e. the object has no acceleration; we say that the forces are balanced. The forces that produce this balanced condition are called balanced forces.

It is seen in figure 3.1 that an object is suspended with a thread. The force of attraction of earth on the object i.e. the weight of the object *W* is acting vertically downward. The tension of the thread *T* is acting vertically upward. Here the two forces are equal in magnitude but opposite in direction thus canceling each other's action and producing a balanced condition.

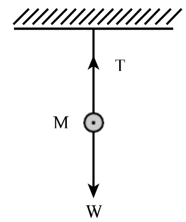


Fig. 3.1

Only the attractive force of the earth i.e. the force of gravity will act on the object if the thread is cut. Then the object will fall down with acceleration due to gravity. Here, the force of gravity or weight of the object is the unbalanced force. If the body is displaced slightly along one side, the tension of the thread *T* and the weight *W* will not be in a straight line. Then a resultant force will act on the body without creating balanced condition. Due to this, the body will oscillate. This is an example of unbalanced force.

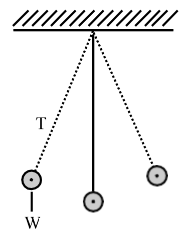


Fig. 3.2

Another example of balanced and unbalanced forces can be seen in the game of tug-of-war competition. In this game, a handkerchief is tied to the center of the rope. In this competition equal numbers of competitors pull on the rope in two sides and try to move the handkerchief to their side. If the handkerchief does not move then it is understood that either the team are applying equal amount of force and the rope or the handkerchief is in balanced condition. Here, forces applied by the two teams are balanced forces.

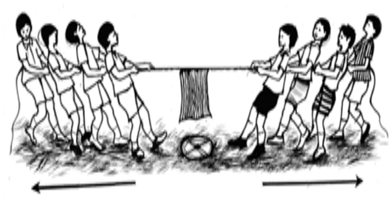


Fig. 3.3

If one team applies more force than the other, then the resultant force will act along them thus creating unbalanced force and the handkerchief will move to their side. Then this team will be declared as the winning team in the competition.

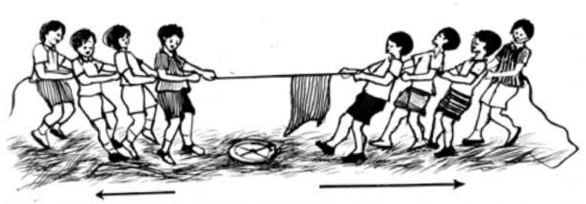


Fig. 3.4: Tug-of-war (unbalanced force)

3.4 Momentum

The physical quantity which is produced by the combination of mass and velocity of a moving body is the momentum. Momentum depends on the mass and velocity of the body. Think about a loaded truck and a private car. You have to stop both the cars within the same distance. Which car needs hard brake to stop? The answer is truck. Though the truck and the car are moving with the same speed, the truck possesses that physical quantity which is more is its momentum.

Momentum is a measure of how difficult it is to stop something that is moving. Momentum is related to the force. This relation is obtained quantitatively in Newton's second law of motion.

Momentum is the product of the mass and velocity of a moving body.

Let, the mass of a body = m

Velocity = v

$$\therefore \text{ Momentum} = mv \qquad (3.1)$$

Momentum is a vector quantity. Its direction is in the direction of velocity. It is observed from equation (3.1) that the momentum of a body will be large if the body has a large mass and moving faster.

Unit: the unit of momentum is, unit of mass × unit of velocity, i.e. $\text{kg} \times \text{ms}^{-1}$ or kg ms^{-1} .

If a body of 1 kg moves with a velocity of 1ms^{-1}, its momentum will be 1kg ms^{-1}.

Dimension: The dimension of momentum: $[p] = MLT^{-1}$.

3.5 Effect of force on motion

A force can cause a stationary object to start moving.

What happens when a stationary football is kicked by a player? It is seen that the ball moves off in the direction it is kicked from its stationary state. In this case the ball accelerates from rest. Here acceleration is positive, and in the same direction as the force exerted by the kick.

A force can cause a moving object to increase its velocity.

What would be the velocity when a cricket ball is hit by the batsman in the same direction as the ball moves? It is observed that the ball moves faster after the hit. In this case the acceleration is positive and its velocity increases. The velocity of a moving marble increases if it is stroked in same direction as it moves.

A force can cause a moving object to decrease speed.

Think you are riding a bicycle in the village road. After a while you observed that the road is slanting downwards. Now what will you do? Will you continue the pedaling as before or give a brake? You have to apply brake to cross this sloping road safely. Due to this, the cycle decelerates.

A force can cause a moving object to change its velocity or direction of motion.

A batsman hits the cricket ball coming from opposite direction during a game of cricket. Due to the hit, the magnitude and direction of the velocity of the ball change. The ball moves in a different direction due to this hit by the bat. In this case too, the ball has acceleration.

Effect of forces on shape

There are many examples around us where the shape of a body changes by the application of force. The shape of an empty plastic bottle changes when it is pressed. Again when a rubber band is stretched by pulling it, it becomes narrow and its shape changes.

Sometimes, the changes of shape of the bodies are temporary in nature. Sometimes, the shape of the object is permanently changed due to the application of force. Such changes occur in the crushed metallic can or a car after a collision.

A temporary change of shape may provide a useful way of absorbing and storing energy. Compressing the spring by rotation of the key the potential energy is stored in a toy car. When the car is released the potential energy is transformed into kinetic energy. A permanent change of shape may mean the failure of a structure- as a bridge collapse due to excess load.

3.6 Relation between force and acceleration- Newton's second law

Newton's first law gives qualitative definition of force. Newton's second law gives the equation for the measurement of force. From Newton's second law we know the relationship between the force acting on a body and the acceleration produced due to this force. The law is as follows:

The rate of change of momentum of a body is proportional to the applied force acting on it and takes place in the direction in which the force acts.

Let a body of mass m is moving with an initial velocity u. Now a constant force F acts on the body for a time t in the direction of its velocity. Let the velocity of the body changed from u to v due to the application of the force.

Therefore,

$\therefore$ the initial momentum of the body $= mu$

$\therefore$ the final momentum of the body $= mv$

The change of momentum in time $t = mv - mu$

So, the rate of change of momentum $= \dfrac{mv - mu}{t}$

$$= ma \quad \text{[Since, acceleration, } a = \frac{v-u}{t}\text{]}$$

According to Newton's second law of motion, the rate of change of momentum is proportional to the applied force.

i.e., $ma \propto F$

$$= kF \qquad (3.2)$$

Here, k is a constant of proportionality. To define the unit of force Newton consider k=1. The unit of force is Newton (N). One newton (N) is defined as the force that will produce an acceleration of 1ms^{-2} when it acts on a mass of 1 kg.

Thus if mass m is in kg, acceleration a is in ms^{-2}, and force F is in N, then equation (3.2) becomes,

$$ma = 1.F$$

$$\text{or } F = ma \qquad (3.3)$$

$$\text{or Force} = \text{mass} \times \text{acceleration}$$

The dimension of force: [F] **=** MLT^{-2}

Mathematical Example 3.1: What is the force to be applied to a mass of 50 kg to produce an acceleration of 4 ms^{-2} ?

We know,

F = ma = 50 kg × 4 ms^{-2} = 200 kg ms^{-2} = 200 N	Here, mass of the body, m = 50 kg acceleration, a = 4 ms^{-2} force, F = ?

Ans: 200 N

Mathematical Example 3.2: A boy pushes a box of mass 20 kg with a force of 50 N. What will be the acceleration of the box?

We know $F = ma$ $a = \dfrac{F}{m}$ $= \dfrac{50N}{20kg}$ = 2.5 ms^{-2}	Here, mass of the box, m = 20 kg applied force, F = 50 N acceleration of the box, a = ?

Ans: 2.5 ms^{-2}

3.7 Action and reaction force- Newton's third law

Whenever a force acts on one body, at that time an equal and opposite force acts on some other body. This matter is generally stated as-

To every action there is an equal and opposite reaction.

This statement is known as Newton's third law of motion.

Therefore, according to Newton's third law, the values of the action and reaction forces are same but their directions are opposite to each other. In figure 3.5 if the object P exerts a force F_1 on the object Q, then according to this law, the object Q will also exert an equal and opposite force F_2 on the object P. The force exerted by the object P on object Q is called action force and the force exerted by Q on P is called reaction force.

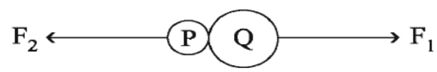


Figure 3.5

Therefore, according to Newton's third law, $F_1 = - F_2$

It is noticeable that the action and reaction force act on different bodies. The reaction force will exist as long as the there is action.

Example:

Walking on road

In our daily life we walk or run on the ground [Figure 3.6]. When we walk on the ground, we exert a backward force on the ground by the leg behind obliquely. This is the action force. According to the third law a reaction force is produced opposite to this. We are able to walk on the road due to this reaction force.

Figure 3.6

Firing by a gun

When a person fire with a gun, he feels a backward push at that time. What is the reason behind this? In this case, action and reaction force of bullet and gun exists for the same time. According to the Newton's second law of motion, the bullet and the gun acquire equal and opposite momentum. As a result the bullet moves forward with a particular momentum and the gun moves backward with a momentum of same magnitude but opposite in direction. Due to this, the person will feel a backward thrust. The backward velocity of the gun will be smaller in comparison to that of the bullet as the mass of the gun is large.

Collision

Among you, those who have played marble probably had seen how one marble hits another marble. In addition, you are familiar with different types of road accident through newspapers or television. These events are the practical examples of collision.

Therefore, when a moving object hits another body at rest or in motion, then it is said that a collision has taken place. During collision a force acts on each of the two bodies. If the force exerted by the first body on the second body is called action force, then the force exerted by the second body on the first one is called the reaction force. These two forces acting during collision are same in magnitude but opposite in direction. No other external force acts during the collision except the action and reaction force. From Newton's second law we get,

$$F = \frac{mv - mu}{t}$$

We can express the change of momentum from this equation as-

$$F \times t = mv - mu \tag{3.4}$$

i.e. force × time = change of momentum.

The product of force and time is defined as impulse of force.

Therefore, impulse of force = change of momentum

Let two bodies A and B having masses m_1 and m_2 are moving with velocities u_1 and u_2 respectively along a straight line. If the velocity of A is greater than that of B, at any time the object A will collide with the object B [Figure 3.7]. The force exerted on B by A is the action F_1. The object B will also exert a force F_2 on A, this F_2 is the reaction force. According to Newton's third law of motion, $F_1 = -F_2$

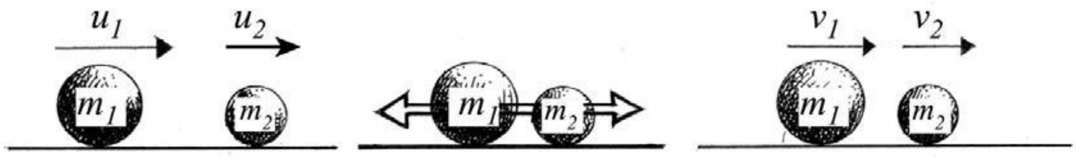


Figure: 3.7

During collision, the action and reaction force exists for the same time. Let the time duration of action and reaction be *t*. After the collision the two objects will continue to move along the same straight line with their changed velocities. Let v_1 and v_2 be the changed velocities of A and B respectively. If due to action and reaction, the accelerations of A and B are a_1 and a_2 respectively, then

$$F_1 = -F_2$$

$$\text{or, } m_1 a_1 = -m_2 a_2$$

$$\text{or, } m_1 \frac{v_1 - u_1}{t} = -m_2 \frac{v_2 - u_2}{t}$$

$$\text{or, } m_1 v_1 - m_1 u_1 = -m_2 v_2 + m_2 u_2$$

$$\text{or, } m_1 u_1 + m_2 u_2 = m_1 v_1 + m_2 v_2$$

Therefore, the sum of the momentum of the objects A and B remains same before and after the collision. It is the law of conservation of momentum.

Mathematical Example 3.3: A force of 2000 N acts on a body of mass 20 kg for a time of 0.1 s. What is the change of momentum of the body?

Solution:

We know,

change of momentum = force × time

$mv - mu = Ft$

$= 2000 \text{ N} \times 0.1 \text{ s}$

$= 200 \text{ kg ms}^{-2} \text{ s}$

$= 200 \text{ kg ms}^{-1}$

Here,

applied force, $F = 2000$ N

time duration, $t = 0.1$ s

change of momentum, $mv - mu = ?$

Ans: change of momentum = 200 kg ms^{-1}

Mathematical Example 3.4: A bullet of mass 10 g was shot from a gun with a velocity of 500 ms^{-1}. If the mass of the gun is 2 kg, find the backward velocity of the gun.

Solution:

Let the direction of the bullet's velocity i.e. the forward direction be positive. From the conservation of momentum,

We get,

$m_1 u_1 + m_2 u_2 = m_1 v_1 + m_2 v_2$

ev $m_1 \times 0 \text{ ms}^{-1} + m_2 \text{ kg} \times 0 \text{ ms}^{-1} = 10^{-2} \text{ kg} \times 500 \text{ ms}^{-1} + 2 \text{ kg} \times v_2$

ev $v_2 = -\dfrac{5 \text{ kg ms}^{-1}}{2 \text{kg}}$

$= -2.5 \text{ ms}^{-1}$

Here, the velocity of the gun is negative, i.e. the gun will move backward.

Ans: backward velocity=2.5 ms^{-1}

Here,

mass of the bullet, $m_1 = 10$ g

$= 10 \times 10^{-3}$ kg

$= 10^{-2}$ kg

mass of the gun, $m_2 = 2$ kg

initial velocity of the bullet, $u_1 = 0 \text{ ms}^{-1}$

initial velocity of the gun, $u_2 = 0 \text{ ms}^{-1}$

final velocity of the bullet, $v_1 = 500 \text{ ms}^{-1}$

final velocity of the gun, $v_2 = ?$

3.8 Safe journey: force and motion

To control the speed of car is an important issue for a safe journey. We travel in a car to meet the necessity of our daily lives. We use different vehicles during the journey. Sometimes in bus or train or we use personal vehicles. The speed of a vehicle and force is inseparably related to each other during the journey in such vehicles. The speed of a car plays a vital role for a safe journey. The speed or velocity would not be such that which is not controllable. To travel in a distant destination, it is necessary to know about the road condition and environment.

The driver has to check the car well before start journey. As an example, whether the tyre or brake is perfectly right or not. He has to ensure whether the engine, used battery, front and rear lamps, wiper, and signal lights of two sides are right and properly working. In addition, he has to properly adjust the mirrors used in the car.

At first the driver and the passengers will wear the seat belt during driving time. It is observed that most of the road accidents occur due to very fast driving. So, the driver must be cautious to control the speed of the car. The kinetic energy becomes more due to increased speed. For example- if the velocity of the car is doubled, its kinetic energy is increased by four times in comparison to that of the earlier value. If the velocity is increased by three times, kinetic energy is increased by nine times. Then it becomes difficult to reduce or to control the velocity and the accident becomes terrible.

Drivers are advised to choose a vehicle which they are used to driving earlier. It is not wise to try to drive a new vehicle suddenly. It is observed that the youth try to drive a new car emotionally. It’s not proper at all. Slow down the vehicle’s speed when you meet other vehicles from opposite direction. To obey the traffic sign and traffic law is the citizen responsibility of the vehicle driver. The driver should concentrate on driving absolutely during driving.

3.9 Friction and force of friction

We are familiar with friction in various ways in our daily lives. From Newton’s first law of motion we know that if no force acts on a body the body will continue in its state of rest or of uniform motion in a straight line. Does it actually happen in reality? Take a marble and roll it on the floor. When you roll the marble, you apply a force on it. As a result, the marble becomes mobile on the ground. According to Newton’s law the marble should remain in uniform velocity. In practice, it is seen that the marble comes to rest after traversing a small distance. This happens due to the friction of the floor. When the marble is in motion on the floor, a frictional force is developed due to the mutual friction between the marble and the floor. This force acts in the direction opposite to the motion and hinders the motion. If the friction of the floor was absent, then the marble would continue its perpetual motion with uniform velocity.

When a body moves or tends to move over another body, then a resistance is developed between the two surfaces in contact, which is known as friction. This resistive force is called frictional force.

The frictional force always acts opposite to the motion and obstructs the motion.

Origin of friction

Whenever the surface of an object slides over the surface of another object, each object exerts a frictional force on the other. The question arises- why friction occur? Friction is the result of the surface irregularities of any two surfaces. Each object has a surface. Again, the surface may be smooth or rough. Apparently, the surface of an object seems to be smooth, but it is observed that there are high and low grooves on it when viewed by a microscope [Figure 3.8]. When an object moves on another object, then the grooves of the two surfaces in contact catch onto one another. As a result of which the motion of one surface over another surface gets obstacled.

As the grooves of a surface deepend and their number increases i.e. as the surface become rougher, the motion of one surface over another becomes more obstructed. Then the magnitude of frictional force also increases. The body becomes mobile if it can overcome the resistance of the surface in contact. The frictional force causes the object to slow down and stop thereby.

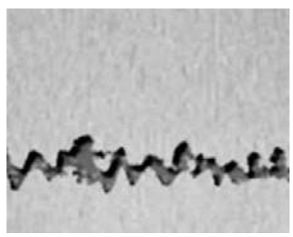


Figure: 3.8

Types of friction

Generally there are four types of friction.

1. Static friction
2. Sliding friction
3. Rolling friction
4. Fluid friction

Static friction

Static friction is the friction between two surfaces that aren't moving relatively to each other.

When a force is applied to an object, but it does not cause it to move, then static friction works. When a massive body on a floor is pulled by a force but it does not move, then the frictional force created is called force of static friction. The static frictional force is developed opposite to the applied force and acts until motion is produced.

When two bodies at rest are in contact with one another and one body is made to move on the other body, the friction produced between them until a relative motion is created is called static friction.

Sliding friction

Sliding friction is friction where an object slides, or rubs against, another surface.

We fall down and traverse a small distance when we move in a slippery road. When a hard brake is applied on a car moving fast, the car does not stop rather cross a small distance by sliding.

Rolling friction

Rolling friction is friction between a rolling object and the surface that it is rolling on.

The wheel's motion of a cycle, motion of marble is example of rolling friction. During travelling we use luggage carrier having wheels to carry goods. If there was no wheel in the luggage carrier then it was too difficult to pull it by sliding from one place to another. Due to the attachment of wheel it becomes easier to pull it i.e. the force of rolling friction is less than that of the static friction.

Fluid friction

When an object moves in a fluid i.e. a liquid or gas, the friction acts is called fluid friction.

We have to overcome a barrier in water while swimming in the pond. This barrier is the fluid friction. A parachute works by harnessing the air resistance. The air resistance is a type of frictional force which works against the force of gravity of the earth. As an open parachute has a large surface area, it helps provide enough air resistance. As a result, the sky-diver's falling speed is decreased mostly. So, the skydiver will then be able to descend slowly and safely.

3.10 Effects of friction on motion

Friction has enormous influence on the motion of an object. Friction is a kind of resistive force which slows down the motion of a body. Though friction creates many problems in our daily lives, it plays a vital role for movement and vehicle operaration. In this section we shall discuss about tyre's surface, smoothness of road and role of friction for controlling motion.

Figure: 3.9

Tyre's surface

Driving vehicles is possible because of the friction between the tyres and the road surface. The friction force between the tyres and the road depends on condition of the tyres and surface of the road. It also depends on the weight of the vehicle. The tyre's rubber surface is designed with treads i.e. grooves or teeth. The tyre surface is up and down due to these grooves. If the tyre is new, these grooves are distinct; as a result the force of friction between the tyre and the road is maximum. When the tyre becomes old, their grooves are worn out and the surface becomes flat. As a result the frictional force between the tyre and the road decreased mostly. Say, what inconvenience may arise due to this.

Smoothness of road

The smoothness of road has a great impact on the motion of a body. When the road is smooth, movement of vehicles on the road becomes easier and the journey becomes comfortable. As the road becomes smoother, the resistive force of friction becomes lesser. The magnitude of the frictional force between the car's tyre and the road depends on the smoothness of the tyre as well as on the smoothness of the road. Many types of problems arise when amount of the frictional force is decreased largely. So, the road should not be too smooth. If the road is too smooth, it is not possible to stop the car within a certain distance in spite of applying brake. The friction is important for the motion of a car. If the road is too smooth, the necessary reaction force is not produced. The amount of the frictional force is largely reduced when the road is too smooth, as a result the car will not be able to move forward. So, the smoothness of the road will be such that it can supply the necessary frictional force.

Controlling motion and braking force

The speed of the vehicle has to increase or decrease according to the necessity at the time of vehicle movement. That is, we have to control the motion of a vehicle.

Brake is such an arrangement, which controls the speed of the car or rotation of the wheels according to the necessity by increasing the friction. With this it is possible to halt a vehicle in a certain place. When the driver applies the brakes, the shoe or pad made of asbestos press the metallic disc on the wheel. The friction between the pad and disc slows down the wheel's speed. As a result, the velocity of a car decreases.

3.11 Increasing and decreasing friction

Friction is inextricably related to our daily lives. Friction can be increased in necessity; again friction can be decreased too in necessity. How friction can be decrease and increase would be discussed in this section.

Reducing friction

Smoothing the surface

Friction makes many troubles to displace one body from one place to another. Let, you want to displace a massive box on the floor. If the friction of the contact surface is large enough, then it takes a lot of labor to displace it. By polishing or smoothing the surface it can be decreased.

Using wheels

There are wheels in bus, truck and many types of machinery. The wheel is an ingenious invention. Its circular shape reduces friction to a minimum. Without wheel was it possible to use this machinery? Using wheel in a suitcase reduces the friction and it becomes easier to pull it. The value of the rolling friction in comparison to the sliding friction is reduced greatly due to the attachment of wheels.

Using lubricants

Oil, mobil and grease like materials are called lubricants or greasy materials in short. A layer of lubricant between the two surfaces can greatly reduce the friction. So, lubricants are used between the moving parts of an engine. In addition, we use oil in sewing machine, lock and hinges.

Using ball bearings

Another important invention similar to the wheel is the invention of ball bearing. It was possible to reduce the friction greatly between the surfaces by using ball bearing. Ball bearings are the small, smooth metal balls. Generally these are made of steel. Ball bearings are placed between the moving parts of a machine. They roll around so that the moving parts of the machine do not rub against each other directly. That is, the surfaces roll over one another instead of sliding and friction reduces. There are uses of ball bearing in car's wheel, cycle and electric fan [Figure 3.10].

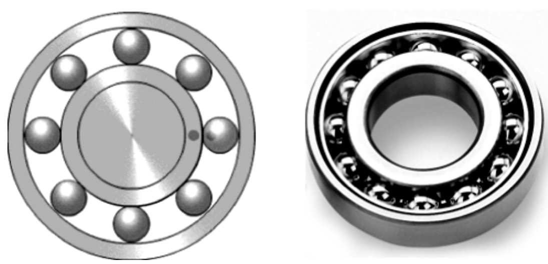


Figure 3.10

Increasing friction

Driving cars

Without friction in the road, the tyres of a car will just spin around at the same spot. Possibly you have seen how truck and bus is blocked in a slippery or muddy road in the rainy days. What is the reason behind this? This is due to the large decrease in friction. So friction is to be increased according to the necessity. The car tyres are so designed that they are able to grip the road properly and create necessary frictional force. Therefore the surface of the tyres are designed with treads i.e. grooves and teeth. In the rainy days, the water or mud enters the grooves and water and mud are thrown outside boldly. As a result, the tyres are able to grip the road surface well.

i.e. friction can be increased by making the surface rough.

Mountain climbing

Mountain climbers need to grip the rock or mountain surface with their hands and feet, in order to climb a mountain. They use chalk powder to grip the rock.

There are spikes under the boot of players so that they do not fall down while running.

3.12 Friction: a necessary evil

Though friction has many disadvantages it is considered as a necessary evil. What causes it? We cannot do anything without the force of friction. If there was no friction, the motion of a body would not cease at all and continue perpetually. Due to friction, a nail is fixed in a wall. It became possible to construct buildings and houses because of friction. Friction has made it possible to write on a paper with a pencil or a pen. We can walk as there is a friction between our shoes and the ground. We can change the direction of motion of a car owing to friction. Using a parachute it is possible to descend safely to the ground by harnessing the air resistance. In spite of having so many advantages we have to suffer a lot for friction. Because of excess friction the vehicles cannot move easily. Any device that has moving parts can wear out and tear due to friction. In any type of vehicles- may be car, boat or airplane, extra fuel has to be spent to overcome the excess friction. Fuel energy is being wasted because of friction.

The energy that is wasted for friction mainly appears as heat energy. Not only that energy is converted to heat due to friction, but also the parts of an engine may be overheated. As a result of friction, the soles of your shoes wear and tear out. So to make the life and works easier we need friction but excess friction is the cause of many losses too. Therefore to produce the necessary friction, we have to control it. Sometimes we need to increase or decrease friction by some processes. Therefore, we cannot discard friction totally; also friction is beneficial to us in many cases. For this reason friction is called a necessary evil.

Preparing report

Present a report to your teacher about the positive impact of friction in our life in the light of section 3.9 to 3.12.

Teacher will select the best report and tell the student to present in the class room.

Investigation 3.1: Measurement of force acting on a body

Objective: To measure force by simple experiment

Formula: We know, if a force F acts on a body of mass m and the resulting acceleration due to the force is a, then $F=ma$. The acceleration a of the body can be expressed by g in case of force due to gravity. That is, the force of gravity or weight of the body, $W = mg$. We shall measure weight of a body as an example of force.

Chapter foru

WORK, POWER AND ENERGY

[By work we mean to do something in our everyday life. But in physics it refers to a specific concept. In the beginning of this chapter we will present this concept. The most important topic in science is energy. From our experience we see that the world becomes inactive without energy. We get energy in different forms. Such as kinetic energy for motion, potential energy for object in higher position from the ground, the energy of spring at contract condition or expanding condition, heat energy of hot body, electrical energy of charged body etc. The energy is transforming from one form to another gradually although the total energy of the universe remains unchanged and constant. In this chapter we will discuss about the transformation of energy and the law of conservation of energy, one of the important laws of science.]

By the end of this chapter we will be able to -

1. Explain the relation between work and energy.
2. Establish the relation among work, force and displacement.
3. Explain kinetic and potential energy.
4. Explain the transformation of energy in its source.
5. Analyze the contribution of the source of energy regarding economic, social and environmental influence.
6. Explain the relation between transformation of energy and conservation of energy.
7. Explain transformation of energy and how its uses hamper the balance of environment.
8. Explain the effective use of energy in developing activities.
9. Be conscious about the effective and safe use of energy.
10. Explain the mass-energy relation.
11. Establish the relation between transmission of energy and power.
12. Measure the efficiency.

4.1 Work:

Work means to do something in our everyday life but in science doing anything is not work. In science the term work represents a definite concept. A gateman guards a house all day long sitting at a place and can say he has done his work. A boat was floating with the current of a river or canal and Mr. Karim was pulling it back. He might say he has done work to hold the boat otherwise the current of the river could pull it away. These are recognized as work in our daily life but these are not work in the point of view of science. Rather had the gateman guarded the house walking instead of sitting or had the boat floated with the current of the river, work could have been done. The concept of work in science is different from that of daily life. In fact in science work is done when displacement is associated with force. So, if a force acts on a body and causes its displacement only then work is said to be done. We see many examples of work around us in our daily life. For example, bull pulls the plough; a laborer pushes forward a push cart, someone throws iron sphere is sports competition etc.

Let us consider the following examples:

a) Ratan is standing still with a packet of book in his hand.
b) Mita is pushing her physics book from one end to another of a table.
c) Niru is lifting a heavy bag through stairs.
d) Rimi is pushing the wall strongly.

As work is said to be done only when a force is acted on a body and displaces it, so in the above examples (b) and (c) work is done but in the example (a) and (d) no work is done. We can apply force to shift a body from one place to another. We can change the shape of any body by applying force. In these cases work is done.

If a construction laborer wants to get to the second floor of a building with ten bricks, he has to do more work than that of lifting a single brick to the same place as he has to use more force. He has to do more work if he wants to lift those brick on the third floor. Therefore, the amount of work depends on the applied force and the distance. Work is measured by the product of applied force on a body and its displacement along the direction of force. Therefore,

Work = Force × Distance travelled along the direction of force

If a force F is applied on a body and the body travels a distance s along the direction of force (fig: 4.1) then the work done (W) will be,

$W= Fs$… … … (4.1)

Work has no direction. It is a scalar quantity.

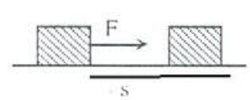


Figure: 4.1

Dimension of Work:

Dimension of work will be the dimension of force × dimension of displacement or, Work = Force × displacement

$$= \text{mass} \times \text{acceleration} \times \text{displacement}$$

$$= \text{mass} \times \frac{\text{displacement}}{(\text{time})^2} \times \text{displacement}$$

$$= \text{mass} \times \frac{(\text{displacement})^2}{(\text{time})^2}$$

or, $W = \frac{ML^2}{T^2}$

$\therefore [W] = [ML^2T^{-2}]$

Unit of work: The unit of work is obtained by multiplying the unit of force with unit of distance. Since the unit of force is Newton (N) and the unit of distance is meter (m) then the unit of work will be newton-meter (Nm) which is called joule. Joule is expressed by J. If a force of 1N is applied on a body and the body gets a displacement of 1m along the direction of force then the work done is said to be 1joule (1J), i.e. 1J = 1Nm.

If the displacement takes place along the direction of force then work done is said to be work done by the force.

If a duster falls on a floor from a table the work is done here by the force of gravity.

If the displacement of a body takes place opposite to the direction of force then the work done is called work done against force.

If a duster is lifted on the top of a table from the floor then the work is done against the force of gravity. This is because the displacement takes place opposite to the direction of the force of gravity.

Mathematical example 4.1: A man of mass 70kg climbs on a mountain of height 200m. How much work will he do?

Given,
Mass of man, m = 70kg
Force, F = weight of the man = mg
$= 70\text{kg} \times 9.8\ \text{ms}^{-2}$
$= 686\text{N}$
Displacement, S = 200m
Work, W =?

We know,
W = Fs
$= 686\text{N} \times 200\text{m}$
$= 1.372 \times 10^5$ J
Ans: 1.372×10^5 J

4.2 Energy

Nothing can move or work without energy. We need energy for our survival. The amount of work we do everyday depends on our energy level. We get energy from the food we take. Plants need energy for growth. Engine also needs energy for its functioning. Some engines use electricity and some need fuel for energy. Energy is stored in fuel.

What do we mean by energy? The energy of a body means its ability to work. So the body which is able to work has energy in it and the body that does not have energy in it cannot work.

When we say a body has energy in it we mean the body can apply force on other and can work. Again the amount of work done on a body is equal to the energy we use.

The energy of a body refers to its ability to work. Here work means the transformation of energy from one form to another. It means that the total amount of work that a body can do is its energy. The amount of work a body can do is the measure of its energy. So, the amount of work done is the amount of energy used.

Therefore, Work done = Energy used

Energy has no direction. So it is a scalar quantity.

The unit of energy and work is the same and it is joule (J).

Different forms of energy

We need different types energy for doing different kinds of work. For example we need heat to boil water. We get light energy from an electric bulb. There is sound energy in the music we hear. We need muscular energy to shift or to lift any object. Electrical energy is necessary to operate an electrical device. We get chemical energy by chemical reaction in the electric cell. A piece of paper flies due to energy of air. Nuclear energy is released when the atoms are accumulated or broken.

The universe is in motion as there is energy. If no energy existed the universe would be motionless. As there is light energy we can see and hear because of sound energy. We can move for mechanical energy. Fan rotates and factory runs with the help of electric energy. Energy exists in the universe in different forms.

Generally we observe the following forms of energy. Such as, mechanical energy, heat energy, sound energy, light energy, magnetic energy, electrical energy, chemical energy, nuclear energy and solar energy.

The most common form of energy is mechanical energy. The energy that is stored in a body due to its position or motion is called mechanical energy. In this lesson we will discuss two forms of mechanical energy-kinetic energy is produced due to motion and potential energy is produced due to the position of object.

Kinetic Energy: We sometimes notice that cricket ball hits the stamp and strikes it down. If anything hard hits the glass of window the glass breaks down. If we throw stones at mango or jujube it may fall down.

From the above example we can see energy exists in the body in motion. The capacity of doing work acquired by a moving body due to its motion is called kinetic energy.

Do it yourself: Keep a pen on a table or a desk in front of you. Put a light object before the pen. Hit the pen by your finger towards the object.

Why does the object displace from its initial position? This is because the hit makes the pen move and the pen obtains the ability to work that is kinetic energy is produced in it. So it could displace the object.

Creating velocity in a body in rest or increasing the velocity of a moving object means to produce acceleration in it. For this force has to be applied. As a result work will be done on the body. For this the body will obtain the ability to work and this work will be stored in the object as kinetic energy. This is why all moving objects are in possession of kinetic energy. The body will be able to perform this amount of work before it rests.

Let a force F be applied on a body of mass m at rest. The body attains a velocity v. Suppose the body moves a distance s in the direction of the force. The work done to produce this velocity of the body is its kinetic energy.

Therefore,

Kinetic energy = Work done

= Force × displacement

= $F \times s$

or, $E_k = mas$; [as, $F = ma$]

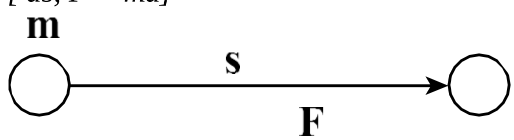


Fig: 4.2

But, $v^2 = u^2 + 2as$

or, $as = \frac{v^2}{2}$; [since, initial velocity, $u = 0$]

$\therefore E_k = \frac{1}{2} mv^2$ … … … (4.2)

$\therefore$ Kinetic energy = $\frac{1}{2}$ × mass × (velocity)^2

Kinetic energy depends on the mass of object. The more is the mass the higher is the kinetic energy. With the same velocity a light tennis ball and a heavy cricket ball are thrown at you. The hit will be more by the cricket ball than that of tennis ball.

Kinetic energy also depends on the velocity of objects. The more is the velocity the higher will be the kinetic energy. The damage will be less if a truck hits a wall with less velocity but the damage will be more in case of higher velocity.

Mathematical Example 4.2: The kinetic energy of a runner of mass 70 kg is 1715 J. What is his velocity?

We know,

$E_k = \frac{1}{2} mv^2$

or, $v^2 = \frac{2E_k}{m}$

$\therefore v = \sqrt{\left(\frac{2E_k}{m}\right)}$

$= \sqrt{\left(\frac{2 \times 1715\ J}{70\ kg}\right)}$

$= 7\ ms^{-1}$

Ans: $7\ ms^{-1}$

Here,
Mass, m = 70 kg
Kinetic energy, E_k = 1715 J
Velocity, v =?

Potential Energy:

If a piece of stone or brick falls on a body from the roof of a building it may flatten or break the body. When the stone or brick was in rest on the roof potential energy was stored in it but the potential energy works when it falls down. The energy was stored in the stone because it was above the ground.

What will happen when the two ends of a spring is stretched and tied to two objects and then released? The objects will move fast and collide with each other. The stretched spring was at rest but potential energy was there in it. If it is released it may work. The energy was stored in the stretched spring because it was strained.

The ability of a body to do work when its normal position or configuration is changed to some other position or configuration is called potential energy.

Expanded Activities: Take a pulley and place a rope on it. Tie a heavy object A with its one end and a light object B with the other end. Such that, A remains above the ground but B remains on the ground [Fig: 4.3]. Remove your hand.

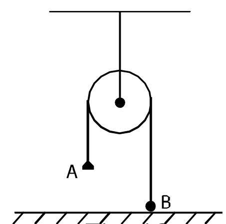


Fig: 4.3

What did you see? The object A goes down and object B goes up. The potential energy was stored in the object A as it was above the ground from its normal position and gained ability to work. It can work till it reaches the ground that is it can raise the object B.

Experiment: Take a spring and tie its one end with a strong support and a block to its other end. Place them on a smooth surface. Now apply force on the block and contract the spring and keep another object in front of the block [Fig: 4.4] then remove your hand.

Why did the object move fast? Spring could work while regaining its original configuration and was able to displace the other body. This ability of spring to work for the change of its normal configuration is its potential energy. If some work is done against the force at the time of changing from normal position or configuration to some other position or configuration then the body obtains the capacity of doing work that is same amount of energy is stored in it. This principle is applicable within the sphere of influence of conservative force such as electric force, magnetic force, spring force etc. This sphere of influence is called the field of that force such as gravitational field, electric field etc. We work against the force of gravity when we lift anything higher from the ground. As a result the object obtains some amount of potential energy. It can perform the same amount of work when it falls on the ground.

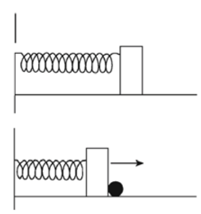


Fig: 4.4

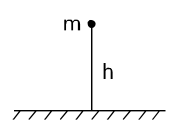


Fig: 4.5

If a body of mass m is raised to a height h (fig:4.5) above the surface of the earth, the work done in such a process is a measure of potential energy stored in the body. In this case, the work done is the product of the applied gravitational force i.e. the weight of the body and the vertical height.

$\therefore$ Potential energy = weight of the body × vertical height

$= mgh$

$$\therefore E_p = mgh \qquad (4.3)$$

i.e. potential energy = mass of the body × acceleration due to gravity × vertical height Potential energy depends on the vertical height of the object from the surface of the earth. The more is the height, the higher will be the potential energy. Potential energy also depends on the mass of the object. The more the mass the more will be the potential energy of the object.

To use the potential energy stored in a body it is necessary to transform it into other form of energy. For example, a piece of stone is not dangerous as long as it is on the roof and its potential energy transforms into kinetic energy i.e. it starts to fall.

Mathematical Example 4.3: What will be the potential energy of a body of mass 6kg if it is raised to a height of 20m above the surface of the earth? $g = 9.8\ ms^{-2}$.

We know,

$E_p = mgh$

$= 6kg \times 9.8\ ms^{-2} \times 20m$

$= 1176\ J$

Ans: 1176 J

Here,
Mass of the body, m = 6 kg
Height, h = 20m
$g = 9.8\ ms^{-2}$
Potential Energy, E_p = ?

4.3 Prime Sources of Energy

The modern mechanized civilization cannot proceed a moment without energy. Work is available at the expense of energy. Uninterrupted energy supply is essential for the survival of all living creatures. The demand of energy is increasing day by day with the development of life style. For this increasing demand of energy man is looking for newer sources of energy. We need to have clear idea about the sources of energy to save the living beings and to continue the supply of energy. We know that the sun is the only source of all energy. Moreover, the nuclear energy in the nucleus and the energy from the hot melted substances are considered to be the sources of energy. All the existing energy of the world is directly or indirectly comes from the sun or are produced using the radiation of the sun.

Chemical Energy/Fuel Energy:

Man in the ancient time was dependent wholly on the energy of their muscles. Afterwards, they learnt to tame the wild animals and use their energy in different work. They used to carry their goods and cultivate land with the help of animals. The initial stage of civilization was to produce heat energy from burning wood and leaves and mechanical energy from current of water and flow of wind. The economic development of human being begins from the use of machine energy. Industrial revolution and invention of steam engine reduced men's dependence on muscle energy of human and animals. Man kept operating different machines with the help of steam energy. Fuel is necessary to produce this steam energy. So we consider different kinds of fuels to be the sources of energy.

The most common sources of energy are coal, mineral oil and natural gas. Coal, mineral oil and natural gas from underground are used as fuel directly or by refining them slightly.

Coal:

Coal is best known to us as one of the sources of energy. It is an organic substance. Once upon a time there were numerous plants and trees. Due to different natural calamities and natural consequences the leaves of the trees and their stems were buried underneath the earth and began to coagulate. As a result of chemical changes, the leaves of the trees and stems were transformed into coal. Combustion of coal gives us heat directly. This is a well known fuel. Many essential substances can be produced from coal apart from using it as a fuel. Some of the coal products are coal gas, tar, benzene, ammonia, toluene etc. Coal is used to cook food and to drive the steam engines. In modern age, the main use of coal is in thermal power plants. The main fuel in a thermal power station is coal.

The main problem of a coal fueled power station is that it emits sulphur smog which causes acid rain. Though this acid is very weak, it kills the fishes of pond, cannel and lake, destroys forest and damages the sculptures of stone.

Mineral Oil:

Petroleum or mineral oil is one of the principal sources of energy. It is widely used as a fuel in the present world. It is being used right from a rural cottage to the most modern transport system. Petrol, pitch that is used to pave roads, kerosene and chemical fertilizers are all petroleum products. There is nothing like petrol to be used as fuel. On the other hand, many kinds of artificial fabrics can be developed from petroleum. These are terry line, polyester, cashmilon etc. Moreover, various types of cosmetics are produced from petroleum. But it is basically used as a fuel. Petroleum products are used to produce electric and mechanical energy. Petroleum is a Latin word. It is a combination of two minor words: Petro and Olium. In Latin language ‘petro’ means stone and ‘olium’ means oil. So, petroleum means oil of stones i.e. oil stored inside stones. In tertiary age i.e. almost five to six crores of years ago the trees and the animals fell buried in the different layers of sedimentary rock on the bottom of the sea. Due to different chemical changes these were transformed into mineral oil. Most of the solid regions of the present world were a part of the bottom region of the sea in prehistoric age.

Natural Gas:

Natural gas is a well known source of energy. Specially, the use of natural gas in Bangladesh is wider. Use of natural gas is very high in all advanced countries. It is also used in different industries as fuel. In Bangladesh it is widely used for domestic requirement basically for cooking purposes. It is also used in fertilizer factories. Heat energy is produced by the combustion of gas and electric energy is produced from heat energy in a thermal power station.

Natural gas is obtained from underneath the earth. Digging very deep well the gas may be taken out from underneath the earth. Tremendous temperature and pressure inside the earth is the root cause of the creation of the gas. Natural gas is also available in petroleum well. The principal element in a natural gas is the methane gas. These are called fossil energy.

The three sources of energy discussed above are reducing very fast due to the men's increasing demand of energy. The physical condition of the world is such that these sources-coal, mineral oil, natural gas cannot be recreated, these are called nonrenewable energy. So men are looking for alternate sources of energy of which solar energy, energy from water flow, energy from tide and ebb, geothermal energy, wind energy, biomass etc are the main sources. These sources are directly or indirectly dependent on the sun. As long as earth receives sunlight the energy supply from these sources is possible. These are called renewable sources.

Solar Energy:

The energy that we obtain from the sun is called Solar Energy. It is known to all that the sun is the source of all energy. The origin of all forms of energy is from the solar energy in one way or the other. For an example, the fossil fuel such as coal, mineral, oil, and natural gas is actually a store of solar energy for a long time.

From ancient times man is using sunlight directly to dry things. At present man is adopting various means to use the solar energy round the clock. Ignition can be done by concentrating sun's rays- with the help of a convex lens. Solar cooker consists of a metallic bowl on which the solar rays are reflected. The cooker can be used in cooking purposes.

Do it yourself: Take a concave mirror with a focal length of 15cm or 20cm. Hold the mirror facing the sun. Take a piece of paper and concentrate the sunlight with the help of the mirror on it. Hold the mirror till the paper ignites.

The solar rays are used to keep the dwelling houses warm in cold countries. Solar energy is used for drying purposes of crops, fish, vegetables etc. Dried fish can be preserved for many days. More examples of solar energy are- solar water heater, solar cooker etc.

Solar cell has been made by using modern technology. The characteristics of a solar cell are that the cell produces electricity instantly while solar rays fall upon it. There are various uses of solar cell.

1. This cell is used to supply electricity in artificial satellites. For this reason the artificial satellites move along their orbits for a long time.
2. Solar energy is being used to operate different electronic devices like pocket calculator, pocket radio and electronic watch.
3. Currently electrical energy is produced from solar energy in the rural area, houses or offices to meet up the need of electricity.

The advantage of solar energy is that it does not pollute the environment. There is almost no possibility of danger in using this energy. There is also no possibility of sudden exhaustion of solar energy. This is why it is likely to be used as a prospective fuel instead of fossil fuel.

Hydroelectricity (Transformation of mechanical energy):

Water is one of the renewable sources of energy. Energy can be produced by means of water current and tide and ebb. There are different forms of energy in the water current such as, kinetic and potential energy. Electricity produced by means of water current is known as hydroelectricity. Different countries of the world make use of potential energy for producing electricity in hydroelectric projects. The method of producing hydroelectricity using the water current is simple. The current of water is used to rotate a turbine. A co-ordination of mechanical and magnetic energy is possible from the rotation of turbines.

Electricity produced by mechanical energy created by water current in co-ordination of magnetic energy is called hydroelectricity.

Making a model: Make a model of a hydroelectric station that uses the energy of falling water to turn a turbine to operate a dynamo to produce hydroelectricity. [Fig: 4.6]

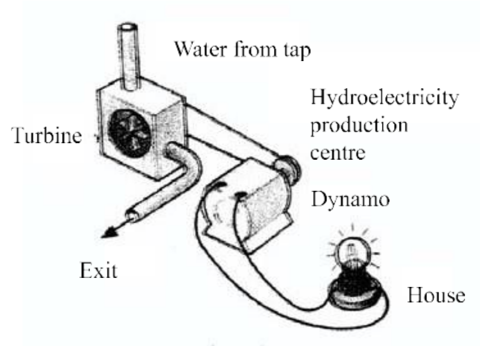


Figure: 4.6

Potential energy is used to produce electricity in the Kaptai electricity production station of our country.

Man is trying to use the energy of tide and ebb of river or ocean for a long time. The operation of different machines using the energy of tide and ebb has been invented a long time ago.

In France electric energy production projects are being successfully implemented using the energy of tide and ebb. Other countries of the world are also trying to set up tidal energy projects to produce electricity.

Wind Energy

Wind flows due to the difference of temperature in the earth surface. Kinetic energy due to the air flow can be transferred into electric energy. The machine that transforms energy is called Windmill. People in the ancient time used to lift water from well, sail ship using the wind blow. Still today people sail in the boat using air energy. Nowadays electric energy is produced using windmill with the help of technology.

Geo-Thermal Energy

The heat in the earth can be used as the source of energy. The heat in the deep of earth is so high that it can melt pieces of rocks. This melted rock is called Magma. This Magma sometimes rises up and remains stored just below the surface of the ground due to geological changes. These types of places are known as hot spot. When the water under the ground comes in contact with the hot spot it turns into steam which remains stored in the ground. This steam could be let out passing a pipe through a hole on the hot spot with the help of high pressure. Electricity can be produced rotating a turbine with the help of this steam. There is such kind of power station in Newzealand.

Biomass Energy

A small fraction of solar energy is transformed into chemical energy by the green plants in the process of photosynthesis and remains stored as biomass in different parts of the trees. Biomass refers to all those organic materials that can transform into energy. Man along with other animals takes biomass as food and keeps their activities of life active by transforming biomass into energy. Biomass can be considered as a multiple source of energy. The organic substances that can be used as the source of energy are – plants and trees, dry wood, waste of wood, crops, husk of rice, herbs, waste of birds and animals, garbage etc. Biomass is mainly composed of Carbon and Hydrogen. One of the renewable sources of energy is biomass.

Biogas can be produced easily from biomass. We can use this gas as the alternate to natural gas and use for cooking even for the production of electricity. The production of biogas is very simple. If we keep cow dung and water in 1:2 ratio in a closed pot for dumping, biogas will be produced. This gas comes out through a tube. This gas is used for cooking. For the cooking and lighting bulbs for a family of 4/5 persons the requirement of gas can be supplied from the cow dung of only 2/3 cows.

Nuclear energy

Electricity can be produced by using the energy produced in nuclear reaction. The nuclear reaction from which the obtained energy is used to produce electricity is called nuclear fission. Here, uranium is made to react with a neutron of particular amount of energy. This reaction takes place in a nuclear reactor.

In nuclear reaction usually matter that is mass is transformed into energy. But in nuclear reaction only a small fraction of energy of the total mass is transformed into energy. If mass is transformed and E amount of energy is obtained, then,

$E = mc^2$

Here m is the mass transformed into energy.

c is the speed of light that is equal to $3 \times 10^8 \ ms^{-1}$.

From experiment it is known that in a fission reaction, that is, if a neutron of definite energy strikes a uranium nucleus, then almost

200 Mev = 200×10^6 ev = $200 \times 10^6 \times 1.6 \times 10^{-19}$ J = 3.2×10^{-11} J energy is released.

Since nuclear fission is a chain reaction, hence in a moment crores of reactions take place and huge amount of energy is released.

Calculate: If a substance of 1kg mass is converted completely into energy, then how many kilowatt energy will be produced? 1 kilowatt-hour (1 kWh) = 3.6×10^6 J

The energy obtained from this reaction can be transferred to another container as the internal energy of carbon dioxide, by pumping continuously at high pressure in a controlled way. This heated gas moves around a special steam boiler and heats the steam inside which can rotate a turbine and produce electricity. The amount of energy obtained from a ton of uranium by a nuclear reaction will be equal to the amount of energy obtained from burning ten lac tons of coal.

But there are some problems of nuclear power plants. The waste of nuclear fuel is extremely radioactive and so it has to be preserved for thousands of years to make it safe. Moreover, in a nuclear reactor high temperature and pressure is produced. So it has to be made of such a material that can tolerate the high temperature and pressure. Any nuclear accident is very dangerous which we can realize from the accidents of Chernobyl in Soviet Union (at present Ukraine) and Fukushima in Japan. In nuclear power production less greenhouse gas is released in the environment.

The Social Effects and Advantages of Renewable Energy

Uses of renewable energy have a far-reaching effect on our social life. In comparison with the demand of our country the storage of coal, petroleum and natural gas is very poor. So, we have to import mineral oil and coal from abroad to meet up the demand of energy by spending a lot of valuable foreign currency. But utilizing the renewable energy sources that we have in our country especially if we can encourage the people to produce and use biogas, we will be able to change the infrastructure of rural area. We can focus our attention to electricity production using windmill. If we can make the use of solar energy available through research, we will be able to meet up all our demands of energy from this unlimited source.

The main advantage of using of renewable energy is that there is no possibility of diminishing of energy. Moreover it will be possible to protect our country from environment pollution.

4.4 Transformation of energy

Energy is being transformed continuously from one form to another. Various incidents are taking place in this universe due to transformation of energy. Though energy is transforming from one form to more than one form, the total amount of energy in this universe remains unchanged.

Transformation of energy is required for man, computer or any other machine to work or to make any change or to process anything. One form of energy can be used to produce another different form of energy. Actually, one form of energy is simultaneously transforming into another form which is known as the transformation of energy. What happens when anyone plays guitar? The muscle energy of the artist transforms into mechanical energy on the vibrating string which transforms into sound energy as a melodious music and travels to our ears. When wood is burned chemical energy is released and transforms into heat and light energy. A chemical reaction takes place in an electric cell and the chemical energy of these reactions transforms into electric energy which is used for various purposes.

When a definite amount of energy of a particular form is transformed how much energy is obtained? It can be known from the law of conservation of energy.

When such a transformation takes place there is no net loss of energy. The energy lost by one body is exactly equal to the energy gained by another body.

In fact, we can neither create energy nor destroy it. In other words the total energy of the universe does neither increase nor decrease. The amount of energy that existed in the universe at the moment of its creation exists till today. This known as conservation of energy.

Principle of Conservation of Energy:

Energy can be transformed form one form to another or more forms. The total energy of the universe is constant and unchangeable.

Transformation of energy:

We have mentioned earlier about different forms of energy. All of them are related to one another. In other words, it is possible to transform one form of energy into another. This is known as transformation of energy. In fact, almost every natural phenomenon can be considered as a transformation of energy. Several examples of energy transformation are described below.

1. Transformation of mechanical Energy:

Rubbing of hands produces heat. In this case mechanical energy is converted into heat energy. If we low air in an empty pen cap, mechanical energy is converted into sound energy. When water is on a hill or a mountain, potential energy is stored in it. When this water flows down through a spring or river then the potential energy is transformed into kinetic energy. This flow of water can rotate a wheel to produce electricity. In this way mechanical energy can be transformed into electrical energy.

2. Transformation of heat Energy:

In steam engine heat is used to produce steam for driving train etc. Here heat energy is converted into mechanical energy. Heat energy is converted into light energy by conducting electric current through the filament of a bulb. If the junction of two different metallic substances is heated, the heat energy is converted into electric energy.

3. Transformation of light energy:

If we touch the chimney of a lantern we feel it to be hot. Here the light energy is converted into heat energy. Action of light on a photovoltaic cell converts light energy into electric energy. Due to the action of light on a photographic film light energy is transformed into chemical energy.

4. Transformation of chemical energy:

Food and fuel, such as oil, gas, coal and wood are the sources of chemical energy. The energy of food is released in our body by chemical reaction and we can work when this energy is transformed into other forms of energy. When fuel is burnt in an engine or boiler, transformation of energy takes place. In an electric cell chemical energy is transformed into electrical energy. In the filament of an electric bulb, electrical energy is transformed into light and heat energy.

5. Transformation of electrical energy:

In electric motor electric energy is transformed into mechanical energy. In instruments like heater, electric iron etc. electric energy is converted into heat energy. In electric bulbs electric energy is converted into light energy. The receiver of a telephone or radio converts electrical energy into sound energy. In a storage cell electric energy is converted into chemical energy. In electromagnets electric energy is converted into magnetic energy.

6. Transformation of Nuclear energy:

In nuclear submarine nuclear energy is transformed into mechanical energy. Devastating action of atom bomb is nothing but the transformation of nuclear energy. Nowadays, transformation of nuclear energy into other forms of energy especially electrical energy in a nuclear reactor mostly satisfies the demand of energy.

We can understand from the electric power station that the way energy is transformed from one form to another and we get light and heat energy in our houses. By burning coal and natural gas in a power station, we can obtain chemical and heat energy. Heat energy is converted into mechanical energy with the help of turbine which rotates the coil of electric generator. In this process electrical energy is produced. Electric bulb and heater of houses and factories transform electrical into light and heat energy.

Again, which energy is transformed into what type of energy when we pierce a nail into wood by hammering it? The chemical energy of our boy is used to lift the hammer upward which is stored as potential energy due to the higher position of it. When it moves down the potential energy stored is transformed into kinetic energy. This kinetic energy is used to pierce the nail into wood. At the same time sound energy and heat energy in nail, wood and in hammer is produced.

During the transformation energy may not be created or destroyed but reduced. Such as, we cannot make use of all the heat energy as we can use light or electric energy.

4.5 Power

We all are familiar with the word power. In our daily life power is usually related to taking decision and implementation. In science the word “power” is related to the devices motor, pump, and engine etc. i.e. any device that can work. Sometimes we want to solve any task quickly. Suppose we want to fill a water tank on the roof of a multistoried building taking water from its reservoir at the ground floor or from a pond. It takes a lot of time if we want to fill the tank carrying water with a bucket. It takes less time to fill the tank with the help of a motor or a pump. Sometimes a work is done quickly or slowly. Power is the measure of a source by which how fast or how slow a source can work is measured. Suppose two friends-Roni and Oni live on the fifth floor of a building. The mass of the two friends is the same. Coming to the lift at the ground floor they found the lift not working. They had to use the stairs to go up the building. Roni took 40 seconds and Oni took 80 seconds to reach the 5th floor. We say Roni has more power than Oni. Though both of them has done same amount of work to reach the same height Roni has more power because he has done the work faster. Power is the rate of doing work or transformation of energy. Power of a person or a source is measured by the amount of work done per unit time.

$$\text{Power} = \frac{\text{Work}}{\text{Time}}$$

If as person or a device can do *W* amount of work or transform energy at time *t* then the power P will be,

$$P = \frac{W}{t} \qquad (4.4)$$

Power has no direction. So it is a scalar quantity.

Dimension: The dimension of power is the dimension of $\frac{\text{Work}}{\text{Time}}$.

$$\text{Power} = \frac{\text{Work}}{\text{Time}} = \frac{\text{Force x Displacement}}{\text{Time}} = \frac{\text{Mass x Acceleration x Displacement}}{\text{Time}}$$

$$= \frac{\text{Mass x Displacement x Displacement}}{\text{Time x Time}^2} = \frac{\text{Mass x Displacement}^2}{\text{Time}^3}$$

$$\therefore [P] = \frac{ML^2}{T^3} = [ML^2T^{-3}]$$

Unit: We can get the unit of power by dividing the unit of work with that of time. Since the unit of work is joule (J) and the unit of time is second (s), the unit of power will be Joule/second (J/s). It is called Watt. Watt is denoted by W.

If one joule work is done in one second or the rate of transformation of energy is called one watt.

$1W = \frac{1J}{1S} = 1\ Js^{-1}$

Since watt is very smaller, its thousand times larger unit kilo-watt is used.

1 kilo-watt = 1000 watt

You have probably heard the word "Horse Power". This unit of power was used earlier. Still today this unit is sometimes used to mean the power of a motor or a car.

1 Horse Power = 746 watt

Have you heard the word "kilowatt-hour"? What does it mean? Actually it is the unit of work or energy. We usually pay the bill of electricity of houses, factories etc measured in this unit. One kilowatt-hour means the energy that a machine with a power of one kilowatt uses in one hour. 60 watt mark on a bulb means that it transforms 60 Joules electrical energy to light and heat energy in one second.

200 megawatt power of an electrical power station means that it supplies 200000000 joules energy in one second. We are using this energy in houses, factories and offices.

Mathematical Example 4.4: A person of mass 70 kg can stair up 30 steps of 25 cm height each in 15 s. What is his power?

($g = 9.8\ ms^{-2}$)

Here,

Mass of the person, m = 70 kg

Force = Weight of the person = mg

$= 70\ kg \times 9.8\ ms^{-2}$

$= 686\ N$

Displacement, S = 35 x 25 cm

= 750 cm

= 7.5 m

Time, t=15s

Power, P = ?

We know,

$P = \frac{Work}{Time} = \frac{Fs}{t}$

$= \frac{686\ N \times 7.5\ m}{15\ s}$

$= 343\ W$

Ans: 343 W

Do it: Count the number of steps of the stairs to reach the roof of your school or house or any other building. Measure the height of the roof in meter. Measure your mass with the help of a weight measuring machine in kilogram. Multiply your mass with 9.8 and then you will find your weight in newton. Then run to the top of the roof. Measure the total time of reaching the roof with the help of a stop watch.

Your work done will be, your weight × total height

Your power will be, your total work done ÷ total time i.e., $\frac{\text{Work done}}{\text{Total Time}}$.

Perform these activities with your friends and compare your power with them. Who is the most powerful student in your class?

4.6 Efficiency:

We fulfill our daily needs with the help of transformation of energy. For example we run an engine by transforming chemical energy stored in petrol into kinetic energy. According to the principle of conservation of energy, we should obtain the amount of energy which is given to the engine. But it is seen that the energy gained is always less than the energy given to. This is because some energy is lost due to the work done against the frictional force of the engine. The amount of energy obtained from the engine is called effective energy. In this case the equation of energy is,

Given energy = Effective energy + the energy lost in other ways

The efficiency of an engine means that how much of the given energy is obtained as effective energy. So, the efficiency means the ratio of effective energy and the total given energy. Usually the efficiency is expressed in percentage.

$\therefore$ efficiency, $\eta = \frac{\text{Effective energy}}{\text{Total input energy}} \times 100\%$

Energy transformation takes place in different steps in a normal electricity production centre. This transformation continues from coal, oil, natural gas or Uranium up to the production of electricity. It is seen that up to 70% of this energy is lost as heat energy.

At last only the 30% of input energy is transformed into useable electrical energy. So, we can say the efficiency of the electricity production centre is 30%.

Mathematical Example 4.5: An electric motor is used to lift a body of weight 10N at a height 5m. It uses electrical energy of 65J.

a) What is the energy lost by the motor?

b) Find the efficiency of the motor.

Ans:

a) Here, energy used = work done

= Force x displacement

= Weight x height

= 10N x 5m

= 50J

$\therefore$ The energy lost = Energy supplied – energy used

= 65J – 50J

= 15J

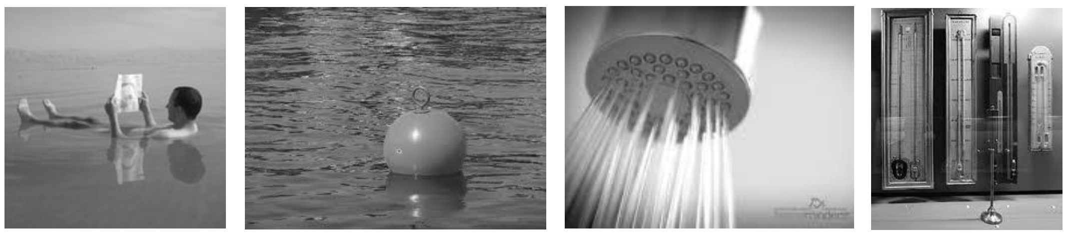
b) Efficiency, $\eta = \frac{\text{Effective energy}}{\text{Total input energy}} \times 100\%$

$= \frac{50J}{65J} \times 100\%$

= 76.92%

Chapter five

PRESSURE AND STATES OF MATTER



[We know matter can exist in three states- solid, liquid and gas. Plasma is another state of matter. Liquids and gases can flow easily so they are called fluids. The fluid can create pressure. We can do many works using pressure of fluids. Elasticity is a special characteristic of matter. We will discuss all these in this chapter.]

By the end of the chapter, we will be able to -

1. Explain the change of pressure with the change of force and area.
2. Explain the density.
3. Explain the usage of density in our everyday life.
4. Explain the atmospheric pressure.
5. Find the atmospheric pressure by using the height of the liquid column.
6. Analyze the change of atmospheric pressure with the increase of height.
7. Analyze the effect of change of atmospheric pressure on weather.
8. Determine the expression for pressure at a point in a liquid at rest.
9. Explain the upward pressure of submerged body in liquid.
10. Explain why object floats on water.
11. Analyze the causes of accidents in waterway in Bangladesh.
12. Explain Pascal's law.
13. Demonstrate practical application of Pascal's law.
14. Explain stress and strain.
15. Explain Hooke's law.
16. Explain the molecular kinetic theory of matter.
17. Explain the plasma state of matter.

5.1 Pressure and Area

Can you stand on a single leg easily that you can do by using your two legs? The shoes pierce into the mud when one walks on soft mud wearing a high hill. But if one does so wearing a flat pair of shoes, then it does not get into the mud. We will see that it happens due to the change of pressure.

Fig-5.1

The force exerted perpendicularly to unit are of a body is called pressure. Let a force F act perpendicularly on area A of a surface, then pressure, $P = \frac{F}{A}$

i.e. $\text{Pressure} = \frac{\text{Force}}{\text{Area}}$

It is noted that less the area A, more is the pressure P and more the force F, more is the pressure P.

Example:

(i) The area of the sharp edge of a nail is very small. So when the sharp end of the nail is placed on a wood like surface and hammered on the flat head of the nail, comparatively more pressure is exerted on the sharp end as a result the nail easily enters into the substance.

(ii) The area of the sharp edge of the knife is very small. So, by placing the sharp edge of the knife on a substance if force is applied, then more pressure acts on the substance along edge. Therefore the substance can easily be cut.

> **Do it yourself:** Hole a paper by a very sharp pin and by a blunt pin. Which one is easier to hole? Explain.

More pressure is felt on the sharper edge of the pin when force is applied on its flat end. When force is applied on the flat end of the blunt pin, less pressure is exerted on the blunt end .So, it is easy to hole a paper by a sharper pin.

Verify: Which one is more painful to walk bare footed on plain bricks soling road or a brick chucked road? Explain

Unit of pressure:

If we divide the unit of force by the unit of area, we get the unit of pressure. Therefore the unit of pressure is Nm^{-2}. It is called pascal (Pa).

$\therefore$ $1Pa = 1Nm^{-2}$

If a force of 1N force is applied perpendicularly to an area of $1m^2$, then the pressure generated is known as 1Pa.

Mathematical Example 5.1: The mass of a woman wearing a shoe is 50kg. The area of the bottom of the shoe is $200cm^2$. Find the pressure.

We know.

Pressure

$$P = {}^{F}/_{A} = {}^{W}/_{A}$$

$$= \frac{490N}{200\times10^{-4}m^2}$$

$$= 2.45\times10^4 Pa$$

Given,

mass, m=50kg

force, $F = w = mg = 50kg\times9.8ms^{-2}$

$= 490N$

Area of the bottom of the shoe, $A = 200cm^2$

$= 200\times10^{-4}m^2$

5.2: Density

The space occupied by a body is called its volume. If we drop a piece of cork and a piece of iron of the same volume into water, we see that the piece of cork floats on water but the piece of iron gets submerged into water. We may say in general that the density of iron is more than the density of cork. So, iron gets sunk into water. Though the volume of the substances are the same, actually the more the density, the heavier the object is, and the less the density, the lighter the object is. The mass per unit volume of a substance is called the density of its material. Density is a general property of matter. Density of a body depends on its material and temperature.

Density is denoted by ρ. If the mass of a body is m and its volume is V,

then density $\rho = \frac{m}{V} = \frac{\text{mass of the body}}{\text{volume of the body}}$

The unit of density is kgm^{-3}.

Task: Take two jugs of equal volume. Fill up one jug with water and the other with honey. Lift both the jugs by your hands. Which one is felt heavier?

The jug filled with honey will appear heavier because the density of honey is more.

Some substances and their density

Substances	Density (kg^{-3})	Substances	Density (kg^{-3})
Air	1.29	Water (at 4°C)	1000
Cork	250	Iron	7,800
Glycerin	1260	Silver	10,500
Ice	920	Gold	19,300


Figur: 5.2

Of course you have heard the name of Dead Sea. It is in Jordan. Due to Salt and other impurities the density of the water of the sea is so high that man does not get sunk into it.

Uses of density in every day life:

The balloons are released in different inaugural ceremonies. The balloons are puffed of by hydrogen gas. The density of hydrogen is considerably less than the density of air. So, these light balloons filled with gas go up easily.

When electricity goes off many of us use IPS and huge battery is used in an IPS. This type of battery known as storage cell is also used in cars and microphones. Sulphuric acid used in these cells has density ranging from $1.5 x 10^3 kgm^{-3}$ to $1.3 x 10^3 kgm^{-3}$. Sometimes, hydrometer is used to measure the density. The cell will damage if the density of acid increases. For this reason necessary amount of water is added to it time to time to keep the density at desired level.

Eggs sink in water, but rotten eggs remain floating. As the density of the rotten egg is less than the water, it floats on water

Mathematical example 5.2: what is the density of liquid of mass 2000kg and volume $2m^3$?

We know,

Density, $\rho = {}^{mass}/_{volume} = {}^{m}/_{v}$

$= \frac{2000kg}{2m^3}$

$= 1000\ kgm^{-3}$

Given

Mass, m = 2000 kg

volume, v = $2m^3$

Density, ρ= ?

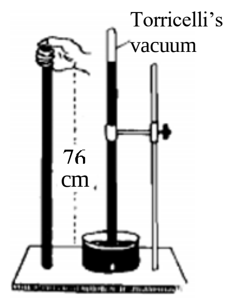
5.3 Atmospheric pressure

This earth is surrounded by air. Atmosphere has weight. So it has pressure. This very pressure on earth surface is almost 10^5N per square meter. The atmospheric pressure is $1.5x10^5$N on the body of an adult if the area of his body is $1.5m^2$. As the internal blood pressure of a human body is greater to some extent than the atmospheric pressure, generally it is not felt by the people.

The atmosphere for its weight applies force on the earth's surface and the amount of force acting perpendicularly on per-unit surface area of the earth, is called atmospheric pressure.

Torricelli's experiment and the measure of atmospheric pressure

Take a glass tube about one meter long opened at one end having uniform diameter. Fill the whole tube with pure mercury. Close the open end of the tube tightly with finger and invert the tube. Take this inverted end of the tube along with your finger inside the pure mercury contained in a container. Now remove the finger and take necessary steps to keep the tube vertical. It will be observed that the mercury has come down to some extent and has attained a steady position. It might appear apparently that the mercury inside the tube is in standing position by itself. But in reality it is not so. It happens so due to air pressure. Atmosphere is always exerting pressure on the mercury of the container. This pressure is convoyed through the mercury and acts in the upward direction in the tube. This very pressure holds the mercury column of the tube. In absence of this pressure the mercury of the tube will come down due to the force of gravity. Therefore, atmospheric pressure is equal to the pressure of the mercury column of the tube. Generally the height of the mercury column that remains in the tube in about 76cm i.e. the air pressure supports the pressure of 76cm column of mercury. In this way using the height of a liquid the atmospheric pressure can be measured.

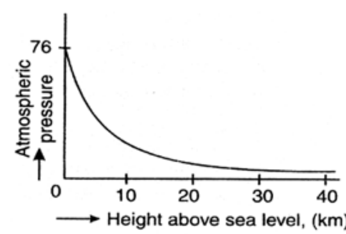


Figur: 5.3

The space that remains just above the mercury column in the tube up to its closed end is totally empty. This empty space is termed as Torricelli's vacuum. Only a scarce amount of mercury vapor exists there. The apparatus used to measure the air pressure is called barometer.

5.4: Altitude and atmospheric pressure

The atmospheric pressure depends on the density and height of the atmosphere. On the earth's surface and on sea level the normal air pressure is 76cm of mercury pressure. With the increase of altitude from the sea-level the weight and density of air-column decreases. So, the air pressure reduces with the increase of height. The atmospheric pressure on the peak of Mount Everest is about 30% of the sea-level air pressure. For this reason respiration becomes difficult at such a high level. There is a possibility of bleeding from the nose at high altitude as atmospheric pressure is considerably low there. Nowadays normal pressure is kept inside a plane for the convenience of the passengers when it flies at a very high altitude and low pressure region. With the increase of height from the earth's surface the pressure of the atmosphere decreases. The change of pressure of the atmosphere with altitude is shown in the graph [Fig: 5.4].



Figur: 5.4

5.5 Change in atmospheric pressure and weather

With the change of time the atmospheric pressure of a certain place also changes. The variation of water vapor in air is the cause of this change. The density of air also changes with the change of vapor in air. We can understand the change of atmospheric pressure by observing the change in the height of the mercury column of a barometer.

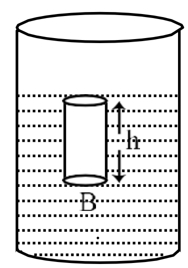
1. If the height of the mercury decreases gradually then it would be understood that the pressure of water vapor is gradually increasing because water vapor is lighter than air. It indicates the possibility of rain.

2. All of a sudden if the mercury height falls down then it is to be realized that the atmospheric pressure of the surrounding area has fallen down and low pressure has been created. The air at a high pressure from the neighboring area will rush with tremendous speed to the depression area. So, there is a possibility of storm.

3. When the height of the mercury column of the barometer slowly increases, then it indicates that water vapor from the air is being disappeared and dry air is occupying that space. So, the weather will remain dry and clear. By determining the air pressure by a barometer in this way weather can be forecast.

5.6 Pressure at a point in a liquid at equilibrium

Pressure at a point in a liquid means a force exerted perpendicularly by the liquid on unit area around that point in the liquid. In fig. 5.5 some liquid is kept in a vessel.



Figur: 5.5

Let the area of the base of the vessel = A

density of the liquid = ρ

depth of the liquid = h

acceleration due to gravity = g

We know, pressure = force ÷ area

Now, the force acting on area A = weight of the liquid

= mass of the liquid × g

= volume of the liquid × density × g

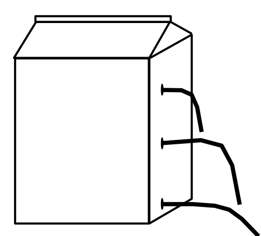
= area of the base × depth × density × g

= $Ah\rho g$

Pressure, $P = Ah\rho g/A$

or, Pressure, $P = h\rho g$

Again as 'g' is a constant, so $P \propto h\rho$


Figur: 5.6

i.e. the pressure at a point in a liquid at equilibrium is directly proportional to the depth of that point from the free surface of the liquid and its density. Therefore pressure rises with the increase of depth of the liquid and also increase in density causes the rise of pressure. As pressure rises with the increase of depth, the liquid comes out with more speed from a hole at greater depth (shown in the figure 5.6).

Mathematical Example 5.3 : A vessel contains kerosene. Find the magnitude of pressure at a point 75cm deep from the surface of kerosene. [Density of kerosene is $800 kgm^{-3}$]

Solution

Given,

Depth of the liquid, h=75cm = 0.75m

Density of the liquid, ρ = 800 kgm^{-3}

Acceleration due to gravity, g= 9.8ms^{-2}

Pressure P =?

We know,

P= hρg

or, P = 0.75 m × 800 kgm^{-3} × 9.8 ms^{-2}

= 5880Pa

Ans: 5880Pa

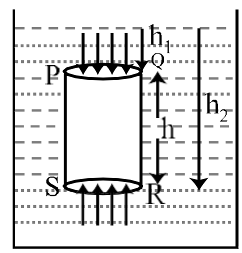
5.7 Pressure of a fluid and buoyancy

A fluid is a substance which flows or is capable of flowing. Fluids are of two types - liquids and gases.

Pressure of a fluid: The force exerted perpendicularly by a fluid at rest on unit area of a surface is called pressure. If the area of the surface is A and the force applied perpendicularly by the fluid is F, then pressure p = $^F/_A$.

Buoyancy: A water filled pitcher is easy to move in water but it is not that much easy to move keeping it out of water. The pitcher is felt considerably lighter in immersed condition as upward thrust acts on it.

Therefore, the thrust acting vertically upward is equal to the weight of equal volume of water displaced by the submersed body. For this reason an immersed body apparently losses its weight.



Figur: 5.7

Magnitude of buoyancy:

Every point of a body immersed in a fluid will experience thrust in all directions. Let a cylinder PQRS is of cross-sectional area A and height h. It is submersed in a fluid of density ρ. The depth of the upper and lower surface of the cylinder from the free surface of the fluid are h_1 and h_2 respectively.

So, $h = h_2 - h_1$

The downward force acting on the surface PQ of the cylinder, $F_1 = Ah_1\rho g$

The upward thrust exerted by the liquid on the surface SR of the cylinder, $F_2 = Ah_2\rho g$

The lateral pressures experienced by the curved surface of the cylinder being equal and opposite of each other it become neutralized.

$\therefore$ Upward thrust or buoyancy

$= F_2 - F_1$

$= Ah_2\rho g - Ah_1\rho g$

$= A(h_2 - h_1)\rho g$

$= Ah\rho g.$

$= (hA)\rho g$

$= V\rho g$ [V = hA = volume of the cylinder]

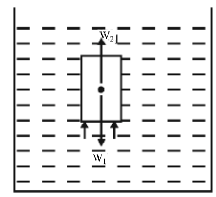
= weight of the displaced fluid by the cylinder.

So, the upward thrust or buoyancy acting on a submersed body is equal to the weight of the fluid displaced by it. For this upward thrust it seems that a submersed body losses weight.

5.8 Floatation and immersion of a body

Two forces act simultaneously on a body when it is released in a liquid at rest.

1. The weight of the body, W_1 acts vertically downwards.
2. The buoyancy W_2 acts vertically upward on an immersed body. There are three conditions of floatation and immersion of a body-



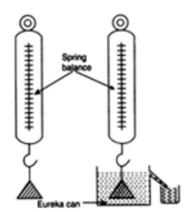
Figur: 5.8

a) If $W_1 > W_2$, i.e. when the weight of the body is greater than the buoyancy of the liquid the body sinks.
   In this case the weight of the body is more than the weight of the displaced liquid.

b) If $W_1 = W_2$ i.e. when the weight of the body equals to the buoyancy of the liquid the body floats being fully immersed in liquid. In such situation the weight of the body is equal to the weight of the liquid displaced.

c) If $W_1 < W_2$ i.e. the weight of the body is less than the buoyancy of the liquid, the body does not sink. It floats being partly immersed in liquid. In such a position the weight of the body is less than the displaced water.

5.9 : Archimedes Law:



Figur: 5.9

From the experience of our daily life we observe that any solid substance when immersed in liquid it appears lighter. Its cause is on an immersing body vertically upward force or buoyancy acts on it.

Before 300 B.C. the Greek philosopher Archimedes invented that if a body is partly or fully immersed in a liquid or gas in equilibrium, it seems to have lost a part of its weight. This apparent loss of weight is equal to the weight of the displaced liquid or gas.

Experiment: Take a body of known weight. Tie the body by a light thread and dip it into a container completely filled with water. Some water will spill out of the vessel. Take the weight of the body in completely submersed condition. Now find out the apparent loss of weight by subtracting the weight of the body immersed in water from the known weight of the body in air. Now determine the weight of the spilled out water. It will be observed that the apparent loss of weight of the body is equal to the weight of the displaced liquid. Thus we may have a proof of Archimedes' principle in a simple way.

Calculate: The surface area of the bottom of a rectangular block is $25cm^2$. It is dipped in water. Density of water is $1000kgm^{-3}$. The depth of the upper surface of the block from the open surface of the water is 5cm. If the height of the block is 2cm, then

1. Find the water pressure P_1 on the upper surface of the block
2. Calculate the pressure P_2 at the bottom of the block
3. How much force will be applied by water on the upper surface of the block?
4. How much force will be applied by water at the bottom of the block?

Make comments on the results.

Causes of accidents in waterway in Bangladesh

Accidents occur frequently in the waterways in our country. When a ship is made, its size and shape both are made in such a way that at the floating state the weight of the water displaced by the immersed part of the body is equal to the weight of the ship.

Now as more passengers get onboard, the more of its weight increases and it keeps immersing into water. When more passengers than its capacity get on the ship, it sinks. According to weather signals a ship will have to sail carefully taking less number of passengers than its capacity as current and waves are there in the river. Due to defective design of the ship its centre of mass changes and becomes the cause of accident. One should not get onboard being an excess passenger.

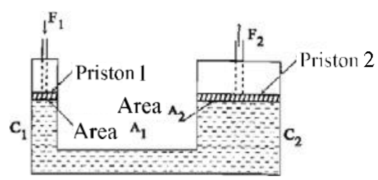
5.10 : Pascal's Law

If pressure is applied on any point of an enclosed liquid or gas it is transmitted in all directions. Pascal stated a law about this transmission of pressure.

Pascal's law: External pressure applied to any portion of a liquid or a gas enclosed in a container is equally transmitted in all directions in the liquid or the gas without any trace of diminution and acts perpendicularly on the surface of the container in contact with the liquid or gas.

Mathematical explanation of Pascal's law: principle of multiplications of force

On any portion of a confined liquid if force is applied by a smaller piston, then forces of greater magnitudes are exerted on the pistons of greater cross sectional area. This is known as principle of multiplication of force.



Figur: 5.10

Let, C_1 and C_2 be two cylinders (Fig:5.10) and A_1 and A_2 be their cross sectional areas respectively. The two cylinders are connected by a pipe. There is an air tight piston in each cylinder. The two cylinders are filled up with a liquid. Now a force F applied to the smaller piston generates a pressure F_1/A_1. According to Pascal's law this pressure is transmitted in all directions through the liquid. Therefore the upward pressure exerted on the larger piston is F_1/A_1. Because of this pressure, the larger piston experiences an upward force equal to $(F_1/A_1) \times A_2$. If the upward force of larger piston is F_2,

then $F_2 = \dfrac{F_1}{A_1} \times A_2$

$$\therefore \quad \frac{F_2}{F_1} = \frac{A_2}{A_1} \qquad (5.4)$$

So, greater is the cross sectional area of the larger piston, the greater is the force exerted on it. If the cross sectional area of the larger one is 100 times greater than that of the smaller one, then a force of 1N applied to the smaller one will produce an upward force of 100N on the larger piston.

5.11 Elasticity: Stress and Strain

From our general knowledge we know a rubber tape elongates along its length when it is pulled. As soon as the tape is released of the tension it regains its original length or tends to get back its previous length. Here pull means application of force and elongation in length means deformation. Actually as deformation of a body occurs, a resistive force generates within the body for which it tends to get back its original size and shape.

Elasticity is defined as the attributed property by which a body is able to resist deformation, either in shape or in volume or both and recovers its original shape and size when the deforming force is removed. The substances which possess this property are called elastic substances. There is a certain limit of the deforming force and if the force applied exceeds the limit the body then unable to regain its previous shape and size. This limit of applied force is termed as elastic limit.

The molecules of a substance move away form each other when external force is applied on elastic bodies. Original length, volume or size and shape of a body are changed due to this applied deforming force. The change per unit length or per unit volume of an object is called strain. Whenever an external force deforms a body, an internal resistive force will develop inside the body due to its elastic property. This opposing force comes into play to resist the applied external force. This developed internal restoring force acting perpendicularly per unit area of the body is called strain.

Hooke's law: Scientist Robert Hooke invented the basic law of elasticity. According to this law- within elastic limit stress is directly proportional to strain.

Mathematically we may write,

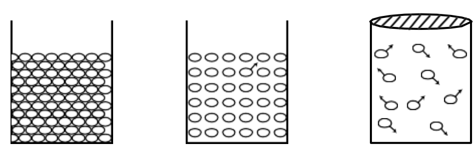
stress $\propto$ strain

$\therefore$ stress = constant $\times$ strain.

This constant is called the modulus of elasticity of the material of the body. Strain has no unit. The unit of stress is Nm^{-2}. The unit of modulus of elasticity is also Nm^{-2}.

5.12. Molecular kinetic theory of matter

The basic conception of the molecular kinetic theory of matter is to consider that the molecules of a matter are in motion. The kinetic theory of matter is based on the following postulates:



Figur: 5.11

1. Any substance consists of innumerable number of minute particles. These particles are called molecules.
2. The molecules are so small that they are considered as points.
3. The molecules of a substance are always in motion.
4. The gaseous molecules remain at a considerable distance. For this reason almost no force of attraction and repulsion act between them. Though the liquid molecules remain at some distance, force of attraction between them prevails. This cause

compels the liquid to take the shape of the container in which it is kept. In solid substances the particles remain very close to each other and very strong attractive force exists in them which give the solid substance a definite size and volume.

5. The molecules move at random in liquid and gas. So, these molecules collide among themselves and also on the surface of the walls of the container.

5.13. Plasma state of matter

The forth state of matter is called plasma state. This plasma is the ionized gas at very high temperature. The main source of plasma is the Sun. Except this the other stars are also the sources of plasma. The plasma state is formed at a few thousand degrees of temperature. Plasma has no definite shape and volume like gases. The plasma particles carry charges and act as conductor of electricity. Metals substances are cut by plasma torch in the industry.

Investigation: 5.1

To determine the density of a solid

Objective: To find the density of a solid body of any shape.

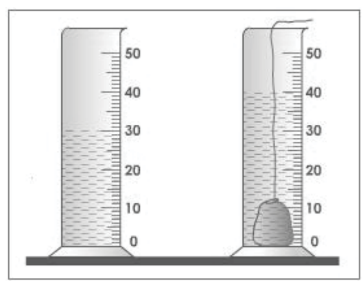
Apparatus: Measuring cylinder, balance, a solid substance of any shape.

Theory: The space occupied by a solid substance is called its volume and the mass per unit volume of a body is called density. When a solid is dipped into liquid it displaces liquid equal to its own volume. The readings of the water level before and after the immersion of the solid in the measuring cylinder are $V_1 cm^3$ and $V_2 cm^3$.

$\therefore$ The volume of the solid, $V = (V_2 - V_1)\ cm^3 \ldots \ldots \ldots (1)$

Let M gm be the mass of the body, therefore density,

$$d = \frac{M\ gm}{V\ cm^3} = \frac{M}{V} \times 10^3\ Kg\ m^{-3} \ldots \ldots \ldots (2)$$



Figur: 5.12

Working procedure:

1. Measure the mass of the solid substance by a balance.
2. Fill up the half portion of the measuring cylinder with water and take the reading of the upper level of the water.
3. Tie the solid by a string and dip it into the water of the cylinder so that it stays at the bottom of it. When the water comes to a standstill position take the reading of the upper level of the water.
4. Repeat working process 2 and 3 taking different amount of water in the measuring cylinder and write down the readings in the table.
5. Find the volume of the solid substance with the help of necessary calculations. Using equation no.2 determine the density of the solid substance.

Chapter six

EFFECT OF HEAT ON SUBSTANCES




[Heat is a form of energy related to the motion of molecules of substances. Temperature is an indicator to indicate the direction at which heat energy will flow. By the application or elimination of heat, shape of solid, volume of liquid and volume and pressure of gasses are changed. Application or removal of heat transforms a substance from one state to another. Such effects of heat on substances will be discussed in this chapter.]

By the end of this chapter, we will be able to -

1. Explain heat and temperature.
2. Explain the thermal properties of matter.
3. Analyze the relationship among Fahrenheit, Celsius and Kelvin scale.
4. Explain the increase in temperature with the increase of internal energy of the substances.
5. Explain the thermal expansion of substances.
6. Explain the expansion in length, area and volume of a solid.
7. Explain the real and apparent expansion of liquid.
8. Explain the effect of heat in changing the state of matter.
9. Explain melting, vaporization and condensation.
10. Explain melting and boiling point.
11. Explain the effect of pressure on melting point.
12. Explain boiling and evaporation.
13. Explain the latent heat of fusion and vaporization.
14. Explain the cooling effect of evaporation.
15. Explain the influence of factors on vaporization.
16. Explain specific heat and heat capacity.
17. Explain the principle of measurement of heat.

6.1 Heat and Temperature

Heat:

Heat is a kind of energy which creates the sensation of hotness and coldness. Heat flows from hotter to colder bodies. Therefore the energy that transfers from one body to another due to the difference of temperature is called heat.

The molecules of a substance always remain in the state of vibratory motion. So they possess kinetic energy. The total amount of energy of a substance is directly proportional to the sum of the kinetic energy of the molecules constituting the substance. When heat is applied to a body the motion of the molecules increases and as a result the kinetic energy of the molecules increases.

Unit of Heat: In SI system the unit of heat is joule (J). Earlier the unit of heat used to be calorie (Cal). The relation between joule and calorie is 1Cal = 4.2 J.

Task: Label three containers A, B, C kept on the table. Take water at room temperature in container A and take reasonably hot water (that your hand can tolerate) in container C. Mix some amount of hot water and water at room temperature in the container B. Now dip your right hand in the container A and left hand in the container C. After one minute bring out both hands and immerse both hands at the same time in the container B. What are the feelings of your two hands?

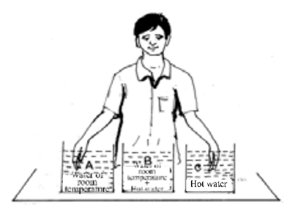


Fig: 6.1

Water at a certain temperature is in the container B; yet hotness will be felt by the right hand and coldness by the left hand. Because the water in which the right hand was immersed previously was at a lower temperature than the water contained in B. Similarly coldness will be felt by the left hand because the water in which the left hand was immersed previously was at a higher temperature than the water contained in B.

Temperature

Temperature is such a thermal condition of a body which determines whether the body will receive or give up heat when it comes in thermal contact with another body.

Temperature may be compared with the free surface of a liquid. We know that liquid flows from a higher level to a lower level. In the figure the height of liquid in vessel A is more than that of the liquid in vessel B. But the amount of liquid in vessel A is less than the amount of liquid in vessel B. When stop cork S is opened the liquid from vessel A will start flowing to vessel B until the height of the liquid on both sides become equal. In the same way after the thermal contact, heat continues to flow from hotter body to colder one until the temperatures of the both bodies come to equilibrium position. The body with more temperature will lose heat whereas the body having less temperature will gain heat. The name of the apparatus used to measure the temperature is called thermometer.

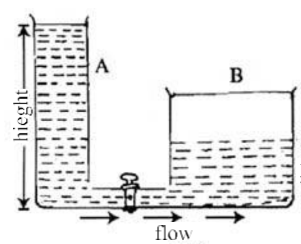


Fig: 6.2

Unit of temperature: In SI system the unit of temperature is Kelvin (K).

Kelvin: The particular temperature and pressure at which water remains at its three states- solid, liquid and gas, is called the triple point of water. The temperature of the triple point of water is considered as

273 K. $\frac{1}{273.16}$ th part of the temperature of the triple point of water is called 1K.

6.2 Thermometric properties of matter:

Special properties of matter are used to measure the temperature. Some physical properties of substances change uniformly with the change of temperature. Using that physical property of substance temperature can be measured easily and accurately and it is called the thermometric property of that substance. Thermometric substances are used in thermometers.

Thermometric properties of substances are – volume, resistance and pressure etc. In mercury thermometer the mercury in the capillary glass tube is called thermometric substance and the length of the mercury column is called thermometric property. Similarly in the case of gas thermometer the gas kept in the container at a constant volume is termed as thermometric substance and the pressure of the gas is called thermometric property.

6.3 Relation among Celsius, Fahrenheit and Kelvin scale:

A scale of temperature is essential to indicate the temperature of a body accurately. Two definite temperatures are taken as constant to prepare a temperature scale. These two temperatures are called fixed points. The two fixed points are lower fixed point and the upper fixed point. At standard pressure and at the temperature at which pure ice melts to water or pure water freezes to ice is called the lower fixed point. It is also termed as freezing point or ice point. Again at standard pressure and at the temperature at which pure boiling water converts into water vapor is called upper fixed point. The upper fixed point is also called boiling point or steam point. The temperature difference between the two fixed points is called the fundamental interval of a thermometer. The fundamental interval i.e. ` the space

\in between the two fixed points is divided in different ways to prepare different scales of temperature. There are three scales of temperature in use – Celsius, Fahrenheit and Kelvin scale. The units of temperature of these three scales are °C, °F and K respectively. The lower fixed point in Celsius scale is 0°C, in Fahrenheit scale 32°F and in Kelvin scale it is 273K. The upper fixed point in Celsius scale is 100°C, in Fahrenheit scale 212°F and in Kelvin scale it is 373K.

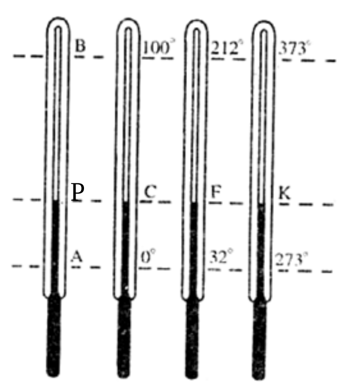


Fig: 6.3

Establishing a relation among different scales of temperature:

Let A and B be the lower fixed point and upper fixed point of a thermometer respectively (figure 6.3). Three more thermometers graduated in Celsius, Fahrenheit and Kelvin scale are kept side by side. The readings of the point P of the thermometer AB in other three scales are C, F and K respectively. Therefore the readings of distance PA in these three scales are C-0, F-32 and K-273 respectively. Since $\frac{PA}{BA}$ is a constant it can be written,

$$\frac{PA}{BA} = \frac{C-0}{100-0} = \frac{F-32}{212-32} = \frac{K-273}{373-273}$$

or, $\frac{C}{100} = \frac{F-32}{180} = \frac{K-273}{100}$

$$\text{or, } \frac{C}{5} = \frac{F-32}{9} = \frac{K-273}{5} \qquad (6.1)$$

Equation (6.1) indicates the relation among Celsius, Fahrenheit and Kelvin scale.

The convenient relation between Celsius and Kelvin scale is – by adding 273 to Celsius scale reading the Kelvin scale reading can be obtained. For example, 1°C temperature = (1+273) K = 274 K temperature. But if the temperature difference is 1K, then it is equal to 1°C.

Mathematical example 6.1: The temperature of body of a healthy man is 98.4°F. What would be the reading in Celsius scale?

Given,
Temperature in Fahrenheit scale, F = 98.4°F
Temperature in Celsius scale, C = ?

We know,

$\frac{C}{5} = \frac{F-32}{9}$

or, $\frac{C}{5} = \frac{98.4-32}{9}$

or, C = 36.89 °C

Ans: 36.89 °C

6.4 Raise of temperature and internal energy of body:

On the basis of molecular kinetic theory of substances we know that the molecules of a substance always remain in motion. The molecules of a solid vibrate about a fixed point. The molecules of liquids and gases move at random in different directions. Kinetic energy develops due to this motion of the molecules. Again attraction and repulsion forces are present among the molecules of a solid and this is the cause for the generation of potential energy. Among the gaseous molecules attraction-repulsion force does not exist and so there is no potential energy. The sum of the kinetic and potential energy of the molecules of a substance is called its internal energy. Evidently a part of the internal energy originates from kinetic energy and the other part from potential energy. If thermal energy is applied to a body then its internal energy will increase. But only the kinetic energy of the internal energy causes the raise of temperature of the body.

6.5 Thermal Expansion of substance:

Almost all the substances expand due to application of heat and contract for the extraction of heat. When a body is heated the heat energy and as such the kinetic energy of each molecule of the body increases. In solids the molecules vibrate with enhance energy against the intermolecular force and as a result the displacements of the molecules from their equilibrium position increase. But during displacement of a molecule from its equilibrium position a force of attraction is exerted on it. When the molecule tends to go near to its neighboring molecules then a repulsive force acts on it. Again with the increase of intermolecular distance a force of attraction acts on the molecule. For the increase in temperature the molecules of a solid vibrate but it is not a simple harmonic oscillation. Because, if the distance between two molecules is lessened than the distance in their equilibrium position then the repulsive force increases rapidly. But as the distance between two molecules relative to their equilibrium position increases, then the attractive force increases. But it does not happen as quickly as in the case of repulsive force. As a result due to increase of temperature when the molecules of a body vibrate at a random fashion they approach further towards the exterior than towards the interior. As such the average equilibrium position of each molecule gets displaced towards the exterior and the body expands. Since intermolecular force is less in liquids, expansion due to heat is more in it. For gaseous substances with the increase of temperature the random motion of the molecules increases. The thermal expansion of gases is maximum. The expansion of liquid is lower than that of gas and expansion of solid is the least.

6.6 Expansion of solids:

With the application of heat the length, area and volume of solid substance expands.

Linear expansion of solid and coefficient of linear expansion:

When heat is applied to a solid substance elongation of its length occurs towards a definite direction and the expansion along its length is called linear expansion.

Let the length of a bar at θ_1 temperature be l_1 and at θ_2 temperature the length be l_2.

Increase in length = $l_2 - l_1$

And increase of temperature = $\theta_2 - \theta_1$

The coefficient of linear expansion is denoted by α and it can be expressed as,

$$\alpha = \frac{l_2 - l_1}{l_1(\theta_2 - \theta_1)} \quad \dots \dots \dots (6.2)$$

$$= \frac{\text{Increase in length}}{\text{Initial length x increase of temperature}}$$

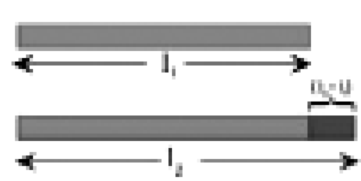


Fig: 6.4

In equation 6.2, if the initial length l_1 = 1m and increase of temperature, $\theta_2 - \theta_1$ = 1K, then

$\alpha = l_2 - l_1$ = increase in length.

So, the increase in length of a solid rod of 1m for a rise of temperature 1K is defined as the coefficient of linear expansion of the material of the solid.

Its unit is K^{-1}. The coefficient of linear expansion of copper is 16.7×10^{-6} K^{-1} means if the temperature of copper rod is raised through 1K, then its length increases by 16.7×10^{-6} m.

Mathematical example 6.2: The length of a steel rod is 100m at 20°C. If its length becomes 100.033m at 50°C, then determine the coefficient of linear expansion of steel.

We know,

Coefficient of linear expansion, $\alpha = \frac{l_2 - l_1}{l_1(\theta_2 - \theta_1)}$

$= \frac{0.033\text{m}}{100\text{m} \times 30\text{K}}$

$= 11 \times 10^{-6}$ K^{-1}

Initial length, $l_1 = 100$m
Final length, $l_2 = 100.033$m
Initial temperature, $\theta_1 = 20$°C
Final temperature, $\theta_2 = 50$°C
Increase of temperature $(\theta_2 - \theta_1) = 30$K
Increase in length, $(l_2 - l_1) = 0.033$m
Coefficient of linear expansion, $\alpha = ?$

Observation: Why a gap is kept at the joining point of two rails of a rail line?

The rails expand due to heat of the sun or due to heat produced by friction between the wheels and rails while the train runs. For this expansion sufficient space is kept between the two rails. If gaps between the rails are not kept, the rail line will bend due to its expansion.

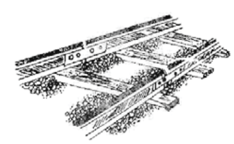


Fig: 6.5

Superficial expansion and coefficient of superficial expansion:

The area of a solid is increased with the increase of temperature. It is called superficial expansion.

Let initial surface area of a solid at θ_1 temperature = A_1

When the temperature is increased to θ_2 the final surface area = A_2

$\therefore$ Increase in temperature = $\theta_2 - \theta_1$

And increase in area = $A_2 - A_1$

The coefficient of superficial expansion is expressed by the symbol β

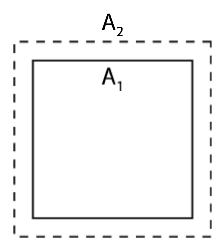


Fig: 6.6

$$\therefore \text{ Superficial expansion, } \beta = \frac{A_2 - A_1}{A_1(\theta_2 - \theta_1)} \qquad \ldots\ \ldots\ \ldots\ (6.3)$$

$$= \frac{\text{Increase in surface area}}{\text{Initial area x increase of temperature}}$$

In equation 6.3 if the surface area $A_1 = 1\text{m}^2$ and the increase of temperature $(\theta_2 - \theta_1) =$ 1K is considered, then the increase in surface area $\beta = A_2 - A_1$=increase in surface area.

So, the increase in surface area of 1m^2 surface area of a solid for the rise of temperature 1K is called the coefficient of superficial expansion of the material of that solid. Its unit is K^{-1}. The coefficient of superficial expansion of copper is 33.4×10^{-6} K^{-1}. It means that if the temperature of a copper body is increased through 1K, then the increase in surface area of copper is 33.4×10^{-6} m^2.

Volume Expansion and Coefficient of Volume Expansion:

The volume of a solid substance increases if its temperature is increased. It is called volume expansion.

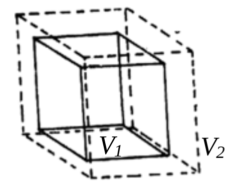


Fig: 6.7

Let, the initial volume of a substance be V_1 and initial temperature be θ_1. When the temperature is raised to θ_2, its volume becomes V_2 after being increased. There increase in volume is $V_2 - V_1$ and increase of temperature = θ_2 - θ_1.

Now if the coefficient of volume expansion is represented by γ, then

$$\gamma = \frac{V_2 - V_1}{V_1(\theta_2 - \theta_1)} \quad \dots \dots \dots (6.4)$$

$$= \frac{\text{Increase in volume}}{\text{Initial volume x increase of temperature}}$$

In equation 6.4 if the initial volume V_1 = 1m^3 and increase of temperature, θ_2 - θ_1 = 1K, then

$\gamma = V_2 - V_1$ = increase in volume.

Therefore, the increase in volume of a solid of volume 1m^3 for a rise of temperature 1K is called the coefficient of volume expansion of the material of the solid.

The coefficient of volume expansion of copper is 50.1×10^{-6} m^3 means that if the temperature of a copper body with a volume of 1m^3 increases through 1K then its volume will increase by 50.1×10^{-6} m^3.

The relations among α, β and γ are as follow:

$\gamma = 3\alpha$ and $\beta = 2\alpha$

6.7 Expansion of liquids:

Liquids have no definite length or area. But it has definite volume. If the temperature is increased its volume increases. So, the expansion of liquid means the expansion in volume of the liquid. The rates of increase in volume of all the liquids are not the same. Different liquids having the same volume expand differently for the same rise of temperature.

Experiment:

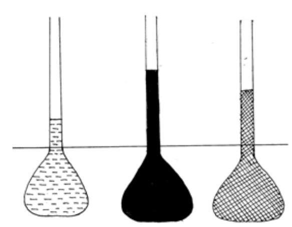


Fig: 6.8

A number of long necked glass bulbs of equal volume and size are taken. Equal volume of water, alcohol, kerosene, ether etc are taken in these bulbs (fig 6.8). Now water at room temperature is taken in a comparatively larger vessel and the bulbs are placed vertically in it. The upper level of the liquids in all the bulbs will be the same. Now some hot water is poured into the vessel. After some time the bulbs will attain a higher temperature and it will be seen in the stem of the bulbs the upper level of different liquids are not at the same height rather their heights are different. So, it is understood that the volumes of different liquids of same volume expand differently for a definite increase of temperature.

6.8 Real and apparent expansion of liquids

Liquid always has to be heated keeping it in a container. The liquid as well as the container expand when heat is applied. So, the expansion of the liquid observed by us is not the real expansion but it is an apparent expansion.

There are two types of expansions of liquids-

a. Real expansion
b. Apparent expansion

Real expansion:

If it had been possible to heat a liquid without keeping it in a vessel then the real expansion of the liquid that would be obtained is called real expansion of the liquid. But heating a liquid without a container is not possible. So, considering the expansion of the container the actual expansion of the liquid that is obtained is called the real expansion. It is expressed by V_r.

Apparent expansion:

The expansion of liquid apparently observed without considering the expansion of the container is called the apparent expansion of liquid. It is denoted by V_a.

Relation between real expansion and apparent expansion:

A glass bulb with a long graduated stem is filled with liquid up to the mark A. Now keeping an eye on the liquid column the bulb is heated and it is observed that the upper level of the liquid comes down from position A to position B. After that it moves up from the graduated line B crossing the mark A and reaches to mark C. The reason is that when heat is applied the volume of the bulb increases at first. Due to this cause liquid comes down to B from A. Later on as soon as the liquid gets heated its volume starts to increase and reaches from B to C. It happens so as the expansion of liquid is more than the expansion of solid. Apparently it appears to us that the liquid was at mark A and finally reaches to mark C. Therefore, CA is the apparent expansion. CB is the real expansion and AB indicates the expansion of the container.

From figure it is observed that,

CB = CA+AB

or, Real expansion = Apparent expansion + expansion of the container

$\therefore V_r = V_a + V_g$ … … … (6.5)

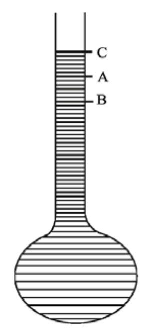


Fig: 6.8

6.9 Effect of heat on change of state:

Matter can exist in three states e.g. solid, liquid and gas. All of us know that water has three states-ice, water and vapor. These three states are called solid, liquid and gas. These states of water depend on air pressure and temperature.

A solid may be liquefied by applying heat. This process is called fusion. At the beginning the temperature of a body rises with the application of heat and at one stage the temperature does not change even if more heat is applied. At this moment the amount of heat absorbed by a body is used to convert the solid into liquid only. If heat is applied to ice below 0°C, temperature will rise and reach at 0°C. After this if more heat is applied the temperature will not rise but the ice will begin to melt to water. The amount of heat absorbed during the conversion of a solid to liquid is used to break the intermolecular bond of the molecules.

On further heating the temperature of water of 0°C starts to rise. At a stage, water starts vaporizing and the temperature remains unchanged. During this time water absorbs heat to become vapor. Here also the effect of heat is used to break the intermolecular bond among the liquid molecules. On the other way around, gaseous substance may be converted to liquid and liquid to solid by extracting heat from them. So, on the transformation of substances effect of heat is remarkable.

6.10 Fusion, Vaporization and Condensation:

Fusion

To transform a substance from solid to liquid by applying heat is called fusion. The definite temperature at which a solid starts to melt is called its melting point. This temperature remains unchanged until all of the substance melts.

Vaporization

The phenomenon of transformation of a liquid from its liquid state to gaseous state is called vaporization. This vaporization may occur in two processes-

i) Evaporation
ii) Boiling

Evaporation

The process in which a liquid at any temperature slowly changes from its free surface into vapor state is called evaporation.

Activities: Take some water in a bowl and keep it at a corner of your room. Observe what happens to the water after one or two days. It will be observed that the water has been reduced. What is the cause for the reduction of this water?

The water has been converted into vapor even at the room temperature and for this the amount of water has been lessened. This is called evaporation.

Boiling

The process in which a liquid is rapidly converted into vapor by increasing its temperature through application of heat is called boiling.

The temperature at which boiling of liquid begins is called the boiling point of that liquid. The value of boiling point depends on pressure.

Experiment: Pouring some water in a container and supplying heat the gradual increase of temperature would be observed. At a certain temperature the water will begin to boil and get converted into water vapor. It is called boiling. So, it is understood that liquid may be converted into its gaseous state at any temperature or at its boiling point.

Condensation:

The process of converting a gaseous substance from its gaseous state to liquid state by lowering the temperature is called condensation.

6.11 Effect of pressure on boiling point

Do it yourself: Press two pieces of ice together for some time keeping them in contact with each other and then release. What do you observe? The pieces of ice have joined together. Why?

As the pressure acts on the surface of contact of the two pieces of ice, the melting point goes down i.e. the melting point becomes less than 0°C. But the temperature of the surface of contact remains at 0°C. So, ice at the surface of contact melts. The required amount of heat needed for melting is collected from the ice. After the removal of pressure the melting point again becomes 0°C. As a result the water obtained from the fusion of ice at the surface of contact again freezes to ice. For this reason if pressure is applied then two pieces of ice unite together to form a single piece.

To melt a solid substance into liquid by applying pressure and again to bring it back to the solid state by reducing the pressure is called regelation.

The melting point of a substance changes due to the variation of pressure on the substance. The changes of melting point may occur in two different ways for pressure.

- The solid substances whose volumes contract on melting, their melting points reduce with the increase of pressure i.e. they melt at a lower temperature.
- The solid substances whose volumes expand on melting, their melting points increase with the increase of pressure i.e. they melt at a higher temperature.

6.12 Latent heat of fusion and latent heat of vaporization

Latent heat of fusion: We know, when the temperature of a solid reaches the melting point due to application of heat then the temperature remain unchanged until all the substances transform into liquid. Here the amount of heat required to transform the solid into liquid is nothing but latent heat of fusion.

This heat energy does not change the temperature but is used to loosen the intermolecular bond of the molecules of the substances.

Latent heat of vaporization: If heat is applied to a liquid and its temperature reaches at the boiling point then whatever amount of heat is applied the temperature will remain unchanged until all the liquid is converted into vapor state. Here the amount of heat required to convert the liquid into vapor state is called latent heat of vaporization.

Evaporation produces cooling:

In summer days the water kept in a new earthen pitcher becomes cold. Uncountable numbers of pores are there on the body of an earthen pitcher. Through these pores water seeps out and evaporates. The needed amount of latent heat is provided by the water of the pitcher and as such the water becomes cold.

Water kept in the glass or brass vessel does not become cold. Because the body of this kind of container has no pore and there is no possibility of evaporation.
Now explain why do you feel cold when air blows over your sweating body?

6.13 Dependence of Evaporation on Various Factors:

Evaporation depends on the following factors:

Flow of air: The speed of evaporation increases if the air flows faster over the liquid.

The area of the exposed surface of the liquid: Evaporation increases as the area of the exposed surface of the liquid increases.

Nature of liquid: The rates of evaporation of different liquids are different. Less the boiling point of a liquid, more would be the rate of evaporation. The rate of evaporation of volatile substances is maximum.

Pressure on the liquid: The rate of evaporation decreases with the increase of atmospheric pressure on the liquid. The rate of evaporation increases with the decrease of pressure. The rate of evaporation in vacuum is maximum.

Liquid and the temperature of the air in contact with the liquid: If the temperature of the air in contact with the liquid increases then the rate of evaporation will increase.

Effect of dryness: The more the dryness of the air over the liquid surface i.e. the less the amount of water vapor in the air more will be the rate of evaporation. The soaked cloths dry up quickly in winter because air remains dry at that time.

6.14 Thermal Capacity:

The amount of heat required to raise the temperature of a body through 1K is called the heat capacity of that body. The heat capacity depends on the material and the mass of the body. Its unit is JK^{-1}. The heat capacity of a body is $10JK^{-1}$ means 10J heat is required to raise the temperature of the body through 1K.

Let, Q amount heat is required to increase the temperature of a body through $\Delta\theta$. Therefore the amount of heat required to raise the temperature of the body through 1K is $\frac{Q}{\Delta\theta}$.

$\therefore$ Heat capacity, $C = \frac{Q}{\Delta\theta}$ … … … (6.6)

6.15 Specific Heat

The amount of heat required to raise the temperature of a body of mass 1Kg through 1K is called the specific heat of the material of that body. It is denoted by the letter S.

Mathematically we can express,

Specific heat, $S = \frac{C}{m} = \frac{1}{m} \times \frac{Q}{\Delta\theta} = \frac{Q}{m\Delta\theta}$ … … (6.7)

Unit: The unit of specific heat is $Jkg^{-1}K^{-1}$.

The specific heat of lead is $130Jkg^{-1}K^{-1}$ means 130J heat is required to raise the temperature of 1kg of lead through 1K.

Here,
C = Heat Capacity
Q = Absorbed Heat
$\Delta\theta$ = Increase of temperature
m = Mass of the body

Specific heat of some matters

Matter	**Specific Heat ($Jkg^{-1}K^{-1}$)**
Water	4200

Matter	Specific Heat ($Jkg^{-1}K^{-1}$)
Ice	2100
Water Vapor	2000
Lead	130
Copper	400
Silver	230

6.16 Relation between specific heat and thermal capacity

We know, the amount of heat required to increase the temperature of a body through 1K is called its heat capacity. Again if the specific heat of the material of a body is S, then S joule heat is required to raise the temperature of the body through 1K.

Therefore,

to increase the temperature through 1K of a body with a mass of 1kg the amount of heat required = S joule

$\therefore$ to increase the temperature through 1K of a body with a mass of m kg the amount of heat required = mS joule

It is the heat capacity of the body with a mass of m kg.

$\therefore$ Heat capacity, C = mS joule … … … (6.8)

or, Heat capacity = mass × specific heat

$$\therefore \text{ Specific heat} = \frac{\text{Heat Capacity}}{\text{mass}}$$

It is the relation between heat capacity and specific heat.

6.17 Fundamental principle of Calorimetry

When two bodies of different temperatures are brought in thermal contact then reception and donation of heat take place. The body at higher temperature leaves heat whereas the body at lower temperature receives heat. This give and take will continue until they reach at the thermal equilibrium.

If no heat is lost during donation and reception of heat, then the amount of heat given up by the body at higher temperature will be equal to the heat gained by the body at lower temperature.

So, Heat lost = Heat gained … … … (6.9)

It is called the principle of Calorimetry.

Investigation no 6.1

Determination of melting point of ice

Aim: To observe the melting of ice and to find the relation between temperature and melting point and to draw a graph.

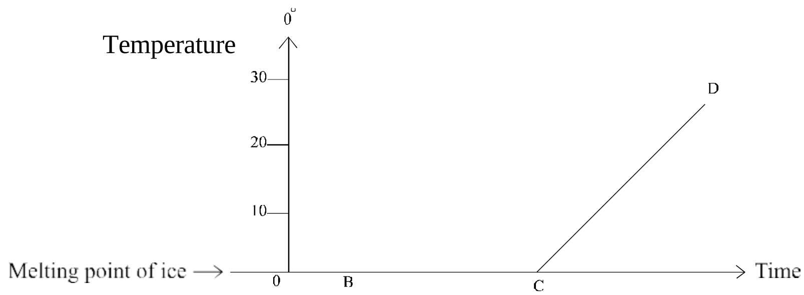
Apparatus: Celsius thermometer, ice, stand, burner, beaker, stopwatch.

Working procedure:

1. After grinding some ice put them in a beaker.

2. Carefully dip the thermometer in ice in such a way that the bulb remains in the ice but it does not come in contact with the wall of the beaker.
3. The temperature is to be recorded slowly after applying heat.
4. Take the reading of the temperature every after each minute until all the ice melts.
5. Following the above procedure continue to apply heat even after all the ice melts and the temperature becomes 20°C-25°C. Record the temperature every after each minute.
6. Draw a temperature vs. time graph using the obtained data.
7. Find the melting point of ice from the graph.
8. Analyze the nature of the graph.

Drawing of temperature vs. time graph.



Investigation no. 6.2

Name of the Experiment: Determination of boiling point of water.

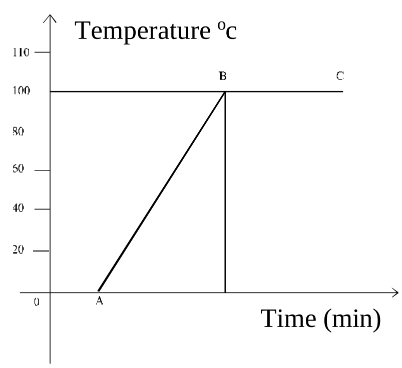
Objective: To observe the boiling point of water and to find the relation between temperature and boiling point and to draw a graph.

Apparatus: Thermometer, burner, beaker and stopwatch.

Working Procedure:

1. Take some water in a beaker at room temperature. Place the thermometer in the water of the beaker in such a way that the bulb may not touch the wall of the beaker.
2. Heat the water with a burner and take the reading every after each minute to record the rise of temperature.
3. Notice that after reaching the temperature of 100°C, the temperature of water does not increase even after the application of more heat.
4. Draw a temperature vs. time graph on the basis of obtained data.
5. Determine the boiling point of water from the graph.
6. Analyze the nature of the graph.

Drawing of temperature vs. time graph.



Chapter seven

WAVES AND SOUND

[If we throw a stone into pond water, we see the wave. Wave carries energy from one place to another. Sound is a kind of wave. The sound energy can create the sensation of hearing. We can send information using sound. So the sound is closely related to our life. But sound pollution causes much harm to us. We shall discuss wave, sound, echo of sound, velocity of sound, sound pollution etc. in this chapter.]

By the end of this chapter, we will be able to-

1. Explain the characteristics of waves.
2. Set and measure the simple mathematical relation among the quantities related to wave.
3. Explain the characteristics of sound waves.
4. Explain the creation of echo.
5. Explain the uses of echo in our daily life.
6. Set up the mathematical relation among the velocity of sound, frequency and wave length and measure the quantities from it.
7. Explain the change of the velocity of sound.
8. Explain the range of hearing and its uses.
9. Explain the pitch and intensity of sound.
10. Explain the reasons and consequences of sound pollution and the techniques to prevent it.

7.1 Periodic Motion Oscillatory or Harmonic Motion

Periodic motion:

If the motion of a moving particle is such that it passes through a definite point along the path of its motion in the same direction in a definite interval of time, this type of motion is called periodic motion. The hands of the watch and the electric fans are the examples of circular periodic motion. The contraction and expansion of spring is the linear periodic motion. The time required for a complete oscillation of an object executing periodic motion is called its time period.


Figure: 7.1

Oscillatory or harmonic motion:

If a body executing periodic motion moves in a definite direction for one half of its time period and exactly for the other half in the opposite direction then this motion is called oscillatory or harmonic motion. If any spring is hung from a strong support and an object is attached at the lower end and released after stretching, the spring will vibrate up and down. This type of motion is known as oscillatory or harmonic or vibratory motion. Motion of a simple pendulum and motion of a vibrating tuning fork is harmonic motion.

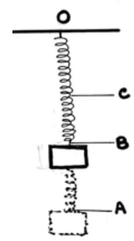


Figure: 7.2

7.2 Waves

A stone is thrown on the still water of the pond. When the stone hits the water then the particles of water of that region start to vibrate. These vibrating particles vibrate the neighboring of particles. Thus the vibration reaches to the edge of the pond by vibrating the particles of water. The particles of water oscillate up and down but do not move forward. The periodic vibration that passes over the surface of water due to the oscillatory motion of the particles is called wave. The mechanical energy produced due to the vibration of water particles is transferred from one place to another through vibration. So, energy is transferred from one place to another through wave.

The periodic motion of particles which transfers energy from one place to another through a material medium but does not displace the particles permanently is called wave.


Figure: 7.3

The wave produced in solid, liquid or gaseous medium is called mechanical wave. Water wave, sound wave etc. are mechanical waves. To transfer the mechanical wave elastic medium is needed. There is another type of wave that does not need any medium to propagate which are called electromagnetic wave.

It is mentionable that we will limit discussion only to the mechanical wave in this chapter. Here the wave means the wave produced in elastic medium.

The characteristics of waves are the followings:

1. The wave is produced due to the harmonic motion of the particles but the particles are not displaced permanently.

2. A medium is necessary for the propagation of mechanical wave.
3. The wave transfers energy from one place to another.
4. The velocity of wave depends on the nature of medium.
5. The reflection, refraction and superposition occur in case of wave.

Classification of wave:

There are two kinds of wave:

1. Transverse wave 2. Longitudinal wave

> **Task:** Take a long rope as in the figure. Attach one end of the rope with a strong support. Move your hand right and left or up and down by holding the other end.

A wave will be created in the rope as in the figure 7.4. Observe that the movement or the vibration of the hand is from left to right or from top to bottom but the motion of wave is horizontal. Here the direction of vibration of the particles is perpendicular to the direction of propagation of wave. This very wave is transverse wave. So we can say that the wave which moves perpendicularly to the direction of vibration of the particles is called transverse wave. Water wave is an example of transverse wave.

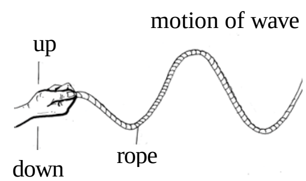


Figure: 7.4

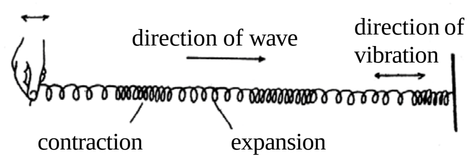


Figure: 7.5

A spring is set as in the figure 7.5. Now let's move our hand forward and backward by holding the free end of the spring. When we move the hand forward a flow of contraction will be created in the spring. Again if we move the hand backward, a flow of rarefaction will be created in the spring. The flow of contraction and rarefaction continues to move forward. In this case the movement of hand and the wave moves in the same direction. That means, the direction of vibration of the spring and the motion of wave are parallel to each other. So we can say that the wave that travels in a direction parallel to the direction of vibration of the particles of the medium is known as longitudinal wave. The sound wave in the air medium is an example of longitudinal wave.

The highest and the lowest point of a transverse wave are called wave crest and wave trough. The similar quantities in the longitudinal wave are contraction and rarefaction.

7.3 Wave related quantities

Complete vibration:

If a wave transmitting particle moves from a certain point and again comes back to the same point then the motion is called complete vibration.

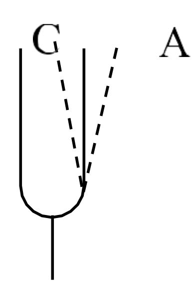


Figure: 7.6

Time period:

The time interval in which the wave is repeated that is the times required for one complete vibration of a wave transmitting particle is known as its time period. It is expressed by the letter T and its unit is second (s).

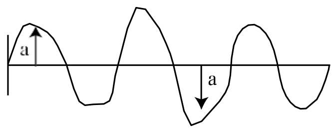


Figure: 7.7

Frequency:

The number of complete vibrations in one second of a wave transmitting particle is known as its frequency. Wave is produced from a vibrating object. So the frequency of vibrating object is equal to the frequency of the wave. The unit of frequency is Hertz (Hz). If a vibrating particle executes one complete vibration in one second then its frequency is called 1 Hz. It is expressed by '*f*'. The relation between frequency and time period is $f = \frac{1}{T}$

Amplitude:

To produce a wave the particles need to vibrate about their equilibrium position. The maximum displacement of a wave transmitting particle from the position of equilibrium is called amplitude. In the figure 'a' is amplitude.

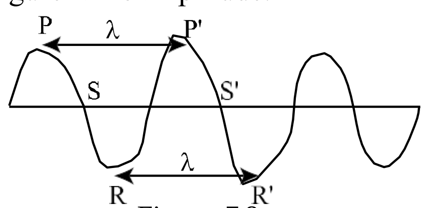


Figure: 7.8

Phase:

The overall condition of motion of a wave transmitting particle at any moment is known as phase. The overall condition means the displacement, velocity and acceleration etc of the particle at a certain time. The wave crest or the wave trough always remains in the same phase in case of a transverse wave.

In the figure the particles of points *P* and *P*' or R and R' are in same phase.

Wavelength:

The distance between the two successive particles of same phase is called wave length. Wave length is defined as the distance through which a wave travels in a time during which a wave transmitting particle completes one oscillation. Wave length is expressed by λ. Its unit is meter (m).

In the figure the distance PP' or RR' or SS' is wavelength, λ.

Wave velocity:

The distance that a wave travels in one second in a particular direction is called wave velocity.

7.4 A few relations

The relation between frequency and time period:

We know that the number of complete vibrations of a vibrating particle in one second is called its frequency. Frequency is denoted by f. Again the time period is the time of one complete vibration.

If the time period is T, then in T second, the number of vibration is 1

Therefore, the number of vibration in one second is $\frac{1}{T}$

The number of vibration in 1 second is frequency. So, the frequency, $f=\frac{1}{T}$ (7.1)

The relation between wave velocity and wavelength:

We know that number of complete vibrations in one second is called frequency. Again the distance travelled by the wave during one complete oscillation is called wavelength. So, if the wavelength is λ,

therefore, the distance travelled in the time of 1 complete vibration= λ

$\therefore$ the distance travelled in the time of f complete vibrations = $f\lambda$

Since the frequency is f, so f numbers of waves are produced in 1 second.

$\therefore$ the distance travelled in one second by the wave = $f\lambda$

This is the velocity of wave, v.

Therefore, velocity of wave, $v = f\lambda$ … … … (7.2)

Mathematical example 7.1: The wavelength of sound produced by an object in the air is 20cm .If the velocity of sound in the air is $340ms^{-1}$, find the frequency and period of the object.

We know,

Velocity= $f\lambda$

$$f = \frac{v}{\lambda} = 340ms^{-1}/0.20m = 1700Hz$$

$$T=\frac{1}{f} = \frac{1}{1700s^{-1}} = 0.000588s=5.88\times10^{-4}s$$

Here,
Wave-length, λ=20cm=0.2m
Sound-velocity=$340ms^{-1}$
Frequency, f =?
Period (time), T=?

The frequency 1700 Hz; Period (time) 05.88×10^{-4}s

7.5. Sound Wave:

We know that the sound is a power. This power is circulated through wave. Sound wave is a longitudinal wave. During the circulation of this wave, the detraction and expansion of the substance are created (Fig 7.9).This sound wave makes a sense of hearing in our ear by being circulated from the medium. It is noticeable that the sound is not created without vibration. When tune-pin copper, bowl, the bell of school is ringing, you will understand that they are vibrating if you touch them. When you speak, you will see that your throat is vibrating.

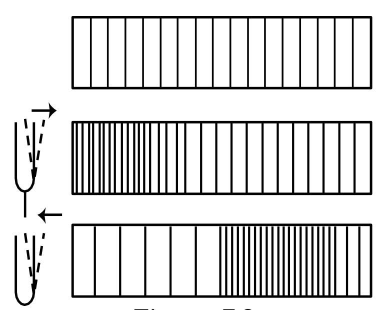


Figure: 7.9

Activities: Take water in a brass bowl. Strike the bowl. You can hear sound. Small waves are seen on the water. Now hold the bowl by your hand. Can you hear sound now? Is there any wave in water?

Figure: 7.10

As long as the bowl produces sound it continues its vibration. So, small waves are produced in water. While the vibration of the bowl stops, the sound stops, so does the wave. So it is understood that a vibrating object can produce sound. But it does not mean that any vibration of any object can produce audible sound. For an audible sound there must have a material medium between the source of sound and the listener, and the frequency will be in between 20Hz to 20000Hz.

Characteristics of sound wave:

Vibration of an objects produces sound wave and an elastic material medium is needed for its propagation. So, sound is called a mechanical wave. Since the direction of propagation of wave and of particles are in the same direction, so is longitudinal. The velocity of sound wave depends on the nature of the medium. The velocity of sound in gaseous medium is less, high in liquid and higher in solid. The intensity of sound wave is directly to the square of its amplitude. So higher the amplitude, the higher is the intensity. Reflection, refraction and superposition are possible in case of sound wave. The velocity of sound wave depends on the temperature and the humidity of medium too.

7.6 Echo

If anyone produces a sound standing near the bank of a river, many of us have the experience of hearing the repetition of that sound after a while. The same case happens if we produce sound standing near a hill or a building. If a sound is produced in a big empty house, the same sound is heard just after a while. These phenomena take place due to the reflection of sound. When a sound becomes separate from its original sound and is repeated due to reflection then this reflected sound is called echo. Simply we can say that the reflection of sound is echo.

The minimum distance of reflector

A sound that is heard persists 0.1 second in our brain. It is called the persistence period of hearing. If any new sound reaches our ear in this period we cannot hear it. Therefore for hearing an echo of any sound the distance between the source of sound and reflector must be such that the reflected wave cannot come back to the listener before a time of 0.1 second. If the velocity of sound in the air at 0°C is considered to be 332ms^{-1} then in 0.1 sec sound can travel 33.2 m. Therefore a reflector must be placed at a minimum distance of 33.2/2 or 16.6 m from the listener.

Now tell why echo is not heard in a small house?

7.7 Uses of echo

Determination of the depth of a well:

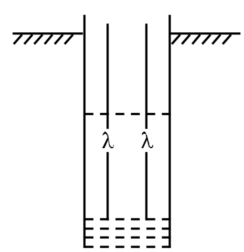


Figure: 7.11

Depth of water surface of a well can be very easily determined by means of echo. When a sound is produced at the mouth of the well, it being reflected from its water surface heard in the form of echo. The time between the production of sound and the hearing of echo is determined by means of a stopwatch.

Let,

depth of well = h

the time difference between the production of sound and hearing of echo = t

Speed of sound = v

Now the distance travelled by reflected sound to the listener is 2h.

Therefore,

$2h = V \times t$

or, $h = \frac{V \times t}{2}$

If the depth of the well is less than 16.6m, it will not be possible to perform this experiment as it is based on echo.

In the same way this method can also be used to find mineral substances in the earth.

Flying of bat:

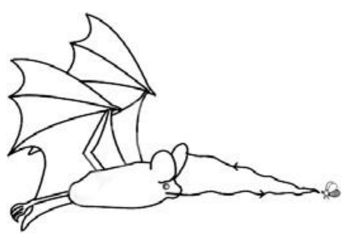


Figure: 7.12

Bat flies using the echo of sound as it cannot see. Bat can produce and hear ultrasonic sound. We cannot hear ultrasonic sound. Bat produces ultrasonic sound and spread it forward which reflects back to the bat from a reflector. Bat can understand from the reflected sound if there is any object before it. It hunts its prey using this technique. If the sound does not reflect back then it can understand that there is open space and it flies that way. Sometimes the bat fails to detect the position of wires of electric lines and flies through the parallel wires and gets stuck and becomes dead as soon as the positive and negative electric lines get connected with its body. This is why sometimes bats are found hanging dead from electric lines.

Bat can produce and hear the sound of frequency about 1,00,000 Hz.

7.8 Variation of velocity of sound

It takes some time when sound reaches our ear from its source. The distance travelled by sound in one second is called velocity of sound. The velocity of sound depends on some factors.

Nature of medium: Velocity of sound in different media is different. For example velocity of sound in air, water and iron is different. At 20°C the velocity of sound in air is $344ms^{-1}$, in water it is $1450ms^{-1}$ and in iron it is $5130ms^{-1}$. Generally we can see the velocity of sound in air is less, in liquid it is higher and highest in solid.

Do it yourself: Take two empty pots of tin. Connect the pots with a thin wire of approximately twenty meter long. Your friend is speaking through a pot. Try to hear that sound by putting your ear in contact with another pot.

Can you hear what your friend is saying? Yes, I can. Here sound is travelling through the wire which is a solid substance.

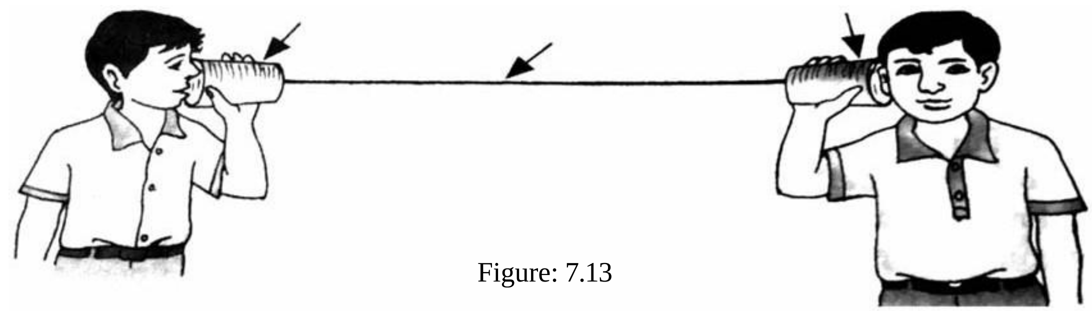


Figure: 7.13

Temperature: The more the temperature increases, the more the velocity of sound in the air increases. For this reason, the velocity of sound is more in summer than that of in winter.

Calculate: The velocity of sound is $344ms^{-1}$ at 20˚C temperature and $332ms^{-1}$ at 0˚. How much does the velocity of sound increases for the increase of temperature by 1°C?

Humidity of air: The velocity of sound increases with the increase of humidity. For this reason, the velocity of sound is more in the humid air than that of in dry air.

7.9 Audibility range and their uses:

We know, the sound is not produced without vibration. If an object vibrates at least 20 times per second then the sound produced from that will be heard. Thus, if the frequency is more than 20000 Hz; the sound will not be heard also. So, the range of sound that we can hear is from 20 Hz to 20000 Hz. This frequency range is called range of audibility. If the frequency of any source is less than 20 Hz then it is called infrasonic vibration. If the frequency of any source is more than 20000 Hz then it is called ultrasonic vibration. Though man cannot hear the ultrasonic sound animals like bats, dogs, bees can produce and hear it.

The application and use of Ultrasonic sound:

Determination of the depth of ocean:

To measure the depth of ocean a machine is used which is called SONAR. The elaboration of SONAR is Sound Navigation And Ranging. There is a system of receiving and transmitting ultrasonic sound in this machine.

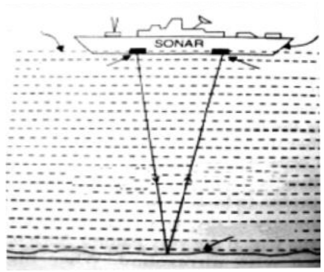


Figure: 7.14

The ultrasonic sound is produced and transmitted through the water with the help of this machine and if this sound returns being reflected from the bottom of the ocean, it is received by the receiver of the machine. If the recorded time of transmitting and receiving is subtracted then the time of traveling is found. Suppose this time is t and the depth of the ocean is d. If the velocity of sound in the water is v, then

it = vt

or, $d = \frac{vt}{2}$ (7.3)

The summation of the distance travelled during return and transmission of sound is d+d = 2d.

By knowing the velocity of sound, the depth of ocean can be measured with the help of the above equation.

To clear the dirt of clothes: The clothes can be washed by the modern washing machine. Mixing soap or powder soap with water the clothes are soaked in it then ultrasonic sound is passed through it. This sound removes the dirt from the clothes and they are cleaned.

To diagnose disease: As the internal photograph of human body can be captured by X-ray, in the same way the disease can also be identified by capturing picture through ultrasonic sound. This process is known as Ultrasonography. This sound is transmitted inside the body and the reflected sound is converted into light energy and casted on the television screen. As a result, the disease can be identified.

In medical science: Ultrasonic sound is used for scaling the teeth or to remove the stones from teeth. Ultrasonic sound is also used to remove small stones from kidney by turning them into dust.

For other uses:

Ultrasonic sound is used to find out fine cracks in metal blocks or metal sheets, to clean tiny electronic machines and also to destroy the harmful germs.

The uses of infrasonic sound:

The range of infrasonic sound is from 1 Hz to 20 Hz. Men cannot hear this sound but some animals can hear it. Elephants communicate with each other using infrasonic sound. This sound can travel a long distance without any

Figure: 7.15

change. This type of sound is produced during earth quakes and nuclear explosions and destroys many things with great shake.

Mathematical example 7.3

A man clapped standing on one of the banks of a river. Echo is heard after 1.5s due to the reflection of the sound from another bank. If the velocity of sound at that time is $340ms^{-1}$, what is the breadth of the river?

Solution:

Suppose the breadth of river d.

We know,

$2d = v.t$

So, $d = \frac{vt}{2}$

$= \frac{340ms\text{-}1 \times 1.5\ s}{2}$

$=255m$

Here,
velocity, $v=340ms^{-1}$
time, t=1.55
distance, d=?

so, the width of river is 255m.

7.10. Musical sound and its characteristics:

We hear different kind of sounds every day. We hear the sound of vehicles, the sound of market, the sound of rainfall, the sound of musical instruments etc every day. Some of these sounds are sweet and some are harsh. If we judge by our sensation the sweet sounds are musical sounds.

The characteristics of musical sound:

The three characteristics of musical sounds are-

1) Loudness or Intensity 2) Pitch and 3) Quality or Timbre.

Loudness or Intensity:

Loudness or intensity means how loud the sound is. Intensity is the amount of sound energy flowing per second per unit area perpendicular to the direction of propagation of sound. In SI system of unit the unit of intensity of sound is Wm^{-2}.

Pitch:

The characteristic of musical sound by which we can differentiate between a shrill sound and a dull sound of same intensity is called pitch. Pitch depends on the frequency of the source. With the increase of frequency the pitch becomes higher making the note more and more shrill.

Quality or Timbre:

The characteristic of musical sound by which we can differentiate between two sounds of same intensity and pitch is called quality or timbre.

Why the voice of men is deep and the voice of women and children is sharp?

There are two membranes in our vocal which are known as vocal chords. The sound is produced due to the vibration of vocal chords and so people can speak.

The vocal chords of adult men become thick as they age but the vocal chords of children and women are not thick. For this, the frequency of voice of the adult men is less and the frequency of voice of women and children are more. So the voice of men is deep but the voice of children and women is sharp.

7.11. Noise pollution

Sound is necessary for mutual communication and exchanging feelings. But the unnecessary sounds and noises are intolerable. When the sound from different sources cross the normal limit of tolerance and causes annoyance and harm to health then it is called noise pollution.

The excessive use of mike, the sound of dram, the sound of the explosion of bomb, the sound from industries, the horn of vehicles, loud sound from tape-recorder and television put, the sound from the engine of old car, the sound of aero plane and fighter plane etc. are the main causes of noise pollution.

Continuous loud sound increases mental stress and makes the temper rough. It causes vomiting tendency, lack of appetite, high blood-pressure, complex diseases of heart and brain, sickness from lack of sleep, tiredness, lack of potentiality, lack of memory, headache etc. Sudden loud sound can damage our hearing.

At present, noise pollution is creating many severe problems. Very often the patients and the examinees become sick due to noise pollution. Reducing noise is the way to remain safe from noise pollution. We can take a few steps in this regard. We have to refrain ourselves from using mike loudly in any ceremony. The use of fireworks and bang sticks must be banned in the festivals. We should avoid using the horn of vehicles unnecessarily and loudly. We can reduce noise pollution by buying low sound producing engine and by establishing industries and airport far from residential area. Open areas should be preserved in the city and more and more trees should be planted to absorb the noise. By using noise-absorbing machine in the industries and by making people conscious the noise pollution can be controlled.

Exercise

A. Multiple Choice Questions:

Tick (√) the correct answer.

1. What type of wave sound is?

   a) Transverse wave b) Electromagnetic wave

   c) Longitudinal wave d) Radio wave

2. In which medium the velocity of sound is maximum?

   a) Solid b) Light

   c) Gaseous d) Plasma

Chapter eight

REFLECTION OF LIGHT

[We see many things around us. When light comes directly to our eyes from any source, we can see the source. Again, when light emitted from a light source comes to our eyes after reflection from the surface of any object, we see the object too. Light is a kind of energy or external cause which enables us to see or creates the sense of vision in our eyes. In this chapter we will discuss about nature of light, mirrors, laws of reflection of light, types of mirror, how image is formed in a mirror, uses of mirror and magnification of images.]

By the end of this chapter, we will be able to-

13. Explain nature of light.
14. Explain the laws of reflection of light.
15. Explain mirrors.
16. Explain images.
17. Explain formation of images in mirrors by drawing action line of light rays.
18. Explain some common phenomena of formation of images in plane and spherical mirrors.
19. Explain uses of mirrors.
20. Explain magnification.
21. Demonstrate formation of images.
22. Realize the influence of different optical phenomena and their contributions in our life and appreciate them.

8.1 Nature of light

We know, light is a form of energy by which we are able to see the objects. When light comes from an object to our eyes, we see the object at that time. The light entered into the eyes forms an image of the object in the retina and develops a sense of vision similar to the object in our brain through a complex process. Men have been trying to achieve knowledge about the nature of light from an ancient period. Once it was thought that light falls on an object from our eyes, so we see that object. Actually, when light comes to our eyes from an object, only then we can see the object.

The major properties of light are:

1. Light travels in a straightway through a transparent homogeneous medium.
2. Light travels with a definite velocity in a definite medium. The value of this velocity in vacuum is $c = 3\times10^8$ ms^{-1}.
3. Reflection, refraction, interference, diffraction, dispersion and polarization of light take place.
4. Light is a form of energy.
5. Light is a kind of electromagnetic wave.
6. Light behaves as wave in some cases and also as particle in some incidents.

8.2 Laws of reflection of light

We see many kinds of objects around us. Some of them give off light all around and some are not. The objects (such as- sun, star, lighted candle etc.) emit light of their own are called luminous objects. Conversely, objects (such as men, trees, table, wall, picture, chalk board etc.) that have no light of their own or do not emit light are called non-luminous objects. When light comes from the luminous object to our eyes we see the object. The common objects which we see around us are not luminous; in spite of this we can see them. The reason behind it is the reflection of light. Figure 8.1 shows how we can see a luminous (sun) and a non-luminous (cat) object. Eye sees the luminous object because light enters the eye directly from it. The light coming from the luminous object reflected by the cat enters our eyes and so we can see the cat.

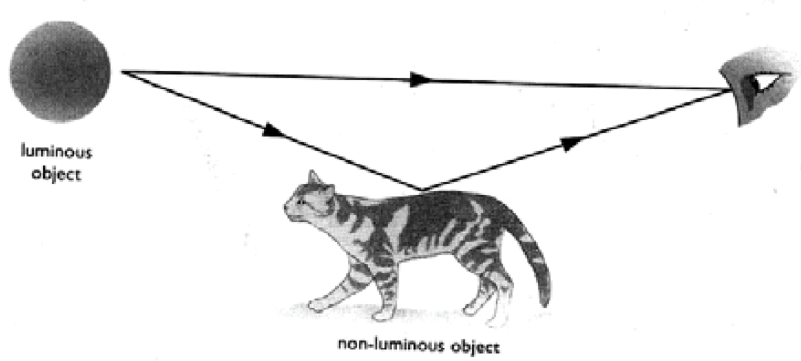


Figure 8.1

In a homogenous transparent medium (e.g.- glass) light travels in straight line with the same velocity. But when light travelling through the first medium falls on the surface of a second medium, then a portion of the light returns back to the first medium from the surface of separation of two medium. This phenomenon is called reflection of light.

Laws of reflection:

The incident and reflected ray obey two simple laws:

1. **First law:** The incident ray, reflected ray and the normal at the point of incidence on the reflector lie in the same plane.
2. **Second law:** The angle of incidence is equal to the angle of reflection.

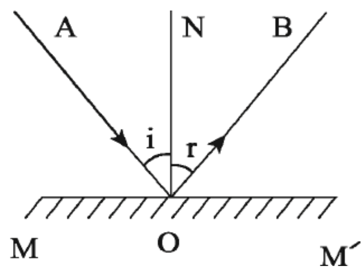


Figure 8.2: Reflection of light

When light is reflected from a surface, then it must obey the laws of reflection. How light will be reflected from a surface depends upon the nature of the reflecting surface. Depending on the nature of the reflecting surface, reflection may be of two kinds.

1. Regular or uniform reflection
2. Diffused or irregular reflection

1. Regular reflection: If a parallel beam of light falls on a smooth surface and after reflection remains parallel, or is converted into a convergent or a divergent beam, then such type of reflection is called regular reflection. For example- when a parallel beam of light incident on a plane mirror or on a well polished metal surface, the beam remains parallel even after reflection. In this case, the angle of incidence for each incident ray is the same and the angle of reflection for each of the ray is also the same due to regular reflection.

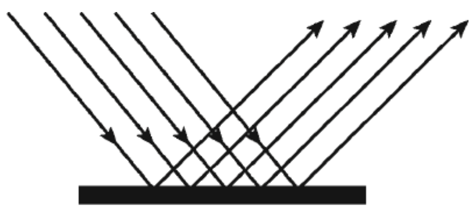


Figure 8.3: Regular reflection

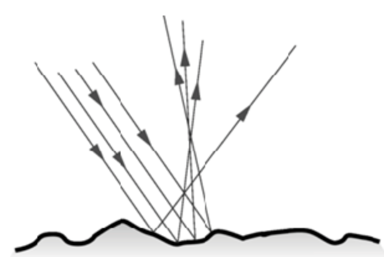


Figure 8.4: Diffused reflection

Diffused reflection

If a parallel beam of light is incident on a surface and after reflection it is neither parallel nor converted into a convergent or a divergent beam, then such reflection is called diffused or irregular reflection.

Figure 8.4 shows that a parallel beam of light incidents on a rough surface. In this case, the rays incident at different angles at different point of incidence on the rough surface, as a result the corresponding angle of reflection of these rays become different. Due to this, the reflected rays are no more parallel. Objects which we see around us, most of their surfaces are not smooth. As a result, the reflected rays which enter to our eyes are diffused in nature. Due to this, the objects appear dim instead of bright. Most of the surfaces which appear smooth to naked eyes actually are not smooth. When these objects are viewed with a microscope then they appear rough.

8.3 Mirror

A mirror is a smooth surface on which regular reflection takes place. A clear image of an object placed in front of a mirror is formed due to reflection of light.

A mirror is made by giving a reflecting coating on a smooth surface. Generally a mirror is prepared by giving metal coating on one surface of glass. This process of coating with mercury or silver on glass is called silvering. Here, the surface opposite to the surface having metal coating works as the reflecting surface. Besides, surface of calm water, smooth ice etc. works as mirror.

Mirrors are mainly of two types. Namely-

1. Plane mirror
2. Spherical mirror

Plane mirror: If the reflecting surface is plane and smooth and regular reflection of light takes place on it, then this surface is called plane mirror. The mirror which we usually use is plane mirror.

Spherical mirror

If the reflecting surface is smooth and spherical, that means if the reflecting surface is a part of a sphere and regular reflection takes place on it, it is called spherical mirror. Spherical mirrors are shown in figures 8.5 and 8.6. If a part of a hollow glass sphere is cut off and silvering is done on one surface, then a spherical mirror is made. Again, spherical mirrors are of two types. These are:

1. Concave mirror
2. Convex mirror

Concave mirror: If the concave surface of a sphere acts as the reflector, that is if regular reflection of light takes place from the concave surface of the spherical mirror, then it is called a concave mirror. In this case, concave mirror is made by silvering on the convex surface of the part of the sphere [figure 8.5]. The concave mirror is a converging mirror since the parallel beam of light converges at a point or meets together after reflection from its surface.

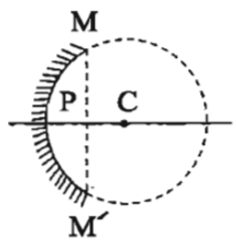


Figure: 8.5

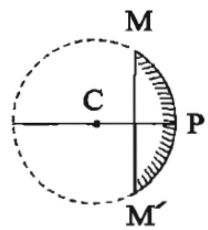


Figure: 8.6

Convex mirror: If the convex surface of a sphere acts as the reflector, that is if regular reflection of light takes place from the convex surface of the spherical mirror, then it is called a convex mirror. In this case, convex mirror is made by silvering on the concave or inner surface of the part of the sphere [Figure 8.5]. The convex mirror is a diverging mirror since the parallel beam of light diverges from a point or spreads over and never meets at a point after reflection [Figure 8.6].

Some definitions related to spherical mirrors

Pole: The central point of the reflecting surface of a spherical mirror is called the pole of the mirror. In figure 8.7, P is the pole of the mirror. Pole is the lowest point of the reflecting surface in case of a concave mirror, while it is the highest point in a convex mirror.

Center of curvature: The centre of the sphere of which the spherical mirror is a part is called the centre of curvature of that mirror. In figure 8.7, C is the centre of curvature.

Radius of curvature: The radius of the sphere of which the spherical mirror is a part is called the radius of curvature of that mirror. In figure 8.7, PC or MC is the radius of curvature. Radius of curvature is denoted by r.

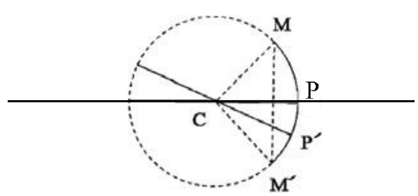


Figure: 8.7

Principal axis: The straight line passing through the pole and the centre of curvature of a spherical mirror is called the principal axis of that mirror. In figure 8.7, PC is the principal axis.

Secondary axis: The straight line passing through the centre of curvature and any point other than the pole on the reflecting surface of the sphere is called the secondary axis. In figure 8.7, P′C is the secondary axis.

Principal focus:

A beam of rays adjacent and parallel to the principal axis being incident on a spherical mirror converges at a point on the principal axis (in case of concave mirror) or appears to be diverging from a point on the principal axis (in case of convex mirror) after reflection, then this point is called the principal focus of the mirror.

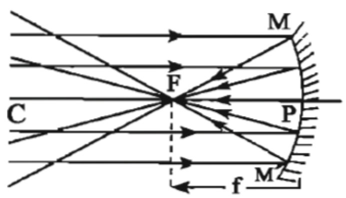


Figure: 8.8

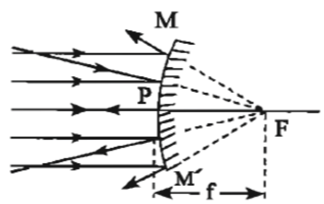


Figure: 8.9

Focal length: The distance between the pole and the principal focus of a spherical mirror is called the focal length of the mirror. In figure 8.8 and 8.9, PF is the focal length. In a spherical mirror, the focal length is half of the radius of curvature. Therefore, $f = \frac{r}{2}$.

Focal plane: The plane imagined that passes through the principal focus and perpendicular to the principal axis is called the focal plane.

8.4 Image

When you look at a mirror, you see your image. It is not only in the case of mirrors, when you walk by the side of a pond or a river, your image appears in water that time also. This reflection is your image. When light is reflected in a mirror from your body or an object and comes to your eyes we see the image at that time.

When light reflected from an object comes directly to our eyes, we see the object then. Again, if light does not enter our eyes directly rather it comes to our eyes being reflected or refracted in another medium, then also we see the object. Then it seems that the object is not in its actual position. When you see your image in a mirror, then it appears to you that you are behind the mirror. Actually you are in front of the mirror. The reflection of an object seen at the new position due to the presence of the mirror is called the image of that object.

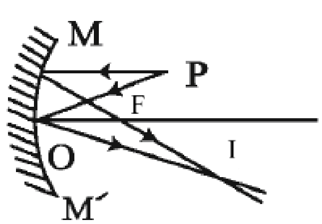


Figure 8.10

In figure 8.10, O is a point object in front of a concave mirror. The ray OM from the point O being parallel to the principal axis incident on the mirror and reflected through the principal focus along the line MFI. The ray OP incident on the pole P reflects along the path PI. The reflected rays intersects at the point I. The point I is the image of the point O.

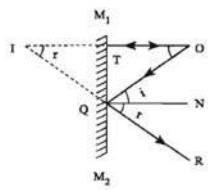


Figure 8.11

In figure 8.11, O is a point object in front of a plane mirror. From the point O, the ray OT incident perpendicularly on the mirror and reflects along the path TO. The ray OQ incident obliquely on the mirror and reflects along QR. As these two rays are diverging, if they are extended backward they meet at the point I. Therefore, the reflected rays seem to be diverging from the point I behind the mirror. This point I is the image of the point O.

If a beam of rays after being reflected from or refracted through any surface meet at a second point or appears to diverge from the second point, then the second point is called the image of the first point. An object is the sum of innumerable points. As a result, image of an object is formed as like as an individual point.

Classification of images

When you see your appearance in a mirror, you see your image behind the mirror. This happens due to the reflection of light. Image like this formed in a mirror, through which light ray do not actually meet, is called virtual image. Images in which light rays actually meet together (e.g.- images on a cinema screen) are called real images. The pictures formed in the screen of a digital camera are real images. Real images can be displayed in a screen but the virtual images cannot be displayed in a screen. Images are of two types-

(A) Real image
(B) Virtual image

(A) Real image: If light rays emitted from a point after being reflected or refracted on a surface actually converge at a second point, then this second point is called the real image of the first point. In figure 8.10, I is the real image due to reflection.

(B) Virtual image: If light rays emitted from a point after being reflected or refracted on a surface seem to diverge from a second point, then this second point is called the virtual image of the first point. In figure 8.11, I is the virtual image due to reflection.

8.5 Image in a mirror

We know, mirrors are of two types. (A) Plane mirror (B) Spherical mirror. We will discuss how images are formed in plane and spherical mirrors.

Formation of image in a plane mirror

(A) Point object

In figure 8.12, O is an object in front of a plane mirror M_1M_2. Ray OT from the point O incident normally on the plane mirror and reflected back along TO. Another ray OQ incident obliquely on the mirror and reflected along the path QR. If the reflected rays QR and TO are extended backward, they meet at the point I. As if the reflected rays are coming from the point I situated behind the mirror. Therefore, the point I is the virtual image of the point O.

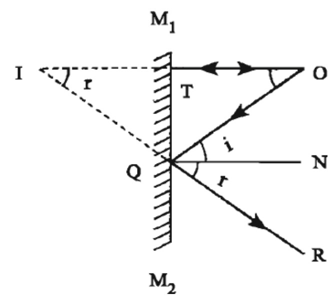


Figure: 8.12

The normal QN is drawn at the point Q.

Since TO and QN are parallel, OQ is the interjector.

$\therefore \angle TOQ = \angle OQN = i$ (8.1)

Again, OI and QN are parallel, line RQI has intersected them.

$\therefore \angle TIQ = \angle NQR = r$ (8.2)

We know, $i = r$

We get from equations (8.1) and (8.2),

$\angle TOQ = \angle TIQ$

Now between ΔQOT and ΔQIT,

$\angle TOQ = \angle TIQ$, TQ is a common arm,

and $\angle QTO = \angle QTI = 90°$

Therefore, the triangles are equal in all respects.

Hence, OT = TI

The image I in a plane mirror is at the same distance behind the mirror as the object O is in front.

(B) Extended object

The image of an extended object can also be drawn as the point object. In this case, the extended object should be considered as an aggregation of infinite number of points. Here, a virtual image is formed for each point behind the mirror [Figure 8.13].

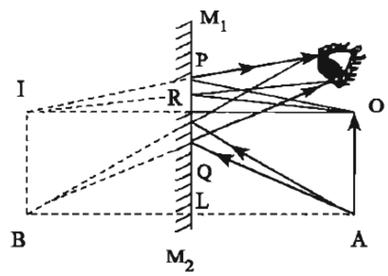


Figure: 8.13

In the figure an object AO and its image BI are shown. From the points O and A, perpendiculars are drawn on the mirror M_1M_2. They intersect the mirror at the points R and L. Now OR and AL are extended backward to the points I and B respectively, such that OR=IR and AL=BL. Two rays from each of the points O and A incident obliquely on the mirror and get reflected. When the two reflected rays are produced backward, they seem to be coming from the points I and B respectively. Now I and B are joined. Therefore, BI is the virtual image of the object AO formed in the plane mirror.

The size of the image formed in a plane mirror is always equal to that of the object.

The characteristics of the image formed in a plane mirror.

The images formed by a plane mirror have the following properties:

1. The image in a plane mirror is at the same distance as the object is in front.
2. The size of the image is equal to the size of the object.
3. The image is virtual and erect.

Images formed in a spherical mirror

If an object is placed in front of a spherical mirror, that may be concave or convex, an image of the object is formed in the mirror. To know the position, size and nature of the image, we have to know the direction of the reflected beam of light emitted by an object. We can draw an image in a spherical mirror considering any two of the three rays described below.

1. Rays incident along the radius of curvature returns back along the same path after reflection in a spherical mirror [Figure: 8.14].

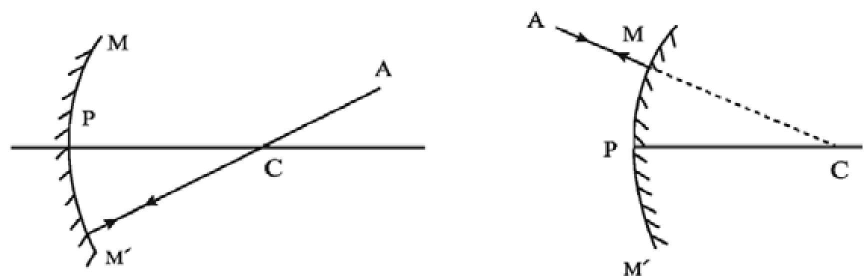
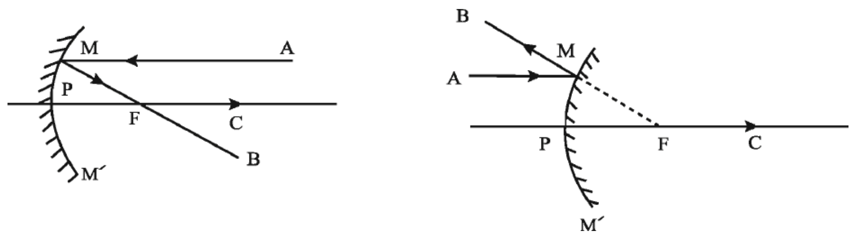


Figure: 8.14

2. Rays incident parallel to the principal axis are reflected through the principal focus in a concave mirror. Rays incident parallel to the principal axis after reflection in a convex mirror appear to diverge from the principal focus [Figure: 8.15].



A Figure: 8.15 B

In a concave mirror, rays incident through the principal focus are reflected parallel to the principal axis. Rays directed towards the principal focus after reflection become parallel to the principal axis [Figure: 8.16].

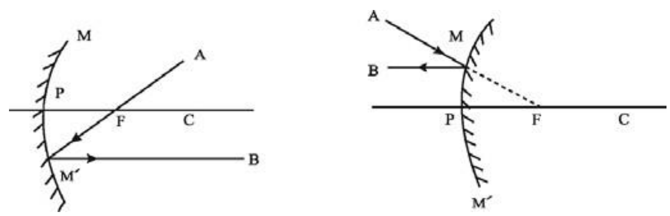


Figure: 8.16

Images formed in a concave mirror: The position, size and nature of an image formed in a spherical mirror depend on the position of the object placed in front of the mirror. If there is a change in the position of the object, then a corresponding change in the position, size and nature of the image also takes place. Let, MPM′ be a concave mirror. Here, P is the pole, F is the principal focus and C is the centre of curvature of it. AO is the object situated perpendicularly on the principal axis in front of it.

If the object is placed anywhere between infinity and the principal focus, the image thus formed will always be real and inverted. Again, in case of an object placed in between the principal focus and the pole, the image will be virtual and erect. The real and virtual images formed by a concave mirror are described below:

Real image

From the point O, a ray OM incident at the point M parallel to the principal axis and reflected through the principal focus along the path MI. Another ray OCM′ from the point O incident through the centre of curvature C on the mirror and reflects back along the same path. After reflection, the two rays meet at the point I actually. Therefore I is the real image of the point O. From A, ray incident along the principal axis reflects back along the same path. So, the image of A will be formed on that line. Let us draw normal, IB, from the point I on the principal axis. Now, BI is the real image of the object AO [8.17]. The nature of the image is real and inverted.

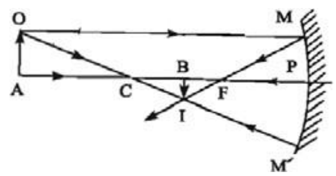


Figure: 8.17

Virtual image:

In figure 8.18 the object is situated between the pole and the principal focus. From the point O, a ray incident parallel to the principal axis and reflected through the principal focus. Another ray incident on the mirror through the centre of curvature reflects back along the same path. After reflection, two rays become mutually diverging. If the two rays are extended backward, they appear to come from the point I. So, point I is the virtual image of the point O. Normal IB is drawn on the principal axis from the point I. therefore, BI is the virtual and erect image of the object. The position of the image so developed is behind the mirror, its nature is virtual and erect, and magnified i.e. larger than the size of the object.

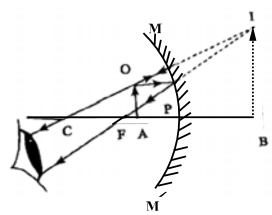


Figure: 8.18

Images formed in a convex mirror: Depending on the position of the object in a concave mirror, real or virtual images are formed. But a virtual image of an object is always formed in a convex mirror. The image is always erect and smaller in size than that of the object. In figure 8.19 MPM′ is a convex mirror whose centre of curvature is C, principal focus is F and P is the pole. The object AO is placed perpendicular to the principal axis in front of the mirror. From the point O, the ray OM incident parallels to the principal axis of the mirror. After reflection the ray seems to diverge from the principal focus F of the mirror. Another ray OD incident perpendicularly through the centre of curvature and reflects back along the same path. If these two diverging reflected rays are extended backward, they intersect at the point I and appear to be coming from the point I, therefore the point I is the virtual image of the point O. Now perpendicular IB is drawn on the principal axis from the point I. This BI is the virtual image of the object AO. Since the image is formed behind the mirror, it is virtual, erect and smaller in size in comparison to the object. If the object is gradually brought nearer to the mirror, the

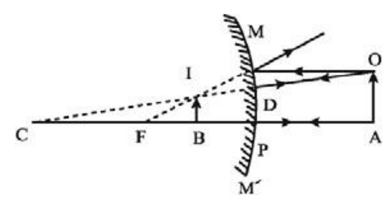


Figure: 8.19

image will also be displaced nearer to the mirror and the size of the image will increase gradually. But the image will always be smaller in size than that of the object.

8.6 Some common phenomena of formation of images in plane and spherical mirrors

1. Simple periscope: Periscope is used to see a distant object directly if there is an obstacle. A simple periscope is constructed using two plane mirrors. This instrument is formed utilizing successive reflection of light. In figure 8.20 a simple periscope is shown. Here, two plane mirrors are placed parallel to each other at an angle of 45° with the axis of a long rectangular wood or metal tube. At first parallel light rays from the distant object incident on the mirror M_1 at angle of 45° with the normal to the mirror. The incident ray is reflected by the mirror M_1 at an angle 45° and incident on the mirror M_2 travelling along the axis. The light ray is again reflected by the mirror M_2 and enters the eyes horizontally. So, the object can be seen.

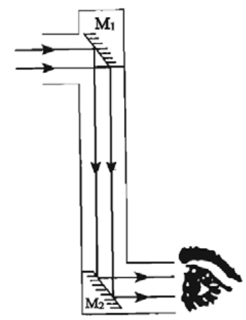


Figure: 8.20

Thus by changing the direction of light we can see objects which cannot be seen directly using plane mirrors.

Periscope is used to watch games in a crowd, to see something behind a wall, to observe the movement of the enemy soldiers etc. More developed types of periscope are used using prism in a submarine.

2. Plane mirror in a saloon: We see plane mirrors in a saloon or a parlor while cutting hair situated in front and behind. We can see the anterior protion of head in the front mirror. The image of the back portion of the head formed in the mirror behind. This image works as a virtual object for the front mirror and again forms image in the front mirror. Thus, we are able to see the back portion of the head in the front mirror.

3. Plane mirrors in medical field: The dentists use concave mirrors to examine the teeth. The mirror is placed very close to the teeth. As a result, a virtual and magnified image is formed in the mirror. Besides, the ENT doctors use concave mirrors for different purposes.

8.7 Uses of mirror

We use different types of mirror for different purposes. These are described below:

Plane mirror

1. We see our appearance by using plane mirrors.
2. The ophthalmologist uses plane mirrors to examine the vision of a patient for reading the alphabets easily.
3. Periscopes are constructed using plane mirrors.
4. It is used to avoid accidents in the turns of hilly road.

5. Optical instruments like telescope, overhead projector, and laser are made using plane mirrors.
6. During shooting of drama, cinema etc. brightness of any place is increased by reflecting light by plane mirror.

Concave mirror

1. Using suitable size of the concave mirror, the magnified and erect image of the face is formed in a concave mirror. It helps in beautification and shaving.
2. The dentists use concave mirror.
3. Concave mirrors are used as reflectors. For example- the concave mirror is used in torch light, search light of launch and steamers to determine the path.
4. Using concave mirror, the light and heat energy, etc. is centralized to heat a body. Besides, it is used to collect Radar and TV signal. For instance- dish antenna, solar oven, telescope and Radar collector etc.
5. Since, the light rays can be centralized at a point using a concave mirror, the doctor use this mirror to examine eye, ear, nose and throat.

Convex mirror

1. Since, a convex mirror always produce a virtual, erect and diminished image, it is used in cars to see the vehicles and passersby behind. In marriage ceremony it is used as view mirrors.
2. Since a wide range of area can be seen with the help of a convex mirror it is used in shopping mall or shop for security purpose.
3. It is used to prepare reflecting telescope.
4. It is used as reflector in the street lamps, since it spreads light over a large area.

8.8 Safe driving

To drive vehicles like car, motor cycle etc. safely the driver should have an eye to many things. At the very first, he has to check all the lamps in the car by switching them on. For perfect and safe driving, the drivers need not only to see what remains in front of him. Instead, he has to be careful about what remains behind the car. The mirrors are very important and indispensible parts of a car. For this, he has to adjust all the mirrors just after he gets on the car.

8.9 Blinds turns on hilly roads

To drive safely is an utmost duty for all drivers. Besides, it is more difficult to drive in bad weather like rainfall and fogs. Especially, driving in a hilly road is very risky. Since, hilly roads are zigzag as well as there are too ups and downs [Figure 8.23]. Sometimes, it becomes necessary to take turn by 90° for driving in a hilly road. While taking a turn, the driver has to take enough precautions. In a blind turn, the drivers coming from opposite directions cannot see themselves, besides they are not at all aware of what remains on the other side. To solve this problem, large area mirrors are fitted at an angle of 45° in the turn. As a result, the drivers can see everything around the turn and become able to drive safely. It is to be remembered that it is not appropriate to drive fast in the hilly turns. Besides this, one should not drive a car in a hilly road during the night time except there is an emergency. Since the vision is reduced a lot due to the scarcity of light.

Figure: 8.21

8.10 Magnification

When we see an image produced by a mirror or a lens, then it may be larger, smaller or equal in size with respect to that of the object.

Magnification is used to measure how large or small the size of the image is compared to that of the object formed in a mirror or a lens.

In other words, the ratio of the length of the image of that object is called linear magnification or in short magnification.

If an image of length l' is formed in a mirror or a lens for an object of length l, then magnification of the object is the ratio of l' to l.

Therefore, $m = \frac{l'}{l}$ (8.3)

From the magnitude of magnification m, we know how many times larger or smaller the image is compared to that of the object.

Investigation 8.1

To Form and demonstrate an image using a concave mirror.

Objective: Use of a concave mirror in the laboratory and formation of a real image.

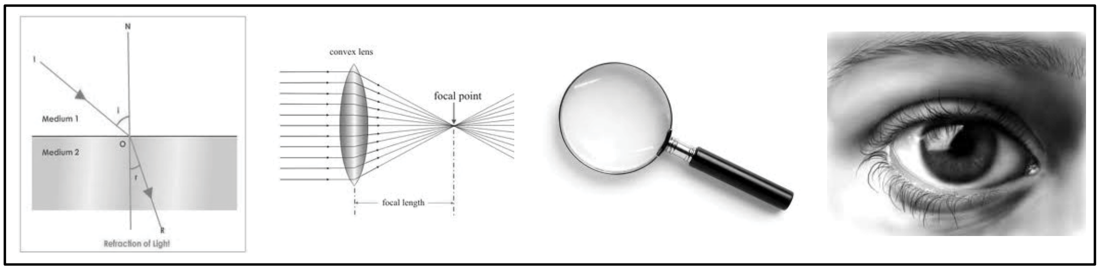
Instrument: A concave mirror.

Procedure:

1. Take a concave mirror.
2. Stand beside a door or a window of your laboratory with the mirror.
3. Now hold the mirror towards any external scene, for example- trees, buildings, etc.
4. Form an image of the scenery on a very adjacent smooth wall, by moving the mirror right and left.
5. Move the mirror back and forth from the wall to make the image distinct.
6. At a certain distance, you will see a distinct image of the object on the wall.
7. Thus a distinct image of an object at a long distance can be demonstrated on a wall.
8. Discuss about the nature of the image.

Chapter nine

REFRACTION OF LIGHT



[A straight stick appears to be bent when it is obliquely immersed partly in water. If we look directly to the bottom of a jug full of transparent water its bottom seems to be raised up. Of course we observe these phenomena in our everyday life. These events results from a special property of light called refraction. A special event of refraction is total internal reflection. Mirage is formed in the desert, diamond looks bright and information signals are sent through optical fiber because of total internal reflection of light. Many of us use spectacles to remove the defects of eyes. The glass of the spectacle is a lens. We will discuss all these phenomena in this chapter.]

By the end of this chapter we will be able to **-**

1. Explain the laws of refraction
2. Explain the refractive index
3. Explain the total internal reflection
4. Explain the use of optical fiber
5. Explain the lens and its classification
6. Describe the different quantities of lens by drawing ray diagram
7. Describe the image formed by the lens by drawing ray diagram
8. Describe the power of lens
9. Describe the function of eyes by drawing ray diagram
10. Describe least distance of distinct vision
11. Describe the defects of eyes
12. Describe the uses of lens to remedy the defects of eye by drawing ray diagram
13. Explain the perception of coloured objects
14. Describe the uses of refraction of light in our everyday life

9.1 Refraction of light:

Look at figure 9.1. here two media, air and glass are shown. Coming from air medium following the path AB, light ray incidents at point B of the separation surface PQ of two media. If the light ray goes straight it will follow the path BC′ but it changes its path and follows BC. This phenomenon of bending of ray of light is called refraction. Therefore, when the ray of light travels obliquely from one transparent medium to another, the bending of ray of light at the surface of separation of the two media is called the refraction of light.

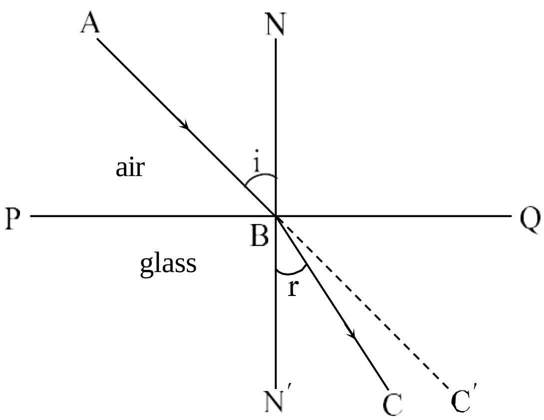


Fig-9.1

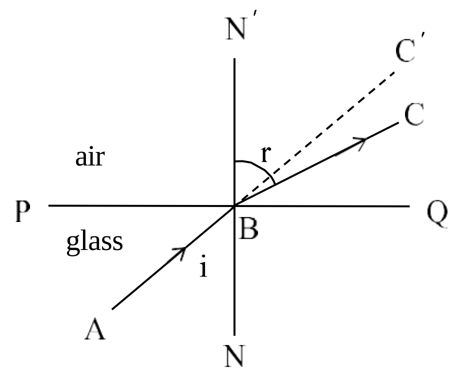


Fig – 9.2

In figure 9.1 the incident ray is AB, the refracted ray is BC and NBN' is the normal drawn at point B on PQ. ∠ ABN is called the angle of incidence *i* and ∠ N'BC is called the angle of refraction *r*.

Since the velocity of light differs from medium to medium, during the change of medium refraction takes place. When ray of light enters from a rarer medium (air) to a denser medium (glass) the refracted ray bends towards the normal i.e. in this case $i>r$ again when it enters from a denser medium to a rarer medium it goes away from the normal i.e. in this case $r>i$.

Do it: Put an ink mark on a white paper and place a transparent glass slab on it

The point O has raised at point O'. This happens because of refraction of light. The ray of light coming from O enters the rarer medium from denser medium. As a result the refracted ray goes away from the normal. If the refracted ray is extended backward it appears to come from O'. Here the point O' is the virtual image of the point O. If we look directly at the point O it seems to be raised at point O' (fig: 9.3).

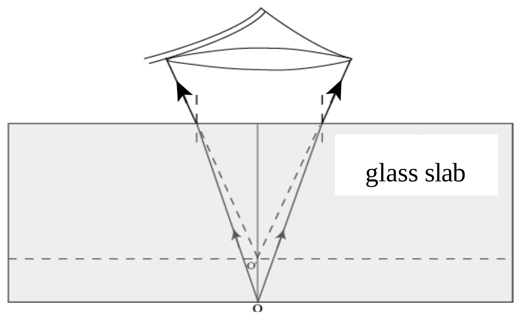


Fig:9.3

Laws of refraction of light:

We have already noticed that in the fig: 9.1 (here fig: 9.4) AB is the incident ray, BC is the refracted ray and NBN′ is the normal drawn at B on PQ. ∠ ABN is the angle of incidence *i* and ∠ N′BC is the angle of refraction *r*.

Now if the angle of incidence is increased the angle of refraction will also increase but the angle of refraction will not be proportional to the angle of incidence that is if the angle of incidence *i* is doubled the angle of refraction *r* will never be so. It is seen that if the angles of incidence are i_1, i_2, i_3, ……. and their respective angles of refraction are r_1, r_2, r_3, …. then, $\frac{\sin i_1}{\sin r_1} = \frac{\sin i_2}{\sin r_2} = \frac{\sin i_3}{\sin r_3}$ = constant

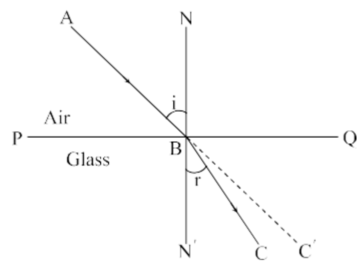


Fig. 9.4

The value of this constant depends upon the nature of media and the colour of the light used. Again it is seen that AB, BC and the normal NBN′ are on the plane of your book. From this observation we see that refraction of light follows the following two laws.

First law: The incident ray, normal drawn at the point of incidence on the surface of separation and the refracted ray lie on the same plane.

Second law: When light enters obliquely to a transparent medium from another transparent medium then for a fixed pair of media and for a fixed colour of light the ratio of the *sine* of the angle of incidence to the *sine* of the angle of refraction always remains constant.

This law is also known as Snell’s law.

9.2 Refractive index

For a particular pair of transparent medium and a particular colour of light when ray of light refracts from one medium to another, then if the angle of incidence is *i* and the angle of refraction is *r*, then $\frac{\sin i}{\sin r}$ will be a constant and it is called refractive index of the second medium with respect to the first medium for that colour of light. It is expressed by *n*.

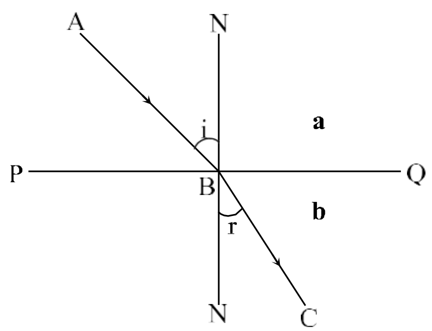


Fig:9.5

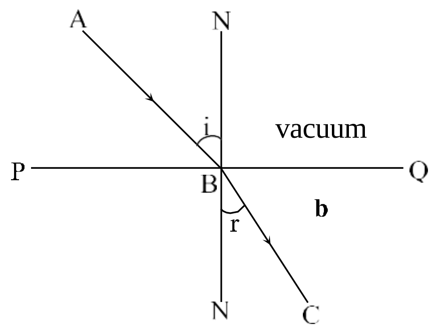


Fig:9.6

If the ray of light enters in the medium *b* from medium *a* then the refractive index of medium *b* with respect to *a* is (fig 9.5), $_an_b = \dfrac{\sin i}{\sin r}$ (9.1)

The right subscript of *n* indicates the medium of which refractive index is and the left subscript of *n* indicates the medium with respect to which the refractive index is.

Again when the ray of light enters obliquely to a medium from vacuum, then the refractive index of the medium with respect to vacuum is called absolute refractive index of the medium for that particular colour of light (fig:9.6). If the ray of light refracts into medium *b* from vacuum, then the absolute refractive index of medium *b* is $n_b = \dfrac{\sin i}{\sin r}$. During expressing absolute refractive index of given medium nothing on left side of *n* is used as subscript and on right side of *n* the medium is written as subscript. For example, absolute refractive index of medium *b* is n_b.

When light passes from medium *b* to the medium *a* then according to the reversibility of ray of light (fig 9.5) CB will be the incident ray and BA will be the refracted ray, i.e. here the angle of incidence = *r* and the angle of refraction = *i*. Therefore the refractive index of medium *a* with respect to *b* will be [according to equation 9.1]

$$_bn_a = \frac{\sin r}{\sin i} = \frac{1}{\sin i / \sin r} = \frac{1}{_an_b} \qquad (9.2)$$

Bear in mind that the refractive index of medium *a* with respect to medium *b* is reciprocal of the refractive index of medium *b* with respect to medium *a*.

$$\therefore\ _bn_a = \frac{1}{_an_b} \text{ and reversely } _an_b = \frac{1}{_bn_a}$$

Again the refractive index can also be expressed in terms of velocity of light,

$$\therefore\ _an_b = \frac{\text{velocity of light in medium a}}{\text{velocity of light in medium b}}$$

$$\text{And } _0n_b = \frac{\text{velocity of light in vacuum}}{\text{velocity of light in medium b}}$$

The medium whose refractive index is greater, density of that medium is greater and velocity of light is less in it. On the other hand, the medium whose refractive index is less, density of that medium is less and velocity of light is greater in it.

Mathematical example 9.1: When light refracts from air to water, the angle of incidence is 30° and angle of refraction is 19°. Find the refractive index of water with respect to air.

We know,

$$\frac{\text{Sin } i}{\text{Sin } r} = n$$

$$\therefore {}_a n_w = \frac{\text{Sin } i}{\text{Sin } r} = \frac{\text{Sin } 30°}{\text{Sin } 19°} = \frac{0.5}{0.325} = 1.538$$

Ans: Refractive index 1.538

Given,

Angle of incidence, i= 30°

Angle of refraction, r= 19°

Refractive index of water with respect to air, ${}_a n_w$ =?

Mathematical example 9.2: The refractive index of water with respect to air is 1.33. What is the refractive index of air with respect to water?

We know,

$${}_w n_a = \frac{1}{{}_a n_w}$$

$$= \frac{1}{1.33} = 0.75$$

Ans: 0.75

Given,

Refractive index of water with respect to air, ${}_a n_w$ = 1.33

Refractive index of air with respect to water, ${}_w n_a$ =?

9.3 Critical angle and total internal reflection:

Critical angle:

When ray of light passes from a denser medium to a rarer medium, then the refracted ray is deviated away from the normal. As a result the angle of refraction becomes greater than the angle of incidence.

1. Suppose AB is the separating surface of glass and air. Glass is denser and air is rarer medium. P is a point in the glass medium. From P a ray of light PQ incidents at point Q of separating surface AB at a small angle. QR is the refracted ray in air [Fig: 9.7(a)]. In this case the angle of refraction ($\angle$ NQR) will be greater than the angle of incidence ($\angle$ PQN′).

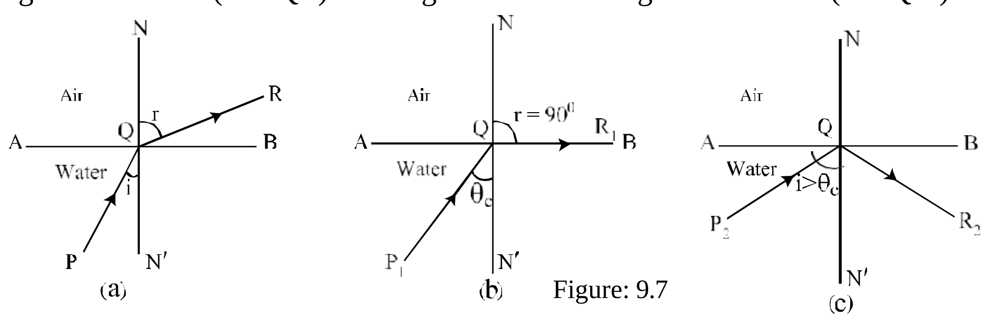


Figure: 9.7

2. Now in denser medium if the angle of incidence gradually increases, the corresponding angle of refraction in rarer medium will also increase. In this way if the angle of incidence is increased finally for a definite angle of incidence $\angle P_1QN'$ will be

obtained [Fig: 9.7(b)] for which the refracted ray QR will pass along the separating surface AB, i.e. the angle of refraction will be $\angle NQR_1 = 90°$. In this situation the angle of incidence in the denser medium ($\angle P_1QN'$) is called the critical angle with respect to the rarer medium. In fig: 9.7(b) $\angle P_1QN' = \theta_c$ = critical angle. The value of this critical angle also depends on the nature of the medium and the colour of light.

Total Internal Reflection:

If the angle of incidence in denser medium is increased further ($i > \theta_c$), then the incident ray of light will be totally reflected in the denser medium. In this case no refracted ray can be observed. In this situation the separating surface of the two media behaves like a mirror. This phenomenon is called the total internal reflection.

In fig: 9.7(c) the angle of incidence in denser medium $\angle P_2QN'$ is greater than the critical angle θ_c of the two media. For this reason the light ray P_2Q incidents on separating surface AB and reflects along QR_2 following the laws of reflection.

Conditions for total internal reflection:

i) The ray of light must incident from a denser medium at the surface of separation of a denser and a rarer medium.

ii) The angle of incidence in the denser medium must be greater than the critical angle.

9.4 Mirage

Sometimes thirsty traveler in desert sees the inverted image of a distant tree and thinks there is water. When he comes close to the tree he realizes his mistake that there is no water. This happens due to total internal reflection of light. This very event is called mirage. The sandy surface of desert is rapidly heated by the tremendous heat coming from the sun. So, the layers of air in contact with the sandy surface become hot. As a result the lower layers become hot and lighter but the upper layers are comparatively colder and denser. The ray of light coming from the tree enters continuously into rarer medium from denser medium. As a result the refracted ray continues to go away from the normal. In a certain moment the ray of light incidents on a layer at an angle which is greater than the critical angle and total internal reflection occurs. At that time the upside down image is seen (fig 9.8) and we call it mirage.

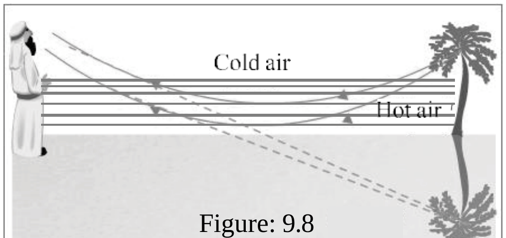


Figure: 9.8

Observation: While walking or travelling in vehicle on a pitch covered road during summer days you may have noticed that the road is wet and silvery. It seems that there is water on the road. A similar phenomenon like mirage in a desert has happened here.

9.5 Optical Fiber

Optical fiber is made of very long thin flexible but solid glass or plastic fiber. The refractive index of the material of fiber is 1.7. A layer is made on this fiber by a material of comparatively less refractive index (1.5). When light ray that incidents at a small angle enters through one end of the fiber, then successive total internal reflections of light take place on the wall of the fiber and finally it emerges through the other end.

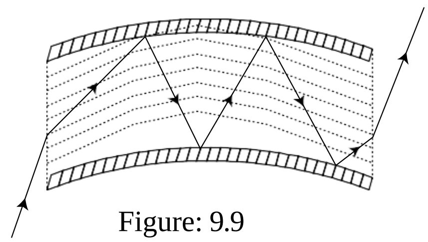


Figure: 9.9

Light can be sent through the fiber almost without any loss of energy even if it is bent or coiled. A set of optical fiber is called optical tube.

Uses of optical fiber in the field of health and telecommunication:

An optical tube is passed through the mouth to stomach in order to examine the inner wall of the stomach of any patient. A set of optical fiber of this optical tube is sent to lighten the stomach and the other set helps to see the lightened portion of stomach from the outside. This process is known as endoscopy. In this way by sending optical tube the block inside the artery, vein and function of valves of heart can be observed. Optical fiber is used for sending or receiving electrical signals from one place to another. Before sending, the electrical signal has to be converted into optical signal.

Near about 2000 telephone signals can be transmitted at a time through a single optical fiber. Almost no change takes place to the intensity of the signals for this kind of transmission. The use of optical fiber at present has brought about a significant change in communication system.

9.6 Lenses and their Classification:

A lens is a transparent refractive medium bounded by two spherical surfaces.

Lenses are of two types:

i) Convex lens or converging lens

ii) Concave lens or diverging lens

Convex lens: The lens whose mid portion is thick but the edges are thin is called convex lens. As the convex lens can converge a beam of parallel light rays after refraction hence it is also called converging lens. [Fig. 9.10A]

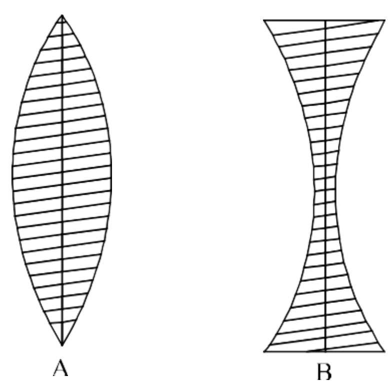


Figure: 9.10

Concave lens: The lens whose mid portion is thin but the edges are thick is called concave lens. As the concave lens can diverge a beam of parallel light rays after refraction hence it is also called diverging lens. [Fig. 9.10 B]

9.7 Few definitions related to lens:

Centre of curvature: Both surfaces of a lens are parts of different spheres. The centre of each sphere is called the centre of curvature of the respective surface. In figure: 9.11 C_1 and C_2 are two centres of curvature of the lens LN. If one of the surfaces is plane instead of spherical then its centre of curvature will be at infinity.

Principal axis: Generally there are two spherical surfaces of a lens. The straight line passing through the two centres of curvature of the two spherical surfaces is called the principal axis. In figure 9.11 the straight line C_1C_2 is the principal axis of the lens.

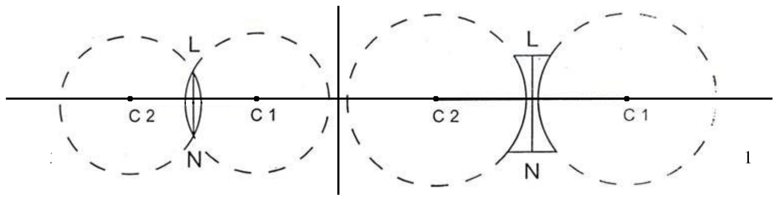


Figure: 9.11

Optical centre: The point on the principal axis inside a lens through which if a ray of light is passed then due to refraction if the ray emerges from the other surface being parallel to the incident ray then it is called optical centre.

In figure 9.12 a ray of light PQ incidents on a surface of lens and refracts along the path QR. This ray emerges from the other surface along the path RS. The emergent ray RS and incident ray PQ are parallel to each other. The refracted ray QR intersects the principal axis C_1C_2 at point O inside the lens. The point O is called the optical centre of the lens.

Figure: 9.12

For a thin lens the point on the principal axis through which if the ray of light is passed and due to refraction no deviation of ray takes place that point inside the lens is called optical centre.

Principal focus: When a pencil of parallel rays adjacent to the principal axis incident on a lens in a direction parallel to principal axis, then after refraction the refracted rays either actually converge to a point on the principal axis (in the case of convex lens) or they appear to diverge from a point on the principal axis (in the case of concave lens). This point on the principal axis is called the principal focus of the lens. In figure 9.13 the point F is the principal focus of the lens.

Focal length: The distance of the principal focus from the optical centre of a lens is called the focal length of the lens. Focal length is expressed by f. In the figure 9.13 OF is the focal length of the lens.

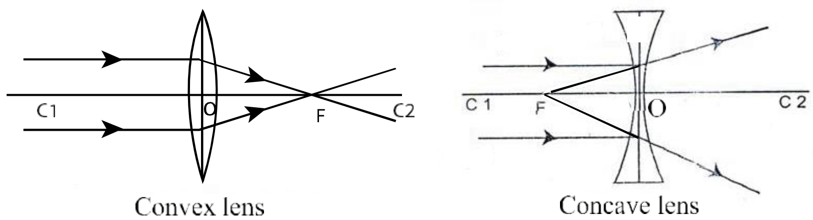


Figure: 9.13

Focal plane: The imaginary plane at the principal focus perpendicular to the principal axis is called focal plane of the lens. In the figure 9.14 ABCD is the focal plane of the lens.

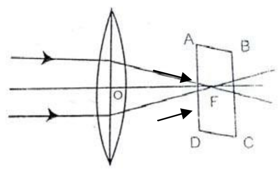


Figure: 9.14

Rules of drawing ray diagram in lens:

1. Rays of light incident in a direction through the optical centre of a lens is refracted along the same straight line without any deviation (Fig: 9.15 A and B)
2. Rays incident in a direction parallel to the principal axis after refraction passes through the principal focus (in the case of a convex lens) [9.15 (C)] or appear to diverge from the principal focus (in the case of a concave lens) [9.15 (D)].
3. A ray of light incidents through the principal focus (in the case of a convex lens) [9.15 (E)] or directed towards the principal focus (in the case of concave lens) [9.15 (F)] after refraction through the lens becomes parallel to the principal axis.

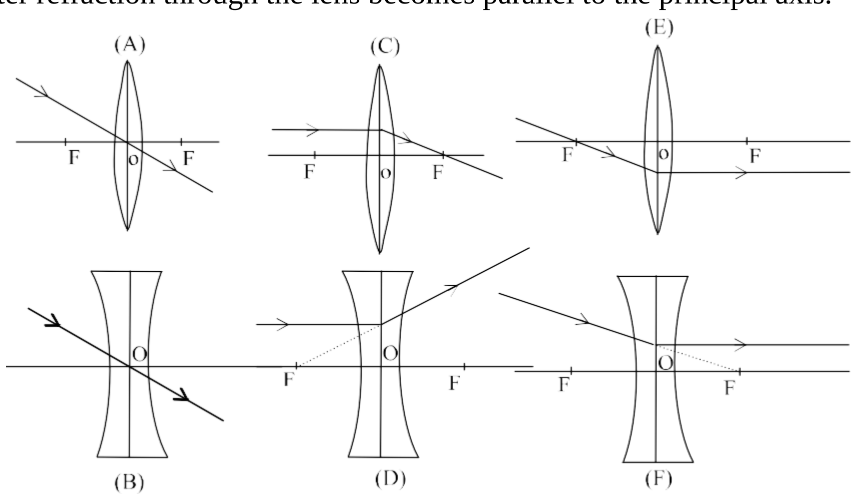


Figure: 9.15

Image of an extended object

Convex Lens:

Suppose LOL_1 is a convex lens. FOF′ is its principal axis, O is its optical centre and F is its principal focus. An extended object PQ is placed perpendicularly on the principal axis in front of the lens at a point between f and 2f. The image of the object PQ is to be drawn.

A ray of light PR coming from P parallel to the principal axis incidents at R and is refracted through the principal focus F along the path RFP_1. Another ray PO from P passes through the optical centre O and is refracted along the path OP_1. The refracted rays RFP_1 and OP_1 meet at point P_1. So, P_1 is the real image of point P. From point P_1 a perpendicular P_1Q_1 is drawn on the principal axis. So, P_1Q_1 is the real image of PQ. Here OQ is the distance of object and OQ_1 is the distance of image [figure 9.16].

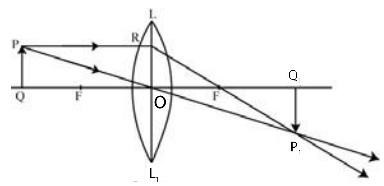


Figure: 9.16

In this case the image is real, inverted and magnified.

Depending on the position of the object on the principal axis the nature of image may be real, virtual, erect, inverted, magnified, diminished or equal in size to the object.

If the position of the object is between the focus and optical centre the image will be virtual, erect and magnified.

Image of an extended object

Concave Lens:

Suppose LOL_1 is a concave lens. FOF′ is its principal axis, O is its optical centre and F is its principal focus. An extended object PQ is placed perpendicularly on the principal axis in front of the lens [fig: 9.17].The image of the object PQ is to be drawn.

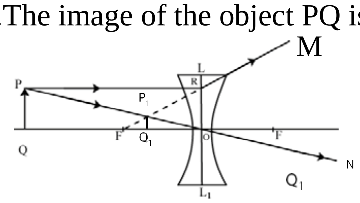


Figure: 9.17

A ray of light PR emitted from P parallel to the principal axis incidents at R and is refracted along RM in such a way that it appears that the ray is coming from principal focus F. Another ray PO from P passes through the optical centre O` and refracts straight along PON. These two refracted rays are divergent so they do not meet. If they are extended in the backward direction then it appears that they are coming from the point P_1. Now if we draw a perpendicular P_1Q_1 on the principal axis from P_1 then P_1Q_1 will be the virtual image of PQ. This image is virtual, erect and smaller than the object in size. Concave lens always forms image which is virtual, erect and smaller in size than the object.

Identification of lens:

When we hold a finger in front and very near of a lens and then look from the other side if a virtual, erect and magnified image of the finger is found to be formed, the lens is a convex one. But if the image is virtual, erect and diminished, the lens is a concave one.

Do it yourself: Hold a convex lens close to your book. Do the writings seem larger? Why?

After being refracted by convex lens, magnified image is formed and so you are seeing the writings larger.

9.8 Power of lens:

Suppose there are two convex lenses. The focal length of the first one is greater and the focal length of the second one is smaller.

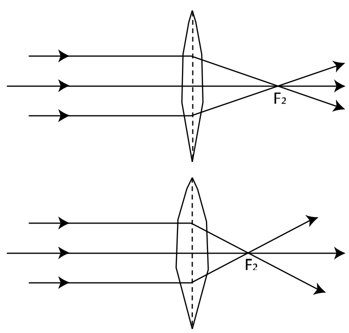


Figure: 9.18

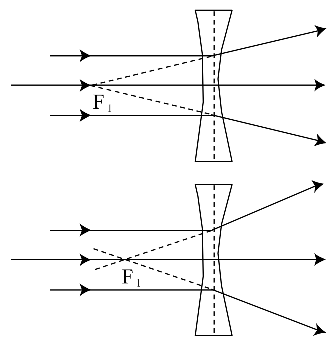


Figure: 9.19

Now if a beam of parallel rays of light parallel to the principal axis incidents on the lens then after refraction the rays will meet at the principal focus. In the case of second lens that focal point will not be as far as the first one, rather it will be nearer. The power of a convex lens is the ability to convert a parallel beam of light into a convergent beam. Therefore it can be said that the power of the first lens is less than that of the second one. The power of a lens is greater if its focal length is less and the power will be less if the focal length is greater.

In figure: 9.19 the refraction of parallel rays in concave lens is shown. In the case of concave lens the ability to convert a parallel beam of light into a divergent beam is called its power. The more the concave lens can diverge a beam of parallel rays the more is its power. That is the shorter the focal length of a lens, the greater is its power.

In general we can say that the capacity of a lens to convert a parallel beam of light into a convergent beam or into a divergent beam is called the power of the lens.

There is a relation between the power P and focal length f. That is, $P = \frac{1}{f}$.

The power of a lens of focal length one meter is called one diapter (d). The power of spectacle that the eye specialists recommend is written in diapter unit.

Sign convention:

All distances are to be measured starting from the optical centre of the lens. All real distances are positive and real distances means the distance actually covered by the ray of light. SO, distance of real object, distance of real image and distance of real focus are all taken to be positive. All virtual distances are negative. Distance of virtual object, distance of virtual image and distance of virtual focus are all taken to be virtual distance.

Focal length of convex lens is positive and focal length of concave lens is negative.

Mathematical example 9.3: If the focal length of a lens is +0.1m then what is the power of the lens?

We know,

$$P = \frac{1}{f} = \frac{1}{+0.1} = 10D$$

Ans: 10D

Given,

Focal length, f = +0.1m

Power, P =?

9.9 Human eye

The structure and functions of human eyes are similar to a camera. We know that photograph is taken by keeping the object before a camera. Similarly if any object is placed before the eyes, there is a picture of that image inside the eyes. The structure and functions of eyes are discussed below.

The structure of eyes:

1. **Eye-ball:** The circular object situated in the eye cavity/orbit is called the eye-ball. This ball is flattened in its front and back. It can rotate around a certain area in the eye cavity.
2. **Sclerotic:** It is composed of white, strong and dense fibrous tissues [fig: 9.20]. It determines the size of the eyes and protects the eyes and save them from any external hazards.
3. **Cornea:** It is the frontal part of sclerotic. This part of sclerotic is transparent and slightly convex at the outer side.
4. **Choroid:** There is a deep black layer on the inner side of the sclera. This is called choroids. Due to this black layer light is not reflected internally within the eye.

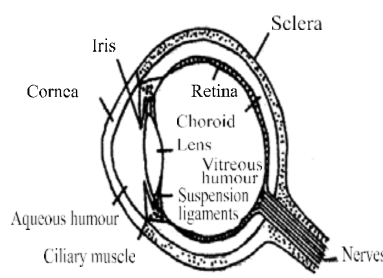


Figure: 9.20

5. **Iris:** Just behind the cornea, there is an opaque diaphragm. It is called Iris. The colour of the Iris may vary from person to person. Usually the colour of Iris is black, light azure or deep brown. Iris regulates the amount of light falling on the eye lens.
6. **Pupil:** The hole at the centre of the Iris is called Pupil. Through this pupil, light enters the eyes.
7. **Eye lens:** It is the most important part of the eye. It is situated just behind the pupil. It is made of transparent organic substances. Its radius of curvature of the back side is greater than that of the front side. This lens is hooked in the eye ball by ciliary

muscles and suspensor ligaments. Due to the contractions and suspension of these muscles and ligaments, the curvature of the lens changes. It ultimately changes the focal length. To see different objects of near and distance, we need to adjust our focal length.

8. **Retina:** Just behind the eye lens, there is a layer of semi-transparent light sensitive membrane in the innermost side of the eye ball. It is called the retina. It is made of some nerve-fibers called rods and cones. These nerve-fibers are connected to the eye-nerves. When light falls on the retina, it creates a kind of excitement in nerve-fibers. Hence, a sensation of vision is created in the brain.

Aqueous humour and Vitreous humour: The saline watery fluid that fills up the space between the eye lens and cornea is called aqueous humour. On the other hand, the jelly like substance that fills the gap between retina and eye lens is called vitreous humour.

Accommodation of eye: If an object is placed before a convex lens, it forms a real image at the back of the lens. If a screen is placed at the back of the lens an inverted image of the object is found on the screen.

Experiment proves that in a certain place of the screen the image is most clear. For any reason, if the object is moved forward to or backward from the lens, the screen is to be moved forward or backward as well to get a clear image. Now if we want to get a clear image of the object on the screen at its previous position, we have to use lenses of different focal lengths.

Things happen in a similar way in case of eyes. The cornea, aqueous humour, eye lens and vitreous humour together work as a convergent lens system. If any object is placed before our eyes and if the image of that object is reflected on our retina, then there will be a sensation of vision in the brain. As a result, we see the object. We see objects of different distances through our eyes. The specialty of the eye lens is that it changes its shape according to the necessity and thus it changes its focal length. Due to the change of the focal length, image of objects at any position is always formed at the same distance from the lens. Therefore, clear images are formed on the retina. The capacity of eyes to change their focal length to see objects of any distance is called the accommodation power of eyes. And the process is called accommodation of eye.

Least distance of distinct vision: From our daily experience, we see that the closer the object is to the eyes the clearer it is to see. But, there is a point after which it cannot be seen clearly. The nearest point at which eyes can see without any difficulty is called the distance of distinct vision. For any normal eye, this distance is nearly 25cm. So, the near point of a normal eye is 25 cm away from the eye. It is difficult for our eyes to see any object clearly that stays closer to this distance.

Again, the distance which is maximum from the eye to see an object is called the farthest distance of distinct vision. It is also called the far point of the eye. The far point of any normal eye is at infinity. This means that a normal eye can see up to a huge distance.

Persistence of vision: If any object is placed before our eyes an image of the object is formed in our retina. As a result of it, we see the object. For any reason, if the object is removed from our eyes, a sensation of that object stays in our brain for about 0.1 second. This period is called the persistence of vision.

Advantage of having two eyes:

If we see an object by our two eyes we can only see a single object. Though each eye forms individual images on their own retinas but the brain combines the two images to make a single one. We can measure the distance accurately for having two eyes. So, it is very difficult to thread a needle keeping one eye closed. Apart from that, due to the relative position of our eyes with respect to the object we see the right portion of the object better with our right eye and the left portion better with our left eye. If we see an object by our two eyes the superimposition of two images will happen and we will be able to see the object clearly.

9.10 Function of an eye:

We have known earlier that there is a convex lens just behind the pupil of the eye which is called eye lens. It is necessary to change the focal length of eye lens to see the distant as well as near objects.

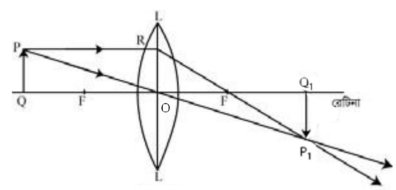


Figure: 9.21

In figure 9.21 the eye lens is shown. In front of the eye i.e. in front of the lens PQ is an object. A ray of light PR coming from P parallel to the principal axis incidents at R and is refracted through the principal focus F along the path RFP_1. Another ray PO coming from P passes through the optical centre O and is refracted along the path OP_1. The refracted rays RP_1 and OP_1 meet at point P_1. From point P_1 a perpendicular P_1Q_1 is drawn on the principal axis. So, P_1Q_1 is the real and inverted image of PQ.

Where the image is formed is known as retina. It consists of some light sensitive cells or nerve-fibers called rods and cones. When image or light falls on retina a kind of stimulation is created in the nerve-fibers and as a result a sensation of vision is created in the brain and we can see the object.

It is mentionable that the inverted image of an object is formed on retina. This sensation is transmitted to the brain by the eye nerves. The brain then and there inverts the inverted image formed in the retina and we can see the object in its right shape and size.

9.11 Defects of vision and its remedy

The range of vision of a normal eye is 25 cm to infinite distance. This means that normal eye can see any object at a distance between 25 cm to infinity. An eye which is unable to see any object distinctly within this distance that eye is a defective eye. Usually an eye has two kinds of defects. These are:

1. Short sight or Myopia
2. Long sight or Hypermetropia

1. Short sight or Myopia: If anybody has this problem, he or she cannot see any distant object distinctly but can see anything of near distance distinctly. Sometimes the distance of near point for such an eye is less than 25 cm. Therefore, if the near point of the eye is less than 25cm then that is also considered as short sight.

Cause: This defect may be caused if the radius of the eye ball increases or if the focal length decreases for any reason and thereby increases the power of convergence of the eye lens. [Figure 9.22 (a)]

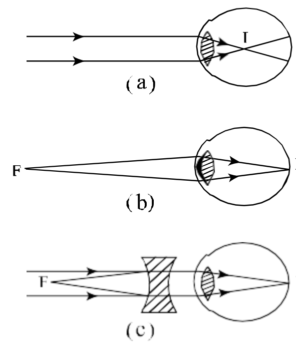


Figure: 9.22

Effects of such problem: In this case, rays of light coming from any object placed at large distance, after refraction through the eye lens converge to a point I in front of the retina (Fig. 9.22 a). As a result, objects are not seen distinctly. For this kind of eye, the far point is not situated at infinity. Rather, it is a certain finite point F. For this reason, such type of eye cannot see object distinctly placed beyond F (Fig 9.22(b)]

Remedy: It has been said earlier that such type of defect arises due to the increase in the power of convergence of the eye lens. To remedy this defect, we need to decrease the power of convergence of the eye lens. For doing this, concave lens is used as aid lens or as spectacles.

Besides, only a concave lens can create a virtual, erect and diminished image at a position nearer than that of the object. Therefore, to rectify short sight, a concave lens or spectacles should be used as aid lens in front of the eye. They should have such focal length or power so that due to refraction through the image of an object placed at infinity the image is formed at the far point of the defective eye [fig 9.22 c]. We know that when the object is at infinity its virtual image is formed at the principal focus of the concave lens. Therefore, the focal length of the concave lens used as spectacles should be equal to the distance of the far point of the defective eye.

2. Long sight or hypermetropia: If any eye has this type of defect, it can see distant objects distinctly but cannot see near objects distinctly.

Effect of such problem: In such a case, rays coming from the object placed at the near point of a normal eye, after refraction through the eye lens converge to a point I behind the retina [Fig. 9.23 (a)]. As a result, the image becomes blurred. The near point N of such an eye shifts away to O, which is more than 25 cm (the distance of the near point for a normal eye). Therefore, such a defective eye cannot see any objects distinctly, which is placed nearer to O [Fig 9.23 (b)].

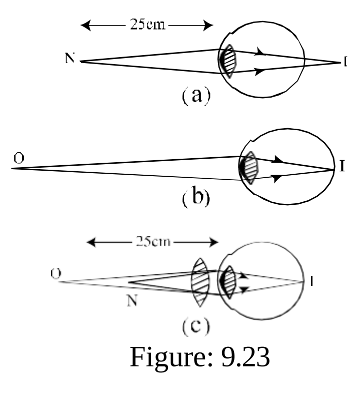


Figure: 9.23

Remedy: It is already said that such defect of eye arises due to the decrease in the power of convergence of the eye lens. Therefore, to rectify the defect, the power of convergence of the eye lens should be increased. For this, convex lens of suitable focal length i.e. of suitable power should be used as aid lens or spectacles.

We also know that only a convex lens can provide a virtual and erect image at a distance greater than that of the object. For this reason, a convex lens of suitable focal length or power is used in this case as aid lens or spectacles in front of the eye. The focal length of this lens should be such so that due to the refraction the virtual image of an object placed at normal near point N, is formed at the near point O of the defective eye. [Fig 9.23 (c)]

9.12 Perceptions of coloured object:

When we see an object, then the light from the object falls on our eyes. The light being refracted by the lens of eye forms an image of the object on retina. There are numerous nerves in retina which send this perception to brain. We can see the object after the perfect analysis of the signals in the brain. The nerves that have reached the brain from retinas are called rods and cones. Among them the cones cells are colour sensitive. There are three types of cone cells – blue colour sensitive, red colour sensitive and green colour sensitive cone cells. It does not matter whether the colour is compound or complex, the eye perceives the colour of an object in terms of these three colours. The cone cells of retina send the accumulated information to brain. Brain separates all these colours through a particular process. Thus we can perceive the colour of coloured object.

9.13 Uses of refraction in our daily life:

There is a convex lens in our eyes. When we seen an object, the light from the object, being refracted by the lens of the eye, forms an image on retina. We can see the object when a real and inverted image of that object is formed on retina. So, refraction of light helps us to see an object.

There are many people who have defects in their eyes. Among them some cannot see the distant object, some cannot see near object. For the remedy of the defects we use spectacles made by lens of particular power. The incoming light refracted through the lens falls on our eyes and helps to see the object properly. Therefore, refraction plays an important role to see an object.

By using the property of refraction of light we can take photograph with camera, we can see very small object magnifying it by microscope and see the distant object by telescope.

The optical fiber that we use in the field of health and telecommunication is also the contribution of refraction of light.

There are fish aquariums in many of our houses. If we keep some colour fish in the aquarium we can enjoy their interesting movement. The light from the fish coming through water at first falls on the glass of the aquarium. After the refraction of light through the glass, the sight reaches our eyes. Therefore it is also a contribution of refraction of light.

Chapter ten

STATICAL ELECTRICITY

[We know that every matter consists of protons and electrons. Do you know that there are more than 10^{28} protons and almost equal number of electrons in your body? The basic property of these protons and electrons is charge. The charge of proton is considered as positive and of electron is negative. The charged objects that apply force on each other is known as electric force. The electric force is a basic and important force of nature. In this chapter we will see how a body is charged. We will also learn detect the presence of charge and measure the force between them. As the discussed charges will remain static we will call the chapter Statical Electricity. Finally we will discuss the usage of this static charge and some of its danger and the ways to remain safe from them.]

By the end of this chapter we will be able to-

1. Explain the basic causes of production of charge on the basis of structure of atom.
2. Explain the causes of production of charges by the process induction and friction.
3. Detect the nature of charge by electroscope.
4. Measure the electric force applying Coulomb’s law.
5. Explain the cause of production of electric field.
6. Explain the direction of electric lines of force can represent the direction of electric field.
7. Explain the electric potential.
8. Explain the function of capacitor to preserve electric energy.
9. Explain the usage of static electricity.
10. Explain the strategy to be safe from the risk of danger of static electricity.

10.1 Charge

In a winter morning Sourov took his plastic comb to comb his hair. Before combing his hair he rubbed the comb with his woolen pullover for a while. While combing his hair he observed surprisingly that he cannot do it because all the hair was becoming straight and repels away each other. As soon as Sourov brings the comb close to the tale he observes the comb attracting some pieces of paper on the table. Some of you may have the same kind of experience like Sourov. In our daily life we observe that many objects around us behave like the comb of Sourov.

Do it yourself: Rub your dry hair with your plastic scale for a while and hold it near some pieces of paper.

We see that an object attracts another object in a special condition or becomes charged that is electricity produced in the object. Their charge remains static in the place of its production. So it is called static electricity. Now let us see what we mean by being charged.

We know that each matter is consisted of small particles. The atom of every matter consists of electrons and which revolves around the nucleus. In the nucleus there are two type of particles-proton and neutron. The fundamental and special property of primary particles (electron and proton) of which the matter consist of is electrical property, which is determined by charge. The charges of electrons are negative and the charges of protons are considered to be positive. Neutron is electrically neutral that is it has no charge. The amount of charge in a proton is equal to the charge of an electron. Naturally an atom has an equal number of protons and electrons. As a result in the atom whole atom there is no electrical property to be detected. The number of electrons and protons in different matters is different.

As long as the number of electron and proton are equal in any atom, it is electrically neutral. But if their number is not equal in any atom, then the atom will be charged. If the number of electron decreases, the number of proton increases. This situation is said to be charged positively. Again, if these scattered electrons are joined with any atom, the number of its electron increases, as a result it is charged negatively. The shortage or excess of electrons in any atom is considered to be charged.

The substances through which electricity or electric charge can pass easily are called conductors, e.g. metal, soil, human body etc. Generally the metals are good conductors. Copper, silver, aluminium etc are good conductors. On the other hand the substances through which electricity or electric charge cannot pass easily are called nonconductors or insulator, such as wood, paper, glass etc.

10.2 Electrification by friction:

Experiment: Suspend a light pith ball freely with a string from a stand or a hook. Rub one end of a glass rod with a piece of dry silk cloth very well. It will be more convenient if the glass rod and the silk are dried to make them warm. Now bring the rubbed end of the glass rod near the freely suspended pith ball.

In normal condition the number of protons and electrons in any atom is equal. But every atom has got affinity for getting excess electrons. This affinity for excess electron is different in different substances. That is why when two bodies are brought in contact with each other, the body which has greater affinity for electron collect electrons from other body and gets charged negatively this happens when a glass rod is rubbed with silk.

Figure: 10.1

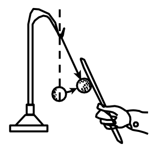


Figure: 10.2

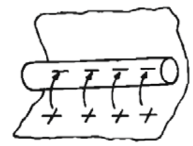


Figure: 10.3

[Fig: 10.1] Silk has more electron affinity than glass and as such these two are rubbed together, the electron of glass goes to silk. As a result, the silk gets charged negatively and the glass rod becomes positively charged. This is why glass rod attracts pith ball [Fig; 10.2]. Again when a rod of ebonite or polythene is rubbed with flannel, polythene rod gets charged negatively and the flannel becomes positively charged. Because polythene has more affinity for electrons than that of flannel and so when they are rubbed together free electrons of flannel moves to ebonite or polythene and gets charged negatively [Fig 10.3].

10.3 Electric Induction

We know that when two bodies are rubbed together electric charge is produced. Again when a charged body is brought in contact with another neutral body the later is charged. When the neutral body is placed not in contact with the charged body but close to the charged body, the former becomes charged. This happens due to induction. The process of charging a neutral body by bringing it very near to the charged body is called electrostatic induction. With a simple experiment the electrostatic induction has been explained below.

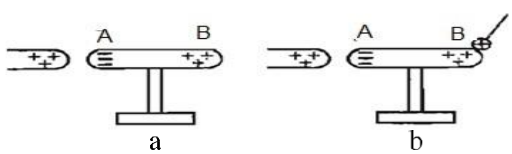


Figure: 10.4

Experiment: A dry glass rod is rubbed with silk. One end of the rod is brought very near to the neutral conductor rod AB keeping the other end of the glass rod in hand [Fig: 10.4(a)]. As a result the free electrons of the conductor are attracted by the positive charges of the glass rod and move the end A. Therefore, the end B falls in short of electrons and is charged positively. The end A is charged negatively. With a charge collector [a small metal sheet attached to a nonconductor handle] if some charges are collected from end B and their nature is detected with the help of an electroscope then the above discussion will be proved.

Here no new charge is produced. Due to the presence of the charges glass rod equal amount of opposite charges are separated only and move towards the end o the conductor. As long as the glass rod is present near the conductor AB, the opposite charges are separated and remain at the end of the conductor.

In the above experiment the positive charges in the glass rod which has created induction in the conductor AB is called inducing charge. The charges which are accumulated in the conductor A are called induced charge.

Extended activities: Rub a balloon full of air with your shirt. Then press the balloon with the wall of your house for a while and then release it. What did you observe? The balloon becomes attached to the wall.

Extended activities: Rub a plastic object with your shirt. Then hold it near a narrow flow of water falling from a tap. The flow of water will bend towards the plastic object.

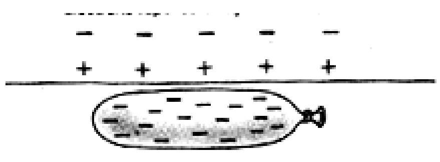


Figure: 10.5

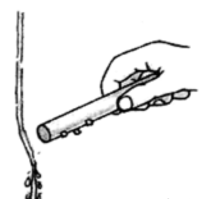


Figure: 10.6

The negative charge of the balloon produces electrostatic induction in the wall. The induced positive charge in the wall attracts the negatively charged balloon [Fig: 10.5]. Same case occurs with the narrow flow of tap water [Fig 10.6].

10.4 Electroscope

The instrument which detects the presence and nature of charge in any body is called electroscope. A metallic circular disk is fixed on the top of brass or any metallic rod R [Fig: 10.7] and at lower end of the rod two light leaves of gold are attached. Instead of gold aluminium or any other light metal can also be used. The lower end of the rod with the leaves is placed in a glass jar passing through a cork of nonconductor matter C. As the apparatus is kept inside a glass jar, the humidity and the wind cannot damage the instrument.

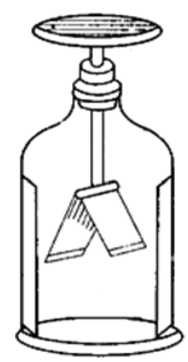


Figure: 10.7

Charging the electroscope:

If a glass rod is rubbed with silk, it becomes positively charged. If that charged rod is attached to the disk or sphere of the electroscope, some charge is transferred from the rod to the disk. This charge reaches to the gold leaves through conducting metal rod. As the gold leaves receive similar charges, they repel each other and move away from each other or explode. In this situation, if the glass is removed but the gap between the leaves is not reduced, then it can be decided that the electroscope is charged with positive ions. To charge the electroscope with negative ions, an ebonite rod should be rubbed with flannel and this negatively charged ebonite rod be allowed to touch the disk in the above mentioned process. As a result, the gold leaves of the electroscope will be charged negatively and they will repel each other and will remain in that position. The more is the quantity of charge the more will be the gap between the leaves.

Detection of existence of electric charge:

To determine the presence of charge in any body, the body may be brought to an unchanged electroscope. If the two leaves move away from each other then it is understood that there is an existence of charge in the body but if they don't move away from each other then it is understood that the body has no charge.

Detection of the nature of charge:

To know the nature of charge in any charged body, the electroscope should be charged either positively or negatively. Suppose the electroscope is charged positively. In this position, the leaves having positive charge will stay apart. Now if the experimental body is brought in contact with the disk of the electroscope and if the gap between the leaves decreases, then it is understood that the body is charged negatively. On the other hand if the gap increases due to touching the disk with the experimental body, then it is understood that the body is positively charged.

10.5 Electric Force:

Nature of force:

A positively charged plastic rod is suspended by nylon string. [Fig: 10.8]

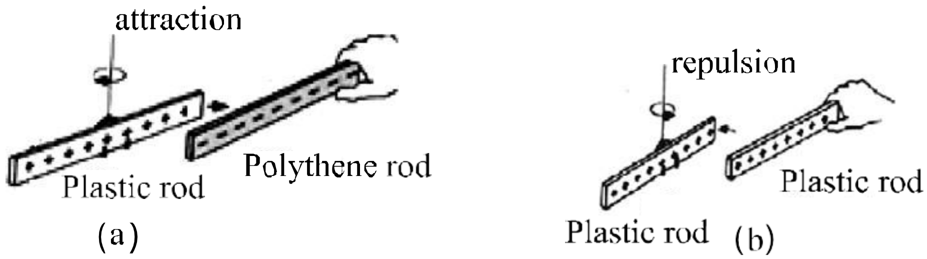


Figure: 10.8

Now a negatively charged polythene rod is brought near it. What do you observe? The plastic rod will move towards the polythene rod. So, it is proved that two oppositely charged object attract each other. [Fig: 10.8 (a)]

Now what will you observe when a positively charged plastic rod is brought near a freely suspended positively charged plastic rod the suspended rod will move apart quickly. That is charges of same nature repel each other.

Coulomb's Law:

We know that the charges of opposite nature attract each other and charges of same nature repel each other. The force of attraction or repulsion between the two charges depends on,

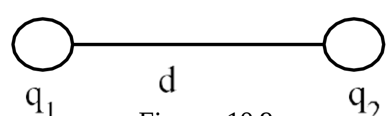


Figure: 10.9

1. quantity of charges.
2. distance between two charges.
3. the nature of the medium between the two charges.

Scientist Coulomb states a law about the force of attraction or repulsion between the two charges. This is called Coulomb's law.

Law:

The forces of attraction or repulsion between two charged bodies in particular medium is directly proportional to the product of the charges and inversely proportional to the square of the distance between them and the force acts along the straight line connecting them.

Suppose, two charges q_1 and q_2 are at a distance d from each other [Fig: 10.9]. If the force of attraction or repulsion between these two is F, then according to Coulomb's law,

$$F \propto \frac{q_1 q}{d^2}$$

$$\text{or, } F = \frac{Cq_1 q}{d^2} \qquad (10.1)$$

Here C is a constant of proportionality. Its value in vacuum is $9 \times 10^9\ Nm^2C^{-2}$. Sometimes it is called coulomb's constant.

Unit of charge: The unit of charge is coulomb (C). It is a derived unit. Coulomb is defined from ampere.

If 1 ampere (1 A) current flows through a conductor for 1 second (1 s), then the amount of charge that passes through any cross section of the conductor is called coulomb (1 C).

Mathematical Example 10.1: Two bodies of charges 20C and 50C are placed at a distance of 2m in vacuum. Find the amount of force between the charges.

We know,

$$F = \frac{Cq_1q_2}{d^2}$$

$$= \frac{9 \times 10^9\ Nm^2C^{-2} \times (20C \times}{(2m)^2}$$

$$= 2.25 \times 10^{12}\ N$$

Here,
1st charge, $q_1 = 20C$
2nd charge, $q_2 = 50C$
Distance = 2m
Force, F = ?

10.6 Electric Field

Suppose A is a positively charged body. Now if a charge $+q$ is placed at point P, then due to the charge of A, the $+q$ charge will gain a force. We say that at point P there is a an electric field, the source of which a charged body A. That is if a charged body, in which the influence of the charged body exists is called the electric field of the charged body.

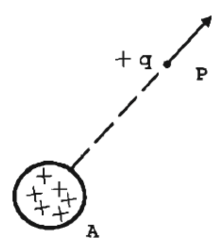


Figure: 10.10

Electric Intensity:

According to coulomb's law, it is found that the nearer the point P [Fig 10.10] to the charged body A, the more will be the strength of electric field at that point. The strength of the electric field is called intensity. If at any point of an electric field a unit of positive charge is placed and the force that it acquires is called the electric intensity at that point. If the charge at point P acquires a force F, then the intensity of electric field at that point P,

$$E = \frac{F}{q} \qquad (10.2)$$

Electric intensity is a vector quantity and its direction is along the force acting on a unit positive charge placed in an electric field. The unit of electric charge is newton/coulomb (NC^{-1}).

Mathematical Problem 10.2: If a body of charge 5C is placed at a point in an electric field then it gains a force of 200N. Find the magnitude of electric intensity of that point.

We know,

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

$= \frac{200N}{5C}$

$= 40\ NC^{-1}$

Ans: $40\ NC^{-1}$

Here,
Charge, q= 5C
Force, F= 200N
Electric intensity, E= ?

Electric Lines of Force:

Michel Faraday introduced electric lines of force to get an idea about electric field. If a positive charge is placed in an electric field it would experience a force. If the charge is a free one, gaining this force instead of remaining stationary it would move in a definite path. Electric line of force is the path of a free positive charge that moves in an electric field. There is no real existence of lines of force. These lines are imaginary. The electric lines of force are used to for measuring the electric intensity and explaining its direction at a point in an electric field. The lines of force of an electric field are such that, the tangent drawn at a point to a line of force indicates the direction of electric intensity at that point. The number of lines of force passing through unit area perpendicular to the lines of force at a point in the electric field is proportional to magnitude of the electric intensity at that point. In a diagram of lines of force of an electric field, the gap between the lines indicates the magnitude of intensity of electric field. In an electric field where the lines of forces are closer magnitude of E is greater there and where the lines of forces are away magnitude of E is less there.

For different positions of charged object, the nature of the lines of force of an electric field varies. Lines of force of a few electric are described below. For the simplicity of description the conductors are taken as spherical.

1. For an isolated positive charge the nature of lines of force is shown in figure 10.11(a). In this case the lines of force emerged uniformly from the surface of the conductor perpendicularly. If the charge of the body increases then the number of lines of force also increases.
2. The lines of force of an electric field produced by two equal and opposite charges are shown in figure 10.11(b). In this case the line of force emerges from positive charge and terminates at negative charge.
3. The lines of force of an electric field produced by two equal positive charges placed nearby are shown in figure 10.11(c). In this case the lines of force go far away from each other; as a result there will be no lines of force in between them.

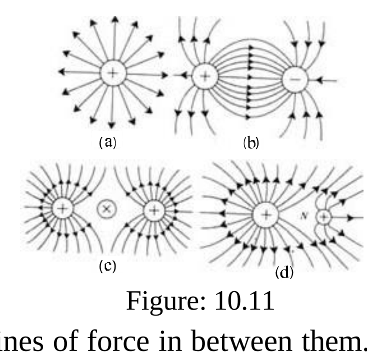


Figure: 10.11

In figure this place is indicated by ‘X’ sign. If a charge is placed at this place it will experience no force. This point is called neutral force.

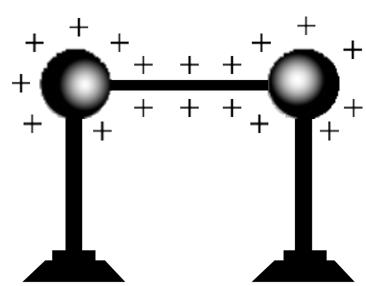
4. The lines of force of an electric field produced by two unequal positive charges placed nearby are shown in figure 10.11(d). In this case, the neutral point ‘N’ would not be nearer to the smaller charges.

10.7 Electric Potential

As there is intensity of an electric field, it also has electric potential. Potential determines the direction of motion of a charge in an electric field and also determines the direction in which the charge will flow when two charged conductors are connected by a conductor wire. If the charge creating field is positive, some work is done against the force of repulsion if another positive charge is brought near it. Therefore, the more positive charge is brought from a point at infinity nearer to the body, the more work will have to be done. So, within the electric field of a positively charged body, the more a point is brought nearer to the body, the more will be the quantity of potential. If any electric field created by a positively charged body and a free positive charge is placed and allowed to move freely, it would go away from the body. Therefore, we can say that positive charge moves from higher potential to lower potential. On the other hand, negative charge moves towards positively charged body. Thus, negative charge moves from lower potential to higher potential. If the body creating the electric field is charged negatively, then some work will be done due to attraction of a unit positive charge bringing towards it. A positive charge itself does work while coming from infinity towards a negatively charged body, which creates an electric field. As a result the charge loses energy and the potential at a point in the electric field is considered as negative.

Measurement of potential: The work done to bring a unit positive charge from infinity to a point in an electric field is called the potential of that point. Again from infinity if a unit of positive charge is brought near to the conductor, the work done by the electric force or against the electric force is called potential of that conductor.

If a unit positive charge q is brought very near to the conductor from a point at infinity and if the amount of work done is W, the potential ‘V’ of the conductor or of that point will be, $V = \frac{W}{q}$



Electric potential determines in which direction the flow of electric charge takes place when two charged conductors are electrically connected.

If two positively charged metallic spheres are connected by conducting wire (fig:10.12) then any of the following phenomena may occur.

1. Some charge from the left sphere may go to the right sphere.
2. Some charge from the right sphere may go to the left sphere.
3. The charges may remain as it is.

The movement of charge from one sphere to another does not depend on the quantity of charge of the spheres but it depends on electric potential. The positive charge will flow from sphere to sphere of higher potential to that if lower potential. This flow of charge will continue until the potential of these two spheres become equal. So, potential is an electric condition of a charged conductor that determines whether it takes or gives up charge when connected to another charged conductor by a connecting wire.

Similarity between potential and temperature and free surface of liquid:

The role which is played by temperature and the height of free surface of liquid in heat and hydrostatics respectively, potential plays the same role in electrostatics. We know, if we connect two bodies thermally, there may be exchange of heat between them. The flow of heat does not depend on the mass of i.e. inherent heat within it, but on the temperature. If we connect a highly heated body with another body which is much heavier but of low in temperature, then heat will flow from the small body to the large body, though the amount of heat is much greater in the larger body than the smaller one.

Two tubes A and B are placed at same horizontal level. They are connected by a tube with a stop cock S (Fig: 10.13). Closing the stop cock water is poured in to A and B tubes in such a way so the height of water column is same in two tubes. As the diameter of B is much greater than that of A, to raise the water level at same height much more water is requires for tube B. Now if the stop cock is opened there would be no change in water height i.e. there is no flow of water. Though the amount of water is different in two tubes, but as there is height is same, so there is no flow of water. Now if closing the stop cock a little amount water is poured into A tube, the amount of water in it will still be less than that of B, but the height of water level will increase slightly. After if the stop cock is opened, then water will flow from A to and the height of the water column will w same in both A and B. It is thus understood that flow of water does not depend on the amount of water rather the height.

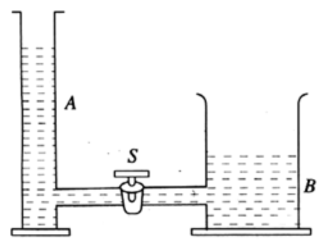


Figure: 10.13

Suppose two conductors are positively charged. The amount of charge in first conductor is greater than that of second conductor but the potential of the first one is less than that of the second. Now if, two conductors are connected electricity then positively charge will flow from second conductor to first conductor. Though the amount of charge is greater in first conductor yet it will take charge because its potential is low. As a result of flow of charges when the potential of the two conductor become equal then the flow will stop.

Therefore it can be said, the role of temperature in heat, role of free surface of liquid in hydrostatic and the role of potential in electrostatic are same.

Electric Potential of Earth:

Earth is an electric conductor. When a charged body is connected to the earth, it becomes electrically neutral. When a positively charged body is grounded electrons coming from the earth neutralize the body. When a negatively charged body is grounded electrons from the body flow to the earth and the body becomes neutral. The earth is so big that if charge is added or taken away from it its potential does not change at all. Likewise if water is taken away from sea or poured in the water level does not change. The earth is always taking charge from different bodies and simultaneously it supplies charge to other bodies. Hence earth is considered charge less. To determine the height of a place the height of the sea level is taken as zero, similarly to determine the potential of a body, the potential of earth is taken as zero.

Zero, Positive and Negative Potential:

The potential of an uncharged conductor is taken as zero. When a charged conductor is connected to the earth its potential becomes zero. Because, in the connected state , both the conductor and the earth is considered as a single conductor. The potential of a positively charged body is positive and negatively charged body is negative.

Unit of potential, Volt:

If the work done in bringing 1 coulomb (1C) of positive charge from infinity to a point in the electric field is 1 joule (1J), then the potential at that point is called 1 volt (1V).

The potential at a point in an electric field is 20V means to bring 1 coulomb (1C) positive charge from infinity to that point 20J work is to be done.

Potential difference:

Let, in an electric field A and B are two points and the potentials of the points are V_A and V_B respectively (fig: 10.14). The work done in bringing a unit positive charge from infinity to point A is V_A and to point B is V_B. Therefore the work done in bringing a unit positive charge from point B to point A is $V_A - V_B$ i.e. the potential difference between these two points.

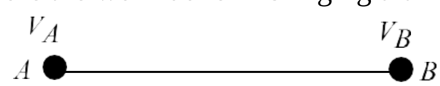


Figure: 10.14

The work done in transferring a unit positive charge from one point to another point in an electric field is called potential difference between two points.

10.8 Electric capacitor:

The capability of storing energy as electric charge is called capacitor. Capacitor is the mechanical device designed to sustain the capacitance. Capacitor stores energy from a source such as electric cell and again uses it. A capacitor is made by placing an insulating material such as air, glass, plastic etc. Therefore, the mechanical process of storing energy as electric charges by placing an insulating medium in between two nearby conductors is called capacitor.

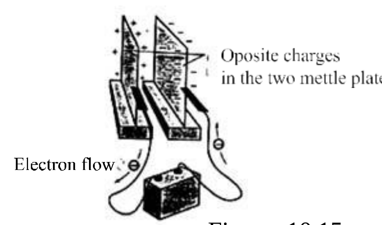


Figure: 10.15

A simple capacitor is made by placing two insulating metal plates parallel to each other. When a battery is connected to its two plates (Fig:10.15) then electrons may flow to a plate from its negative rod and is charged negatively. Electrons flow to the positive rod of battery from the other plate of the capacitor. As a result that plate is charged positively. The amount of charge deposited in the plates depends on the voltage of the battery.

Capacitors are used in radio, television, record player and the circuits of other electronic devices widely.

10.9 Uses and Dangers of Static Electricity:

1. Electrostatic Painting Spray: Nowadays painting spray is used to colour car, cycle, cupboard or other things with help of static electricity. Spray gun is made in such a way that it produces very small charged particles of colour. The sharp edge of the painting spray gun is connected to a terminal of the static electrical generator. The other terminal of the generator is connected to the metal plate to be coloured which must be connected with earth. In case of colouring a car the charged small particle emitted from the spray gun attracts the outer frame of the car. As a result a uniform layer of colour is formed on the outer surface of the car. Moreover these small particles move along the electric lines of force and reach the narrower places of its surface and colour it.

Figure: 10.16

2. Ink Jet Printer: This is the most ordinary printer which remains connected to the computer. An ink-gun with its narrow mouth projects very small particles of ink. These small particles are positively charged. These ink particles move through the space between two plates. These positively charged ink particles are repelled by the positive plate and attracted by the negative plate.

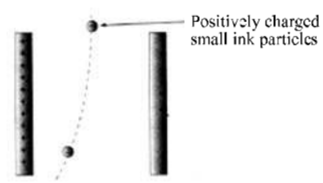


Figure: 10.17

A computer controls the voltage of the plates in such a way that the plates are sometimes positively charged and sometimes negatively charged. And the ink particles fall on moving paper scattered in different places to give the necessary shape of letters and pictures. For colour print four kinds of colour are used.

3. Photocopier: Nowadays photocopier or photocopy machine is very essential and thus it has become very popular machine. Not only the educational institutions and other offices but also general people use this machine to photocopy any kind of necessary papers and documents. Static energy is also used in this machine. There is a rotating dram inside the dark part of the photocopier. Positive charge is sprayed over the dram. A bright light lights up the page to be photocopied. The white part of the page reflects light but the dark or printed part does not reflect light. The reflected light centers on the dram. Charges releases from the part of the dram where the reflected light from white paper falls. Only the dark part of the dram is charged positively. Negatively charged ink of carbon powder (toner) is sprayed over the dram. Negatively charged ink particles get stick to the positively charged part of the dram. A piece of white paper is positively charged and is kept pressed with the dram. This paper picks up the pattern of carbon powder on its surface from the dram. Positively charged paper attracts the negatively charged toner. Then the paper is passed through the heated roller. As a result the ink of the toner gets melted and mixed with the paper and makes a permanent copy.

Danger of static electricity:

Sometimes the presence of static electricity is harmful and may cause danger.

Loading of fuel in aero plane: When aero plane flies in the air it may electrify due to the friction with air. If the charge increases continuously the potential difference between the aero plane and the earth increases simultaneously. Due to this high potential difference when the fuel is loaded there is possibility of releasing some charge to the ground which may create spark. This spark may lead to a huge explosion. This is why the wheels of aero plane are made of conductor rubber so that the stored charges in the aero plane can be released safely to the ground when it lands.

The solution of the problem is that a conductor is to be connected to the aero plane and to the ground as soon as it lands and just before the loading is started.

Loading of Fuel into Tanker: Sparking or explosion may occur when a truck or tanker etc carries fuel from one place to another. To prevent this type of danger the tanker should be connected to the ground by a conductor.

Television and Monitors of Computer: During the operating period television and monitor of computer, electrostatic charges are produced. These charges attract the uncharged dust particles thus they become dirty soon.

Change of clothes: Sometimes our wearing clothes may be charged due to the friction with us. When we change our clothes, there is a possibility of getting light shock as the charges pass to the ground through our body.

Operation Theater: Necessary measures have to be taken to keep the surgeons, concerned people and treatment equipments of the operation theater in a hospital free from electric charges as they attract dirt and germs. This is why they have to wear conductor shoes of rubber and use rubber gloves. So that electron can pass through them to the ground.

Hanging metal chain with petrol transporting truck: A metal chain has to be hung touching the road with the trucks that carries petrol, diesel or other liquid fuels. When a truck moves along the road, the petrol in the tank dashes against the inner surface of the tank and oscillates to and fro. As a result of this, friction charge is stored in petrol. If any spark takes place from the edge of the tank it may cause serious accident and may set fire. So the charges in petrol are not safe. Therefore a chain is connected at the back of the tank so that the charge can pass through it to the ground easily as metal is a good conductor.

No direct connection between metal pillar and electric line: The metal pillars on the road have no direct connection with electric lines pulled over the pillars. As metals are good conductors, the electricity of the wire may pass through the pillar to the ground if the pillar has connection with wires. If anyone touches the pillar he could immediately be electrified causing serious accident. So the wires are connected to the pillars by a porcelain cup.

Thunder bolt and lightning conductors: We know that there is water vapor in atmosphere. This water vapor being condensed on the charged ions on the atmosphere and form water droplets and become charged with electricity. When these water droplets gather together cloud is formed. Cloud can be charged either positively or negatively. When two oppositely charged clouds come close to each other then electrical discharge takes place between them and makes huge spark. This is called lightning or electric flash.

During electric flash the air around the cloud expands suddenly by getting heated. Due to sudden expansion the pressure of the air lowers much. Then neighboring air at higher pressure contracts the expanded air. Due to this sudden expansion and contraction of air, violent sound is produced. This is known as roaring of thunder. If there is too much charge on a cloud then it includes opposite charge on the surface of the earth and electric discharge takes place. This is known as thunder bolt.

Lightning conductor or lightning arrester: In order to protect buildings from the ravage of lightning the lightning conductor is used. The metallic rod R (Fig 10.18) with several sharp points at the top is fixed in such a way that its upper end extends several feet above the roof of the building and lowers end runs down along the outer surface of the building and buried well inside the moist earth.

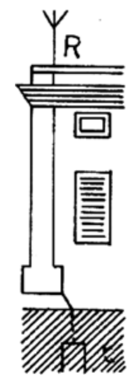


Fig: 10.18

When a charged cloud passes above the building then the charge of opposite kind is induced in the conductor rod R. The accumulation of charge is at maximum at the pointed ends of lightning conductor and pointed ends discharges their charge to the air particles around it. The air particles around the sharp points are charged by conduction and are attracted by the opposite charges of cloud and moves towards the cloud is neutralized. As a result the probability of thunder bolt decreases.

Electricity always passes following the shortest path through a conductor. The charge produced in the clouds tends to reach the earth through the high standing objects. During storm and rain it is rather good to wet in rain than to stand under an umbrella, any tree, near any conductor, iron bridge or fence of sharp iron wire.

Investigation:10.1

Production of the charge in the process of friction and induction.

Objectives: Demonstration of charges produced in the process of friction and induction.

Apparatus: Pith ball, glass rod, silk cloth, piece of rubber and a conductor rod.

Working procedure:

1. Suspend a light pith ball from a stand or a hook by a string.
2. Take a dry glass rod.
3. Cover one end of a glass rod by a piece of rubber and hold it.
4. Rub the other end of the glass rod by a piece of silk cloth properly.
5. Bring the rubbed end of the glass rod near a freely suspended pith ball.
6. The glass rod attracts the pith ball towards it as the glass rod is charged due to friction.
7. The glass rod is charged positively. (You can prove that with the help of an electroscope)
8. Now bring the charged glass rod near to an end of an uncharged conductor.

Chapter eleven

CURRENT ELECTRICITY



[We rely on electricity in different areas of our daily lives. Most of the modern instruments and equipments are run by electricity. We have come to depend so much on electricity that it is difficult to imagine what would be life without electricity. In the previous chapter we have discussed about static electricity. In this chapter different quantities related to current electricity e.g. electric current, resistance, electromotive force and potential difference will be described. In addition, the direction of electricity, conductor, insulator and semiconductor, electric circuit, Ohm's law, fixed and variable resistance, dependence of resistance, series and parallel combination of resistance, electric power, system loss of electricity and load shedding, safe and effective use of electricity will be discussed.]

By the end of this chapter we will be able to-

1. Demonstrate production of current electricity from static electricity.
2. Explain the direction of electric current and flow of electrons.
3. Draw the circuit by using the symbols of electric devices and appliances.
4. Explain conductor, insulator and semiconductor.
5. Establish a relationship between electric current and potential difference by using graph.
6. Explain fixed resistance and variable resistance.
7. Explain electromotive force and potential difference.
8. Explain dependence of resistance.
9. Explain resistivity and conductivity.
10. Use series and parallel circuit.
11. Use an equivalent resistance in a circuit.
12. Calculate electric power in a circuit.
13. Explain system loss and load shedding in a circuit.
14. Describe the safe and effective use of electricity.
15. Draw a typical house circuit and demonstrate the use of ac sources in its different parts.
16. Develop consciousness about the safe and effective use of electricity.
17. Draw poster to build consciousness about dissipation of electricity and conservation.

11.1 Production of current electricity from static electricity

Electric current

When two bodies of different potential are connected by a conducting wire, electrons flow from the body of low potential to that of higher potential. This flow of electron continues until the potential difference between the two bodies becomes zero. If by any process the potential difference between the two objects is maintained, then this flow of electron goes on continuously. This continuous flow of electrons is electric current.

The amount of charge that flows in unit time through any cross section of a conductor is called electric current. If through any cross section of a conductor, the quantity of charge Q flows in time t, then the electric current will be $I = \frac{Q}{t}$

Unit: The unit of electric current is ampere. If an amount of charge 1 C flows in 1 second through any cross section of a conductor, then the quantity of electric current produced is called 1 A. [But this is not the fundamental definition of ampere. It is given in chapter one, section 1.5.]

$$I = \frac{1C}{1s} = 1Cs^{-1} = 1A$$

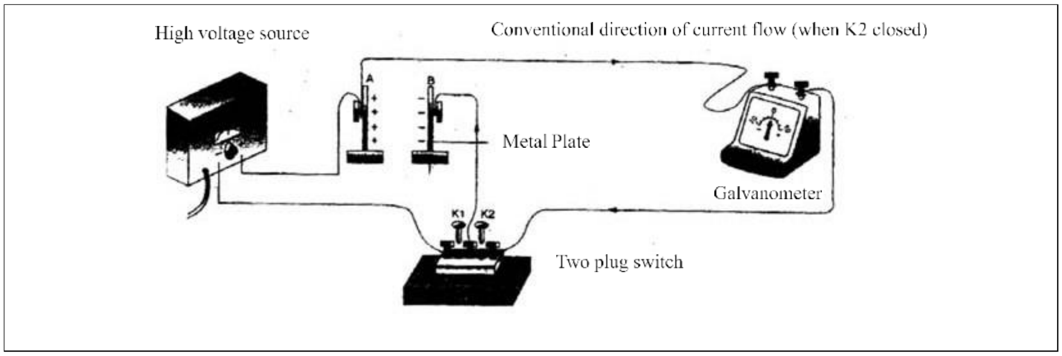


Figure: 11.1

In an isolated charged conductor, the charge stays on its surface and do not move. Such type of charges is called electrostatic charge. However, if we can provide a conducting path, the charges will flow instead of being bound on the conductor. When it happens, we say an electric current is produced.

How electric current is produced from moving charges is described in terms of the circuit as shown in figure 11.1. At the start of the experiment, two plug keys K1 and K2 are taken out and the two metal plates A and B are uncharged by touching with hand. Now, if the plug K1 is closed, the high voltage source will be connected to the two metal plates.

Next, switch on the high voltage source to charge up the two metal plates positively and negatively by an equal amount. Now, key K1 is removed and key K2 is pluged in to provide a continuous conducting path linking the positively and negatively charged metal plates to the galvanometer. Here, the galvanometer is a device that can detect the existence of flow of current. It would be observed that the pointer in the galvanometer is seen to deflect momentarily to one side and then quickly return to its initial position.

The galvanometer's deflection shows that an electric current is produced. How this electric current is produced? The current is caused by the flow of electrons from the negatively charged plate B through the galvanometer and then to positively charged plate A. The positive charges of plate A are neutralized by the incoming negatively charged electrons. As a result, the transient current which is detected by the galvanometer is produced due to the discharge of the two metal plates.

11.2 Direction of electric current and direction of electron flow

When current electricity was invented first, it was assumed that the electricity was produced due to the flow of positive charges. This positive charge flows from higher potential to lower potential. So, the direction of conventional current is taken to be from higher potential to lower potential or from positive plate to negative plate of an electric cell. But we know that actually electric current is the flow of negative charges or of electrons, so the actual direction of electric current is from lower potential to higher potential. That is from negative plate to positive plate of an electric cell. Therefore, the actual direction of electric current is opposite to that of conventional current. The arrow demonstrated in the diagram is indicating the direction of conventional current.

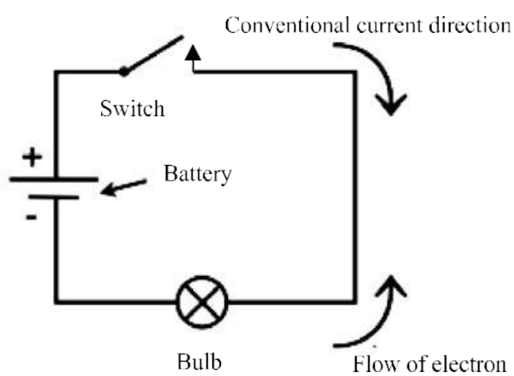


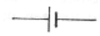
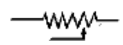
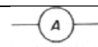
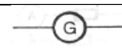
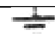
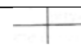
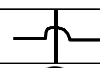
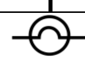
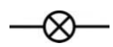
Figure: 11.2

11.3 Electric symbols

The complete path through which electric current can flow is called electric circuit. When two plates of a cell are joined to the two ends of a resistor or an electric devices an electric circuit is formed.

We have to draw simple and clear circuit diagrams to study current electricity. Symbols that are used to represent common electrical devices that are employed to draw electric circuits are shown in table.

Table 11.1: Symbols of circuit

Device	Symbol
Switch	
Cell	
Battery	
Fixed resistor	
Variable resistor	
Fuse	
Ammeter	
Voltmeter	
Galvanometer	
Earth connector	
Wires crossed	
Wires not connected	
Bulb	 **or** 

Do yourself: Using a switch, electric cell, fixed resistor and ammeter draw a series circuit. Now, connect a voltmeter in parallel with two terminals of a fixed resistor.

11.4 Conductor, insulator and semiconductor

We know, electric current is the flow of charges through a material. This electric current can move very easily through some substance. There are some mediums through which electricity cannot move at all. Solid materials are classified into three groups depending on their electricity conduction. For example: (1) conductor (2) insulator (3) semiconductor.

1. Conductor: The materials through which electric current can flow very easily are called conductors. Electrons can flow freely within these materials. In metal wires the charges are carried by electrons. So, the metallic materials are good conductors of electricity. Copper, silver, aluminium etc. are good conductors. Due to this reason, metallic wires are used as electric connectors.

2. Insulator: The materials through which electric current cannot flow are called insulators. Therefore, the materials where electrons are not free to move about are the insulators. For example: Plastic, rubber, wood, glass etc. There are no free electrons inside insulating materials. Electrons do not flow easily through plastic type materials. As a result plastics are insulator for electricity. Due to this, the handles of screwdrivers and pliers used by electricians are covered with plastic type materials. In addition, the copper wires which we use in our daily needs are covered with plastic.

3. Semiconductor: The materials whose current conduction capacity lies between that of conductors and insulators in normal temperature are called semiconductors. For example- germanium, silicon etc. The current conduction capacity of semiconductor can be increased by adding suitable impurities.

11.5 Relationship between potential difference and electric current- Ohm's law

We know, if there is a potential difference between the two terminals of a conductor, current flows through it. The quantity of this electric current depends on the potential difference between the two ends of the conductor, the conductor itself and the temperature of it. George Simon Ohm has discovered the law regarding the relationship between the electric current that flows in a conductor and the potential difference between the two terminals of it- which is known as Ohm's law.

Ohm's law

The current passing through a conductor at constant temperature is directly proportional to the potential difference between the two ends of the conductor.

By proportionality it means- if the potential difference between the two ends is doubled, the current flowing through the conductor will be doubled. Again, if the potential difference between the two terminals is made one third, the current passing through the conductor will be one third.

Assume AB is a conducting wire. The potential of its two terminals are V_A and V_B [Figure 11.3] respectively. If $V_A > V_B$, The potential difference between the two terminals of the conductor will be $V = V_A - V_B$.

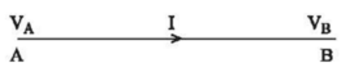


Figure: 11.3

Now at constant temperature, if the current passing through the conductor is *I*, then according to ohm's law,

$I \propto V$

$\Rightarrow \dfrac{V}{I} = R$ = constant

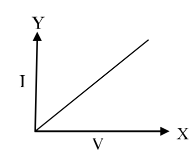


Fig: 11.14

This constant is called the resistance of the conductor at that temperature.

or, $I = \dfrac{V}{R}$

Graph of V-I is shown in fig. 11.4

Mathematical Example11.1: A current of 4 A is flowing through the filament of the headlight of a motor car. If the potential difference between the two ends of the filament is 12 V, what is the resistance of it?

Here,
Electric current, I = 4 A
Potential difference, V = 12 V
Resistance, R =?

We know

$$I = \frac{V}{R}$$

$$\text{or, } R = \frac{V}{I}$$

$$= \frac{12V}{4A}$$

$$= 3\ \Omega$$

Answer: 3 Ω.

11.6 Resistance: Fixed and variable resistance

We know electric current is the flow of electrons. When the electrons move within the bulk of a conductor, they collide with the atoms and molecules of the conductor. Due to this their motion is resisted and electric current is obstructed. This property of a conductor is called resistance.

At particular temperature,

$$\text{Resistance, } R = \frac{V}{I}$$

$$= \frac{\text{Potential difference of two ends}}{\text{Electric current}}$$

The SI unit for resistance is **ohm**. It is expressed by the capital letter omega (Ω).

1 Ω is the resistance of a conductor through which a current of 1A flows when a potential difference of 1 V is applied across it.

Resistors: A resistor is a conductor used in a circuit that has a known value of resistance. The main objective of using resistors is to control the quantity of the current flowing in a circuit. There are two types of resistors that are used in a circuit. These are:

1. Fixed resistors
2. Variable resistors

1. Fixed resistors: The fixed resistors are those who have fixed values of resistance. The fixed resistors that are generally used in laboratory are shown in figure 11.5.

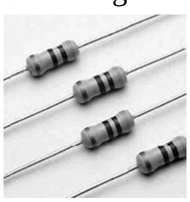


Figure: 11.5

2. Variable resistors: The variable resistors are those whose value of the resistance can be changed according to the necessity. These are called rheostat too. A rheostat is included in a circuit to vary the current flowing through it. Figure 11.6 shows a rheostat commonly used in the laboratories.

Fig. 11.6

11.7 Electromotive force and potential difference

Electromotive force

Electrical energy is needed to produce electric current in a circuit. The electromotive force of an electrical energy source is defined as the work done by the source or the energy spent by the source in driving a unit positive charge from one point of the circuit to the same point by traversing the complete circuit along with the source.

If the work done is W J in bringing Q C of charge in a complete circuit, then the work done in bringing 1 C of charge is $\frac{W}{Q}$. Therefore the electromotive force of the source is, $E = \frac{W}{Q}$

Unit: The SI unit of electromotive force is JC^{-1} or volt (V).

The devices which can transform some other forms of energy into electrical energy they only have electromotive force. For example: cell, generator, etc. An electric cell converts chemical energy into electrical energy and a generator coverts mechanical energy into electrical energy. The electromotive force of a cell is the sum of the potential differences which develops in different parts of the circuit along with the cell.

Potential difference:

The electricity flows through a conductor due to the potential difference between the two terminals. The potential difference between any two points is defined as the amount of work done to carry unit positive charge from one point to another of a circuit. When a dry cell is used in a torch, the electrical energy provided by the dry cell is converted into light and heat energy. The conservation of energy is maintained in this process of transformation of energy. The amount of energy converted across the light bulb for migration of unit positive charge is the potential difference between the two terminals of the bulb. Therefore, the potential difference between the two points of a circuit is defined as the amount of electrical energy converted to other forms of energy (e.g. - heat, light) when unit positive charge migrates between the two points. If W is the amount of electrical energy converted to other forms for migration of Q amount of charge, then the potential difference between the two points is

$$V = \frac{W}{Q}$$

The SI unit for potential difference is the same as that for electromotive force. That is volt (V). The potential difference between the two points will be 1 V if 1 J of electrical energy is converted to other forms when 1C positive charge flows between the two points.

Experiment: Measure the potential difference between the two terminals of a dry cell. This is the electromotive force. Now connect this cell to the bulb and again measure the potential difference between the two terminals of the cell.

The voltmeter reading is the potential difference between the two ends of the bulb or of resistance during the current flow. Now compare the values of the measured electromotive force and potential difference. You will observe that the value of E is larger than that of V.

11.8 **Dependence of resistance**

We know, when temperature and other physical conditions (e.g. - length, cross section, area) remain the same, the resistance of a conductor is a constant. The resistance of a conductor depends on four factors.

1. Length of the conductor.
2. Cross sectional area of the conductor.
3. Materials of the conductor and.
4. Temperature of the conductor.

We know, if the temperature remains constant, the resistance of a conductor depends only on its length, area of cross section and the material of the conductor. This dependence of resistance is expressed by two laws.

Figure 11.7 shows two conducting wires P and Q with the same cross sectional area and made of the same material. The length of wire P is longer than that of Q. Its resistance is greater as it is longer.

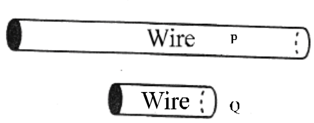


Figure: 11.7

Law of length: The resistance of a conductor is directly proportional to its length when the cross sectional area, material and temperature of the conductor remain the same.

If the length of the conductor is *L*, area of cross section is *A*, and its resistance is *R*, then according to this law,

$R \propto L$, when temperature, material and A is constant. (11.1)

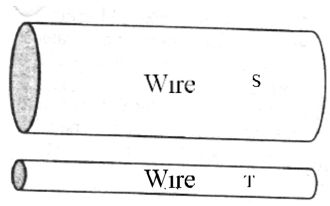


Figure: 11.8

Figure 11.8 shows two conducting wires S and T with the same length and made of the same material. The area of cross section of wire S is bigger than the area of cross section of wire T. Larger the area of cross section of a wire, the lower its resistance.

Law of cross section: The resistance of a conductor is inversely proportional to its cross sectional area when the length, material and temperature of the conductor remain the same.

That is, $R \propto \frac{1}{A}$, when temperature, material and L is constant (11.2)

11.9 **Resistivity and Conductivity**

At constant temperature, the resistance of a conductor of particular material varies proportionately with the length and inversely with the area of cross section. Therefore, we get from the laws of resistance,

$R \propto \frac{L}{A}$ when temperature and material remain the same.

$$or,\ R = \rho \frac{L}{A} \quad (11.3)$$

Here ρ is a constant, the value of which depends on the material of the conductor and its temperature. This constant is called the resistivity or specific resistance of the material at that temperature.

In equation (11.3), if L=1 unit, A=1 unit, then, $\rho = R$.

Therefore, at a particular temperature, the resistance of a conductor of unit length and unit cross sectional area is called the specific resistance of that material at that temperature.

At a certain temperature, the resistance of a conductor depends on its physical conditions (e.g. length, cross section etc.). But the resistivity of a conductor depends only on its material.

Unit of specific resistance: Rewriting equation (11.3) we can write,

$$\rho = R\frac{A}{L} \quad (11.4)$$

Substituting the units of the quantities on the right side of the equation, the unit of ρ is

$$\frac{\Omega\, m^2}{m} = \Omega\, m$$

Significance: The resistivity of silver at 20 °C is 1.6×10^{-8} Ω m. Therefore, the resistance of a silver wire of length 1m and cross sectional area of $1 m^2$ is 1.6×10^{-8} Ω. Table shows the values of the resistivity of some common materials.

Table 11.2 Resistivities of different materials

Material	Resistivity (Ω m)
Silver	1.6×10^{-8}
Copper	1.7×10^{-8}
Tungsten	5.5×10^{-8}
Nichrome	100×10^{-8}

From the table above we see that the materials with lower resistivities are good conductors of electricity. For example- copper is much better conductor of electricity than nichrome. Due to this, copper is widely used as connecting wires in electrical circuits.

Besides, materials with higher resistivities also have multiple uses. One example is the nichrome wire. The resistivity and melting point of nichrome is much higher than that of copper. Due to the high resistivity of nichrome, a lot of thermal energy is produced when a current flows through it. This property of nichrome causes water to boil very quickly in electric kettle. The filament of electric bulbs that are used in our houses is made of tungsten. Tungsten can convert electrical energy to light and thermal energy owing to its high resistivity and melting point.

Conductivity

The reciprocal quantity of resistance is called conductance. Like that, the reciprocal quantity of specific resistance is called conductivity. Conductivity is expressed by the letter σ. The value of σ depends on the type of material of the conductor and its temperature.

Say, the specific resistance of the material of a conductor = ρ

Therefore, the conductivity of its material is $\sigma = \frac{1}{\rho}$

As unit of ρ is Ω m, Therefore, the unit of σ is $(\Omega\ m)^{-1}$.

Mathematics Example 11.2: The specific resistance of the nichrome wire used in an electrical heater is 100×10^{-8} Ω m. What will be the resistance of 15 m long wire having cross sectional area $2.0 \times 10^{-7}\ m^2$?

We know,

$$R = \rho \frac{L}{A}$$

$$= \frac{(100\times10^{-8}\ \Omega\ m)(15\ m)}{2.0\times10^{-7}\ m^2}$$

$$= 75\ \Omega$$

Here,
Specific resistance, $\rho = 100\times10^{-8}\ \Omega\ m$
Cross sectional area, $A = 2.0\times10^{-7}\ m^2$
Length of the wire, $L = 15$ m
Resistance, R =?

Answer: Resistance 75 Ω |

11.10 **Making series and parallel circuits and their uses**

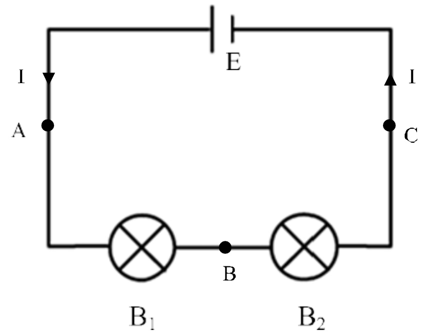


Figure: 11.9

Series circuit

The circuit in which the electric components are connected one after another in a single loop is called a series circuit. By arranging a cell E, two bulbs B_1 and B_2 one after another a series circuit is formed in figure 11.9. As there is a single path in the circuit, the same current will flow throughout the whole circuit. Now if the ammeter is connected at the points A, B or C, the value of the electric current will found to be the same.

The little bulbs that are used for decoration purpose in wedding ceremony or in different programs are connected in series. We increase the voltage by connecting more than one battery in series in a torch light. The ammeter is connected in series to measure the electric current in a circuit.

Parallel circuit

The circuit in which the electric components are arranged in such a way that one terminal of all the components are joined at a common point and the other terminal are joined at another common point then this circuit is called a parallel circuit.

In figure 11.10 one end of the bulbs B_1 and B_2 are connected at the point and the other end at the point **b** and so formed a parallel circuit. In a parallel circuit there are alternative paths for the current to flow.

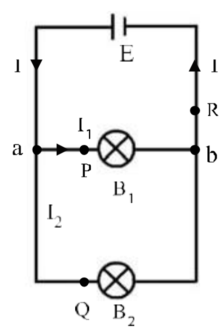


Figure: 11.3

Say, the total current in the circuit is I which splits into two parts I_1 and I_2 at the junction **a**. Let I_1 and I_2 are the currents flowing through the bulbs B_1 and B_2 respectively. At the junction **b** the currents I_1 and I_2 recombine to form the current I again. If the current at the points P, Q and R is measured by an ammeter, then it will be found that

$I = I_1 + I_2$

Here, total current of the circuit $= I$

i.e. in a parallel circuit, the sum of the individual currents flowing through each of the parallel branches is equal to the total current.

The electrical appliances such as- light, fan etc. which we use in houses or offices is connected in parallel to the AC mains. Each of the appliances gets the same voltage supply due to parallel connection. But they get different amounts of current.

11.11 Equivalent resistance and its uses in circuit

Sometimes several resistances are connected together for different purposes. Connection of more than one resistance together is called combination of resistances.

Equivalent resistance: If a single resistance is used instead of combination of resistances and if the current and potential difference is not changed in the circuit, then that resistance is called the equivalent resistance of the combination.

Combination of resistances is of two types, e.g. - series combination and parallel combination.

Series combination of resistances

Figure shows resistors R_1, R_2 and R_3 are connected in series. The resistances are connected one after another successively. In this case, the same current I is flowing through each of the resistors. Now we shall calculate the equivalent resistance of these three resistances those are connected in series.

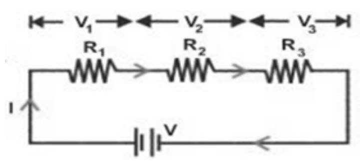


Figure: 11.11

From Ohm's law we get,

The potential difference across resistance R_1, $V_1 = IR_1$

The potential difference across resistance R_2, $V_2 = IR_2$

The potential difference across resistance R_3, $V_3 = IR_3$

If V is the potential difference between the two terminals of all the resistors, i.e. the potential difference across the combination,

$$\therefore \; V = V_1 + V_2 + V_3$$
$$= IR_1 + IR_2 + IR_3$$

$$= I(R_1 + R_2 + R_3) \qquad (11.5)$$

Now if three resistances R_1, R_2 and R_3 are replaced by a single resistance R_S , so that same current I flows through the circuit and the potential difference V across them remains unchanged, then R_S is the equivalent resistance of the combination.

In case of equivalent resistance, $V = IR_s$ (11.6)

Comparing equations we get,

$$IR_S = I(R_1 + R_2 + R_3)$$
$$R_S = R_1 + R_2 + R_3$$

If instead of three resistances, n number of resistances are connected in series then equivalent resistance R_s will be

$$R_S = R_1 + R_2 + R_3 + ... + R_n$$

Therefore, the equivalent resistance of resistors connected is series is equal to the sum of the different resistances included in the combination. The value of the equivalent resistance in series combination is greater than that of individual resistances.

Parallel combination of resistances

When several resistances are connected in such a way that one terminal of all the resistances are joined at a common point A and the other terminals are joined at another common point B and potential difference across each of the resistors remains the same, then this combination of resistances are called parallel combination of resistances.

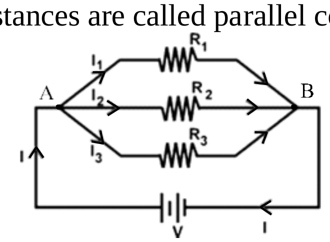


Fig. 11.12

Three resistors R_1, R_2 and R_3 are connected in a parallel combination. In this case, same potential difference V is maintained across the two terminals of the three resistors. Different amount of current is flowing through each of the resistors owing to their different values. The main current I of the circuit splits into three parts at the junction a and later recombine at the point b. Let I_1, I_2 and I_3 are the currents flowing through the resistances R_1, R_2 and R_3 respectively. Therefore, sum of the currents I_1, I_2 and I_3 of parallel paths is equal to the current I at the junction a**.** Therefore,

$I = I_1 + I_2 + I_3$ (11.7)

Here, the potential difference between the two terminals being V, applying Ohm's law we get,

$$I_1 = \frac{V}{R_1},\ I_2 = \frac{V}{R_2} \text{ and } I_3 = \frac{V}{R_3}$$

Substituting the values of I_1, I_2 and I_3 in equation (11.7) we get,

$$I = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

$$= V\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right) \tag{11.8}$$

Now if three resistances R_1, R_2 and R_3 are replaced by a single resistance R_P, so that same current I flows through the circuit and the potential difference V across them remains unchanged, then R_P is the equivalent resistance of the combination.

$$\therefore \quad I = \frac{V}{R_P} \tag{11.9}$$

Comparing equations (11.8) I (11.9) we get,

$$\frac{V}{R_P} = V\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)$$

$$\frac{1}{R_P} = \left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)$$

If instead of three resistances, n numbers of resistances are connected in parallel then the equivalent resistance R_P can be expressed as

$$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots + \frac{1}{R_n} \tag{11.10}$$

That is, resistances connected in parallel combination, the sum of the inverse of the individual resistances is equal to the inverse of the equivalent resistance.

Mathematical Example 11.3: If two resistances of values 5 Ω and10 Ω are connected in series and parallel combination separately, calculate the equivalent resistance in both cases.

Here,
First resistance, R_1 = 5 Ω
Second resistance, R_2 = 10 Ω
Equivalent resistance in series, R_S =?
Equivalent resistance in parallel, R_P =?

We know,

$$R_S = R_1 + R_2$$
$$= 5\ \Omega + 10\ \Omega$$
$$= 15\ \Omega$$

Again,

$$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$\frac{1}{R_P} = \frac{1}{5\Omega} + \frac{1}{10\Omega}$$

$$= \frac{2+1}{10}\Omega^{-1}$$

$$= \frac{3}{10}\Omega^{-1}$$

$R_P = 3.33\ \Omega$

Answer: $R_S = 15\ \Omega$ and $R_P = 3.33\ \Omega$

11.12 Electric power

When a potential difference is applied between the two terminals of a conductor, an electric current is set up. Due to this, work is done and the electrons acquire energy. This electrical energy may be transformed into different forms of energy (e.g.- heat, light, mechanical energy etc.) according to the nature of the circuit.

Figure 11.13

Say, AB is a conductor of resistance R and Q amount of charge is flowing through it. The potential difference between the points A and B is V. We know, if the potential difference between the two terminals of a conductor is 1 volt and 1 coulomb charge flows through it, then the amount of work done or energy spent is 1joule. Now, if Q coulomb charge flows through the conductor, the amount of work done = VQ joule.

Therefore, energy spent or the amount of energy converted is

$$W = VQ$$

Again, electric current, $I = \frac{Q}{t}$

or, $Q = It$

$$\therefore\ W = VIt \tag{11.11}$$

Using ohm's law this relationship can be expressed as below,

$$\therefore\ W = VIt = I^2Rt = \frac{V^2}{R}t \text{ Joule} \tag{11.12}$$

Electric power

The electric appliances which we use in houses or in offices are generally marked with the voltage by which it runs and the electric power in watt. We know the rate of work done or the rate of energy conversion is called power. Therefore, the rate at which energy is converted into other forms in an electric device is its power.

Therefore, power = $\frac{\text{Work done}}{\text{time}} = \frac{\text{energy converted}}{\text{time}}$

$$\therefore\ P = \frac{W}{t} \tag{11.13}$$

Substituting the value of *W* from equation (11.11) we get,

$$P = VI \tag{11.14}$$

Applying Ohm's law *P* can be expressed in terms of *V*, *I* and *R* as below-

$$P = VI = I^2R = \frac{V^2}{R} \tag{11.15}$$

We know the unit of power is watt (W). In the calculations of electric energy generally kW, MW etc. are used instead of watt. 1 kW=10^3 W and 1 MW=10^6 W.

The power of some of the electric appliances which we use in our houses is mentioned below. The power of an electric bulb is generally 40, 60 and 100 W. The power of an electric fan is found to 65-75 W commonly. Power of a television is generally 60-70 W. The energy saving bulbs which we use now-a-days has power of 11-30 W.

Besides this, we use refrigerator, heater, iron etc. in houses- their power is more. So, it is commended not to use these appliances during peak hour.

Calculation of electrical energy spent

We have to pay for the electrical energy we utilize in our houses, shops, mills and factories. There is an electricity meter in the houses those use electricity, which maintain the accounts of spent electrical energy. Throughout the world, the electricity supply authority measures the amount of electrical energy consumed in units of kilowatt-hour (kWh). We call this kilowatt-hour unit as 'board of trade' unit or in brief 'unit'. From the difference of the readings of two times in the electricity meter, we get the amount of consumed electric power during this period.

Since power, P = $\frac{\textit{Work done}}{\textit{time}} = \frac{\textit{Converted energy}}{\textit{time}}$

$$= \frac{W}{t}$$

$$\therefore \quad W = Pt$$

If P=1 kW and t =1h, then W=1 kW×1h=1 kWh.

Therefore, the amount of electrical energy converted or spent when an electric device of 1 kilowatt power works for 1 hour is called 1 kilowatt-hour or 1 unit.

Do yourself: Express 1kWh in terms of joule.

1 kWh = 3.6× 10^6 J

When power is expressed in watt and time in hour, the amount of electrical energy consumed can be expressed as:

$$W = Pt \ \text{Wh}$$

Dividing this by 1000, the electricity consumed is found to be in kWh.

Do yourself: If there is an electrical connection in the house you are dwelling in, then prepare a list of the electric devices those are in that house. From this, determine the probable amount of electrical energy to be consumed for one month.

Example 11.4: On the body of an electric bulb 100 W-220 V is written. What is its filament resistance? What amount of electricity will flow through it?

We know,

$$P = \frac{V^2}{R}$$

$$R = \frac{V^2}{P}$$

$$= \frac{220 \text{ V} \times 220 \text{ V}}{100 \text{ W}}$$

$$= 484\ \Omega$$

Again, $P = VI$

$$I = \frac{P}{V}$$

$$= \frac{100 \text{ W}}{220 \text{ V}}$$

$$= 0.455 \text{ A}$$

Here,

Potential difference, V = 220 V

Power, P = 100 W

Resistance, R =?

Electric current, I =?

Answer: 484 Ω and 0.455 A

11.13 System loss and load shedding

We know, electrical energy is produced in power stations situated at different places. The electricity thus generated has to be transmitted at different places according to the demand. The electrical energy produced is transmitted to the different substations situated at different places by the electricity transmission system. Then from different substations this electrical energy is distributed to the consumers by electricity distribution system again.

In the power station the electrical energy is generated at low voltage. Then this low voltage is transformed into high voltage by the step-up transformer. The conducting wires which are used for electricity transmission have a definite amount of resistance. As a result, to overcome this resistance, part of the electrical energy is converted to heat. That is, a loss or decay of energy occurs. This loss of energy is termed as system loss. Due to the transmission of electricity at high voltage, the loss that occurs due to the power grid or of conductor is decreased to a great extent. For a definite amount of electrical energy, the value of the electric current becomes lower due to high voltage transmission. As an example- if the transmission line voltage is increased by ten times, then the electric current becomes one tenth. As a result, the i^2R loss of the power grid becomes one hundredth. Therefore, by increasing the transmission line voltage we can lower the system loss.

Load shedding

Each of the power stations generates a definite amount of electric power. The electricity generated by all the power stations is added in the national power grid. According to the demand of different locality power sub-stations collect electricity from the national grid. Then the power sub-station delivers or distributes the electricity to the consumer level.

When in a particular area, the demand of electricity exceeds the supply or generation; the power sub-station can no longer fulfill the demand of electricity. Then the sub-station authority is forced to switch off or to disconnect the power distribution for a while in some parts of the distribution network. This is called load shedding. When the sub-station gets the supply according to its demand, then it distributes electricity in that region again.

If the load shedding takes place for a couple of hours continuously, authority load sheds circularly in different area to make load shedding tolerable at the consumer level.

11.14 Safe and effective use of electricity

Dangers of electricity

Electricity plays a very important role in our daily lives. Though electricity is very useful to us, it can also be very dangerous in the careless uses. Any type of faults in electrical appliances or circuits can cause fires and electric shocks. Due to the passage of electricity through the body there is a risk of death of people.

Uses of electricity can be dangerous due to three reasons described below.

1. Damaged insulation
2. Overheating of the cables
3. Damped conditions

1. Damaged insulation:

The electrical appliances work when these are connected to the voltage source by two conducting wires to complete the circuit. These two wires are called live and neutral wire. These conducting wires are usually insulated with rubber. Then they are wound together to form a cable and enclosed by PVC or rubber.

These insulating materials become worn with time and use. For example- the electrical cables of the electric iron which we use in home get bent and twisted because of the way they are used. This might cause the electrical insulation to crack and break. As a result, the conducting wires inside is exposed. If by any means a person comes into contact with the exposed live wire, it may cause severe electric shock to the user. If the live and neural wires come into mutual contact due to the damaged insulation, a short circuit will happen and may cause a fire.

2. Overheating of the cables: Overheating of cables occur when unusually large current flows through the electric cables or conducting wires. For example- an unusual large current flows, when an electric fan motor overheats and melts, as a result the live and neutral wire is fused together. Besides this, we make connection of too many electrical devices in a wall socket by using a multi-plug. Due to this, the conducting wire connected to the socket draws more current from the main line than the current which the conducting wire can draw safely. As a result, the cable wire is overheated, insulation is melted and causes fire.

3. Damped conditions: Many electrical accidents may occur in damped conditions. We know, electricity can pass through water. The parts of an electric appliance which are not insulated must be kept dry. Otherwise, there is a risk of short circuits and electric shocks. As an example, leaving a hair dryer on a wet sink is very dangerous. The person using the sink could be electrocuted if the wires were exposed or the insulation had damaged. Besides this, switching on or off of an electric switch by wet hand is risky.

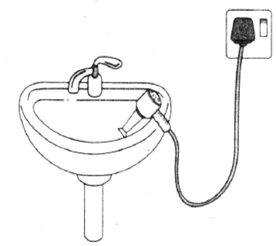


Figure: 11.14

Safe use of electricity

In the previous section you were informed about the dangers of electricity. In the present section, we will learn about the safe uses of electricity.

When using electricity at home, the safety measures that are needed:

1. Circuit breaker
2. Fuses
3. Correct connection of switch
4. Earth wire

1. **Circuit breaker**

Circuit breakers are used as safety devices. Generally this is placed near the front door of a house. Circuit breaker switches off the electrical supply in a circuit when there is an overflow of current. Circuit breaker disconnects the electrical supply in a definite part of the house. Without circuit breaker in a circuit, this excessive current can cause damage of home appliances or even start a fire.

2. **Fuses:** A fuse is a safety device. A fuse is included in an electrical circuit to prevent excessive current flow. The fuse is always connected to the live wire of electrical cables. A short thin piece of wire is used as a fuse. The fuse becomes hot and melts when the electric current flowing through it is greater than a definite value. As a result, the circuit is disconnected and the electrical appliances will be safe. The fuse is marked with definite amount of current on its body. Fuses will be such that it can bring slightly higher current than the maximum current an electrical device or appliance can tolerate safely. If the fuse burns, the appliance will not be electrified any more. Before changing fuse, you have to switch off the mains of electricity supply.

3. **Correct connection of switch:** A switch breaks or completes an electrical circuit. During switch connection in a circuit, an important precaution is that the switch must be fitted onto the live wire. For this, switching off will disconnect the high voltage source from the appliance instantly [Figure 11.15]. If the switch is fitted onto the neutral wire wrongly, the electric appliance will be 'live' even if the switch is 'off' [Figure 11.16] and increase the risk of electric shock.

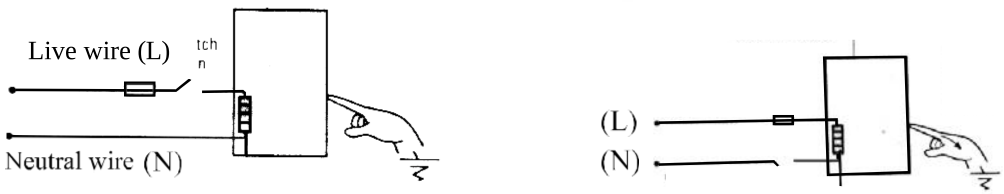


Figure 11.15 and 11.16

4. **Earth wire:** All electrical appliances or devices need at least two wires to form a complete circuit. These are the live (L) and neutral (N) wire. The live wire delivers the electrical energy to the appliance. On the contrary, the current returns back to the supply through the neutral wire and complete the circuit. The potential of neutral wire is zero. The earth wire is a low-resistance wire. It is usually connected to the metallic casing of the appliance. The circuit may be faulty from different reasons. If the live wire is not properly connected and it touches the metal casing of the appliance- the user may be electrocuted from an electric shock. Earthing of the casing prevents this from happening. In this case, the large current will flow from the live wire to the earth through the metal casing. As a result, the fuse will blow out and cut off the electric supply to the appliance. It is strongly recommended to provide an earthing to the refrigerator in houses for safe use of it. Figure 11.17 demonstrates how a washing machine without earthing may be risky. How earth wire works as a safety precaution is demonstrated in figure 11.18.

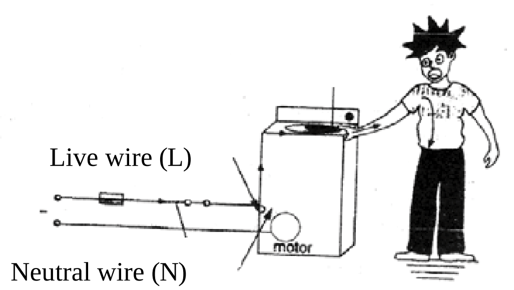


Figure 11.17 and 11.18

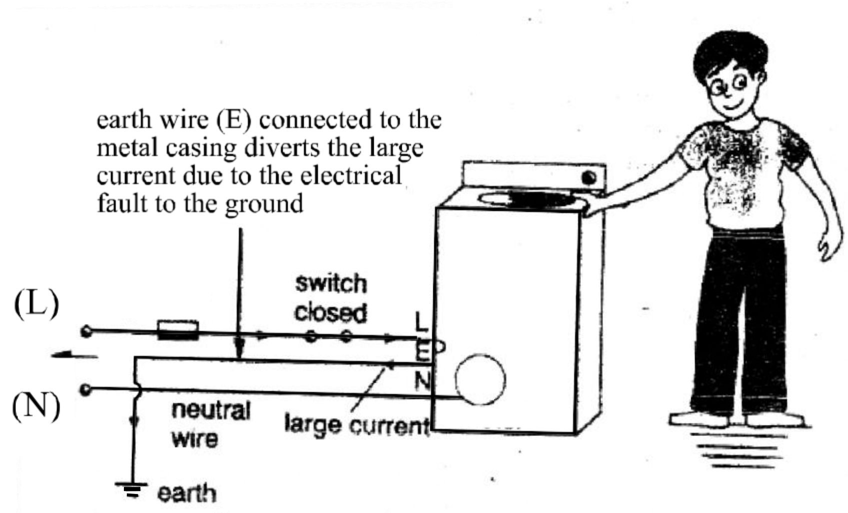


Figure: 11.18

In addition, three-pin plugs are used in many portable devices. Fuses are connected in these plugs as safety measures. Fuse keeps the device safe.

Investigation-11.1

To design an electric circuit suitable for home and demonstration of its uses.

Objectives: The learners will design an electric circuit suitable for home and demonstrate the uses of AC source in different parts of it.

Procedure:

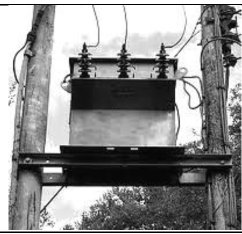
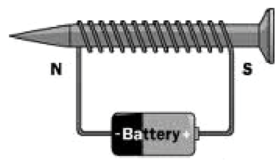
1. Draw the live (L) and neutral (N) wire of the electric cable at the beginning.
2. Now connect this two wires to main fuse box, electricity meter and distribution box one after another.
3. Draw main switch in the distribution box.
4. Now draw two fuses in the distribution box. The fuses must be connected to the live (L) wire.
5. Connect two lamps and a fan with the fuse in parallel and complete the circuit. Draw switch on the L wire for each of the lamp and fan.
6. Give connection to different power sockets for television set, electric iron etc. using the other fuse.

Do yourself:Draw poster to build consciousness about the dissipation and preservation of electrical energy.

1. Collect poster papers from shop to make poster.
2. Write on poster using different colour pen what necessary steps should be taken to protect dissipation and preservation of electrical energy.
3. The teacher will select the best poster and give award.

Chapter twelve

MAGNETIC EFFECT OF CURRENT


[As the current has magnetic effect, the magnet has the electric effect also. Many electric tools have been made by using these two effects. These tools have solved many problems of us, have brought out various comforts and have developed the standard of our life. In this chapter, we shall discus about the functions and uses of electromagnet, electromagnetic induction, induced current and induced electric power, electric motor, generator, transformer etc.]

By the end of this chapter we will be able to -

1) Explain magnetic effect of electric current

2) Explain electromagnetic induction.

3) Explain induced current and induced electric power

4) Explain the main principles of motor and generator.

5) Explain the main principles of transformer.

6) Explain the functions of step-up and step-down transformer.

7) Praise the various uses and contributions of current in our life.

12.1. Magnetic Effect of Current.

[Figure 12.1]

Oersted invented the magnetic effect of current.

> Do yourself. Make a circuit like the picture aside. Place a compass under the wire as if it faced to North-South. Now let the switch on. What is happening to the needle of compass?

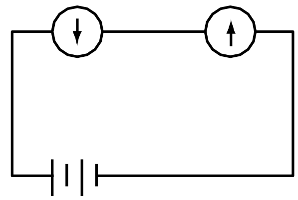


Figure: 12.1

We see that the needle is moving to one side after switching on the current on circuit. If we alter the electric connection, the needle of the compass will move the other side. From this effect, we can understand that a magnetic field is produced when a current flows through a wire.

12.2. Magnetic effect of current carrying conductor.

> Experiment: Make an electric circuit by putting a conducting wire into hard paper. Keep the paper horizontal and spread some dust of iron on the paper. Now connect the current through circuit or conductor and strike slowly with your finger on hard paper.

It is seen that the dust of the iron will get them arranged like the figure 12.2.If you draw a dot using a small compass and added to it, you will find the same. If you change the direction of the current, the needle of the compass will direct the opposite side which will remain facing to the opposite direction. So the flow of electricity produced magnetic field around the conductor also.

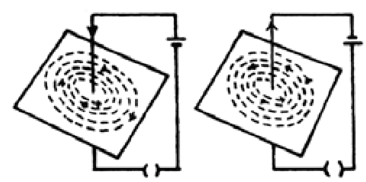


Figure: 12.2

12.3. Solenoid

We can increase the magnetic field intensity by coiling the above mentioned wire (see the figure 12.3).Due to flow of the current through the coil, most of the lines of the force will be concentrated in the centre of the coil. The magnetic field will be look alike the magnetic field of bar magnet. This type of coil is called Solenoid. If we insert any iron rod through it, the iron rod will be turned into magnet. If we stop the current, it will not remain magnet. If the direction of current is changed, the pole of magnet will be changed. Through this process, the iron is turned into magnet which is called electromagnet.

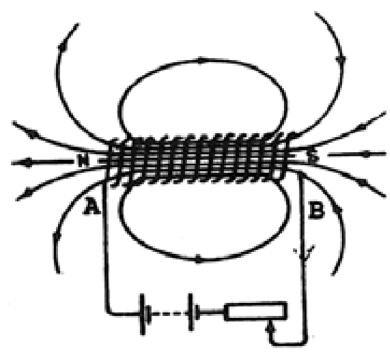


Figure: 12.3

12.4. Electromagnet.

If we insert any iron rod through the solenoid, we can get more powerful magnetic field that the solenoid has. During the flow of current, it is converted into more powerful magnet. This is called electromagnet. The intensity of this magnet can be increased -

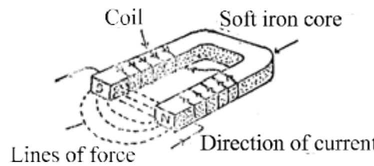


Figure: 12.3 a

-by increasing the flow of current

- by increasing the number of coil of the solenoid

- by bending the iron rod in the form of alphabet U and keeping two ends of U as close as possible .

Now examine with the help of your teacher, how much paper clips or alpines are attracted by the magnetic iron rod for the flow of various current or for increasing the numbers of turn of the solenoid coil. Electromagnet is used to make the electric bell, to carry the heavy load up and down made by steel or iron or to make crane which is used to remove the rubbish. This magnet is used to remove the dust of iron from the eye. Besides, this magnet is also used as earpiece of telephone and lock of magnetic door.

12.5. Electromagnetic Induction

Many scientists tried to invent electric current from the magnetic field when Oerested invented electromagnetic effect. Among the scientists who worked on this subject, Michael Faraday of England, Joseph Henry of America and H.F.E. Lenz of Russia achieved success individually. But at first Michael Faraday published the result of his experiments in 1831.He shows that a variable magnetic field can produce electromotive force which creats electric current through a closed circuit. The phenomena to produce electric current in a closed circuit by variable magnetic field is called electromagnetic induction. Faraday made two experiments to invent electromagnetic induction. You can also do the experiments.

Experiment-1: An insulated wire is wound over a card board cylinder in the form of a coil. Connect a galvanometer with two sides of this coil to understand the presence of electric current. You have to open the non conducting cover during the time of connection. Now insert the south pole of a magnet bar inside the coil. What's happening? Deflection of the galvanometer is taking place. It means the current is flowing through the coil. Now remove the magnet. What's happening? The deflection of galvanometer will be the opposite of that time when magnet was entered to the coil. If the magnet is kept stationary now, the galvanometer will show the deflections when the coil is moved towards or away from the magnet. If the coil is moved away from the magnet, we can see the deflection at the opposite side.

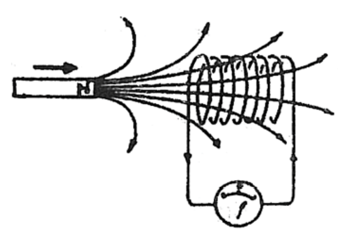


Figure: 12.4

Experiment-2: For this experiment two closed coil made of insulated copper wire to be taken. A galvanometer is to be connected with the first coil. In the second coil, a battery, a rheostat and a tapping key are to be connected [12.5a]. The coil which is connected to the sources of emf is called the primary coil and which is connected to the galvanometer is called secondary coil. When the current is switched on in the primary coil, the deflection of galvanometer will be seen for a moment in the secondary coil [12.5b]. Again the deflection of galvanometer will be seen at the time of disconnecting the electric current but the deflection will be opposite to the direction of former.

If the current is continuously varied in the primary coil, the galvanometer will show the deflections. In this case, the direction in which the galvanometer will deflect during rise of current is opposite to that during fall of current. Keeping the current fixed in the primary coil a variation of the distance between the two coils will produce a momentary deflection of the galvanometer. The direction of deflection due to increase of distance is opposite to that due to reduction in distance between the coils.

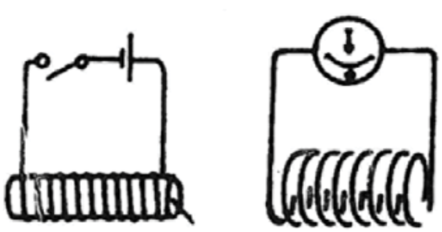


Figure: 12.5 a

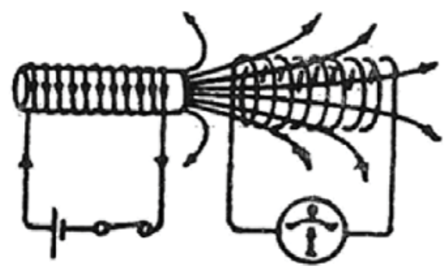


Figure: 12.5 b

12.6. Induced current and induced voltage

From these two experiments, it is observed that the deflection of the galvanometer proves the existence of an emf. So if we move a magnet towards or away from the the coil or if we move a coil towards or away from a magnet, the electric current will be produced there. This is called electromagnetic induction. If we move a coil towards or away from electric circuit or electric wire, the electric current will be produced there also. This is also called electromagnetic induction. So we can say that the process of creating electric current through the change of the distance of the circuit which can create voltage temporarily to another closed circuit is called electromagnetic induction. This voltage is known as induced voltage and the current is known as induced current. If there have no relative motion between magnet and coil, the deflection will not be seen. The more will be the relative motion, the more will be the deflection. So it is said that how long the relative motion will last between magnet and coil, induced current will be durable for that period. If the pole of magnet is altered, the side of induced current will be altered. Induced current and induced voltage can be created in the following way-

-by increasing the polar power of magnet

-by moving the magnet quickly

-by increasing the number of coil.

12.7. Effect of magnet on current carrying wire

We know that current carrying wire produced a magnetic field of its own. There happens action and reaction between magnetic field exsisting inside the opposite pole of a powerful magnet and the magnetic field of current carrying wire.

Your teacher can show you the action and reaction. You can do it yourself or with the help of your teacher.

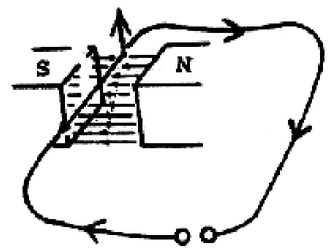


Figure: 12.6

Put an electric wire between the two poles of a powerful magnet like the picture. Let the electricity flow through this wire. You will see that it will jump to the up. It is understood that a force is working on that. From where does this come?

If you look at the picture 12.7(a), you will see the lines of force between the poles of the magnet. The magnetic field created by electric current has also been shown. The lines of force created from the combination of two fields has also been shown in the picture 12.7(b). The lines of force are more in the down than that of the up of the wire. The reason is that both the fields are working towards the same direction. [Again see the picture 12.7(a)].The fields above the wire are opposing each-other, some lines of force are rejecting one-another. As a result the number of lines is less there. As the line wants to keep themselves very tight to each other (like elastic rubber), they apply upward force on the wire.

Figure: 12.7 a

Figure: 12.7 b

If the wire remains free, it moves upward. If the direction of electric current is changed to opposite, the wire goes to downward.

12.8. Electric motor:

Suppose a loop or coil of wire like picture 12.8(a) is used between the two poles of magnet .As the loop has returned to the opposite direction from A to B, the opposite electricity will flow between the two half of the loop or coil. So, the wire will go to the upward in A and downward in B. For this the wire moves in clockwise. At the vertical position of the wire like figure 12.8(b) no force will act on it. For this it will be stopped. To keep the coil rotating, we will use a device named commutator. It consists of two equal segments made of copper (see figure12.9). Each segment is connected to A and B respectively. The outer part of the separated segment makes a contact with the electric source through carbon brush. The segment moves with the coil and when its' gap between two side remains opposite to the carbon brush, no current will flow. But despite this fact, the movement will remain continue for its inertia and it will get force newly when it will come to the contact of the moving brush. Thus the rotation will remain continue.

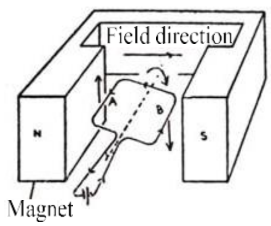


Figure:12.8 a,

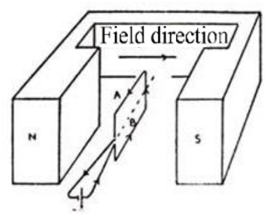


Figure: 12.8 b

It is noticeable that though A and B have changed their position, the comutator current will enter from the right side of the loop like before and will come out from the left, (see the figure 12.9) and the coil will rotate clockwise. This is the principle of electric motor. Electric motor converted the electric energy into mechanical energy. To increase the speed and power of it, the intensity pf the magnetic field will have to increase.

The intensity of the of the magnetic field can be increased in many ways. These are –

-By increasing the electric current.

-By increasing the number of turn in the loop or coil.

-By using powerful magnet.

-By increasing length and width of the coil.

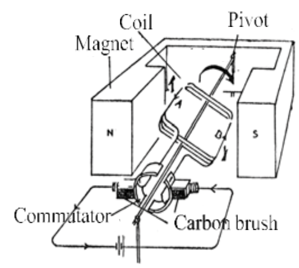


Figure: 12.9

The electric motor that we use also works in the same way. But extra parts will have to add to increase the power and flexibility of the rotation. Many coils or loops are made instead of only one coil or loop and they are arranged neatly around the central axis or orbit. Each of these wires is connected to its commutator. It helps to move continuously and easily.

Each of coils is made of hundred scrape on the soft rod of iron (which is called armature).For this, the armature is magnetized during current flow and increase the intensity of the magnetic field. (In figure 12.10, two broken lines of three armatures have been shown).The rotation can be increased by bending two sides of the magnet.

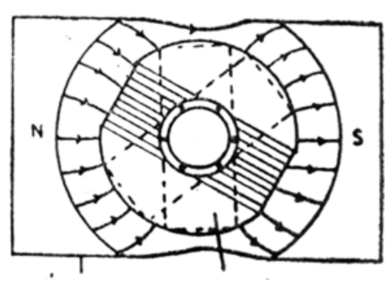


Figure: 12.10

Uses: Electric motor is used to electric fan, pump, rolling mill etc.

12.9. Generator

The electric machine in which mechanical energy is converted into electrical energy is called generator. The basic principals of this machine are established on the basis of electromagnetic induction. Generator can be of two kinds. Such as

1) AC generator

2) DC generator

1. AC generator: The structure and functions of it are being discussed in the following as it is widely used:

Structure : There is a field-magnet NS in it. There is rectangular coil of wire in the middle of the magnet on the soft sheet of iron (AB). The iron sheet is called armature. The armature is rotated at the uniform speed in mechanical way on the middle of the magnet. The two sides of the rectangular coil are connected to two slip rings.

The two slip rings can rotate to same orbit of armature. The two carbon brushes are set in such a way that they touch the two slip rings when the armature is being rotated. The resistance R of external circuit is connected to the brushes.

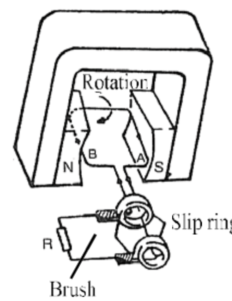


Figure: 12.11

Functions: When the armature undergoes rotation, the armature coil intersect the lines of force of the magnetic field and the electromotive force is induced in the coil according to electromagnetic induction. As the two sides of the coil are connected to the external circuit a alternating current is develop in the circuit. The magnitude of induced current mainly depends on the intensity and speed of the rotation of the magnetic field. During one complete rotation of the coil the direction of the induced curent is changed once. Thus the alternating current is produced from the mechanical energy.

12.10. Transformer:

The electrical device through which the high alternating potential can be changed into low alternating potential and low potential into high potential is called transformer. This device is made on the basis electromagnetic induction. There are two kinds of transformers.

These are -

1. Step up Transformer: The transformer which converts an electric current of greater strength at a low voltage into an electric current of weaker value at high voltage is known as step up transformer.

2. Step down Transformer: The transformer which changes the high potential less electric current into low potential much electric current is step down transformer.

Construction : A transformer is made on a soft iron core in rectangular form in which two coils of insulated copper wire are inserted in its two opposite limbs (Fig 12.12) The coil in which an a.c. or emf is applied is known as primary coil. The coil in which an a.c or emf is induced is known as secondary coil. In step up transformer the number of turns in the secondary coil is greater than that in the primary coil. In step down transformer the number of turns in the secondary is less than that in the primary coil.

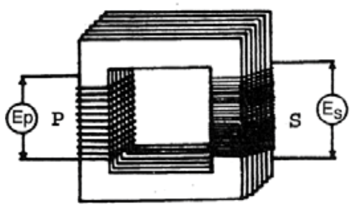


Figure: 12.12 a

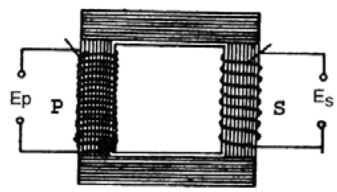


Figure: 12.12 b

Let an a.c emf E_p be applicd to a primary coil n_p turns. A current I_p flows in this coil. This curent by magnetising the core produces magnetic lines of foorce that ultimately produces induced emf in the primary coil. If there is no diminution of the magnctic lines same number of magnetic lines remain associated with each turn of the sccondary coil. Consequently an emf is induced in the secondary coil. If the number of turns in the secondary coil be n_s and the induced emf be E_s,

We have: $$\frac{E_p}{E_s} = \frac{n_p}{n_s} \qquad 12.1$$

That is to say that the induced emf in the coil is proportional to the number of turns.

For a step up transformer $n_s > n_p$ and for a step down transformer $n_s < n_p$. If no energy is dissipated in the transformer core, the energy input to the primary coil is wholly transferred to the secondary coil.

Therefore, voltage of the primary coil x current of primary coil =

Voltage of secondary coil x current of secondary coil

i.c. $E_p I_p = E_s I_s$

Therefore, $$\frac{E_p}{E_s} = \frac{I_s}{I_p} \qquad 12.2$$

This equation suggests that the rate at which a transformer reduces the voltage is exactly equal to the rate at which it increase the current so that the total power remains constant.

Therefore, a transformer transforms both the voltage and the current.

For transmission of electric power over long distances step up transformer is used. Step down transformer is used for domestic power supply such as radio, television, tape recorder, VCR, VCP, electric watch etc.

Mathematical example: 12.1: In a transformer, the voltage of primary coil is 10V and current 6A.If the voltage of secondary coil is 20 V; calculate the current of secondary coil.

We know:

$$\frac{Ep}{Es} = \frac{Is}{Ip}$$

Or, Is= $\frac{Ep}{Es} \times Ip = \frac{10V \times 6A}{20V} = 3A$

Here,
the voltage primary coil, Ep=10V
the voltage of secondary coil, Es=20V
The current of primary coil Ep=6A
The current of secondary coil, Is=?

Ans: 3A

Mathematical example: 12.2.The number of turns of primary coil in a transformer is 50, voltage 210V. If the number of turns in the secondary coil is 100, what will be the voltage?

We know:

$$\frac{E_p}{E_s} = \frac{n_p}{n_s}$$

$$E_s = \frac{n_s}{n_p} \times E_p$$

$$= \frac{100}{50} \times 210V = 420V$$

Here,
The number of round of primary coil, n_p=50 The
voltage of primary coil, Ep=210V
The number of round of secondary coil, ns=100
the voltage of secondary coil, Es=?

Ans: 420V

Mathematical Example: 12.3.The number of turns of primary coil in a transformer is 18 and the number of turns of secondary coil is 90. If the electric current of primary coil is 7A, what will be the electric current of secondary coil?

We know,

$$\frac{I_s}{I_p} = \frac{n_p}{n_s}$$

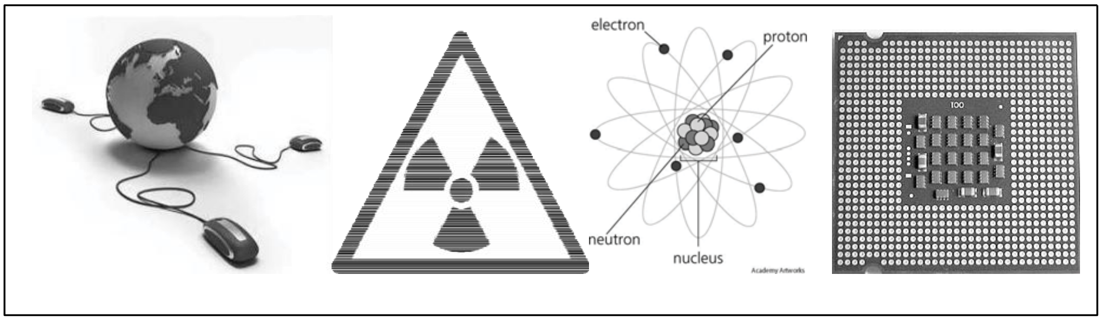
$$I_s = \frac{n_p}{n_s} \times I_p$$

$$\therefore I_s = \frac{18}{90} \times 7A = \frac{7}{5}\ A = 1.4\ A$$

Ans: 1.4*A*

Chapter thirteen

MODERN PHYSICS AND ELECTRONICS



[At the beginning of 20^{th} century, a new era has been introduced in the field of physics. During this time, theory of relativity and quantum theory have been invented. To explain the motion of high speed particles and the various phenomena of nuclear and atomic physics these two theories were needed. Besides, electronics has reached to a more developed stage through the process of evolution, as a result of which we become able to construct and use various developed devices of information and communication. Thus, the modern physics has been evolved. In this chapter, we shall discuss about radioactivity, radioactive particles and rays, the gradual development of electronics, semiconductor and integrated circuit, different electronic devices, microphone, speaker, radio, television, phone, fax machine, internet and e-mail.]

By the end of this chapter, we shall be able to –

1. Explain Radio-activity.
2. Explain the characteristics of alpha, beta and gamma rays.
3. Describe the sequential development of electronics.
4. Differentiate between the analogue and digital electronics.
5. Explain semiconductor and integrated circuit.
6. Explain the functions of microphone and speaker.
7. Explain the principles of the functions of selected communication technology devices.
8. Explain the communication process with the help of internet and e-mail.
9. Investigate how the information and communication technology devices influence our life.
10. Be conscious to make the proper and effective use of information and communication technology devices and raise consciousness among others.

13.1. Radioactivity

In 1896, French scientist Henry Becquerel observes that a radiation with special penetrating power emits spontaneously from the nucleus of Uranium metal in a continuous manner. He also observes that the element that emits radiation, transforms totally into a new element. This is a nuclear event. This event is a spontaneous and continuous phenomenon and fully controlled by the nature. Any manmade external influences such as- pressure, heat, electric and magnetic field cannot stop or increase or decrease the emission of these rays. Later Madame Marie Curie (1867-1934) and her husband Pierre Curie (1859-1906) observed the similar events. They noticed that similar type of radiation also emits from the heavy elements like Polonium, Thorium and Actinium etc. This radiation is now-a-days known as radioactive rays. The phenomenon of emission of radioactive rays or particles from an element is called radioactivity. Radioactive elements emit three energetic rays, namely alpha, beta and gamma. As a result they transform into lighter elements by the process of disintegration. As the Radium metal transforms into Lead step by step through radioactive disintegration. The unit which is used to measure radioactivity is named Becquerel.

13.2. Properties of alpha, beta and gamma rays

Alpha particle: Alpha particle is a Helium nucleus. There are two protons and two neutrons in its nucleus. The penetrating power of alpha particle is less; it cannot pass through 6 cm thick air. These particles are influenced by both the magnetic and electric field. These particles can create intense ionization and are very harmful and dangerous. The mass of this particle is four times than that of the Hydrogen atom and its charge is 3.2×10^{-19} C. Its presence can be detected by photographic films, cloud chamber and gold leaf electroscope. These particles create florescence on zinc sulphide screen. The velocity of it is 10% of the velocity of light.

Beta particle: These particles are negatively charged and largely deflected by magnetic and electric field. The speed of it is 50% of the speed of light but it can be increased up to 98%. Its mass is the same as that of electron i.e. 9.11×10^{-31}kg. Its existence can be detected by photographic film and cloud chamber. These particles can produce fluorescence. Their penetrating power is more than that of the Alpha particles. The motion of these particles can be stopped by a 3mm thick aluminum sheet. Beta particles can produce enough ionization in a gas.

Gamma rays: These rays are charge neutral. This is an electromagnetic wave. It is of short wavelength. It has no mass. It is not deflected by electric and magnetic field. Its speed is same to that of light, which means 3×10^{8} ms^{-1}. Its penetrating power is very high. It can pass through a lead sheet having a few centimeter thickness. Though its ionizing power is less, it can produce fluorescence. Its presence can be identified by photographic film, cloud chamber and Geiger–Müller counter.

13.3. Half–life of a radioactive element

We can't say which atom of a radioactive element will decay and when it will take place. But we can calculate how many atoms will decay in a particular time. A cluster of atoms is considered to study the decay of atoms. The time during which just half of the total number of radioactive atoms undergoes disintegration is called the half-life of that element. As for example, let us assume that there are 800000 atoms in a radioactive element. The time required for the decay of its half i.e. 400000 atoms to transform into a new element is known as its half-life. After a next half-life, there remains 200000 numbers of atoms. After another half-life, the number of atoms will be 100000 and thus it will continue. Here a law of possibility works, which atom will disintegrate when, none can say it.

13.4 : Uses of radioactivity

There are a lot of uses of radioactivity in medical science, agriculture and industries. In medical science especially to treat incurable cancer, the uses of radioactivity are frequent now-a-days. In medical science, the radioactive isotopes are used as radioactive tracers to diagnose different diseases like blockage of kidney, thyroid problems etc. In agriculture, radioactive tracers are being successfully used, especially to develop high yielding variety of seeds and in the research to produce special type of fertilizer necessary for trees. The radioactivity is also widely used in industries. To make the equipment germless, to control the thickness of paper in the paper mill, to identify the presence of smoke in the fire, to verify the welding of metals, the radioactivity is being successfully used. It is also used to measure the quantity of different elements in the minerals. Even the radioactive tracers are being used successfully to diagnose diseases.

The hands and number of many watches are seen glittering even in the dark. This happens because the hands and the numbers in the watches are covered with a mixture of radioactive thorium and zinc sulfide, as a result they glitter. Radioactivity is also used to determine the age or time of things of millions year old.

13.5 : Dangers of radioactivity: Although radioactivity is beneficial to us, it can be very dangerous also. The high dose of radioactive radiation can create serious problems in human body. Life killer cancer may cause from this radiation. The preventive power against disease is reduced if someone keeps oneself in close-contact with excessive radioactive radiation for a long time. Man can be mentally disabled; even he may be physically invalid. The harmful effect of radioactivity can be observed from generation to generation. So the people who work with radioactive radiation should be careful. They should take proper steps to protect themselves from the excessive radioactive radiation.

13.6 : Development of electronics

The present era is the era of electronics. Radio, television, phone, fax, camera, computer, watch etc. are the contributions of electronics. The control of electric current through vacuum tube, special type of crystals and chips is known as electronics. The history of electronics is ancient of more than hundred years. The real journey of electronics begins with the invention of Addison's effect in 1883. When Addison was working with electric lamp, one thing was disturbing him highly. The positive end of the filament of carbon of the lamp was burning again and again. To remove this difficulty, he entered a plate by sealing it with the filament. He saw that when a positive potential is given to the plate with respect to the filament, an electric current flows through the vacuum tube. But when a negative potential is applied to the plate electric current does not flow. Addison explains this phenomenon in this way- as the emitted charge from the hot filament goes to the positive plate, so this charge is negative. If the plate is negative, it repels the emitted charge, as a result no current flows through the circuit. This is known as Addison effect. British physicist Fleming first invented the vacuum tube by using Addison effect. This tube works as a rectifier that means it changes alternating current to direct current. This is the real beginning of electronics. During this time, detector was very necessary for Marconi's Radio. This tube fills up the need of the detector. As there were two electrodes in it, this is called diode.

After two years, an American named Lee de Forest invented another vacuum tube called triode. Since it had three electrodes, it was named as triode. Besides anode and cathode, there was another electrode known as grid in it. Grid controls the flow of electric current from anode to cathode. It is wonderful that the triode can work as an amplifier. So triode plays a vital role in the development of communication.

Figures diode and triode

As the size of diode and triode valves are very large, they create problem to fix them in different electronic devices. The expense of power for it is more, it is less reliable and cooling system is necessary to keep it cool. So the scientists were searching for a semiconductor device as its alternative. Later they invented p-n junction diode. After long experiments, they were able to invent n-p-n transistor. Transistor works as an amplifier.

To set up several components in a single motherboard, problem creates. Sometimes it becomes impossible. So, IC or integrated circuit is invented. IC is such a creation using semiconductors like silicon, where millions of microscopic electric circuits are gathered in a place like a nail of our finger. Revolutionary changes took place in the design of IC chips after its invention in 1960.

13.7. Analogue and Digital electronics

Analogue signal: The magnitude of some quantity which changes continuously is called analogue. The magnitude of the quantities such as sound, light, temperature, pressure can be of any value within a definite extent. Analogue data is sent continuously. Telephone, radio, television broadcast and cable television generally send analogue data.

So the analogue signals are continuously changeable voltage or current. This voltage or current is normally changed and can receive any value between the lowest and the highest value. Analogue signal is really a sine wave. Audio and video voltages are the example of analogue signals.

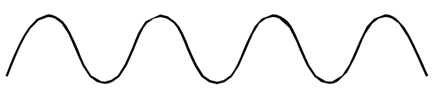


Figure 13.1: Analogue signal

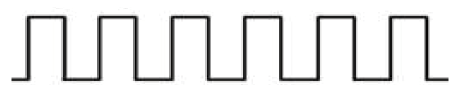


Figure 13.2: Digital signal

Digital signal: Generally the word 'digit' means number. The word 'digital' comes from the word digit. Digital signal means such a communicative signal which can receive some definite value. These can be changed into discrete values and each of them can be identified separately. In this system, with the help of binary code i.e. 0 and 1, any information, number, letter or any special signal etc. can be understood or sent. In this signal system, the value of 'on' state is 1 and the value of 'off' state is 0.

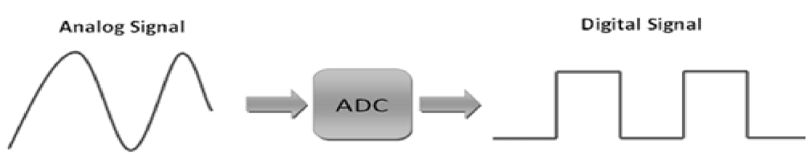


Figure 13.3: transformation of analogue signal to a digital signal

Computer saves, process and sends any data as digital signal. With help of modem, analogue data can be changed into digital and digital data can be changed into analogue data. Analogue clock shows the time by continuous rotation of the hands and digital clock gives the time by changing the digits.

Advantages and disadvantages of analogue and digital signal

Which one is better between analogue and digital signal can be measured by three factors. These are: the qualitative standard of the signal, the elements to maintain the process and cost or expense.

Digital signal is the best to send a signal to a long distance. If the distance is long, the power of analogue signal decreases gradually. Then to sustain the analogue signal, amplification has to be done. As a result noise increases, and the quality of the signal is reduced or distorted and it can be fully lost. But the digital signal is amplified on the way. As a result the signal remains unchanged. Digital signal is used to transmit a signal through an optical fiber, since the qualitative standard of the last signal remains unchanged. Besides many signal can be sent in every second. Though the digital device is more expensive than the analogue device, the total cost is less in digital system than that of the analogue system. Cross connection may be occurred in analogue device but it cannot be happened in digital system.

13.8. Semiconductor and Integrated Circuit

Semiconductor: There are some materials (such as- silicon and germanium) which are neither good conductor nor insulator. These are called semiconductors. Pure semiconductor works as an insulator when it is cold. At normal room temperature it behaves slightly as a conductor. But the conductivity of semiconductor can be increased by adding some definite elements with it. Semiconductor is divided into n-type and p-type on the basis of the elements added to it. Negative and positive charge carriers are denoted by n-type and p-type respectively. The semiconductor made by the addition of phosphorous with silicon is an example of n-type material. The presence of phosphorous atoms increases the number of negatively charged electrons which can move freely in the substance. The semiconductor made by the addition of boron with silicon is the example of p-type material. The boron atoms create gap or positive holes in the electronic structure of atom. The electrons move from one hole to another by jumping within the material.

If an n-type material is sandwiched with a p-type material, a very necessary device is developed which is called a p-n junction diode. It works as a rectifier. Diode makes the electric current unidirectional i.e. the diode transforms the alternating current (AC) into a direct current (DC). It saves radio, TV, computer etc. to be electrified due to faulty connection.

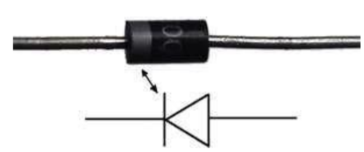


Figure 13.4: Diode and its symbol

It is necessary to amplify the electric current and voltage for various reasons. The instrument which performs this work is called an amplifier. Transistor is such a device which works as an amplifier and high speed switch. A transistor is made when a p-type substance is introduced between two n-type materials like a sandwich. These three layers are called collector, base and emitter. The two n-type regions are the emitter and collector and the narrow p-type region is the base of the

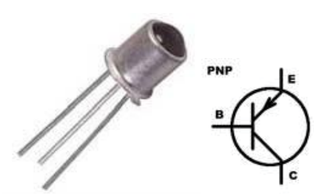


Fig: 13.5: Transistor and its symbol

transistor.

At the same way, transistor is made by using p-type and n-type semiconductor. Here p-type regions are the collector and emitter and n-type region is the base.

Transistor is used to amplify the electric current.

Integrated circuit: Integrated circuit is commonly known as IC. IC is used in most of the electronic appliances starting from computer, mobile phone to microoven which we see around us. IC is such a creation using semiconductor like silicon where millions of microscopic electronic circuits are gathered in a place like the nail of our finger. Revolutionary changes took place in the design of IC chips after its invention in 1960. At the early stage, there were hundreds of circuits or components organized in the IC chips. The number reaches to thousands by 1970. At that time IC was used only in computers and pocket calculators. At present, a single IC chip can contain millions of components which are able to operate or drive many complex devices or machines. The famous Intel chip is an example of it. The interesting matter is that as the number of components is increasing, the size of the chips is getting smaller and the standard of the devices is being developed.

If the IC chips were not invented and developed, we would not get creative devices like mobile phone, internet, MP-3 player and so on. The modern IC chips have brought a revolution and given us many facilities and comforts.

13.9. Microphone and Speaker

Microphone is orally known as mike. In a big meeting or program, a speaker delivers his speech in front of an electronic device which is known as microphone or mike. Microphone converts sound into an electric signal. The audience can hear it loudly through a loud speaker. Because the speaker transforms the electric signal of microphone into sound. Perhaps you will have seen the use of microphone and speaker in various ceremonies of your school. Both microphones and speakers are found in tape-recorder, VCR etc.

Microphone and its functions

We have already said that microphone is such a device that changes sound wave into electrical audio wave or signal. The frequency and relative amplitude of the electrical audio signal remain the same as that of the sound wave.

There is a moving coil and a thin metallic sheet named diaphragm in the microphone. When a person speaks through a microphone, the diaphragm vibrates by the sound wave. Diaphragm is that part of the microphone which is designed to transform the vibration of sound into electricity. The vibration of different types of sounds vibrates the diaphragm differently. This vibration makes the diaphragm move to and fro in the magnetic field. As a result,

Fig: 13.6 Microphone

alternating electric current is induced in the moving coil. Thus microphone converts the sound energy into electrical energy. This is called audio signal. Having amplified, this electric audio signal can be transferred to a long distance through a telephone line or radio. So microphone plays a vital role in television and radio broadcasting, recording and telephone.

Speaker: Speaker does just the opposite task of the microphone. Speaker converts the electric signal of microphone into corresponding sound wave.

Fig: 13.7

Functions of speaker: Most of the loudspeakers are moving coil loudspeaker. It has-

1. A cylindrical permanent magnet which produces a strong magnetic field.
2. A small coil or wire-loop is suspended. This wire-loop can oscillate to and fro in the magnetic field.
3. A paper cone remains attached with wire-loop.

When the alternating current produced by the sound flows through the loop, the loop moves to and fro. For this reason, the paper cone is vibrated. As a result, sound is produced.

13.10 Information and communication technology

At present, information and communication technology is a very popular subject. Starting from simple works of our daily life we can do very important tasks of our professional life by using information and communication technology easily. Communications have greatly influenced the life of human being at the beginning of 20^{th} and 21^{st} century. In 19^{th} century, the development and expansion of telephone and telegraph has taken communication power of human one step forward. In 20^{th} century radio, television, cell-phone, fax-machine have brought a revolution in the field of communication. After these, computer and internet have made great contribution to the development of communication.

Radio: Radio is a wide and important medium of entertainment and communication. We can hear news, song, music, drama, discussion, debate and the advertisements of industrial products. Radio is used to exchange information in army and police department. Radio technology is used in the field of mobile or cellular phone communication. The scientists who have made a great contribution to invent radio are Googlielmo Marcony of Italy and Sir Jagadish Chandra Bose of Bikrampur in Bangladesh.

Fig: 13.8

We can hear sound from radio. How is this sound sent and how can we hear it? In the studio of a radio-telecast station, a person speaks before the microphone. Microphone converts that sound into electric wave. This wave is known as audio signal. The frequency or power of this signal is very weak and its frequency range is 20 hertz to 20000 hertz. This wave cannot go far. So this information carrying low frequency wave is mixed with high frequency electromagnetic wave. This high frequency electromagnetic wave is called carrier wave. This combined wave is called modulated wave. The process of mixing these two waves is called modulation. This modulated wave is also called radio wave. Radio wave is amplified with the help of an amplifier and transmitted to space as electromagnetic wave with the help of antenna of the transmitter. This radio wave spreads out in the space and it is divided into two waves called Ground wave and Sky wave. Ground wave directly reaches to the aerial of receiver. The radio set in our house is a radio wave receiver. The sky wave comes back to the earth by being reflected at the ionosphere and is received by Ariel of the receiver.

The receiver receives the radio wave and converts into electrical signal. After that the sound wave is separated from the carrier wave by the process of demodulation. Later electrical signal is amplified with the help of amplifier and is sent to loudspeaker. Loudspeaker again changes the electrical signal into sound. We can hear this sound.

So, the sound is not transmitted from the transmitter to the radio. The sound wave is sent by changing it into electromagnetic wave, the receiver receives the radio wave, the loudspeaker changes it into sound.

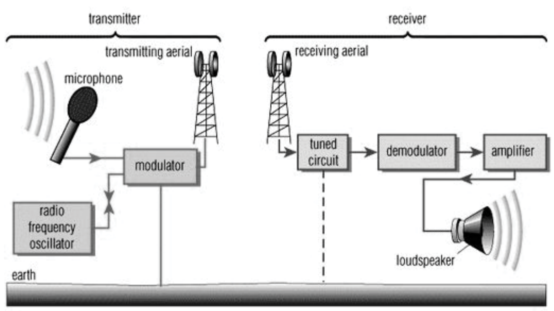


Figure: 13.9

Television: Television is such a device by which we can hear the sound and watch the picture of the speakers on the screen from distant place.

In 1926, Logy Beard was able to send pictures on television. On that day, the TV actor was a talking doll.

Figure: 13.10

How television works: We know that we can see picture on television along with hearing sound. To send the sound and picture on television, there are separate transmitters in the transmitting station by which sound and picture can be sent in the form of electromagnetic wave.

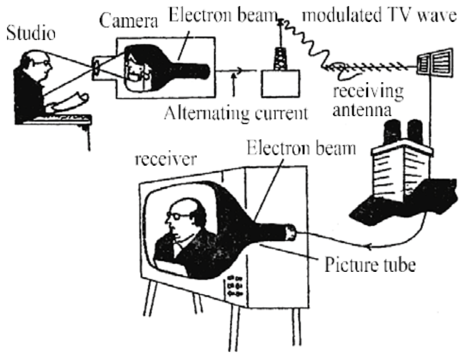


Figure: 13.10

Pictures are transformed into electrical signals and then sent with the help of one of the transmitters. With the help of another transmitter pictures are transformed into electrical signals and then transmitted them in the form of electromagnetic wave. At first we should discuss about sending and receiving picture. The pictures or the scenery are to be sent has to be converted into electrical signals by the TV camera. This signal is mixed with a high frequency carrier in the modulation process. Afterwards it is sent in the form of electromagnetic radio wave with the help of an antenna.

TV set receives electromagnetic carrier wave for the picture with the help of antenna. Rectifier separates video electrical signal from the carrier wave. This electrical signal is amplified by an amplifier and it is sent to the electron gun. This electron gun is attached to the back of the picture tube of the television. After receiving the video signal, the electron gun shoots the narrow electron beam like a needle. When the electron beam from the electron gun incidents on the fluorescent phosphor screen of the TV, then flash of light is created. With the combination of these bright and dark spots, bright and dark light spots and flashes are created on the TV screen. The picture sent from the camera is seen on the TV screen with the combination of these bright and dark spots. This forms 25 still picture on the TV screen in every second which our eyes see as moving picture.

Transmitting and receiving of sound

The picture which will be sent to television and the sound associated are converted into electrical signal with the help of microphone. This electric wave is mixed with a high frequency electromagnetic wave known as carrier wave and it is transmitted with the help of transmitter.

The TV set that we use in our house has separate processes of receiving sound and picture signal. The electromagnetic wave comes to our TV antenna sent by the transmitter and creates electric current. This electric current reaches the receiver of television set passing through the wires. The sound receiving receiver of the television set receives this electrical signal and amplifies it. Later it is sent to the loudspeaker which converts this electrical signal into original sound .We can hear this sound.

Generally these are the functions of black and white television.

Colour television: There are no major differences between the basic principles of colour TV and Black and White TV. There are three separate electron guns in the camera of colour television for three basic colours (Red, Blue and Green) .There are also three electron guns in the receiving machine of colour television. The screen of colour television is made of three kinds of phosphor granules. A particular colour illuminates the phosphor granules of that particular colour. Consequently, the screen of a television tube gives red, blue and green light spots. Hence the coloured image becomes visible on the TV screen.

Telephone

Introduction: Telephone is the largest, most widely used and popular medium of communication in the world. It is used to communicate, send E-mail, Fax, and for computer communication etc. with any other country.

Alexander Graham Bell invented Telephone in 1875. Through many evolutions, the telephone invented by Graham Bell has reached to the modern dimensions and cordless, cellular and mobile-phone has been made.

How does telephone work

In every telephone set, there is a system of receiving and transmitting signal. The mouthpiece of a telephone is microphone, it is the transmitter and the ear-piece is a speaker, and is the receiver. There is a ringer for making the ringing sound and a dialing system in a telephone set. When we speak, the microphone of the mouthpiece converts our voice into electrical signal. This signal reaches to the ear-piece of another telephone through the telephone wire. The speaker of the earpiece converts the electrical signal into sound. As a result, the caller or the called person can hear the sound and answer. This answer of the called person returns to the telephone set of the caller after being converted into electrical signal with the help of microphone of the mouthpiece and it is transformed into sound in the speaker of the earpiece of the caller, then the caller hears the speech of the called person. The electrical signal travels so fast through the telephone wire that it does not delay any single moment to transfer. Every telephone set is connected

Figure: 13.11 Land and mobile telephone

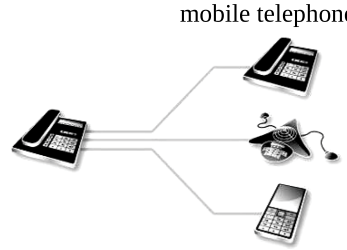


Figure: 13.11 Function of land telephone to the main regional office through wire. The connection with other telephone set is established through the regional head-office.

Cell phone or mobile phone: Cell phone or Mobile phone is the most popular and widely used medium of communication of present time. You can not only communicate with other but also, can play games, download music, songs, hear music, watch film and use internet with the help of it. Besides, you can make cash payment, pay bill, check in at the airport and apply for the admission in a college or university using this phone. You can communicate from one corner of the country to another over phone.

Making and receiving phone call in Mobile:

This phone is not connected to another phone with wire. This type of phone sends and receives information or speech with the help of radio signal instead of wire. A mobile set is connected to the telephone network through dialing to other mobile sets from the keyboard of one set. When you make a call from a mobile from anywhere, the call travels to the transmitter-receiver tower as a radio wave.

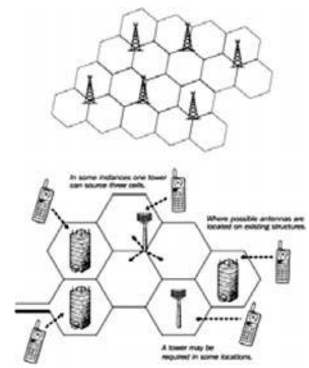


Figure: 13.13 Mobile Network

Then the call travels to the mobile switch station through micro wave or wire. This station sends this call to the local telephone exchange. There the call reaches to the called person as a telephone call. Most of the mobile phones at present work with the combination of sending radio wave and telephone circuit switching.

Fax: Fax is the short form of facsimile. It is used to send a document as it is, without any change.

What is Fax: Fax is such an electronic system through which any information, picture diagram or writing can be sent by copying it as it is. Any original document can be reproduced with the help of this machine.

Though the fax machine was invented in 1842, its journey started in 1930.The scientist Alexander Bain invented fax.

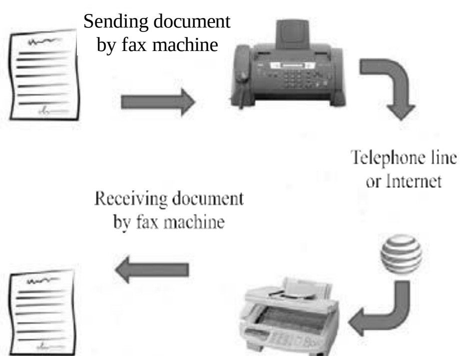


Figure: 13.14

How Fax works: Modern fax machine is an ultra modern technology of electro optical machine. Here the original document is scanned through electronic process. Then, the scanned signal is transformed into binary signal. This signal is sent using standard modem device through telephone. The receiver of fax machine receives the transmitted electronic signal through modem and converts it into original document by demodulating it. A printer prints out this document just as it is.

Computer: This is the era of information and technology. The uses of computer are so excessive in every sphere of life including information technology and communication that this era is also called the era of computer. Most of the works of our daily life are being influenced by computer. Computer has become very essential in the field of science and technology. Computer can perform mathematical calculation and give mathematical logic. Besides, performing mathematical calculation, computer can select or choose anything, can copy, can compose, can decorate respectively etc. The use of computer is increasing day by day in the field of trade and commerce, administration, education, industry, medical science, communication, defense, entertainment etc.

What is computer?

The word computer means calculator. It is not only a calculating machine but also more than that. Computer is such an electronic device that can receive, process, transform, preserve and send any data. All the computers are controlled by the programmed command which tells the computer what it will have to do.

Figure: 13.15 Computer

Structure of computer

Computer is a developed electronic system. Computer collects data, process it according to command and represents results as necessary. Where the computer receives information is called Input. Here the data of the computer is applied. For this, the input devices which are used generally are key-board, mouse-touch pad, scanner, digital camera and microphone. Where data is being processed is called CPU or Central Processing Unit. In this unit, there is memory unit or RAM, control unit and arithmetical logic Unit. The end from where the result is found is Output.

There are mainly monitor, speaker and printer as output device. We get the processed data through them. A basic structure of computer is given below:

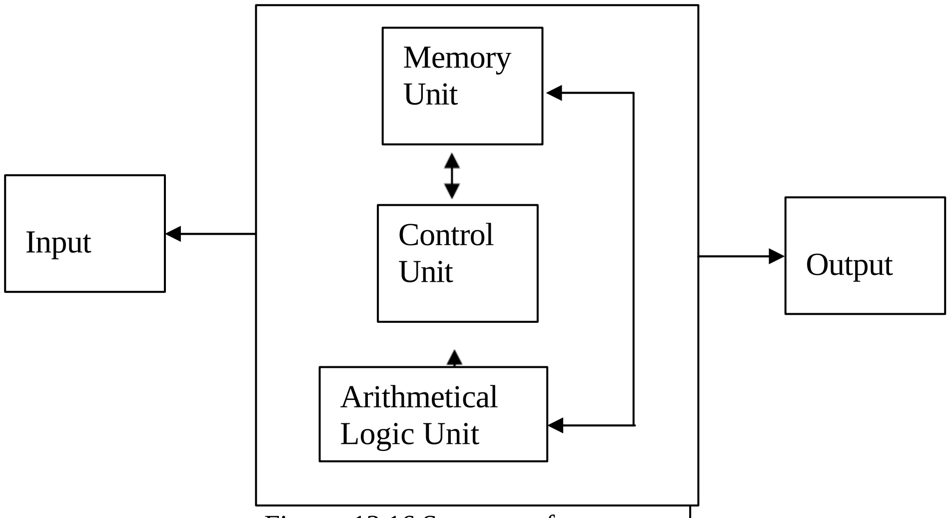


Figure: 13.16 Structure of computer

The elemental devices by which a computer is made are called Hardware. Such as keyboard, mouse, processor, monitor, printer etc. Software is a group of commands that says computer what it will have to do. These are some programs as- Windows-98, Windows-2003, Windows-2007.

Hardware is the body of a computer and software is its soul.

Computer is considered as a very essential machine for its speed, ability of preserving data, relevancy, accuracy, tirelessness and automation. Computer can work in an unbelievable speed; it can make millions of mathematical calculations in a second.

The uses of computer: Computer is being used in many spheres of our life. The fields of using computer are-

1. Treatment: Computer is used for recording the appointment, identity, address, symptoms of diseases etc of patient, the selection of medicine, to examine the eye, X-ray or other diagnosis, the operation of heart and for the study of medical science.

2. Trade and Commerce: Computer is used to control the deposit of goods, for commercial communication, for booking ticket, banking system, for giving salary of the staffs, to make budget of income and expense etc.

3. Transport system: Computer is used to control traffic of ship, aero plane, motorcar, train etc, to control speed, to book ticket etc. Besides, computer is used to send, control and run space craft.

4. Industries: Computer is being used to produce goods in an automated process, to justify the quality of goods, to collect data, to provide salary of the employees, to maintain schedule of the work etc .To run an atomic reactor or to use such complex and modern machine, computer is very essential.

5. Education: Computer is being used for teaching in classrooms, for self-learning, to evaluate answer scripts and to publish results.

6. Defense: Computer is used to conduct Army, to control arms, to communicate etc.

7. Research: The uses of computer are increasing day by day in the field of research.

8. Printing: The use of computer has brought about a revolution the field of printing. The excessive cost of printing has been reduced for using computer to compose, design etc.

Internet and E-mail: You must have heard the name of internet and e-mail. Most of you who are living in a town perhaps have sent e-mail using internet from your residence or school. But most of you who are living in villages might have sent e-mail to your friends or relatives from internet and fax shops. At present e-mail is the widely used mailing medium.

What is internet? Internet is the 'network' of networks or the 'mother of all networks'. It is an international network that has connected more than 400000 small networks of different countries. The American defence division has introduced internet in 1969. Internet is such a group of networks which is made of numerous computers, modems and telephone lines. These elements are mutually connected to one another physically. These networks are able to exchange any kind of information or data among themselves. Internet is the sum of many networks and they work as a single network all together.

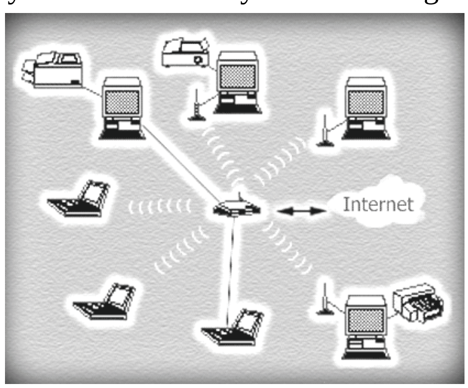


Figure: 13.17 How internet works

We can browse website, send and receive e-mail, make video conferencing through internet. We can gossip, book tickets of bus, train and plane, can perform electronic trade and commerce, e-banking and shopping through internet. We can send and receive any file or document electronically. In addition, we can find millions of books, journals, magazines of the online libraries, read them if necessary and print them by downloading.

E-mail: In short electronic mail is known as e-mail. E-mail is a fast and efficient mode of communication with friends, classmates, relatives or colleagues through internet.

There is no need of stamp, post card or envelope or post man to send this mail or letter. We can send and receive letters from one computer to another, and exchange documents, pictures and any type of data through internet. The block diagram of sending e-mail is given below:

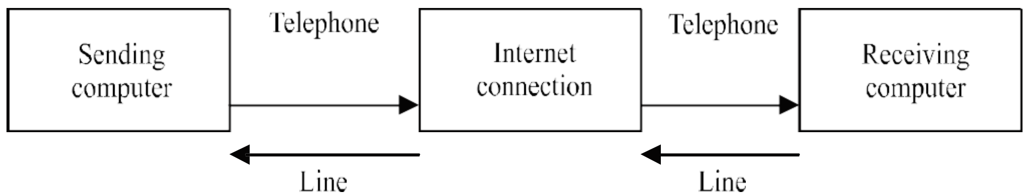
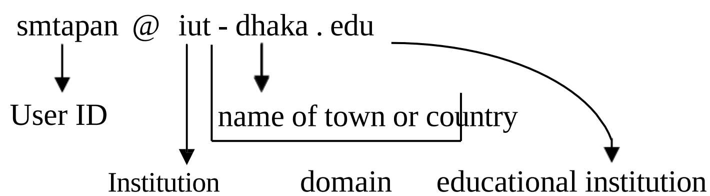


Figure 13.18

E-mail distributes the electronic messages and files among one or more electronic mailboxes. E-mail messages can reach to and come from any corner of the world within a few seconds. E-mail address is necessary for both sender and receiver to use e-mail. Follow the e-mail address given below:



Another example of an easy e-mail address may be,

smtapan@gmail.com

Effective uses of instruments related to information and communication:

We use various types of devices such as phone (land, mobile and cordless), radio, television, fax machine, computer etc. for communication. As a result of using such devices, the world has come to the control of our grip; again many problems have been created also. So we shall have to use them effectively to get maximum advantages from them.

In our country there is a lack of electricity, so we shall not waste electricity by misusing the devices. Many people commit criminal activities using modern communication system. We shall be careful about them and will not do any criminal offence through these devices.

We shall not use computer for a long time. Those who works with computer for a long time, they feel excessive stress in their arteries or veins, nerves, wrists, shoulders and neck for using the mouse and keyboard for a long period of time. If they do not take enough rest during the break of work, various problems may arise in these organs along with pain. Among these problems there are- pain in the hands, arms and fingers, swelling up of the fingers etc.

If anyone works on a computer without taking rest for long time, he or she will fall victim to eye-problems. This is called computer vision syndrome. Among the syndromes there are: burning of eyes, dryness of eyes, itching of eyes and redness of eyes.

When you will work on a computer; you should sit properly and look forward. The hands should not be kept on anything during typing and hands and fingers should be kept straight. The screen of the computer should be kept 20 to 24 inches (50-60 cm) apart from the eyes. The light from the lamp over your head and that on the table should be dimmed so that they cannot fall on your eyes or on the screen of computer.

The problems caused by radio and televisions are mainly health problems related to sound pollution. Many of you play radio and televisions in a high volume. It does not only creats problem in your ears but also if there are patients suffering from heart diseases or high blood pressure or any other patients neighbouring you, they may suffer more and get restless from sound pollution. The people, who listen to radio and television with high volume, may fall victim to headache, hearing problems, tiredness etc. health problems. So, do not play radio and television with high volume.

Many people disturb others misusing mobile phone. We should refrain ourselves from such activities.

Exercise

A. Multiple choice questions
Tick (√) the correct answer.

1. What do mean by alpha particle emitting from radioactive elements?

   (a) a hydrogen nucleus (b) a helium nucleus

   (c) a charge neutral particle (d) a negative particle

2. What is actually beta ray emitted due to the radioactive decay?

   (a) the flow of negative electrons (b) a charge neutral particle

   (c) a positive nucleus (d) flow of positive protons

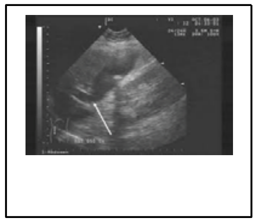
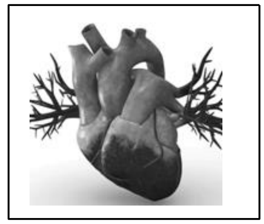
3. What is called a silicon chip if millions of circuit is added to it?

   (a) parallel circuit (b) semiconductor transistor

   (c) integrated circuit (d) semiconductor diode

Chapter fourteen

PHYSICS TO SAVE LIFE

[Establishing a relationship between physics with biology, a new subject has been developed, which is called Bio-physics. We need a healthy, strong and disease free body to survive. To keep a sound health we need proper treatment. In medical science, proper diagnosis is an important issue. Different types of medical instruments are prepared based on different theories and principles of physics. These devices function by utilizing different principles and theories of physics. A few of such instruments will be discussed in this chapter.]

By the end of this chapter we will be able to-

1. Explain the basis of bio-physics.
2. Explain the contributions of Jagdish Chandra Bose in bio-physics.
3. Explain that human body runs following the rules of physics.
4. Explain the applications of ideas and theories of physics in the instruments for diagnosis of diseases in medical science.
5. Explain the hazards of using modern technology and devices and mechanism of prevention.
6. Conscious about the necessity of diagnosis of diseases for proper treatment and raise consciousness among others.
7. Appreciate the contributions of science and technology for diagnosis of diseases.

14.1 Basis of bio-physics

Bio-physics is such a branch of science which is developed on the basis of a number of branches of science. Theories and methods of physical science are employed in biophysics to study a system of biology. Biology is the science of studying living world. How plants and animals collect food, communicate, percept from the environment and reproduce are discussed in biology. On the other hand the mathematical rule which nature follows is the subject-matter of physics. For a long period, the scientists believed that the laws of living world and physical world are different. But with the progress of physical and biological science, a deep harmony is found between these two apparently different disciplines. At first physics and biology has evolved as two different subjects. The mutual relationship and coordination between these two subjects has increased a lot with the advancement of science. It was thought before that living world follows a different rule and the laws of physical science are applicable only for the inanimate objects. But now we know that the animal body can be compared to a machine from many aspects and it is possible to explain many behaviors of animal body with the help of physical laws. Actually, the laws of physics are universal. So, not only the physical world, but also the animal kingdom can be explained with the help of physics in many cases. This is the basis of bio-physics.

The challenge of bio-physics is to explain different complexities of life on the basis of simple laws of physics. Bio-physics is a powerful tool to reach at the depth of life by investigating different secrets of life and analyzing different events using mathematics and physics. Bio-physics is a bridge between biology and physics.

14.2 Contributions of Jagadish Chandra Bose

Acharya Sir Jagdish Chandra Bose was a physicist as well as a biologist. In our sub-continent he is the first internationally recognized scientist. Bose family hailed from the village Rarikhal of Bikrampur under district of Dhaka. He was born in Mymensingh on 30th November, 1958. His father Bhagawan Chandra Bose was a deputy magistrate in the district of Faridpur. Bose's education started at a vernacular school in Faridpur. Next he got admitted to Hare school and Saint Xavier's school and college in Kolkata and passed his student life. After completing B.A. he went to England for higher study in the year 1880. His student life in England was from 1880 to 1884. He completed the B.A. degree with honours in physics from University of Cambridge and a B. Sc. degree from University of London. In 1885, he started as a professor of physics in Presidency College. Though there were not adequate facilities of research in Presidency College, he carried out his research work. As there was scarcity of time in day, he had to conduct his research work in night many times. In the laboratory he researched a lot about, how radio signals can be transmitted to a distant place without the help of wire and succeeded. In 1895, for the first time in history he sent radio signal to a distant place without wire and demonstrated in public. He has mentionable contributions in micro-wave research. He was the first who was able to reduce the wavelength of generated wave to millimeter level (about 5 mm). He was the first to use a semiconductor junction to detect radio signal. Instead of taking commercial benefit from this invention, he opened it for all, so that others can develop this research more.

Subsequently, Jagadish Chandra Bose made a number of important and pioneering discoveries in plant physiology. Among these, invention of crescograph to record the growth of plants, extremely slight movement and how plants respond to various stimuli are notable.

His major contribution in the field of bio-physics is the nature of conduction of the stimuli in plants. Earlier it was thought that, the nature of response of plants to different stimuli is chemical, but he became able to show that it is electric in nature.

In 1917 he established 'Bose Biggan Mandir' in Kolkata in order to research about plant physiology. His writings in Bengali language are compiled in a book named 'Abyakta'. 'Response in the Living and Non-Living' is a mentionable book of him. Jagadish Chandra Bose expired dated on 23rd November 1937.

14.3 Human body and machine

We use different types of devices to meet our various needs of everyday life such as- automobiles, refrigerator, television, steam engine, internal combustion engine etc. Many people designated human body as a machine. Though human body is not a machine at all, it behaves as a machine in many aspects. As like as a machine, it is also made up of many small parts or organs, absence or infirmity of one organ the activities of the whole body is disturbed. Each part of the body, like each part of a machine, does special jobs.

Each organ of human body is interconnected with other organs, each organ runs at its own individual speed, but all function in a specific way and there is a predetermined relationship to each other. In this sense, the human body is analogous to the most complicated man-made machines.

Heart, kidneys, lungs, liver etc. are such parts of human body. As for example- heart is actually an automatic pump, which is able to circulate blood throughout the whole body by its own electric signal without any external stimulation. On the contrary, kidney is a special filtration machine which eliminates the nitrogenated waste materials of the body. Due to the coordination of functions of such small machines the whole human body remains active.

Human body is like an organic machine. Energy is needed in a machine to do work. In different engines using fuels like petrol, diesel, CNG etc. we convert chemical energy into mechanical energy. Similarly, human body also transforms chemical energy into mechanical and heat energy by food ingestion and respiration. Therefore, human body is like an organic machine in fact. But, in many aspects, human body is more amazing than the most complex machine made by humans. Human body can perform such functions which is not possible for any machine. For instance- human body develops from only one cell. With the passage of time, this single cell transforms into a complete human body, which is build with thousand billions of cells. But this doesn’t happen in case of any machine. Sometimes functions of the whole body stops due to infirmity of only one part of the body. For example- when function of the heart stops, functions of all other parts of the body stops too, and functions of the brain also stops very quickly.

14.4 Instruments used for diagnosis of diseases

Once the doctors were used to identifying diseases by observing different external symptoms of the patients and prescribed medicine and diet accordingly. Modern instruments to identify diseases were not invented at that time. As a result, it was not possible to locate the exact positions of different organs. In addition, in which degree a particular organ of the patient is infected was not possible to know. Various types of instruments are invented utilizing different technologies of science to diagnose diseases. With the help of these instruments it became possible to determine diseases properly. It is impossible for a doctor to identify a disease without the right instrument, which is necessary to perform that particular test. The specific cause for a particular disease became known to us due to the invention of different devices. Once people used to believe different superstitions related to disease due to ignorance. In the modern society, the mortality rate is decreased by a large amount. The principal reason behind this is that physical instruments are being used for the purpose of diagnosis and treatment.

In this section, some of the instruments which are generally used for diagnosis of diseases are discussed.

X-ray

X-ray is a kind of electromagnetic radiation. The wavelength of X-ray is much lesser than that of the ordinary light. Its wavelength is about 10^{-10} m. X-ray was invented by Wilhelm Roentgen in 1895. Another name of Roentgen ray is X-ray. When the nature of Roentgen ray was not known, for being an unknown ray it was named X-ray. The power of X-ray to penetrate any material becomes more as its wavelength gets smaller. Ordinary light is visible and divided into different colours, but X-ray is invisible. If an opaque medium is placed in the path of ordinary light, it cannot penetrate the medium. On the other hand X-ray has high penetrating power. X-ray is produced in an X-ray tube. X-ray tube is a vacuum glass tube. There are two electrodes placed at the two ends of the glass tube. One of them is called cathode and the other is anode. There is a coil made of tungsten in cathode which is called filament. The cathode is heated by the current flowing through the filament. As a result, the electrons are freed and come out. If a high potential difference is applied between the electrodes, the electrons are accelerated with very high speed and hit the target anode. Due to this, the motion of electrons suddenly stops and X-ray is produced. Here, the kinetic energy of electrons transforms into electromagnetic wave. This radiation of small wavelength is the X-ray. Therefore, if electrons with high speed strike a metal, then a type of radiation of unknown nature having high penetrating power and of very small wavelength is produced from the metal. This radiation is called is called X-ray. In figure 14.1 the essential parts of an X-ray tube are shown.

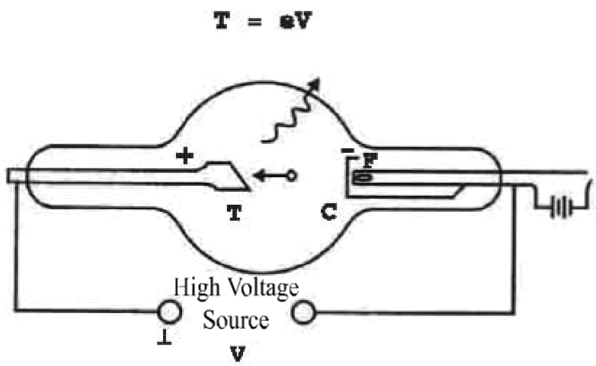


Figure: 14.1

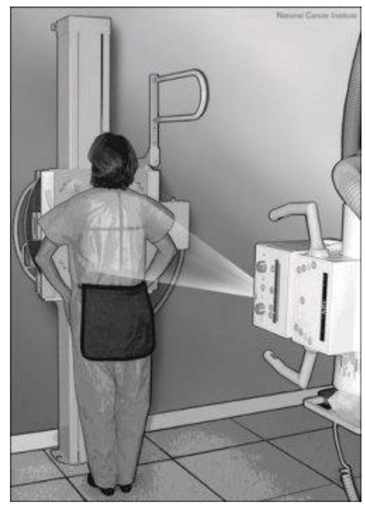


Figure: 14.2

X-ray is used for various purposes. It has tremendous contributions to diagnose diseases in medical science.

1. Displaced bones, cracks in bone, bone fracture etc. can be identified very easily with the help of X-ray.
2. X-ray can be used to diagnose any type of disease in face, for example- to identify ulcer and decay at the root of tooth X-ray is used.
3. Intestinal obstruction can be identified by X-ray of abdomen.
4. The stones present in the gall bladder and kidneys can be identified by X-ray.
5. The diseases of lungs like pneumonia; lung cancer etc. can be traced by X-ray of chest.
6. X-ray is also used for treatment purpose. It can kill cancer cells. Cancer can be treated using radiotherapy.

   Necessary precautions should be taken so that unnecessary exposure of X-ray radiation cannot harm the patient. For this, the patient should be covered with apron made of lead as much as possible. X-ray of abdomen and pelvic region of pregnant women should not be done except in case of emergency. Apron made of lead must be used for other X-ray tests.

Ultra Sonography

Ultra sonography is a procedure that depends on the reflection of sound of high frequency. When sound wave of high frequency is reflected from an organ or muscle within the body, then an image analogous to that organ is formed in the monitor by the reflected waves.

The frequency of the ultrasound is 1-10 MHz which is used for diagnosis of diseases. In an ultra sonography machine, the high frequency ultrasonic waves are produced by electrically stimulating a crystal called a transducer. In an ultra sonography machine, the ultrasonic waves are transformed into a narrow beam. Next this beam is directed toward the organ whose image is to be recorded.

The beam is reflected, absorbed or transmitted by the organ toward which they are directed, depending on the nature of the surface they strike.

As the beam strikes an interface or boundary between tissues of varying density (e.g., muscle and blood) part of the sound waves are reflected back to the transducer as echoes. The echoes are then converted into electrical impulses that are displayed on a monitor presenting a ‘picture’ of the organ or muscle under examination.

Figure: 14.3 Ultrasonography

The most important use of ultra sonography is in the field of obstetrics and gynecology. With this, the fetal size, maturity and normal and abnormal position of fetus can be known. It is a fast, relatively safe, and reliable technique in the field of gynecology. Uterine tumors and other pelvic masses can be identified by ultra sonography.

Ultra sonogram is used in medical tests of different kinds, such as- gall bladder stone, defect in the heart and identification of tumors. When ultrasound is used for examination of the heart, then it is called echocardiography. Ultra sonography is a safer diagnosing method in comparison to X-ray. Yet, it is to be used for a very limited time. Besides, the transducer should always be kept in movement, so that it does not become static at any position.

CT scan

CT scan stands for Computed Tomography Scan. In medical science it is the process of creating image. Tomography is the process of generating a two-dimensional image of a slice or section through a 3-dimensional object. CT scanner is a large machine and uses X-rays. Where X-ray forms a two dimensional image of a three dimensional organ inside the body, there the image formed by CT scan machine is three dimensional.

The CT scan machine uses digital geometry processing to generate a three dimensional of the inside of an object. The three dimensional image is made after many 2-

dimensional X-ray images are taken around a single axis of rotation. This job is done using a computer. A CT scanner emits a series of narrow beams through the human body as it moves through an arc. While an X-ray machine sends just one X-ray beam through the body of the patient. As a result, the final picture formed by CT scan is far more distinct and detailed than an X-ray one. The X-ray detector used in a CT scanner can detect hundreds of different levels of density in patient's body. This data collected by the detector is transmitted to a computer. Computer builds up a three dimensional picture of the part of the body and displays it on the screen.

Three dimensional images of soft tissue, blood carrying veins or arteries, lungs, brain, etc. is obtained by CT scan. CT scan is used for detection of cancer in lever, lungs and pancreas. The image obtained by CT scan helps a physician to detect tumor, to determine the size and position of the tumor and how much the tumor infected the adjacent tumor. By the CT scan of head, any type of bleeding inside the brain, swelling of artery and existence of tumor can be detected. Whether there is a problem in the blood circulation is also known by the CT scan. Generally CT scan test is not done in case of pregnant women. If dye is used in CT scan test there is a possibility of allergic reaction.

Figure: 14.4 CT Scan

Magnetic Resonance Imaging (MRI)

MRI is the abbreviated form of the English term 'Magnetic Resonance Imaging'. In MRI machine extended image of an organ or place of the body is formed utilizing strong magnetic field and radio wave. MRI machine works depending on the physical and chemical principles of 'Nuclear Magnetic Resonance'. Using this principle, information about the nature of any molecule can be known. MRI is a painless and safe disease diagnosis method. X-ray or any other kind of radiation is not used in this machine. The signals received from the part of the body which is scanned with MRI are transformed using computers and a very distinct image of that part of the body is formed. Each individual image acts as a slice of the organ of the body. Thus a number of images are formed, which exhibits all the characteristics of that part of the body.

Figure 14.5: MRI machine

The image obtained by MRI can be compared to each individual slice of bread. When one slice of the bread is picked up, then the interior part of the bread can be seen along with the slice. Similarly, each image found by MRI helps to view everything inside the body. The intensity of the wound is determined using MRI in case of twisting of ankles and back pain. MRI is an extremely valuable test to form an extended image of brain and spinal cord.

ECG

ECG is the abbreviated form of the word electrocardiogram. ECG is a diagnostic procedure that is routinely used to assess the electrical and muscular functions of the heart. We know that the heart produces tiny electrical impulses without any external stimulation. This electrical signal spread through the heart muscle to make the heart contract. We detect these impulses by the ECG machine. With the help of ECG we can measure the rate and rhythms of heartbeats. It gives indirect evidence of blood flow in the heart.

The electrodes placed on the different parts of the body detect the electrical impulses coming from different directions within the heart. To get a complete picture of the heart, twelve signals are identified using ten electrodes. An electrode lead is placed on each arm and leg i.e. total of four and rest six electrodes are placed across the chest wall [Figure 14.6]. The signals received from each electrode are recorded. The printed view of these recordings is the electro gram.

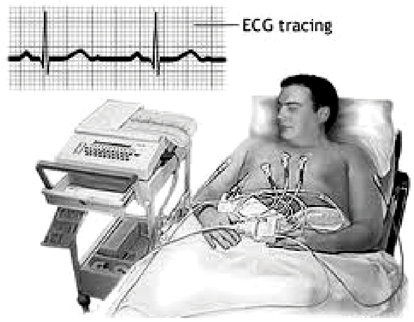


Figure 14.6: ECG procedure

For a healthy person, there are normal patterns of the electrical impulses from each electrode. If any type of abnormal condition is observed in the heart of a person, then the patterns from the electrodes will be different from that of a normal pattern.

Generally, ECG test is done to find the cause of external symptoms such as- palpitations, irregular and fast heart beat, chest pain etc. of some diseases. Sometimes it is done as a part of routine tests- for example, before you have an operation you can take the help of ECG.

The heart disorders that can be detected by ECG are:

1. Abnormal heart rhythms- for example, if the heart is very fast, very slow or irregular.
2. A heart attack- which happened recent or some time ago.
3. An enlarged heart- i.e. the size of the heart is increased.

Endoscopy

Generally endoscopy means looking inside something. But by endoscopy we mean looking interior of a hollow organ or cavity of the body for medical reasons using an endoscope machine. We examine the interior side of hollow organs of our body using endoscope machine.

Figure: 14.7 Endoscopy

In an endoscope machine, there are two tubes. Through one of them light is transferred to a definite organ of patient's body from outside. Due to the total internal reflection of light on the inner wall of the optical fiber, bright light enters the body cavity of patient.

This light illuminates the diseased or injured organ. The reflected part of light returns back through the second fiber optic tube in the same way. The reflected light enters the eyes of doctors through the eyepiece lens. As a result, the doctor can see what is happening inside the examined organ.

Endoscopy allows doctors to check for any type of irritation, ulcer, inflammation and abnormal tissue growth in the internal organ. Endoscopy is used to examine a number of different organs, including:

(A) the lungs, central partition of the chest; (B) the stomach, small intestine, large intestine or colon; (C) the female reproductive organ; (D) the abdomen and pelvis; (E) the inside of urinary bladder; (F) the nasal cavity and sinuses surrounding the nose; (G) the ears.

Radiotherapy

The word radiotherapy is the abbreviated form of the word 'Radiation therapy'. Different diseases like cancer, abnormal nature of thyroid gland, some diseases concerning blood are treated using it. Generally radiotherapy destroys cancer cells utilizing highly energized X-ray. It destroys the power of multiplication of the cells by damaging the DNA inside the tumor cell. Mainly, it is the application of ionizing (radioactive) radiation in the treatment of disease.

Radiotherapy is of two types:

1. External beam radiation or external radiotherapy

2. Internal radiotherapy

In case of external radiotherapy highly energized X-ray, cobalt radiation, electron or proton beams are applied from outside the body. The beam is applied directing to that site of the body where the tumor is located. As a result, the growth and power of multiplication of the cancer cells get destroyed. In this process a very few number of healthy cells also get affected. Yet, our aim is to destroy cancer cells as many as possible than the healthy cells. Most of the healthy cells that got damaged can repair themselves.

Figure 14.8: Radiotherapy machine

In case of internal radiotherapy, radiotherapy is applied from inside the body of a patient. In this process patient takes radioactive liquids as drinks or radioactive liquids are introduced to the body of patient through injection. Radioactive phosphorus in case of blood cancer, radioactive strontium in bone cancer and radioactive iodine in thyroid cancer is used in the liquid. This process is called brachytherapy.

ETT

ETT is the short form of ‘Exercise Tolerance Test’. It is a test of the stimulated heart. Electric activities or functions (rate or rhythm) of the heart during exercise are recorded by ETT. In fact, it is an ECG test of the patient while doing exercise. This test is very important for identifying the diseases related to coronary artery. During this test, extra stress of exercise is imposed on the heart.

Figure 14.9: ETT test

Partial blockage developed in the coronary arteries of heart is identified by this test. Generally, this type of abnormal condition in patient’s body cannot be identified while taking rest.

During the test, the patient is instructed to ride a stationary bicycle or to walk continuously on a treadmill machine. The physician records the ECG of the patient during exercise. By adjusting the speed of rotation of the wheel and slope of the surface, the degree of stress is gradually increased. Physicians become able to identify the changes that occur in the patient’s heart during exercise through ETT.

Angiography

Angiography is such an imaging test where X-ray is used to view the blood vessels of the body. This test is used to study whether the arteries or veins are narrow, blocked or enlarged in the body. The normal flow of blood is obstructed in the body when the blood vessels are blocked and they are narrow or not wide. During angiogram the physicians inject a liquid through a thin and flexible tube into the patient’s body. The liquid is called ‘dye’ and the tube is called ‘catheter’. The blood vessels become visible on an X-ray due to the use of dye. This dye is later eliminated from the body through kidneys and urine. Through a definite entry point the catheter is introduced into a definite artery or vein. The entry point may be in any blood vessel of the body. Sometimes, the ‘dye’ used is also termed as ‘contrast’.

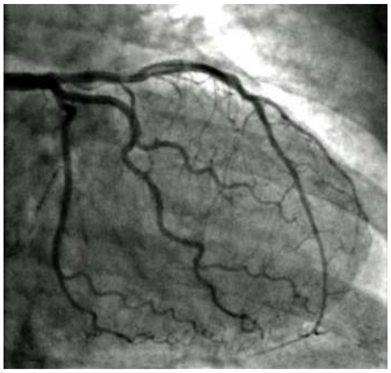


Figure: 14.10

The causes for which the physicians generally recommend an angiogram are as follows-

A. Blockages of the arteries outside the heart.
B. Enlargement of the arteries
C. For understanding the kidney artery conditions
D. Problems with veins

Sometimes the physicians can also treat a blockage in a blood vessel without any surgery during an angiogram. The mechanism or the procedure following which the blocked arteries are cleared during an angiogram is called angioplasty.

Isotopes and its uses

Isotopes are the variants of a definite element. Atoms of the same element having different mass number are called isotopes. That is, in isotopes of an element, the number of protons is same but the number of neutron is different. The number of protons in the nucleus of atom of an element identifies the element uniquely. But in principle, an element may have any number of neutrons. The total number of protons and neutrons present in the nucleus of an element is its mass number. For this reason, each isotope of an element has different mass number. Carbon can be considered as an example. Three isotopes of carbon $^{12}_{6}C$, $^{13}_{6}C$ and $^{14}_{6}C$ - the mass number of them are 12, 13, 14 respectively. The atomic number of carbon is 6, i.e. there are six protons in each carbon atom. As a result, the number of neutrons in the isotopes of carbon is 6, 7 and 8 respectively.

In the field of medical science, radioactive isotopes are widely used in nuclear medicine. Radioisotopes have two types of applications.

A. For diagnosis purpose
B. For treatment purpose

The presence of harmful cancer tumor anywhere in the body or in an organ can be identified by radioisotopes. The energetic gamma rays emitted from the isotope Co-60 is used for the treatment of cancer. The gamma rays emitted from Co-60 is used to sterilize surgical instruments. Iodine-131 (^{131}I) is used for the treatment of the abnormal growth of the thyroid gland. Technetium-99m is the most widely used radioactive isotope for diagnostic studies in nuclear medicine. Technetium is used for brain, bone, liver and spleen imaging or scanning. Blood- Leucaemia caused by excess of white blood cell is treated with phosphate of radioactive phosphorus-32. In nuclear medicine, radioisotopes are introduced into the body of the patient through the veins to diagnose diseases. The radioactive materials are selected depending on the organ which will be examined. Besides these, radioisotopes are widely used in the field of agriculture, food preservation, controlling pests and industries.

Exercise

A. Multiple choice questions

Tick (√) the correct answer.

1. What is concerned to scientist Jagdish Chandra Bose?
   i. establishment of Bose Mandir
   ii. uses of radioactive element
   iiil invention of Cresco graph

Which of the following is correct?

(a) i | (b) i and ii
(c) i and iii | (d) i, ii and iii

1. The cause of distinct vision of a bone in a X-ray film is-

(a) Bone is non-penetrable by X-ray | (b) muscles are non-penetrable by X-ray
(c) Wavelength is very large | (d) high penetrating power

3. The technology to examine blockage in a fine blood vessel-

(a) angiogram | (b) angioplasty
(c) ETT | (d) ECG

4. How the rate of heart beat and rhythm is measured?

(a) Identifying electric signals | (b) using X-ray
(c) by nuclear magnetic resonance | (d) using sound wave