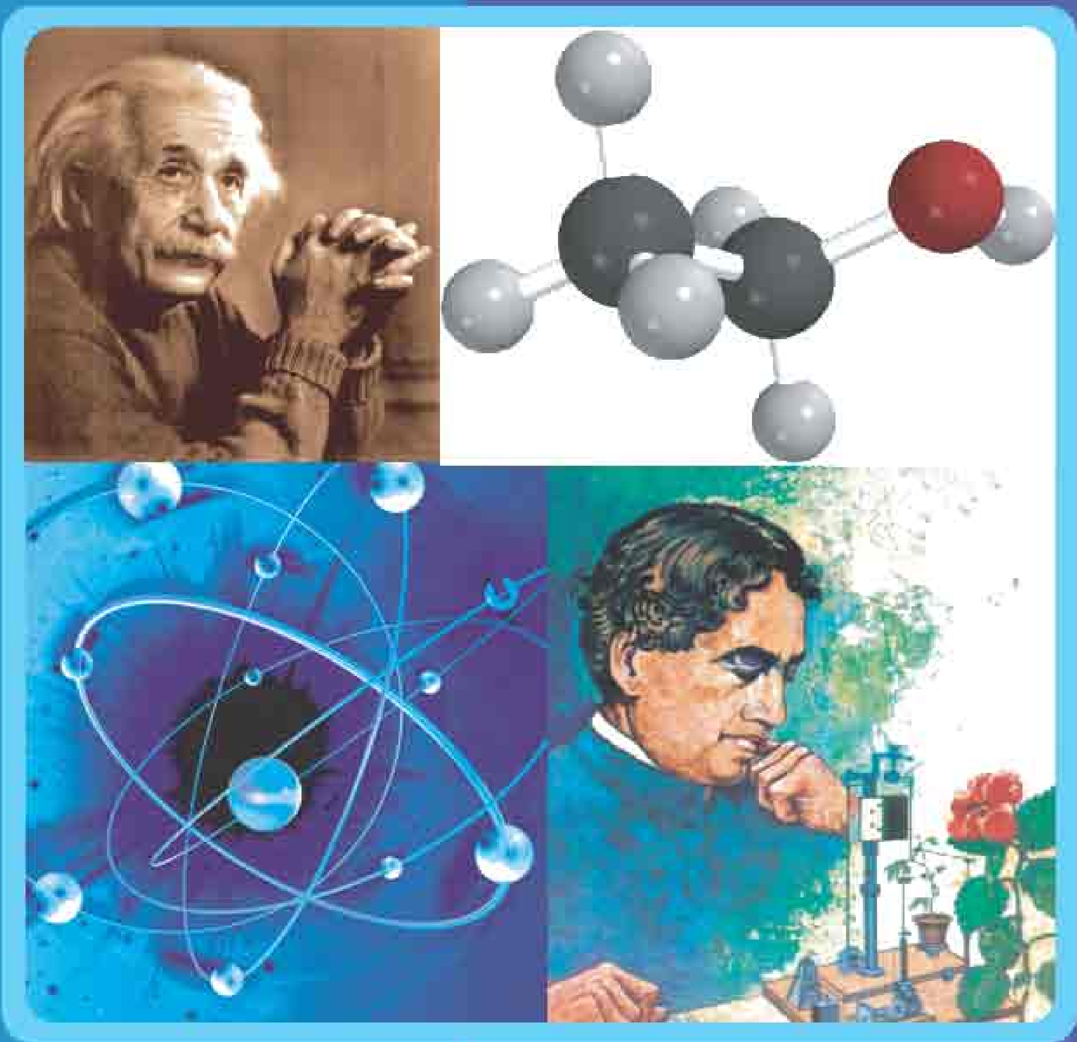
Physics

Classes 9-10



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Physics

[Classes-IX-X]

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PREFACE

Education is the pre-requisite for the holistic development in our national life. To cope with the challenges of the fast changing world and to lead Bangladesh to the doorstep of development and prosperity, a well educated and skilled population is needed. In order to build up a nation imbued with the spirit of the Language Movement and our Liberation War, the secondary education aims at flourishing the talents and prospects inherent in the learners. Besides, the other aims also include expansion and consolidation of the basic knowledge and skills of the learners acquired at the primary level in order to make them fit for entry into higher education.

The aims of secondary education further emphasise on developing these learners as skilled and competent citizens of the country through the process of acquiring knowledge at the backdrop of socio-economic, cultural and environmental settings.

Keeping the aims and objectives of National Education Policy 2010 ahead, the curriculum at the secondary level has been revised. In the revised curriculum the national aims, objectives and contemporary needs have been reflected. Along with these expected learning outcomes have been determined based on the learner‘s age, merit and level of acquisition. Besides, efforts have been made to raise, starting from the level of moral and humanistic values down to awareness on history and tradition, the spirit of the Liberation War, passion for art-culture and literature, patriotism, feelings for nature and equal dignity to all irrespective of religions, caste, creed and sex. Efforts have also been made to apply science in all spheres of our life in order to build a nation advanced in science. Attempts are also there to make the learner capable of implementing the goals envisioned in Digital Bangladesh-2021.

In the light of the present curriculum almost all the textbooks at the secondary level have been introduced. While introducing the textbooks, the capacity, aptitude and prior knowledge of the learners have been taken into utmost consideration. While selecting the contexts and their presentation special attention has been given on the expansion of the learner’s creative faculty. Adding learning outcomes, at the beginning of each chapter, hints about the achievable knowledge of the learners have been given, By adding variety of activities, creative and other questions evaluation has also been made creative.

Physics is inextricably related to the development of technology from the very beginning of civilization. Tools and techniques of physics are widely used in the field of engineering, astronomy, oceanography, biology, psychology etc. The study of physics is necessary for those who are interested in the above mention subjects. The theoretical and practical aspects are explained through read life situation. So it is expected that the learners will be inspired to study this subject for future.

Considering the challenges and commitments of 21st century and following the revised curriculum the textbook has been written. Therefore we welcome with our highest consideration any suggestions, both constructive and rationale as well for the further improvement of the book. Amidst huge activities needed for introducing a textbook, this one has been written within a very short span of time frame. We will continue our effort to make the next edition of this book more beautiful, decent and free from any types of errors.

We appreciate the endeavours of those who assisted very sincerely with their merit and hard work in the process of writing, translating editing, illustration, introducing sample questions and printing of the book. We hope the book will ensure joyful reading and achievement of expected skills from the learners.

Prof. Md. Mostafa Kamaluddin
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National Curriculum and Textbook Board, Dhaka.

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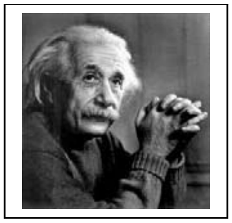
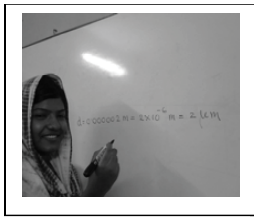
Chapter one

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

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

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

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

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 $2x10^{-7}$ 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 $540x10^{12}$ 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
S	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 $= \text{mass} \times \text{acceleration} = \text{mass} \times \frac{\text{velocity}}{\text{time}}$

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

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

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.

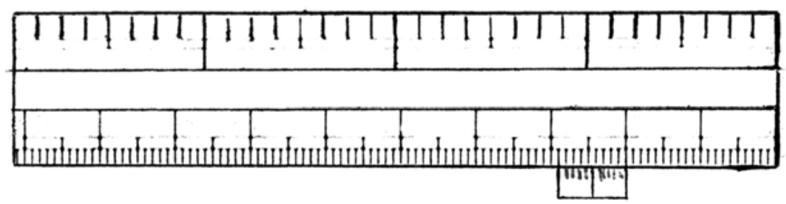


Fig.1.1 Vernier Scale

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, $L = M + V x VC$, 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).

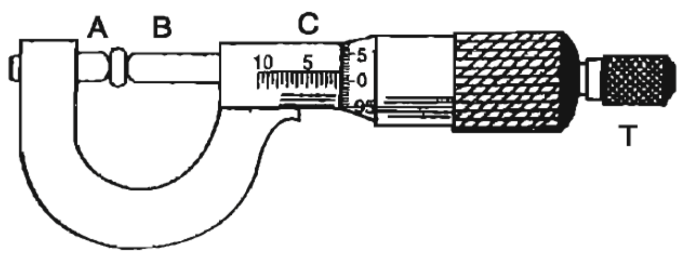


Fig 1.3 Screw Gauge

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 = $\frac{\text{Pitch}}{\text{no. of division of the circular scale.}}$

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

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

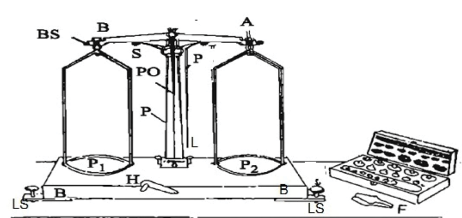


Fig 1.4

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 ± 0.15 while a digital stopwatch can read accurately up to ±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.

In this position where the zero mark of the vernier scale crosses the mark of the main scale, that mark is the reading of the main scale, *M*.

3) In this position which particular mark of the vernier scale coincides with mark of the main scale should be found out. This is vernier super-imposition *V*.
4) The length of the body may take at least thrice in different positions by repeating the process 2 and 3 and then these regarding are written in a table.
5) The breath of the body may take with the slide calipers placing the substance between the jaws of the calipers, the process 2 and 3 should repeat and then results place in the table.
6) Similarly the height of the rectangular body will place in the same way by repeating the process 2 and 3, at least three reading should take and results note in the table.
7) By measuring the length, breath and height of the rectangular body, the volume may determine with the help of the equation i and ii.

Table of investigation

A. **Determination of Vernier constant**:

Smallest division of main scale, *s* =---- cm

Total number of division of Vernier scale, *n* =----

Vernier constant, *VC = s/n*=----cm

B. **Table to determine the length, breadth and height of a rectangular body**.

Rectangular body's	**Number of observation**	**main scale reading *M* (cm)**	**Vernier super imposition *V***	**Vernier constant *VC* (cm)**	**Reading *M* + *V* x *VC* (cm)**	**Mean reading (cm)**
Length *L*	1					
	2					
	3					
Breadth *B*	1					
	2					
	3					
Height *H*	1					
	2					
	3					

Calculation and result :

Area of the rectangular body, $A = L \text{ x } B = \text{..........cm}^2$

$= \text{.......... x } 10^{-4}\text{cm}^2$

and volume of the rectangular body $V = L \text{ x } B \text{ x } H = \text{...........cm}^2$

$= 10^{-6}\text{cm}^3$

Investigation:1.2

Determine the area of cross section of a circular wire.

Objective : Determination of the diameter of the wire by using screw gauge.

Theory : Area of any substance is its surface area. If any wire is cut at right-angle with the length, then the surface obtained is the area of cross section of the wire. If the area of circular cross section of a wire is A then

$A = \pi r^2$, Here r = Radius of the wire

$\pi = 3.14\ (^{22}/_{7})$ a constant

If the diameter of the wire is d, then $r = {}^{d}/_{2}$

So, $A = \pi ({}^{d}/_{2})^2 = 1/4 \pi d^2$.................. (i)

The reading of any length with the help of screw gauge = Linear scale reading (L) + number of divisions in the circular scale (C) x Least count (LC)

That is, $d = L + C \text{ x } LC$..................... (ii)

Apparatus : Screw gauge, wire

Procedure :

1. At first the value of the smallest divisions of linear scale and the total number of divisions of the circular scale are noted.
2. Then the pitch is determined. When the circular scale takes one full turn, the length covered in the linear scale is called the pitch of the instrument. Least count (LC) is determined dividing the pitch by the total number divisions of the circular scale.
3. The wire under experiment is placed between the two ends and the screw is turned in the same direction to touch the wire lightly.
4. In this position the reading of the last mark of linear scale which is seen on the left side of the circular scale is taken. This reading of the linear scale is L. Then one should see which mark of the circular scale coincides with the mark of the linear scale.

5. In this ways at least 5 readings should be taken and they are placed in the table.
6. After finding out the diameter, the area of the cross section of the wire is determined by using the formula (i)

Table of investigation

Findings :

a) Determination of least Count :

The value of one division of linear scale, S = ...mm

Total division number of the circular scale, n = ...

Pitch P = ...mm

$\therefore$ Least count, LC = $^{p}/_{n}$ = ...mm

b) Table of determining the diameter of the wire

Number of observation	Linear scale reading L (mm)	Number of divisions in the circular scale C	Least count LC (mm)	Diameter $d = L + C \times LC$ (mm)	Average diameter $d = d \pm e$ (mm)
1					
2					
3					
4					
5					

Calculation and Result :

Area of the cross section of wire, A = $\frac{1}{4}\pi d^2$ = ...mm^2

= ....$10^{-6}m^2$

Exercise

A. Multiple choice questions

Put the tick (√) mark on correct answer.

1. Who gives quantum theory ?

   a) Planck b) Einstein

   c) Rutherford d) Heisenberg

2. Boson comes after whose name ?

   a) Jagadish Chandra Basu b) Subhash Chandra Basu

   c) Satyendranath Basu d) Sharat Chandra Basu

3. Which one of below is not fundamental quantity ?

   a) Mass b) Heat

   c) Electric current d) Quantity of substance

4. When a rod is placed between the jaws of a slide calipers, the main scale reading is found 4 cm, vernier super-imposition is 7 and if the vernicer constant is 0.1mm, what is the length of the rod?

   a) 4.07 cm b) 4.7cm

   c) 4.07 mm d) 4.7 mm

From the figure below answer the questions no. 5 and 6.

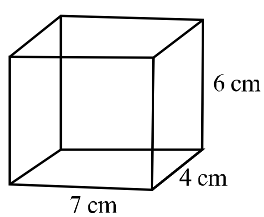


Fig (a)

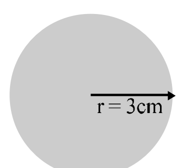


Fig (b)

5. a) $\frac{1}{2}\pi r^3$ b) $\frac{4}{3}\pi r^3$

   c) $\frac{3}{4}\pi r^3$ d) πr^3

6. The ratio of volume of figure (a) and Fig (b):

   a) 1:0.673 b) 1:0.0673

   c) 1:0.763 d) 1:0.637

B. Creative question:

Rashed said that the length of his pencil is 11.73 cm measured by his newly purchased scale. His friend Sujon said that this measurement may not correct too. Rashed said that he obtained the same result measuring by the scale several times. When they went to the teacher, he instructs them to use a vernier scale of constant 0.005 cm. Rashed measured the correct length by the vernier scale.

a) What is vernier constant ?

b) Why unit is required to express the amount of a quantity?

c) Find how many divisions of vernier scale is equal to what number of divisions of main scale.

d) First measurement of length measured by Rashed was irrelevant to accurate measurement, explain with logic.

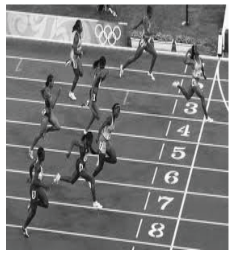
C. General questions :

1. Write a report on why we should study physics.
2. Wonderful advancement took place in the twentieth century- put logic with example in favour of this.
3. a) What do you mean by quantity ?

   b) Write down the difference between fundamental and derived quantities.
4. a) In SI unit which quantities are considered as fundamental quantities ?

   b) Write down the name of units of these quantities.
5. What do you mean by dimension?

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.

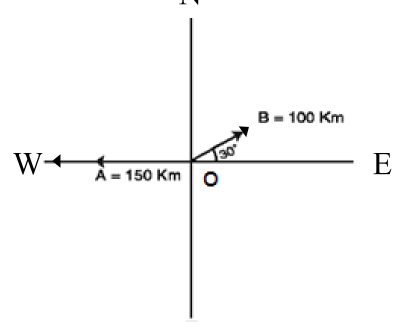


Fig-2.2

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.

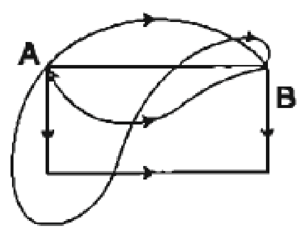


Fig-2.3

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, $[\ s\ ] = \mathrm{L}$

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.

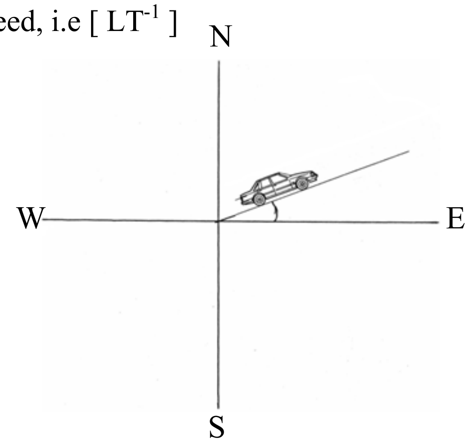


Fig-2.4

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 $^{\text{velocity}}/_{\text{time}}$

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

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

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

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

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

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,

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

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

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

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

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

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

We also find there

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

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

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

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

$\therefore s = ut + \dfrac{1}{2} at^2$ (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.

$\therefore v^2 = u^2 + 2as$ (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 :

We know,

$v = u + at$

or, $at = v - u$

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

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

10s

Ans : 10s

Here,

initial velocity u = 0

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

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

$\therefore$ time = ?

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 :

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

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 = ?

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 :
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 : $40ms^{-1}$

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

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

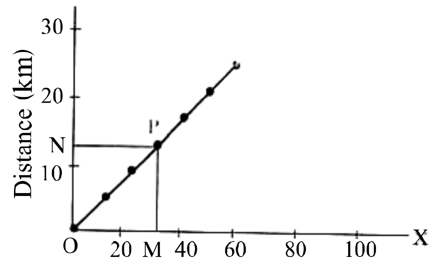


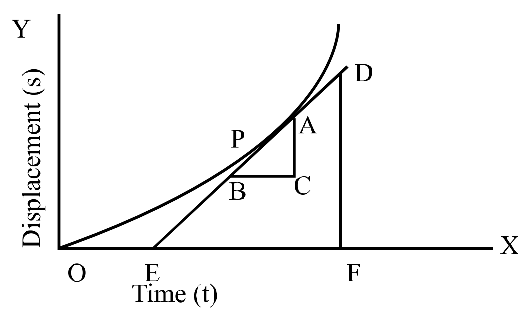
Figure 2.5

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

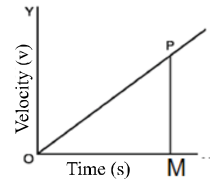
Therefore, the velocity at the point P is the slope or gradient of the tangent drawn at that point. Thus it may be said that the gradient of the tangent at any point on the distance-time graph represents the velocity at that point.

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.

Table of observation

Reading	Traveled distance i.e. length of the plank	Time (s)	Average speed $= \frac{\text{distance}}{\text{time}}$ (ms^{-1})
1			
2			
3			
4			
5			
6			
7			

8. Discuss the causes of change of average speed

Investigation:2.2

Demonstration of models of different kinds of motion through different activities.

Objective : To demonstrate the models of different types of motion and observe their differences by the role play of the students.

Apparatus: Long rope, chalk powder or lime.

Working Procedure :

1. Mark a long straight line by chalk powder or lime in your school field or any play ground nearby or stretch out a long rope straightly
2. Now run to the other end along the rope
3. Put a mark at any place of the field and let one stand on the mark. Then let another one hold the right hand of other straightly by his left hand. Third one holds the right hand of second by his left hand. Stand by holding hands successively in this way. It will be a long straight chain like form.
4. If any one outside the chain produces sound all the members start to run slowly centering the first one holding their hands so that the chain does not break or disorder.
5. Stretch a few meter (Suppose 10 meter) long straight rope at one side of the field. Two of you stand at the two ends of the rope and one of you at the middle of it. Now starting from the first one walk towards second and return to first one just touching him without stopping your walk. Again touching first one go to the second one . Repeat it for several times.
6. Note down the characteristics of the motion mentioned in procedure 2 in your copy.
7. Write down the characteristics of motion in your copy mentioned in procedure 4. In this case the motion of all participants are circular and periodic. Example the causes why these motions are circular and periodic breaking the chain.

8. Note down the characteristics of the motion mentioned in procedure 5. In this case motion of all participants are periodic and vibratory. Explain why this motion is periodic and vibratory
9. By this observation compare various kinds of motion and write down their differences.

Investigation: 2.3

Determination of speed of 100 meter race and its graphical analysis

Objectives : To determine the average speed by the traveled distance in different times, draw distance-time graph determine instantaneous speed at any time and average acceleration.

Apparatus : Meter scale, stopwatch, rope or measuring tape

Working procedure :

1. Stretch out a rope straightly at one end of the school play ground (Use any other field if there is no field in the school)
2. Stretch another four ropes each 25 meter distance. So the final rope will be at 100 meter distance.
3. Stand near the first rope and let your four friends stands by the four ropes with stopwatch.
4. Start running with the whistle of your teacher and every one standing will start their stopwatch.
5. When the runner will just cross the rope the respective person will stop his stopwatch. You will find the amount of time from the stopwatch.
6. Find average speed by dividing the distance by time for that time interval.
7. Draw a graph by plotting time (t) along X-axis and distance (d) along Y-axis.
8. Determine the distance traveled at any time, average speed of that time interval and instantaneous speed of that moment from the graph.
9. Draw the graph again and find the instantaneous speed of two separate time and find the average acceleration by dividing the difference of speed.
10. Repeat this experiment walking and running at different speed.
11. Every student will do the experiment in the same way.

Table

Reading	Traveled distance (m)	Time (s)	Average speed = $^{distance}/_{time}$
1			
2			
3			
4			
5			
6			
7			

Exercise

A. Multiple choice questions

Put the tick (√) mark on the correct answer

1. What is the unit of acceleration ?
   a) ms^{-1} b) ms^{-2}
   c) NS d) kgs^{-2}

2. What type of motion does the hands of a clock have ?
   a) Linear motion b) Elliptical motion
   c) Periodic motion d) Vibratory motion

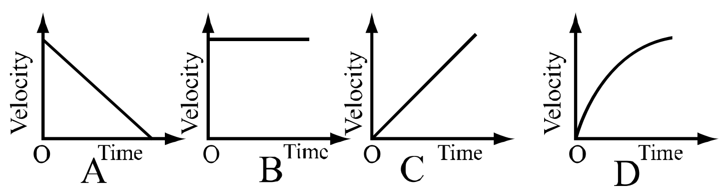
3. The distance traveled in a given time by a freely falling body from rest will be
   a) Proportional of the time
   b) Proportional to the square of that time
   c) Inversely proportional to that time
   d) Inversely proportional to the square of that time

4. A body moves with a uniform acceleration a starting from rest. What will be the traveled distance of the body at a given time ?
   (i) $s = \frac{(u+v)t}{2}$ (ii) $\therefore\ s = ut + \frac{1}{2}at^2$ (iii) $s^2 = u^2 + 2at$

Which one of the following is the correct

(a) i (b) ii (c) ii & iii (d) i, ii & iii

5. Which one of the velocity-time graph below does represent the graph of freely falling body ?



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

6. Creative question

Rajib with his family members started for visiting Jaflong in Sylhet by microbus.He recorded the magnitude velocity i.e. speed of the car from the speedometer after every 5min throughout the journey. The magnitude of velocity he got per hour was 18, 36, 54, 45, 54, 36, and 18 kilometer.

a) What is instantaneous speed ?
b) Explain the acceleration of an object moving with uniform velocity.
c) Find the distance traveled by the car in first 5min.
d) Draw and explain the velocity-time graph by the collected data.