

The Scope of Physics

1.1 DEFINITION OF PHYSICS

The colours in the rainbow, the dropping of a mango from the branch of a tree, the rusting of an iron piece, the growing of Plants, the motion of bodies, the formation of the solar system, etc. are all phenomena of nature. Such Phenomena lead us to the study of science.

The subject of science is classified into two main branches :

- (i) the physical sciences and
- (ii) the biological sciences.

The biological science deal with living things where as the physical sciences are concerned with the properties and behaviour of non-living matter. The branch of Physical science which deals with the interaction of matter and energy is called physics. This is based on experimental observations and quantitative measurements.

Physics is therefore an experimental science which depends heavily upon the objective observations and measurement of natural phenomena.

The history of physics is as old as the history of mankind. Even the cave man was aware of the production of fire by rubbing two stones together. The Chinese for the first time manufactured paper (Papytue). Egyptian used to measure the flood level in the river Nile.

The people of Euphrates and Tigris valleys were aware of calendar and they had the knowledge of geometry. The people of Indus valley were the pioneers of decimal system.

The history of Greeks is full of inventions and discoveries in the field of all sciences, and specially in physics. Archimedes principle is still an important topic in elementary books of physics. He invented lever and screw. Pythagoras, Galen, Ptolemy, and others are famous in the field of mathematics, astronomy, medicine, etc.

The contribution of Muslims in the field of science in general and in physics in particular will be described in detail in section 1.3.

Significant contribution was made by Galileo-Galilei (1564-1642) through his work on the laws of motion in the presence of constant acceleration. Johanne Kepler (1571-1630) was his contemporary and presented Kepler's law of planetary motion.

Prior to 1900 AD, physics comprised of mechanics, sound, light, heat, magnetism and electricity. The new era of modern physics began near the end of 19th century. There are two main branches of physics now, namely Classical Physics and Quantum Physics. Einstein theory of relativity not only revolutionized the traditional concept of mass, time and energy but also modified Newton's laws of motion for describing the bodies moving with the speed comparable with the speed of light. The other branches of Physics are as follows:

- (i) Particle Physics
- (ii) Nuclear Physics
- (iii) Molecular and Atomic Physics
- (iv) Plasma Physics
- (v) Astro Physics
- (vi) Medical Physics.
- (vii) Solid State Physics.

1.2. ISLAM AND SCIENCE

In the field of scientific research the strong incentive comes from no other book and no other philosopher as it comes from the Holy Quran. We are told in Surah Nooh.

"Do you not see how God made seven heavens One above the other?"

"And He has placed the moon as a light in them.

He has made the sun as a lamp

We are further reminded in Surah Al-Imran.

Surely in the making of the heavens & the earth,
And the alternations of the night and the day.

There are signs for people of understanding-

Those who remember God standing and sitting
and on their sides;

And those who use thought about the make of
the heavens and the earth,

" Our Lord! Thou hast not made this in vain,

Glory to be Thee,

So save us from the agony of the fire

Surah Al-Imran Ayah 190 and 191

It is again emphasized

God is He who has ordered the ocean for you that the ships
may sail there, in together with his command.

And you may seek of his grace and in order that you may
give thanks

And He has ordered for your benefit whatever is in the heav-
ens and whatever is in the earth, all is from Him.

Most surely there are signs in this for a people who reflect

Surah Al-Jasiya (Ayah 12 and 13)

1.3 CONTRIBUTION TO PHYSICAL SCIENCES BY THE ISLAMIC WORLD.

Inspired by the Quranic verses and teachings of the Holy Prophet Muhammad (S.A.S), the muslims translated the ancient book and initiated the original search at the end of ninth century A.D. The famous chemist, Jabir-bin-Hayyan, for the first time, derived various laws in chemistry on the basis of experiments. Al-Battani made calculations in connection with solar system, change in seasons, eclipses of moon and sun and other astronomical phenomena. Remarkable and distinguished contributions were made

by most outstanding Muslim scientist, named, Al-Khawarizmi. He was founder of Analytical Algebra. His famous treatise, "Hisabul-Jubr-wal-Muqabla", is the first work on this subject. He invented the term Logarithm (algorithm). Omer Khayyam was one of the prominent mathematicians of the Islamic world. Bertrand Russel remarked about him with the following:

"Omer Khayyam is the only man known to me who was both a poet and mathematician".

Ibn-al-Halham was a great physicist of the Islamic world. He wrote many books. His master piece work was the book named "Kitabul-Manazir". It is the first comprehensive book on light. He developed the laws of reflection and refraction. He constructed the pin hole camera. The most wonderful chapter of his book is on human eye. The information given in it is still valid and correct.

Al-Razi was the most prominent and greatest physician. He wrote about 200 original monographs, half of which pertained to medicine.

Abu-Rehan Al-Beruni was contemporary of Ibn-e-Sina. He was an astronomer, physician and mathematician. He also lived in India for sometime during the reign of Moghul emperor AKBAR. His famous book Kitab-ul-Qanoon-ul-Masoodi is considered as Encyclopaedia of Astronomy.

Yakoob Bin Ishaq Al-Kindi wrote many books on mathematics, astronomy, medicine and other subjects:

Ibn-e-Sina was famous for his original research in the field of medicine. He discovered the use of catheters. He gave intravenous injections by means of a silver syringe. He is famous because of his medical text book named, Al-Qanun-Fil-Tib (Qanoon). He also wrote Al-Shifa an encyclopaedia of philosophy. This comprises comprehensive treatise on logic, physics, mathematics and metaphysics.

1.4 PHYSICS AND SOCIETY

20th century is called the century of Physics and due to the

development in the field of science and technology we are justified to call it the modern scientific age. The development in science in general and in physics in particular made a great impact on our society. On tracing the history of civilization we find that the man used to live in caves (caveman) and he was afraid of lightning and thunder. With the development in the human knowledge the civilization also developed.

Machines were present much before the industrial developments. The motion of a lid of a kettle observed by George Stephenson enabled him to invent heat engine.

In 19th century the scientists were able to use electrical energy. The use of electric motors and generators accelerated the pace of industrialization. With further advances in the field of physics and technology, we are using micro wave ovens, refrigerators, air conditioners, vacuum cleaners, washing machines, etc. for our comfort and luxury. The invention of radio, television, telephone, video cassette recorder and others provided not only the means of recreation and luxury but also proved a mile stone in the field of communications and education.

The intelligent use of physics is observed in many fields of medicine and surgery e.g. from ordinary microscope to a sophisticated scanning electron microscope, the use of laser in surgery, the use of elaborate radiation system in nuclear medicine, the use of ultrasonic radiation for diagnostic purposes.

The impact of such developments and discoveries on our society has indeed been great and it is very likely that future discoveries and developments will be exciting challenging and of great benefit to humanity.

1.5 MEASUREMENT AND THE SYSTEM OF UNITS.

Quantitative physical measurements must be expressed by numerical comparison to some agreed set of standards. Thus all measurements are related to their chosen standards. The necessity for standards of various kinds has given rise to a number of measuring units.

In CGS the fundamental units of length, mass and time are centimetre, gram and second respectively.

In the British engineering system, the unit of force, length and time are chosen as the fundamental units. In it the unit of mass is a derived unit. The unit of force, length and time are pound, foot and second respectively.

In another system known MKS, the length, the mass and time are measured in metre, Kilogram and second respectively. In 1960, the general conference of weights and measures, recommended that a metric system of measurement called International system of units abbreviated (MKSA) SI in all languages, system d'internationale be adopted. The SI units are derived from the earlier MKS system, so called because its first three basic units are metre (m), the kilogram (kg) and the second (s). These are expressed shortly.

1.6 MEASUREMENT OF TIME

Before 1960, the standard of time was defined in terms of mean solar day: Mean solar day is the length of a day measured throughout the year. A solar day is time interval between two successive appearance of the sun overhead. Thus mean second, representing the basic unit of time, was originally defined as $(1/60) (1/60) (1/24)$ of a mean solar day. The time that is referred to rotation of the earth about its axis is called universal time. For reasons which we need not discuss, the length of the day varies throughout the year so that an average value has to be taken.

A high precision device for measuring with tremendously large accuracy is the atomic clock. The time can be measured to an accuracy of one part in 10^{12} . This is equivalent to an uncertainty of less than one second every 30000 years. The atomic clock is too complex a device to be described in detail, but briefly it is a radio transmitter giving out short waves (about 3 cm long), the frequency which is controlled by energy changes in gaseous caesium atoms. The great advantage here is the frequency (i.e the number of vibrations per second) of the changes is constant and not subjected to error. With this much high accuracy of atomic clock, the second was redefined in 1967, as the time interval occupied by 9192 631 770

cycles of radiation corresponding to a specified energy change in the caesium atom.

In addition to the basic unit of length, mass and time there are ampere, Kelvin, candela and mole in SI. For the sake of comprehension all are given below with brief description.

1.7 BASIC SI UNITS

(a) Time - Second (s)

A second is the duration of 9192631 770 periods of radiation corresponding to the transition between two hyperfine levels of the ground state of caesium-133 atom.

(b) Electric Current - ampere (A)

Ampere is the current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross-section, and placed 1 metre apart in vacuum, would produce between the conductors a force equal to 2×10^{-7} newton per metre of length.

(c) Thermodynamic Temperature - Kelvin (K)

Kelvin, the unit of thermodynamic temperature, is $1/273.16$ of the thermodynamic temperature of the triple point of water.

(d) Luminous Intensity - Candela (cd)

Candela is the luminous intensity, in the perpendicular direction of a surface $1/6\,000\,000$ square metre of a black body at the temperature of freezing platinum under a pressure of 101325 newton per square metre.

(e) Amount of substance - mole (mol)

Mole is the amount of substance of a system which contains as many elementary entities as there are atoms in 0.012 kilogram of carbon-12.

1.8 Dimension

The word dimension has special meaning in physics. It is used to denote the nature of a physical quantity. Whether a distance is measured in any units, metres, miles or even light year, it

Is always a distance and its dimension is length.

The symbols L, M and T are the symbols usually used to specify the dimensions of length, mass and time respectively. The dimension of any physical quantity can always be expressed as some combination of the fundamental quantities, such as mass, length and time.

The dimensions of velocity are written as L/T and the dimensions of area are L^2 . The table 1.1 shows the dimension of some physical quantities.

Table 1.1

No.	Quantity	Dimensions
1	Area	L^2
2	Volume	L^3
3	Velocity	$L/T = LT^{-1}$
4	Acceleration	$L/T^2 = LT^{-2}$

In any equation the dimensions of a physical quantity must be same on both sides of equation. The dimensional tables attached to the various quantities may be treated like algebraic quantities and may be combined, cancelled etc. just as if they were factors in the equation.

Example: 1.1

$$S = u_i t + \frac{1}{2} a t^2$$

The dimension of various physical quantities involved in the above are

u_i is initial velocity, a is acceleration and t is time

- (i) S _____ L
- (ii) u_i _____ $\frac{L}{T}$
- (iii) a _____ $\frac{L}{T^2}$

Substituting we get

$$L = \frac{L}{T} \times T + \frac{1}{2} \frac{L}{T^2} \times T^2$$

$$L = L$$

Length = Length

The equation is dimensionally correct.

1.9 SIGNIFICANT FIGURES

All measurements of physical quantities involve some degree of inaccuracy in them due to instrumental error and human error, etc and therefore the knowledge of precision of a measurement is very important. It is essential that we understand the limitations which experimental accuracy places on numbers that we measure. Let us now investigate how we handle numbers that are not exact. Suppose that the length of an object is recorded as 16.7 cm. This measurement is an approximation to the nearest length of a centimetre and its exact value lies between 16.65 and 16.75 cm. If this measurement is exact to the hundredth of a centimetre, it would have been recorded as 16.70 cm. The value 16.7 represents three significant figures (1, 6, 7), while the other value 16.70 represents four significant figures (1, 6, 7, 0).

Thus a significant figure is the one which is known to be reasonably reliable. Similarly, a recorded mass of 6408.2 gm means that the mass was determined to the nearest tenth of a gram and represents five significant figures (6, 4, 0, 8, 2); the last figure 2, being reasonably correct guarantees the certainty of the preceding four figures.

Zeros may be significant, or they may merely serve to locate the decimal point for instance, the statement, that a truck has a weight 2500N, does not indicate definitely the accuracy of weighing. If it was weighed to the nearest 100N, the weight contains only two significant figures (2,5) and may be written as 2.5×10^3 N. If the truck was weighed to the nearest 10N, the first zero is significant, but the second is not, the weight could be written 2.50×10^3 N, displaying three significant figures. If it was weighed to the nearest

1N, the weight could be written as 2.500×10^3 N, four significant figures. If a zero stands between two significant figures, it is itself significant.

If a measured value is 8.3867, only three of whose digits are significant, we round it off to 8.39. A number is rounded off to the desired number of significant figures, by dropping one or more digits to the right. When the first digit dropped is less than 5, the last digit retained should remain unchanged. When the first digit dropped is more than 5 or when it is followed by digits not all zeros, the last digit retained should be increased by 1.

If two numbers are divided or multiplied, the result has the same number of significant figures as the less accurate number. For example, the two numbers 4.71 and 5.642 are multiplied, the result is 26.6 and not 26.57382. Here we can claim three significant figures only since the less accurate number is, 4.71, contains three significant figures.

Problems.

1. Find the area of a rectangular plate having length (21.3 ± 0.2) cm and width (9.80 ± 0.10) cm. Ans $(209 \pm 4) \text{ cm}^2$
2. Calculate (a) the circumference of a circle of radius 3.5 cm and (b) area of a circle of radius 4.65 cm
3. Show that the expression $S = v_i t + \frac{1}{2} a t^2$ is dimensionally correct, when S is a co-ordinate and has unit of length, v_i is velocity, a is acceleration, and t is time.
4. Suppose the displacement of a particle is related to a time according to expression $S = ct^3$. What are the dimensions of the constant c.
5. Estimate the number of litres of gasoline used by all Pakistan's car each year
given:
No of cars in Pakistan = 500000. Average distance travelled per year by each car = 16000 km gasoline consumption 6km/litre.
Ans $(13.33 \times 10^8 \text{ litre})$