

## CHAPTER 1

# PHYSICAL WORLD

- 1.1 Introduction
- 1.2 Physics – Scope and Excitement
- 1.3 Physics, Technology and Society
- 1.4 Fundamental Forces in Nature
- 1.5 Nature of Physical Laws
  - Summary
  - Exercises

### 1.1 Introduction

Dear students, welcome to you all to this first lecture on Physics. Till Std. X, you have gained preliminary ideas about optics, electricity, magnetism, motion, force, gravitation, heat, energy, wave, sound, universe, etc. under the subject science. These topics are related to physics.

Now, you may raise a question : **What is Physics ?** Dear students, physics is one of the basic disciplines in the category of natural sciences. **Physics** is a science to understand nature. The word '**Bhautik Vigyan**' (used in Hindi / Gujarati) related to the science of physical world is derived from Sanskrit word 'Bhautiki'. Science of studying the basic laws of nature and their manifestation in different natural phenomena is Physics. Man has always been curious about the world around him. Because of this curiosity, man has observed the physical environment carefully, searched meaningful patterns and relations in natural phenomena; and still continues to do so. Conclusions, facts, theories etc. derived from all these attempts means physics. The english word '**physics**' comes from a Greek word meaning '**nature**'.

Use of mathematics is very wide spread in physics. Mathematical theories, formulae or mathematical models are inseparable from physics. As a famous quotation states "**physics is the king of science while mathematics is the queen.**" The Mathematical expressions obtained for some physical event, not only provide logical explanation of that event but also make predictions about many other connected events. Our physical facilities, ever since existence of humans to till date, are also due to physics.

## 1.2 Physics - Scope and Excitement

Dear students, a teacher speaks in the classroom and you hear it. Have you analysed this event, any time ?

How is sound produced, when a teacher speaks ?

How does this sound propagate in the classroom ?

How do your ears receive this propagated sound ?

Similarly, have you thought about the annual cycle of seasons, the eclipse, the tides, the regular repetitions of day and night, the bright celestial objects in the night sky, etc. ?

In physics (i) we not only observe such physical events, taking place in our day to day life, but find out definite mechanisms from the series of systematic observations.

(ii) The quantities involved in such events are to be defined unambiguously and meaningfully,

(iii) To derive laws or principles from such studies, and

(iv) Such derived laws or principles are to be tested in wide perspectives.

Physics involves study of two fundamental constituents of the universe : **matter and radiation**, to find out origin of fundamental particles of matter and radiation, the interaction between them, the laws of nature related to them, etc.

If we think further about matter, then comes the nucleus of the atom. Here interaction among neutrons, protons, mesons etc.; the energies of the nucleus with radius of the order  $10^{-14}\text{m}$ , formed due to such interactions; the radiation emitted due to intra nuclear transitions, etc. are the subject matter of nuclear physics.

Electrons revolving around the nucleus in specific orbits of orbit radius  $10^{-10}\text{m}$  with specific numbers and electronic configurations, their transitions, their interactions, special properties of atom because of electrons, etc. are all included in physics.

Due to interaction among atoms, molecules are formed. These atoms do not remain stationary inside a molecule, but perform rotational and vibrational motions. By studying

the radiations emitted from atoms and molecules, we can get insights into their structure. From such physics, various aspects of chemistry are also understood.

When many molecules and atoms combine together, we get different phases of matter namely **gas, liquid and solid**; depending on physical conditions. Under certain temperature and other conditions, we also get the fourth state of matter - **plasma**. The plasma state of matter obtained at extreme high temperature opened up a possibility as a future source of tremendous energy for use of mankind.

The mechanical, thermal, electrical, magnetic and optical properties of matter are studied in physics. Dear students, now you will realise that to know and understand all such properties of different subdisciplines of physics like mechanics, thermodynamics, electromagnetics, optics, electrodynamics have been developed.

Mechanics is based on Newton's laws of motion and law of gravitation. It is concerned with the motion of particles, rigid and deformable bodies, force, work, etc. Electrodynamics deals with electric and magnetic phenomena associated with charged and magnetic bodies. Here, how we forget the contribution of physicists like Coulomb, Oersted, Ampere, Faraday, Maxwell !!!

The working of optical fibre, telescopes and microscopes; colours exhibited by thin films, rainbow, mirage; images formed by the mirrors and lenses, etc. are explained in optics.

Thermodynamics includes changes in internal energy, temperature, entropy, etc., of the system through external work and transfer of heat. The efficiency of heat engines and refrigerators, the direction of physical and chemical process, etc., are also studied in thermodynamics.

In physics we discuss a space having infinite dimensions. The operators in quantum mechanics in such a space and their operations on vectors are also very exciting.

But this is not the end of physics at all. Studies related to sun and its planetary system

is also carried out in physics. Galaxies, and their structure, the large distance of the order of billion light years amongst them, distribution of billions of kilograms of their matter, the intergalactic space; birth, evolution and death of various stars etc. are also studied in astrophysics, a branch of physics.

Dear students, thus we have seen that the span of physics is from almost 'vacuum' to 'infinity'. Even, vacuum is also considered as some definite state in physics.

Thus the scope of physics on the length scale is from very small length of  $10^{-14}\text{m}$

(radius of nucleus) to  $10^{26}\text{m}$  (length of galaxies). Thus the factor of length scales is of the order of  $10^{40}$ .

The range of the time scale, about  $10^{-22}\text{ s}$  to  $10^{18}\text{s}$ , can be obtained by dividing the length scales by the speed of light.

The range of mass varies from  $10^{-30}\text{ kg}$  (mass of an electron) to  $10^{55}\text{ kg}$  (mass of known observable universe).

Table 1.1 to Table 1.3 show the range of these fundamental physical quantities of length, time and mass.

**Table 1.1 : Order of the length scale for different objects (only for information)**

Size or Distance of object	Order of length scale (m)
Radius of a proton	$10^{-15}$
Radius of atomic nucleus	$10^{-14}$
Size of the hydrogen atom	$10^{-10}$
Thickness of a paper	$10^{-4}$
Height of a human	$10^0$
Height of the Mount Everest above sea level	$10^4$
Radius of the Earth	$10^7$
Distance of the Sun from the Earth	$10^{11}$
Size of our galaxy	$10^{21}$
Distance to the boundary of observable Universe	$10^{24}$

**Table 1.2 : Order of the time interval for various events (only for information)**

Event	Order of Time interval (s)
Life span of most unstable particle	$10^{-24}$
Time required for light to cross a nuclear distance	$10^{-22}$
Period of atomic vibrations	$10^{-15}$
Period of a sound wave	$10^{-3}$
Wink of eye	$10^{-1}$
Time between successive human heart beats	$10^0$
Rotation period of the Earth	$10^5$
Revolution period of the Earth	$10^7$
Average human life span	$10^9$
Age of the Universe	$10^{17}$

**Table 1.3 : Order of the mass-scale for different objects (only for information)**

Object	Order of Mass-scale (kg)
Electron	$10^{-30}$
Proton	$10^{-27}$
Dust particle	$10^{-9}$
Mosquito	$10^{-5}$
Grape	$10^{-3}$
Human	$10^2$
Earth	$10^{25}$
Sun	$10^{30}$
Milkyway galaxy	$10^{41}$
Observable Universe	$10^{55}$



The scope of physics extends over two basic and interesting domains : macroscopic to microscopic. In addition, it covers static and dynamic systems. Thus physics is associated with time, matter and energy.

Dear students, normal events like an object falling on the earth under freefall and flight of a balloon filled with light gas from earth; sinking of a pin or needle in water while floating of a ship on water; or the most advanced projects like

Large Hadron Collider (LHC), International Thermonuclear Experimental Reactor (ITER) and moon mission attract us toward the study of physics.

You may be familiar with the names of internationally famous Indian physicists : C. V. Raman, J. C. Bose, M. N. Saha, Homi Bhabha, S. N. Bose, Vikram Sarabhai, S. Chandrasekhar, etc. List of some Indian institutes doing research in the field of physics is given in Table 1.4 for your information, only.

**Table 1.4 : List of some of the Indian Institutes doing Research in the Field of Physics (only for information)**

Name of the Institutes	Place
Bhabha Atomic Research Centre (BARC)	Mumbai
Physical Research Laboratory (PRL)	Ahmedabad
Institute for Plasma Research (IPR)	Gandhinagar
Institute of Physics (IOP)	Bhuaneshwar
National Physical Laboratory (NPL)	Delhi
Inter University Consortium for Astronomy and Astrophysics (IUCAA)	Pune
Indian Institute of Science (IISc)	Bangalore
Raman Research Institute (RRI)	Bangalore
Tata Institute of Fundamental Research (TIFR)	Mumbai
Centre for Advance Technology (CAT)	Indore
Nuclear Science Centre (NSC)	Delhi
Indira Gandhi Centre for Atomic Research (IGCAR)	Kalpakamm
Saha Institute of Nuclear Physics (SINP)	Kolkatta
Regional Research Laboratory (RRL)	Bhopal
Inter University Acelerator Centre (IUAC)	Delhi
Variable Energy Cyclotron Centre (VECC)	Kolkatta
Vikram Sharabhai Space Centre (VSSC)	Banglore
Indian Institute of Astrophysics (IIA)	Banglore
Indian Institute of Geomagnetism (IIG)	Mumbai
Indian Space Research Organization (ISRO)	Various places in India
Space Applications Centre (SAC)	Various places in India
Indian Institute of Technology (IIT)	Various places in India
National Institute of Technology (NIT)	Various places in India
Various Universities	Various places in India

### 1.3 Physics, Technology and Society

Today, we can reach any corner of the world within few hours, we can talk to a person sitting at any corner of the world within few seconds. While sitting at the home, we can see live telecast of an event or a game taking place at other places in the world. We can take photographs of our solar system and galaxies. All these become possible because of physics.

The progress made in transportation vehicles : bullock cart, bicycle, motor cycle, car, ship, aeroplane; telegram, telephone, mobile, satellite phone used in communication; radio, tape recorder, television used in entertainment and heaters kerosene stove, gas stove, microwave oven etc. used in kitchen, have become possible because of the proper use of laws or theories of physics in technology.

It is physics which introduced us to radiations and taught us to accelerate charge particles, physics gave instruments based on ultrasonic and optical fibres. Very useful medical technology like X-rays, sonography, Electro Cardio Graf (ECG), Electron Spin Resonance (ESR), Nuclear Magnetic Resonance (NMR), Endoscopy are also due to physics.

Instruments like microscope, Electron Microscope (EM), Atomic Force Microscope (AFM) have played a vital role in the development of material technology, nanotechnology and biotechnology.

You would possibly not be unaware of space technology. Rocket, missile, space shuttle, man-made satellite, remote sensing, etc. also, are words in common use. You may have heard about lasers, radar and microwaves.

Physics has taught us the technique of achieving very low temperatures which results in the development of cryogenics. Physics is the mother of subjects like electronics and communication, computer technology, and information technology.

Even after this tremendous development we are still not in a position to say that we have fully understood nature. Many problems are still unresolved for physicists. For example does universe consist of a single element ? Are matter

and energy two different aspects of the same thing ? Is unification of various forces in nature possible ? What is the future of universe ?

Forced with several questions like these, Physicist are attempting to solve two principal thrusts in physics : **unification** and **reduction**.

### 1.4 Fundamental Forces in Nature

Dear students, if we want to roll a ball on the ground (surface) then we have to apply force to give motion to the ball. The ball will stop after travelling a certain distance since frictional force is acting on the surface of the ball. We have to use a force to lift a ball from the surface. We also feel force when someone pulls or pushes us. Thus, we experience forces in day-to-day life in various ways. Starting from such rudimentary concept of force we will learn the scientific concept of force.

Isaac Newton was the first physicist who developed clear concept of force in his famous laws of motion. In addition, he also discovered the universal law of gravitation.

In the macroscopic domain, besides gravitational force, we come across many different types of forces such as frictional force between two surfaces, the restoring force arising in a compressed spring, tension produced in a stretched string the force of surface tension prevailing in the free surface of a liquid, the viscous force in a fluid medium, etc.

In addition to these, force is also generated because of electrically charged and magnetic objects. Electric and magnetic forces, nuclear forces, interatomic and intermolecular forces, etc. are the examples of the forces prevailing in the microscopic domain.

At present, it is understood that there exist only four fundamental forces in nature. Let us understand them qualitatively.

#### 1.4.1 Gravitational Force

The gravitational force is a universal force and every object experiences this force due to every other object in the universe. According to Newton's law of gravitation, **the mutual attractive force is directly proportional to the product of their masses and inversely proportional to the square of the distance**

**between them.** The gravitational force is the force of mutual attraction between any two objects by virtue of their masses. It is a long range force and it does not require any intervening medium. Compared to other fundamental forces, gravitational force is the weakest force of nature. Yet it is important for a large portion of physical phenomena in the universe. Because of the gravitational force we are able to stand on the earth, a ball thrown up in the air comes down. Even, tides in the sea are believed due to the gravitational force between earth and moon. The effect of the gravitational force cannot be neglected in the phenomena like motion of the satellites around the earth, motion of the planets around the sun, formation of universe, formation and evolution of stars and galaxies, etc.

#### 1.4.2 Electromagnetic Force

The force acting between charged particles is known as the electromagnetic force. In the simple case, when charged particles are at rest, the force between them is known as static electric force. The magnitude of the force obeys Coulomb's inverse-square law. Thus, **the force between two electric charges is directly proportional to the product of the two charges and inversely proportional to the square of the distance between them.** For like charges the force is repulsive while for unlike charges the force is attractive.

When charges are in motion, they produce magnetic effects. This magnetic field gives rise to a force on the moving charge. The intensity of the magnetic field gets changed because of the motion of the charged particles. The combined effects of the electric and magnetic fields is, in general, inseparable. Hence the combined effect of the force is known as electromagnetic force. The electromagnetic force between two objects, also depends on the medium prevailing between them. Like the gravitational force, electromagnetic force is also a long range force and does not require any medium. It is very strong compared to gravitational force. The electric force between two stationary protons, for example, is  $10^{36}$  times the gravitational force between them, for any given distance.

The effect of the electromagnetic force is seen in the lightning in the sky, electric bell, etc.

#### 1.4.3 Strong Nuclear Force

We know that the nucleus is made up of protons and neutrons. Proton is a positively charged particle while neutron is a chargeless particle. If we think as per Coulomb's law then repulsive force would act between like charged particles proton-proton and then the nucleus would become unstable. This indicates that within the nucleus there must exist a strong attractive force to bind the proton and the neutron together. The charge independent force acting between proton-proton, proton-neutron and neutron-neutron within the nucleus is known as strong nuclear force. This force is 100 times stronger than the electromagnetic force. As this force exists within the nucleus, it is a short range ( $10^{-15}$  m) force. The strong nuclear force is the strongest of all fundamental forces.

Neutrons and protons are thought of as being made of a fundamental particle 'quark'. Hence, according to recent research, this force is believed to be a quark-quark force.

Dear students, please note here that since the electrons are outside the nucleus, the strong nuclear force does not act on them.

#### 1.4.4. Weak Nuclear Force

The weak nuclear force appears only in certain nuclear processes such as the  $\beta$ -decay of a radioactive nucleus. In  $\beta$ -decay, the nucleus emits an electron and a chargeless particle called neutrino. The weak nuclear force arises due to the interaction of neutrino with other particles. This force is stronger than the gravitational force, but much weaker than the strong nuclear force and the electromagnetic force. The range of weak nuclear force is also of the order of  $10^{-15}$  m.

#### 1.4.5 Towards Unification of Forces

In table 1.5, the fundamental forces of nature, their range, and their relative strength, are shown. Since so many years, physicists are thinking on a question that - Do all these fundamental forces arise from a single force ?

Can all the fundamental forces be explained from the hypothesis of a single force ?

Attempts to explore these ideas have opened the door towards unification of forces.



**Table 1.5 : Fundamental Forces in Nature**

Name	Relative Strength	Range	Operating Among
Gravitational Force	$10^{-38}$	Infinite	All objects in the Universe
Weak Nuclear Force	$10^{-13}$	Very short (within the nucleus $10^{-15}$ m)	Elementary Particles (neutrino)
Electromagnetic Force	$10^{-2}$	Infinite	Charged Particles
Strong Nuclear Force	1	Very short (within nucleus $10^{-15}$ m)	Nucleons (Neutron and Proton)

Newton has unified terrestrial and celestial domains under a common law of gravitation.

Oersted and Faraday showed that electric and magnetic phenomena are, in general, inseparable.

Maxwell unified electromagnetism and optics with the discovery that light is an electromagnetic wave.

Einstein attempted to unify gravitational force

and electromagnetic force but could not succeed in this.

Glashow, Salam and Weinberg showed that the weak nuclear force and the electromagnetic force can be viewed as a different aspects of a single electro-weak force.

Efforts towards the unification of fundamental forces are still going on. Table 1.6 highlights the attempts towards unification of fundamental forces in nature.

**Table 1.6 : Progress in Unification of Different Forces (only for information)**

Physicist	Year	Achivement in Unification
Isaac Newton	1687	Unified celestial and terrestrial mechanics. Showed that the same laws of motion and the law of gravitation apply to both the domains.
Hans Christian Oersted Michael Faraday	1820 1830	Electric and magnetic phenomena are inseparable aspects of a Unified domain - electromagnetism.
James Clerk Maxwell	1873	Unified electricity, magnetism and optics by showing light is an electromagnetic wave.
Sheldon Glashow Abdus Salam Steven Weinberg	1979	Showed that the weak nuclear force and the electron agnetic force could be viewed as different aspects of a single electro-weak force.
Carlo Rubia Simon Vander Meer	1984	Experimental verification of the theory of electro-weak force.

### 1.5 Nature of Physical Laws

Dear students, in any physical phenomenon governed by different forces, several physical quantities may change with time while some special physical quantities remain constant with time. The physical quantities that remain unchanged with time are called conserved quantities. In other words conservation of some physical quantity means that the quantity does not change with time.

Laws of conservation of energy, charge, linear momentum and angular momentum are considered as fundamental laws of physics. The laws of conservation play an important and basic role in physics. These laws are as under :

#### Law of Conservation of Energy :

The amount of total energy in the universe remains constant. Energy can neither be created nor be destroyed; it can just be converted from one form to the other.

#### Law of Conservation of Charge :

During any process taking place in an electrically isolated system, the algebraic sum of the charges always remains constant.

#### Law of Conservation of Linear Momentum :

If the resultant external force on a system is zero, the total linear momentum of the system remains constant.

#### Law of Conservation of Angular Momentum :

If the resultant external torque acting on a system is zero, the total angular momentum of the system remains constant.

In future you will study these laws in detail. Student friends, in addition to these four laws we have laws of conservation for spin, baryon number, strangeness, hyper charge, etc., in nuclear and particle physics. We will not study these over here.

Now the obvious question is which tacit form of nature is responsible for the existence of such laws of conservation ?

In Physics, studies is carried out of space and time. In classical mechanics space and time are considered independent of each other while according to the theory of relativity given by Einstein, space and time are interrelated. Space is homogeneous and isotropic, as a result of this, we have the law of conservation of linear momentum and the law of conservation of angular momentum. Likewise, time is also homogeneous and isotropic. Because of homogeneity of time we have the law of conservation of energy. But till today physicists are unable to know, what will be the possible result due to isotropicity of time. The great theoretical physicist of 20<sup>th</sup> century, Dirac was of the opinion that, the law of conservation of charge may be due to isotropic nature of time.

In other words, we know the basic reasons behind the existence of laws of conservation of linear momentum, angular momentum and energy. But the physicists are still putting their efforts to reveal the underlying mystery of nature in the laws of conservation of charge.

Dear students, the doors are still open for you to resolve many such interesting unsolved problems in physics !

### SUMMARY

1. The word 'Bhautik Vigyan' (used in Hindi / Gujarati) related to the science of physical world is derived from Sanskrit word 'Bhautiki'.
2. English word 'physics' comes from a Greek word meaning 'nature'.
3. Physics deals with the study of basic laws of nature related to matter, energy and their manifestation in different phenomena.
4. The scope of the physics is extended on two basic domains : macroscopic to microscopic. It also deals with static and dynamic systems.
5. The basic laws of physics are universal and apply in widely different contexts and conditions.
6. The gravitational force, electromagnetic force, strong nuclear force and weak nuclear force are the four fundamental forces in nature. The attempts towards the unification of forces are going on.
7. The physical quantity that remains unchanged with time is called conserved quantity.
8. The laws of conservation of energy, charge, linear momentum and angular momentum are considered as the fundamental laws of physics.



**EXERCISES**

Choose the correct option from the given options :

1. .... are two fundamental constituents of universe.  
(A) Matter and radiation (B) Heat and light  
(C) Molecule and atom (D) Electron and proton.
2. .... is the fourth state of matter.  
(A) Solid (B) Liquid  
(C) Gas (D) Plasma
3. Nucleus of molecule is made up of which fundamental constituents ?  
(A) Electron and proton (B) Electron and neutron  
(C) Proton and neutron (D) only electron
4. What is a acronym of ECG ?  
(A) Electron cardiogram (B) Electron colour graph  
(C) Electro cardiograph (D) Electric cordiogram
5. What is full form of NMR ?  
(A) Neutron Magnetic Resonance (B) Nuclear Magnetic Resonance  
(C) Neutrino Magnetic Resonance (D) Nuclear Motion Resonance
6. What is full form of ESR ?  
(A) Electric Spin Resonance (B) Electron Spin Resonance  
(C) Electron Spin Radar (D) Electric Space Radar
7. The force exerting between neutron and proton within the nucleus is the  
(A) Gravitational force (B) Electromagnetic force  
(C) Strong nuclear force (D) Weak nuclear force
8. Which particles are emitted during the  $\beta$ -decay from the nucleus ?  
(A) Neutron and proton (B) Electron and proton  
(C) Electron and neutron (D) Electron and neutrino
9. Space is isotropic. Which law of conservation is the result of this ?  
(A) Law of conservation of energy  
(B) Law of conservation of charge  
(C) Law of conservation of linear momentum  
(D) Law of conservation of angular momentum
10. Space is homogenous. Which law of conservation is the result of this ?  
(A) Law of conservation of energy.  
(B) Law of conservation of charge  
(C) Law of conservation of linear momentum.  
(D) Law of conservation of angular momentum
11. Time is homogeneous. Which law of conservation is the result of this ?  
(A) Law of conservation of energy  
(B) Law of conservation of charge  
(C) Law of conservation of linear momentum  
(D) Law of conservation of angular momentum
12. The basic reason behind existance of which conservation of law is still not known ?  
(A) Law of conservation of energy.  
(B) Law of conservation of charge.  
(C) Law of conservation of linear momentum.  
(D) Law of conservation of angular momentum.

**ANSWERS**

1. (A)    2. (D)    3. (C)    4. (C)    5. (B)    6. (B)  
7. (C)    8. (D)    9. (D)    10. (C)    11. (A)    12. (B)

**Answer the following questions :**

1. Which forces are considered as the fundamental forces in nature ?
  2. What is meant by unification of forces ?
  3. Write the law of conservation of energy.
  4. Write the law of conservation of charge.
  5. Write the law of conservation of linear momentum.
  6. Write the law of conservation of angular momentum.
  7. Which are the fundamental laws in physics ?
  8. Which two fundamental forces are different aspects of electroweak interaction ?
  9. What is plasma ?
  10. What is cryogenics ?
  11. Explain gravitational force ?
  12. What is electromagnetic force ?
  13. Explain strong nuclear force ?
  14. What is weak nuclear force ?
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