



# PHYSICAL WORLD AND MEASUREMENT

Have you ever observed the nature and the various spectacular events like formation of rainbow on any rainy day?

Whenever we observe nature keenly, we can easily understand that the various events in nature like blowing of wind, flow of water, motion of planets, formation of rainbow, different forms of energies, the function of human bodies, animals, etc. are happening or taking place according to some basic laws. The systematic study of these laws of nature governing the observed events is called science. For our convenience, clear understanding and systematic study of Science is classified into various branches. Among these branches Chemistry, Mathematics, Botany, Zoology, etc. are ancient branches and Bio-technology, Bio-chemistry, Bio-Physics, Computer science, Space Science, etc. are considered to be modern branches of science and engineering. One of such ancient and reputed branches of this science is physics.

## Scope and Excitement of Physics

The domain of physics consists of wide variety and large number of natural phenomena. Hence, the scope of physics is very vast and obviously the excitement that one gets from the careful study of physics has got no boundaries.

## Scope of Physics

For example, when we study one of the basic physical quantities called mass, we come across the values ranging from minute masses like mass of an electron (of the order of  $10^{-30}$  kg) to heavy masses like mass of universe ( $10^{55}$  kg). Similarly, in case of other basic quantities like length and time also the range is very wide. Hence, the scope of physics can be understood easily, only when we can classify the study of physics chiefly into three levels. They are:

- (a) Macroscopic level study of physics,
- (b) Mesoscopic level study of physics, and
- (c) Microscopic level study of physics.

**Macroscopic level study of physics:** Macroscopic level study of physics mainly includes the study of basic laws of nature and several natural phenomena like gravitational force of attraction between any two bodies in the universe (in mechanics), variation of quantities like pressure, volume, temperature, etc. of gases on their thermal expansion or contraction (in thermodynamics), etc.

**Microscopic level study of physics:** The microscopic level study of physics deals with constitution and structure of matter at the level of atoms or nuclei. For example, interaction between elementary particles like electrons, protons and other particles, etc.

**Mesoscopic level study of physics:** The mesoscopic level study of physics deals with the intermediate domain of macroscopic and microscopic, where we study various physical phenomena of atoms in bulk. So, the edifice of physics is beautiful and one can appreciate the subject as and when one pursues the same seriously.

## Excitement of Physics

The study of physics is exciting in many ways as it explains us the reason behind several interesting features like (A) how day and nights are formed? (b) how different climatic conditions are formed in different seasons?

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(c) how satellite works and helps in using several devices like television, telephones, etc.? (d) how an astronaut travels to celestial space ? (e) how we can convert one form of energy to another ? (f) how different types of forces are governing different types of motion in universe ? etc.

It is quite common and simple that every human being on the earth will be interested to know the answers for at least few of the above questions. As physics is the subject which answers them, naturally the study of physics will be exciting.

### Technology and Society

Physics is almost an integral part of upgradation of technology. Technology was also a branch of science where we study the application of principles of physics for practical purposes. Based on laws and principles of physics, technocrats along with scientists develop technically advanced equipment to help the society.

For example, from the principles of thermodynamics James watt invented steam engine which was responsible for a big industrial revolution in England in the 18<sup>th</sup> century. Another recent example is invention of mobile phones which are creating revolution in wireless communication technology. Yet another important example is invention of micro-processors by using silicon chips which has replaced valve technology and brought the computers from the size of your study room to the size of your geometry box. These are few examples. There are many more areas where physics is involved in upgrading technology and thereby helping the society. The following table gives us a list of various branches of physics that helped the field of technology.

Technology	Scientific principle(s)
Steam engine	Laws of thermodynamics
Nuclear reactor	Nuclear fission
Radio and Television	Propagation of electromagnetic waves
Computers	Digital logic
Lasers	Light amplification by stimulated emission of radiation (population inversion)
Production of ultra-high magnetic fields	Superconductivity
Rocket propulsion	Newton's laws of motion
Electric generator	Faraday's laws of electromagnetic induction
Hydroelectric power	Conversion of gravitational potential energy into electric energy
Aeroplane	Bernoulli's principle in fluid dynamics
Particle accelerators	Motion of charged particles in electromagnetic fields
Air conditioners / Refrigerators	Laws of thermodynamics
Washing machines, centrifuge, etc.	Centrifugal force
Sonar	Reflection of ultrasonic waves

The following table lists the involvement of various renowned physicists all across the world, who helped the society with their noble inventions.

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Name	Major Contribution / Discovery	Country of origin
Isaac Newton	Universal law of gravitation; Laws of motion; reflecting telescope.	U. K.
Galileo Galilei	Law of inertia	Italy
Archimedes	Principle of buoyancy; principle of the lever	Greece
James Clerk Maxwell	Electromagnetic theory; light an electromagnetic wave	U. K.
W. K. Roentgen	x- rays	Germany
Marie Sklodowska Curie	Discovery of radium and polonium; Studies on natural radioactivity	Poland
Albert Einstein	Law of photo-electricity; Theory of relativity	Germany
S. N. Bose	Quantum statistics	India
James Chadwick	Neutron	U.K.
Niels Bohr	Quantum model of hydrogen atom	Denmark
Ernest Rutherford	Nuclear model of atom	New Zealand
C.V. Raman	Inelastic scattering of light by molecules	India
Christiaan Huygens	Wave theory of light	Holland
Michael Faraday	Laws of electromagnetic induction	U.K.
Edwin Hubble	Expanding universe	U.S.A.
Homi Jehangir Bhabha	Cascade process in cosmic radiation	India
Abdus Salam	Unification of weak and electromagnetic interactions	Pakistan
R. A. Millikan	Measurement of electronic charge	U.S.A
Ernest Orlando Lawrence	Cyclotron	U.S.A.
Wolfgang Pauli	Quantum Exclusion Principle	Austria
Louis victor de Broglie	Wave nature of matter	France
J.J. Thomson	Electron	U.K.
S. Chandrasekhar	Chandrasekhar limit, structure and evolution of stars	India
Lev Devidovich Landau	Theory of condensed matter; liquid helium	Russia
Heinrich Rudolf Hertz	Electromagnetic waves	Germany
Victor Francis Hess	Cosmic radiation	Austria
M. N. Saha	Thermal ionisation	India
G. N. Ramachandran	Triple helical structure of proteins	India
Thomas Alwa Edison	Electric bulb, Projector	US
Graham Bell	Telephone	US
Cavendish	Determination of 'G'	England
Robert Boyle	Boyle's law	England

So, to put it in a nut shell, science, technology and society are inseparable as they are deeply intertwined.

## Fundamental Forces in Nature

Force is a very common word which we normally come across in our daily life. We need force to push or pull or throw a body. Even we need it to deform or break the bodies. Sometimes, we experience force like

when we are standing in a great storm, we experience the force exerted by wind. When we are sitting in a bus which is negotiating a turn, we experience an outward push. So, what is this force? Let us try to understand the concept of force in terms of physics.

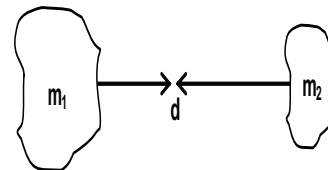
At macroscopic level study of physics, we normally encounter different kinds of forces like gravitational force, muscular force, frictional force, contact force, spring force, buoyant force, viscous force, pressure force, force due to surface tension, electrostatic force, magnetic force, etc. whereas at microscopic level of study we come across nuclear forces, interatomic forces, intermolecular forces, weak forces, etc.

After analysing these various types of forces in nature, it was concluded that all the forces can be comfortably classified into four categories, which are known as fundamental forces in nature. They are (1) Gravitational force (2) Electromagnetic force, (3) Nuclear force, and (4) Weak force.

That means, any force other than the above four forces can be derived from these four basic forces. For example, elastic force or spring force arises due to the net attraction or repulsion between any two neighboring atoms of the spring. When it is elongated or compressed, attractive or repulsive forces produced between the atoms can be treated as the resultant of all electromagnetic forces between charged particles of an atom. Hence, this spring force is known as derived force and electromagnetic force which is the origin of this spring force is called fundamental force. Now, we will study about fundamental forces in brief.

## Gravitational Force

Newton discovered that any two bodies in universe attract each other. This force of attraction exists by virtue of their masses, and is known as gravitational force of attraction. He found that the gravitational force is directly proportional to their masses and is inversely proportional to the square of the distance between them.



i.e.  $F = G \frac{m_1 m_2}{d^2}$  where 'G' is a Universal Gravitational Constant. This force is a

universal force and is independent of any type of intervening medium between the two bodies. Though this is the weakest force in nature when compared to other types of fundamental forces, it plays vital role in governing the motion of planets around sun, natural satellites (like moon around earth), artificial satellites, etc.

## Electromagnetic Force:

The force of attraction or repulsion between any two charged particles is known as electrostatic force. If  $q_1$  and  $q_2$  charges are separated by a distance 'd' in air then the force of attraction or repulsion between them

is given by  $F = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{d^2}$ . This is called Coulomb's law of electric forces.

Charges in motion produce magnetic effects and a magnetic field gives rise to a force on a moving charge. In general electric and magnetic effects are inseparable and hence the name – electromagnetic force. This electromagnetic force between moving charged particles is comparatively more complicated and contains several other terms other than Coulomb's force.

In atoms electromagnetic force between electrons and protons is responsible for several molecular and atomic phenomena. Apart from this it also plays vital role in the dynamics of chemical reactions, mechanical and thermal properties of materials, tension in ropes, friction, normal force, spring force, Vander Waals force

This electromagnetic force is a strong force when compared to the gravitational force. The electromagnetic force between two protons is  $10^{36}$  times the gravitational force between them for any fixed distance.

