PHYSICAL WORLD

PHYSICS

The dictionary definition of physics is “the study of matter, energy, and the interaction between them”, but what that really means is that physics is about asking fundamental questions and trying to answer them by observing and experimenting.

Physicists ask really big questions like:

(i) How did the universe begin ?

(ii) How will the universe change in the future ?

(iii) How does the Sun keep on shining ?

(iv) What are the basic building blocks of matter ?

(v) If you think these questions are fascinating, then you’ll like physics.

What do Physicists do ?

Many physicists work in ‘pure’ research, trying to find answers to these types of question. The answers they come up with often lead to unexpected technological applications. For example, all of the technology we take for granted today, including games consoles, mobile phones, mp3 players, and DVDs, is based on a theoretical understanding of electrons that was developed around the turn of the 20th century.

Physics doesn’t just deal with theoretical concepts. It’s applied in every sphere of human activity, including:

(i) Development of sustainable forms of energy production

(ii) Treating cancer, through radiotherapy, and diagnosing illness through various types of imaging, a all based on physics.

(iii) Developing computer games

(iv) Design and manufacture of sports equipment

(v) Understanding and predicting earthquakes

(vi) In fact, pretty much every sector you can think of needs people with physics knowledge.

What about mathematics ?

Many apparently complicated things in nature can be understood in terms of relatively simple mathematical relationships. Physicists try to uncover these relationships through observing, creating mathematical models, and testing them by doing experiments. The mathematical equations used in physics often look far more complicated than they really are. Nevertheless, if you are going to study physics, you will need to get to grips with a certain amount of maths.

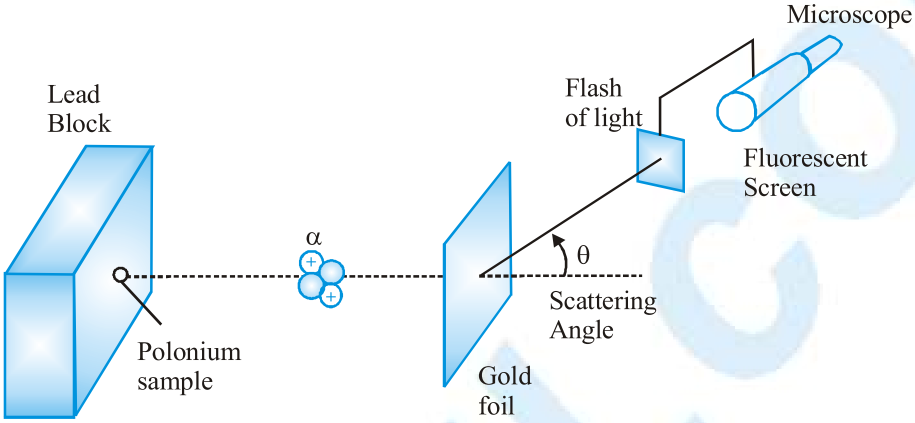
ETOOS KEY POINTS

(i) The universal is far too complex to comprehend all at once. It is therefore, convenient to look at the different aspect of the behaviour of the universe through different approaches. Each one of these leads to a simpler way of understanding. We call each of these units as a discipline/subject of science.

(ii) Physical provides systematic answer to our queries about the physic mena on the basis of logical reasoning and experimentation, is called the scientific method.

SCOPE AND EXCITEMENT OF PHYSICS

The scope of physics is very large. Physics deals with a wide variety of disciplines such as mechanics, heat and light. Study of mechanics helps us to know the forces involved in the flight of a bird, walk of a man and so on. The study of heat helps us to know the rise and fall of temperatures, working of heat engines and so on. Electricity helps to understand the basic principles involved in generators and motors. The exciting discipline of modern physics takes us into the microscopic world of atoms and electrons.



(Figure)

The distribution of charges proposed by Thomson in his model was tested by Ernest Rutherford in 1909 by using subatomic projectiles to bombard a target of atoms. These projectiles, called alpha (α) particles, were identified as one of the products of radioactivity.

Rutherford's famous α-particle scattering experiment is represented in the figure above. A stream of high energy α-particles from a radioactive source is directed at a thin foil (thickness-100 nm) of gold metal (having a circular fluorescent zinc sulphide screen round it). Whenever an α-particle strikes the screen, a tiny flash of light is produced at that point.

PHYSICS IN RELATION TO SCIENCE, SOCIETY AND TECHNOLOGY

Among the various disciplines of science, the only discipline which can be regarded as being most fundamental is physics. It has played a key role in the development of all other disciplines.

1. PHYSICS IN RELATION TO CHEMISTRY

The study of structure of atoms, radioactivity, X-ray, diffraction, etc., in physics has enabled chemists to rearrange elements in the periodic table and to have a better understanding of chemical bonding and complex chemical structures.

2. PHYSICS IN RELATION TO BIOLOGICAL SCIENCE

The optical microscopes developed in physics are extensively used in the study of biological samples. Electron microscope, X-rays and radio isotopes are used widely in medical sciences.

3. PHYSICS IN RELATION TO ASTRONOMY

The giant astronomical telescopes and radio telescopes have enabled the astronomers to observe planets and other heavenly objects.

4. PHYSICS RELATED TO MATHEMATICS

Mathematics has served as a powerful tool in the development of modern theoretical physics.

5. PHYSICS RELATED TO OTHER SCIENCE

The other sciences like Biophysics, Geology, Heterology and Oceanography and Seismology use some of the laws of physics.

6. PHYSICS RELATED TO SOCIETY AND TECHNOLOGY

(i) The development of telephone, telegraph and telex enables us to transmit messages instantly.
(ii) The development of radio and television satellites has revolutionised the means of communication.
(iii) Advances in electronics (computers, calculators and lasers) have greatly enriched the society.
(iv) Rapid means of transport are important for the society.
(v) Generation of power from nuclear reactors is based on the phenomenon of controlled nuclear chain reaction.
(vi) Digital electronics is widely used in modern technological developments.

SOME PHYSICISTS FROM DIFFERENT COUNTRIES OF THE WORLD AND THEIR MAJOR CONTRIBUTIONS

Name	Major contribution/discovery	Country of origin
Archimedes	Principle of buoyancy; Principle of the lever	Greece
Galileo Galilei	Law of inertia	Italy
Christiaan Huygens	Wave theory of light	Holland
Isaac Newtons	Universal law of gravitation; Laws of motion; Reflecting telescope	U.K.
Michael Faraday	Laws of electromagnetic induction	U.K.
James Clerk Maxwell	Electromagnetic theory; Light-an electromagnetic wave	U.K.
Heinrich Rudolf Hertz	Generation of electromagnetic waves	Germany
J.C. Bose	Ultra short radio waves	India
W.K. Roentgen	X-rays	Germany
J.J. Thomson	Electron	U.K.
Marie Sklodowska Curie	Discovery of radium and polonium; Studies on natural radioactivity	Poland
Albert Einstein	Explanation of photoelectric effect; Theory of relativity	Germany
Victor Francis Hess	Cosmic radiation	Austria
R.A. Millikan	Measurement of electronic charge	U.S.A.
Ernest Rutherford	Nuclear model of atom	New Zealand
Niels Bohr	Quantum model of hydrogen atom	Denmark
C.V. Raman	Inelastic scattering of light by molecules	India
Louis Victor de Broglie	Wave nature of matter	France
M.N. Saha	Thermal ionisation	India
S.N. Bose	Quantum statistics	India
Wolfgang Pauli	Exclusion principle	Austria
Enrico Fermi	Controlled nuclear fission	Italy
Werner Heisenberg	Quantum mechanics; Uncertainty principle	Germany
Paul Dirac	Relativistic theory of electron; Quantum statistics	U.K.
Edwin Hubble	Expanding universe	U.S.A.
Ernest Orlando Lawrence	Cyclotron	U.S.A.
James Chadwick	Neutron	U.K.
Hideki Yukawa	Theory of nuclear forces	Japan
Homi Jehangir Bhabha	Cascade process of cosmic radiation	India
Lev Davidovich Landau	Theory of condensed matter; Liquid helium	Russia
S. Chandrasekhar	Chandrasekhar limit, structure and evolution of stars	India
John Bardeen	Transistors; Theory of superconductivity	U.S.A.
C.H. Townes	Maser; Laser	U.S.A.
Abdus Salam	Unification of weak and electromagnetic interactions	Pakistan

LINK BETWEEN TECHNOLOGY & PHYSICS

Technology	Scientific Principle(s)
Steam engine	Laws of thermodynamics
Nuclear reactor	Controlled nuclear fission
Radio and Television	Generation, propagation and detection of electromagnetic waves
Computers	Digital logic
Laser	Light amplification by stimulated emission of radiation
Production of ultra high magnetic field	Superconductivity
Rocket propulsion	Newtons's laws of motion
Electric generator	Faraday's laws of electromagnetic induction
Hydroelectric power	Conversion of gravitational potential energy into electrical energy
Aeroplane	Bernoulli's principle in fluid dynamics
Particle accelerators	Motion of charged particles in electromagnetic field
Sonar	Reflection of ultrasonic waves
Optical fibres	Total internal reflection of light
Non-reflecting coatings	Thin film optical interference
Electrons microscope	Wave nature of electrons
Photocell	Photoelectric effect
Fusion test reactor (Tokamak)	Magnetic confinement of plasma
Giant Metrewave Radio Telescope (GMRT)	Detection of cosmic radio waves
Bose-Einstein Condensate	Trapping and cooling of atoms by laser beams and magnetic fields

FUNDAMENTAL DOMAIN OF PHYSICS

All the diverse physical phenomena (both microscopic and macroscopic) in the universe can be studied using one or more of the following domains of physics.

1. **Classical Mechanics**
The branch concerned with the motion of objects moving at speeds very small compared to the speed of light in vacuum.

2. **Electromagnetism**
The branch of electricity, magnetism, and the electromagnetic fields

3. **Thermodynamics**
The branch dealing with heat, temperature and work.

4. **Relativity**
The special theory of relativity describes the motion of objects moving at any speed, even at speeds approaching the speed of light in vacuum. General theory of relativity is the extension of the special theory of relativity and includes non-inertial frames of reference and their relation to the gravitational fields.

5. **Quantum Theory**
The quantum theory deals with physics of atomic and subatomic particles.

FUNDAMENTAL FORCES IN NATURE

In the whole history of science from Greeks to modern physicists, there have been continuous attempts to reduce the apparent complexity of natural phenomena, to some simple fundamental ideas and relations. Everyone has a basic understanding of the concept of force from everyday experience. For example, you exert a force when you throw or kick a ball. When a coiled spring is pulled, it stretches. These are some examples of contact forces. That is, they involve physical contact between the two objects. Another class of forces, known as field forces, do not involve physical contact between two objects. The gravitational force, the electromagnetic interactions are examples of the field force (or non-contact force). However, as of now, the known fundamental forces in nature are four in number and are all field forces.

1. Gravitational Forces

Any two particles attract each other by virtue of their masses. The force of interaction is called gravitational force. For example, the weight of a body results from the earth's gravitational attraction acting on the body. The gravitational force of attraction between earth and sun keeps earth revolving around the sun. Gravitational force extends from subatomic distances to an infinite distance.

2. Electromagnetic Forces

Electromagnetic interactions include both electric and magnetic forces which extend from subatomic dimensions to infinite distance.

3. Strong Forces

These are forces that operates typically over a range of 10^{-15} m, the size of a nucleus. Protons and neutrons inside a nucleus are held together by strong forces.

4. Weak Forces

Weak forces are the forces by means of which certain elementary particles interact. For example, in β-decay, a neutron can change itself into a proton and simultaneously emit an electron and a particle called antineutrino. These forces have a very small range of influence.

During the past several decades, a unified theory of the electromagnetic and weak interactions has been developed. We now speak of electroweak interaction, and in a sense this reduces the number of interactions from four to three.

Similar attempts have been made to understand all interactions on the basis of a single unified theory called a grand unified theory (GUT). The first tentative steps are being taken towards a possible unification of all interactions into a theory of everything (TOE)!

Fundamental Forces Relative Strength and Range

Name	Relative strength	Range	Oprates among
Gravitational force	10^{-39}	Infinite	All object in the universe
Weak nuclear force	10^{-13}	Very short Sub-nuclear size ~ 10^{-16} m	Some elementry particles particulary electron and neutrino
Electromagnetic force	10^{-2}	Infinite	Charged particles
Strong nuclear force	1	Short nuclear size Nucleons, heavier ~ 10^{-15} m	elementry particles

NATURE OF PHYSICAL LAWS

(a) Physicists explore the universe. Their investigation, based on scientific processes, range from particles that are smaller than atoms in size to starts that are very far away. In addition to finding the facts by observation and experimentation, physicists attempt to discover the laws that summarise (often as mathematical equations) these facts.

(b) In any physical phenomenon governed by different forces, several quantities may change with time. A remarkable fact is that some special physical quantities, however, remain constant in time. They are the conserved quantities of nature. Understanding these conservation principle is very important to describe the observed phenomena quantitatively.

CONSERVATION LAWS IN PHYSICS

During the study of various physical processes, we find that certain quantities remain constant over time. This constancy of a physical quantity over time under certain conditions, within an isolated system, is called a conservation law. For example, we have conservation laws for energy, linear momentum, angular momentum, charge, etc. The law of conservation of energy may be stated as follows.
" For an isolated system, the total energy of the system remains constant".

The number of interactions that occur in the system has no consequence on the total energy of the system. The conservation laws are very basic and their existence is taken valid for any isolated physical system. During any physical process, if there appears a violation of any of the conservation laws, then the scientists conclude that the fault lies elsewhere. The search then begins for a "missing quantity" to conserve the law.

In the case of β-decay, scientists found that while explaining the phenomenon, they observed violations of conservation laws of linear momentum, angular momentum and energy. To satisfy these conservation laws, it was postulated(by Pauli in 1930) that there should exist one more particle along with β-particle during the decay process. This particle was named 'neutrino' which was supposed to carry the missing linear momentum, angular momentum and energy. Neutrino was later discovered experimentally in 1956 (by Frederic Reines and Clyde Cowan).

Conservation laws are a source of deep insight into the simple regularity of nature and are considered as the most fundamental among physical laws. As we sail on the physica ocean, conservation laws are the navigators!