# Chapter 1
# Physical World

It is human nature to observe things and happenings around in the nature and then to relate them. This knowledge is organized so that it becomes well connected and logical. The world has an astonishing variety of materials and a bewildering diversity of life and behavior. The inquiring and imaginative human mind has responded to the wonder and awe of nature in different ways.

## Science and its origin

Science, in a broad sense, is as old as human species. Science is a **systematic understanding of natural phenomena** in detail so that it can be **predicted, controlled and modified**. Science involves exploring, experimenting and speculating phenomena happening around us.

❖ The word **Science** is derived from a latin verb *Scientia* meaning 'to know'. The Sanskrit word *Vijnan* and the Arabic word *Ilm* convey similar meaning, namely 'knowledge'

- **Scientific method** is a way to gain knowledge in a systematic and in-depth way. It involves:
- *Systematic observations*
- *Controlled experiments*
- *Qualitative and Quantitative reasoning* o *Mathematical modeling*
- *Prediction and verification (or falsification) of theories* o *Speculation or Prediction*

***There is no 'final' theory in science and no unquestioned authority in science.***

- The improved observations, accurate tools keep improving the knowledge and perspective. Sometimes the existing theory is unable to explain the new observations, hence either new theories are formed or modification is done in the existing theories.
  - Johannes Kepler used Tycho Brahe's research on planetary motion to improve Nicolas Copernicus theory.
  - Quantum mechanics was developed to deal with atomic and nuclear phenomena. Work of Ernest Rutherford on nuclear model of atom became basis of quantum theory given by Niels Bohr. Antiparticle theory of Paul Dirac led to the discovery of antielectron (positron) by Carl Anderson.

## Natural Sciences

Natural science is a branch of science concerned with the description, prediction, and understanding of natural phenomena, based on observational and empirical evidence. It consists of following disciplines:

- Physics
- Chemistry
- Biology

## Physics

**Physics** is a study of basic laws of nature and their manifestation in different natural phenomena. Physics is the study of physical world and matter and its motion through space and time, along with related concepts such as energy and force.

- Word Physics is derived from a Greek word *phusikḗ* meaning nature.
- Two principal types of approaches in Physics are:

1. **Unification**: Efforts are made to explain different phenomena in nature on the basis of one or minimum laws. This is principle of Unification.This approach considers all of the world's phenomena as a collection of universal laws in different domains and conditions. Example, law of gravitation applies both to a falling apple from a tree as well as motion of planets around the sun. Electromagnetism laws govern all electric and magnetic phenomena.

2. **Reduction**: To understand or to derive the properties of a bigger or more complex system the properties of its simpler constituents are taken into account. This approach is called reductionism. It is supposed to be the heart of Physics.

   Example, temperature studied under thermodynamics is also related to average kinetic energy of molecules in a system (kinetic theory).

## Impact and uses of Physics:

- It can explain a phenomena happening over a large magnitude with a simple theory.
- Experiments and observations are used to develop new theories for unidentified phenomena and improve old theories for existing phenomena.
- Development of devices using laws of physics.

## Scope of Physics

- ***The scope of Physics*** can be divided in to two domains; Macroscopic and Microscopic.
- Macroscopic domain includes phenomena at the level of Laboratory, terrestrial and astronomical scales.
- its scope - **Classical Physics**.
- Microscopic domain includes atomic, molecular and nuclear phenomena. its scope - **Modern Physics**.

Scope of Physics is vast as it covers quantities with length magnitude as high as $10^{40}$m or more (astronomical studies of universe) and as low as $10^{-14}$m or less (study of electrons, protons etc). Similarly the range of time scale goes from $10^{-22}$s to $10^{18}$s and mass from $10^{-30}$kg to $10^{55}$kg.

**Macroscopic Domain**

Macroscopic domain includes phenomena at large scales like laboratory, terrestrial and astronomical. It includes following subjects:

1. **Mechanics** – It is based on Newton's laws on motion and the laws of gravitation. It is concerned with motion/equilibrium of particles, rigid and deformable bodies and general system of particles. Examples,
    a. Propulsion of rocket by ejecting gases
    b. Water/Sound waves
    c. Equilibrium of bent rod under a load
2. **Electrodynamics** – It deals with electric and magnetic phenomena associated with charged and magnetic bodies. Examples,
    a. motion of a current-carrying conductor in a magnetic field
    b. the response of a circuit to an ac voltage (signal)
    c. the propagation of radio waves in the ionosphere
3. **Optics** – It deals with phenomena involving light. Examples,
    a. Reflection and refraction of light
    b. Dispersion of light through a prism
    c. Colour exhibited by thin films
4. **Thermodynamics** – It deals with systems in macroscopic equilibrium and changes in internal energy, temperature, entropy etc. of systems under application of external force or heat. Examples,
    a. Efficiency of heat engines
    b. Direction of physical and chemical process

**Microscopic Domain**

Microscopic domain includes phenomena at minuscule scales like atomic, molecular and nuclear. It also deals with interaction of probes like electrons, photons and other elementary particles. Quantum theory has been developed to handle these phenomena.

**Factors responsible for progress of Physics**

- Quantitative analysis along with qualitative analysis.
- Application of universal laws in different contexts.
- Approximation approach (complex phenomena broken down into collection of basic laws).
- Extracting and focusing on essential features of a phenomenon.

**Hypothesis, Axiom and Models**

a) **Hypothesis** is a supposition without assuming that it is true. It may not be proved but can be verified through a series of experiments.
b) **Axiom** is a self-evident truth that it is accepted without controversy or question.
c) **Model** is a theory proposed to explain observed phenomena.
d) **Assumption** is the basis of physics, where a number of phenomena can be explained. These assumptions are made from experiments, observation and a lot of statistical data.

## Technological applications of Physics

Several examples where Physics and its concepts have led to discoveries/inventions are listed below.

- Steam engine was developed from the industrial revolution in eighteenth century.
- Wireless communication was developed after discovery of laws of electricity and magnetism.
- Neuron-induced fission of uranium, done by Hahn and Meitner in 1938, led to the formation of nuclear power reactors and nuclear weapons.
- Conversion of solar, wind, geothermal etc. energy into electricity.

**The excitement of Physics** is experienced in many fields Like:

- Live transmissions through television.
- Computers with high speed and memory,
- Use of Robots,
- Lasers and their applications

### Physics in relation to other branches of Science

Physics in relation to Chemistry.

- Chemical bonding, atomic number and complex structure can be explained by physics phenomena of Electrostatic forces,

taking help of X-ray diffraction

Physics in relation to other Science

- Physics in relation to Biological Sciences: Physics helps in study of Biology through its inventions. Optical microscope helps to study bio-samples, electron microscope helps to study biological cells. X-rays have many applications in biological sciences. Radio isotopes are used in cancer.

Physics in relation with Astronomy:

- Giant astronomical telescope developed in physics are used for observing planets. Radio telescopes have enabled astronomers to observe distant limits of universe.
- Physics related to other sciences: Laws of Physics are used to study different phenomenas in other sciences like Biophysics, oceanography, seismology etc.

## Fundamental Forces in nature

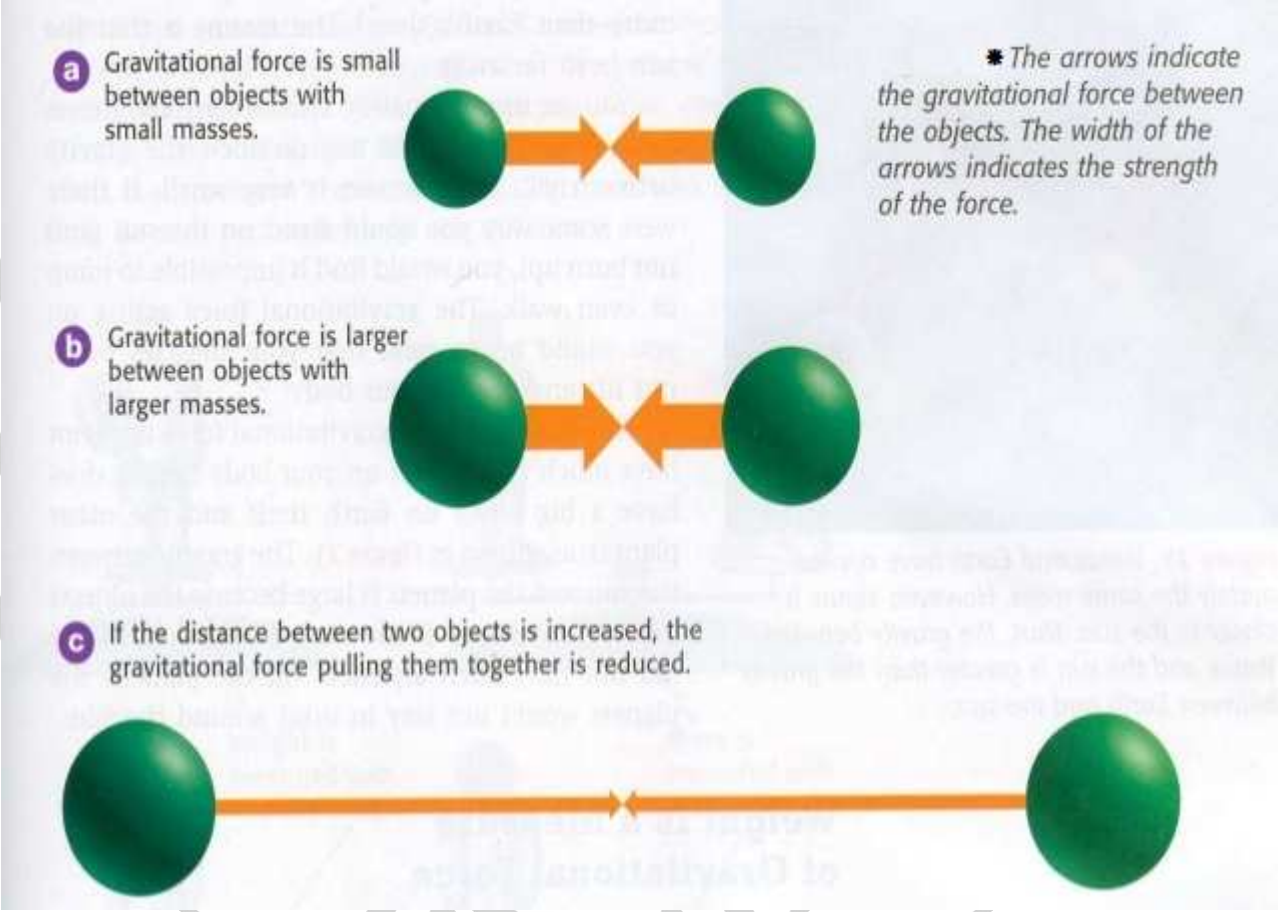
The forces which we see in our day to day life like muscular, friction, forces due to compression and elongation of springs and strings, fluid and gas pressure, electric, magnetic, interatomic and intermolecular forces are **derived forces** as their originations are due to a few fundamental forces in nature. *These may be macroscopic forces like gravitation, and microscopic forces like electromagnetic Forces, nuclear forces.*

A few fundamental forces are:

1. **Gravitational Force**: It is the **force of mutual attraction** between any two objects by virtue of their masses. It is a **universal force** as every object experiences this force due to every other object in the universe.

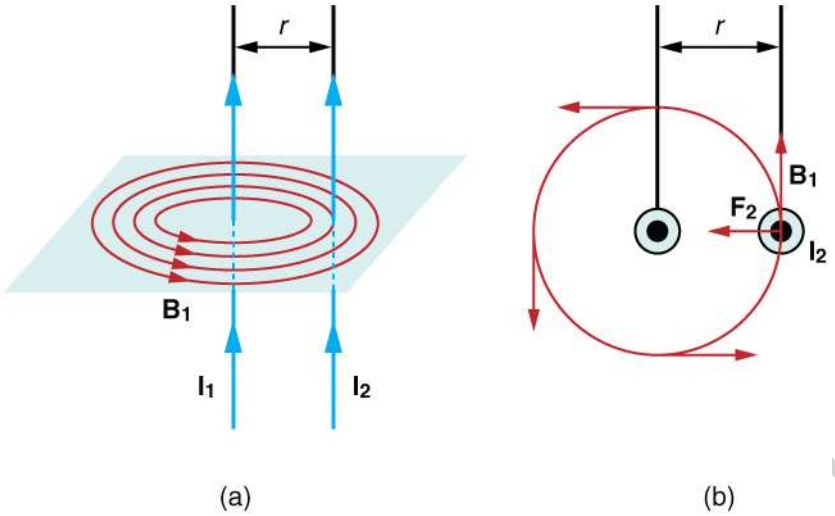
- *It is due to Mass of the two bodies.*
- *It is always attractive.*
- *It operates in all objects of universe.*
- *Its range is infinite*

*It's a weak force. $10^{-38}$ times compared to strong Nuclear force*



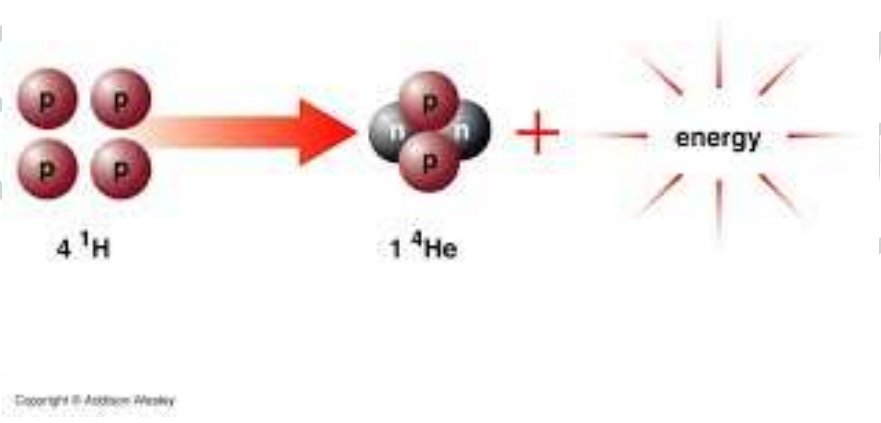

2. **Electromagnetic Force**: It is the **force between charged particles**. Charges at rest have electric attraction (between unlike charges) and repulsion (between like charges). Charges in motion magnetic force. Together they are called Electromagnetic Force.

- It's due to stationery or moving Electrical charge
- It may be attractive or repulsive.
- It operates on charged particles
- Its range is infinite
- Its stronger $10^{36}$ times than gravitational force but $10^{-2}$ times of strong Nuclear force.




3. **Strong Nuclear Force**: It is the **attractive force between protons and neutrons** in a nucleus.It is charge-independent and acts equally between a proton and a proton, a neutron and a neutron, and a proton and a neutron. Recent discoveries show that protons and neutrons are built of elementary particles, **quarks**.

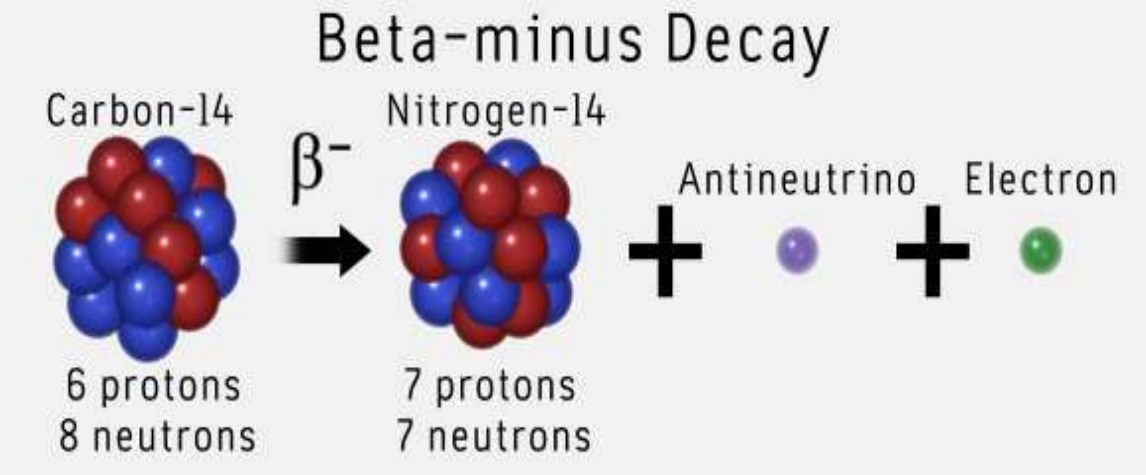
- Operate between Nucleons
- It may be attractive or repulsive
- Its range is very short, within nuclear size ($10^{-15}$ m).
- Its strongest force in nature




4. **Weak Nuclear Force:** This force appears only in certain nuclear processes such as the **β-decay of a nucleus**. In β-decay, the nucleus emits an electron and an uncharged particle called **neutrino**.This particle was first predicted by Wolfgang Pauli in 1931.

- Operate within nucleons I.e. elementary particles like electron and neutrino.
- It appears during radioactive b decay.
- Has very short range $10^{-15}$m.

- $10^{-13}$ times than Strong nuclear force.




**Below table shows difference between the above forces.**

| **Name** | **Relative strength** | **Range** | **Operates among** |
|---|---|---|---|
| Gravitational force | $_{10}$–39 times compared to strong nuclear force | Infinite | All objects in the universe |
| Weak nuclear force | $10^{-13}$ compared to strong nuclear force | Very short, Sub-nuclear size $10^{-16}$m) | Some elementary particles, particularly electron and neutrino |
| Electromagnetic force | $10^{36}$ times stronger than Gravitational force and $10^{-2}$ times than stronger nuclear force | Infinite | Charged particles |
| Strong nuclear force | 1 | Short, nuclear size ($10^{-15}$m) | elementary particles |

**<u>Unification of Forces</u>:** There have been physicists who have tried to combine a few of the above **fundamental forces. These are listed in table below**.

| *Sr. no.* | ***Name of Physicist*** | ***Year*** | ***Achievement in Unification*** |
|---|---|---|---|
| 1. | Isaac Newton | 1687 | Unified celestial and terrestrial mechanics. |
| 2. | Hans Christian Oersted and Michael Faraday | 1820 and 1830 respectively | Unified electric and magnetic phenomena to give rise to electromagnetism. |

| | | | |
|---|---|---|---|
| 3. | James Clerk Maxwell | 1873 | Unified electricity, magnetism and optics to show that Light is an electromagnetic wave. |
| 4. | Sheldon Glashow, Abdus Salam, Steven | 1979 | Gave the idea of electro-weak force which is a combination of electromagnetic and weak nuclear force. |
| 5. | Weinberg Carlo Rubia, Simon Vander Meer | 1984 | Verified the theory of elctro-weak force. |

## LINK BETWEEN TECHNOLOGY AND PHYSICS

| ***Sr. No.*** | ***Invention(Technology)*** | ***Their Laws(scientific Principle)*** |
|---|---|---|
| 1. | Steam engine | Laws of thermodynamics |
| 2. | Nuclear reactor | Controlled nuclear fission |
| 3. | Radio and Television | Generation, propagation and detection of electromagnetic waves |
| 4. | Computers | Digital logic |
| 5. | Lasers | Light amplification by stimulated emission of radiation |
| 6. | Production of ultra high magnetic fields | Superconductivity |
| 7. | Rocket propulsion | Newton's laws of motion |
| 8. | Electric generator | Faraday's laws of electromagnetic induction |
| 9. | Hydroelectric power | Conversion of gravitational potential energy into electrical energy |
| 10. | Aeroplane | Bernoulli's principle in fluid dynamics |
| 11. | Particle accelerators | Motion of charged particles in electromagnetic fields |
| 12. | Sonar | Reflection of ultrasonic waves |
| 13. | Optical fibres | Total internal reflection of light |
| 14. | Non-reflecting coatings | Thin film optical interference |
| 15. | Electron microscope | Wave nature of electrons |
| 16. | Photocell | Photoelectric effect |
| 17. | Fusion test reactor (Tokamak) | Magnetic confinement of plasma |
| 18. | Giant Metrewave Radio Telescope (GMRT) | Detection of cosmic radio waves |
| 19. | Bose-Einstein condensate | Trapping and cooling of atoms by laser beams and magnetic fields. |

## Conserved Quantities

Physics gives laws to summarize the investigations and observations of the phenomena occurring in the universe.

- Physical quantities that remain constant with time are called **conserved quantities**. Example, for a body under external force, the kinetic and potential energy change over time but the total mechanical energy (kinetic + potential) remains constant.
- Conserved quantities can be scalar (Energy) or vector (Total linear momentum and total angular momentum).

## Conservation Laws

A **conservation law** is a hypothesis based on observation and experiments which cannot be proved. These can be verified via experiments.

Law of conservation of Energy

- According to the **general Law of conservation of energy**, the energies remain constant over time and convert from one form to another.
- The law of conservation of energy applies to the whole universe and it is believed that the total energy of the universe remains unchanged.
- Under identical conditions, the nature produces symmetric results at different time.

## Law of conservation of Mass

This is a principle used in analysis of chemical reactions.

- A **chemical reaction** is basically a rearrangement of atoms among different molecules.
- If the total binding energy of the reacting molecules is less than the total binding energy of the product molecules, the difference appears as heat and the reaction is **exothermic**.
- The opposite is true for energy absorbing (**endothermic**) reactions.
- ❖ Since the atoms are merely rearranged but not destroyed, the **total mass of the reactants is the same as the total mass of the products in a chemical reaction**.
- Mass is related to energy through Einstein theory,

  $\mathbf{E = mc^2}$, where c is the speed of light in vacuum

## Law of conservation of linear momentum

- Symmetry of laws of nature with respect to translation in space is termed as law of conservation of linear momentum.
- Example law of gravitation is same on earth and moon even if the acceleration due to gravity at moon is $1/6^{th}$ than that at earth.

## Law of conservation of angular momentum

- Isotropy of space (no intrinsically preferred direction in space) underlies the law of conservation of angular momentum.

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