CHAPTER

1

PHYSICAL WORLD

1.1 WHAT IS SCIENCE ?

1. *What is science ?*

Science. *It is a systematised and organised knowledge about the various natural phenomena which is obtained by careful experimentation, keen observation and accurate reasoning.* The Sanskrit word *Shastra* and Arabic word *Ilm* also have a similar meaning *i.e.*, organised knowledge.

2. *What are physical and biological sciences ?*

Two types of sciences. The knowledge of science can be divided into two broad categories :

1. ***Biological sciences.*** *The sciences which deal with the behaviour of living things are called biological sciences.* These sciences include Botany, Zoology, Orinthology, Anthropology, Entomology, Forensic Science, etc.

2. ***Physical sciences.*** The two main physical sciences are physics and chemistry. **Chemistry** *is the study of every substance, its structure, its composition and changes in which it takes part.* **Physics** *is the study of the natural world which deals with the concepts of space, time, motion, matter, energy, radiation, etc.* Other physical sciences include Geology, Geography, Astronomy, Astrology, Oceanology, etc.

1.2 SCIENTIFIC ATTITUDE AND SCIENTIFIC METHOD

3. *What is scientific attitude ?*

Scientific attitude. The tremendous growth of science has taken place only due to the use of scientific attitude and scientific method. *The scientific attitude requires a flexible, open-minded approach towards solving problems in which other important points of view are not neglected without any reason.* First a solution is suggested for a problem. This solution is tried. If it works satisfactorily, it is adopted and otherwise it is replaced by a better solution to the same problem.

4. *What is scientific method ? Mention the various steps involved in it.*

Scientific method. *The step by step approach used by a scientist in studying natural phenomena and establishing laws which govern these phenomena is called scientific method.*

Generally, it involves the following steps :

1. Taking a large number of systematic *observations* by doing *controlled experiments.*
2. Studying these observations and making *qualitative* and *quantitative reasoning.*
3. Suggesting *mathematical models* to account for the observed behaviour.
4. *Predicting new phenomena* on the basis of suggested model.
5. Modifying the theory, if necessary, in the light of the fresh evidences.

1.3 SCIENTIFIC THEORY

5. *What is scientific theory ?*

Scientific theory. *Theory is the name given to a set of limited number of laws in terms of which the behaviour of a physical system can be explained.* A good theory should not only explain the already existing phenomenon but it should be able to predict and explain the new phenomenon.

6. *When does a scientific theory need modification or replacement by a new theory ? Briefly explain giving suitable examples.*

Need for modification of a scientific theory. In science, no theory is final. A theory must be able to explain what may be observed from time to time. Following two types of problems may arise :

1. When any new observation shows some deviation from the existing theory, the theory has to be duly modified. For example, when Johann Kepler examined the extensive data on planetary motion collected by Tycho Brahe, the planetary circular orbits in heliocentric theory (sun at the centre of the solar system) imagined by Nicholas Coperanicus had to be replaced by elliptical orbits to fit the data better.

2. When even the modification of a theory fails to account for the new observations, the theory has to be replaced by a new theory. For example, it was realised in the beginning of twentieth century that Newtonian mechanics could not explain some basic features of atomic phenomena. Also, the wave theory of light failed to explain photoelectric effect. This resulted in the development of an entirely new theory, called Quantum Mechanics, to deal with microscopic phenomena.

7. *Theory and experiments go hand in hand in physics and help each other's progress. Give two suitable examples in support of your answer.*

Or

With the help of suitable examples, briefly explain the interplay between theoretical models and experiments.

Interplay between theoretical models and experiments. The interplay of theory and experiment (or observation) is important for the progress of science.

This is obvious from the following examples :

1. Sometimes a new experiment suggests an alternative theoretical model. For example, alpha particle scattering experiments in 1911 by Ernest Rutherford established the nuclear model of the atom, which then became the basis of quantum theory of hydrogen atom given by Niels Bohr in 1913.
2. Sometimes a theoretical advancement predicts a new experiment. For example, the concept of antiparticle was introduced theoretically by Paul Dirac in 1930 and was confirmed two years later by the experimental discovery of positron (anti-electron) by Carl Anderson.

1.4 WHAT IS PHYSICS ?

8. *What is physics ? What is the origin of the word physics ? What is its Sanskrit equivalent ?*

Physics. The word physics originates from a Greek word which means nature. This word was introduced by ancient scientist *Aristotle* in the year 350 B.C. The Sanskrit equivalent of physics is *bhauitaka* which refers to the physical world.

Physics is the branch of science that deals with the study of basic laws of nature and their manifestation in various natural phenomena. It is concerned with the interaction of matter with matter or energy. It deals with the various features of the natural world such as space, time, matter, motion, energy, radiation, etc. Physics is the most fundamental of all sciences as it is concerned with the study of various natural phenomena.

1.5 TWO BASIC QUESTS IN PHYSICS

9. *What are the two principal thrusts in physics ? Give suitable examples for each.*

Two basic quests in physics. The two principal thrusts in physics are *unification* and *reductionism.*

1. ***Unification.*** In physics, attempt is made to explain various physical phenomena in terms of just few concepts and laws. We try to see the physical world as manifestation of some universal laws. For example, the same (Newton's) law of gravitation can be used to describe the motion of a body falling towards the earth, motion of the moon around the earth and motion of planets around the sun. Attempts are being made to unify fundamental forces of nature in the persuit of *unification.*

2. ***Reductionism.*** Another attempt made in physics is to explain a macroscopic system in terms of its microscopic constituents. This persuit is called *reductionism.* For example, thermodynamics was developed to explain the macroscopic properties such temperature, internal energy, entropy, etc., of the bulk systems. Later on, these properties were explained in terms of molecules in kinetic theory and statistical mechanics.

1.6 SCOPE OF PHYSICS

Introduction. The scope of physics is very wide. Every event, which occurs around us in our daily life, is governed by one or the other principle of physics.

One way of getting the idea of the scope of physics is to look at its various sub-disciplines. Another way is look at the vast range of magnitude of the physical quantities it deals with.

10. *Briefly explain the main disciplines and sub-disciplines in physics.*

Branches of physics. Physics has two main domains of study—macroscopic and microscopic. **Classical physics** *deals with macroscopic phenomena* which may be at the laboratory, terrestrial and astronomical scales. It includes branches like mechanics, optics, thermodynamics and electrodynamics. **Quantum mechanics** *deals with microscopic phenomena* at the minute scales of atoms, molecules and nuclei.

Main sub-disciplines in physics :

1. ***Mechanics.*** *It deals with the equilibrium or motion of material bodies at low speeds.* It is based on laws of gravitation. The propulsion of rocket, equilibrium of rod bent under a load, propagation of water waves or sound waves in air, etc., are studied in mechanics.

2. ***Optics.*** *It deals with the nature and propagation of light.* It deals with the formation of images by mirrors and lenses, colours in thin films, etc.

3. ***Thermodynamics.*** *It deals with a macroscopic system in equilibrium* and is concerned with the changes in internal energy, temperature, entropy, etc., of the system through external work and heat. Here we study the efficiency of heat engines and refrigerators.

4. ***Electrodynamics.*** *It deals with electric and magnetic phenomena associated with charged and magnetic bodies.* It is based on laws given by Coulomb, Oersted, Ampere and Faraday, which were later on unified by Maxwell. It deals with problems like motion of current-carrying conductor in a magnetic field, propagation of radiowaves through the atmosphere, etc.

5. ***Quantum mechanics.*** *It deals with the mechanical behaviour of sub-microscopic particles* like atoms and nuclei and their interaction with projectiles like electrons, photons and other elementary particles.

6. ***Relativity.*** *It is theory of invariance in nature.* It deals with the motion of the particles having speeds comparable to the speed of light.

For Your Knowledge

- An exciting field of research these days is a new domain, called **mesoscopic physics**, which is intermediate between the microscopic and macroscopic domains and deals with a few tens or hundreds of atoms.

11. *The scope of physics is truly vast. Elaborate.*

The scope of physics is truly vast. We can see in another way that the scope of physics is truly vast. It covers wide ranges of mass, length, time, energy, etc. The mass of an object can vary from 10^{-30} kg (mass of an electron) to 10^{55} kg (mass of the universe). The length of an object can vary from 10^{-14} m (size of a nucleus) to 10^{26} m (size of the universe). Time interval can vary from 10^{-22} s (time taken by light to cross a nuclear distance) to 10^{18} s (life of the sun). The everyday phenomena lie in the middle ranges.

For Your Knowledge

- The scope of physics (or science in general) is very wide. It has been quite aptly described by some scientists as follows :
  - *Science is a method for describing, creating and understanding human experience.* **R. Bruce Lindsay**
  - *Science is the ever unfinished quest to discover all facts, the relationship between things and the laws by which the world runs.* **Gerold Holton**
  - *The two processes that of Science and Art are not very different. Both Science and Art, formed in the course of centuries a human language by which we can speak about the more real part of reality.* **Heisenberg**
  - *The task of science is both to extend the range of our experience and to reduce it to order.* **Niels Bohr**
  - *The most incomprehensible thing about the world is that it is comprehensible.* **Albert Einstein**
  - *Nature is pleased with simplicity and effects, not the pump of superfluous causes.* **Isaac Newton**
  - *We know very little and yet it is astonishing that we know so much and still more astonishing that so little knowledge can give us so much power.* **Bertrand Russel**

1.7 EXCITEMENT OF PHYSICS

12. *Physics is a science of excitement. How ?*

Excitement of physics. The study of physics is not only educative but also exciting in many ways as follows :

1. Inspite of the wide range and complexity of the physical phenomena, it is quite exciting that these phenomena can be analysed and understood in terms of few universal laws and principles.
2. Some other people get excitement in carrying out new challenging experiments to unfold the mysteries of nature and in verifying or falsifying the existing theories.
3. Applied physicists get great satisfaction when they develop technologies for the welfare of the human beings just by using basic laws of physics.

13. *What are the reasons behind the large scale progress of physics in the last few centuries ?*

Reasons behind the phenomenal growth of physics in the last few centuries :

1. Precise and accurate measurements are central to the growth of physics because most of laws of nature can be expressed in mathematical forms.
2. The basic laws of physics are universal. The same laws can be applied in widely different domains and conditions.
3. Because of ability of the scientists to separate the important and essential features from the less important ones, it is easier to understand even a highly complex phenomenon.

1.8 PHYSICS IN RELATION TO OTHER SCIENCES

14. *How is the study of physics useful to the study of other sciences ?*

Physics in relation to other sciences. Physics is the most fundamental discipline of all sciences. It has played a key role in the development of all other sciences.

1. ***Physics in relation to mathematics.*** Physics is a quantitative science. Mathematics provides the necessary signs and tools which the physicists use. It has played an important role in the development of theoretical physics. Had Newton not invented calculus, he would not have been able to discover the universal law of gravitation.

2. ***Physics in relation to chemistry.*** In physics, we study the structure of atom, radioactivity, X-ray diffraction, etc. Such studies have enabled chemists to arrange elements in the periodic table on the basis of their atomic numbers. This has further helped to know the nature of valency and chemical bonding and to understand the complex chemical structures.

3. ***Physics in relation to biological sciences.*** The developments in life sciences owe a great deal to physics. (*i*) Optical microscopes are extensively used in the study of biology. (*ii*) With the help of an electron microscope, one can study the structure of cell. (*iii*) The X-rays and neutron diffraction techniques have helped in understanding the structure of nucleic acids, which helped to control vital life processes. (*iv*) Radioisotopes are used in radiation therapy for the cure of deadly diseases like cancer.

4. ***Physics in relation to Astronomy.*** (*i*) Astronomical telescopes are used to study the motion of planets and other heavenly bodies in the sky. (*ii*) Radiotelescopes have helped to discover quasers, pulsars, etc., and can be used to see upto the farthest limits of the universe. (*iii*) Dopler's effect predicted the big-bang theory of the universe.

5. ***Physics in relation to geology.*** Diffraction techniques help to study the crystal structure of various rocks. Radioactivity is used to estimate the age of rocks and fossils.

6. ***Physics in relation to seismology.*** The movement of the earth crust and types of waves so generated help a lot in the study of earthquake and its effect.

7. ***Physics in relation to meteorology.*** By studying variation of pressure with temperature, we can forecast weather.

1.9 PHYSICS IN RELATION TO SOCIETY

15. *The fate of a society is linked to the developments in physics. Explain.*

Physics in relation to society. The fate of a society is closely linked to physics. Whatever is discovered in physics, it immediately affects the society.

For example :

1. The developments of telephone, telegraph, telex enable us to quickly exchange messages between far off places.
2. The discoveries of radio and television have made possible the instantaneous communication with other parts of the world.
3. The launching of satellites into space has revolutionised the concept of communication.
4. The development of alternative sources of energy is of great importance to the mankind.
5. Microelectronics, lasers, computers, superconductivity and nuclear energy have entirely changed the thinking and the living style of the human beings.

The modern science in general and physics in particular has the potentiality to eradicate poverty and hunger from the surface of the earth and to usher in an age of prosperity. On the other hand, a wrong use of discoveries of physics may bring about a disaster. The knowledge of physics can be applied alike, to the creation of heaven on the earth or to the total annihilation. Our wiseness lies in applying physics to solve the pressing problems the society faces and not to annihilate it.

Table 1.1 *Some great physicists and their discoveries*

S. No.	Name of Scientist	Country	Discovery
1.	Abdus Salam	America (Pakistan born)	Unification of weak and electromagnetic interactions
2.	Alfred Noble	Sweden	Dynamite
3.	Anderson C.D.	America	Positron
4.	Antony Hewert	England	Pulsars
5.	Appleton, E.	England	Exploration of ionosphere
6.	Ampere	France	Magnetism is due to electric current
7.	Archimedes	Greece	Principle of buoyancy, Principle of the lever
8.	Bardeen, John	America	Transistor, superconductivity
9.	Bequerrel, Henry A.	France	Discovery of spontaneous radioactivity
10.	Bhabha, Homi Jehangir	India	Cosmic ray showers
11.	Bose J.C.	India	Ultrashort radiowaves
12.	Bose, S.N.	India	Bose-Einstein statistics
13.	Bohr, Niels	Denmark	Quantum model of hydrogen atom
14.	Bragg, W.H.	England	Crystal structure by X-rays
15.	Bragg, W.L.	England	Crystal structure by X-rays
16.	Barkla, Charles G.	England	Number of electrons in an atom
17.	Cavendish	England	Experimental determination of 'G'
18.	Cerenkov, P.A.	Russia	Cerenkov radiations
19.	Chadwick, James	England	Neutron
20.	Compton, A.H.	America	Compton effect
21.	Coulomb, Charles A. de	France	Coulomb's law
22.	Curie, Marie Sklodowaska	Poland	Studies on natural radioactivity, Discovery of radium and polonium
23.	de-Broglie, Louis Victor	France	Wave nature of matter
24.	Dirac, Paul	England	Relativistic theory of electron, Quantum statics
25.	Einstein, Albert	Germany	Theory of relativity, mass-energy equivalence, photoelectric effect
26.	Edison, A.	America	Electric bulb, telegraphy
27.	Faraday, Michael	England	Laws of electromagnetic induction, laws of electrolysis, designed electric motor
28.	Fermi, Enrico	Italy	Controlled nuclear fission
29.	Gabor, D.	America	Holography
30.	Galileo, Galilei	Italy	Law of inertia
31.	Grahm Bel	America	Telephone
32.	Hertz, Heinrich Rudolf	Germany	Electromagnetic waves
33.	Hess, V.F.	Austria	Cosmic rays
34.	Huygens, Christiaan	Holland	Wave theory of light
35.	Hubble, Edwin	America	Expanding universe
36.	Heisenberg, Wernes	Germany	Uncertainty principle, Quantum mechanics
37.	Kamerling Onnes	Dutch	Low temperature and liquid helium
38.	Kelvin (William Thomson)	England	Second law of thermodynamics, thermodynamic scale of temperature
39.	Landau, Lev Davidovich	Russia	Theory of condensed matter, Liquid helium
40.	Lawrence, E.O.	America	Cyclotron
41.	Lippman, G.	France	Colour photography
42.	Maxwell, James Cleric	England	Electromagnetic theory, Light as an electromagnetic wave
43.	Michelson, A.A.	America	Precision optical instruments
44.	Marconi	Italy	Wireless telegraphy
45.	Millikan, R.A.	America	Measurement of charge on an electron
46.	Newton, Isaac	England	Law of gravitation, Laws of motion, Reflecting telescope

S. No.	Name of Scientist	Country	Discovery
47.	Oersted	France	Magnetic effect of current
48.	Planck, Max	Germany	Quantum theory of radiation
49.	Pauli, W.	America	Exclusion principle for filling electrons in orbitals
50.	Raman, C.V.	India	Inelastic scattering of light (Raman effect)
51.	Ramachandran, G.N.	India	Triple helical structure of proteins molecules
52.	Robert Boyle	England	Boyle's law
53.	Robert Hooke	England	Elasticity of solids, balance wheel of a watch
54.	Rutherford, Ernest	England	Nuclear model of atom
55.	Roentgen, W.K.	Germany	X-rays
56.	S. Chandershekhar	America (India born)	Structure and evolution of stars, Chandrashekhar limit
57.	Schrödinger, E.	Germany	Wave mechanics
58.	Saha, M.N.	India	Thermal ionisation
59.	Thomson, J.J.	England	Electron
60.	Thomson, G.P.	England	Diffraction of electrons by crystals
61.	Townes, C.H.	America	Maser, Laser
62.	Van der Walls, J.D.	Dutch	Expansion of gases and liquids
63.	Von Laue, Max	Germany	Diffraction of X-rays in crystals
64.	Volta	Italy	Discovered first battery
65.	Wein, W.	Germany	Laws of radiation of heat
66.	Watt, James	England	Steam Engine
67.	Yukawa, Hedeki	Japan	Meson theory of nuclear forces

1.10 ▼ PHYSICS IN RELATION TO TECHNOLOGY

16. ***Technological advancements owe a great deal to the developments in physics. Briefly explain.***

Physics in relation to technology. The applications of physics have played a key role in the development of technology. Today we see the applications of physics in every walk of life. Some of the major technologies based on the applications of physics are as follows :

1. Electromagnetic waves are used in radio, television, radar and wireless communication.
2. Newton's concept of gravitation is used in geostationary satellites which help us in forecasting weather and in geophysical survey.
3. X-rays are used in radiotherapy, in detecting fractures or dislocations in bones, in studying crystal systems, in engineering and industry.
4. The study of thermodynamics has helped to design heat engines which have revolutionised the industry.
5. The study of electricity has led to the development of electric appliances like electric motors and generators which are the backbones of industry.
6. Nuclear power stations based on nuclear fission constitute one of the major sources of energy.
7. The concepts of modern electronics find extensive use in telephone exchanges, robots, etc.
8. The discovery of silicon chips has brought a revolution in computer industry.
9. Geothermal energy, *i.e.*, the heat in the depth of the earth is being used these days. The tidal energy in the oceans and solar energy too can be converted into other forms of energy and used.
10. Radioactive isotopes are now being widely used in medicine, agriculture and industry.

These technologies have made our lives comfortable and materially prosperous.

Sometimes physics generates new technology. At other times technology gives rise to new physics. Both have a direct impact on society.

Table 1.2 Some important technologies and their links with 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
Wireless telegraphy	Propagation of electromagnetic waves
Computers	Digital logic of electronic circuits
Lasers	Light amplification by stimulated emission of radiation (population inversion)
Production of ultra high magnetic fields	Superconductivity
Rocket propulsion	Newton's laws of motion

Technology	*Scientific Principle(s)*
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 accelerator / Cyclotron	Motion of charged particles in electromagnetic fields
Sonar	Reflection of ultrasonic waves
Optical fibres	Total internal reflection of light
Non-reflecting coatings	Thin film optical interference
Electron 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

1.11 ▼ FUNDAMENTAL FORCES IN NATURE

17. *Name the four basic forces in nature. Arrange them in the order of their increasing strengths.*

Fundamental forces in nature. In the macroscopic world, we observe several kinds of forces : muscular force, contact forces of support and friction, forces exerted by springs and strings, viscous forces, electric forces, magnetic forces, etc. All these forces between macroscopic objects arise from *two* fundamental forces :

1. Gravitational force 2. Electromagnetic force

In the microscopic world, in addition to the above two forces, two more basic forces are required to account for the various atomic and nuclear processes. These are

1. Strong nuclear force 2. Weak nuclear force

The ratio of the strength of the four fundamental forces in nature is

$$F_G : F_W : F_E : F_S = 1 : 10^{25} : 10^{36} : 10^{38}$$

1.12 ▼ THE GRAVITATIONAL FORCE

18. *What is gravitational force ? Mention its important properties. Give some examples of gravitational force.*

Gravitational force. *It is the force of mutual attraction between two bodies by virtue of their masses.* It is a universal force. Every body attracts every other body of the universe with this force. According to Newton's law of gravitation, the gravitational attraction between two bodies of masses m_1 and m_2 and separated by distance r is given by

$$F = G\frac{m_1 m_2}{r^2}$$

where G is the universal gravitational constant.

Important properties of gravitational force :

1. It is a *universal attractive* force.
2. It is directly proportional to the product of the masses of the two bodies.
3. It obeys *inverse square law.*
4. It is a *long range force* and does not need any intervening medium for its operation.
5. Gravitational force between two bodies does not depend upon the presence of other bodies.
6. It is the *weakest force* known in nature.
7. It is a *central force* (*i.e.,* it acts along the line joining the centres of the two bodies).
8. It is a *conservative force* (*i.e.,* work done in moving a body against the gravitational force is path independent).
9. Gravitational force between two bodies is thought to be caused by an exchange of a particle called *graviton.*

Examples of gravitational force :

1. All bodies fall because of the gravitational force of attraction exerted on them by the earth.
2. Gravitational force governs the motion of the moon and the artificial satellites around the earth ; and the motion of the planets around the sun.
3. Gravitation plays a key role in the formation and evolution of stars, galaxies and galactic clusters.

1.13 ▼ THE ELECTROMAGNETIC FORCE

19. *What is electromagnetic force ? Mention its important properties. Give some examples of the electromagnetic force.*

Electromagnetic force. *The force acting between two electric charges at rest is called electrostatic force.* According to *Coulomb's law,* the magnitude of the electrostatic force F between two point charges q_1 and q_2 separated by distance r in vacuum is given by

$$F = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q_1 q_2}{r^2}$$

where ε_0 is the permittivity of vacuum. *The force acting between two magnetic poles is called magnetic force.* In fact, electrostatic and magnetic forces are closely interrelated. For example, a moving charge produces a

magnetic field. Also, a magnetic field exerts a force on a moving charge. This force depends both on the magnitude and direction of the velocity of the electric charge. Thus the electrostatic and magnetic forces are inseparable and are considered as the two facets of a general force known as *electromagnetic force.*

Important properties of electromagnetic force :

1. Electromagnetic force may be *attractive or repulsive.* Like charges repel each other and unlike charges attract each other.
2. It obeys *inverse square law.*
3. It is a *long range force* and does not require any intervening medium for its operation.
4. It is a *central force.*
5. It is a *conservative force.*
6. It is 10^{36} times stronger than the gravitational force.
7. It is caused by the exchange of *photons* (γ) between two charged particles.

Examples of electromagnetic force :

1. When a spring is compressed/elongated, it exerts a force of elasticity due to the net repulsion / attraction between its neighbouring atoms. This net repulsion or attraction is the sum of the electrostatic forces between the electrons and nuclei of the atoms.
2. The Van der Walls' force between two neutral molecules of a gas is net sum of the electrostatic forces between the electrons and nuclei of the two molecules.

1.14 ▼ ELECTROMAGNETIC NATURE OF SOME MACROSCOPIC FORCES

Introduction. The macroscopic forces of our daily life such as tension, friction, contact force, spring force, etc., are derived from the fundamental electrostatic force only. All matter consists of charged particles like electrons and protons. The strong electromagnetic force between these particles is responsible for the structure of atoms and molecules, rate of chemical reactions, and the mechanical, thermal and electrical properties of materials.

20. *Discuss the electromagnetic nature of (i) contact force between two bodies (ii) force of friction (iii) elastic force in a spring (iv) Van der Walls' force between gas molecules and (v) force in a taut string/rope.*

(*i*) **Contact force between two bodies.** When we place two bodies in contact with each other, their atoms come close to each other at the surface of contact. Large electromagnetic forces begin to act between the charged constituents of these atoms. Generally, these forces act normal to the surface of contact and are of pushing or repelling nature. For example, a book lying on a table pushes it downwards while the table pushes the book upwards.

(*ii*) **Force of friction.** Sometimes, the electromagnetic contact force between two bodies may have a component acting parallel to the surface of contact. This component is called friction. When bodies are placed with their smooth surfaces in contact, they provide only a small parallel component of contact force and hence friction between them is negligibly small. For example, when we climb up a tree, its rough trunk provides sufficient frictional force parallel to the surface of the tree which helps us cling on to the trunk. It is difficult to climb up a smooth metallic lamp post because it does not provide enough parallel frictional force.

(*iii*) **Elastic force in a spring.** When a spring is elongated (or compressed), it exerts a force of elasticity which arises due to the net attraction (or repulsion) between the neighbouring atoms of the spring. This net attraction (or repulsion) is the (unbalanced) sum of the electrostatic forces between the electrons and nuclei of these atoms.

(*iv*) **Van der Walls' force.** The Van der Walls' force between two neutral molecules of a gas is not a fundamental force but a derived force. It is the net residual force obtained by summing up the fundamental electrostatic forces between the various electrons and nuclei of the two molecules.

(*v*) **Force in a taut string/rope.** Consider a block tied to the lower end of a string suspended from a rigid support. The string is in a state of tension. The electrons and protons of the lower end of the string exert electrostatic forces on the electrons and protons of the block. The resultant of these forces balances the weight of the block. Generally, a string under tension exerts an electromagnetic force of pulling nature on the two bodies attached to its two ends.

21. *Electromagnetic force is enormously stronger than the gravitational force. Give an example from daily life to illustrate it.*

Electromagnetic force is much stronger than the gravitational force. When we hold a book in our hand, the earth exerts a very large gravitational force on the book due to its huge mass. This force is balanced by the normal force exerted by our hand. But the latter force is the net electromagnetic force between the charged constituents of our hand and the book at the surface of contact. Clearly, electromagnetic force is much stronger than the gravitational force.

22. *Although gravitational force is incomparably weaker than the electromagnetic force, yet it governs the large scale motion both on terrestrial and astronomical scales. How ?*

Gravitational force governs the large scale motion. Mass is only of one type *i.e.*, there are no positive and negative masses. So the gravitational force is always attractive. But electric charges may be positive and negative. Consequently, the electromagnetic forces may be both attractive and repulsive. Between two neutral objects, the gravitational force goes on adding over all pairs of particles of the two objects while the electromagnetic forces being equally attractive and repulsive, add up to zero. That is why the large scale motion in the universe is controlled by the weakest gravitational force.

1.15 THE STRONG NUCLEAR FORCE

23. *What is strong nuclear force ? Mention its important properties. Give some examples of this force.*

Strong nuclear force. *The strong attractive force which binds together the protons and neutrons in a nucleus is called strong nuclear force.* This force cannot be electrostatic force because positively charged protons strongly repel each other at such small separations of the order of 10^{-15} m. Also the gravitational attraction between two protons being much weaker, cannot overcome this electrostatic repulsion. So a new attractive force must be acting between the nucleons (protons and neutrons). This strong nuclear force is strongest of all the fundamental forces, about 100 times stronger than the electromagnetic force.

Important properties of strong nuclear force :

1. It is the strongest interaction known in nature, which is about 10^{38} times stronger than the gravitational force.
2. It is a short range force that operates only over the size of the nucleus ($=10^{-15}$ m).
3. It is basically an attractive force, but becomes repulsive when the distance between the nucleons becomes less than 0.5 fermi (1 fermi $=10^{-15}$ m).
4. It varies inversely with some higher power (>2) of distance.
5. It is a non-central and non-conservative force.
6. It has charge independent character *i.e.*, nuclear forces between proton-proton, proton-neutron and neutron-neutron are almost equally strong.
7. It is caused by the exchange of particles, called Π-mesons.

Examples of nuclear force :

1. Nuclear forces bind together the protons and neutrons in the nuclei. So they are responsible for stability of nuclei and hence of the atoms and ultimately of all matter that exists in the universe.
2. Radioactivity occurs in heavier nuclei because of insufficient nuclear force between their protons and neutrons.
3. The concept of nuclear force is useful in obtaining nuclear energy via the processes of nuclear fission and fusion.

Note *Electrons do not experience the strong nuclear force.*

1.16 THE WEAK NUCLEAR FORCE

24. *What is weak nuclear force ? Explain with the help of an example. Give important properties of weak nuclear force.*

Weak nuclear force. *It is the force that appears only between elementary particles involved in a nuclear process such as the β-decay of a nucleus.* In a β-decay, the nucleus emits an electron and an uncharged particle called neutrino. The electron and neutrino interact with each other through the weak nuclear force. The weak nuclear force is much stronger than the gravitational force, but much weaker than strong nuclear and electromagnetic forces. This is obvious from the fact that the decay of an elementary particle caused by weak nuclear force (*e.g.*, the decay of a pion to a muon and a neutrino) is much slower than the decays caused by strong nuclear or electromagnetic forces.

Important properties of weak nuclear force :

1. Any process involving neutrino and antineutrino is governed by weak nuclear force beacuase these particles can experience only weak interaction and not the strong nuclear interaction.
2. Weak nuclear force is 10^{25} times stronger than the gravitational interaction.
3. It operates only through a range of nuclear size ($\approx 10^{-15}$ m).
4. The messenger particles that transmit the weak force between elementary particles are the massive vector bosons ($W^{\pm}$, Z).

For Your Knowledge

- Neutrino is an elementary particle with zero rest mass and zero charge.
- It will be more correct to say that β^- decay ejects an electron and an antineutrino while β^+ decay ejects a positron (antielectron) and a neutrino.
- **Elementary particles** are grouped as baryons, mesons, leptons. Nucleons (protons and neutrons) and their higher counterparts are called baryons. The pions, kaons, etc., are mesons. Baryons and mesons are together called hadrons which can interact through strong nuclear force. Electrons, neutrinos and their higher mass counterparts are called leptons. Leptons do not experience the strong force, only the weak force is dominant between them.

1.17 ▼ BASIC MECHANISM OF THE FUNDAMENTAL FORCES

25. *Briefly explain the mechanism that gives rise to the various fundamental forces between elementary particles. Give the names of the exchange particles for each of these forces.*

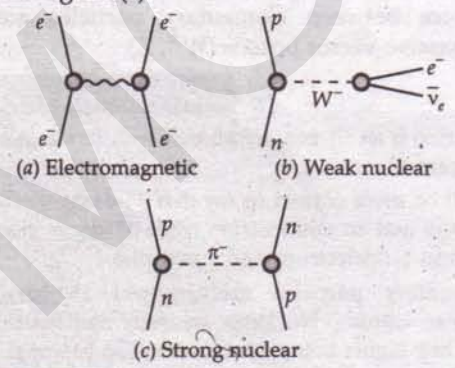
Fundamental forces arise due to exchange of particles. *Each fundamental force between two elementary particles arises from the exchange of its characteristic particles called the quanta of that force or the* **messenger particles**. To understand this mechanism, consider interaction between two persons *A* and *B*. Suppose *A* throws a ball and *B* catches it. By momentum conservation, *A* suffers a recoil when he throws the ball. Similarly, *B* suffers a recoil when he catches the ball. Also the recoil force changes the momentum of each person.

The exchange particles for various fundamental forces are as follows :

1. ***Electromagnetic force*** between two charged particles (like electrons) arises from the exchange of **photons** (γ) between them, as shown in Fig. 1.1(*a*). These photons are emitted by one electron and absorbed by the other within a very short time. As these photons cannot be detected, so they are called **virtual photons.**

2. ***Weak nuclear force*** during the β–decay of a nucleus arises from the exchange of massive particles, called **vector bosons** ($W^{\pm}$, Z) between the elementary particles. As shown in Fig. 1.1(*b*), the charge of vector boson (W^-) is exchanged in the β–decay of a neutron.

3. ***Strong nuclear force*** between two nucleons arises from the exchange of mesons between them. For example, negatively charged pior (π^-) is exchanged in the nuclear force involved in np° pn scattering, as shown in Fig. 1.1(*c*).



(*a*) Electromagnetic (*b*) Weak nuclear

(*c*) Strong nuclear

Fig. 1.1 Origin of fundamental forces due to exchange of particles.

4. ***Gravitational force*** is believed to be caused by the exchange of yet to be detected particles called **gravitons.**

Table 1.3 *Some of the important aspects of fundamental forces in nature*

Fundamental force	*Relative strength*	*Range*	*Particles on which force acts*	*Messenger particle*
Gravitational force	1	Infinite	All particles	Gravitons
Weak nuclear force	10^{25}	Very short, within nuclear size ($\approx 10^{-15}$ m)	Elementary particles	Vector bosons
Electromagnetic force	10^{36}	Infinite	Charged particles	Photons
Strong nuclear force	10^{38}	Very short, within nuclear size ($\approx 10^{-15}$ m)	Nucleons	Mesons

For Your Knowledge

▲ The strong nuclear force is not a true fundamental force. The nucleons themselves are built of subunits called quarks. The quark-quark force, which binds the nucleons together is now regarded as fundamental force. It is caused by the exchange of massless particles called *gluons*.

1.18 ▼ UNIFICATION OF FORCES

26. *What is the basic quest of modern physicists ? Mention the various significant attempts made towards the unification of forces in a chronical order.*

Basic quest of modern physicists is the unification of forces. The great advacements in physics are the result of unification of different theories and domains. Different attempts made by the distinguished physicists from time to time in persuing the goal of unification of forces are listed in Table 1.4.

Table 1.4 *Some of the milestones towards the unification of forces*

Physicist(s)	*Year*	*Achievement in unification*
Issac Newton	1687	Unified celestial and terrestrial domains by explaining both types of phenomena by applying the same laws of motion and law of gravitation.
Hans Cristian Oersted Michael Farady	1820 1830	Showed experimentally that electric and magnetic phenomena are inseparable aspects of a unified domain called electromagnetism.

Physicist(s)	Year	Achievement in unification
James Clerk Maxwell	1873	Unified electromagnetism and optics by discovering that light is an electromagnetic wave.
Albert Einstein	1905-1916	Asserted the equivalence of mass and energy and uni- fied the motions of space, time and gravitation in his theories of relativity.
Sheldon Glashow, Abdus Salam, Steven Weinberg	1979	Showed that the weak nuclear force and the electromagnetic force are different aspects of a unified electro-weak force
Carlo Rubia, Simon Vander Meer	1984	Experimentally verified the theory of electro-weak force.

1.19 ▼ CONSERVATION LAWS

27. *What are conserved quantities and conservation laws ?*

Conservation laws. *In any physical process involving the different forces, some physical quantities remain unchanged with time.* Such quantities are called **conserved quantities**. *The laws which govern the conservation of these quantities are called* **conservation laws.**

In classical physics, we usually deal with the following *four* conservation laws :

1. Law of conservation of energy.
2. Law of conservation of linear momentum.
3. Law of conservation of angular momentum.
4. Law of conservation of charge.

28. *What is an isolated system ?*

Isolated system. *Any system (assembly of particles or bodies) on which no external force acts is called an isolated system.*

1.20 ▼ LAW OF CONSERVATION OF ENERGY

29. *State the law of conservation of energy. Give some examples in which this law is obeyed.*

Law of conservation of energy. *This law states that energy can neither be created nor destroyed but it can be changed from one form to another. Equivalently, we can say that the total energy of an isolated system remains constant.*

Examples : (*i*) When a body falls freely, under gravity, its potential energy gradually changes into kinetic energy. But its total mechanical energy (kinetic energy + potential energy) remains constant at any point of its motion.

(*ii*) During the oscillation of a simple pendulum, the energy of the bob changes gradually from kinetic to potential as it moves from mean position to either extreme position. The energy changes from potential to kinetic as the bob moves from either extreme position to the mean position. At all points of its motion, total energy of the bob remains constant.

For Your Knowledge

- When a body moves under a conservative force, its total mechanical energy is conserved. In the presence of a non-conservative forces such as friction or air resistance, mechanical energy is not conserved. It changes into heat, sound, etc.
- Mechanical energy is conserved whether acceleration is constant or variable.
- Inspite of all kinds of violent phenomena occurring in the universe all the time, the total energy of the universe remains constant. In fact, universe is an example of the most ideal isolated system possible.
- According to Albert Einstein, mass and energy are interconvertible. In 1905, he established the mass-energy equivalence. The energy associated with mass m is given by
$$E = mc^2$$
where c is the speed of light in vacuum.
- As mass can be converted into energy, so in law of conservation of energy, we include mass also.

30. *State the law of conservation of linear momentum. Give some examples in which this law is obeyed.*

Law of conservation of linear momentum. *This law states if no external force acts on a system, then its linear momentum remains constant.*

Examples : (*i*) A rifle gives backward kick on firing a bullet. Before firing, both the bullet and the rifle are at rest and initial momentum of the system is zero. As soon as bullet is fired, it moves forward with a large velocity. In order to conserve momentum, the rifle moves backward with such a velocity that the final momentum of the system is zero.

(*ii*) Suppose a radioactive nucleus, initially at rest, decays spontaneously into fragments. To conserve momentum, the heavier and lighter fragments will fly in opposite directions, with the former having a proportionately smaller speed than the latter.

1.21 ▼ LAW OF CONSERVATION OF ANGULAR MOMENTUM

31. *State the law of conservation of angular momentum. Give some examples in which this law is obeyed.*

Law of conservation of angular momentum. A body rotating about an axis has a rotational inertia, called moment of inertia. Also, it is associated with a

momentum, called angular momentum. We shall prove later on that

Angular momentum (L) = Moment of inertia (I) × angular speed (ω)

The law of conservation of angular momentum states that if no external torque acts on a system, then its angular momentum remains constant.

Examples : (*i*) While revolving in its elliptical orbit, when a planet approaches the sun, its moment of inertia about the sun decreases. To conserve the angular momentum, its angular speed increases.

(*ii*) In a Tornado as the air rushes towards the centre, its moment of inertia decreases. To conserve the angular momentum, the angular speed of the air increases.

1.22 ▼ LAW OF CONSERVATION OF CHARGE

32. *State the law of conservation of charge. Give some examples in which this law is obeyed.*

Law of conservation of charge. *This law states that the total charge of an isolated system remains constant.* This implies that the electric charges can neither be created nor destroyed, only they can be transferred from one body to another.

Examples : (*i*) When a glass rod is rubbed with silk cloth, both develop charges. It is observed that the positive charge developed on the glass rod has the same magnitude as the negative charge developed on silk cloth. So total charge after rubbing is zero as before rubbing *i.e.*, electric charge is conserved.

(*ii*) Electric charge is conserved during the fission of a $^{235}_{92}U$ nucleus by a neutron.

$$^{1}_{0}n + {}^{235}_{92}U \longrightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3\,{}^{1}_{0}n + \text{Energy}$$

Total charge before fission $(0 + 92)$

= Total charge after fission $(56 + 36 + 3 \times 0)$

For Your Knowledge

- In classical physics, we deal with the four conservation laws of energy, momentum, angular momentum and charge. But in nuclear and particle physics, we also deal with the conservation of quantities like parity, baryon number, strangeness, hypercharge, etc.
- A conservation law is a hypothesis, based on observations and experiments. A conservation law cannot be proved. It can only be verified, or disproved, by experiments.
- Some conservation laws may hold for one fundamental force but not for the other. For example, *parity* is conserved by the strong and electromagnetic forces but not by the weak force. Also, *strangeness* is conserved by the strong force but not by the weak force.

1.23 ▼ RELATION BETWEEN CONSERVATION LAWS AND SYMMETRIES OF NATURE

33. *How are the conservation laws related to the symmetries of the nature ?*

Conservation laws are closely related to the symmetries of the nature. *The symmetries of space, time and other types of symmetries have played an important role in developing the modern theories of fundamental forces.*

(*i*) If we perform an experiment at a certain place today and repeat the same experiment after one year at the same place, we obtain exactly the same results. This symmetry of nature with respect to translation or displacement of time is called *homogeneity of time* and it leads to the *law of conservation of energy.*

(*ii*) Laws of nature take the same form everywhere in the universe *i.e.*, there is no preferred location in the universe. This symmetry of the laws of nature with respect to translation in space is called *homogeneity of space and gives rise to the law of conservation of linear momentum.*

(*iii*) *Isotropy of space* (*i.e.*, there is no preferred direction in space) gives rise to the law of conservation of angular momentum.

Very Short Answer Conceptual Problems

Problem 1. Why do we call physics an exact science ? *[Himachal 06C, 08]*

Solution. It is because of high precision and accuracy with which the physical quantities are measured in physics.

Problem 2. Why is physics regarded as basic science ?

Solution. Physics has played a key role in the development of physical sciences, technology, medicine and life science. So many authorities in the other fields of knowledge consider physics to be the basics of all sciences.

Problem 3. Why was science called natural philosophy in earlier days ?

Solution. This is because in earlier days, scientific knowledge was gained from the direct study of natural phenomena without any experimentation.

Problem 4. Should a scientific discovery which has nothing but dangerous consequences for mankind be made public ?

Solution. Science is the search for eternal truth. Any discovery good or bad must be made public. A discovery which appears dangerous today may prove useful to the mankind later on. However, a strong public opinion should be built up against the misuse of a dangerous discovery.

Problem 5. Is science not on speaking terms with huminities ? Comment.

Solution. No, science helps in the growth of huminities by preserving old manuscripts and articles of historical values, enriching music, etc.

Problem 6. Is physics more of a philosophy or more of a mathematical science ?

Solution. Physics is more of a philosophy than a mathematical science. In fact, understanding and appreciation of physics without a philosophical outlook is incomplete.

Problem 7. Does imagination play any role in physics ? *[Himachal 07C]*

Solution. Yes, imagination has played an important role in the development of physics. Huygen's principle, Bohr's theory, Maxwell equations, Heisenberg's uncertainty principle, etc. were the imaginations of the scientists which successfully explained the various natural phenomena.

Problem 8. What are the similarities between science and arts ?

Solution. Both science and arts are creative. Both portray realm of experience.

Problem 9. How is science different from technology ?

Solution. Science is the study of natural laws while technology is the practical application of these laws to the daily life problems.

Problem 10. The physicists think at a level far higher than a normal individual. Is it true ?

Solution. Yes, the physicists are always ahead of their times. In order to predict events much in advance, they have to think far higher than normal individual.

Problem 11. What is gravitational force ? *[Himachal 06]*

Solution. It is the force of mutual attraction between two bodies by virtue of their masses.

Problem 12. What is electromagnetic force ? *[Himachal 06]*

Solution. It is the force due to interaction between two moving charges. It is caused by exchange of photons (γ) between two charged particles.

Problem 13. What is nuclear force ? *[Himachal 06]*

Solution. It is the strongest attractive interaction which binds together the protons and neutrons in a nucleus.

Problem 14. What is weak nuclear force ?

Solution. It is the force that appears only between elementary particles involved in a nuclear process such as β-decay of a nucleus.

Short Answer Conceptual Problems

Problem 1. A theory is not scientific if it is not falsifiable. This means that if a theory is so constructed that it can accommodate any prediction or observation, it is not science. Use this strong argument (and any additional arguments you can think of) to challenge Astrology's claim to being a science.

Solution. Astrology predicts events on the basis of positions of different planets at different times. It predicts the same fate for all children born at the same time which is not found to be true. An astrologer can make any prediction unchallenged. So astrology is not based on scientific laws. It cannot be a science.

Problem 2. Distinguish between classical physics and quantum mechanics.

Solution. Classical physics mainly deals with macroscopic phenomena which may be at the laboratory, terrestrial and astronomical scales. Here the particle size $> 10^{-8}$ m and particle velocity $<< 10^{8}$ m / s. Here we need not consider strong or weak nuclear forces. Gravitational and electromagnetic forces are sufficient to explain these macroscopic phenomena. On the other hand, quantum mechanics deals with microscopic phenomena at the minute scales of atoms, molecules and nuclei. Here the strong and weak nuclear forces become dominant.

Problem 3. Discuss the relation of physics to chemistry. *[Himachal 07]*

Solution. Refer to the answer of Q. 14 on page 1.4.

Problem 4. Discuss the relation of physics with technology. *[Himachal 05, 07, 07C]*

Solution. Refer to answer of Q. 16 on page 1.6.

Problem 5. The fate of society is linked to the developments in physics. Comment. *[Himachal 06C, 07C, 08C]*

Solution. Refer to the answer of Q. 15 on page 1.4.

Problem 6. What is the role of physics in your daily life ? *[Himachal 03, 05, 08]*

Solution. Refer to the answer of Q.16 on page 1.6.

Guidelines to NCERT Exercises

1.1. *Some of the most profound statements on the nature of science have come from Albert Einstein, one of the greatest scientists of all time. What do you think did Einstein mean when he said : "The most incomprehensible thing about the world is that it is comprehensible" ?*

Ans. The physical world is highly complex. It has vast orders of magnitude in respect of mass, length and time. Even then all the physical phenomena can be explained in terms of few basic principles of physics. That is, it is possible to comprehend nature in terms of few basic laws inspite of its vast complexities. This is what Einstein meant to say.

1.2. *Every great physical theory starts as a heresy and ends as a dogma.'' Give some examples from the history of science of the validity of this incisive remark.*

Ans. Any opinion against the conventional belief is a heresy, while dogma is an established belief. The geocentric theory of Copernicus started as a heresy but it ended as dogma when his theory was explained by Tycho Brahe and Johnes Kepler later on.

1.3. *"Politics is the art of the possible''. Similarly, "Science is the art of the soluble''. Explain this beautiful aphorism on the nature and practice of science.*

Ans. In politics, everything is possible. The politicians do not follow any principle, discipline or norm. They tend to remain in power by any means, fair or foul. But a scientist observes a phenomenon carefully and patiently, collects data, analyses it and formulates principles, thus solving the mystery of nature.

1.4. *Though India has a large base in science and technology which is fast expanding, it is still a long way from realising its potential of becoming a world leader in science. Name some important factors which in your view have hindered the advancement of science in India.*

Ans. There are many factors which have hindered the advancement of science in India. Some of these are :

1. There is lack of clear cut policies at the political level. There is undue political interference and bureaucratisation in the management of science and technology.
2. Due to excessive population, our country cannot afford to expend sufficient funds on science and technology
3. Talented scientists and technologists are not encouraged to persue research work in the homeland. Instead, they prefer to migrate to developed countries where they get better salaries and research facilities.
4. There is lack of coordination between researchers and industraliasts. Industralists like to borrow technology from advanced countries rather than to use indigeneous technology.

1.5. *No physicist has ever "seen" an atom. Yet, all physicists believe in the existence of atoms. An intelligent but superstitious man advances this analogy to argue that 'ghosts' exist though no one has 'seen' one. How will you refute his argument ?*

Ans. Many phenomena which are based on the assump- tion of existence of atoms have been theoretically predicted and experimentally verified. These phenomena indirectly establish the existence of atoms. But no such phenomenon has been observed which proves the existence of ghosts or which can be explained on the assumption of ghosts.

1.6. *The shells of crabs found around a particular coastal location in Japan seem mostly to resemble the legendary face of a Samurai. Given below are two explanations of this observed fact. Which of these strikes you as a scientific explanation ?*

(*a*) *A tragic sea accident several centuries ago drowned a young Samurai. As a tribute to his bravery, nature through its inscrutable ways immortalised his face by imprinting it on the crab shells in that area.*

(*b*) *After the sea tragedy, fishermen in that area, in a gesture of honour to their dead hero, let free any crab shell caught by them which accidentally had a shape resembling the face of a Samurai. Consequently, the particular shape of the crab shell survived longer and therefore in course of time the shape was genetically propagated. This is an example of evolution by artificial selection.*

Ans. Explanation (*b*) is a scientific explanation to the fact that the shells of crabs resemble the face of Samurai.

1.7. *The industrial revolution in England and Western Europe more than two centuries ago was triggered by some key scientific and technological advances. What were these advances ?*

Ans. Some of the key advances responsible for industrial revolutions were as follows :

1. Invention of steam engine by James Watt in 1769 AD made it possible to drive machines by using steam power.
2. Invention of flying schuttle by John Key and of power-loom by Cartright brought revolution in textile industry.
3. Setting up of blast furnace helped to convert low grade iron into steel.
4. Invention of safety lamp by Humphry Davy helped work safely in mines.

1.8. *It is often said that the world is witnessing now a second industrial revolution, which will transform the society as radically as did the first. List some key contemporary areas of science and technology which are responsible for this revolution.*

Ans. The key areas of science and technology which may radically transform the present society are as follows :

1. Laser technology which is used for bloodless surgery and for effective automatic control of rockets and satellites.
2. Fabrication of superconductors near the room temperature will help to transmit electric power without any wastage of energy.
3. The extensive use of computers will increase work efficiency.
4. Biotechnology.

1.9. *Write in about 1000 words a fiction piece based on your speculation on the science and technology of the twenty-second century.*

Ans. These days, we go to distant places by means of a car or an aircraft fuelled by petrol. In the twenty-second century, we may plan for a journey to a distant star located hundreds of light years away from the earth by means of a spaceship, without taking care of any fuel needs.

The spaceship is sent into space by firing a rocket engine from a launching pad. As it enters the region of magnetic field in space, it is propelled by electricity generated due to electromagnetic induction. The current induced is fed to the electric motors via superconducting wires. This avoids wastage of electric energy in the form of heat.

Now suppose the spaceship enters a region in space where the temperature is very high. The connecting wires at once lose the superconducting properties. This may cause a panic in the spaceship as no power is available. Another spaceship containing both matter and antimatter in separate chambers may come to its rescue. Hence the spaceship may continue its journey to distant star without bothering about any fuel crisis.

1.10. *Attempt to formulate your 'moral' views on the practice of science. Imagine yourself stumbling upon a discovery, which has great academic interest but is certain to have nothing but dangerous consequences for the human society. How, if at all, will you resolve your dilemma ?*

Ans. Science is the search for eternal truth. It is the moral duty of a scientist to expose the truth. If there is any danger to the mankind from a discovery, he should try to build a public opinion against the misuse of discovery. Moveover, he should develop the means to prevent its misuse. It is equally possible that this discovery may prove to be of immense importance to the mankind later on.

1.11. *Science, like any knowledge, can be put to good or bad use, depending on the user. Given below are some of the applications of science. Formulate your views on whether the particular application is good, bad or something that cannot be so clearly categorised :*

(*a*) *Mass vaccination against small pox to curb and finally eradicate this disease from the population. (This has already been successfully done in India).*

(*b*) *Television for eradication of illiteracy and for mass communication of news and ideas.*

(*c*) *Prenatal sex determination.*

(*d*) *Computers for increase in work efficiency.*

(*e*) *Putting artificial satellites into orbits around the Earth.*

(*f*) *Development of nuclear weapons.*

(*g*) *Development of new and powerful techniques of chemical and biological warfare.*

(*h*) *Purification of water for drinking.*

(*i*) *Plastic surgery.*

(*j*) *Cloning.*

Ans.

(*a*) Good, mass vaccination protects us from this dreaded disease.

(*b*) Good, it educates, entertains and creates awareness amongst the people.

(*c*) It cannot be clearly categorised as it may be misused by people.

(*d*) Good, computers work very fast and with great accuracy.

(*e*) Good, artificial satellites are useful for studying universe, as communication means and in forecasting weather.

(*f*) Bad, nuclear weapons are weapons of mass destruction.

(*g*) Bad, these techniques are the weapons of mass destruction.

(*h*) Good, otherwise the polluted water may cause many diseases.

(*i*) Good, it helps to remove deformations in the body.

(*j*) Good.

1.12. *India has had a long and unbroken tradition of great scholarship – in mathematics, astronomy, linguistics, logic and ethics. Yet, in parallel with this, several superstitious and obscurantistic attitudes and practices flourished in our society and unfortunately continue even today – among many educated people too. How will you use your knowledge of science to develop strategies to counter these attitudes ?*

Ans. Educating the common man is the only way to get rid of superstitious and obscurantistic attitudes and practices flourished in our society. The phenomena which people attribute to evil spirits and gods should be explained scientifically through mass media such as radio, television, newspapers, cinema, etc. The school students must be explained the day to day phenomena occurring around them in an effective scientific manner.

1.13. *Though the law gives women equal status in India, many people hold unscientific views on a woman's innate nature, capacity and intelligence, and in practice give them a secondary status and role. Demolish this view using scientific arguments, and by quoting examples of great women in science and other spheres ; and persuade yourself and others that, given equal opportunity, women are on par with men.*

Ans. The development of human mind depends mainly on the nutrition content of prenatal and postnatal

diet and the environment around it. The gender factor has no role in the development of human mind. When given equal opportunities, mental development of females will be as rapid as that of males. Madam Marie Curie won the Noble prize twice in science which is a rare gesture. Mrs. Indira Gandhi and Mrs. Margret Thatcher have flourished excellently well in politics.

1.14. *"It is more important to have beauty in the equations of physics than to have them agree with experiments". The great British physicist P. A. M. Dirac held this view. Criticize this statement. Look out for some equations and results in this book which strike you as beautiful.*

Ans. Dirac was his genious best when he pronounced this statement. A physical equation must be simple and hence beautiful. It will automatically agree with the experimental results. For example, consider Einstein mass-energy relationship : $E = mc^2$

This simple equation not only governs energy generation in the sun and the other stars but it is also mainly responsible for energy generation on the earth from the processes of nuclear fission and nuclear fusion.

However, it is not always true. Although some equations of Quantum Mechanics and Theory of Relativity are highly cumbersome and difficult to understand, yet they agree with the experiments.

1.15. *Though the statement quoted above may be disputed, most physicists do have a feeling that the great laws of physics are at once simple and beautiful. Some of the notable physicists, besides Dirac, who have articulated this feeling, are : Einstein, Bohr, Heisenberg, Chandrasekhar and Feynman. You are urged to make special efforts to get access to the general books and writings by these and other great masters of physics. Their writings are truly inspiring.*

Ans. There is no doubt that the great laws of physics are at once simple and beautiful. The Einstein's mass-energy equivalence relation : $E = mc^2$ has tremendous impact on various physical phenomena and on human lives yet it is so simple. Bohr's quantum condition : $L = nh / 2\pi$ and Planck's quantum condition : $E = h\nu$ are quite simple, yet quite important laws of physics. Heisenberg's uncertainty principle : $\Delta x \cdot \Delta p \geq h / 2\pi$ is a simple law but changed the thinking of physicists drastically. These are just few examples of the beauty of physics laws which inspired the physicists and opened up new vistas in physics.

1.16. *Textbooks on science may give you a wrong impression that studying science is dry and all too serious and that scientists are absent-minded introverts who never laugh or grin. This image of science and scientists is patently false. Scientists, like any other group of humans, have their share of humorists, and many have led their lives with a great sense of fun and adventure, even as they seriously pursued their scientific work. Two great physicists of this genre are Gamow and Feynman. You will enjoy reading their books.*

Ans. True, the scientists like any other group of humans have their share of humorists, and many have led their lives with a great sense of fun and adventure inspite of pursuing their scientific work seriously. Two such great physicists were Gamow and Feynman.

Text Based Exercises

Type A : Very Short Answer Questions **1 Mark Each**

1. What is science ?
2. What is the origin of the word science ?
3. What is meant by the sanskrit word Shastra and Arbic word Ilm ?
4. What is the basic aim of science ?
5. What is the difference between physical and biological sciences ?
6. What is scientific attitude ?
7. What is a theory ?
8. What is physics ?
9. What is the origin of the word physics ?
10. What are the two basic quests in physics ?
11. Name the domain of physics that deals with phenomena intermediate between macroscopic and microscopic domains.
12. Physics has a very limited scope and is only the pastime of a few blessed ones. Is it true ?
13. State one law that holds good in all natural processes.
14. Some exciting and educative physical phenomena and experience lead to the development of a theory. Give two such examples.
15. Name two Indian born physicists who have been awarded Noble Price in physics. **[Chandigarh 02]**
16. Name the scientist who replaced circular orbits by elliptical orbits in the heliocentric theory of the sun.
17. Name the scientist who discovered X –rays.
18. Who discovered electrons ?
19. Name the scientist who first proposed the wave theory of light.
20. Name the famous scientist who discovered the law of gravitation.
21. Name the physicist who first proposed the nuclear model of the atom.
22. Who gave the quantum model of hydorgen atom ?
23. Name the scientists responsible for the development of Quantum Mechanics.

24. Name the physicist who first proposed the concept of antiparticle.
25. Which physicist first confirmed the existence of positrons experimentally ?
26. Name the physicist who first measured the charge on an electron experimentally.
27. Name the physicist associated with wave- particle duality.
28. Who first discovered neutrons ?
29. Name the scientist who received Nobel Prize twice in physics.
30. Name the physicist who first gave the exchange theory of nuclear forces.
31. Name the scientist who was first awarded two Nobel Prizes.
32. What were the important contributions of Madame Marie Curie ?
33. Who first discovered radioactivity ?
34. Who first gave theory of expanding universe ?
35. Mention some important contributions of Albert Einstein to physics.
36. Name the Indian physicist, who was first awarded the Nobel Prize.
37. What was the important discovery of C.V. Raman ?
38. What was the major contribution of Indian physicist S.N. Bose ?
39. With which field work was the famous Indian physicist H.J. Bhabha associated ?
40. Name the Indian physicist associated with the triple helical structure of proteins.
41. Mention the major areas of modern scientific research in chemical and biological sciences that are bound to affect the human society of the twenty-first century.
42. On which scientific principle does an aeroplane work ?
43. On which scientific principle calculators and computers are based ?
44. Which technology of physics has triggered the computer revolution in the last three decades of the twentieth century ?
45. What does the word LASER stand for ? On what basic principle does it work ?
46. Name the phenomenon used in the production of ultra high magnetic fields.
47. Name the philosopher who said about science "we know very little yet it is astonishing that we know so much and still astonishing that so little knowledge (of science) can give us so much power".
48. Name the four fundamental forces in nature.
49. Name the forces having the longest and shortest ranges of operation.
50. Arrange the weak-nuclear force, electromagnetic force and gravitational force in the decreasing order of the strengths.
51. Give the ratio of the strengths of the four fundamental forces in nature.
52. What is the nature of the intermolecular Van der Walls' forces ?
53. How many times is the strong nuclear force stronger than the electromagnetic force ?
54. Is strong nuclear force a true fundamental force ?
55. Which force mainly governs the structure of atoms and molecules ?
56. Which fundamental force governs the large scale motion in the universe ?
57. What is meant by charge independent character of strong nuclear force ?
58. Which class of elementary particles experiences the weak nuclear force and not the strong nuclear force ?
59. Among which type of elementary particles does the electromagnetic force act ?
60. Name the class of elementary particldes on which strong nuclear force acts.
61. Which particle initiates the electromagnetic force between two electrons ?
62. What are the exchange particles for the operation of (*i*) strong nuclear force and (*ii*) weak nuclear force ?
63. How much is the range of gravitational force ? What are the messenger particles for this force ?
64. Name the physicists who first unified the electric and magnetic phenomena.
65. Name the unified domain of weak nuclear force and electromagnetic force.
66. Name the physicists who first predicted the existence of electro-weak force.
67. What are the conserved quantities in nature ? Give two examples of such quantities.
68. State the law of conservation of momentum. From which symmetry principle is this law obtained ?
69. Which symmetry laws lead to (*i*) law of conservation of energy and (*ii*) law of conservation of angular momentum ?
70. Some conservation laws are true for one fundamental force but not for other. Give two such examples.

Answers

1. Science is a systematised knowledge about the various natural phenomena gained by the man through his careful experimentation, keen observation and accurate reasoning.
2. The word science originated from the Latin verb *scientia* which means *to know*.
3. Both of these words stand for organised knowledge.

4. The basic aim of science is to search for truth. It tends to analyse the natural phenomena occurring around us.
5. Physical sciences deal with the properties and behaviour of non-living matter while biological sciences deal with living things.
6. Scientific attitude requires a flexible open-minded approach towards solving problems in which other important points of view are not neglected.
7. Theory is the name given to a minium number of laws in terms of which the behaviour of a physical system can be explained.
8. Physics is the study of the basic laws of nature and their manifestations in various natural phenomena.
9. The word physics originates from a Greek word meaning nature.
10. (*i*) Unification and (*ii*) Reductionism.
11. Meso-scopic physics which deals with a few tens or hundreds of atoms.
12. No, physics has a very wide scope. We find application of physics in every walk of life.
13. One such law is the Newton's law of gravitation. It states that every body in the universe attracts every other body with a force which is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.
14. (*i*) The fall of an apple from a tree and motion of the moon led Newton to his famous law of gravitation.
    (*ii*) The spherical shape of the liquid drops led to the concept of surface tension.
15. (*i*) C.V. Raman & (*ii*) Subramanium Chandrasekhar.
16. Johann Kepler.
17. W.K. Roentgen.
18. J.J. Thomson.
19. Christiaan Huygens.
20. Isaac Newton.
21. Earnest Rutherford.
22. Neils Bohr in 1913.
23. Heisenberg and Schrödinger.
24. Paul Dirac in 1930.
25. Carl Anderson in 1932.
26. R.A. Millikan.
27. de Broglie.
28. James Chadwick in 1932.
29. John Bardeen.
30. Hideki Yukava of Japan.
31. Madame Marie Skladowak Curie, for physics in 1903 and for chemistry in 1911.
32. (*i*) Discoveries of radium and polonium.
    (*ii*) Studies on natural radioactivity.
33. A.H. Becquerrel in 1896.
34. Edwin Hubble of U.S.A.
35. (*i*) Mass-energy equivalence (*ii*) Photoectric effect and (*iii*) Theory of relativity.
36. C.V. Raman.
37. Inelastic scattery of light by molecules.
38. Quantum statistics (Bose-Einstein statistics).
39. Cascade process in cosmic radiation.
40. G.N. Ramchandran.
41. Genetic engineering, biotechnology, new chemical materials, etc.
42. Bernoulli's principle in fluid dynamics.
43. Digital logic of electronic circuits.
44. Technology of silicon chip.
45. The word LASER stands for light amplification by stimulated emission of radiation. It works on the principle of population inversion.
46. Superconductivity.
47. Bertrand Russel.
48. (*i*) Gravitational force (*ii*) Electromagnetic force
    (*iii*) Strong nuclear force and
    (*iv*) Weak nuclear force.
49. Gravitational force has the longest range and nuclear force has the shortest range.
50. Electromagnetic force > Weak nuclear force > Gravitational force.
51. $F_G : F_W : F_E : F_N = 1 : 10^{25} : 10^{36} : 10^{38}$.
52. Intermolecular Van der Walls' forces are electromagnetic in nature.
53. 100 times.
54. No, strong nuclear force is now thought to be a force derived from quark-quark force.
55. Electromagnetic force.
56. Gravitational force.
57. Nuclear forces between a proton and proton, a neutron and a neutron, and a proton and a neutron are nearly equally strong. This indicates that the strong nuclear force does not depend on the charge of the nucleons.
58. Leptons.
59. Electromagnetic force acts on all electrically charged particles.
60. Hadrons.
61. Photon (γ).
62. (*i*) Mesons
    (*ii*) Vector bosons.
63. The range of gravitational force is infinite. Gravitons are thought to be the exchange particles for this force.
64. Oersted and Faraday.
65. Electro-weak force.

66. Sheldon Glashow, Abdus Salam, Steven Weinberg in 1979.
67. The physical quantities that remain unchanged in a process are called conserved quantities. For example, energy, linear momentum, etc.
68. Law of conservation of linear momentum states that if no external force acts on a system then, its total linear momentum remains constant. This law follows from the homogeneity of space.
69. (*i*) Homogeneity of time leads to the law of conservation of energy.
    (*ii*) Isotropy of space leads to the law of conservation of angular momentum.
70. (*i*) Parity is conserved by the strong and electromagnetic forces but not by the weak force.
    (*ii*) Strangeness is conserved by the strong force but not by the weak force.

Type B : Short Answer Questions — 2 or 3 Marks Each

1. What is a scientific method ? Mention the various steps involved in a scientific method.
2. Mathematics is an important tool in the development of physics. Comment on this statement.
3. Mention four important discoveries of physics which have revolutionised modern chemistry.
4. Name some advancements in physics which have played an important role in the development of medical sciences.
5. Name *two* advancements made in technology on the basis of physics. **[Himachal 06C]**
6. Theory and experiments go hand in hand in physics and help each other's progress. Give two suitable examples in support of this view.
7. The scope of physics is truly vast. Comment.
8. Physics is a science of excitement. How ?
9. Give reasons for the tremendous progress in physics in the last few centuries.
10. Discuss the relation of physics with other sciences. **[Himachal 02, 04]**
11. Discuss the relation of physics with mathematics and chemistry. **[Himachal 03]**
12. What is physics ? Discuss the relation of physics with technology. **[Himachal 03, 04, 05]**
13. Discuss the scope and excitement of physics. **[Himachal 04]**
14. Explain the electromagnetic nature of the contact forces between two bodies.
15. Briefly discuss the nature of the force of friction.
16. Explain how does the elastic force in a spring arise.
17. Briefly explain the origin of Van der Walls' force between two neutral molecules.
18. Taking a suitable example from daily life, show that electromagnetic force is enormously stronger than the gravitational force.
19. Although gravitational force is the weakest of the four fundamental forces, yet it governs the large scale motion in the universe. Explain how.
20. What is a strong nuclear force ? Give its important properties. Give an example of nuclear force.
21. What is a weak nuclear force ? Give its important properties. Give an example of a weak nuclear force.
22. Name the *four* fundamental forces in nature. Out of the four which one is (*a*) strongest, and (*b*) weakest ? **[Delhi 03]**
23. Write the names of the *four* fundamental forces in nature. Give any *two* main characteristics of each type. **[Delhi 03C]**
24. How do we classify elementary particles as baryons, mesons and leptons ? Amongst which of these particles is the strong nuclear force dominant and amongst which is the weak nuclear force dominant ?
25. State the law of conservation of energy. Give a suitable example for it.
26. State the law of conservation of linear momentum. Give an example for it.
27. State the law of conservation of angular momentum. Give an example for it.
28. Explain the law of conservation of charge with the help of a suitable example.
29. How are the conservation laws related with the symmetries of nature ?
30. Match the scientist's name against discovery :

A. Scientist	B. Discovery
1. Faraday	1. Law of gravitation
2. Rutherford	2. Quantum model of hydrogen atom
3. Chadwick	3. Unification of light and electromagnetism
4. Bohr	4. Theory of Relativity
5. Newton	5. Inelastic scattering of light by molecules
6. Maxwell	6. Unification of weak and strong electromagnetic interaction
7. Salam	7. Law of electromagnetic induction
8. Einstein	8. Expansion of the Universe
9. Raman	9. Neutron
10. Hubble	10. Nuclear model of the atom

31. Match the scientist in column A against the country of origin in column B :

	A. Scientist	B. Country of origin
1.	Michelson	1. Denmark
2.	Newton	2. U.S.A.
3.	Landau	3. Italy
4.	Bhabha	4. France
5.	Bohr	5. India
6.	Archimedes	6. Germany
7.	Galileo	7. U.S.S.R.
8.	Curie	8. Britain
9.	Heisenberg	9. Japan
10.	Yukawa	10. Greece

32. Match the technology in column A to its related scientific principle(s) in column B :

	A. Technology	B. Scientific principle(s)
1.	Steam engine	1. Propagation of electromagnetic waves
2.	Nuclear reactor	2. Newton's laws of motion
3.	Radio and T.V.	3. Superconductivity
4.	Computers	4. Role of DNA in heredity
5.	Lasers	5. Thermodynamics
6.	Production of ultra high magnetic fields	6. Faraday's law of induction
7.	Rocket propulsion	7. Conversion of gravitational potential energy into electrical energy
8.	Genetic engineering	8. Motion of charged particles in electromagnetic fields
9.	Electric generator	9. Fission of uranium by slow neutrons
10.	Hydroelectric power	10. Amplification by population inversion
11.	Aeroplane	11. Digital logic of electronic circuits
12.	Particle accelerators	12. Bernoulli's principle in fluid dynamics

Answers

1. Refer answer to Q. 4 on page 1.1.

2. Refer answer to Q. 14 on page 1.4.

3. (*i*) X-ray diffraction techniques (*ii*) Study of radioactivity (*iii*) Discovery of isotopes by mass spectrographs (*iv*) Nuclear magnetic resonance.

4. (*i*) Electron microscope in studying structure of a cell.

(*ii*) X-ray and neutron diffraction techniques in studying the structure of nucleic acids.

(*iii*) Radioisotopes in radiation therapy for curing skin cancer.

(*iv*) Ultrasonics in diagonosing the human body.

5. Refer answer to Q. 16 on page 1.6.

6. (*i*) The alpha scattering experiments of Rutherford gave the nuclear model of the atom.

(*ii*) Dirac's theoretical work introduced the concept of antiparticle, which was later confirmed experimentally by Anderson's discovery of positron.

7. Refer answer to Q. 11 on page 1.3.

8. Refer answer to Q. 12 on page 1.3.

9. Refer answer to Q. 13 on page 1.4.

10. Refer answer to Q. 14 on page 1.4.

11. Refer answer to Q. 14 on page 1.4.

12. Refer answer to Q. 16 on page 1.6.

13. Refer answer to Q. 11 & Q. 12 on page 1.3.

14. Refer answer to Q. 20(*i*) on page 1.8.

15. Refer answer to Q. 20(*ii*) on page 1.8.

16. Refer answer to Q. 20(*iii*) on page 1.8.

17. Refer answer to Q. 20(*iv*) on page 1.8.

18. Refer answer to Q. 21 on page 1.8.

19. Refer answer to Q. 22 on page 1.8.

20. Refer answer to Q. 23 on page 1.9.

21. Refer answer to Q. 24 on page 1.9.

22. Refer answer to Q. 17 on page 1.7.

23. Refer answer to Q. 18 and Q. 19 on page 1.7 and Q. 23 and Q. 24 on page 1.9.

24. Refer to 'For your knowledge' box on page 1.9.

25. Refer answer to Q. 29 on page 1.11.

26. Refer answer to Q. 30 on page 1.11.

27. Refer answer to Q. 31 on page 1.12.

28. Refer answer to Q. 32 on page 1.12.

29. Refer answer to Q. 33 on page 1.12.

30. (1 – 7) ; (2 – 10) ; (3 – 9) ; (4 – 2) ; (5 – 1) ; (6 – 3) ; (7 – 6) ; (8 – 4) ; (9 – 5) ; (10 – 8).

31. (1 – 2) ; (2 – 8) ; (3 – 7) ; (4 – 5) ; (5 – 1) ; (6 – 10) ; (7 – 3) ; (8 – 4) ; (9 – 6) ; (10 – 9).

32. (1 – 5) ; (2 – 9) ; (3 – 1) ; (4 – 11) ; (5 – 10) ; (6 – 3) ; (7 – 2) ; (8 – 4) ; (9 – 6) ; (10 – 7) ; (11 – 12) ; (12 – 8).

Competition Section

Physical World

GLIMPSES

1. **Science.** Science is the systematised and organised knowledge about the various natural phenomena which is obtained by careful experimentation, keen observation, and accurate reasoning. It has *two* main branches, (*a*) physical sciences, (*b*) biological sciences.
   (*i*) **Physical sciences.** These sciences deal with the properties and behaviour of non-living things.
   (*i*) **Biological sciences.** These sciences deal with the behaviour of living things.
2. **Physics.** The word physics comes from a Greek word which means nature. Physics is the study of the natural laws and their manifestation in the natural phenomena. It deals with the concepts of space, time, motion, matter, energy, radiation, etc.
3. **Chemistry.** Chemistry is the study of every substance, its structure, its composition and changes in which it takes part.
4. **Scientific attitude.** Scientific attitude requires a flexible, open-minded approach towards solving problems in which other important points of view are not neglected.
5. **Scientific method.** The step by step approach used by a scientist in studying natural phenomena and establishing laws which govern these phenomena, is called scientific method. It involves the steps like (*i*) experimentation and observation, (*ii*) formation of hypothesis, (*iii*) verification of hypothesis and (*iv*) theoretical predictions.
6. **Scientific theory.** Theory is the name given to a set of a limited number of laws in terms of which the behaviour of a physical system can be explained.
7. **Physics is an exact science.** It is because of high precision and accuracy obtainable in the measurement of physical quantities.
8. **Physics is a basic science.** Because of its important role played in the development of life science, medicine, technology and industry, physics is considered as the most basic of all sciences.
9. **Physics and mathematics.** Mathematics has proved to be the most important tool in the development of physics.
10. **Mechanics.** It deals with the slow motion or equilibrium of material bodies.
11. **Optics.** It deals with the nature and propagation of light.
12. **Thermodynamics.** It deals with the change in internal energy, temperature, entropy etc., of the macroscopic systems through external work and heat.
13. **Electrodynamics.** It deals with electric and magnetic phenomena associated with charged and magnetic bodies.
14. **Quantum mechanics.** It deals with the mechanical behaviour of atoms, molecules and nuclei.
15. **Relativity.** It deals with the particles having speeds comparable to the speed of light. It is the theory of invariance in nature.
16. **Physics, technology and society.** Sometimes, physics generates new technology. At other times technology gives rise to new physics. Both have a direct impact on society.
17. **Scope of physics.** The scope of physics is truly vast. It covers a wide range of magnitudes of physical quantities such as mass, length, time, energy, etc.
18. **Basic quests in physics.** The *two* basic quests in modern physics are : (*i*) unification and (*ii*) reductionism. These have resulted in great advances in physics.

19. **Fundamental forces in nature.** There are four fundamental forces which govern both macroscopic and microscopic phenomena. These are : (*i*) gravitational force, (*ii*) electromagnetic force, (*iii*) strong nuclear force and (*iv*) weak nuclear force.

The relative strengths of these forces are

$$F_G : F_W : F_E : E_S = 1 : 10^{25} : 10^{36} : 10^{38}.$$

20. **Gravitational force.** It is the force of mutual attraction between two bodies by virtue of their masses. It obeys Newton's law of gravitation. It is caused by the exchange particles called *gravitons*.

21. **Electromagnetic force.** It is the force due to interaction between two moving charges. It is caused by exchange of photons (γ) between two charged particles.

22. **Strong nuclear force.** It is the strongest attractive interaction which binds together the protons and neutrons in a nucleus. Electrons do not experience this force.

23. **Weak nuclear force.** It is the force that appears only between elementary particles involved in a nuclear process such as the β–decay of a nucleus. It is caused by exchange of vector bosons.

24. **Isolated system.** Any system on which no external force acts is called isolated system. Universe is the most ideal isolated system possible.

25. **Law of conservation of energy.** It states that the total energy of an isolated system remains constant. It follows from the nature's symmetry called homogeneity of time.

26. **Law of conservation of linear momentum.** It states that if no external force acts on a system, then its total linear momentum remains constant. It follows from nature's symmetry called homogeneity of space.

27. **Law of conservation of angular momentum.** It states that if no external torque acts on a system, then its angular momentum remains constant. It follows from nature's symmetry called isotropy of space.

28. **Law of conservation of charge.** It states that the total charge of an isolated system remains constant.

Multiple Choice Questions

1. A supposition that is put forward as a probable solution to a natural phenomenon is called a

(*a*) hypothesis (*b*) theory

(*c*) law (*d*) relief.

2. A thought experiment in physics is one

(*a*) which is theoretically possible but experimentally not feasible.

(*b*) which is neither theoretically nor experimentally feasible.

(*c*) which is performed by non-physicist.

(*d*) none of the above.

3. "Nature is pleased with simplicity and effects not the pump of superfluous causes". It has been said by the great scientist

(*a*) Einstein (*b*) Dirac

(*c*) Russel (*d*) Newton.

4. The book titled 'Principia' was written by

(*a*) Maxwell (*b*) Einstein

(*c*) Newton (*d*) Galileo. [AFMC 01]

5. "It is more important to have beauty in the equations of physics than to have them agree with experiments". The scientist who made this statement is

(a) Dirac (*b*) Maxwell

(*c*) Faraday (*d*) Raman.

6. "The most incomprehensible thing about the world is that it is comprehensible." This statement was made by the scientist

(*a*) Aristotle (*b*) Newton

(*c*) Galileo (*d*) Einstein.

7. The country which awards the prestigeous Nobel prize is

(*a*) U.S.A. (*b*) U.K.

(*c*) Sweden (*d*) France.

8. An Indian scientist who won Nobel prize for physics is

(a) Sir J.C. Bose (*b*) H.J. Bhaba

(*c*) M.N. Saha (*d*) Sir C.V. Raman.

[AFMC 01]

9. The man who has won Nobel Prize twice in physics is

(*a*) Einstein (*b*) Bardeen

(*c*) Heisenberg (*d*) Faraday.

[AFMC 01]

10. Madam Marie Curie won Nobel Prize twice which were in the field of

(*a*) Physics and chemistry

(*b*) Chemistry only

(*c*) Physics only

(*d*) Biology only.

11. Prof. Albert Einstein got noble prize in physics for his work on

(*a*) special theory of relativity

(*b*) general theory of relativity

(*c*) photoelectric effect

(*d*) theory of specific heats. [CBSE 91]

12. The value of universal gravitational constant 'G' was first experimentally determined by

(*a*) Newton (*b*) Galileo

(*c*) Kelvin (*d*) Cavendish.

13. Charge on an electron was first determined by :

(*a*) Millikan (*b*) Bohr

(*c*) Thomson (*d*) Rutherford.

14. J. D. Van der Walls discovered equation of gases and liquids. He was a

(*a*) English scientist (*b*) French scientist

(*c*) Dutch scientist (*d*) German scientist.

15. X-rays were discovered by

(*a*) Coolidge (*b*) Roentgen

(*c*) Maxwell (*d*) Fermi.

16. The working of an aeroplane is based on

(*a*) Newton's third law of motion

(*b*) Bernoulli's principle

(*c*) Newton's law of gravitation

(*d*) Law of conservation of momentum.

17. Chandershekher, an America based Indian scientist was awarded Nobel Prize in physics on the subject concerning

(*a*) Geophysics (*b*) Astronomy

(*c*) Superconductivity

(*d*) Laser Technology.

18. Radioactivity was discovered by

(*a*) Chadwick (*b*) Rutherford

(*c*) Becquerel (*d*) Roentgen.

19. Abdus Salam, an America based Pakistani physicist won Nobel Prize in the field of

(a) Inelastic scattering of light by molecules

(*b*) Unification of weak and electromagnetic forces

(*c*) Superconductivity

(*d*) Laser technology.

20. Neutrons were discovered by

(*a*) Fermi (*b*) Yukawa

(*c*) Dirac (*d*) Chadwick.

21. Louis de-Broglie is credited for his work on

(*a*) Theory of relativity

(*b*) Electromagnetic theory

(*c*) Matter waves

(*d*) Law of distribution of velocities.

22. The country to which de Broglie belongs is

(a) Germany (*b*) England

(*c*) France (*d*) America.

23. Lightning was discovered by [AFMC 96]

(*a*) Faraday (*b*) Franklin

(*c*) Ohm (*d*) Edison.

24. The discoverer of loudness and intensity of sound is

(*a*) Newton (*b*) Bell

(*c*) Leplace (*d*) Edison.

25. The man who is known as the Father of Experimental Physics is

(*a*) Newton (*b*) Albert Einstein

(*c*) Galileo (*d*) Rutherford.

26. The total number of discoveries made by Michael Faraday is

(*a*) 16 (*b*) 41

(*c*) 5 (*d*) 16401.

27. The person who has been awarded the title of the Father of Physics of 20th century is

(*a*) Madame Curie (*b*) Sir C.V. Raman

(*c*) Neils Bohar (*d*) Albert Einstein.

28. It has been postulated that there may be some particles moving with speed greater than the speed of light. Such particles are known as

(*a*) Electrons (*b*) Neutrons

(*c*) Nucleons (*d*) Tachyons. [AFMC 01]

29. The book "Pisces of Physics" has been written by

(*a*) Einstein (*b*) Newton

(*c*) Archimedes

(*d*) Galileo. [AFMC 01]

30. Which of the following is wrongly matched ?

(*a*) Barometer-Pressure

(*b*) Lactometer-Milk

(*c*) Coulomb's law-charges

(*d*) Humidity-Calorimeter [AFMC 01]

31. C.V. Raman got Nobel Prize for his experiment on

(*a*) dispersion of light

(*b*) reflection of light

(*c*) deflection of light

(*d*) scattering of light. [AFMC 01]

32. The idea of calculus was given by

(*a*) Newton

(*b*) Einstein

(*c*) Marconi

(*d*) Planck. [AFMC 03]

33. Which of the following principles is being used in Sonar Technology ?

(*a*) Reflection of ultrasonic waves

(*b*) Newton's laws of motion

(*c*) Reflection of electromagnetic waves

(*d*) Laws of thermodynamics [DPMT 2011]

Answers

1. (*a*)	**2.** (*b*)	**3.** (*d*)	**4.** (*c*)	**5.** (*a*)	**6.** (*d*)
7. (*c*)	**8.** (*d*)	**9.** (*b*)	**10.** (*a*)	**11.** (*c*)	**12.** (*d*)
13. (*a*)	**14.** (*c*)	**15.** (*b*)	**16.** (*b*)	**17.** (*b*)	**18.** (*c*)
19. (*b*)	**20.** (*d*)	**21.** (*c*)	**22.** (*c*)	**23.** (*b*)	**24.** (*b*)
25. (*c*)	**26.** (*d*)	**27.** (*d*)	**28.** (*d*)	**29.** (*a*)	**30.** (*d*)
31. (*d*)	**32.** (*a*)	**33.** (*a*)			