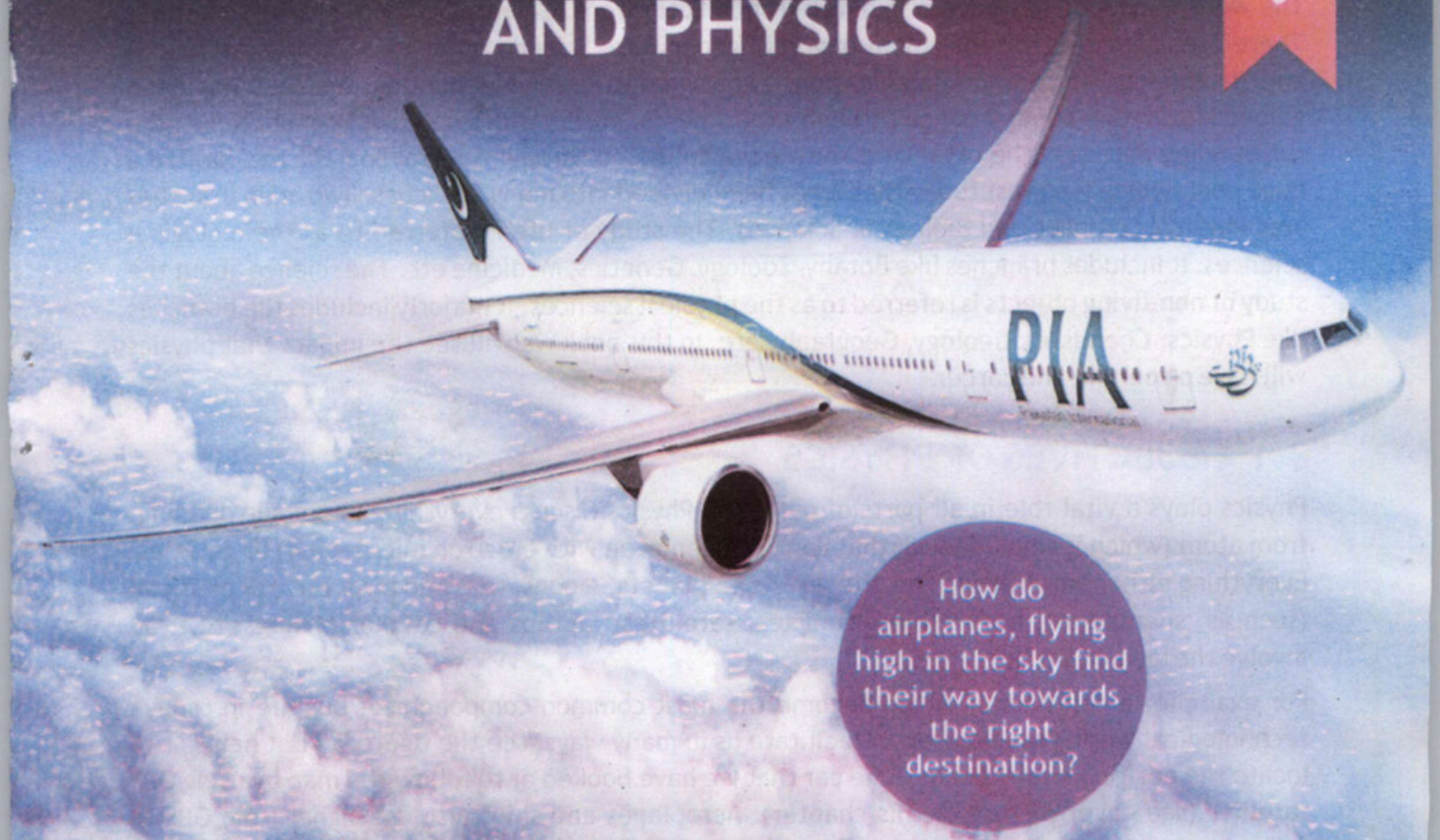
UNIT 9

NATURE OF SCIENCE AND PHYSICS



How do airplanes, flying high in the sky find their way towards the right destination?

Student Learning Outcomes (SLOs)

The students will

- [SLO: P-09-G-01] Describe physics as the study of matter, energy, space, time and their mutual connections and interactions.
- [SLO: P-09-G-02] Explain with examples that physics has many sub-fields, and in today's world involves interdisciplinary fields.
- [SLO: P-09-G-03] Explain with examples how Physics is a subset of the Physical Sciences and of the natural sciences.
- [SLO: P-09-G-04] State that scientists who specialize in the research of physics are called Physicists.
- [SLO: P-09-G-05] Brief with examples that science is a collaborative field that requires interdisciplinary researchers working together to share knowledge and critique ideas.
- [SLO: P-09-G-06] Understand the terms 'hypothesis', 'theory' and 'law' in the context of research in the physics.
- SLO: P-10-G-07] Explain, with examples in Physics, falsifiability as the idea that a theory is scientific only if it makes assertions that can be disproven.
- [SLO: P-09-G-08] Differentiate the terms 'science', 'technology' and 'engineering' with suitable examples.

UNIT 9 NATURE OF SCIENCE AND PHYSICS

The word "science" has been originated from a Latin word "Scientia" which means "to know". Therefore, science is to know about everything in nature. Science is the study of physical nature and its aspects. It contains imagination, experimentation and deduction. Humans has been gained knowledge about Science through experiments, observations and trials conducted on the surrounding matters. The organized knowledge collected through several sources has formed a huge pool, which is so vast today that it has been divided into many branches. Two main branches are: Physical Sciences and Biological Sciences. The study of life is referred to as the biological sciences. It includes branches like Botany, Zoology, Genetics, Medicine etc. The science about the study of non-living objects is referred to as the physical sciences. It majorly includes the branches like Physics, Chemistry, Geology, Geography etc. In this book we will see the impact that physics will have on our life and career.

9.1 OBJECTIVES OF PHYSICS

Physics plays a vital role in all parts of our lives. Physics discuss everything in our surrounding: from atom (which is small enough that can't be seen even with electron microscope) to galaxies. Everything either natural (such as, the sky, stars, planets, moons, seas and birds etc.) or artificial (such as, submarines, heavy ships, vehicles, satellites, laptops and cellular phones etc.), all involve the laws of physics.

For example, a cell phone, which become the most common component of our life in today's technological world, can be used to facilitate us in many ways (see the figure 9.1). It helps us to locate the position of any person, the car that we have booked or to follow the map by using GPS satellite (see cover picture of this chapter). Aeroplanes and ships also use signal from GPS to follow their path towards the right destination and stay connected with the control office.

FIGURE 9.1 GOOGLE MAP WORKS WITH GPS

Aeroplane runs on the runway to create a pressure difference above and below its wings before it takes off. Similarly, birds use the difference in air pressures above and below their wings to keep themselves high up. Feathers of birds give good thermal insulation especially when fluffed up during winter (see figure 9.2). The sky seems blue when sunlight strikes and scatters off by the gas molecules in our atmosphere. The presence of large water reservoirs such as lakes and seas keep the climates of nearby land moderate due to the large heat capacity of water. Vehicles use the principles of mechanics and thermodynamics to transfer stored chemical energy in fuel to kinetic energy in rotating wheels. Submarines and heavy ships work on the principle of floatation. Cellular phones use electronic components and the principles of electromagnetic waves to transfer energy and information from one cellular phone to another. These are just a few examples that involve physics.

FIGURE 9.2 PHYSICS AND BIRDS

Birds fluff their feathers during winter to gather more warm air

FOR YOUR INFORMATION

Physics is the branch of science that describes the matter, energy, space, time and their mutual connections and interactions throughout the universe.

The objective of physics is to offer an understanding of the physical world by developing theories based on observations and experiments. A scientist who specializes in the field of physics is termed as *'physicist'*. Physicists engage in theoretical and experimental research to explore and explain the fundamental laws of nature. Physicists express everyday happenings in mathematical formulas. These mathematical formulas are then used by all physicists and engineers to guess results of their experiments. For example, Isaac Newton (1642-1727) found the laws behind the motion of bodies, which we now used to design rockets that travel in outer space (to the moon and other planets). Physicists also improve the laws of physics from time to time according to experimental results. For example, Isaac Newton established the laws of motion working at normal speeds, but these laws fail for object's moving with high speed that approaches the speed of light. Albert Einstein (1879-1955) solved this issue by giving the theory of relativity. Theory of relativity gives the same result as Newton's laws of motion at slow speeds, but is more accurate as speeds approaches the speed of light. Hence science is a collaborative field that requires interdisciplinary researchers working together to share knowledge and critique ideas.

ACTIVITY

- Look around in your class-room and give name of some devices or things which involve physics.
- Discuss the phenomenon of physics that is working there.
- Discuss one natural physics phenomenon that is happening around you.

9.2 FIELDS OF PHYSICS

Physics is considered to be the most fundamental of all the sciences. Physics has many sub-fields, and in today's world it involves interdisciplinary fields. In order to study biology, chemistry, or any other natural science, one should have a firm understanding of the principles of physics. For example, biology uses the physics principles of fluid movement to understand how the blood flows through the heart, arteries, and veins. Chemistry relies on the physics of subatomic particles to understand why chemical reactions take place. Geology uses the physics of seismic waves and energy transfer to determine the magnitude and location of earthquakes. Astronomy and cosmology rely on the laws of physics such as theory of relativity to describe the workings of the universe. Some fields of physics are given below.

BIOPHYSICS: Biophysics is the study of various characteristics and systems of living body. Fluid dynamics of blood flow and respiration, radiation in diagnostics and treatment etc., are studied in biophysics.

ASTRONOMY: Astronomy is the study of everything in the universe beyond Earth's atmosphere. It deals with celestial objects (such as the Sun, the Moon, the planets, and the stars), space and the physical universe as a whole. To study astronomy, astronomers have to stay up late at night to see the celestial objects with the help of a powerful telescope.

ASTROPHYSICS: Astrophysics is the study of physical nature of stars and other celestial bodies, and the application of the laws and theories of physics to the interpretation of astronomical observations.

An Astrophysicist investigate the astronomical events such as formation of stars, planets and galaxies, to learn more about the universe.

COSMOLOGY: Cosmology is the study of the origin, development, structure, history, and future of the entire universe. cosmology spans the entire universe from birth to death, with a wealth of mysteries at every stage.

THERMAL PHYSICS: Thermal physics is the collective study of statistical mechanics, thermodynamics and kinetic theory of gases.

OPTICS: Optics is the branch of physics that studies the nature and properties of light, its interactions with matter and the construction of instruments that use or detect it.

Nuclear Physics: Nuclear physics is the study of the structure, properties and behaviour of atomic nuclei.

the radiation from unstable nuclei.

PARTICLE PHYSICS: Particle physics (or high energy physics) is the study of fundamental particles and forces that create matter and radiation.

ELECTROMAGNETISM: Electromagnetism is a branch of physics in which we study the electromagnetic forces between electrically charged particles.

ACOUSTICS: Acoustics is the branch of physics that deals with the production, transmission, control, reception, and effects of sound.

COMPUTATIONAL PHYSICS: Computational physics is the study and implementation of numerical analysis to solve complex problems in physics.

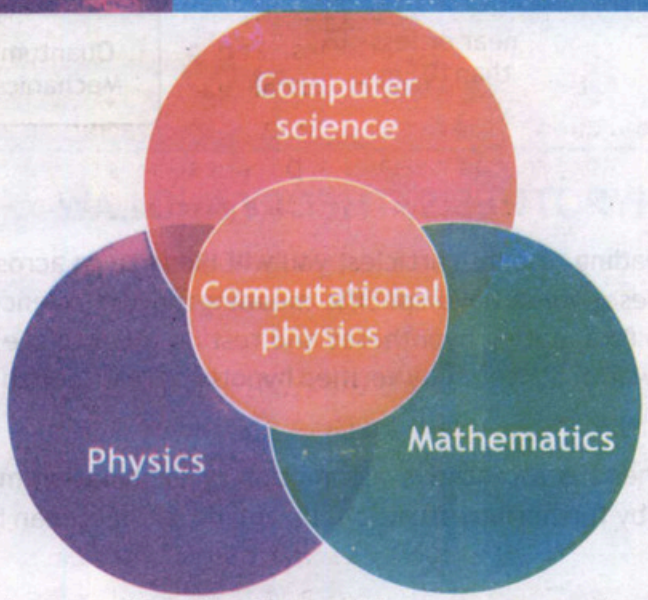
GEOPHYSICS: Geophysics is the branch of physics in which we study about the structure of the Earth, physical processes and phenomena occurring especially in the earth and in its vicinity.

CLIMATE PHYSICS: Climate Physics is the branch of physics that deals with the study of the Earth's climate.

CLASSICAL MECHANICS: Classical mechanics is the branch of physics in which we study the motion of macroscopic objects under the action of forces.

QUANTUM MECHANICS: Quantum mechanics is the branch of physics in which we study the mathematical description of motion and behavior of microscopic particles under different situations.

FIGURE 9.3 COMPUTATIONAL PHYSICS



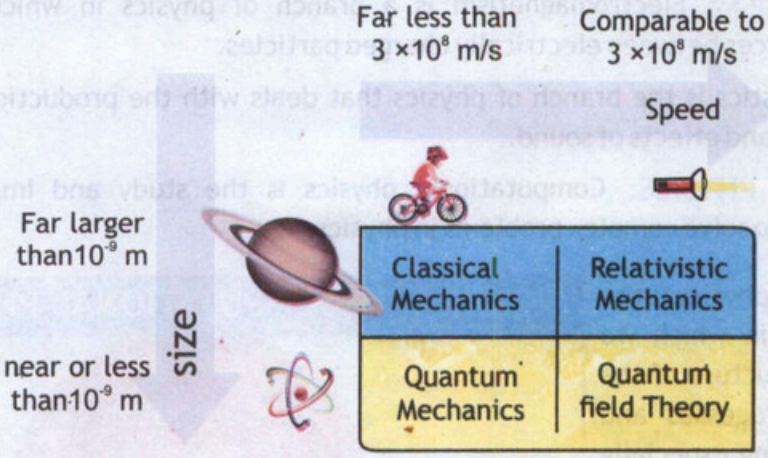
Computational Physics combines computer science, physics and applied mathematics to develop scientific solutions to complex problems

RELATIVISTIC MECHANICS: Relativistic mechanics is the branch of physics in which we study the system of bodies whose relative velocities approaches to the speed of light c, or whose kinetic energies are comparable with the product of their masses (m) and the square of the velocity of light (c).

A physicist is a scientist who specializes in any field of physics, which covers the interactions of matter and energy at all length and time scales in the physical universe. A Physicists conduct in-depth research on different topics.

FOR YOUR INFORMATION

Relation between Classical Mechanics, Quantum Mechanics, Relativistic Mechanics and Quantum Field Theory can be easily cleared by the diagram below.



9.3 HYPOTHESIS, THEORY AND LAW

When reading research articles, you will likely to go across the terms HYPOTHESIS, THEORY and LAW. These words have specific meanings in the science. The scientific method of research includes formulating hypotheses and testing them to see if they hold up to the realities of the natural world. Successfully verified hypotheses can lead to either theories or laws.

HYPOTHESIS

A hypothesis is a tentative assumption or explanation made before any research that can be verified by further investigation. It is made so that it can be verified to see if it might be true or false.

THEORY

In order to put a hypothesis into a proven theory, researchers design experiments to challenge their ideas under the conditions of the natural world. By following to the scientific method and working carefully, scientists can finally accumulate enough evidence to prove their hypothesis, thus making it a theory with predictive and extrapolative power. A scientific theory is a description of the nature that scientists have verified through rigorous testing. A theory explains how nature behaves under specific conditions. Theories tend to be as broad as their supporting scientific evidence will permit. A theory is a well-supported explanation of some aspect of the natural world of observations.

Some examples of famous scientific theories that have shaped our understanding of the natural world, are listed below.

- Kinetic Molecular Theory.
- Theory of General Relativity.

LAW

A law is a statement that summarises an observed regularity or pattern in nature and gives the relationship between variables. Like theories, laws describe phenomena that the scientists have found to be provably true. Laws develop from discoveries and rigorously tested hypotheses, and new theories generally uphold and expand laws.

Examples of some famous laws include:

- Newton's Law of Universal Gravitation.
- Newton's Laws of Motion.
- Boyle's Law.
- Laws of Thermodynamics.

Both scientific laws and theories are considered as fact. However, theories and laws can be disproven when new evidence appears. For example, certain accepted truths of Newtonian physics were partially disproven by Albert Einstein's theory of relativity. The work of Louis Pasteur disproved prior theories of disease in animals. If thorough scientific research upends a previously held belief, scientists must find new hypotheses that better describe how nature works.

DIFFERENCE BETWEEN THEORY AND LAW

Scientific laws differ from theories in sense that laws tend to describe a narrower set of conditions. A scientific law might explain the relationship between two specific forces or between two changing substances in a chemical reaction. Theories are normally more expansive and they focus on the how and why of natural phenomena.

9.4 SCIENCE, TECHNOLOGY AND ENGINEERING

Science and technology are quite different. Science is a system of knowledge that is concerned with establishing accurate conclusions about the behavior of everything in the universe. It is a field in which hypotheses are made, information is gathered, and experiments are performed to determine how something in our natural world works or behaves. Technology, on the other hand, is a field that uses scientific knowledge to develop material products or processes that satisfy human needs and desires.

Science is the pursuit of knowledge and understanding through systematic study, experimentation, and observation. It is the pursuit and application of knowledge and understanding of the natural and social world.

For example in physics, scientists study the principles of motion and energy to understand the behavior of objects. This may include conducting experiments to establish the laws of motion or formulating theories to clarify the forces of gravity.

Technology is the application of scientific knowledge for practical purposes, resulting in the development of tools, machines, and systems. It involves the creation and use of tools, machines, systems, and techniques to solve problems, achieve goals, or perform specific functions.

The development of smartphones for instance is a technological advancement. It involves the application of scientific principles in physics, materials science, and engineering to create a device that combines communication, computation, and various other functions.

Engineering is the practical use of scientific and mathematical principles to create and construct structures, devices, and processes. It requires the application of knowledge to solve real-world problems in a creative and organized manner.

For instance, civil engineering focuses on designing and building infrastructure like bridges, roads, and buildings. Civil engineers utilize scientific principles, such as materials science and structural mechanics, to ensure the development of secure and effective structures.

While these fields are distinct, they are interconnected. Advances in science often lead to technological innovations, and engineers use scientific knowledge to create new technologies that, in turn, drive further scientific exploration.

SUMMARY

Physics is the branch of science that describes the matter, energy and their mutual relationship.

A hypothesis is a tentative assumption or explanation made before any research that can be verified by further investigation.

A theory explains how nature behaves under specific conditions.

A law is a statement that summarises an observed regularity or pattern in nature and gives the relationship between variables.

Technology is tools, including methods, that assist people in accomplishing tasks.

Engineering is the process of studying and developing technology.

EXERCISE

MULTIPLE CHOICE QUESTIONS

Q1. Choose the best possible option.

1. What is the best definition of the term "theory," as it is used in science?
   A. A theory is a guess or hunch about something that has occurred in nature.
   B. A theory is a comprehensive set of ideas explaining a phenomenon in nature.
   C. A theory is based on verifiable laws and can be proven true
   D. A theory is a hypothesis that uses laws and observation to make an assumption.
2. Which statement below correctly identifies the difference between laws and theories?
   A. Laws describe phenomena, while theories explain why phenomena exist.
   B. Laws are a statement of fact, while theories are a statement of opinion.
   C. Laws explain why phenomena exist, while theories explain how.
   D. Laws are a prediction of phenomena, while theories are an explanation.

3. Why do scientists develop a hypothesis before conducting research?
   A. It gives them direction on how to interpret the results of their research.
   B. It helps to predict outcomes and define the parameters of the research.
   C. Hypotheses give the researcher an outcome to shape their work around
   D. Hypotheses help a researcher decide which observations to record and which to ignore.
4. The Branch of Physics that is most important when studying how glasses help people see:
   A. Thermodynamics B. Electromagnetism C. Mechanics D. Optics
5. when studying how air conditioners cool your house, then it is:
   A. Thermodynamics B. Electromagnetism C. Nuclear Physics D. Optics
6. The branch of Physics that deals with the particles such as neutrons and protons:
   A. Solid State Physics B. Plasma Physics C. Electricity D. Nuclear Physics
7. Which branch of science plays an important role in engineering?
   A. Biology B. Chemistry C. Physics D. Genetics
8. Physics is one of the branches of:
   A. Physical sciences B. Biological sciences C. Social science D. Life sciences

SHORT RESPONSE QUESTIONS

Give a short response to the following questions

1. Define the following branches of physics:
   Biophysics, Astrophysics, Optics, Relativistic Mechanics, Nuclear Physics, Acoustics, Computational Physics
   Define the terms theory and law. Also give two examples of each.
2. Define Hypothesis?
3. What is the difference between classical mechanics and quantum mechanics?
4. What determines the validity of a theory?
5. Which part of the study is not handled by the classical study of physics?

LONG RESPONSE QUESTIONS

Give a detailed response to the questions below.

1. Discuss the importance of physics in our daily life.
2. Briefly discuss the importance of physics in other disciplines of science.
3. Differentiate the terms 'science', "technology' and 'engineering' with suitable examples.
4. Explain the terms, hypothesis, theory and law with examples.

GLOSSARY

Acceleration is the time rate of change of velocity and is a vector quantity.

Atmospheric Pressure or barometric pressure is the force exerted by the air (its weight) on unit area.

Bar magnet and solenoid have same pattern of magnetic fields.

Barometer is a device used to measure atmospheric pressure.

Centre of gravity is a single point where the whole weight of an object appears to act.

Centre of mass of the body is the point about which mass is equally distributed in all directions.

Centripetal force is the force that compels a body to travel a circular path. It may be electric, gravitational, or any other force.

Density is mass per unit volume

Diamagnetic materials have zero net magnetic fields per atom.

Displacement is the shortest distance from the initial and final position of a body.

Distance is how much ground an object has covered during its motion.

Drag Force is the force applies acting opposite towards the motion of the object which is moving submerge in a certain fluid.

Dynamics is the branch of mechanics in which we discuss the motion of bodies along with causes of motion of bodies.

Earth has a magnetic field which resembles with the field of a bar magnet and shield all the life on it from cosmic rays and radiation from the Sun and outer space.

Earth's geographical and magnetic poles are not same but inclined at an angle of 11.3 degrees.

Efficiency is the ratio of useful energy or work output to the total energy or work input.

Elasticity is the property of a body, which enables the body to regain its original dimension when the deforming force acting on the body is removed.

Energy is the capacity of a body to do work.

Engineering is the process of studying and developing technology.

Error is the difference between the measured and actual values.

Ferromagnetic materials have large net magnetic field per atom.

Force is a physical quantity which moves or tends to move a body, stops or tends to stop a moving body or which tends to change the speed and direction of a moving body.

Frictional force is the force that resists motion of objects on a surface.

Graph is a line straight or curved that shows relation between two quantities out of which one varies as a result of change in other.

Gravitational Field Strength is defined as the force per unit mass that earth exerts on a body.

Gravitational potential energy is the energy possessed or acquired by an object due to a change in its position when it is present in a gravitational field and is given by $E = mgh$

Heat is the form of energy which is transferred from one body to another body due to the difference in temperature.

Hooke's law states that within elastic limits the extension (or compression) is directly proportional to the force applied.

Hypothesis is a tentative assumption or explanation made before any research that can be verified by further investigation.

Impulse is a certain amount of force you apply for a certain amount of time to cause a change in momentum

Induced magnetism is the phenomenon in which a material is magnetized by placing it inside an external magnetic field.

Inertia is a property of matter by which it remains at the state of rest or in uniform motion

Kinetic Energy is the energy of an object due to its motion and is given by $E = \frac{1}{2} mv^2$

Law is a statement that summarizes an observed regularity or pattern in nature and gives the relationship between variables.

Law of conservation of energy states that energy can neither be created nor destroyed. It can be converted from one form to another or transferred from one body to another, but the total amount remains constant.

Law of Conservation of Momentum states that if there is no external force applied to a system, the momentum of that system remain constant.

Like poles of magnets always repel each other, while unlike poles attract each other.

Liquid Pressure is the force exerts by water on the walls of the container from inside

Magnetic domain is the group of atoms whose N-poles are aligned in the same direction.

Magnetic field is the region of space around a magnet in which it is attracted by the magnetic pole of opposite polarity.

Magnetic field lines originate from the north-pole and terminate at south-pole.

Magnetic materials are always attracted by magnets and other magnetic materials.

Magnetic shielding is the phenomenon in which some region of space is made free from magnetic field.

Magnets are always found in dipole, i.e. they have an N-pole and an S-pole.

Mass is the quantity of matter in a body.

Migrating birds and animals use Earth's magnetic field to navigate.

Moment of a force or Torque is the measure of an object tendency to rotate about some point O. *Moment of a force = force × perpendicular distance of the force to the point.*

Momentum is the product of mass and velocity. It is a vector quantity.

Monometer is one of the most accurate devices for measuring pressure, including atmospheric pressure in the lower ranges.

Newton's First Law of Motion states that everybody continues in its state of rest or uniform motion in a straight line unless an external net force acts upon it.

Newton's Second Law of Motion states that whenever a net force acts on a body, it produces acceleration in the direction of the net force. The acceleration is directly proportional to the net force and inversely proportional to the mass of the body.

Newton's Third Law of Motion states that to every action there is an equal and opposite reaction.

Orbital velocity is the speed of an object revolving around another heavy object in an orbit.

Paramagnetic materials have small net magnetic field per atom.

Pascal's Principle states that if the pressure at one point of a confined fluid is increased by an amount, the pressure increases by the same amount at all other parts throughout the fluid.

Permanent magnets are those magnets which behave like a magnet even in the absence of current.

Physical quantities are measurable quantities

Physics is the branch of science which deals with the study of matter and energy.

Plasma is called fourth state of matter which is the ionized state of matter.

Position is the distance and direction of a body from a fixed reference point.

Potential Energy is the energy of an object due to its position.

Power is the rate of doing work or rate of conversion of energy. $P = W/t$

Prefix is a word placed before quantities to modify their meaning.

Pressure is force applied per unit area.

Principle of moments states that for an object in equilibrium, the sum of the clockwise moments taken about the pivot must be equal to the sum of the anti-clockwise moments taken about the same pivot.

Renewable & Non-renewable Energy Resources are such that renewable resources can naturally replenish themselves while non-renewable

resources cannot.

Scalars are physical quantities with magnitude only.

Science is natural explanations for apparent phenomena.

Scientific Notation is an internationally accepted way of writing numbers in which

Screw Gauge is a device used to measure a fraction of smallest scale division by

Seven Base SI Units are metre (length), kilogram (mass), second (time), ampere (current), candela (luminous intensity), Kelvin (temperature) and mole (amount of substance).

Significant Figures are the accurately known digits and first doubt full digit in any

sliding another scale over it.

Speed is time rate of change of distance and is a scalar quantity.

Stability of an object refers to the ability of the object to return to its original position when the force that changed its orientation is removed.

States of matter are four, which are named as Solids, Liquids, Gases and Plasma.

Stop Watch is an instrument used for measurement of time interval

System International (SI) is the system of units which consists of seven base units and a number of derived units.

Technology is tools, including methods, that assist people in accomplishing tasks.

Temperature is the measure of degree of hotness or coldness of a body.

Temporary magnets are those magnets which behave like a magnet only in the presence of current.

Terminal velocity is the maximum constant velocity that a body can achieve while passing through a resistive (viscous) medium.

Theory explains how nature behaves under specific conditions.

Thermometer is a device which is used to measure temperature.

Thermometry is the branch of physics, which deals with the measurements of temperature.

Vectors are physical quantities with magnitude as well as direction.

Velocity is the time rate of change of displacement and is a vector quantity.

Vernier calipers is a device used to measure a fraction of smallest scale division by

Weight is the downward force with which the earth pulls a body towards its center.

Work is force multiplied by distance moved in the direction of the force $W = FS$

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