Class 9 Science

Complete Interactive Textbook

Table of Contents

Definitions & Formulae

Chemistry

Matter: Anything that has mass and occupies space.

Diffusion: The intermixing of particles of two different types of matter on their own.

Latent Heat of Fusion: The amount of heat energy required to change 1 kg of a solid into liquid at atmospheric pressure at its melting point.

Sublimation: A change of state directly from solid to gas without changing into liquid state.

Pure Substance: A substance consisting of a single type of particle, where all constituent particles are the same in their chemical nature.

Element: A basic form of matter that cannot be broken down into simpler substances by chemical reactions.

Compound: A substance composed of two or more elements, chemically combined with one another in a fixed proportion.

Atom: The smallest particle of an element that cannot usually exist independently and retains all its chemical properties.

Molecule: A group of two or more atoms that are chemically bonded together; the smallest particle of an element or compound capable of independent existence.

Valency: The combining power (or capacity) of an element.

Isotopes: Atoms of the same element, having the same atomic number but different mass numbers.

Isobars: Atoms of different elements with different atomic numbers, which have the same mass number.

Physics

Displacement: The shortest distance measured from the initial to the final position of an object.

Velocity: The speed of an object moving in a definite direction.

Acceleration: The measure of the change in the velocity of an object per unit time. $a = (v - u) / t$

Newton's First Law: An object remains in a state of rest or of uniform motion in a straight line unless compelled to change that state by an applied force.

Inertia: The natural tendency of an object to resist a change in its state of motion or of rest.

Momentum (p): The product of an object's mass (m) and velocity (v). $p = mv$

Newton's Second Law: The rate of change of momentum of an object is proportional to the applied unbalanced force in the direction of force. $F = ma$

Newton's Third Law: To every action, there is an equal and opposite reaction, acting on two different objects simultaneously.

Universal Law of Gravitation: $F = G * (M * m) / d^2$

Thrust: The force acting on an object perpendicular to the surface.

Pressure: The thrust acting per unit area. Pressure = Thrust / Area

Archimedes' Principle: When a body is immersed fully or partially in a fluid, it experiences an upward force that is equal to the weight of the fluid displaced by it.

Work: The product of the force and displacement in the direction of the force. $W = Fs$

Kinetic Energy: The energy possessed by an object due to its motion. $E_k = \frac{1}{2}mv^2$

Potential Energy: The energy possessed by an object by virtue of its position or configuration. $E_p = mgh$

Power: The rate of doing work or the rate of transfer of energy. $P = W / t$

Biology

Cell: The fundamental structural and functional unit of living organisms.

Plasma Membrane: The selectively permeable outermost covering of the cell that regulates the entry and exit of materials.

Osmosis: The movement of water molecules through a selectively permeable membrane toward a higher solute concentration.

Nucleus: The control center of the cell containing chromosomes and DNA (genetic information).

Prokaryotes: Organisms whose cells lack a nuclear membrane (e.g., bacteria).

Eukaryotes: Organisms with cells that have a nuclear membrane and membrane-enclosed organelles.

Tissue: A group of cells that are similar in structure and work together to achieve a particular function.

Meristematic Tissue: The dividing tissue in plants located only in certain specific regions of growth.

Xylem: Complex permanent tissue in plants that transports water and minerals vertically.

Phloem: Complex permanent tissue in plants that transports food from leaves to other parts.

Neuron: The unit of nervous tissue, highly specialised for transmitting stimuli rapidly within the body.

Mitosis: The process of cell division for growth, producing two identical daughter cells.

Meiosis: The process of cell division for forming gametes, producing four new cells with half the number of chromosomes.

Chapter 1: Matter in Our Surroundings

Introduction to Matter

Everything is Matter

As we look at our surroundings, we see a large variety of things with different shapes, sizes and textures. Everything in this universe is made up of material which scientists have named 'matter'. The air we breathe, the food we eat, stones, clouds, stars, plants and animals, even a small drop of water or a particle of sand — every thing is matter.

Mass and Volume

We can also see as we look around that all the things mentioned above occupy space and have mass. In other words, they have both mass and volume. The SI unit of mass is kilogram (kg). The SI unit of volume is cubic metre (m^3).

Historical Classification

Since early times, human beings have been trying to understand their surroundings. Early Indian philosophers classified matter in the form of five basic elements — the 'Panch Tatva' — air, earth, fire, sky and water. According to them everything, living or non-living, was made up of these five basic elements.

Physical Nature of Matter

Particulate Nature

For a long time, two schools of thought prevailed regarding the nature of matter. One school believed matter to be continuous like a block of wood, whereas, the other thought that matter was made up of particles like sand. Experiments show that matter is particulate.

How Small are Particles?

The particles of matter are very small – they are small beyond our imagination. For example, just a few crystals of potassium permanganate can colour a large volume of water (about 1000 L). So we conclude that there must be millions of tiny particles in just one crystal.

Characteristics of Particles: Space and Movement

Space Between Particles

Particles of matter have space between them. When we make tea, coffee or lemonade, particles of one type of matter get into the spaces between particles of the other. This shows that there is enough space between particles of matter.

Continuous Movement

Particles of matter are continuously moving, that is, they possess what we call the kinetic energy. As the temperature rises, particles move faster. So, we can say that with increase in temperature the kinetic energy of the particles also increases.

Diffusion

Particles of matter intermix on their own with each other. They do so by getting into the spaces between the particles. This intermixing of particles of two different types of matter on their own is called diffusion. We also observe that on heating, diffusion becomes faster.

Characteristics of Particles: Attraction

Force of Attraction

Particles of matter have force acting between them. This force keeps the particles together. The strength of this force of attraction varies from one kind of matter to another.

Varying Strength

For example, it is easy to move your hand through water, but difficult to do so through a solid block of wood. This suggests that the particles in a solid are held together by a stronger force of attraction than in a liquid.

States of Matter: The Solid State

Properties of Solids

Solids have a definite shape, distinct boundaries and fixed volumes, that is, have negligible compressibility. Solids have a tendency to maintain their shape when subjected to outside force.

Rigidity

Solids may break under force but it is difficult to change their shape, so they are rigid. Examples include a pen, a book, a needle, and a piece of wooden stick.

Exceptions?

A rubber band changes shape under force and regains the same shape when the force is removed. If excessive force is applied, it breaks. A sponge has minute holes, in which air is trapped, when we press it, the air is expelled out and we are able to compress it. Both are still considered solids.

The Liquid State

Properties of Liquids

Liquids have no fixed shape but have a fixed volume. They take up the shape of the container in which they are kept. Liquids flow and change shape, so they are not rigid but can be called fluid.

Diffusion in Liquids

Solids, liquids, and gases can diffuse into liquids. The gases from the atmosphere diffuse and dissolve in water. These gases, especially oxygen and carbon dioxide, are essential for the survival of aquatic animals and plants.

Particle Movement

The rate of diffusion of liquids is higher than that of solids. This is due to the fact that in the liquid state, particles move freely and have greater space between each other as compared to particles in the solid state.

The Gaseous State

Compressibility

Gases are highly compressible as compared to solids and liquids. The liquefied petroleum gas (LPG) cylinder that we get in our home for cooking or the oxygen supplied to hospitals in cylinders is compressed gas. Compressed natural gas (CNG) is used as fuel these days in vehicles.

High Speed Diffusion

Due to high speed of particles and large space between them, gases show the property of diffusing very fast into other gases. For example, the smell of hot cooked food reaches us in seconds.

Pressure

In the gaseous state, the particles move about randomly at high speed. Due to this random movement, the particles hit each other and also the walls of the container. The pressure exerted by the gas is because of this force exerted by gas particles per unit area on the walls of the container.

Can Matter Change its State?

States of Water

Water can exist in three states of matter: solid, as ice; liquid, as the familiar water; and gas, as water vapour. The state of matter can be changed by changing temperature or pressure.

Melting

On increasing the temperature of solids, the kinetic energy of the particles increases. The particles start vibrating with greater speed. The energy supplied by heat overcomes the forces of attraction between the particles. A stage is reached when the solid melts and is converted to a liquid. This temperature is called the melting point.

Fusion

The process of melting, that is, change of solid state into liquid state is also known as fusion.

Latent Heat

Hidden Heat

During the experiment of melting, the temperature of the system does not change after the melting point is reached, till all the ice melts. This happens even though we continue to supply heat. This heat gets used up in changing the state by overcoming the forces of attraction between the particles.

Latent Heat of Fusion

As this heat energy is absorbed by ice without showing any rise in temperature, it is considered that it gets hidden into the contents of the beaker and is known as the latent heat. The amount of heat energy that is required to change 1 kg of a solid into liquid at atmospheric pressure at its melting point is known as the latent heat of fusion.

Latent Heat of Vaporisation

Similarly, particles in steam (water vapour) at 100°C (373 K) have more energy than water at the same temperature. This is because particles in steam have absorbed extra energy in the form of latent heat of vaporisation.

Sublimation

Direct Change

There are some substances that change directly from solid state to gaseous state and vice versa without changing into the liquid state. Camphor is an example.

Definitions

A change of state directly from solid to gas without changing into liquid state is called sublimation. The direct change of gas to solid without changing into liquid is called deposition.

Effect of Change of Pressure

Compressing Gases

Applying pressure and reducing temperature can liquefy gases. By applying pressure, particles of matter can be brought close together.

Dry Ice

Solid carbon dioxide (CO2) is stored under high pressure. Solid CO2 gets converted directly into gaseous state on decrease of pressure to 1 atmosphere without coming into liquid state. This is the reason that solid carbon dioxide is also known as dry ice.

Determinants of State

Thus, we can say that pressure and temperature determine the state of a substance, whether it will be solid, liquid or gas.

Evaporation

Surface Phenomenon

The phenomenon of change of liquid into vapours at any temperature below its boiling point is called evaporation. Particles of matter are always moving and are never at rest.

Mechanism

In the case of liquids, a small fraction of particles at the surface, having higher kinetic energy, is able to break away from the forces of attraction of other particles and gets converted into vapour.

Factors Affecting Evaporation

Surface Area

The rate of evaporation increases with an increase of surface area. For example, while putting clothes for drying up we spread them out.

Temperature

With the increase of temperature, more number of particles get enough kinetic energy to go into the vapour state, increasing the rate of evaporation.

Humidity and Wind Speed

Humidity is the amount of water vapour present in air. If the amount of water in air is already high, the rate of evaporation decreases. With the increase in wind speed, the particles of water vapour move away with the wind, increasing the rate of evaporation.

How Does Evaporation Cause Cooling?

Absorption of Energy

In an open vessel, the liquid keeps on evaporating. The particles of liquid absorb energy from the surrounding to regain the energy lost during evaporation. This absorption of energy from the surroundings makes the surroundings cold.

Examples

When you pour some acetone (nail polish remover) on your palm, the particles gain energy from your palm or surroundings and evaporate causing the palm to feel cool. Sprinkling water on the roof after a hot day helps cool the surface because of the large latent heat of vaporisation of water.

Cotton Clothes in Summer

Cotton, being a good absorber of water helps in absorbing the sweat and exposing it to the atmosphere for easy evaporation. The heat energy equal to the latent heat of vaporisation is absorbed from the body leaving the body cool.

Summary of States of Matter

Inter-convertibility

The states of matter are inter-convertible. The state of matter can be changed by changing temperature or pressure.

Key Differences

Forces of attraction are maximum in solids, intermediate in liquids and minimum in gases. Spaces between particles are minimum in solids, intermediate in liquids and maximum in gases. Kinetic energy is minimum in solids, intermediate in liquids and maximum in gases.

Chapter 2: Is Matter Around Us Pure?

Is Matter Around Us Pure?

Everyday vs. Scientific Meaning

For a common person, 'pure' means having no adulteration. But for a scientist, most things like milk, ghee, and juice are mixtures of different substances and hence not pure. Milk, for example, is a mixture of water, fat, and proteins.

Scientific Definition of Pure

When a scientist says something is pure, it means all the constituent particles of that substance are the same in their chemical nature. A pure substance consists of a single type of particle.

What is a Mixture?

Definition

Mixtures are constituted by more than one kind of pure form of matter. For example, sea water, minerals, and soil are all mixtures.

Properties

A mixture contains more than one pure substance. Dissolved sodium chloride can be separated from water by evaporation, but sodium chloride itself is a pure substance.

Types of Mixtures

Homogeneous Mixtures

Mixtures which have a uniform composition throughout are called homogeneous mixtures or solutions. Examples include salt dissolved in water and sugar dissolved in water.

Heterogeneous Mixtures

Mixtures which contain physically distinct parts and have non-uniform compositions are called heterogeneous mixtures. Examples include mixtures of sodium chloride and iron filings, salt and sulphur, and oil and water.

What is a Solution?

Definition

A solution is a homogeneous mixture of two or more substances. Examples include lemonade and soda water. In a solution, there is homogeneity at the particle level.

Solute and Solvent

A solution has a solvent and a solute as its components. The component that dissolves the other component (usually present in larger amount) is called the solvent. The component that is dissolved (usually present in lesser quantity) is called the solute.

Examples

Tincture of iodine has iodine (solid) as the solute and alcohol (liquid) as the solvent. Air is a mixture of gas in gas.

Properties of a Solution

Particle Size

A solution is a homogeneous mixture. The particles are smaller than 1 nm in diameter and cannot be seen by naked eyes.

Path of Light

Because of very small particle size, they do not scatter a beam of light passing through the solution. So, the path of light is not visible in a solution.

Stability

The solute particles cannot be separated by filtration. The solute particles do not settle down when left undisturbed, meaning a solution is stable.

Concentration of a Solution

Dilute vs. Concentrated

Depending upon the amount of solute present, a solution can be called dilute, concentrated, or saturated. At any particular temperature, a solution that has dissolved as much solute as it is capable of dissolving is said to be a saturated solution.

Solubility

The amount of solute present in the saturated solution at this temperature is called its solubility.

Calculating Concentration

The concentration of a solution is the amount of solute present in a given amount of solution. Common methods include mass by mass percentage and mass by volume percentage.

What is a Suspension?

Definition

A suspension is a heterogeneous mixture in which the solute particles do not dissolve but remain suspended throughout the bulk of the medium. Particles of a suspension are visible to the naked eye.

Properties of a Suspension

Visibility and Scattering

Suspension is a heterogeneous mixture. The particles can be seen by the naked eye. They scatter a beam of light passing through it and make its path visible.

Instability

The solute particles settle down when a suspension is left undisturbed, meaning it is unstable. They can be separated by filtration.

What is a Colloidal Solution?

Definition

A colloid is a mixture that appears homogeneous but is actually heterogeneous (like milk). The particles are uniformly spread throughout the solution.

Tyndall Effect

Because of the small size of colloidal particles, we cannot see them with naked eyes. However, they can scatter a beam of visible light. This scattering is called the Tyndall effect.

Properties of a Colloid

Nature

A colloid is a heterogeneous mixture. The size of particles is too small to be seen with naked eyes but big enough to scatter light.

Stability

They do not settle down when left undisturbed, so a colloid is quite stable. They cannot be separated by filtration but can be separated by centrifugation.

Components

The components are the dispersed phase (solute-like) and the dispersing medium. Examples include fog (liquid in gas), smoke (solid in gas), and milk (liquid in liquid).

Physical and Chemical Changes

Physical Changes

Properties that can be observed and specified like colour, hardness, density, melting point are physical properties. Changes like interconversion of states (ice to water) are physical changes because they occur without a change in composition or chemical nature.

Chemical Changes

Burning is a chemical change. During this process, one substance reacts with another to undergo a change in chemical composition. Chemical change brings change in chemical properties and we get new substances. It is also called a chemical reaction.

What are the Types of Pure Substances?

Classification

On the basis of chemical composition, substances can be classified as elements or compounds.

Elements

Robert Boyle was the first to use the term element. Lavoisier defined an element as a basic form of matter that cannot be broken down into simpler substances by chemical reactions. Elements are divided into metals, non-metals, and metalloids.

Metals and Non-metals

Metals are usually lustrous, ductile, malleable, and good conductors (e.g., gold, iron). Non-metals are poor conductors and not lustrous (e.g., hydrogen, oxygen).

Compounds

Definition

A compound is a substance composed of two or more elements, chemically combined with one another in a fixed proportion.

Properties

The properties of a compound are totally different from its constituent elements. For example, water (a liquid that extinguishes fire) is made of hydrogen (combustible gas) and oxygen (supports combustion).

Mixtures vs. Compounds

Formation

In mixtures, elements or compounds just mix together and no new compound is formed. In compounds, elements react to form new compounds.

Composition

A mixture has a variable composition. A compound has a fixed composition.

Properties and Separation

A mixture shows the properties of its constituents and can be separated by physical methods. A compound has different properties and can be separated only by chemical reactions.

Chapter 3: Atoms and Molecules

Introduction to Atoms and Molecules

Ancient Philosophy

Ancient Indian and Greek philosophers wondered about the unseen form of matter. Maharishi Kanad postulated that if we divide matter (padarth), we will get smaller particles called 'Parmanu'. Democritus called these indivisible particles 'atoms'.

Foundation of Chemical Sciences

By the end of the eighteenth century, scientists recognised the difference between elements and compounds. Antoine L. Lavoisier laid the foundation of chemical sciences by establishing two important laws of chemical combination.

Law of Conservation of Mass

The Law

Is there a change in mass when a chemical reaction takes place? The Law of Conservation of Mass states that mass can neither be created nor destroyed in a chemical reaction.

Experiment

If you carry out a reaction in a closed flask (so nothing escapes), the total mass of the flask and its contents remains unchanged before and after the reaction.

Law of Constant Proportions

Definite Proportions

This law, also known as the Law of Definite Proportions, was stated by Proust: 'In a chemical substance the elements are always present in definite proportions by mass'.

Example: Water

In water, the ratio of the mass of hydrogen to the mass of oxygen is always 1:8. Thus, if 9g of water is decomposed, 1g of hydrogen and 8g of oxygen are always obtained, regardless of the source.

Dalton's Atomic Theory

The Theory

John Dalton provided the basic theory about the nature of matter in 1808. It provided an explanation for the laws of conservation of mass and definite proportions.

Postulates

1. All matter is made of tiny atoms. 2. Atoms are indivisible and cannot be created or destroyed. 3. Atoms of a given element are identical in mass and properties. 4. Atoms of different elements have different masses and properties. 5. Atoms combine in small whole numbers to form compounds.

What is an Atom?

Building Blocks

Atoms are the building blocks of all matter. Just as a small grain of sand is the building block of an ant-hill, atoms build up everything we see.

Size of Atoms

Atoms are very small, smaller than anything we can imagine. Atomic radius is measured in nanometres. 1 nm = 10^-9 m. Millions of atoms stacked would barely make a sheet of paper.

Modern Day Symbols of Elements

IUPAC Symbols

Dalton was the first to use specific symbols. Nowadays, IUPAC approves names and symbols. Symbols are usually the first one or two letters of the element's name in English (e.g., Hydrogen is H, Aluminium is Al).

Latin Roots

Some symbols come from Latin names. For example, Iron is Fe (Ferrum), Sodium is Na (Natrium), and Potassium is K (Kalium).

Atomic Mass

Relative Mass

Dalton proposed that each element had a characteristic atomic mass. Since individual atoms are too small to weigh, scientists determine relative atomic masses.

Carbon-12 Standard

In 1961, the carbon-12 isotope was chosen as the standard reference. One atomic mass unit (u) is a mass unit equal to exactly one-twelfth (1/12th) the mass of one atom of carbon-12.

How Do Atoms Exist?

Stability

Atoms of most elements are not able to exist independently. Atoms form molecules and ions. These aggregate in large numbers to form the matter that we can see, feel, or touch.

What is a Molecule?

Definition

A molecule is a group of two or more atoms that are chemically bonded together. It is the smallest particle of an element or compound that is capable of independent existence and shows all properties of that substance.

Molecules of Elements

Same Type of Atoms

The molecules of an element are constituted by the same type of atoms. For example, Argon (Ar) and Helium (He) are monoatomic.

Atomicity

Most non-metals exist as molecules of multiple atoms. Oxygen is diatomic (O_2). Ozone is triatomic (O_3). Phosphorus is tetra-atomic (P_4). The number of atoms constituting a molecule is known as its atomicity.

Molecules of Compounds

Different Types of Atoms

Atoms of different elements join together in definite proportions to form molecules of compounds. For example, Water (H_2O) has Hydrogen and Oxygen in a 1:8 mass ratio.

What is an Ion?

Charged Species

Compounds composed of metals and non-metals contain charged species known as ions. An ion can be negatively or positively charged.

Cations and Anions

A negatively charged ion is called an 'anion' (e.g., Chloride Cl-). A positively charged ion is called a 'cation' (e.g., Sodium Na+). A group of atoms carrying a charge is known as a polyatomic ion.

Writing Chemical Formulae

Valency

The chemical formula is a symbolic representation of composition. The combining power of an element is known as its valency. Valency is used to find out how atoms of an element will combine with another.

Rules

1. Valencies or charges must balance. 2. Metal symbol is written first (on the left). 3. Polyatomic ions are enclosed in brackets if more than one is present.

Formulae of Simple Compounds

Criss-Cross Method

To write the formula, write the constituent elements and their valencies below them. Then crossover the valencies of the combining atoms.

Example

For Hydrogen Chloride: Symbol H and Cl. Valency 1 and 1. Formula is HCl. For Magnesium Chloride: Symbol Mg and Cl. Valency 2 and 1. Formula is $MgCl_2$.

Molecular Mass

Calculation

The molecular mass of a substance is the sum of the atomic masses of all the atoms in a molecule. It is expressed in atomic mass units (u).

Example

For water (H_2O): 2 x (mass of H) + 1 x (mass of O) = 2x1 + 16 = 18 u.

Formula Unit Mass

It is calculated in the same way but used for substances whose constituent particles are ions (like NaCl).

Chapter 4: Structure of the Atom

Introduction to Structure of Atom

Fundamental Building Blocks

Atoms and molecules are the fundamental building blocks of matter. Different kinds of matter exist because of different atoms constituting them.

Key Questions

What makes the atom of one element different from another? Are atoms really indivisible as proposed by Dalton, or are there smaller constituents inside?

Charged Particles in Matter

Static Electricity

One of the first indications that atoms are not indivisible comes from studying static electricity. For example, rubbing a glass rod with silk cloth makes it electrically charged.

Source of Charge

This charge comes from within the atom, indicating that the atom is divisible and consists of charged particles.

Discovery of Sub-atomic Particles

Electrons and Protons

By 1900, it was known that the atom contained at least one sub-atomic particle, the electron, identified by J.J. Thomson. E. Goldstein discovered canal rays, which were positively charged radiations that led to the discovery of the proton.

Properties

The proton has a charge equal in magnitude but opposite in sign to the electron. Its mass is approximately 2000 times that of the electron.

The Structure of an Atom

Failure of Dalton's Theory

The discovery of electrons and protons led to the failure of the aspect of Dalton's theory that atoms are indivisible. Scientists then needed to understand how these particles are arranged within an atom.

Thomson’s Model of an Atom

Christmas Pudding Model

J.J. Thomson proposed that an atom was similar to a Christmas pudding or a watermelon. The positive charge is spread all over like the red edible part of a watermelon, while electrons are studded in it like seeds.

Neutrality

Thomson proposed that the negative and positive charges are equal in magnitude, making the atom electrically neutral.

Rutherford’s Model of an Atom

Gold Foil Experiment

Ernest Rutherford designed an experiment where fast-moving alpha particles were made to fall on a thin gold foil. He expected small deflections.

Unexpected Results

Most alpha particles passed straight through. Some were deflected by small angles. Surprisingly, one out of every 12000 particles appeared to rebound.

Nuclear Model

Rutherford concluded that most space inside the atom is empty. The positive charge and mass are concentrated in a very small volume called the nucleus. Electrons revolve around the nucleus.

Drawbacks of Rutherford’s Model

Instability Issue

The revolution of the electron in a circular orbit is not expected to be stable. Any particle in a circular orbit would undergo acceleration and radiate energy. Thus, the revolving electron would lose energy and fall into the nucleus, making the atom unstable. But we know atoms are stable.

Bohr’s Model of Atom

Discrete Orbits

Neils Bohr overcame the objections to Rutherford's model. He postulated that only certain special orbits known as discrete orbits of electrons are allowed inside the atom.

No Energy Radiation

While revolving in these discrete orbits, the electrons do not radiate energy. These orbits or shells are called energy levels (K, L, M, N).

Neutrons

Discovery

In 1932, J. Chadwick discovered another sub-atomic particle with no charge and a mass nearly equal to that of a proton. It was named the neutron.

Location

Neutrons are present in the nucleus of all atoms, except hydrogen. The mass of an atom is the sum of the masses of protons and neutrons.

Distribution of Electrons

Bohr-Bury Scheme

The maximum number of electrons in a shell is given by the formula 2n^2. For example, K-shell (n=1) can hold 2 electrons, L-shell (n=2) can hold 8.

Rules

The maximum number of electrons in the outermost orbit is 8. Shells are filled in a step-wise manner.

Valency

Combining Capacity

The electrons present in the outermost shell are called valence electrons. The combining capacity of an atom, or valency, is determined by the number of valence electrons.

Octet Rule

Atoms react to achieve a fully-filled outermost shell (usually 8 electrons), known as an octet. This is done by sharing, gaining, or losing electrons.

Atomic Number

Definition

The atomic number (Z) is defined as the total number of protons present in the nucleus of an atom. Elements are defined by the number of protons they possess.

Example

For Hydrogen, Z=1. For Carbon, Z=6. All atoms of an element have the same atomic number.

Mass Number

Nucleons

The mass of an atom is practically due to protons and neutrons alone, which are present in the nucleus. They are called nucleons.

Definition

The mass number (A) is the sum of the total number of protons and neutrons present in the nucleus of an atom.

Isotopes

Same Element, Different Mass

Isotopes are atoms of the same element having the same atomic number but different mass numbers. For example, Hydrogen has three isotopes: Protium, Deuterium, and Tritium.

Applications

Isotopes have similar chemical properties but different physical properties. Uranium isotope is used in nuclear reactors; Cobalt isotope is used in cancer treatment.

Isobars

Different Elements, Same Mass

Atoms of different elements with different atomic numbers, which have the same mass number, are known as isobars. For example, Calcium (Z=20) and Argon (Z=18) both have a mass number of 40.

Chapter 5: The Fundamental Unit of Life

The Fundamental Unit of Life

Introduction

Welcome to the amazing world of cells! In this chapter, we will learn about the fundamental unit of life.

Robert Hooke's Discovery

While examining a thin slice of cork, Robert Hooke saw that the cork resembled the structure of a honeycomb consisting of many little compartments. Cork is a substance which comes from the bark of a tree. This was in the year 1665 when Hooke made this chance observation through a self-designed microscope. Robert Hooke called these boxes 'cells'. Cell is a Latin word for ‘a little room’.

The Importance of the Discovery

This may seem to be a very small and insignificant incident, but it is very important in the history of science. This was the very first time that someone had observed that living things appear to consist of separate units. The use of the word ‘cell’ to describe these units is being used till this day in biology.

Timeline of Key Discoveries

Cells were first discovered by Robert Hooke in 1665. He observed the cells in a cork slice with the help of a primitive microscope. Leeuwenhoek (1674), with the improved microscope, discovered the free living cells in pond water for the first time. It was Robert Brown in 1831 who discovered the nucleus in the cell. Purkinje in 1839 coined the term ‘protoplasm’ for the fluid substance of the cell.

The Cell Theory

The cell theory, stating that all plants and animals are composed of cells and that the cell is the basic unit of life, was presented by two biologists, Schleiden (1838) and Schwann (1839). The cell theory was further expanded by Virchow (1855) by suggesting that all cells arise from pre-existing cells. With the discovery of the electron microscope in 1940, it was possible to observe and understand the complex structure of the cell and its various organelles.

What are Living Organisms Made Up of?

Building Blocks of Life

All organisms that we observe around are made up of cells. These small structures are the basic building units of life. For example, the cells of an onion peel will all look the same, regardless of the size of the onion they came from.

Unicellular vs. Multicellular Organisms

Some organisms consist of a single cell that lives on its own; these are called unicellular organisms. Examples include Amoeba, Chlamydomonas, and bacteria. In contrast, many cells group together in a single body to form various parts in multicellular organisms, such as fungi, plants, and animals. Every multi-cellular organism has come from a single cell, as cells divide to produce cells of their own kind.

Variety in Cells

Some organisms also have cells of different kinds. The shape and size of cells are related to the specific function they perform. Some cells, like Amoeba, have changing shapes. In other cases, the cell shape is more or less fixed, like nerve cells which have a typical long shape to transmit messages.

Division of Labour

Each living cell can perform certain basic functions. There is a division of labour in multicellular organisms, meaning different parts of the body perform different functions. Similarly, division of labour is also seen within a single cell. Each cell has specific components within it known as cell organelles, which each perform a special function.

What is a Cell Made Up of?

The Three Main Features

If we study a cell under a microscope, we would come across three features in almost every cell: the plasma membrane, the nucleus, and the cytoplasm. All activities inside the cell and interactions with its environment are possible due to these features.

Plasma Membrane or Cell Membrane

The Cell's Gatekeeper

This is the outermost covering of the cell that separates its contents from the external environment. The plasma membrane allows the entry and exit of some materials but prevents the movement of others. Therefore, it is called a selectively permeable membrane.

Diffusion and Osmosis

Substances like carbon dioxide or oxygen can move across the cell membrane by a process called diffusion—the movement from a region of high concentration to low concentration. The movement of water across this membrane is called osmosis. Osmosis is the net diffusion of water across a selectively permeable membrane toward a higher solute concentration.

Effect of Solutions on Cells

If the surrounding medium is a hypotonic solution (dilute), the cell will gain water and swell. In an isotonic solution (same concentration), there is no net water movement. In a hypertonic solution (concentrated), the cell will lose water and shrink.

Structure and Function

The plasma membrane is flexible and made of lipids and proteins. Its flexibility also allows the cell to engulf food from its external environment through a process known as endocytosis, which is how an Amoeba acquires its food.

Cell Wall

The Rigid Outer Layer

Plant cells have another rigid outer covering outside the plasma membrane called the cell wall. It is mainly composed of cellulose, a complex substance that provides structural strength to plants.

Plasmolysis and Turgidity

When a living plant cell loses water, the contents shrink away from the cell wall, a phenomenon known as plasmolysis. Conversely, the cell wall allows plant, fungi, and bacterial cells to withstand dilute external media without bursting. The cell swells, building pressure against the wall, which exerts an equal pressure back.

Nucleus

The Cell's Control Center

The nucleus has a double-layered covering called the nuclear membrane, which has pores to allow the transfer of material to the cytoplasm. The nucleus contains chromosomes, which are visible as rod-shaped structures only when the cell is about to divide.

Chromosomes and DNA

Chromosomes contain information for inheritance in the form of DNA (Deoxyribonucleic Acid) molecules. DNA molecules contain the information necessary for constructing and organizing cells. Functional segments of DNA are called genes. In a non-dividing cell, DNA is present as part of chromatin material.

Prokaryotes vs. Eukaryotes

In some organisms like bacteria, the nuclear region is poorly defined and lacks a nuclear membrane. This region, called a nucleoid, characterizes them as prokaryotes. Organisms with a true nuclear membrane are called eukaryotes.

Cytoplasm

The Cell's Interior

The cytoplasm is the fluid content inside the plasma membrane. It contains many specialised cell organelles, each performing a specific function. In prokaryotes, which lack membrane-bound organelles, many functions are performed by poorly organised parts of the cytoplasm.

The Importance of Membranes

The significance of membranes is illustrated by viruses, which lack any membranes and thus do not show characteristics of life until they enter a living body and use its cell machinery to multiply.

Cell Organelles

Specialized Structures

To support their complex structure and function, large eukaryotic cells use membrane-bound little structures, or 'organelles', to keep their chemical activities separate from each other. Some of these are visible only with an electron microscope. We will now discuss some of the most important ones.

Endoplasmic Reticulum (ER)

The Cell's Network

The ER is a large network of membrane-bound tubes and sheets. There are two types: rough ER (RER) and smooth ER (SER). RER looks rough because it has ribosomes attached to its surface, which are the sites of protein manufacture. SER helps in the manufacture of fat molecules, or lipids.

Functions of the ER

One function of the ER is to serve as a channel for transporting materials, especially proteins. It also functions as a cytoplasmic framework. In liver cells, SER plays a crucial role in detoxifying many poisons and drugs. The process of building the cell membrane using proteins and lipids from the ER is known as membrane biogenesis.

Golgi Apparatus

The Cell's Post Office

The Golgi apparatus consists of a system of membrane-bound vesicles arranged in stacks called cisterns. It receives material synthesized near the ER, which is then packaged and dispatched to various targets inside and outside the cell. Its functions include the storage, modification, and packaging of products. It is also involved in the formation of lysosomes.

Lysosomes

The Waste Disposal System

Lysosomes are membrane-bound sacs filled with powerful digestive enzymes made by the RER. They help to keep the cell clean by digesting any foreign material as well as worn-out cell organelles. When a cell gets damaged, lysosomes may burst and the enzymes digest their own cell. Therefore, they are also known as the ‘suicide bags’ of a cell.

Mitochondria

The Powerhouses of the Cell

Mitochondria are known as the powerhouses of the cell because they release the energy required for various chemical activities. This energy is in the form of ATP (Adenosine triphosphate) molecules, the energy currency of the cell. Mitochondria have two membrane coverings; the inner one is deeply folded to increase the surface area for ATP-generating reactions. Strangely, they have their own DNA and ribosomes.

Plastids

Plant Cell Organelles

Plastids are present only in plant cells. There are two types: chromoplasts (coloured) and leucoplasts (white or colourless). Chromoplasts that contain chlorophyll are known as chloroplasts and are important for photosynthesis. Leucoplasts are primarily for storing materials like starch, oils, and proteins. Like mitochondria, plastids also have their own DNA and ribosomes.

Vacuoles

Storage Sacs

Vacuoles are storage sacs for solid or liquid contents. Plant cells have very large vacuoles that can occupy 50-90% of the cell volume, providing turgidity and rigidity. Animal cells have small vacuoles. In single-celled organisms like Amoeba, the food vacuole contains consumed food items. In others, they play a role in expelling excess water and wastes.

Cell Division

Creating New Cells

The process by which new cells are made is called cell division. It's essential for growth, replacing old or injured cells, and forming gametes for reproduction. There are two main types: mitosis and meiosis.

Mitosis

The process of cell division for growth is called mitosis. In this process, a mother cell divides to form two identical daughter cells that have the same number of chromosomes as the mother cell.

Meiosis

Specific cells in reproductive organs divide by meiosis to form gametes (like sperm and eggs). This process involves two consecutive divisions and produces four new cells, each with half the number of chromosomes as the mother cell.

Chapter 6: Tissues

Introduction to Tissues

From Cells to Tissues

In unicellular organisms like Amoeba, a single cell performs all basic functions such as movement, food intake, and excretion. However, multicellular organisms have millions of cells, most of which are specialised to carry out specific functions.

Specialisation and Efficiency

Each specialised function is taken up by a different group of cells. Since these cells carry out only a particular function, they do it very efficiently. For example, muscle cells contract and relax to cause movement, while nerve cells carry messages.

Defining a Tissue

Cells specialising in one function are often grouped together in the body. This cluster of cells, called a tissue, is arranged and designed to give the highest possible efficiency of function. A group of cells that are similar in structure and/or work together to achieve a particular function forms a tissue.

Plants vs. Animals Tissues

Stationary vs. Mobile

Plants are stationary or fixed; they don't move. Since they have to be upright, they possess a large quantity of supportive tissue, which generally consists of dead cells. Animals, on the other hand, move around in search of food, mates, and shelter, consuming more energy. Most of their tissues are living.

Pattern of Growth

Growth in plants is limited to certain regions, where tissues divide throughout their life. Based on dividing capacity, plant tissues are classified as growing (meristematic) or permanent. Cell growth in animals is more uniform, with no clear demarcation of dividing and non-dividing regions.

Organ System Complexity

The structural organisation of organs and organ systems is far more specialised and localised in complex animals than in plants. This reflects their different modes of life: sedentary existence for plants and active locomotion for animals.

Meristematic Tissue

Regions of Growth

The growth of plants occurs only in certain specific regions because the dividing tissue, known as meristematic tissue, is located only at these points. Depending on the region, they are classified as apical, lateral, and intercalary.

Types of Meristem

Apical meristem is present at the growing tips of stems and roots and increases their length. Lateral meristem (cambium) increases the girth of the stem or root. Intercalary meristem is seen in some plants located near the node.

Characteristics of Cells

Cells of meristematic tissue are very active, have dense cytoplasm, thin cellulose walls, and prominent nuclei. They typically lack vacuoles.

Permanent Tissue

Differentiation

What happens to cells formed by meristematic tissue? They take up a specific role and lose the ability to divide. This process of taking up a permanent shape, size, and function is called differentiation, leading to the development of various types of permanent tissues.

Simple Permanent Tissue (Parenchyma)

Structure and Function

Parenchyma is the most common simple permanent tissue. It consists of relatively unspecialised living cells with thin cell walls. They are usually loosely arranged with large intercellular spaces. This tissue generally stores food.

Special Types

In some situations, parenchyma contains chlorophyll and performs photosynthesis; it is then called chlorenchyma. In aquatic plants, large air cavities are present in parenchyma to help them float; this type is called aerenchyma.

Collenchyma and Sclerenchyma

Collenchyma: Flexibility

The flexibility in plants is due to collenchyma. It allows bending of various parts like tendrils and stems without breaking and provides mechanical support. Its cells are living, elongated, and irregularly thickened at the corners with very little intercellular space.

Sclerenchyma: Stiffness

Sclerenchyma makes the plant hard and stiff (e.g., coconut husk). The cells are dead, long, and narrow with walls thickened due to lignin. There is often no internal space inside the cell. It provides strength to plant parts.

Protective Tissue

Epidermis

The outermost layer of cells is called the epidermis. It is usually a single layer of flat cells without intercellular spaces. It protects all parts of the plant. In dry habitats, it may be thicker with a waxy coating (cutin) to prevent water loss.

Stomata

Small pores in the epidermis of the leaf are called stomata. They are enclosed by two kidney-shaped guard cells and are necessary for gas exchange and transpiration.

Cork

As plants grow older, the outer protective tissue changes. A strip of secondary meristem forms layers of cork cells which are dead and compactly arranged. They have a substance called suberin in their walls that makes them impervious to gases and water.

Complex Permanent Tissue: Xylem

Complex Tissues

Complex tissues are made of more than one type of cells coordinating to perform a common function. Xylem and phloem are conducting tissues and constitute a vascular bundle.

Components of Xylem

Xylem consists of tracheids, vessels, xylem parenchyma, and xylem fibres. Tracheids and vessels have thick walls and are often dead when mature. They are tubular structures that transport water and minerals vertically. Xylem parenchyma stores food.

Complex Permanent Tissue: Phloem

Components of Phloem

Phloem is made up of five types of cells: sieve cells, sieve tubes, companion cells, phloem fibres, and phloem parenchyma. Sieve tubes are tubular cells with perforated walls.

Function

Phloem transports food from leaves to other parts of the plant. Unlike xylem, materials can move in both directions in phloem. Except for phloem fibres, other phloem cells are living cells.

Animal Tissues Overview

Types of Animal Tissues

On the basis of the functions they perform, animal tissues are classified into four main types: epithelial tissue, connective tissue, muscular tissue, and nervous tissue.

Epithelial Tissue

Protective Covering

Epithelial tissue is the covering or protective tissue in the animal body. It covers most organs and cavities and forms a barrier to keep different body systems separate. Cells are tightly packed with almost no intercellular spaces.

Types of Epithelium

Different types include: Simple squamous (thin and flat, lining blood vessels), Stratified squamous (arranged in layers, skin), Columnar (pillar-like, intestine), Ciliated columnar (with hair-like cilia, respiratory tract), and Cuboidal (cube-shaped, kidney tubules).

Connective Tissue: Blood and Bone

Characteristics

The cells of connective tissue are loosely spaced and embedded in an intercellular matrix. The matrix may be jelly-like, fluid, dense, or rigid.

Blood

Blood has a fluid matrix called plasma, in which RBCs, WBCs, and platelets are suspended. It transports gases, food, hormones, and waste materials.

Bone

Bone forms the framework that supports the body. It is a strong and nonflexible tissue. Bone cells are embedded in a hard matrix composed of calcium and phosphorus compounds.

Other Connective Tissues

Ligaments and Tendons

Ligaments connect two bones; they are very elastic and have considerable strength. Tendons connect muscles to bones; they are fibrous with great strength but limited flexibility.

Cartilage

Cartilage has widely spaced cells and a solid matrix of proteins and sugars. It smoothens bone surfaces at joints and is present in the nose, ear, trachea, and larynx.

Areolar and Adipose

Areolar tissue is found between skin and muscles, around blood vessels, and in bone marrow; it aids in repair. Adipose tissue stores fat below the skin and between internal organs, acting as an insulator.

Muscular Tissue

Movement

Muscular tissue consists of elongated cells called muscle fibres. It is responsible for movement. Muscles contain contractile proteins which contract and relax.

Types of Muscles

Striated (skeletal/voluntary) muscles are attached to bones and show light and dark bands. Smooth (involuntary) muscles control movements in the alimentary canal and blood vessels; they are unstriated. Cardiac muscles are involuntary muscles of the heart that show rhythmic contraction throughout life.

Nervous Tissue

Transmission of Stimuli

Nervous tissue is highly specialised for transmitting stimuli very rapidly. The brain, spinal cord, and nerves are composed of this tissue.

Neurons

The cells are called nerve cells or neurons. A neuron consists of a cell body with a nucleus, an axon (long part), and dendrites (short branched parts). Nerve impulses allow us to move our muscles when we want to.

Chapter 7: Motion

Introduction to Motion

Motion is Everywhere

In everyday life, we see objects at rest and in motion. Birds fly, cars move, and blood flows. Even atoms, planets, and stars are in motion.

Perception of Motion

We often perceive an object to be in motion when its position changes with time. Sometimes motion is inferred indirectly, like observing dust movement to know the wind is blowing.

Relative Motion

An object may appear moving to one person and stationary to another. For example, roadside trees appear to move backwards to passengers in a moving bus, but are stationary to a person on the road.

Describing Motion

Reference Point

To describe the location of an object, we specify a reference point called the origin. For example, if a school is 2 km north of the railway station, the station is the reference point.

Motion Along a Straight Line

Distance

The total path length covered by an object is the distance. It has only magnitude (numerical value) and no direction.

Displacement

The shortest distance measured from the initial to the final position of an object is known as displacement. It has both magnitude and direction.

Difference

The magnitude of displacement can be zero (if the object returns to the start), but the distance covered will not be zero.

Uniform and Non-Uniform Motion

Uniform Motion

If an object covers equal distances in equal intervals of time, it is said to be in uniform motion.

Non-Uniform Motion

If an object covers unequal distances in equal intervals of time, it is in non-uniform motion. Example: A car moving on a crowded street.

Measuring the Rate of Motion

Speed

The distance travelled by an object in unit time is called speed. The SI unit is metre per second (m/s).

Average Speed

Since speed is often not constant, we use average speed. Average speed = Total distance travelled / Total time taken.

Speed with Direction: Velocity

Definition

Velocity is the speed of an object moving in a definite direction. It specifies both magnitude and direction.

Changing Velocity

Velocity can change by changing the object's speed, direction of motion, or both.

Average Velocity

If velocity changes at a uniform rate, Average velocity = (Initial velocity + Final velocity) / 2.

Rate of Change of Velocity: Acceleration

Definition

Acceleration is the measure of the change in the velocity of an object per unit time. Acceleration = (Change in velocity) / (Time taken).

Formula

If velocity changes from u (initial) to v (final) in time t, then acceleration a = (v - u) / t. The SI unit is m/s^2.

Uniform Acceleration

If velocity changes by equal amounts in equal time intervals, acceleration is uniform (e.g., a freely falling body).

Graphical Representation: Distance-Time Graphs

Uniform Speed

For an object moving with uniform speed, the distance-time graph is a straight line. The slope of the line indicates the speed.

Non-Uniform Speed

For non-uniform speed, the graph is a curved line, showing non-linear variation of distance with time.

Velocity-Time Graphs

Uniform Motion

If an object moves at uniform velocity, the graph is a straight line parallel to the time axis. The area under the graph gives the displacement.

Uniform Acceleration

For uniformly accelerated motion, the velocity-time graph is a straight line. The area under the graph gives the distance travelled.

Equations of Motion

The Three Equations

For an object moving along a straight line with uniform acceleration: 1) $v = u + at$ (Velocity-time relation), 2) $s = ut + \frac{1}{2}at^2$ (Position-time relation), 3) $2as = v^2 - u^2$ (Position-velocity relation).

Symbols

u = initial velocity, v = final velocity, a = acceleration, t = time, s = distance.

Uniform Circular Motion

Accelerated Motion

When an object moves in a circular path with uniform speed, its direction changes continuously. Therefore, the velocity changes, making it an accelerated motion.

Examples

Examples include the motion of the moon around the earth, a satellite in orbit, or a stone tied to a thread and whirled in a circle.

Formula

Speed $v = (2\pi r) / t$, where r is the radius of the circular path and t is the time taken for one round.

Chapter 8: Force and Laws of Motion

Force and its Effects

What is Force?

In everyday life, we use muscular effort to push, hit, or pull objects to change their state of motion. The concept of force is based on this push, hit, or pull.

Effects of Force

Force can change the magnitude of velocity of an object (make it move faster or slower) or change its direction of motion. Force can also change the shape and size of objects (e.g., stretching a spring, pressing a rubber ball).

Balanced Forces

Definition

Balanced forces are forces that are equal in magnitude but opposite in direction. When balanced forces act on an object, they do not change its state of rest or of motion.

Example

If a wooden block is pulled from both sides with equal forces, the block will not move. The net force is zero.

Unbalanced Forces

Definition

When two opposite forces of different magnitudes act on an object, the forces are not balanced. The unbalanced force acts in the direction of the greater force.

Effect

An unbalanced force acting on an object brings it in motion or changes its speed or direction. To accelerate the motion of an object, an unbalanced force is required.

Friction

Opposing Force

Friction is a force that opposes motion. It arises between two surfaces in contact. For example, when you push a box on a rough floor, friction acts in the direction opposite to the push.

Balancing Push

If you push a box with a small force and it doesn't move, it's because the friction force balances the pushing force. The box only moves when the pushing force becomes bigger than the friction force.

First Law of Motion

Statement

An object remains in a state of rest or of uniform motion in a straight line unless compelled to change that state by an applied force.

Explanation

All objects resist a change in their state of motion. This tendency is called inertia. Therefore, the first law of motion is also known as the law of inertia.

Inertia

Definition

Inertia is the natural tendency of an object to resist a change in its state of motion or of rest.

Examples

When a bus starts suddenly, passengers fall backwards because their feet move with the bus but their bodies tend to remain at rest. When a bus stops suddenly, passengers fall forward because their bodies tend to continue moving.

Inertia and Mass

Measure of Inertia

Mass is a measure of inertia. Heavier or more massive objects offer larger inertia.

Comparison

It is easier to push an empty box than a box full of books. A force that can move a small cart will produce negligible change in a train. The train has more inertia than the cart.

Momentum

Definition

Momentum (p) of an object is defined as the product of its mass (m) and velocity (v). $p = mv$.

Properties

Momentum has both direction and magnitude. Its direction is the same as that of velocity. The SI unit is kilogram-metre per second (kg m/s).

Second Law of Motion

Statement

The rate of change of momentum of an object is proportional to the applied unbalanced force in the direction of force.

Significance

This law helps us measure the force acting on an object as a product of its mass and acceleration.

Mathematical Formulation of Second Law

Formula

Force (F) is proportional to the rate of change of momentum. $F = ma$, where m is mass and a is acceleration.

Derivation

Change in momentum = $m(v - u)$. Rate of change = $m(v - u)/t = ma$. Thus, $F = kma$. We choose units such that $k=1$, so $F = ma$.

Unit of Force

Newton

The SI unit of force is the newton (N). One newton is defined as the amount of force that produces an acceleration of 1 m/s^2 in an object of 1 kg mass.

Calculation

$1 \text{ N} = 1 \text{ kg} \times 1 \text{ m/s}^2$.

Applications of Second Law

Catching a Cricket Ball

A fielder pulls his hands backwards while catching a fast-moving cricket ball. This increases the time during which the high velocity of the ball decreases to zero.

Why?

Increasing the time decreases the rate of change of momentum, which in turn decreases the force exerted by the ball on the hands, preventing injury.

Third Law of Motion

Statement

To every action, there is an equal and opposite reaction.

Different Bodies

It is important to remember that the action and reaction forces always act on two different objects, simultaneously. They never act on the same object.

Action and Reaction

Example: Walking

When you walk, you push the road backwards (action). The road exerts an equal and opposite force on your feet (reaction) to make you move forward.

Accelerations

Even though action and reaction forces are equal in magnitude, they may produce different accelerations because they act on objects with different masses.

Recoil of a Gun

Mechanism

When a gun is fired, it exerts a forward force on the bullet. The bullet exerts an equal and opposite force on the gun. This results in the recoil of the gun.

Mass Difference

Since the gun has a much greater mass than the bullet, the acceleration of the gun is much less than the acceleration of the bullet.

Chapter 9: Gravitation

Introduction to Gravitation

Falling Objects

We observe that an object dropped from a height falls towards the earth. All planets go around the Sun, and the moon goes around the earth. Isaac Newton grasped that the same force is responsible for all these: the gravitational force.

Newton's Insight

Newton famously thought: if the earth can attract an apple, can it not attract the moon? He conjectured that the same type of force is responsible in both cases.

Centripetal Force

Circular Motion

The moon moves in a circular path around the earth. At every point, it changes direction, which involves a change in velocity or acceleration.

Centre-Seeking Force

The force that causes this acceleration and keeps the body moving along the circular path is acting towards the centre. This force is called the centripetal (meaning 'centre-seeking') force.

Absence of Force

In the absence of this force, the moon would fly off along a straight line tangential to the circular path.

Universal Law of Gravitation

The Law

Every object in the universe attracts every other object with a force which is proportional to the product of their masses and inversely proportional to the square of the distance between them.

Formula

$F = G * (M * m) / d^2$, where G is the universal gravitation constant, M and m are masses, and d is the distance.

Direction

The force is along the line joining the centres of two objects.

Free Fall

Falling Under Gravity

Whenever objects fall towards the earth under the gravitational force alone, we say that the objects are in free fall.

Acceleration

While falling, there is no change in the direction of motion, but the magnitude of velocity changes. This change involves acceleration.

Acceleration due to Gravity

Definition

The acceleration during free fall is due to the earth's gravitational force. It is denoted by 'g'. The unit is m/s^2.

Value of g

The value of g on the surface of the earth is approximately 9.8 m/s^2.

Independence of Mass

The acceleration experienced by an object during free fall is independent of its mass. This means all objects, hollow or solid, big or small, fall at the same rate (in vacuum).

Motion under Gravity Equations

Equations

Since g is constant near the earth, the equations of motion apply with 'a' replaced by 'g'. 1) $v = u + gt$, 2) $s = ut + \frac{1}{2}gt^2$, 3) $v^2 = u^2 + 2gs$.

Sign Convention

Acceleration 'a' is taken as positive when it is in the direction of velocity (downward motion) and negative when it opposes motion (upward motion).

Mass vs Weight

Mass

The mass of an object is the measure of its inertia. It remains the same everywhere, whether on earth, moon, or outer space. It is a constant quantity.

Weight

The weight of an object is the force with which it is attracted towards the earth. $W = m * g$. Weight has both magnitude and direction (downwards).

Variation

Weight depends on the value of g, so it changes from place to place. Mass does not change.

Weight on the Moon

Lesser Attraction

The mass of the moon is less than that of the earth. Due to this, the moon exerts lesser force of attraction on objects.

Comparison

The weight of an object on the moon is about one-sixth (1/6th) of its weight on the earth.

Thrust and Pressure

Thrust

The force acting on an object perpendicular to the surface is called thrust.

Pressure

The thrust on unit area is called pressure. Pressure = Thrust / Area. The SI unit is pascal (Pa).

Effect of Area

The same force acting on a smaller area exerts a larger pressure, and a smaller pressure on a larger area.

Pressure Examples

Everyday Applications

Why does a nail have a pointed tip? The small area of the tip results in high pressure, allowing it to penetrate wood easily.

Other Examples

Knives have sharp edges to cut easily (small area, high pressure). Buildings have wide foundations to distribute weight over a large area (low pressure).

Buoyancy

Upward Force

When an object is immersed in a fluid (liquid or gas), it experiences an upward force exerted by the fluid. This is called the buoyant force or upthrust.

Magnitude

The magnitude of the buoyant force depends on the density of the fluid.

Why Objects Float or Sink

Density Comparison

An iron nail sinks while a cork floats. This happens because of the difference in their densities relative to water.

Rule

Objects of density less than that of a liquid float on the liquid. Objects of density greater than that of a liquid sink in the liquid.

Archimedes' Principle

The Principle

When a body is immersed fully or partially in a fluid, it experiences an upward force that is equal to the weight of the fluid displaced by it.

Eureka!

Archimedes discovered this principle while taking a bath, noticing the water level rise.

Applications of Archimedes' Principle

Ships and Submarines

It is used in designing ships and submarines to ensure they float and can control their depth.

Instruments

Lactometers (used to determine purity of milk) and hydrometers (used for determining density of liquids) are based on this principle.

Summary of Gravitation

Key Points

The Law of Gravitation explains the force between any two objects. Weight varies with location; mass is constant. Objects float if less dense than the fluid.

Chapter 10: Work and Energy

Introduction to Work and Energy

Life Processes

All living beings need food for energy to perform basic activities. We also need energy for playing, singing, reading, etc.

Machines

Machines also need energy for their working. Some engines require fuel like petrol and diesel.

Connection

Work, energy, and power are closely related concepts that help us understand natural phenomena.

Scientific Conception of Work

Difference in Meaning

There is a difference between 'work' in day-to-day life and 'work' in science. Mental labour like studying is not considered work in science.

No Displacement, No Work

Pushing a huge rock that doesn't move involves a lot of effort but no work is done on the rock because there is no displacement.

Two Conditions for Work

The Conditions

For work to be done in science, two conditions must be satisfied: (i) a force should act on an object, and (ii) the object must be displaced.

Examples

A girl pulling a trolley is doing work because force is applied and displacement occurs. A book lifted up involves work.

Work Done by a Constant Force

Definition

Work done by a force acting on an object is equal to the magnitude of the force multiplied by the distance moved in the direction of the force.

Formula

Work (W) = Force (F) × Displacement (s). Work has only magnitude and no direction.

Unit

The unit of work is newton metre (N m) or joule (J). 1 J is the work done when a force of 1 N displaces an object by 1 m.

Positive and Negative Work

Positive Work

Work done is positive when the force is in the direction of displacement. Example: A baby pulling a toy car parallel to the ground.

Negative Work

Work done is negative when the force acts opposite to the direction of displacement. Example: Retarding force applied to a moving object.

Energy

Capacity to Do Work

An object having a capability to do work is said to possess energy. The object doing work loses energy, and the object on which work is done gains energy.

Measurement

Energy possessed by an object is measured in terms of its capacity of doing work. The unit of energy is the same as work: joule (J).

Sources

The Sun is the biggest natural source of energy. Other sources include nuclei of atoms, interior of earth, and tides.

Forms of Energy

Variety

Energy exists in many forms: mechanical energy (potential + kinetic), heat energy, chemical energy, electrical energy, and light energy.

Kinetic Energy

Energy of Motion

Kinetic energy is the energy possessed by an object due to its motion. A moving bullet, blowing wind, and a running athlete possess kinetic energy.

Speed Factor

The kinetic energy of an object increases with its speed. An object moving faster can do more work than an identical object moving relatively slow.

Formula for Kinetic Energy

Derivation

Work done to accelerate an object from velocity u to v is the change in kinetic energy. If starting from rest ($u=0$), Work = $\frac{1}{2}mv^2$.

Formula

Kinetic Energy (E_k) = $\frac{1}{2}mv^2$, where m is the mass and v is the velocity.

Potential Energy

Stored Energy

The energy transferred to an object is stored as potential energy if it is not used to cause a change in velocity. It is the energy present by virtue of position or configuration.

Examples

Stretching a rubber band or winding a toy car stores potential energy.

Potential Energy of an Object at a Height

Gravitational Potential Energy

When an object is raised through a height, work is done against gravity. The energy gained is gravitational potential energy.

Formula

$E_p = mgh$, where m is mass, g is acceleration due to gravity, and h is the height.

Path Independence

The work done by gravity depends on the difference in vertical heights, not on the path taken.

Interconversion of Energy

Transformation

Energy can be converted from one form to another. In nature, green plants convert solar energy to chemical energy (food).

Gadgets

Many human activities and gadgets involve energy conversion, like an electric bulb converting electrical energy to light and heat.

Law of Conservation of Energy

Statement

Energy can only be converted from one form to another; it can neither be created nor destroyed. The total energy before and after the transformation remains the same.

Free Fall Example

During free fall, potential energy decreases while kinetic energy increases. The sum (mechanical energy) remains constant at all points: $mgh + \frac{1}{2}mv^2 =$ constant.

Rate of Doing Work (Power)

Definition

Power is defined as the rate of doing work or the rate of transfer of energy. Power = Work / Time.

Unit

The unit of power is watt (W). 1 W = 1 Joule/second. Larger unit is kilowatt (kW).

Average Power

Since power may vary with time, we use average power = Total energy consumed / Total time taken.

Commercial Unit of Energy

Kilowatt-hour

The joule is too small for large energy quantities. We use kilowatt-hour (kWh). 1 kWh is the energy used in one hour at the rate of 1000 J/s.

Conversion

1 kWh = 3.6×10^6 J. This is commonly known as one 'unit' of electricity.

Chapter 11: Sound

Production of Sound

Vibration

Sound is produced by vibrating objects. Vibration means a kind of rapid to and fro motion of an object.

Examples

The sound of the human voice is produced due to vibrations in the vocal cords. A stretched rubber band when plucked vibrates and produces sound.

Propagation of Sound

Medium

The matter or substance through which sound is transmitted is called a medium. It can be solid, liquid, or gas.

Mechanism

When an object vibrates, it sets the particles of the medium around it vibrating. The particles do not travel all the way from the vibrating object to the ear, but the disturbance travels.

Sound Waves are Longitudinal

Compressions and Rarefactions

When a vibrating object moves forward, it creates a region of high pressure called compression (C). When it moves backward, it creates a region of low pressure called rarefaction (R).

Longitudinal Nature

In sound waves, the individual particles of the medium move in a direction parallel to the direction of propagation of the disturbance. Hence, sound waves are longitudinal waves.

Characteristics of a Sound Wave

Description

We can describe a sound wave by its frequency, amplitude, and speed.

Graphical Representation

A sound wave represents how density and pressure change. A peak represents the region of maximum compression (crest) and a valley represents the region of maximum rarefaction (trough).

Wavelength and Frequency

Wavelength

The distance between two consecutive compressions or two consecutive rarefactions is called the wavelength (λ). Its SI unit is metre (m).

Frequency

The number of complete oscillations per unit time is the frequency (ν). Its SI unit is hertz (Hz).

Time Period

The time taken for one complete oscillation is called the time period (T). Frequency $v = 1/T$.

Pitch and Loudness

Pitch

How the brain interprets the frequency of an emitted sound is called its pitch. Faster vibration means higher frequency and higher pitch.

Loudness

Loudness is determined by the amplitude of the wave. Large amplitude means loud sound. It depends on the force with which an object is made to vibrate.

Quality

Quality or timber enables us to distinguish one sound from another having the same pitch and loudness. A sound of single frequency is a tone; a mixture is a note.

Speed of Sound

Formula

Speed (v) = distance / time = wavelength (λ) × frequency (ν).

Factors

The speed of sound depends on the properties of the medium (temperature, state). It decreases from solid to gaseous state. In air at 22°C, it is 344 m/s.

Reflection of Sound

Laws of Reflection

Sound bounces off a solid or a liquid like a rubber ball. The directions of incident and reflected sound make equal angles with the normal, and all three are in the same plane.

Echo

Definition

If we shout near a reflecting object, we hear the same sound again. This is called an echo.

Conditions

To hear a distinct echo, the time interval between the original and reflected sound must be at least 0.1 s. At 22°C, the minimum distance to the obstacle must be 17.2 m.

Reverberation

Persistence of Sound

The repeated reflection that results in the persistence of sound in a big hall is called reverberation.

Reduction

To reduce reverberation, the roof and walls of the auditorium are generally covered with sound-absorbent materials like compressed fibreboard or draperies.

Uses of Multiple Reflection

Instruments

Megaphones, horns, and trumpets are designed to send sound in a particular direction using multiple reflection.

Stethoscope

In stethoscopes, the sound of the patient's heartbeat reaches the doctor's ears by multiple reflection of sound.

Ceilings

Ceilings of concert halls are curved so that sound after reflection reaches all corners.

Range of Hearing

Audible Range

The audible range of sound for human beings extends from about 20 Hz to 20000 Hz (20 kHz).

Age Factor

Children under five and some animals like dogs can hear up to 25 kHz. As people grow older, their ears become less sensitive to higher frequencies.

Infrasound and Ultrasound

Infrasound

Sounds of frequencies below 20 Hz are called infrasonic sound or infrasound. Whales and elephants produce sound in the infrasound range.

Ultrasound

Frequencies higher than 20 kHz are called ultrasonic sound or ultrasound. Dolphins, bats, and porpoises produce ultrasound.

Applications of Ultrasound

Cleaning

Ultrasound is used to clean parts located in hard-to-reach places (e.g., spiral tubes, electronic components). Dust and dirt get detached due to high frequency.

Flaw Detection

Ultrasounds can be used to detect cracks and flaws in metal blocks. If there is a defect, the ultrasound gets reflected back.

Medical Applications

Echocardiography

Ultrasonic waves are made to reflect from various parts of the heart and form the image of the heart.

Ultrasonography

Ultrasound scanner is used for getting images of internal organs (liver, kidney, etc.) and for examining the foetus during pregnancy.

Lithotripsy

Ultrasound may be employed to break small 'stones' formed in the kidneys into fine grains.

Chapter 12: Improvement in Food Resources

Introduction to Food Resources

Basic Needs

All living organisms need food. Food supplies proteins, carbohydrates, fats, vitamins, and minerals, which are required for body development, growth, and health.

Sources of Food

Both plants and animals are major sources of food for us. We obtain most of this food from agriculture and animal husbandry.

Need for Improvement

With a growing population, the demand for food is increasing. Since land for cultivation is limited, it is necessary to increase production efficiency for both crops and livestock.

Sustainable Practices

Increasing food production should not degrade our environment. Therefore, sustainable practices in agriculture and animal husbandry are essential.

Improvement in Crop Yields

Types of Crops

Cereals (wheat, rice, maize) provide carbohydrates for energy. Pulses (gram, pea) provide protein. Oil seeds (soyabean, groundnut) provide fats. Vegetables, spices, and fruits provide vitamins and minerals.

Crop Seasons

Different crops require different climatic conditions. Kharif crops (paddy, soyabean) are grown in the rainy season (June to October). Rabi crops (wheat, gram) are grown in the winter season (November to April).

Stages of Farming

Farming practices can be divided into three stages: choice of seeds, nurturing of crop plants, and protection of growing and harvested crops.

Crop Variety Improvement

Selecting Varieties

This approach depends on finding a crop variety that can give a good yield. Varieties can be selected by breeding for useful characteristics such as disease resistance, response to fertilisers, product quality, and high yields.

Hybridisation

One way to improve varieties is by hybridisation, which refers to crossing between genetically dissimilar plants. Another way is by introducing a gene that provides a desired characteristic, resulting in genetically modified crops.

Factors for Improvement

Varieties are improved for higher yield, improved quality, biotic and abiotic resistance (to diseases, drought, salinity), change in maturity duration (shorter duration is more economical), wider adaptability, and desirable agronomic characteristics.

Crop Production Management

Farming Levels

Farming ranges from small to very large farms. The farmer's purchasing capacity for inputs decides the production practices, which can be 'no cost', 'low cost', or 'high cost' production.

Nutrient Requirements

Plants require nutrients for growth. Air supplies carbon and oxygen, water supplies hydrogen, and soil supplies thirteen other nutrients.

Nutrient Management

Macronutrients

Six nutrients are required in large quantities and are called macronutrients: nitrogen, phosphorus, potassium, calcium, magnesium, and sulphur.

Micronutrients

Seven nutrients are used in small quantities and are called micronutrients: iron, manganese, boron, zinc, copper, molybdenum, and chlorine.

Deficiency

Deficiency of these nutrients affects physiological processes in plants including reproduction, growth, and susceptibility to diseases. Soil can be enriched by supplying manure and fertilizers.

Manure

Organic Matter

Manure contains large quantities of organic matter and small quantities of nutrients. It is prepared by the decomposition of animal excreta and plant waste. It increases soil fertility and improves soil structure.

Types of Manure

Compost is farm waste decomposed in pits. Vermi-compost uses earthworms to hasten decomposition. Green manure involves ploughing green plants like sun hemp into the soil to enrich it in nitrogen and phosphorus.

Benefits

Using manure recycles farm waste and protects the environment from excessive use of fertilizers.

Fertilizers

Commercial Nutrients

Fertilizers are commercially produced plant nutrients. They supply nitrogen, phosphorus, and potassium to ensure good vegetative growth (leaves, branches, flowers).

Precautions

Fertilizers should be applied carefully in terms of dose and time. Excessive irrigation can wash them away, leading to water pollution.

Long-term Effect

Continuous use of fertilizers can destroy soil fertility because organic matter is not replenished and micro-organisms are harmed. Organic farming is a system with minimal use of chemicals and maximum input of organic manures.

Irrigation

Water for Crops

Most agriculture in India is rain-fed. Ensuring crops get water at the right stages increases yields. Irrigation systems include wells (dug and tube wells), canals, river lift systems, and tanks.

Water Management

Fresh initiatives for increasing water availability include rainwater harvesting and watershed management. This involves building small check-dams to increase groundwater levels and reduce soil erosion.

Cropping Patterns

Mixed Cropping

Mixed cropping is growing two or more crops simultaneously on the same piece of land (e.g., wheat + gram). This reduces risk and gives insurance against failure of one crop.

Inter-cropping

Inter-cropping is growing two or more crops simultaneously in a definite pattern (e.g., alternating rows). Crops are selected with different nutrient requirements to ensure maximum utilisation of nutrients and prevent pest spread.

Crop Rotation

The growing of different crops on a piece of land in a pre-planned succession is known as crop rotation. Properly done, two or three crops can be grown in a year.

Crop Protection Management

Weeds

Weeds are unwanted plants (e.g., Xanthium, Parthenium) that compete for food, space, and light, reducing crop growth.

Pests and Diseases

Insect pests attack plants by cutting parts, sucking sap, or boring into stems/fruits. Diseases are caused by pathogens like bacteria, fungi, and viruses.

Control Methods

Control methods include pesticides (herbicides, insecticides, fungicides), mechanical removal, and preventive methods like proper seed bed preparation, timely sowing, and using resistant varieties.

Storage of Grains

Storage Losses

Losses in agricultural produce can be high due to biotic factors (insects, rodents, fungi) and abiotic factors (inappropriate moisture and temperature).

Effects

These factors cause degradation in quality, loss in weight, poor germinability, and discolouration.

Preventive Measures

Measures include strict cleaning of produce before storage, proper drying in sunlight and then shade, and fumigation using chemicals to kill pests.

Animal Husbandry & Cattle Farming

Cattle Farming Purposes

Cattle husbandry is done for milk (milch animals) and draught labour (draught animals) for agricultural work.

Breeds

Exotic breeds (e.g., Jersey) are selected for long lactation periods, while local breeds (e.g., Red Sindhi) show excellent disease resistance. They can be cross-bred to get both qualities.

Care and Feed

Proper shelter and hygiene are important. Feed includes roughage (fibre) and concentrates (protein-rich). Cattle suffer from diseases caused by parasites, bacteria, and viruses, necessitating vaccinations.

Poultry Farming

Egg and Meat Production

Poultry farming raises domestic fowl for egg production (layers) and chicken meat (broilers).

Variety Improvement

Cross-breeding programs focus on desirable traits like number and quality of chicks, dwarf broiler parents, summer adaptation, and low maintenance requirements.

Management

Broilers require protein-rich feed with adequate fat and high vitamins A and K. Maintenance of temperature, hygienic conditions, and disease control are crucial.

Fish Production

Sources of Fish

Fish production includes finned true fish and shellfish. It can be from natural resources (capture fishing) or fish farming (culture fishery). Sources include marine (seawater) and fresh water.

Marine Fisheries

Includes catching fish like pomphret and tuna using nets and satellites. Mariculture involves farming high-value marine fish like mullets, prawns, and oysters.

Inland Fisheries

Includes freshwater resources like canals and ponds. Composite fish culture uses a combination of 5-6 fish species in a single pond (e.g., Catla, Rohu, Mrigal) to utilise all food in the pond.

Bee-keeping

Honey Production

Bee-keeping is an agricultural enterprise for making honey and wax. It needs low investment.

Bee Varieties

Local varieties include the Indian bee (Apis cerana indica), rock bee (A. dorsata), and little bee (A. florae). The Italian bee (A. mellifera) is used for high honey collection capacity and less stinging.

Pasturage

The quality and taste of honey depend upon the pasturage, or the flowers available to the bees for nectar and pollen collection.