# SCIENCE

## Grade 10

## Part - I

Educational Publications Department

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# Contents

Biology

# 01

# Chemical Basis of Life

The bodies of all organisms are composed of variety of chemical compounds. These chemical compounds are formed by the bonding of naturally existing elements in different ways.

There are only about 25 elements in the living body out of the 92 elements present in nature. They are present at different locations in the body in different forms.

The most common 4 elements in the living body are Carbon, Hydrogen, Oxygen and Nitrogen. Other than above Sulphur, Phosphorous, Sodium, Potassium, Calcium, Magnesium, Iron and Chlorine are essential for the survival of organisms.

Figure 1.1 shows the percentages of main elements in the human body.

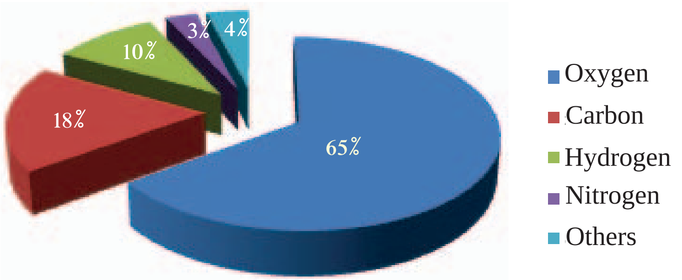



**Figure 1.1- Percentages of 4 common elements in the human body (mass basis)**

Chemical compounds that build up living matter can be divided into two categories as organic compounds and inorganic compounds. Compounds which contain Carbon are known as organic compounds and compounds which do not contain Carbon are known as inorganic compounds. (Carbon dioxide, Carbon monoxide,Carbonates and Bicarbonates are some of the inorganic compounds which contain Carbon) Those organic compounds that build up the living body or living matter are known as bio molecules. They are:

- Carbohydrates
- Proteins
- Lipids
- Nucleic acids

These are considered as the main types of bio molecules. Instead of these four types, Vitamins are also one of the organic compounds found in living matter. Water, minerals and gases are some of the inorganic molecules that are essential for the maintenance of life.

**For extra knowledge**

| Element | Percentage based on mass% | Locations present in human body |
|---|---|---|
| O | 65 | All fluids, tissues, bones, proteins |
| C | 18 | everywhere in the body |
| H | 10 | All fluids, tissues, bones, proteins |
| N | 3 | All fluids, tissues, proteins |
| Ca | 1.5 | Brain, lungs, kidneys, liver, heart, thyroid gland, muscles, bones |
| P | 1.0 | Urine, bones |
| K | 0.35 | Enzymes |
| S | 0.25 | Proteins |
| Na | 0.15 | All fluids, tissues |
| Mg | 0.05 | Brain, lungs, kidneys, liver, heart, thyroid gland, muscles |
| Cl | 0.2 | Skin cells |
| Fe | 0.007 | Haemoglobin in blood |
| I | 0.0002 | Hormones in thyroid gland |

## 1.1 Carbohydrates

This is the most abundant organic compound on earth. They are produced during the photosynthesis of green plants. Potato, sweet potato, grains, sugar, flour are some of the examples for foods which contain carbohydrates.

**The main elemental composition of carbohydrates is Carbon (C), Hydrogen (H) and Oxygen (O).**

Hydrogen and oxygen combine in 2:1 ratio in carbohydrates.

**Common molecular formula**

$C_x(H_2O)_y$

Carbohydrates can be classified into three groups as below according to the way they are formed.

**Carbohydrates**

| **Monosaccharides** ($C_6H_{12}O_6$) | **Disaccharides** ($C_{12}H_{22}O_{11}$) | **Polysaccharides** ($(C_6H_{10}O_5)_n$) |
|---|---|---|
| • Glucose | • Maltose | • Starch |
| • Fructose | • Sucrose | • Cellulose |
| • Galactose | • Lactose | • Glycogen |

n = Number of monosaccharide molecules

## • Monosaccharides

Monosaccharide is the structural unit of carbohydrates. They are commonly known as simple sugars. They are crystal shaped, generally sweet and water soluble molecules. Glucose, Fructose, and Galactose are examples for monosaccharides.

The characters of monosaccharides are discussed in the table below.

**Table 1.1- Characters of different types of monosaccharides**

| Type of monosaccharide | Location it's present | Other facts |
|---|---|---|
| Glucose | Ripen fruits<br>Bee honey | • The end product during hydrolysis of all starchy food is glucose. These glucose is absorbed into blood<br>• Plants produce glucose during photosynthesis<br>• Energy is released during breakdown of glucose in cellular respiration |
| Fructose | Ripen fruits<br>Beehoney<br>Pumpkin<br>carrots | • Known as "fruit sugar"<br>• Fructose is formed during ripening of fruits<br>• This is the sweetest sugar |
| Galactose | Dairy products | • The end product during hydrolysis of lactose<br>• No sweet taste |

- ## Disaccharides

Two Monosaccharides join to form a Disaccharide. During this process a water molecule is released. In the same way relevant Monosaccharides can be obtained by hydrolyzing Disaccharides. Disaccharides are sweet, water soluble crystals.

$$\text{Monosaccharide} + \text{Monosaccharide} \rightleftharpoons \text{Disaccharide} + \text{Water molecule}$$

$$2\,C_6H_{12}O_6 \rightleftharpoons C_{12}H_{22}O_{11} + H_2O$$

**Maltose, Sucrose** and **Lactose** are examples for disaccharides.

The characters of disaccharides are discussed in the table below.

**Table 1.2 - Characters of different types of disaccharides**

| Type of disaccharide | Location it's Present | Other Facts |
|---|---|---|
| Maltose | Germinating seeds | • Union of two glucose molecules forms a Maltose molecule .<br>Glucose + Glucose ⟶ Maltose + Water<br>• An intermediate product of starch hydrolysis |
| Sucrose | White and brown Sugar<br>Sugar cane and Beet<br>Some fruits<br>Phloem sap in trees | • Union of a Glucose molecule with a Fructose molecule forms a Sucrose molecule<br>Glucose + Fructose ⟶ Sucrose + Water |
| Lactose | In dairy products | • Union of a Glucose molecule with a Galactose molecule forms a Lactose molecule<br>Galactose + Glucose ⟶ Lactose + Water<br>• The only sugar that is absent in plants<br>• Not sweet as Sucrose<br>• The percentage of Lactose in cows milk according to the composition is 4% - 6%<br>• The percentage of Lactose in human milk according to the composition is 6% - 7% |

## Polysaccharides

Polymerisation of a large number of monosaccharides form a polysaccharide molecule. Hydrolysis of Polysaccharide results relevant monosaccharides. Insoluble in normal water. They are not crystals. **Cellulose**, **Starch** and **Glycogen** are examples for polysaccharides. The structural unit of Cellulose, Starch and Glycogen is Glucose , but their properties are different according to the number of Glucose molecules and how they are bound with each other.

The characters of polysaccharides are discussed in the table below.

**Table 1.3 - Characters of different types of polysaccharides**

| Type of polysaccharide | Location it's Present | Other Facts |
|---|---|---|
| Cellulose | Cell wall of plant cells<br>In fibres | • It is not digested in the human digestive system, but it helps to avoid constipation. |
| Starch | Grains, Yams, Jak, Bread Fruit | • The type of carbohydrate that stores in plants is starch. |
| Glycogen | Animal liver and muscles | • The type of carbohydrate that stores in animal body is Glycogen |

**For extra knowledge**

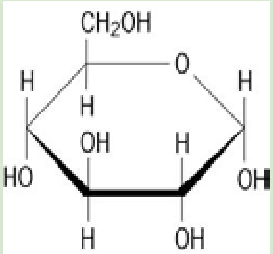



**Figure 1.2 Structure of a glucose molecule**

## Significance of Carbohydrates

- **As an energy Source**

  The main source to obtain energy for the activities ofor ganisms ist he c arbohydrate.The Monosaccharides (Glucose) produced due to hydrolysis of those compounds release energy.
- **As a storage compound**
- **As a structural component in plant cell wall**
- **As a constituent of Nucleic acid**

## Tests to identify Carbohydrates

The below mentioned tests can be conducted to test Starch, Monosaccharides and Disaccharides which are some of the identified Carbohydrates in foods.

### Starch test

- Small amount of food is obtained and grind well with water.
- A drop of Iodine solution is added to the above solution.

  Purplish blue colour appears

### Test for Glucose

- A solution of Glucose is obtained into a test tube.
- Few drops of Benedict solution to the above solution is added.
- The above solution is immersed in a water bath and heated.
- Can observe colour changes as below.

Blue → Green → Green yellow → Orange → Brick red precipitate

### Test for (Sucrose)

- A sucrose solution is obtained into a test tube.
- Few drops of Benedict solution is added to it.
- The test tube is immersed in a water bath and heated.

  No colour change.
- Few drops of diluted Sulphuric acid ($H_2SO_4$) is added to a freshly prepared sugar solution and heated.
- Next few drops of Benedict solution is added to it.
- Can observe colour changes as below.

Blue → Green → Green yellow → Orange → Brick red precipitate

## 1.2 Proteins

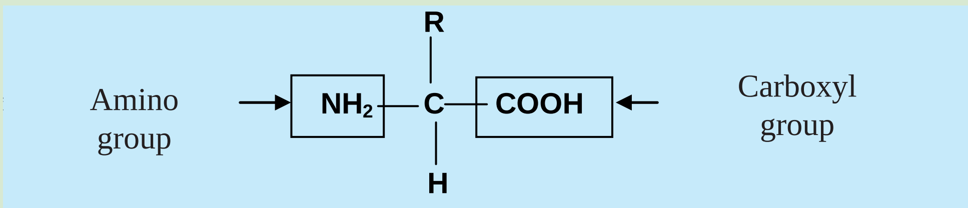
Protein is an essential constituent in all living cells. **Carbon(C) Hydrogen (H), Oxygen (O) and Nitrogen (N) are always present in proteins.** Sometimes Sulphur can also be present.

17% of the mature human body is composed of proteins. Protein is a complex molecule made up of polymerized amino acid molecules. Meat, fish, egg white cereals are some of the foods rich with proteins.

**For extra knowledge**

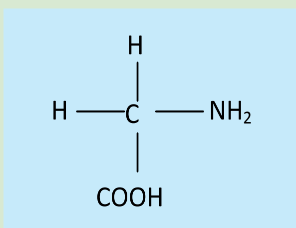
- ### Amino acids

Below is the structure of a typical amino acid molecule.




R-represents a group containing both Carbon (C) and Hydrogen (H). Due to the change in R group, 20 different amino acids are present. All proteins present in organisms from bacteria to human are made up of these 20 different amino acids combined in different sequences.

**The simplest Amino acid is Glycine. Here Hydrogen (H) is present as the R group.**




Some amino acids cannot be synthesized within the body. So they have to be taken from outside with food. Therefore they are known as essential amino acids.

**For extra knowledge**

Different proteins present in plants and animals

- Proteins present in muscles - Myosin, actin
- Proteins present in bones - Osein
- Proteins present in Red blood cells - Haemoglobin
- Proteins present in hairs - Keratin
- Proteins present in Leguminous food - Legumin
- Proteins present in wheat - Gluten
- Proteins present in egg white - Albumin

## • Significance of Proteins

- **As an energy source**

  When energy supply from Lipids and Carbohydrates is not sufficient protein is used in energy generation.

- **To make structural components**

  Proteins are important components in making cell membrane. Hairs and feathers also contain keratin protein.

- **As enzymes**

  All the bio-chemical reactions take place in organisms are catalyzed by enzymes. The enzymes are proteins.

- **As hormones**

  Some hormones are proteins which involve in homeostasis and coordination of organisms.

- **As antibodies**

  The antibodies that are produced in the body to protect the body against microorganisms that enter into the body are proteins.

### Test to identify proteins

**Biurete test**

- A solution made by grinding dhal or an egg white is obtained into a test tube.
- An extra amount of Sodium hydroxide (NaOH) and then few drops of Copper Sulphate is added into it.($CuSO_4$)

  Solution turn to purple colour

## ■ Enzymes

The special proteins (organic catalysts) that are produced within the organism to increase the rate of bio-chemical reactions are known as enzymes.

For example to convert Sucrose into Glucose, Sucrose has to be heated with a dilute acid. But the enzymes present in the digestive system do the same reaction at a low temperature.

Therefore the activity of enzyme is to catalyze the bio-chemical reactions.

Engage in the following activity on how enzymes function.

**Activity 01**

### Activity of Amylase on Starch

### Materials required

Flour, Amylase, Test tube, white porcelain tile, Iodine solution, Water, A stop watch

### Method

- Put 2ml of Starch solution into a test tube.
- Add 2ml of Amylase (Filter a solution of ground germinating green gram (Mung) seedlings) into it and mix well.
- Get a drop from the solution after 2 minutes and place it on a white porcelain tile.
- Add a drop of Iodine onto the drop of mixture.
- Continue same procedure for about 20 minutes in 2 minute intervals.

The blue colour of the drop obtained from the mixture gradually reduces with time and finally obtains the colour of Iodine (yellow /brown colour)

Starch gives black blue colour with Iodine but it does not give colour change with Iodine after 20 minutes as there is no Starch there.That is because Starch is converted to Maltose by Amylase enzyme.

## 1.3 Lipids

Fats and oils belong to this group. Lipids which are solid at room temperature are called fats and liquids are called oils.

**Similar to carbohydrates, fats also contain Carbon, Hydrogen and Oxygen as constituent elements.** But a lipid contains much less oxygen than a carbohydrate. Lipids are insoluble in polar solvents including water. They are soluble in organic solvents.

Ground nut, coconut, gingelly, butter and margarine are examples for foods which contain lipids.

Fatty acids and glycerol react to form Lipids.

$$\text{Fatty acids} + \text{Glycerol} \longrightarrow \text{Lipids} + \text{Water}$$

### • Significance of Lipids

- **As an energy source**

  Lipids act as an energy source as carbohydrates and proteins. More energy is produced during burning of lipids.

- **To form different structural components**

  Lipid is one of the most important compounds in cell membrane. (Specially phospho lipids and cholesterol)

- **For conservation of water**

  The wax known as cutin present on the surface of the plant body conserve water. Most animals' body covering also contains wax which helps to avoid desiccation as it is impermeable to water.

- **To maintain the body temperature**

  Warm blooded animals such as birds and mammals possess a hypodermal fat layer which acts as a thermal insulator. It helps to maintain their body temperature.

- **To protect internal body organs**

  The fat layer surrounds the organs and structures in the body and absorbs external shocks. Thereby provides protection.

- **To synthesize some hormones**

  Some Hormones of vertebrates (Oestrogen, Testosterone, Cortisone) are lipid compounds.

## Test to identify lipids

### Sudan III test

- Some amount of gingelly oil or coconut oil is added into a test tube.
- Sudan III reagent is added into it.

Appearance of red fat globules

### For extra knowledge

Fatty acids can be divided into two groups as follows.

**fatty acids**

**saturated fatty acids** | **unsaturated fatty acids**

**Saturated fatty acids**

fatty acids which contain only single bonds within Carbon atoms are called saturated fatty acids. Saturated fatty acids exist in room temperature as solids or semi-solids.

**Unsaturated fatty acids**

fatty acids which contain one or several double bonds within Carbon atoms are called unsaturated fatty acids.

Unsaturated fatty acids exist in room temperature as liquids.

## 1.4 Nucleic Acids

Nucleic acid is the most important molecule out of the main bio molecules in living matter in genetical aspect. It is a linear polymer made up of large number of nucleotides. **It contains Carbon (C), Hydrogen (H), Oxygen (O), Nitrogen (N) and Phosphorous (P).**

**For knowledge**

Each nucleotide is made up of 3 components. They are ;

- **Nitrogenous base**
- **Pentose suger group**
- **Phosphate group**

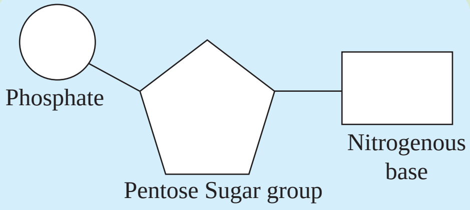



**Figure 1.3 - A nucleotide**

**There are two types of Nucleic acids**

- DNA - Deoxy ribo Nucleci Acid
- RNA - Ribo Nucleic Acid

- **DNA**

The structural unit of DNA is Deoxy ribo Nucleotide. DNA transfers genetic characteristics from generation to generation

- **RNA**

Except DNA, the other nucleic acid present in organisms is RNA.

The structural unit of RNA is Ribonucleotide.

Protein synthesis is the function of RNA.

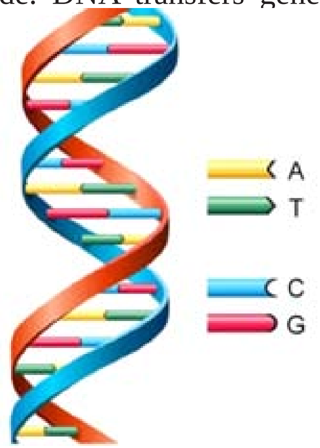



**Figure 1.4- The structure of a DNA molecule**

- **Significance of Nucleic acid**

- Important in storage of genetic information of organisms.
- Important in transferring genetic information from generation to generation.
- Important in protein synthesis process.
- Important in controlling all cellular activities in a cell. The information to control cellular activities is present in DNA.
- RNA is important in storing genetic information of some viruses.
- The variations occur in DNA due to mutations are important in evolution.

The above bio molecules contain mainly Carbon (C), Hydrogen (H),Oxygen (O) and Nitrogen (N). We will conduct below mentioned activities to confirm the presence of those elements.

**Activity 02**

### Identification of water as a constituent in food

**Materials required**

Meat, Egg shell, Plant leaves, Crucibles

**Method**

- Grind /crush meat, egg shell, and leaves in their dried form separately.
- Put them separately into the crucibles and heat them.
- During heating, hold a glass sheet above the crucible.
- Use Anhydrous Cobalt Chloride / Copper Sulphate to identify whether the liquid drops on the glass is water.

Blue coloured Anhydrous Cobalt Chloride turn to pink and white coloured Anhydrous Copper Sulphate turn to blue. Then it is confirmed that water is formed on the glass sheet. Therefore the food that is used for the experiment contains water as a constituent.

**Activity 03**

### Identification of presence of Carbon(C) in bio-molecules

**Materials required**

Several crucibles, Spinach stems, Piece of fish, Chick pea

**Method**

- Make pulps by crushing all above materials separately.
- Put them separately into crucibles and heat well.
- The final residue obtained should be rubbed against a white paper.

Lines drawn due to coal is observed.

Can confirm the food that is used for the experiment contains Carbon (C).

Activity 04

### Identification of presence of Nitrogen(N) in bio-molecules

**Materials Required**

Two test tubes, solution of Sodium hydroxide, solution of Copper sulphate, egg white, piece of fish.

**Method**

- Crush fish thoroughly, add water and mix well. Filter the solution.
- Put 2ml of the fish extraction and egg white into separate test tubes.
- Add equal volume of sodium hydroxide.
- Add few drops of copper sulphate to it.

Purple colour appears in the solution and this confirms the presence of Protein in food. As Nitrogen is a constituent of Proteins, it is confirmed that the above tissues contain Nitrogen.

## 1.5 Water

The highest proportion of the body mass of living organisms is composed of water which is an inorganic compound. Two third ($2/3^{rd}$) of the body weight of most of organisms is by water. Water is an essential medium for the maintenance of living matter. Life originated in water. Composition of water is simple. As water is the most abundant inorganic compound found in livings beings, it is important in many biological functions. The table below, shows the specific properties of water and contribution of them to the maintenance of life.

**Assignment - 1.1**

As a group, collect information about specific features of water and functions to maintain life. Use internet, news papers and other journals. Present those information in a creative way to the class.

**Table 1.4 - Specific properties of water and its contribution for the maintenance of life**

| Specific Property | The contribution for the maintenance of life |
|---|---|
| • A good solvent | • Provides a medium for bio-chemical reactions in the cells of organisms.<br>• The main constituent in the extra-cellular fluids of organisms.<br>• Facilitates removal of excretory material and faecal matter of animals.<br>• Important in respiration of aquatic organisms as Oxygen ($O_2$) is soluble in water. |
| • A coolant | • Due to high specific heat capacity (Amount of heat needed to increare temperature by $1^0C$ in 1kg of mass) the body temperature does not fluctuate quickly with changes in the environment. |
| • High cohesive and adhesive force | • Being the main constituent of blood,it helps to transport nutrients, vitamins and hormones to relevant locations.<br>• Transports water to the upper parts of the plant due to high cohesive (water-water attractions) and adhesive (water-another molecule attractions) force of water molecules |
| • Differential expansion in freezing | • Density of water is higher than density of ice. When ice is formed they come to top layers of water keeping water as it is in the bottom. This provides living environment for aquatic organisms. |

## 1.6 Minerals

Minerals are important as a nutrient constituent to maintain the life processes of organisms. They are absorbed as trace or macro elements into the body. The elements needed in higher amounts are known as macro elements and the elements needed in small amounts are known as trace elements.

7% of the body weight is by minerals. ¾ th of the above amount is by Calcium and Phosphorous. Other than that Potassium, Iron, Magnesium, Copper and Iodine are also included. when the elements are not present in correct amounts, plants and animals show deficiency symptoms.

**Table 1.5 Functions of minerals in human body and deficiency symptoms of them**

| Element | Functions | Deficiency Symptoms |
|---|---|---|
| Potassium | • Controls the ionic balance of the fluid in the cell<br>• For the activity of heart and muscles<br>• Transmission of nerve impulses | • Weakening of muscles<br>• Psychological disorders |
| Sodium | • Activates enzymes<br>• Constituent of digestive juice<br>• To maintain constant osmotic pressure in cells<br>• Transmission of nerve impulses | • Respiratory disorders<br>• Cramps<br>• Nausea<br>• Diarrhoea |
| Magnesium | • Constituent of bones and teeth<br>• To control nerve activity in skeletal muscles<br>• Help in metabolic activities | • High heart beat<br>• Nerve irritability |
| Calcium | • Growth of bones and teeth<br>• Blood clotting<br>• Proper function of nerves<br>• Milk production<br>• Absorption of Vitamin B | • Weakening of bones and teeth<br>• Growth disorders<br>• Osteoporosis |

| | | |
|---|---|---|
| Phosphorous | • Growth of bones and teeth<br>• As a constituent of nucleic acid<br>• For carbohydrate and fat metabolism<br>• Instant release of energy in muscles and nerves | • Weakening of bones and become fragile |
| Iron | • Synthesis of haemoglobin<br>• Storage of oxygen in muscles<br>• As a constituent of enzymes | • Anaemia<br>• Sleepiness<br>• Hypoactive nature<br>• Weakness in psychological development |
| Iodine | • Synthesis of Thyroxin hormone | • Affects development of intelligence<br>• Lethargic attitude towards studies<br>• Limits body height |

Functions of minerals in plants and deficiency symptoms of them are mentioned in the following table.

**Table 1.6 Functions of minerals in plants and deficiency symptoms of them**

| Element | Functions | Deficiency Symptoms |
|---|---|---|
| Nitrogen | • As a constituent of amino acid, proteins, nucleic acid and chlorophyll | • Retardation in growth<br>• Chlorosis in mature leaves |
| Phosphorous | • As a constituent of nucleic acid and ATP (Adenosine Tri Phosphate) | • Retarded growth of roots<br>• Red and purple patches on leaves |
| Potassium | • Protein synthesis<br>• Opening and closing of stomata | • Chlorosis in leaves<br>• Yellow or brown patches in leaves |

| | | |
|---|---|---|
| Iron | • Synthesis of chlorophyll<br>• Synthesis of respiratory enzymes | • Chlorosis in tender leaves |
| Calcium | • Component of cell wall To maintain the structure and functions of plasma membrane For the Activity of enzymes | • Dying of tissues at the tips of the leaves |
| Zinc | • For the activity of most enzymes Synthesis of chlorophyll | • Dead cells and tissues throughout the plant. Extra thickness in leaves |
| Sulphur | • As a constituent of amino acids and proteins | • Chlorosis in veins and areas between veins. |

Nitrogen deficiency symptoms
(Chlorosis in mature leaves)

Zinc deficiency symptoms
(Extra thickness in leaves)

Phosphrous deficiency symptoms
(Red and purple patches on leaves)

Potassium deficiency symptoms
(Yellow or brown patches in leaves)

Calcium deficiency symptoms
(Dying of tissues at tips of the leaves)

**Figure 1.5- Deficiency symptoms in plants**

**Assignment 1.2**

Observe a field or a farm and collect different parts of plants with different deficiency symptoms. Identify the deficient element for the relevent disease condition. (Make sure not to harm the cultivation)

## 1.7 Vitamins

They are organic compounds important in bio chemical reaction. Vitamins can be classified into 2 groups according to the solubility in water. Vitamin B and C are water soluble and A, D, E, and K are insoluble in water. But these are fat soluble.

The vitamins are needed for activities of human body, Their uses and deficiency symptoms are given in table 1.7.

**Table 1.7 - Uses of vitamins and their deficiency symptoms**

| Type of Vitamin | Use | Deficiency Symptoms |
|---|---|---|
| Vitamin A | • Formation of visual pigments important in eye vision<br>• To keep skin healthy and fair | • Night blindness<br>• Bitot's patches in the eye<br>• Dryness in the skin<br>• Blisters on knees and elbow<br>• Diseases associated with respiratory tract |
| Vitamin B | • Maintenance of nerves<br>• To maintain a healthy skin<br>• Formation of bone marrow<br>• Maturation of Red Blood Cells<br>• Antibody production | • Beriberi<br>• Anaemia<br>• Dryness in skin<br>• Change in complexion<br>• Reduction in antibody production |
| Vitamin C | • To keep skin healthy<br>• To form enamel.<br>• To synthesize collagen fibers. | • Weakening of gum<br>• Internal bleeding<br>• Delays recovery from diseases<br>• Scurvy |

| | | |
|---|---|---|
| Vitamin D | • Controls absorption of calcium and phosphorous | • Rickets (Deforming of bones) |
| Vitamin E | • Growth of tissues and cells | • Premature births<br>• Increase rate of breaking down of red blood cells<br>• Weaknesses in cell division<br>• Weaknesses in reproduction |
| Vitamin K | • To produce components needed for blood clotting | • Delays blood clotting |

**For knowledge**

Vitamin B is a complex vitamin. There are vitamins as $B_1$, $B_2$, $B_6$, $B_{12}$ in that complex. These are obtained through food and some vitamins are synthesized by bacteria living in human intestine.

Vitamin A deficiency symptoms
(Bito patches in the eye)

Vitamin B deficiency symptoms
(Change in complexion)

Vitamin C deficiency symptoms
(Weakening and bleeding of gum)

Vitamin D deficiency symptoms
(Deforming of bones)

**Figure 1.6- Deficiency symptoms in Vitamins**

## Summary

- The main substances that form the living body are carbohydrates, proteins, lipids and nucleic acids. They are known as bio molecules belong to living matter.
- Beside organic compounds, inorganic compounds such as water, mineral salts also play an important role in living systems.
- Main elements found in bio molecules are C,H,O,N.
- The proteins that catalyze biochemical reactions are enzymes.
- Although Minerals and vitamins are needed in small amounts, when they are deficient in supply, organisms show deficiency symptoms.
- The specific properties of water are highly important in maintenance of life.

## Exercises

01. Select the most appropriate answer.

(1) The food that contains highest amount of starch is,

1. Potato 2. Peanut 3. Cucumber 4. Gotukola

(2) Which belongs to monosaccharide?

1. Fructose 2. Sucrose 3. Maltose 4. Lactose

(3) A carbohydrate specially found in plants is,

1. Glycogen 2. Lactose 3. Cutin 4. Cellulose

(4) A Vitamin that helps in blood clotting is

1. Vitamin A 2. Vitamin D 3. Vitamin C 4. Vitamin K

(5) Not an organic compound present in living body,

1. Proteins 2. Water 3. Carbohydrates 4. Lipids

(6) An advantage of containing fibres in food is,

1. Low risk in cancers in large intestine 2. Prevent constipation

3. Helps, control blood sugar level 4. All the above

02. Below mentioned deficiency symptoms were identified at a health clinic conducted for grade 6 students in a particular school. Identify the relevant vitamin for the deficiency symptoms.

- Weaknesses in eye sight and bitot's patches in eyes..............................
- Weaknesses in growth of teeth and tooth decay..............................
- Bleeding gum ..............................
- Wounds at ends of mouth ..............................
- Anaemia ..............................

(03) State 3 specific features of water. Explain one briefly mentioning how it helps in continuation of life.

## Technical terms

| | | |
|---|---|---|
| Bio molecules | ජෛව අණු | உயிரியல் மூலக்கூறு |
| Enzymes | එන්සයිම | நொதியம் |
| Catalysts | උත්ප්‍රේරක | ஊக்கி |

Motion in a straight line

Physics 02

## 2.1 Distance and displacement

Distance is a concept familiar to you. When you go from home to school, you have to travel a certain distance. Sometimes, there can be several paths you could use to travel between home and school. Some of them could be shorter and some longer.

Figure 2.1 shows several paths that a child could take, to travel from a point *A* to another point *B*.

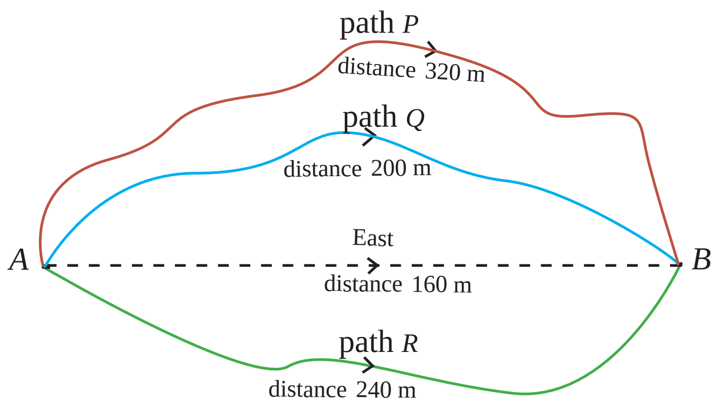



Figure 2.1 – Several paths between points *A* to *B*

If path *P* is used, the distance between point *A* to point *B* would be 320 m. If path *Q* is used, this distance would be 200 m. If path *R* is taken, the travel distance would be 240 m. This shows that the distance depends not only on the starting and the end points, but also on the path used to traverse the distance.

Whichever the path the child uses to reach *B* after starting from *A*, the ultimate result is that he has moved a distance of 160 m from *A* to *B* on a straight line towards the east . A change of position like this, that occurs from one point to another point in a particular direction is called **displacement**. The magnitude of the displacement is the shortest distance between the two points.

A physical quantity which can be described only by its magnitude is called a **scalar quantity**.

eg: speed, mass, time, distance

A physical quantity which can be described by its magnitude and direction is called a **vector quantity**.

eg: displacement, acceleration, velocity, weight

In the example above, the displacement of the child is 160 m to the east. Although the distance has changed according to the path taken, the displacement has remained the same.

In addition, there is another important difference between distance and displacement. Because we do not take the direction into account when measuring the distance, distance has only a magnitude. It does not have a direction. Therefore, distance is a scalar quantity. However, when measuring the displacement, the direction is important. In other words, the displacement has both a magnitude and a direction. Therefore it is a vector quantity.

Let us understand this concept further with following examples.

(i) Black colour arrow in the figure 2.2 shows the path taken by a child to travel from home to school.

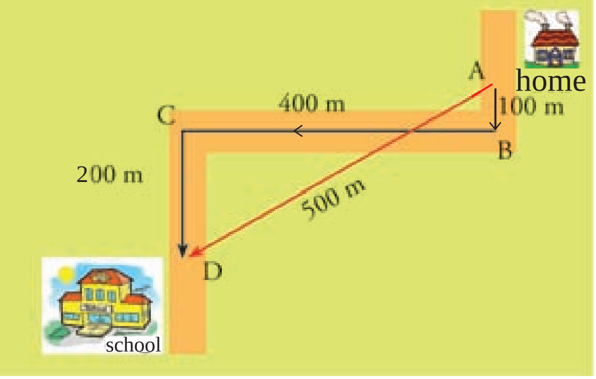



Figure 2.2 - Path taken by a child to travel from home to school

Total distance that the child has travelled between home and school is

$= AB + BC + CD = 100 \text{ m} + 400 \text{ m} + 200 \text{ m} = 700 \text{ m}$

However, the straight line distance from home to school is 500 m. This means that the magnitude of the displacement is 500 m while its direction is along *AD*.

(ii) Now consider Figure 2.3. A child starts from point *A* and reaches the point *B* along the path indicated by the arrows.

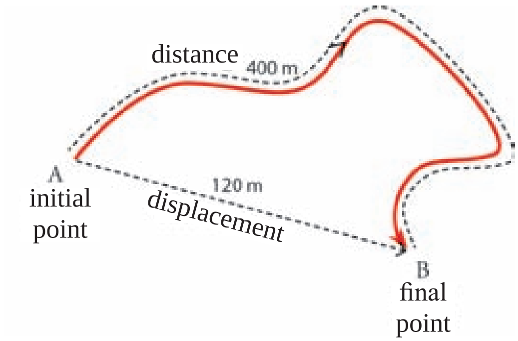



Figure 2.3 – A path between A and B

Even though the distance travelled by the child along this path is 400 m, the magnitude of his displacement is 120 m and the direction is along *AB*.

(iii) A 200 m running track used in track events is shown in Figure 2.4.

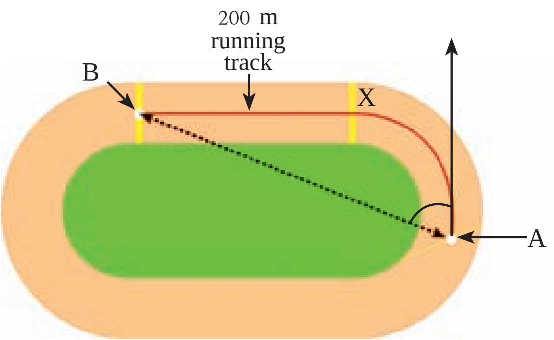



Figure 2.4 – A 200 m running track

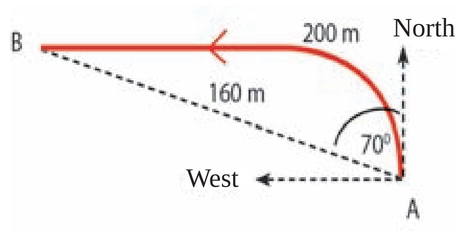



Figure 2.5 – Finding the direction of the athlete

An athlete who runs in this track from *A* to *B* reaches the point *B* after running a distance of 200 m. Then the displacement of the athlete can be indicated by the straight line *AB*. The magnitude of his displacement is 160 m. Its direction according to Figure 2.5 is $70^{o}$ from the north to west. This displacement can be expressed in the following manner.

**160 m in the direction $70^{0}$ from north to west.**

(iv) Now consider a situation where a child is walking 60 m from *A* to *B* along the straight line path as shown in Figure 2.6.

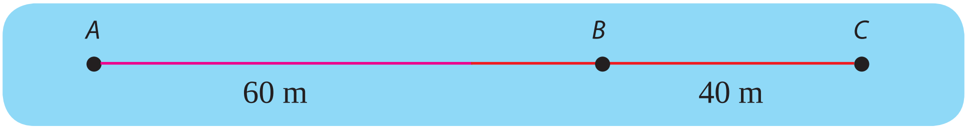



Figure 2.6 – Path of a child walking from *A*

The displacement of the child is 60 m along *AB*. Thereafter, if the child walks another 40 m along the same direction and reaches point *C*, what would be his total displacement?

When two or more displacements occur along the same direction, they can be either added or subtracted using ordinary arithmetic.

Since the displacements in the above example are in the same direction, total displacement = 60 m + 40 m = 100 m

This means that the child is now at a point 100 m away on a straight line from the starting point.

Now suppose that the child walks back 40 m after reaching the point *B*, as shown in Figure 2.7, instead of walking forward. The displacement corresponding to 40 m is in the opposite direction to that of *AB*. According to the figure 2.7 it is clear that the total displacement is given by the line AC. Therefore, although the distance traversed in this case too is 100 m, his displacement would be 60 m + (–40 m). That is 20 m.

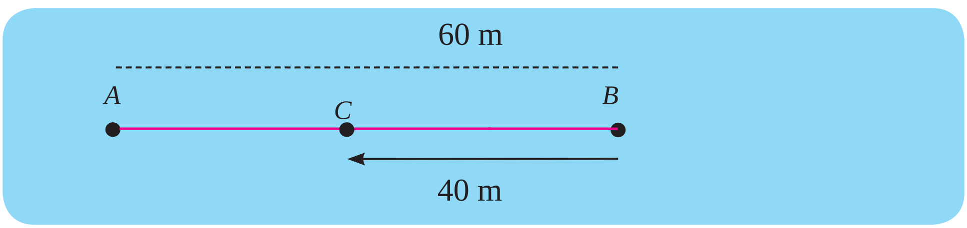



Figure 2.7 – Walking back 40 m after reaching point *B*

If he walked the same distance in the opposite direction after reaching the point *B*, his displacement would be 60 m + (–60 m). That is, a zero (0) displacement. From this we know that the child is back at the starting point.

### Exercise 2.1

A child starts from a point $A$ and walks 40 m to the East until he reaches another point $B$ and from $B$ he walks 30 m to the North to reach the point $C$ as shown in Figure 2.8.

- What is the total distance traversed by the child?
- What is his displacement?

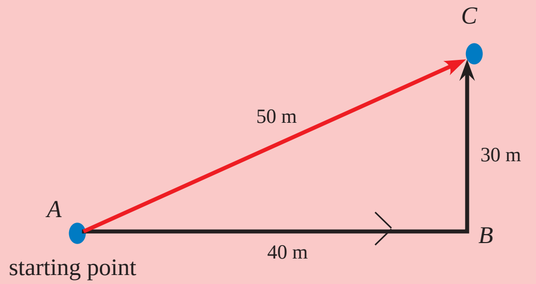



Figure 2.8 - A path walked by a child from $A$ to $C$

## 2.2 Speed

We frequently hear about accidents caused by vehicles moving at high speeds.


Due to this reason, there are different regulatory speed limits assigned to different roadways. We should obey these speed limits in order to prevent accidents, particularly in highways with high speed limits.

What we mean by **speed** is the rate at which a given distance is traversed.

$$\textbf{speed} = \frac{\textbf{distance}}{\textbf{time}}$$

In other words, speed is the **distance traversed in a unit time.**

Vehicles moving in roadways cannot maintain the same speed throughout the travel time. The speedometer of a motor vehicle usually indicates only the speed of the vehicle at a particular instant. When there is heavy traffic, vehicles have to slow down, and when there are pedestrians crossing the road, the vehicles even have to stop. On the other hand, if there are only a few other vehicles in the road, the same speed can be maintained for a fairly long distance. Let us consider two such instances, one where the same speed is maintained, and the other where the speed changes with time, through the following examples.

The distance traversed by a certain object at different instances in time is shown in the table below.

| Time $t$ (s) | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| Distance traversed $d$ (m) | 0 | 3 | 6 | 9 | 12 | 15 | 18 |

According to these data,

Distance traversed by the object during the first second = (3 - 0) = 3 m

Distance traversed during the next second = (6 - 3) = 3 m

Similarly, the distances traversed during each of the third, fourth, fifth and sixth seconds is also 3 m.

That is, the object has traversed 3 m during each 1 s time interval. Therefore, in this case we can say that the object has moved at a **uniform or constant speed.**

$$\text{speed} = \frac{\text{distance}}{\text{time}}$$

Since the time is given in seconds and the distance in meters, the speed has the unit $ms^{-1}$ ($\frac{m}{s}$). Accordingly, the above object has a speed of 3 m $s^{-1}$.

Now let us consider the motion of another object described by the following data table.

| Time $t$ (s) | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| Distance traversed $d$ (m) | 0 | 3 | 5 | 9 | 12 | 16 | 18 |

The distance traversed by this object is 3 m in first second, 2 m in second second and 4 m in third second etc.

Therefore the distance traversed by this object during each interval of one second is not the same. That is, this object has not travelled with a uniform speed.

In such instances, where an object does not travel with a uniform speed, it is useful to calculate the **mean speed** of the object during a given time interval. The mean speed of an object can be calculated by dividing the total distance travelled, by the corresponding time interval. Mean speed is also known as the average speed.

$$\textbf{mean speed or average speed} = \frac{\text{total distance travelled}}{\text{total time duration}}$$

The total distance travelled by this object during 6 s is 18 m. Therefore, the average distance travelled during a second = $\frac{18}{6} = 3$ m.

That is, the mean speed or average speed of the object $= \frac{18\text{ m}}{6\text{ s}}$

$= 3\text{ m s}^{-1}$

As another example, let us consider a vehicle that travelled a distance of 100 km from a location near Colombo to Peradeniya in 2 hours. In such a journey, a vehicle cannot maintain the same speed throughout the whole journey. However we could divide the total distance of 100 km by the total time duration of 2 hours as done above to calculate the average speed, which is 50 kilometers per hour.

## 2.3 Velocity

Because we calculate the speed in terms of distance, we do not consider the direction when we calculate the speed. Therefore, it must be clear to you by now, that the speed is a scalar quantity. The velocity however, is defined as the rate of change of the displacement. Therefore, it is a **vector quantity** that has both a magnitude and a direction.

The velocity of an object can be obtained by dividing its displacement by time.

$$\textbf{Velocity} = \frac{\textbf{displacement}}{\textbf{time}}$$

We learnt earlier that sometimes, bodies could move with uniform speeds while at other times they could move with non-uniform speeds. In a similar manner, the velocity of a body too can be uniform during certain time intervals while it can be non-uniform at other intervals.

The table below shows the displacement of a body along a specific direction, at the end of each 1 s time interval, as measured from the starting point.

| Time *t* (s) | 0 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| Displacement *s* (m) | 0 | 3 | 5 | 9 | 12 |

Since the increase in the displacement of the body during each second is 3 m, the motion has taken place at a **constant or uniform velocity**.

**When a body is moving at a constant velocity, neither the magnitude nor the direction of its velocity changes with time.**

If a body moves along a straight line at a constant velocity of 6 m $s^{-1}$, then the change in the displacement during each 1 s interval is 6 m. The direction of the motion too remains constant. If the body moves at this constant velocity for 5 s,

then its displacement after 5 s = 6 m $s^{-1}$× 5 s = 30 m.

That is, for a body moving at a constant velocity, the displacement after a certain time interval can be obtained by multiplying the velocity by the relevant time interval.

$$\text{Displacement} = \text{velocity} \times \text{time}$$

The following table shows the displacement of another object moving on a straight line, as measured during each 1 s time interval.

| Time *t* (s) | 0 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| Displacement *s* (m) | 0 | 4 | 7 | 9 | 12 |

The displacement of this object is 4 m in the first second, 3 m in the second second, and 2m in the third second etc. As the displacement is not the same in every second, the velocity of the object is not uniform. In such occasions we can calculate the **mean velocity.**

Mean velocity of the above object $= \dfrac{\text{displacement}}{\text{time}}$

$$= \frac{12 \text{ m}}{4 \text{ s}}$$

$$= \underline{\underline{3 \text{ m s}^{-1}}}$$

**Example 1**

The variation of the displacement, measured with respect to the starting point, of a child riding a bicycle on a straight path during each 1 s time interval is shown in the table below.

| Time *t* (s) | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Displacement *s* (m) | 0 | 2 | 4 | 6 | 8 | 8 | 8 | 8 | 8 | 4 | 0 |

(i) What kind of motion has the child undergone during the first 4 s?

(ii) What is the rate of change of the displacement during the first 4 s?

(iii) Give one word to describe the rate of change of the displacement.

(iv) What can you say about the motion of the child during the time period from 4 s to 8 s?

(v) Describe the motion during the time interval from 8 s to 10 s.

(vi) Find the velocity of the child during the last 2 s.

**Answers**

(i) The child has moved forward by 8 m at a uniform velocity during the first 4 s.

(ii) Rate of change of the displacement during the first 4 s $= \dfrac{\text{change of displacement}}{\text{time}}$

$$= \frac{\text{Final displacement - initial displacement}}{\text{time}}$$

$$= \frac{(8\text{-}0) \text{ m}}{4 \text{ s}}$$

$$= 2 \text{ m s}^{-1}$$

(iii) Rate of change of the displacement is the velocity.

(iv) The child has not moved during the time period from 4 s to 8 s.

(v) The displacement during the time interval from 8 s to 10 s has taken place in the opposite direction. He has come back to the starting point after 10 s.

(vi) Velocity of the child during the last 2 s

$$= \frac{\text{change of displacement}}{\text{time}}$$

$$= \frac{(0 - 8)\text{ m}}{2\text{ s}}$$

$$= -4\text{ m s}^{-1}$$

That is, the velocity is 4 m $s^{-1}$ in the opposite direction.

## 2.4 Acceleration

In everyday life we mostly encounter, objects that move with non-uniform velocities. Vehicles moving in roadways have to increase or decrease their velocities frequently. Sometimes they have to change their direction. The result of all these changes is the change of velocity.

The following table shows the manner in which the velocity of a body that travelled along a straight line varied with time.

| Time $t$ (s) | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| Velocity $v$ (m $s^{-1}$) | 0 | 2 | 4 | 6 | 8 | 10 | 12 |

According to the above data, the velocity of the body has changed from 0 m $s^{-1}$ to 12 m $s^{-1}$ during a 6 s period

Change in the velocity during 6 s = velocity at the end of 6 s − initial velocity

When we divide the above velocity change (12 m $s^{-1}$) by the time duration for this change (6 s), we get the rate of change of the velocity.

The rate of change of the velocity is known as the **acceleration**. That is, the change in velocity per unit time is the acceleration.

We already know that the unit of the velocity is m $s^{-1}$. Since the acceleration is the velocity change in a second, the acceleration has the unit $ms^{-2}$($\frac{ms^{-1}}{s}$).

Therefore we can calculate the acceleration of the above object in the following manner.

$$\text{Acceleration} = \frac{\text{final velocity - initial velocity}}{\text{time}}$$

$$= \frac{(12 - 0)\ m\ s^{-1}}{6\ s}$$

$$= 2\ m\ s^{-2}$$

When a body has an acceleration of 2 m $s^{-2}$, it means that its velocity changes by 2 m $s^{-1}$ during each second. If the acceleration has a positive value, it implies that the velocity is increasing. A negative acceleration means a decrease in the velocity.

Suppose that a body moving in a straight line had an initial velocity of 12 m $s^{-1}$, which later varied with time as shown in the following table.

| Time $t$ (s) | 0 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| Velocity $v$ (m $s^{-1}$) | 12 | 9 | 6 | 3 | 0 |

Here, the velocity has decreased. The acceleration of this body can be calculated in the following manner.

$$\text{Acceleration} = \frac{\text{change of velocity}}{\text{time}}$$

$$= \frac{(0 - 12)\ m\ s^{-1}}{4\ s}$$

$$= -3\ m\ s^{-2}$$

Here, we have obtained a negative value for the acceleration. It means that the velocity has decreased by 3 m $s^{-1}$ each second.

If the velocity is decreasing, the acceleration takes a negative value. A negative acceleration is known as a **deceleration**.

If a body has an acceleration of -3 m $s^{-2}$, it means that the body has a deceleration of 3 m $s^{-2}$.

If the velocity of a body either increases or decreases by the same amount every second, then that body is said to have a uniform acceleration or deceleration.

In order to find the displacement of a body moving at a uniform acceleration, we should find the mean velocity of the body and multiply it by the corresponding time.

**Displacement = mean velocity × time**

$$\text{Mean velocity} = \frac{\text{initial velocity} + \text{final velocity}}{\text{time}}$$

## Example 1

A body that starts from rest, is subjected to a uniform acceleration for 6 s after which, it acquires a velocity of 12 m $s^{-1}$. What is the displacement of the body during this time interval?

Since the acceleration is uniform, we can find the mean velocity by dividing the sum of the initial and final velocities by two.

$$\begin{aligned} \text{Displacement of the body} &= \text{mean velocity} \times \text{time} \\ &= \frac{(0 + 12)}{2}\ \text{m s}^{-1} \times 6\ \text{s} \\ &= \underline{\underline{36\ \text{m}}} \end{aligned}$$

## Example 2

A body starting from rest, accelerates for 4 s and acquires a velocity of 12 m $s^{-1}$. Thereafter it moves at a constant velocity of 12 m $s^{-1}$ for 4 s and ultimately comes to rest after decelerating for 2 s.

(i) Calculate the acceleration during the first 4 s.

(ii) Find the deceleration during the last 2 s.

(iii) What is the displacement of the body during the 10 s?

## Answers

(i) Acceleration during the first 4 s $= \dfrac{(12-0)\text{ m s}^{-1}}{4\text{ s}}$

$= 3\text{ m s}^{-2}$

(ii) Acceleration during the last 2 s $= \dfrac{(0-12)\text{m s}^{-1}}{2\text{ s}}$

$= -6\text{ m s}^{-2}$

Deceleration $= 6\text{ m s}^{-2}$

(iii) Displacement during the first 4 s = mean velocity × time

$= \dfrac{(0+12)\text{ m s}^{-1}}{2} \times 4\text{ s}$

$= 24\text{ m}$

Displacement during the next 4 s = uniform velocity × time

$= 12 \times 4$

$= 48\text{ m}$

Displacement during last 2 s = mean velocity × time

$= \dfrac{(12+0)\text{ m s}^{-1}}{2} \times 2\text{ s}$

$= 12\text{ m}$

Total displacement during the 10 s = 24 m +48 m +12 m

= 84 m

That is, the final position of the object after 10 s is 84 m away on a straight line from the starting point.

**Exercise 2.2**

1. If the velocity of an object increased uniformly from 0 to 12 m $s^{-1}$ during 6 s, find the acceleration of the object.

2. If the velocity of an object decreased uniformly from 16 m $s^{-1}$ to 4 m $s^{-1}$ during 4 s, calculate the deceleration of the object.

3. Starting from rest, if an object travelled with an acceleration of 0.5 m $s^{-2}$, for 10 s find the velocity of the object at the end of 10 s period.

4. The velocity of an object moving on a straight line was 2 m $s^{-1}$ at a certain instant. Its velocity changed to 6 m $s^{-1}$, after accelerating for 4 s. Find the acceleration during the 4 s period.

## 2. 5 Displacement-time graphs

Graphs that illustrate how the displacement of a body varies with time are known as displacement - time graphs. These graphs are plotted by marking the time on the *x*-axis and the displacement on the *y*-axis.

The following table shows the variation of the displacement of a body with time.

| Time *t* (s) | 0 | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| Displacement *s* (m) | 0 | 3 | 6 | 9 | 12 | 15 |

The displacement - time graph for the above data set is shown in Figure 2.9.

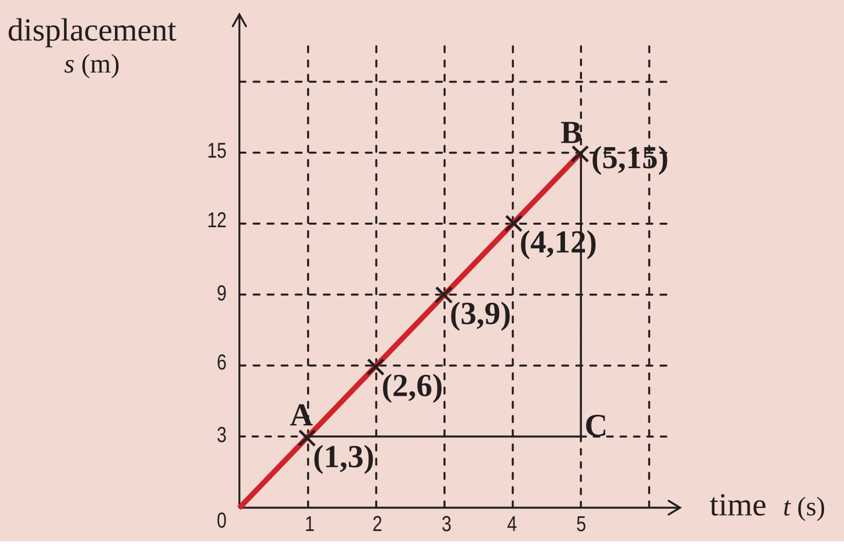



Figure 2.9 - A displacement - time graph

Since the velocity is uniform in this case, we get a straight line for the graph. For a body with the non - uniform velocity, we get a curve for the graph. The velocity can be obtained by determining the gradient of the graph.

The gradient of a straight line can be calculated by dividing the difference between the *y*-coordinates of any two points on that line by the difference between the corresponding *x*-coordinates of the two points. However, if two distant points are chosen to find the gradient the result will be more accurate.

Since the *x*-axis represents time, the difference between the *x*-coordinates of two points is a time interval. The corresponding difference between the *y*-coordinates is the displacement of the body during that time interval. What we get when the displacement is divided by time is a velocity.

$$\text{Gradient} = \frac{\text{difference between } y \text{ - coordinates}}{\text{difference between } x \text{ - coordinates}}$$

$$= \frac{\text{displacement}}{\text{time}} = \text{velocity}$$

Therefore, the velocity can be calculated by choosing two fairly distant points *A* and *B* on the above graph and by calculating the gradient as shown below.

$$\text{Gradient} = \frac{BC}{AC}$$

$$= \frac{(15\text{-}3)\text{m}}{(5\text{-}1)\text{ s}} = \frac{12\text{m}}{4\text{ s}} = 3\text{ m s}^{-1}$$

Therefore, the velocity of the motion represented by the above graph is $3\text{ m s}^{-1}$.

## 2.6 Velocity-time graphs

In order to represent the variation of velocity with time, velocity-time graphs are used. In velocity-time graphs, the time is plotted on the *x*-axis while the velocity is plotted on the *y*-axis.

The table below gives the variation of velocity with time for the motion of an object.

| Time $t$ (s) | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| Velocity $v$ (m $s^{-1}$) | 0 | 3 | 6 | 9 | 12 | 15 | 18 |

A velocity - time graph plotted using the above data is shown in Figure 2.10.

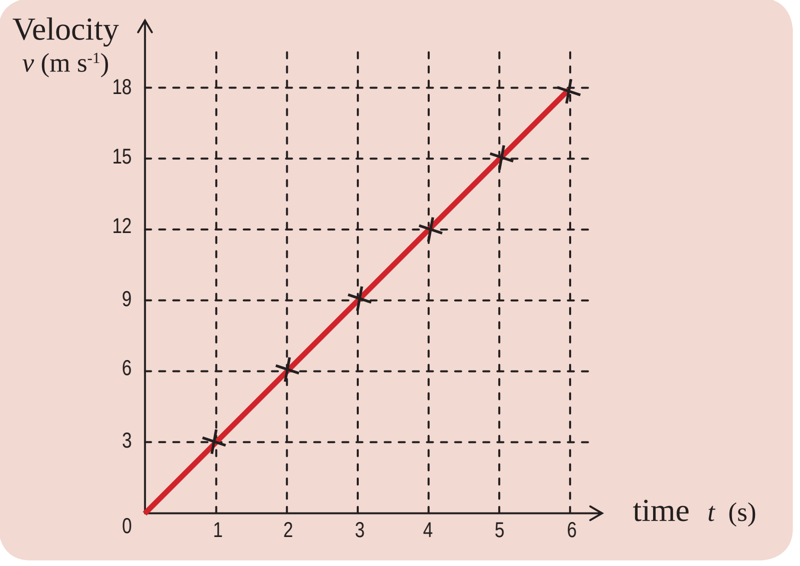



Figure 2.10 - A velocity - time graph

This graph is a straight line, because the increase in the velocity during each 1 s interval is the same. This represents a motion with a uniform (constant) acceleration.

As mentioned before, the gradient of the straight line can be obtained by dividing the difference between the $y$-coordinates of any two points on the graph by the difference between the corresponding $x$-coordinates.

In this graph also, the $x$-axis represents time. Therefore, the difference between $x$ coordinates gives a time interval. The corresponding difference in the $y$ coordinates gives the velocity difference during this time interval. Velocity difference divided by time gives an acceleration.

$$\text{Gradient} = \frac{\text{difference between velocities}}{\text{time}}$$
$$= \text{acceleration}$$

For the above graph,

$$\text{Acceleration} = \frac{(18 - 0)\ \text{m s}^{-1}}{6\ \text{s}}$$

$$= 3\ \text{m s}^{-2}$$

Figure 2.11 shows the velocity - time graph for the motion of a body moving at a constant velocity of 6 m $s^{-1}$. Since the velocity remains the same in a motion taking place with a constant velocity, this graph is a straight line parallel to the *x*-axis.

Since the velocity of the motion described by the above graph is 6 m $s^{-1}$, you can calculate the displacement as shown below, using the formula you learnt in section 2.3.

$$\text{Velocity} = \frac{\text{displcement}}{\text{time}}$$

$$\text{Displacement} = \text{velocity} \times \text{time}$$

$$= 6\ \text{m s}^{-1} \times 8\ \text{s}$$

$$= 48\ \text{m}$$

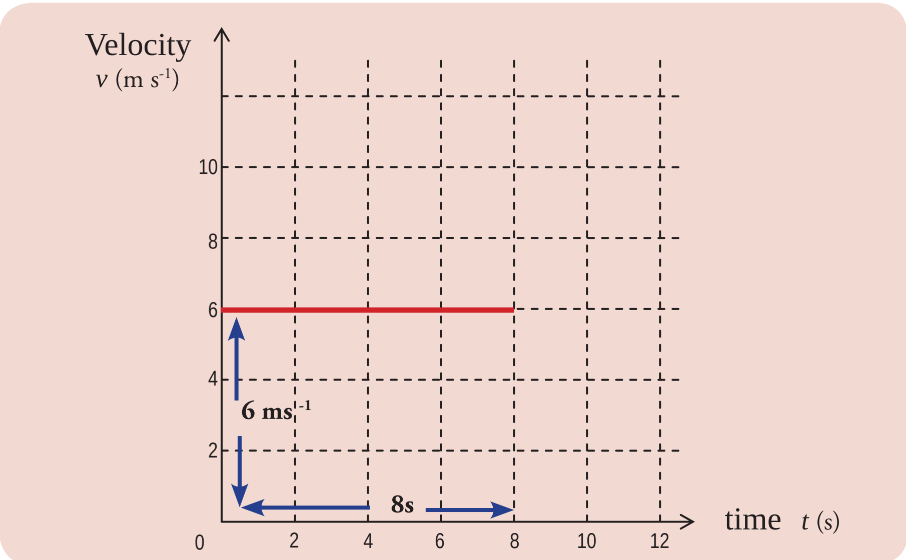



Figure 2.11 - Velocity - time graph of a body moving at a constant velocity

As shown in Figure 2.11 , the area under the straight line is $6 \times 8 = 48$ m. This area is calculated by multiplying the length along the *x*-axis (time) by the length along the *y*-axis (velocity).

That is, the displacement is equal to the area under the velocity - time graph.

Let us now consider how we could find the displacement of a body moving at a uniform acceleration using its velocity - time graph.

A body starting from rest, acquires a velocity of 12 m $s^{-1}$ after moving at a constant acceleration for 4 s. A velocity - time graph plotted for this motion is shown in Figure 2.12.

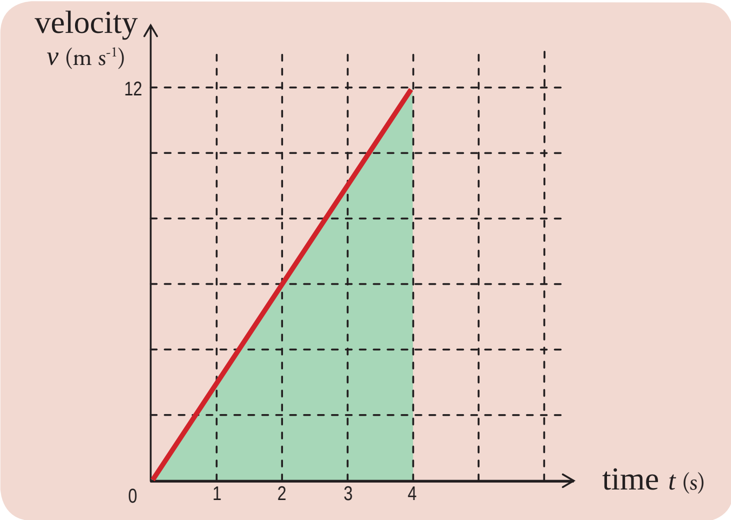



Figure 2.12 - A velocity - time graph of a body moving at a uniform acceleration

According what we learnt in section 2.4, the displacement of a body moving with a uniform acceleration can be found using the formula,

$$\text{Displacement} = \text{mean velocity} \times \text{time}$$

Therefore, for the motion shown in Figure 2.12,

$$\text{Displacement} = \frac{12 \text{ m s}^{-1}}{2} \times 4 \text{ s}$$

$$= 24 \text{ m}$$

The shaded area of the region below the graph of Figure 2.12,= $\frac{1}{2} \times 12 \times 4 = 24$

Again see how this area was calculated.

$$\frac{12 \times 4}{2}$$

12/2 is the mean velocity.

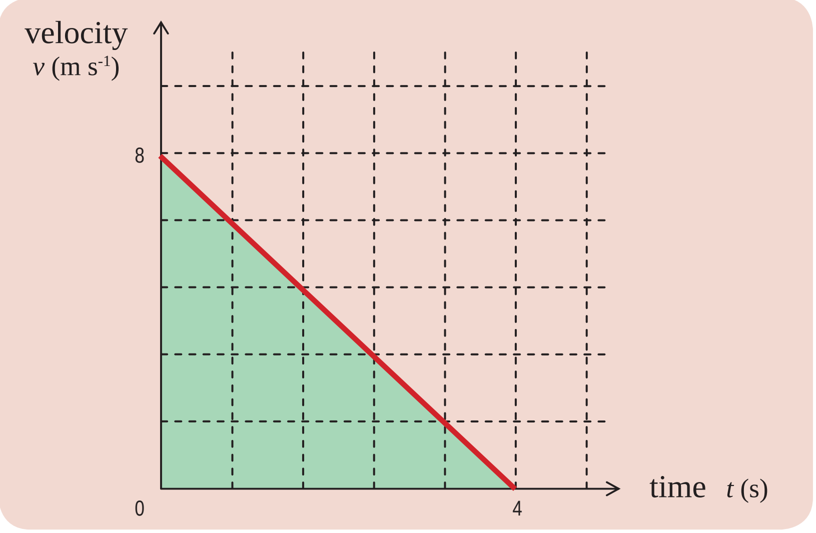
Displacement = mean velocity × time

**That is, the displacement of a body moving at a uniform acceleration is equal to the magnitude of the area under the velocity-time graph.**

This graphical method provides you with another way of finding the displacement of an object.

## Example

A body with an initial velocity of 8 m s$^{-1}$ moves under a constant deceleration, and comes to rest after 4 s. Plot the velocity - time graph for this motion and find the displacement during the 4 s.




The velocity - time graph is shown in the figure. The displacement is equal to the area of the shaded region.

$$\text{Displacement of the body} = \frac{8 \times 4}{2}$$

$$= 16 \text{ m}$$

- Now consider the following problem.

An object starting from rest, acquires a velocity of 15 m $s^{-1}$ after moving for 6 s under a uniform acceleration. Then the object moves with that velocity for 6 s and comes to rest after decelerating for 3 s.

(i) Plot the velocity - time graph for this motion.

(ii) Find the acceleration during the first 6 s.

(iii) What is the displacement during these 6 s?

(iv) What is the displacement travelled under the uniform velocity?

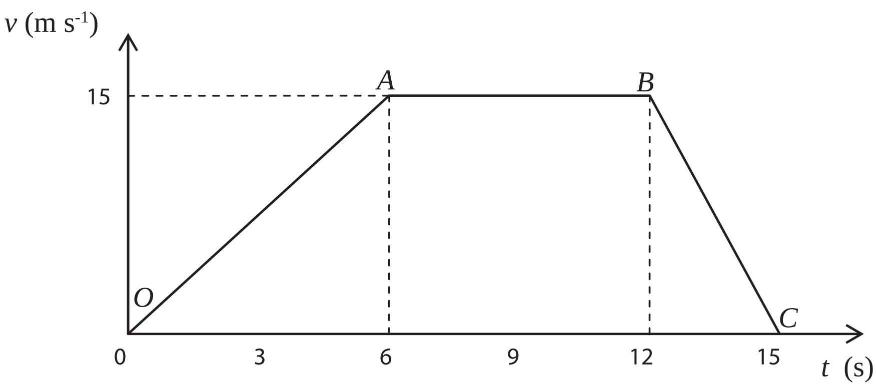
(v) What is the deceleration during the last 3 s?

(vi) What is the displacement during the last 3 s?

(vii) (a) Write down an expression in order to find the total displacement travelled by the object during the complete motion, using the velocity - time graph.

(b) Find the total displacement travelled using the above expression.

**Answer**




(i) The velocity - time graph is shown in the above figure .

(ii) Acceleration during the first 6 s = Gradient of the *OA* part of the graph

$$= \frac{15 \text{ m s}^{-1}}{6 \text{ s}}$$

$$= 2.5 \text{ m s}^{-2}$$

(iii) Displacement during the first 6 s = Area of the graph below *OA*

$$= \frac{15 \times 6}{2}$$

$$= 45 \text{ m}$$

(iv) Displacement at uniform speed = Area of the graph below *AB*

$= 15 \text{ m s}^{-1} \times 6 \text{ s}$

$= 90 \text{ m}$

(v) Acceleration during the last 3 s $= \dfrac{(0 - 15) \text{ m s}^{-1}}{3 \text{ s}}$

$= -5 \text{ m s}^{-2}$

That is, deceleration $= 5 \text{ m s}^{-2}$

(vi) Displacement during the last 3 s = Area of the graph below *BC*

$= \dfrac{15 \text{ m s}^{-1}}{2} \times 3 \text{ s}$

$= 22.5 \text{ m}$

(vii) (a)Toal displacement travelled = Area of the trapezoid *OABC*

(b) Total displacement travelled $= \dfrac{(OC + AB)}{2} \times 15 \text{ m s}^{-1}$

$= \dfrac{(15 + 6)\text{s}}{2} \times 15 \text{ m s}^{-1}$

$= \dfrac{21\text{s}}{2} \times 15 \text{ m s}^{-1}$

$= 157.5 \text{ m}$

- During the periods of heavy traffic, vehicles have to reduce the speed frequently. When the vehicles begin to move again, the engine has to produce extra power. This process causes an energy loss. Such losses can be minimized by travelling during hours of low traffic whenever possible.

## 2.7 Gravitational acceleration

By experience we know that when a body falls, its velocity increases gradually. That is, the body accelerates. In order to give rise to an acceleration, a **force** must act on the body. The force that acts on a falling body is the gravitational force exerted by the earth. The acceleration caused by the earth's gravitational attraction is known as the gravitational acceleration. Its symbol is *g*.

The average value for the gravitational acceleration at sea level is about $9.8 \text{ m s}^{-2}$.

This means that the velocity of a free falling body increases by $9.8 \text{ m s}^{-1}$ every second.

When a body is moving vertically upwards, the velocity decreases by 9.8 m $s^{-1}$ every second. Therefore, the gravitational acceleration of a body moving vertically upwards is, –9.8 m $s^{-2}$.

Suppose that a body falling vertically down after starting from rest takes 4 s to reach the ground. Its velocity change during each second can be stated as follows.

Initial velocity = 0

Velocity at the end of 1 s = 9.8 m $s^{-1}$

Velocity at the end of 2 s = 19.6 m $s^{-1}$

Velocity at the end of 3 s = 29.4 m $s^{-1}$

Since it took 4 s to fall to the ground, the velocity upon reaching the ground, that is the velocity at the end of 4 s = 39.2 m $s^{-1}$

Height that the body fell during 4 s = mean velocity × time

$$= \frac{(0 + 39.2)\ \text{m s}^{-1}}{2} \times 4\ \text{s}$$

$$= 78.4\ \text{m}$$

The velocity - time graph for the above motion is shown in Figure 2.13.

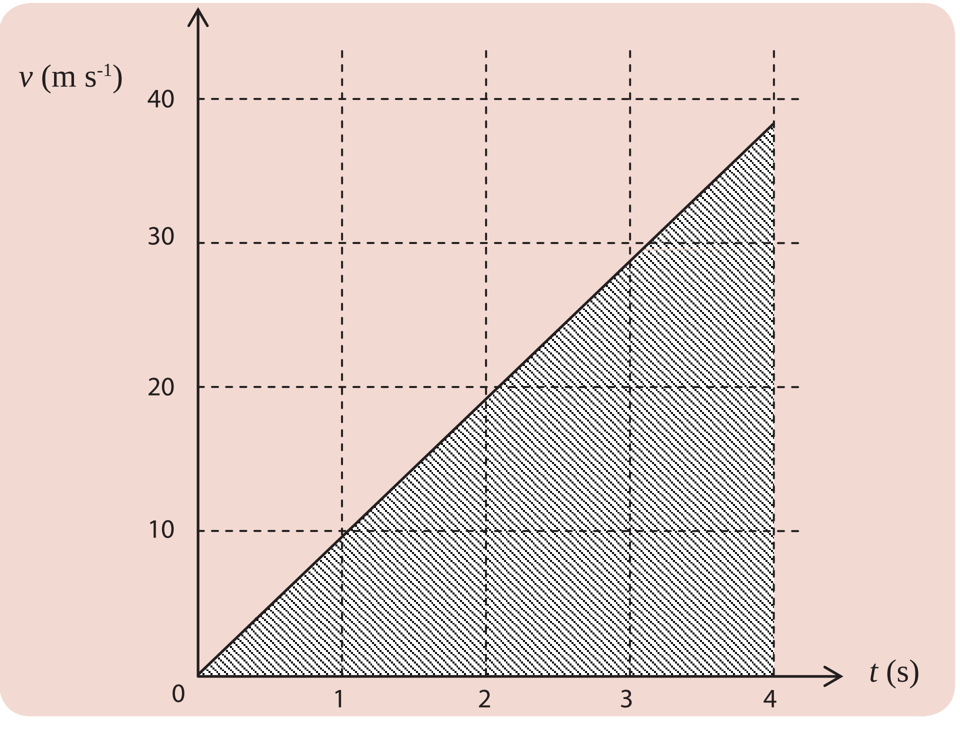



Figure 2.13 - Velocity - time graph of a body falling vertically down

Distance fallen during the 4 s $= \text{Shaded area below the graph}$

$$= \frac{39.2 \text{ m s}^{-1} \times 4 \text{ s}}{2}$$

$$= 78.4 \text{ m}$$

Let us next plot a velocity - time graph for a body reaching the maximum height after being initially projected vertically upwards with a velocity of 20 m $s^{-1}$ ( Take g = 10 m $s^{-2}$ for convenience of the calculations)

The change in the velocity with time is shown in the table below, and the corresponding velocity - time graph is shown in Figure 2.14.

| $t$ (s) | 0 | 1 | 2 |
|---|---|---|---|
| $v$ (m $s^{-1}$) | 20 | 10 | 0 |

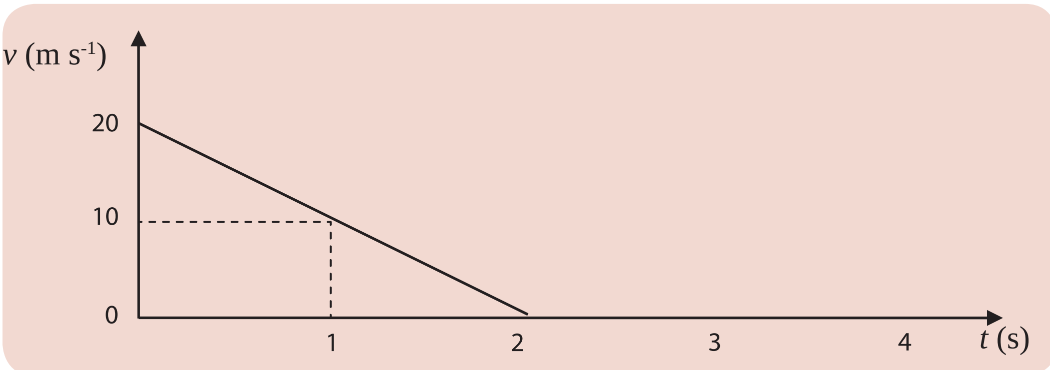



Figure 2.14 - Velocity - time graph of a body reaching its maximum height after being projected vertically upward

In plotting the above graph, velocities directed upwards have been taken as positive. Therefore this graph shows gravitational acceleration as a negative acceleration.

## Example

An object was projected vertically upward at a velocity of 30 m $s^{-1}$.

(i) Prepare a velocity - time data table indicating the variation of the velocity with time from the moment the object was projected until it reaches the maximum height.

(ii) Sketch a velocity - time graph to describe the motion.

(iii) Find the maximum height reached by the object.

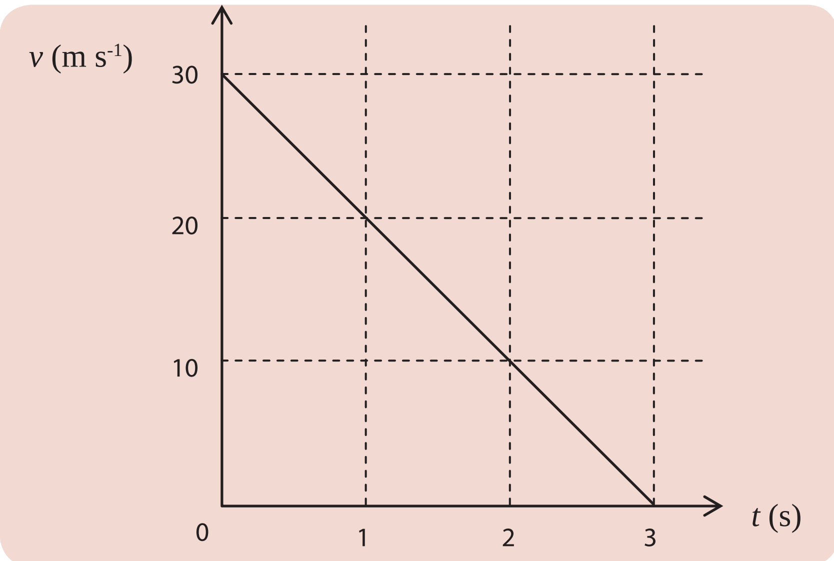
Take $g = 10 \text{ m s}^{-2}$ for convenience of the calculations

**Answer**

(i) Velocity-time data table is shown below.

| Time $t$ (s) | 0 | 1 | 2 | 3 |
|---|---|---|---|---|
| Velocity $v$ (m $s^{-1}$) | 30 | 20 | 10 | 0 |

(ii) Velocity-time graph is shown in the figure below.




(iii) Maximum distance reached by the object = Area under the graph

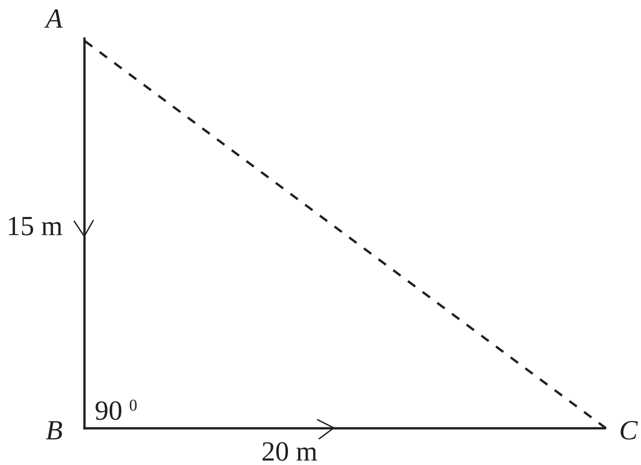
$$= \frac{30 \text{ m s}^{-1}}{2} \times 3 \text{ s}$$

$$= 45 \text{ m}$$

## Miscellaneous exercises

1. (i) Explain the difference between distance and displacement.

   (ii) The path taken by a child in order to walk from a point $A$ to a point $C$ is shown in the figure below.




(a) What is the total distance traversed by the child?

(b) What is the displacement of the child?

(c) If the child walked from $A$ to $C$ via $B$ in 5 s, without stopping, find the

(i) mean speed

(ii) mean velocity of the child.

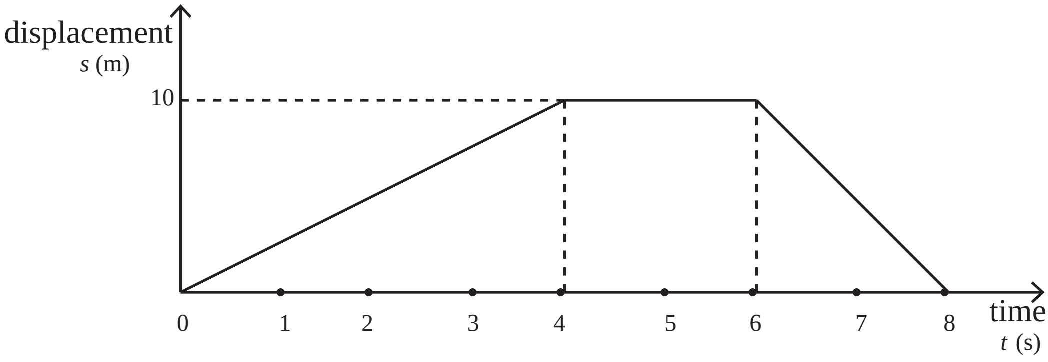
over the 5 s period.

2. (i) Briefly explain the difference between scalars and vectors.

   (ii) Classify the following physical quantities as scalars or vectors.

   Distance, displacement, speed, velocity

   (iii) The displacement-time graph of an object moving along a straight line is shown in the figure below .




(a) How far has the object moved after starting from rest?

(b) How long has it taken to travel the above distance?

(c) Find the maximum velocity of the object during that period.

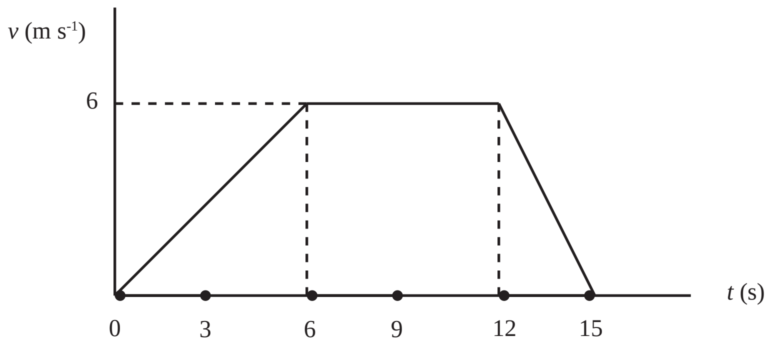
(d) What can you say about the motion during the interval from 4 s to 6 s?

(e) Comment on the motion during the interval from 6 s to 8 s.

3. (i) If the velocity of a body varied uniformly from 10 m $s^{-1}$ to 25 m $s^{-1}$ during a time interval of 5 s what was the acceleration of the body?

(ii) Sketch the velocity - time graph for the above motion and find the distance travelled during the 5 s.

(iii) The variation of the velocity of a certain object that travelled along a straight line is shown in the graph below .




(a) Find the acceleration of the object during the first 6 s.
(b) Find the distance traversed by the object during the first 6 s.
(c) What is the distance traversed at a uniform velocity?
(d) Find the deceleration during the last 3 s.

4. An object starting from rest and moving on a straight line at a constant acceleration acquires a velocity of 12 m $s^{-1}$ in 8 s. Thereafter it moves for another 4 s at a uniform velocity of 12 m $s^{-1}$. Ultimately it decelerates for 4 s and comes to rest.

   (i) Sketch the velocity - time graph for the above motion.
   (ii) What is the acceleration of the object during the first 8 s?
   (iii) What is the distance traversed by the object during the first 8 s?
   (iv) What is the distance travelled at uniform velocity?
   (v) What is the deceleration of the object during the interval from 12 s to 16 s?
   (vi) What is the displacement of the object after 16 s?

5. An object starting from rest and travelling along a straight line takes 8 s to acquire a velocity of 16 m $s^{-1}$. Next, it moves at a uniform velocity for 4 s and ultimately decelerates for 4 s before coming to rest.

   (i) Sketch a velocity-time graph for the above motion.
   (ii) Find the deceleration during the first 8 s.
   (iii) What is the distance traversed by the object during the first 8 s?
   (iv) What is the distance traversed at a uniform velocity of 16 m $s^{-1}$?
   (v) Find the deceleration during the last 4 s.
   (vi) What is the distance moved during the last 4 s?

6. (i) A fruit in a tree that detaches from the stalk takes 4 s to fall to the ground
   (a) What is its velocity when it reaches the ground?
   (b) What is the height that it fell from?

   (ii) An object is projected vertically upwards at an initial velocity of 30 m $s^{-1}$.

   (a) Find the time taken by the object to reach its maximum height.
   (b) What is the maximum height reached by the object?
   (c) Sketch the velocity-time graph for the motion of the object from the time it was projected until it reaches the maximum height.

## Summary

- The distance traversed by a body to move from a certain point to another point depends on the path taken. But its displacement depends only on the initial and final points.

- Distance has a magnitude only. It is a scalar quantity.

- Displacement is a vector quantity. The magnitude of the displacement is the straight line distance between the initial and final points. Its direction is the direction of the straight line segment drawn from the initial to the final point.

- The rate of change of distance or the distance traversed in a unit time is known as the speed of an object. Speed is a scalar quantity.

- $$\text{speed} = \frac{\text{distance}}{\text{time}}$$

- The rate of change of displacement is known as the velocity. It is a vector quantity.

- $$\text{velocity} = \frac{\text{displacement}}{\text{time}}$$

- The rate of change of the velocity is known as the acceleration. A negative acceleration is known as a deceleration. Both acceleration and deceleration are vector quantities.

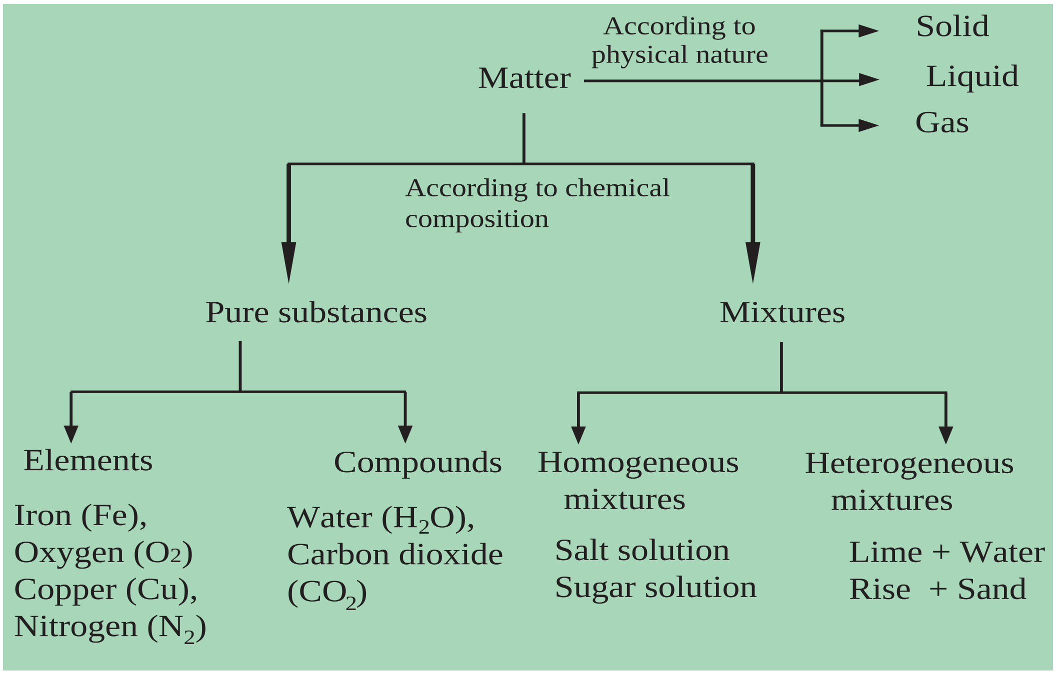
- $$\text{acceleration} = \frac{\text{change of velocity}}{\text{time}}$$

| Technical terms | | |
|---|---|---|
| Distance | දුර | தூரம் |
| Displacement | විස්ථාපනය | இடப்பெயர்ச்சி |
| Object | වස්තුව | பொருள் |
| Vector quantity | දෛශික රාශිය | காவிக் கணியம் |
| Scalar quantity | අදිශ රාශිය | எண்ணிக் கணியம் |
| Speed | වේගය | கதி |
| Velocity | ප්‍රවේගය | வேகம் |
| Acceleration | ත්වරණය | ஆர்முடுகல் |
| Retardation / (Deceleration) | මන්දනය | அமர்முடுகல் |
| Acceleration due to gravity | ගුරුත්වජ ත්වරණය | புவியீர்ப்பினாலான ஆர்முடுகல் |

Chemistry

# Structure of Matter 03

The things in our environment can be classified into two main categories as matter and energy. Those that occupy space and have a mass are called matter. The classification of matter according to their physical nature and chemical composition is shown in the following chart.




Atoms are the building units of matter. The atom is composed of subatomic particles. Among them, protons, electrons and neutrons are the main subatomic particles.

The electron is a negatively charged particle. Proton has a positive charge while neutrons have no charge. With the identification that particles called electrons, protons and neutrons constitute matter, and as a result of the effort taken to describe how those particles are organized in matter, the atomic model was introduced. According to the nuclear model put forward by Ernest Rutherford in 1911, there is a very small area called nucleus at the centre of the atom.

If the atom is a football ground, nucleus is a small volume, even smaller than a chickpea at its centre. From this example, it is clear that the nucleus of an atom is very small relative to an atom. Protons and neutrons are accumulated in the nucleus. The nucleus is positively charged.

Electrons revole around the nucleus. The number of electrons in an atom is equal to the number of protons. However the protons and electrons are oppositely charged and therefore, the atom is electrically neutral.

## 3.1 The Planetary Model of the Atom

The planetary model of the atom was introduced by Ernest Rutherford. Electrons move around the nucleus in which the positive charge of the atom is concentrated. This is similar to the solar system where the planets revolve around the sun (Fig. 3.1).

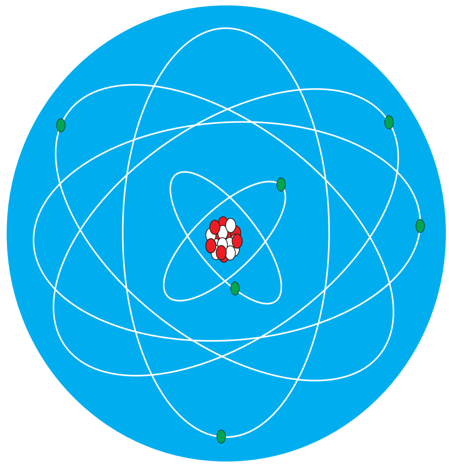


Fig - 3.1 - The planetary model of the atom

Though electrons are attracted by the positive charge of the nucleus, they do not fall on the nucleus. This is because electrons revolve very fast around the nucleus. Niels Bohr who further elaborated the Rutherford's model stated that the electrons move in definite paths or shells around the positively charged nucleus.The shells in which the electrons revole around the nucleus are assigned either numbers 1, 2, 3, 4...... or letters K, L, M, N...... respectively starting from the nearest to the nucleus.

The shells are also known as energy levels. Each energy level has a specific energy. When moving away from the nucleus this energy increases. Nevertheless, the difference between the energy levels decreases (Fig 3.2). In an atom, there is a maximum number of electrons in any energy level.Table 3.1 gives the total number of electrons in the first four energy levels nearest to the nucleus. There is a specified energy for each energy level.

Table 3-1

| Level | Maximum number of electrons |
|---|---|
| 1 (K) | 2 |
| 2 (L) | 8 |
| 3 (M) | 18 |
| 4 (N) | 32 |

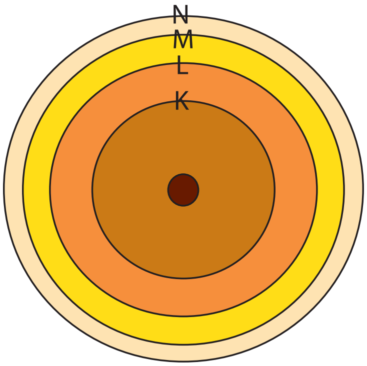


Fig - 3.2

**Assignment 3.1**

Make models of the atom to show its three dimentional nature by selecting suitable materials according to the instructions of the teacher. Display your creations in your classroom.

## • Atomic number

**The atomic number is the number of protons in an atom of the element.**

**Atomic number of the element = number of protons in an atom of the element**

For example, there are 11 protons in the nucleus of a sodium atom. Thus, the atomic number of sodium is 11.The number of protons in every atom of the same element is equal. The number of protons in different elements is different. Therefore, the atomic numbers of two atoms of different elements will never be the same. **Hence, the atomic number of an element is a unique characteristic of that element.** For instance, if the atomic number of an element is 6, it means that the element is carbon. In no other element, the atomic number is equal to 6. The atomic number of an element is symbolised by Z. In a neutral atom, the number of protons is equal to the number of electrons in it. So, it implies that the atomic number of an element is equal to the number of electrons in an atom of that element.

However, when chemical reactions take place, electrons may be either lost from or gained by atoms. Such charged atoms are called ions. The number of electrons in an ion may be less or more than the number of protons. But, since the number of protons in an ion formed by a particular atom does not change, its atomic number remains unchanged.

## • Mass number

Of the fundermental subatomic particles called protons, neutrons and electrons contained in an atom, electrons are very light. The mass of protons and neutrons is nearly equal.Approximately, the mass of an electron is 1/1840 the mass of a proton. So in comparison to the mass of protons and neutrons in an atom, the mass of electrons is negligibly small. Therefore, the mass of an atom depends only on the mass of protons and neutrons. **The sum of the number of protons and neutrons in the nucleus of an atom is called the mass number.**

$\therefore$ **mass number = number of protons + number of neutrons**

Symbol A signifies the mass number of an element.

- Atomic number of sodium is 11.
- Hence, a sodium atom contains 11 protons.
- If it contains 12 neutrons,the mass number of the sodium atom = 11+12=23.

There is a standard way of writing the atomic number and mass number of an element. On the left hand side of the symbol of the relevant element, the atomic number is written at the bottom and the mass number at the top.

Example : The mass number of sodium (Na) is 23.
Its atomic number is 11.

$${}^{A}_{Z}\mathbf{X} \qquad\qquad {}^{23}_{11}\mathbf{Na}$$

| | |
|---|---|
| A - mass number | atomic number - 11 |
| Z - atomic number | mass number - 23 |

The difference between the mass number and the atomic number gives the number of neutrons in the atom.

## 3.2 Electronic Configuration

The maximum number of electrons that can be accomodated in the respective energy levels according to the atomic model accepted at present was discussed earlier. **Representing how electrons are filled in the respective energy levels from the one nearest to the nucleus of an atom and outwards is called electronic configuration.** Let's look at an example. The atomic number of sodium is 11. Therefore, a sodium atom has 11 protons and 11 electrons. Those eleven electrons in the sodium atom are distributed as 2 electrons in the first energy level, 8 electrons in the second energy level and 1 electron in the third energy level. Hence the electronic configuration of sodium can be written as follows.

Na - 2, 8, 1

Table 3.2 - Electronic configurations of the elements with atomic numbers from 1 to 20

| Element | Symbol | Atomic number | Electronic configuration | | | |
|---|---|---|---|---|---|---|
| | | | K | L | M | N |
| Hydrogen | H | 1 | 1 | | | |
| Helium | He | 2 | 2 | | | |
| Lithium | Li | 3 | 2 | 1 | | |
| Beryllium | Be | 4 | 2 | 2 | | |
| Boron | B | 5 | 2 | 3 | | |
| Carbon | C | 6 | 2 | 4 | | |
| Nitrogen | N | 7 | 2 | 5 | | |
| Oxygen | O | 8 | 2 | 6 | | |
| Fluorine | F | 9 | 2 | 7 | | |
| Neon | Ne | 10 | 2 | 8 | | |
| Sodium | Na | 11 | 2 | 8 | 1 | |
| Magnesium | Mg | 12 | 2 | 8 | 2 | |
| Aluminium | Al | 13 | 2 | 8 | 3 | |
| Silicon | Si | 14 | 2 | 8 | 4 | |
| Phosphorus | P | 15 | 2 | 8 | 5 | |
| Sulphur | S | 16 | 2 | 8 | 6 | |
| Chlorine | Cl | 17 | 2 | 8 | 7 | |
| Argon | Ar | 18 | 2 | 8 | 8 | |
| Potassium | K | 19 | 2 | 8 | 8 | 1 |
| Calcium | Ca | 20 | 2 | 8 | 8 | 2 |

When an energy level of an atom of an element is the last energy level bearing electrons, the maximum number of electrons it can accommodate is 8. Thus, the number of electrons in the energy levels of potassium and calcium are not 9 and 10.

## 3.3 Modern Periodic Table

As at present, more than 115 elements have been discovered. Studying their properties individually is a very tedious task. Scientists in various parts of the world collect information about elements and their compounds continuously. This host of information is so large and diverse that no one is able to memorise all the facts about them. Therefore different scientists have attempted to classify elements in various ways.The periodic classification is the greatest result of this attempt. A Periodic Table for classifying elements was first introduced by Dmitri Mendeleeff ,a Russian scientist.

The modern Periodic Table (Fig. 3.3) is based on the atomic number and the electronic configuration. The periodic law states that the properties of elements are periodic functions of their atomic number. This means that when the elements are arranged in the ascending order of their atomic numbers, elements with similar properties recur at regular intervals of elements.

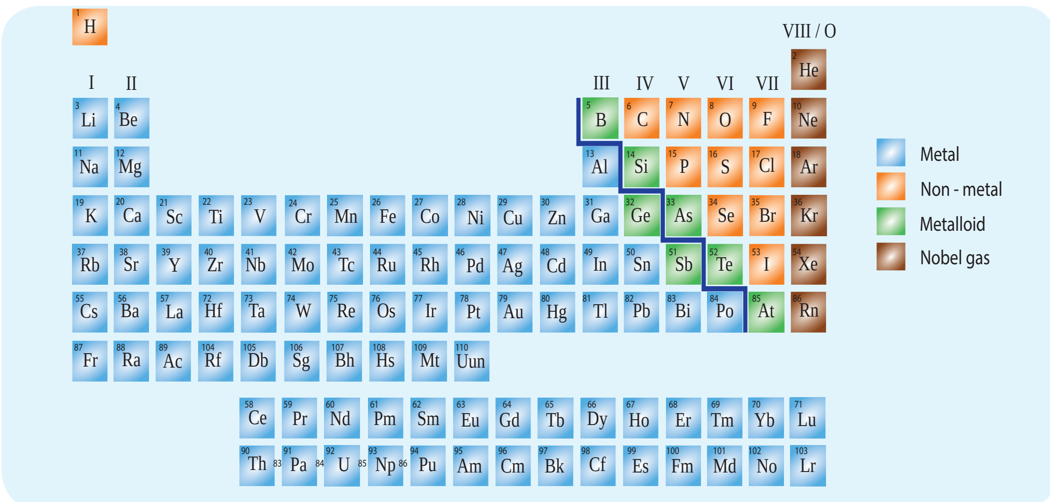



Fig. 3.3 - The modern Perodic Table

In this grade only the elements with atomic numbers from 1 - 20 are studied. Fig 3.4 shows that part.

In the PeriodicTable, horizontal rows are called **Periods** while vertical columns are known as **Groups**.

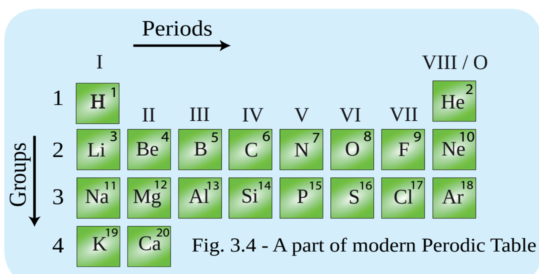



Fig. 3.4 - A part of modern Perodic Table

## • Dividing Elements into Periods

The Period to which an element belongs is decided by the number of energy levels (shells) carrying electrons in an atom of that element.

Period 1 - Only the first energy level carries electrons

Period 2 - Only the first and second energy levels carry electrons

Period 3 - Only the first, second, and third energy levels carry electrons

Period 4 - Only the first, second, third and fourth energy levels carry electrons

| | | |
|---|---|---|
| H | 1 | Period 1 |
| He | 2 | |
| Li | 2, 1 | Period 2 |
| Be | 2, 2 | |
| B | 2, 3 | |
| C | 2, 4 | |
| N | 2, 5 | |
| O | 2, 6 | |
| F | 2, 7 | |
| Ne | 2, 8 | |
| Na | 2, 8, 1 | Period 3 |
| Mg | 2, 8, 2 | |
| Al | 2, 8, 3 | |
| Si | 2, 8, 4 | |
| P | 2, 8, 5 | |
| S | 2, 8, 6 | |
| Cl | 2, 8, 7 | |
| Ar | 2, 8, 8 | |
| K | 2, 8, 8, 1 | Period 4 |
| Ca | 2, 8, 8, 2 | |

## • Dividing Elements into Groups

The properties of an element depends on the number of electrons present in its outermost energy level. These are known as valence electrons. As per the above table, it is seen that the properties of lithium which has only one valence electron is similar to that of sodium.

Sodium too which has only one valence electron. It is seen that the properties of any element in the upper horizontal row is similar to those of the element below it.

The group to which an element belongs is decided by the number of electrons in its outermost energy level.

| Number of electrons in the outer energy level | Group to which the element belongs |
|---|---|
| Elements with 1 electron in the outer energy level | Group I |
| Elements with 2 electrons in the outer energy level | Group II |
| Elements with 3 electrons in the outer energy level | Group III |
| Elements with 4 electrons in the outer energy level | Group IV |
| Elements with 5 electrons in the outer energy level | Group V |
| Elements with 6 electrons in the outer energy level | Group VI |
| Elements with 7 electrons in the outer energy level | Group VII |
| Elements with 8 electrons in the outer energy level or with a stable electronic configuration | Group VIII / 0 |

**Groups to which the 20 elements from hydrogen to calcium belong**

| Element | Atomic number | E lectronic configuration | Group to which the element belongs |
|---|---|---|---|
| H | 1 | 1 | I |
| He | 2 | 2 | VIII / 0 |
| Li | 3 | 2, 1 | I |
| Be | 4 | 2, 2 | II |
| B | 5 | 2, 3 | III |
| C | 6 | 2, 4 | IV |
| N | 7 | 2, 5 | V |
| O | 8 | 2, 6 | VI |
| F | 9 | 2, 7 | VII |
| Ne | 10 | 2, 8 | VIII / 0 |
| Na | 11 | 2, 8, 1 | I |
| Mg | 12 | 2,8,2 | II |
| Al | 13 | 2, 8, 3 | III |

| | | | |
|---|---|---|---|
| Si | 14 | 2, 8, 4 | IV |
| P | 15 | 2, 8, 5 | V |
| S | 16 | 2, 8, 6 | VI |
| Cl | 17 | 2, 8, 7 | VII |
| Ar | 18 | 2, 8, 8 | VIII / 0 |
| K | 19 | 2, 8, 8, 1 | I |
| Ca | 20 | 2, 8, 8, 2 | II |

## How to Find the Position of an Element in the Periodic Table

Example :- Atomic number of magnesium (Mg) is 12.

Electronic configuration - 2, 8, 2

The number of energy levels carrying electrons in a magnesium atom is 3.

So, it is an element in Period 3. Number of electrons in the outer energy level of a magnesium atom is 2.

Therefore it belongs to Group II

Magnesium is in Group II and Period 3 of the Periodic Table.

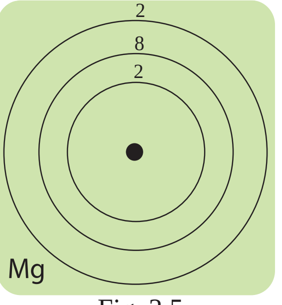


Fig. 3.5

Example - Atomic number of potassium (K) is 19.

Electronic configuration - 2, 8, 8,1

The number of energy levels carrying electrons in a potassium atom is 4.Therefore it is an element in Period 4.

A potassium atom has one electron in its outer energy level.

Therefore it belongs to Group I.

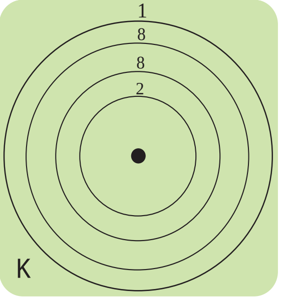


Fig 3.5

Thus potassium is found in Group I and Period 4 of the Periodic Table.

### The location of the elements with atomic number 1 - 20 in the periodic table

Table 3.3 Groups and periodic of first 20 elements

| Atomic number | Element | Electronic Configuration | Period of the element | Group of the element |
|---|---|---|---|---|
| 1 | H | 1 | 1 | I |
| 2 | He | 2 | 1 | VII / 0 |
| 3 | Li | 2, 1 | 2 | I |
| 4 | Be | 2, 2 | 2 | II |
| 5 | B | 2, 3 | 2 | III |
| 6 | C | 2, 4 | 2 | IV |
| 7 | N | 2, 5 | 2 | V |
| 8 | O | 2, 6 | 2 | VI |
| 9 | F | 2, 7 | 2 | VII |
| 10 | Ne | 2, 8 | 2 | VIII / 0 |
| 11 | Na | 2, 8, 1 | 3 | I |
| 12 | Mg | 2, 8, 2 | 3 | II |
| 13 | Al | 2, 8, 3 | 3 | III |
| 14 | Si | 2, 8, 4 | 3 | IV |
| 15 | P | 2, 8, 5 | 3 | V |
| 16 | S | 2, 8, 6 | 3 | VI |
| 17 | Cl | 2, 8, 7 | 3 | VII |
| 18 | Ar | 2, 8, 8 | 3 | VIII / 0 |
| 19 | K | 2, 8, 8, 1 | 4 | I |
| 20 | Ca | 2, 8, 8, 2 | 4 | II |

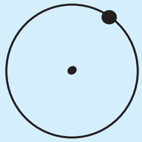
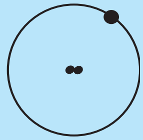
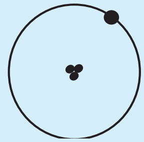
## 3.4 Isotopes

Among the atoms of the same element too, there may be atoms with different number of neutrons. But their atomic number, that is the number of protons, is equal. That means, there may be atoms with different mass numbers in the same element. **The atoms with different mass numbers in the same element are known as isotopes of that element.**

### Examples for isotopes

Hydrogen has three isotopes. They are called protium, deuterium and tritium.

Table 3.4 - Isotopes of hydrogen

| Isotope | Protium | Deuterium | Tritium |
|---|---|---|---|
| Atomic model | <br>electrons 1<br>protons 1<br>neutrons 0 | <br>electrons 1<br>protons 1<br>neutrons 1 | <br>electrons 1<br>protons 1<br>neutrons 2 |
| Atomic number | 1 | 1 | 1 |
| Mass number | 1 | 2 | 3 |
| Standard representation | ${}^{1}_{1}H$ | ${}^{2}_{1}H$ | ${}^{3}_{1}H$ |

Chlorine has two isotopes. They are ${}^{35}_{17}Cl$ , ${}^{37}_{17}Cl$ .

Chlorine gas does not contain ${}^{35}_{17}Cl$ and ${}^{37}_{17}Cl$ in equal amounts. In hundred parts of gas, 75 parts are ${}^{35}_{17}Cl$ and 25 parts are ${}^{37}_{17}Cl$. This is called the percentage abundance of the respective isotopes.

## 3.5 Patterns Seen in the Periodic Table

In the Periodic Table it can be seen that the physical and chemical properties of the elements change according to a systematic pattern across a Period from left to right and from top to bottom of a Group. To study those patterns, let's consider the following properties of the elements.

- First ionisation energy
- Electronegativity

### • First ionisation energy

In accordance with the nuclear model of the atom, its electrons orbit the nucleus. The negatively charged electrons are attracted by the positively charged nucleus, so to remove an electron from an atom energy must be supplied to overcome that attraction. When an electron is removed from an atom, it becomes a positive ion.

| I | II | III | IV | V | VI | VII | VIII / O |
|---|---|---|---|---|---|---|---|
| H 1310 | | | | | | | He 2372 |
| Li 519 | Be 897 | B 799 | C 1085 | N 1406 | O 1314 | F 1682 | Ne 2080 |
| Na 495 | Mg 738 | Al 577 | Si 786 | P 1018 | S 1000 | Cl 1255 | Ar 1521 |
| K 418 | Ca 590 | | | | | | |

Fig. 3.7 - First ionisation energy values of the elements with atomic numbers 1-20 (kJ mol$^{-1}$)

The first ionisation energy of an element is the minimum energy that should be supplied to an atom in the gaseous state to remove an electron to form a unipositive gaseous ion. The formation of a unipositive gaseous ion by removing an electron from an atom in the gaseous state can be represented by a chemical equation as follows.

$$Na(g) \longrightarrow Na^{+}(g) + e$$

This energy is a comparatively small value for an atom. Therefore, this value is given for 6.022 x $10^{23}$ atoms or a mole of atoms. Fig. 3.7. indicates the values for one mole of atoms of respective elements. Accordingly, the first ionisation energy of sodium is 495 kJ mol$^{-1}$ .

In a given Period, the Group I elements have the minimum first ionisation energy. Also in every Period, Group VIII elements have the maximum ionisation energy .From left to right in a Period, the first ionisation energy varies in a regular manner. This is confirmed when the variation of ionisation energies in the second and third periods are examined using the graph (Fig 3.8).

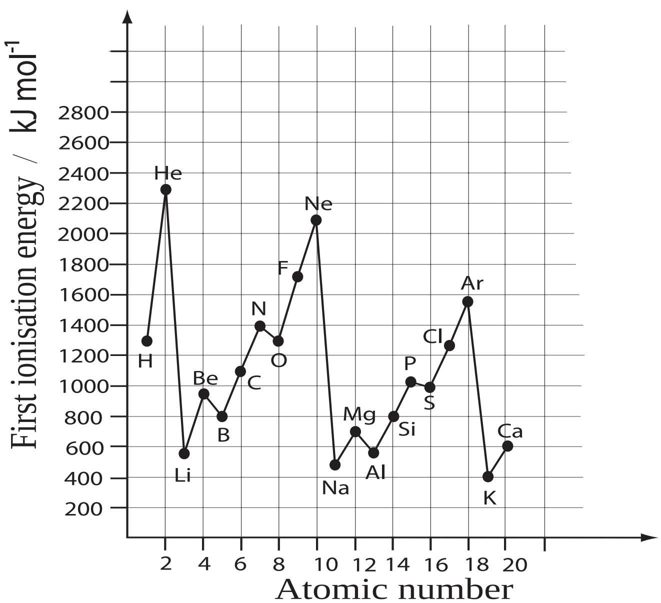



Fig. 3.8 - The graph of ionisation energy variation against atomic number for first 20 elements

**Assignment - 3.2**

Draw a graph of the first ionisation energy values of elements of atomic numbers 1 - 20 given in the Fig. 3.7, against the atomic number. Use a graph paper for this assignment. Describe how the first ionisation energy varies across a Period from left to right and from top to bottom in a Group using your graph.

It is seen that in Group I elements, values of the first ionisation energy decrease from top to bottom of the Group. You can understand this by examining the values of the other groups also. Therefore, it can be concluded that, from top to bottom of a Group, the ionisation energy decreases. Descending a group, the number of energy levels in an atom increases.Therefore, the attraction exerted by the nucleus on the electrons in the outer energy level becomes less making the removal of electrons easier.

- ## Electronegativity

**Electronegativity means the ability of an atom of an element to attract the electrons of a bond towards itself when it is bonded to an atom of another element.** The attraction of an atom of higher electronegativity towards electrons is greater than that of lower electronegativity. More about electronegativity will be discussed under the unit on chemical bonds.

As per the Pauling scale, fluorine is considered the element of highest electronegativity. There are several scales to quantify the electronegativity of which the Pauling scale has been adopted here. Pauling scale does not assign electronegativity values to noble gases (Noble gases show less tendency to form chemical bonds).

Study the electronegativity values and the graph that illustrates the variation of electronegativity values well. It can be seen that the electronegativity increases from left to right across a Period. It is also seen that, down a Group, electronegativity decreases.

| I | II | III | IV | V | VI | VII | VIII / O |
|---|---|---|---|---|---|---|---|
| H 2.1 | | | | | | | He - |
| Li 1.0 | Be 1.5 | B 2.0 | C 2.5 | N 3.0 | O 3.5 | F 4.0 | Ne - |
| Na 0.9 | Mg 1.2 | Al 1.5 | Si 1.8 | P 2.1 | S 2.5 | Cl 3.0 | Ar - |
| K 0.8 | Ca 1.0 | | | | | | |

Fig 3.9 - Pauling electronegativity values of the elements with atomic numbers 1-20

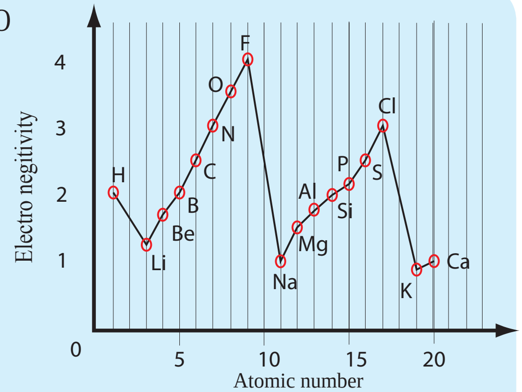



Fig 3.10 - Variation of electronegitivity against atomic number

## 3.6 Metals, Non - metals and Metalloids

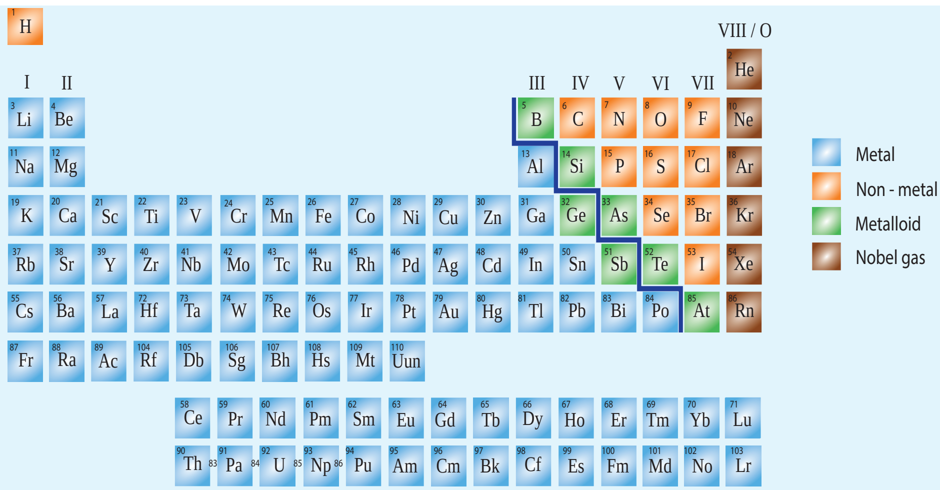



Fig. 3.11 - The modern Perodic Table

The elements written in blue in the boxes on the left hand side of this pattern are metals. The elements indicated in brown on the right hand side are non - metals(including nobel gasses).The elements indicated in light green around the steps have properties in between the metals and non - metals. Therefore they are called metalloids.

## • Metals

Of the elements identified so far, more them 80 are metals. In nature, these exist as native metals as well as compounds of metals. Metals such as silver and gold are found as native metals in nature whereas many metals such as iron, aluminium, magnesium and sodium exist as their compounds.

### Physical Properties of Metals

Given below are some properties of metals.

- Have a metallic lustre (have a shiny surface).
- Sonorous (give a ringing sound when struck).
- Exist in solid state at room temperature (mercury, though a metal is a liquid )
- Malleable (can be hammered into sheets) and ductile (can be drawn into wires)
- Good conductors of heat and electricity
- Generally have a high density

### Chemical Properties of Metals

- Metals form positive ions or cations by losing electrons.
- They combine with oxygen to form basic oxides.
- The oxides when dissolved in water form basic solutions.

## • Some Metallic Elements

### Sodium

Fig 3.12 - Sodium

Sodium is a metallic element belonging to Group I of the Periodic Table. It is a highly reactive element. It never exists as the native metal. Because of its high reactivity it exists only as compounds. Sodium chloride, the main compound containing sodium occurs in sea water.

**Activity 1**

Do this activity under the directions of your teacher.

- Observe and report on how sodium metal is stored in the laboratory.
- Take out a piece of sodium using forceps, place it on a dry surface and cut it with a knife.
- Leave it for about five minutes. Note the observations.

Sodium metal is stored in paraffin oil or kerosene so that it does not come into contact with air. When sodium metal is taken out of paraffin oil, its lustre disappears. The metal can easily be cut with a knife. The freshly cut surface offers a silvery lustre but it gets tarnished after some time.

## Physical properties of sodium metal

- It is a soft metal which can easily be cut with a knife.
- It floats on water because its density (0.97 g $cm^{-3}$) is less than that of water.
- It is a conductor of heat and electricity.

## Chemical properties of sodium metal

- Sodium shows a high reactivity towards oxygen. It reacts rapidly with oxygen in air to form the oxide of the metal.
- Sodium metal vigourously reacts with cold water forming sodium hydroxide and hydrogen gas.
- It reacts violently with dilute acids and forms salt and hydrogen gas (Since this is extremely dangerous you shouldn't attempt this. )

## Uses of sodium

- Production of sodium cyanide used in the extraction of gold and silver
- Making sodium amalgam which is used as a reducing agent in organic chemistry
- Extraction of metals such as titanium and zirconium from their compounds
- Production of indigo dye used to dye trouser materials (Denim)
- Using the production of street lamps with a yellow glow

## Magnesium

Fig 3.13 - Magnesium

Magnesium is a light, reactive metal. It does not exist as the native metal in nature. In sea water it occurs as magnesium chloride. When exposed to air magnesium tarnishes so its lustre cannot be seen. But when cleaned with a sand paper, the lustre becomes visible.

## Physical properties of magnesium

- It is a good coductors of heat and electricity.
- Has a higher density than that of water (Density is 1740 kg $m^{-3}$).

## Chemical properties of magnesium

- When heated in air, magnesium burns with a bright white flame giving white magnesium oxide.
- Magnesium does not react with cold water but reacts with hot water. As a result, it forms magnesium hydroxide and hydrogen gas. When the metal is strongly heated in steam, magnesium oxide and hydrogen gas are formed.
- Magnesium rapidly reacts with dilute acids and forms the corresponding magnesium salt and hydrogen gas.

## Uses of magnesium

- By mixing magnesium with aluminium, an alloy called magnelium is produced(This alloy is strong and resistant to corrosion. It is used in aircraft industry and in making parts of automobiles).
- Production of medicines (e.g. milk of magnesia).
- Used as a metal that prevents corrosion of iron.

## • Non - metals

Generally, non – metals have properties opposite to those of metals. There are non – metals which occur as native elements as well as compounds of other elements. Some non – metals occur in solid state while some others exist in liquid and gaseous states. At room temperature carbon, sulphur, phosphorus and iodine exist in the solid state. Bromine is a liquid at room temperature. Chlorine, fluorine, nitrogen and oxygen are some non - metals occurring in the gaseous state. Non - metals do not have a metallic lustre. They cannot be hammered into sheets or drawn into wires. Many non – metals are brittle and are poor conductors of heat and electricity. However graphite, a non - metal is a conductor of electricity. Non-metals have a relatively low density but the density of diamond is high.

### Chemical Properties of Non – metals

- Non - metals form negative ions (anions).
- Many oxides formed by non – metals with oxygen are acidic. Mostly these exist in the gaseous state. They easily dissolve in water and form acids.

## • Some Non – metallic Elements

### Nitrogen

Nitrogen exists as a free and diatomic gas in the atmosphere. About 78.1% by volume in the atmosphere is nitrogen gas. Nitrogen is also present as a component in animal and plant proteins. Nitrogen also exists as a constituent element in soil air, in organic substances such as humus and in nitrates, nitrites and ammonium compounds.

### Physical properties of nitrogen

- It is colourless and odourless.
- It is lighter than air and is slightly soluble in water.

### Chemical properties of nitrogen

- Nitrogen is a non - supporter of combustion.
- It is a gas of very low reactivity. Nevertheless, at high temperatures, nitrogen gas reacts with non metals such as oxygen, hydrogen, carbon and silicon as well as with metallic elements such as magnesium and aluminium.
- When sent through a strong electric arc, nitrogen combines with oxygen in the atmosphere to form unstable nitric oxide gas. The nitric oxide gas so formed reacts further with oxygen in air to form an acidic gas, nitrogen dioxide. During lightning, this process occurs naturally.

- Under special conditions nitrogen gas reacts with hydrogen gas to form ammonia gas. Industrially ammonia is manufactured by this method. Ammonia so prepared is used as a raw material to produce nitrogen containing fertilizers and explosives.
- When heated, nitrogen gas reacts with metals like magnesium to form metal nitrides.

## Uses of nitrogen gas

- Nitrogen gas is used to produce ammonia in industrial scale, chemical fertilizers and other nitrogen compounds.
- Since it is an inert gas, it is used to fill electric bulbs and thermometers.
- When making electronic devices, a nitrogen gas environment is used.
- When storing some substances, nitrogen is used as a blanketing gas.
- When packaging milk powder, nitrogen is used.
- Liquid nitrogen is used as a coolant.
- It is also used to fill vehicle tires.

## Sulphur

Fig 3.14 - Sulphur

Sulphur is an element that exists in different forms in nature. Those forms are referred to as **allotropes.** Sulphur occurs in crystalline form as a yellow brittle solid (Fig. 3.14) and in amorphous form as a white powder. In nature, it is found both as a native element as well as compounds like sulphates and sulphides. It is a constituent element in some amino acids found in the bodies of living beings. Sulphur clearly shows the properties of non – metals.

## Physical properties of sulphur

- It is a poor conductor of electricity.
- Sulphur is insoluble in water. It is slightly soluble in organic solvents and highly soluble in carbon disulphide.

## Chemical Properties of sulphur

- Sulphur burns with a blue flame in air and forms sulphur dioxide gas.

- When heated with sulphur, many metals form the metal sulphide.

## Uses of sulphur

- Sulphur is used to produce sulphuric acid, vulcanize rubber,and make calcium and magnesium sulphites which are used to bleach wood pulp.Its is also used to produce paints containing sulphides, solvents like carbon disulphide, sulphur dioxide gas, matches, crackers, and gun powder.
- Sulphur is also used in the production of vine, beer and medicines and is used as a fungicide.

## Carbon

Diamond graphite

Fig - 3.15

Carbon is a non – metal element occurring in abundance. It occurs as carbon dioxide gas in the atmosphere, animal and plant tissues, all organic compounds, coal, petroleum products and other hydrocarbons containing carbon. It is an element showing allotropy. Carbon has crystalline forms as well as amorphous forms. In crystalline forms, atoms are orderly arranged but in amorphous forms there is no such arrangment.

Crystalline carbon (allotrops of carbon) : diamond, graphite, Fulorine
Amorphous carbon : charcoal, lamp soot, coal

## Physical properties of carbon

Physical properties of carbon differ according to the allotropic form of carbon. Except diamond, the other forms of carbon are black in colour and exit in the solid state. Their density is relatively low. But diamond is the form with highest density. Diamond is much valued because of its high refractive index and hardness. Diamond is a poor conductor of electricity. But, graphite is a good conductor of electricity. Charcoal has the ability to absorb gases.

## Chemical properties of carbon

Carbon is an element of low reactivity. It combines with oxygen at very high temperatures but does not react with substances like acids, bases and chlorine. Amorphous forms like charcoal react chemically.

- When strongly heated and ignited charcoal reacts with oxygen to form carbon dioxide.
- At high temperatures, carbon reacts with calcium oxide forming calcium carbide.

## Uses of Carbon

Different allotrops of carbon has different uses. Some of the uses of carbon are given in the table 3.5 given below

Table 3.7

| Form of carbon | Uses |
|---|---|
| Amorphous carbon | • Production of black colour ink<br>• Vulacanizing rubber |
| Coal | • A fuel |
| Graphite | • Making pencils<br>• Making electrodes of electrochemical cells<br>• Used as a lubricant |
| Diamond | • Making jewellery<br>• Cutting glass and gems<br>• Used as pivots at points in machines that are subject to wear away |
| Charcoal | • Absorbing gases<br>• Purification of water |
| Carbo nfi br es and Carbon tubes | • Used to produce goods reinforced by Nano materials.<br>• Carbon fiber is very light and it is very strong. |

## Some Metalloids

### Silicon


Fig 3.16 - Silicon

Except oxygen, silicon is the most abundant element in the Earth's crust. As compounds, silicon occurs in both crystalline and amorphous forms. Quartz, sand and gems such as emerald are crystalline silicon compounds. Clay is an amorphous silicon compound. The melting point of silicon is 1410 $^0C$.

## Uses Of Silicon

- Used in making transistors and diodes.
- Used in making solar cells.
- Used in makings computer equipments.

## Boron

Pure boron occurs as a black, crystalline solid. It melts at 2200 $^{0}$C and has a density of 3300 kg m$^{-3}$.Its reactivity is relatively low. Therefore it does not react even if heated to high temperatures in air. At very high temperatures amorphous boron reacts with substances like oxygen, nitrogen , nitric acid , concentrated sulphuric acid, carbon and sulphur to form the corresponding compounds.


Fig 3.17 - Boron

### Uses of Boron

- Used in welding metals.
- Used in making skin cream.
- Used in making glass that can be heated into a high temperature.

## • Acidic, basic and amphoteric nature of oxides

An oxide is a chemical compound that combined element with oxygon.

| Elements in Period 3 | Na | Mg | Al | Si | P | S | Cl |
|---|---|---|---|---|---|---|---|
| Oxide | $Na_2O$ | $MgO$ | $Al_2O_3$ | $SiO_2$ | $P_2O_5$ | $SO_3$ | $Cl_2O_7$ |
| Acidic/ basic nature | Strongly basic | Weakly basic | Amphoteric | Very weekly acidic | Weakly acidic | Strongly acidic | Very stongly acidic |

Acidity of the oxides increases →

Basicity of the oxides decreases

When the oxides of elements in Period 3 are considered, there is a clear pattern in the variation of their acidic and basic properties.The oxide of sodium which is on the left of the Period 3 is strongly basic and magnesium oxide is weakly basic.

From silicon to chlorine, the acidity of the oxides increases. Aluminium oxide shows both acidic and basic properties. Such oxides are called amphoteric oxides. Accordingly, from left to right of a Period in the Periodic Table, the basicity of the oxides decreases and their acidity increases.

**Assignment - 3.3**

Find a long form of a Periodic Table. Study it well and refering to it report information on the elements.

**Assignment - 3.4**

Select one element from the metals, non - metals and metalloids you studied. Gather information about it (textbooks, internet, supplementary readers on chemistry may be used). Make a poster contaning the information of the element. Present your information to the class.

## 3.7 Chemical Formulae

### • Valency

The combining ability of an atom of an element is known as the valency. This is measured relative to hydrogen. Accordingly, the valency of an element is either the number of hydrogen atoms which can combine with or can be replaced by an atom of that element. The electrons present in the outermost energy level of an atom of an element are called valence electrons. Some elements can have several valencies. The number of valence electrons in an atom of an element is generally equal to its highest valency.

The valency of an element is equal to the number of electrons lost from or gained by an atom of that element or the number of pairs of electrons shared between the atoms during chemical combination.

We know that chemical symbols are used to identify elements easily.

| | | | |
|---|---|---|---|
| Carbon | C | Calcium | Ca |
| Potassium | K | Sulphur | S |

Similarly, chemical symbols are also used to signify chemical compounds with ease. For instance, $H_2O$ is used to represent water, a compound consisting of two hydrogen atoms and one oxygen atom. This is called the chemical formula of water.

If there is a number at the bottom of the symbol of an element in a chemical formula, it indicates the number of atoms of that element present in a molecule of the compound. If there is no such number, only one atom of that element is present in a molecule of that compound.

For example, chemical formula of glucose is $C_6 H_{12}O_6$. This means that a glucose molecule comprises 6 carbon atoms, 12 hydrogen atom and 6 oxygen atoms.

There are instances where the chemical formula does not represent a molecule. Table salt, known as sodium chloride is such a compound. Solid sodium chloride does not contain discrete molecules.

It is an ionic lattice composed of alternately arranged $Na^+$ and $Cl^-$ ions. In the lattice $Na^+$ and $Cl^-$ ions are present in the ratio of 1:1, so its formula is written as NaCl.

## • Writing Formulae Using Valency

Compounds are formed by the attachment of atoms or ions of elements by chemical bonds. Therefore, to write the formula of a compound, their combining powers or valencies should be known. The formula is written so that the respective combining powers are balanced.

- The valency of hydrogen is 1.
- The valency of oxygen is 2.
- So, two hydrogen atoms can combine with one oxygen atom.
- This is written as $H_2O$.
- The valency of nitrogen is 3.
- Hence, three hydrogen atoms can combine with one nitrogen atom.
- This is written as $NH_3$.
- The valency of carbon is 4. So, four hydrogen atoms can combine with one carbon atom.
- This is written as $CH_4$.

Table 3.6 - Valencies of the elements from atomic numbers 1 to 20

| Atomic number | Element | Symbol | Valency |
|---|---|---|---|
| 1 | Hydrogen | H | 1 |
| 2 | Helium | He | 0 |
| 3 | Lithium | Li | 1 |
| 4 | Beryllium | Be | 2 |
| 5 | Boron | B | 3 |
| 6 | Carbon | C | 4 |
| 7 | Nitrogen | N | 3 |
| 8 | Oxygen | O | 2 |
| 9 | Fluorine | F | 1 |
| 10 | Neon | Ne | 0 |
| 11 | Sodium | Na | 1 |
| 12 | Magnesium | Mg | 2 |
| 13 | Aluminium | Al | 3 |
| 14 | Silicon | Si | 4 |
| 15 | Phosphorus | P | 5,3 |
| 16 | Sulphur | S | 6,2 |
| 17 | Chlorine | Cl | 7,1 |
| 18 | Argon | Ar | 0 |
| 19 | Potassium | K | 1 |
| 20 | Calcium | Ca | 2 |

So, what is done in writing the chemical formula of a compound is connecting the atoms so that their combining powers become equal. This is done by exchanging the valencies of the two elements and writing them at the bottom end on the right hand side of the respective symbols.

| | | | |
|---|---|---|---|
| 01. | **Sodium chloride** | | |
| | Symbol | Na | Cl |
| | Valency | 1 | 1 |
| | | $Na_1Cl_1$ | |
| | Chemical formula | $NaCl$ | |
| 02. | **Calcium chloride** | | |
| | Symbol | Ca | Cl |
| | Valency | 2 | 1 |
| | | $Ca_1Cl_2$ | |
| | Chemical formula | $CaCl_2$ | |
| 03. | **Sodium oxide** | | |
| | Symbol | Na | O |
| | Valency | 1 | 2 |
| | | $Na_2O_1$ | |
| | Chemical formula | $Na_2O$ | |
| 04. | **Calcium oxide** | | |
| | Symbol | Ca | O |
| | Valency | 2 | 2 |
| | | $Ca_2O_2$ | |
| | Chemical formula | $CaO$ | |
| 05. | **Magnesium nitride** | | |
| | Symbol | Mg | N |
| | Valency | 2 | 3 |
| | | $Mg_3N_2$ | |
| | Chemical formula | $Mg_3N_2$ | |

## • Polyatomic Ions (Radicals)

**A polyatomic ions is an orderly arranged group of atoms of elements with a charge.**

Table 3.7 - Some common polyatomic ions

| Radical | Chemical formula | Valency |
|---|---|---|
| Ammonium | $NH_4^+$ | 1 |
| Hydronium | $H_3O^+$ | 1 |
| Nitrate | $NO_3^-$ | 1 |
| Hydrogencarbonate (Bicarbonate) | $HCO_3^-$ | 1 |
| Hydroxide | $OH^-$ | 1 |
| Permanganate | $MnO_4^-$ | 1 |
| Hydrogensulphate (Bisulphate) | $HSO_4^-$ | 1 |
| Chromate | $CrO_4^{2-}$ | 2 |
| Dichromate | $Cr_2O_7^{2-}$ | 2 |
| Sulphate | $SO_4^{2-}$ | 2 |
| Carbonate | $CO_3^{2-}$ | 2 |
| Phosphate | $PO_4^{3-}$ | 3 |

Let's consider the formulae of the following as examples for compounds with polyatomic ions.

**Sodium nitrate**

$Na^+$ $NO_3^-$

Valency 1 1

$NaNO_3$

Chemical formula $NaNO_3$

**Potassium carbonate**

$K^+$ $CO_3^{2-}$

Valency 1 2

$K_2CO_3$

Chemical formula $K_2CO_3$

**Magnesium nitrate**

$Mg^{2+}$ $NO_3^-$

Valency 2 1

$Mg_1(NO_3)_2$

Chemical formula $Mg(NO_3)_2$

**Ammonium phosphate**

$NH_4^+$ $PO_4^{3-}$

Valency 1 3

$(NH_4)_3PO_4$

Chemical formula $(NH_4)_3PO_4$

When there are more than one radical in the chemical formula of a compound, they are written within parentheses.

## Summary

- Atoms are the building units of matter.
- Atoms are formed by the three main subatomic particles, electrons, protons and neutrons.
- At different times different models were proposed for the structure of the atom.
- Ernest Rutherford presented the planetary model for the atom.
- Niels Bohr stated that electrons move in definite paths or shells around the positively charged nucleus.
- The modern Periodic Table is based on the patterns observable in the properties of elements when they are arranged in the ascending order of their atomic number.
- Elements are divided into Groups according to the number of electrons in the outermost shell (energy level) of their atoms.
- Element are divided into Periods in accordance with the number of shells (energy levels) with electrons in their atoms.
- The minimum amount of energy required to remove an electron from a gaseous atom of an element to form a unipositive ion in gaseous state is known as its first ionisation energy.
- A regular pattern can be seen in the variation of the first ionisation energy of elements across a Period from left to right.
- Down a Group, the first ionisation energy of elements decreases.
- When an atom is joined to another atom by a covalent bond, the ability of that atom to attract electrons in the bond towards itself is called its electronegativity.
- The electronegativity of elements increases across a Period and decreases down a Group.
- Across a Period from left to right accidity of oxides formed by the elements increases; their basicity decreases.
- Across a Period from left to right, the metallic properties of elements decrease; non - metallic properties increase.
- Based on the physical and chemical properties, elements can be classified as metals, non –metals and metalloids.
- Majority of the elements so far identified are metals.

## Exercise

01. Complete the following sentences.

i. The mass number of an element is 14 and its atomic number is 6. This atom contains .............. electrons.

ii. An atom of an element consists of 19 protons, 19 electrons and 18 neutrons. The mass number of this atom is ..................

iii. The sum of the number of protons and the number of neutrons in the nucleus of an atom is known as its..................

02. The atomic number of aluminium is 13 and its mass number is 27.

i. Write the atomic number and mass number of aluminium in the standard form.

ii. What is the number of neutrons in an aluminium atom?

03. Complete the following table.

| Element | Number of | | |
|---|---|---|---|
| | electrons in an atom | protons in an atom | neutrons in an atom |
| $^{31}_{15}P$ | | | |
| $^{7}_{3}Li$ | | | |
| $^{24}_{12}Mg$ | | | |
| $^{40}_{20}Ca$ | | | |
| $^{35}_{17}Cl$ | | | |

04. Write the chemical formulae of the following compounds.

i. Lithium fluoride

ii. Beryllium chloride

iii. Aluminium oxide

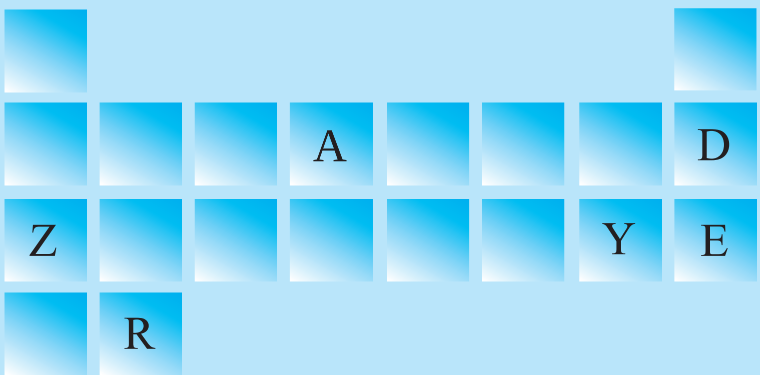
05. Write the chemical formulae of the following compounds.

i. Ammonium chloride
ii. Calcium hydroxide
iii. Calcium phosphate
iv. Magnesium sulphate
v. Aluminium nitrate
vi. Potassium permanganate
vii. Calcium chromate
viii. Ammonium dichromate
ix. Sodium hydrogencarbonate (Sodium bicarbonate)
x. Potassium carbonate

06. What valencies should the following elements have?

i. Lithium
ii. Carbon
iii. Calcium
iv. Sulphur
v. Chlorine

07. A part of the Periodic Table is shown below. The symbols given in it are not true symbols of the respective elements. Answer the questions below that are based on them.




i. Identify the element / elements that behave (s) as a noble gas.
ii. Mass number of Y is 35. Find the number of protons and neutrons in an atom of Y.
iii. Write the electronic configuration of R.

iv. How many valencies are shown by A?

v. A compound is formed by the reaction between A and Y. Write the probable formula of this compound.

vi. Name two metallic elements.

08. D, E, G, J, L, M, Q, R, and T are nine consecutive elements in the Periodic Table. R is a noble gas belonging to Period 3.

i. Of these elements, identify the two elements belonging to the same Group.

ii. To which Group of the Periodic Table do those element belong?

iii. Of the above, name the element of highest electronegativity?

iv. Write the formula of the compound formed by the reaction between E and M.

v. Of the above, identity the element with four valence electrons and write its electronic configuration.

vi. Of the above, name the element with highest first ionisation energy.

## Technical terms

| | | |
|---|---|---|
| Electronic configuration | ඉලෙක්ට්‍රෝන වින්‍යාසය | இலத்திரன் நிலையமைப்பு |
| Isotopes | සමස්ථානික | சமதானிகள் |
| Periodic table | ආවර්තිතා වගුව | ஆவர்த்தன அட்டவணை |
| Periods | ආවර්ත | ஆவர்த்தனம் |
| Groups | කාණ්ඩ | கூட்டம் |
| Valency | සංයුජතාව | வலுவளவு |
| First ionization energy | ප්‍රථම අයනීකරණ ශක්තිය | முதலாம் அயனாக்கச் சக்தி |
| Electro negativity | විද්‍යුත් සෘණතාව | மின்னெதிர்த்தன்மை |
| Metals | ලෝහ | உலோகம் |
| Non- metals | අලෝහ | அல்லுலோகம் |
| Metalloids | ලෝහාලෝහ | உலோகப்போலி |
| Acidic | ආම්ලික | அமிலம் |
| Basic | භාෂ්මික | காரம் |
| Amphoteric | උභයගුණී | ஈரியல்பு |

# Newton's laws of motion

Physics

04

## 4.1 Nature of force and its effects

You have studied about force in your previous classes. When we push something, we apply a force. When we pull something also, we apply a force. Lifting, compressing are also results of applying forces.

What should we do to move a body which is at rest? We have to apply a force in the direction we need to move the body. However, does it start to move as soon as we apply the force?

Try to push a table as shown in Figure 4.1. If it does not move, increase the force. When you keep increasing the force, at some point, it will begin to move.

Figure 4.1 - Pushing a table

If you try to move a bus yourself, in the same manner that you tried to move the table, the bus would not move. But if you push it with the help of a group of people as shown in Figure 4.2, it would move. That is, if we apply a force sufficient to overcome a force that tends to oppose the motion of an object, then it would begin to move. The force that opposes the motion of the object is a resistive force called friction. If the force that we apply is small, it would balance with the resistive force. Since the net force acting on the object at such an instance is zero, the object would not move. If we apply a sufficiently large force, the resistive force would not be able to balance it, and then there would be an **unbalanced force** acting on the object, which could set the object in motion.

Figure 4.2 - Pushing a bus

If the above mentioned table was on a very smooth surface, such as ice, even a very small force would be sufficient to start the motion. That is because, when there is no resistive force, the whole force that we apply becomes an unbalanced force and contributes to the motion of the table. When ever an unbalanced force acts on an object at rest, the object starts to move.

Figure 4.3 shows a cart loaded with goods being pulled by a bull. If someone applies a force from behind, in the direction that the cart is moving, then the cart would move faster. If a force is applied in the direction opposite to the direction of motion, the cart would slow down. This shows that the result of applying a force depends on the direction of the force.

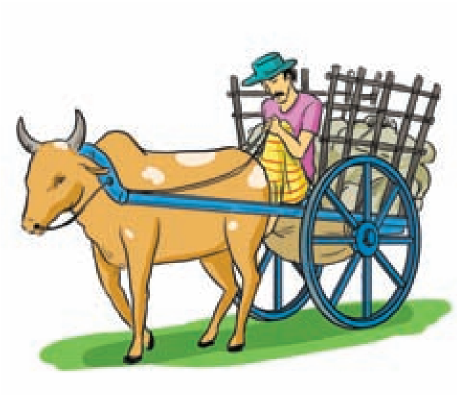


Figure 4.3 - A cart pulled by a bull

This means that the force has both a magnitude and a direction. Since there is a magnitude as well as a direction, the **force is a vector.** The direction of a force acting on some point can be indicated by a straight line drawn from that point. This line is called the line of action of the force.

What we experience about force and motion has been studied in depth by the famous scientist, Sir Isaac Newton. He has formulated three laws of motion based on his studies. Let us now investigate each of these laws.

## Newton's first law

**Until an unbalanced force is applied on it, bodies at rest remain stationary and bodies in motion continue to move at uniform velocities.**

From day to day experience we know that bodies at rest do not start moving without external forces acting on them. However, we often observe that moving bodies come to rest without an external force exerted on them by us. Let us consider the following example in order to understand this.

Consider the case of striking on the carom disc on a carom board with your fingernail as shown in Figure 4.4. Then the disc would move a short distance and come to rest. If we apply some talcum powder on the carom board to make the surface smoother and then repeat the above action by striking on the disc with roughly the same force as before, the disc would move a much longer distance before coming to rest.


Figure 4.4 - Striking a carom disc

The action of the talcum powder on the board is to reduce the resistive forces exerted on the disc by the carom board. The resistive force that opposes the motion of an object on a surface, is called friction. If by some means we could make the frictional force equal to zero, the disc would move without stopping.

Let us consider another example that we experience in daily life, connected to this law. Suppose a passenger is standing on a moving bus without holding any thing for support. If the bus suddenly stops by applying brakes, the passenger would fall towards the forward direction. What is the reason for this?

Since his feet were in contact with the floor board of the bus, the floor board exerts a resistive force on the feet and brings the feet (which too had the speed of the bus) to rest. Since no such force is exerted on the upper parts of his body, their velocity, carries him forward. He falls in the forward direction because of this.

Now suppose that the above passenger is in a bus at rest. If the bus starts to move without his knowledge, the passenger would now fall in the backward direction. As the bus starts, it would exert a force on the feet of the passenger giving the lower part of his body a velocity. The upper part of his body however does not have this velocity and remains at rest, resulting in his falling back.

Seat belts must be worn when riding in a vehicle to prevent the passenger from falling forward upon applying brakes. As the seat belt exerts a force on the upper part of his body as well, the whole body remains at the velocity of the vehicle even when brakes are applied. if no belts are worn the upper part of the body has some velocity and tends to go forward.

Figure 4.5 – Seat belt privents the driver being thrown forward when breaks are applied.

## Newton’s second law

**The acceleration of a body is directly proportional to the unbalanced force acting on it, while it is inversely proportional to its mass.**

Here, "the acceleration is **directly proportional** to the unbalanced force" means that when the magnitude of the unbalanced force is increased or decreased by a certain ratio then the acceleration also increases or decreases by the same ratio.

This is symbolically written as $a \propto F$.

Similarly "the acceleration is **inversely proportional** to the mass" means that if the mass is increased by a certain ratio, then the acceleration decreases by the same ratio, and if the mass is decreased by a certain ratio, then the acceleration increases by the same ratio.

This statement is symbolically written as, $a \propto \frac{1}{m}$.

Therefore Newton’s second law can be written as

$$a \propto F \text{ and}$$

$$a \propto \frac{1}{m}$$

$$\text{or, } a \propto \frac{F}{m}$$

$F / m$

Therefore we have, $\frac{\mathrm{F} / \mathrm{m}}{\mathrm{a}}$ = constant

The unit of force is defined in such a way that the above constant is equal to one. That is, if the unit of force is defined in such a way that the force required to produce a unit acceleration (1 m s$^{-2}$) in a body of unit mass (1 kg) is equal to 1 Newton (1 N), Then the value of the left hand side of the above equation becomes 1, That means when

$$F / m$$

$$\frac{F / m}{a} = 1$$

then the constant will also become 1. Therefore, Newton's second law can be written as

$$F = ma$$

A force is acting on an object, gives rise to an acceleration.

Let us consider the following experiment in order to verify Newton’s second law.

Figure 4.6 - Demonstrating that the acceleration of a trolley increases with force

- Place a trolley on a horizontal surface, attach a rubber band to the trolley and hold the trolley with one hand.
- Hold the free end of the rubber band with the other hand as shown in Figure 4.6 and pull it until it is extended to the other end of the trolley.
- Next, release the trolley and move your hand along with the trolley, without changing the extension of the rubber band. You will notice that the trolley moves with an acceleration.
- Attach another rubber band similar to the first one to the trolley and stretch both to the other end of the trolley as before and repeat the experiment. As the force on the trolley is now twice the force in the previous step, you will be able to observe that the trolley moves with a larger acceleration than before.
- Repeat the experiment with three rubber bands and observe that the acceleration is even larger than that in the second time. Since there are three rubber bands, the force exerted on the trolley is three times as large as in the first time.
- Accordingly, it can be observed that the acceleration of the trolley increases as the force exerted on it is increased.

- Now place a mass on the trolley and repeat the experiment with one rubber band and observe the motion of the trolley. You will observe that the acceleration has decreased.

- Then repeat the experiment with another mass placed on the trolley and you will notice that the acceleration decreases further.

From this it will be clear that the acceleration decreases with increasing mass if the force is constant.

$$a = \frac{F}{m}$$

It is clear from the above equation that for a constant force, the acceleration increases if the mass is decreased and the acceleration decreases if the mass is increased.

## Example 1

What is the force required to give an acceleration of 2 m s$^{-2}$ to a 5 kg mass?

$$\begin{aligned} F &= ma \\ &= 5\text{ kg} \times 2\text{ m s}^{-2} \\ &= 10\text{ N} \\ &\quad (1\text{ kg m s}^{-2} = 1\text{ N}) \end{aligned}$$

## Example 2

A force of 12 N is applied on a body of mass 6 kg, moving at a uniform velocity, in the direction of its motion. Find the acceleration of the body.

$$\begin{aligned} F &= ma \\ 12 &= 6 \times a \\ a &= \frac{12}{6} \\ a &= 2\text{ m s}^{-2} \end{aligned}$$

### Example 3

If an acceleration of 2 m $s^{-2}$ results when a force of 8 N is applied on a certain object, find the mass of the object.

$$F = ma$$
$$8 = m \times 2$$
$$m = \frac{8}{2}$$
$$m = 4 \text{ kg}$$

### Exercise 4.1

Fill in the blanks in the table given below.

(1)

| Force ( N ) | Mass ( kg ) | Acceleration ( m $s^{-2}$ ) |
|---|---|---|
| .................... | 3 kg | 2 m $s^{-2}$ |
| 40 N | 10 kg | .................... |
| 30 N | .................... | 1.5 m $s^{-2}$ |
| 2 N | 500 kg | .................... |

(2) (a) If a force of 6 N is applied on a body of mass 4 kg, moving at a uniform velocity, in the direction of its motion, find the resulting acceleration.

(b) If the above force is applied in the direction opposite to the direction of motion of the body, find its deceleration.

## Newton's third law

**For every action, there is an equal and opposite reaction.**

Here, an **action** means a force exerted by an object on another object. Then the **reaction** is a force exerted on the first object, by the second object.

Expulsion of air from an inflated balloon is a practical situation where this law can be applied. Hold a balloon filled with air, with its opening turned downwards.

Loosen the hold on the opening and release the balloon as shown in Figure 4.7. You will notice that the balloon would initially move upwards rapidly and later fall down. Air leaves the balloon as its rubber walls push the air molecules downwards. The balloon moves upward due to the reaction force exerted on the rubber walls by the air molecules moving out.

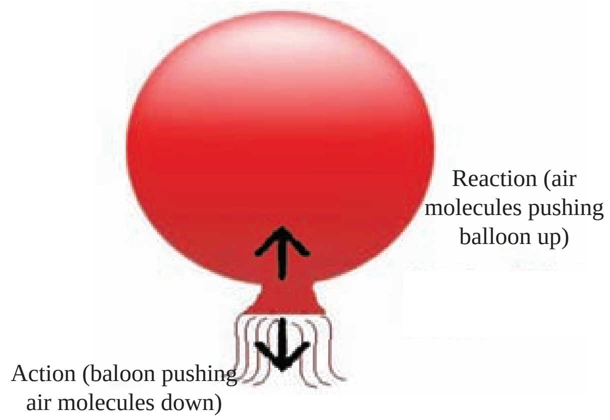



Figure 4.7 –Air inside the balloon leaving it and the balloon moving upwards.

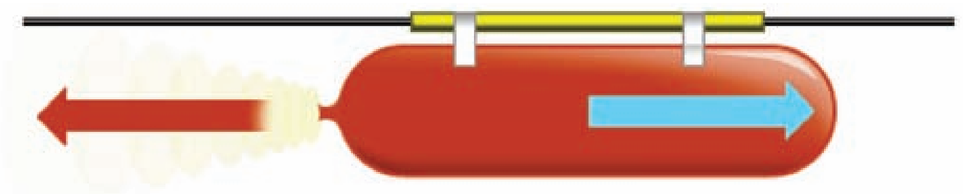


Figure 4.8 – Air leaving the balloon and the balloon moving in the opposite direction

A balloon moving due to air leaving the balloon can also be illustrated as shown in Figure 4.8. Attach a straw to an air filled balloon as shown in Figure 4.8, using cellotape. Insert a metal wire through the straw and fix it horizontally from the two ends. Allow the air in the balloon to leave by removing the thread that closes the opening of the balloon.

You will be able to observe the balloon moving on the metal wire in the direction opposite to that of the air leaving the balloon.

Another instance illustrating the action and reaction is shown in Figure 4.9. Place two planks of wood on a few glass balls. Let two children sit on the two planks. If they push each other with their palms as shown, it would be possible to observe them moving in opposite directions.

Figure 4.9 - Two children being pushed in opposite directions when pushing each other with their palms.

A few other instances where Newton’s third law is applied are mentioned below.

When rowing a boat (Figure 4.10), water is pushed in the backward direction using the oars. That is, a force is applied on water by the oars. Then the boat moves forward due to the reaction force applied on the oars by water.

Figure 4.10 – Force applied on the water by the oars and the reaction force acting on the boat.

In swimming (Figure 4.11), the swimmer exerts a force on water in the backward direction. Then water exerts the reaction force on the swimmer's body in the forward direction. Because of this, the swimmer moves forward. The action in this case is the backward force applied by the hands. The reaction is the forward thrust exerted by water.

Figure 4.11 - Hands applying a force on water and an equal and opposite force exerted on the hands by water.

## 4.2 Momentum

The momentum of a moving body is a measure of how difficult it is to stop the motion of that body.

It would be an easy task to catch a pen or pencil thrown to you by a friend. If however, somebody throws a putt or some other heavy object towards you, it would not be so easy to catch it. If the same object is handed over to you without throwing then it would not be difficult to take it to your hand.

The reason for the difficulty in catching such an object is not only its large mass but also the speed with which it is moving. A bullet fired from a gun has very small mass. But once it is fired, we cannot even think of catching it.

Therefore, we can conclude that the level of difficulty in stopping a moving body depends on two factors; mass and velocity.

In physics, the momentum ($p$) of a body is defined as the product of the mass ($m$) of the object and its velocity ($v$).

**Momentum = mass × velocity**

$$p = m \times v$$

**The unit of mass is kg. The unit of velocity is m s$^{-1}$. Therefore, the unit of momentum is kg m s$^{-1}$.**

Since the velocity is a vector, the momentum is also a vector.

When a motor vehicle is moving fast, it possesses a large momentum. When it reduces its velocity, the momentum decreases. When it speeds up, the momentum increases.

### Example 1

What is the momentum of a body of mass 2000 kg moving at a velocity of 20 m $s^{-1}$?

$$\text{Momentum} = m \times v$$
$$= 2000 \text{ kg} \times 20 \text{ m s}^{-1}$$
$$= 40000 \text{ kg m s}^{-1}$$

### Example 2

A bullet of mass 10 g fired by a gun moves at a velocity of 400 m $s^{-1}$. Find its momentum.

In this problem, when we substitute the value of mass to the equation, we must convert the mass to kg.

$$\text{Momentum} = m \times v$$
$$= \frac{10}{1000} \text{ kg} \times 400 \text{ m s}^{-1}$$
$$= 4 \text{ kg m s}^{-1}$$

### Exercise 4.2

1. The mass of a motor car is 800 kg. Find its momentum when it is moving at a velocity of 5 m $s^{-1}$.
2. The mass of an object is 600 g. Find its momentum when it is moving at a velocity of 5 m $s^{-1}$.
3. A certain object has a mass of 200 g. if it moves with a velocity of 4 m $s^{-1}$ what is the momentum of the object ?
4. The momentum of a moving object is 6 kg m $s^{-1}$. Find its velocity if it has a mass of 500 g.
5. An object of mass 3 kg is projected upwards. At the beginning of the motion its velocity is 10 m $s^{-1}$.
   (a) What was its momentum at the moment when it was projected?
   (b) What would be the momentum when it reaches the highest point?

## 4.3 Mass and weight

The mass of an object is the amount of matter in it. The international unit of mass is the kg.

The weight of an object is the force with which it is attracted towards the earth. That is, the force acting on it due to gravitational attraction of the earth.

According to Newton's second law, the force acting on a body moving at an acceleration is given by,

$$F = m a$$

If it is moving under gravity, then its acceleration would be the gravitational acceleration g. Then, the force exerted on the body is its weight and it is given by,

$$\text{Weight} = \text{mass} \times \text{acceleration} = m g$$

Because the weight is defined as a force, its international unit is the Newton (N).

The point of which this force acts is the centre of gravity ot the body.

Since the gravitational acceleration near the surface of the earth at sea level is 9.8 m $s^{-2}$, the weight of a body of mass $m$ is 9.8$m$. The weight of an object of mass 1 kg would be 9.8 N.

Attractive force exerted by the earth on a mass of 3 kg (weight) = 3 kg × 9.8 m $s^{-2}$
= 29.4 N

When we go up, starting from sea level, the gravitational acceleration gradually decreases. Therefore, if we take an object to the top of a mountain, the weight of the object becomes less, while the mass remains constant. On the moon, the gravitational acceleration is about 1/6 of that on the earth. Therefore, the weight of an object on the moon is about 1/6 of the weight of that object on the earth.

### Miscellaneous exercises

(1) (i) State Newton's first law.

(ii) Why are the passengers standing on a moving bus, thrust forward when brakes are suddenly applied?

(iii) A passenger is seated in a bus at rest. If the bus starts to move without his knowledge, why is he pushed backwards?

(iv) What is the benefit of wearing seat belts when travelling in vehicles?

(2) (i) State Newton's second law.

(ii) The mass of a body is 12 kg. What is the resulting acceleration if a force of 6 N is applied on it in the direction of motion?

(3) Fill in the blanks of the table given below.

| Force ($F$) | Mass ($m$) | Acceleration ($a$) |
|---|---|---|
| ............... | 10 kg | 2 m $s^{-2}$ |
| 60 N | 12 kg | .................... |
| 4 N | 500 g | ..................... |
| 40 N | ................ | 5 m $s^{-2}$ |

(4) The mass of a certain object is 6 kg. What is the force that could have acted on it, if its velocity increased from 5 m $s^{-1}$ to 13 m $s^{-1}$ during 5 s?

(5) (i) State Newton's third law.

(ii) Give three instances where Newton's third law is applied.

(iii) What are the factors affecting the momentum of an object.

(6) What is the momentum of an object of mass 10 kg, moving at a velocity of 4 m $s^{-1}$?

(7) The mass of an object is 750 g. At a certain instant, its velocity is 8 m $s^{-1}$. What is its momentum at this instant?

(8) At a certain instant, the momentum of an object is 6 kg m $s^{-1}$. If its velocity at that instant is 3 m $s^{-1}$, what is its mass?

(9) (i) The mass of an object is 60 kg. What is its weight? (g = 10 m $s^{-2}$)

(ii) If the gravitational acceleration on the moon is 1/6$^{th}$ that of the earth, what would be the weight of the above object on the moon?

(10) The weight of an object is 5 N. At a certain instant, its momentum is 6 kg m $s^{-1}$. Due to a force applied in the direction opposite to the direction of motion. the velocity is of the object decreased to 4 m $s^{-1}$ during 4 s. what is the force exerted on the object ?

## Summary

- According to Newton's first law, until an unbalanced force acts on it, a stationary body remains at rest and a moving body continues its motion at a uniform velocity.
- Newton's second law states that the acceleration of a body is directly proportional to the force acting on it and inversely proportional to its mass.
- Newton's third law states that for every action, there is a reaction equal in magnitude and opposite in direction to the action.
- The weight of an object is the force with which it is attracted to the center of the earth. It is equal to the force that is required to accelerate it with the gravitational acceleration $g$.

| Technical terms | | |
|---|---|---|
| Force | බලය | விசை |
| Unbalanced Force | අසංතුලිත බලය | சமநிலைப்படாத விசை |
| Uniform acceleration | ඒකාකාර ත්වරණය | சீரான ஆர்முடுகல் |
| Uniform velocity | ඒකාකාර ප්‍රවේගය | சீரான வேகம் |
| Mass | ස්කන්ධය | திணிவு |
| Acceleration | ත්වරණය | ஆர்முடுகல் |
| Action | ක්‍රියාව | தாக்கம் |
| Reaction | ප්‍රතික්‍රියාව | மறுதாக்கம் |
| Momentum | ගම්‍යතාව | உந்தம் |

# Friction

Physics

05

## 5.1 Nature of friction

If we place an object such as a pencil on a table and tap on it so that it starts to move on the table, we know from experience that its speed would gradually decrease until it ultimately comes to rest. If we place the same object on a surface smoother than that of the table, the object would move a longer distance on the surface before coming to rest.

An object moving on a surface gradually slows down and comes to rest as described above, because the surface exerts a force on the object to oppose its motion. This opposing force is known as a frictional force. Friction always opposes the motion of an obiect.

Let us consider a situation where a table needs to be pushed along a horizontal floor as shown in Figure 5.1.

Figure 5.1 – Pushing a table

If we try to move the table with a very small force, it might not move. This is because the floor exerts a force on the table which opposes the force that we apply. The two forces have equal magnitudes but opposite directions. Therefore they cancel out.

Now suppose that we slightly increase the force that we apply on the table. If the table still does not start to move, it means that the frictional force exerted by the floor has automatically increased in order to balance the force that we applied. The frictional force is a force which automatically adjusts to balance the force we apply. However, if we keep on increasing the force on the table, at some instant, the table will begin to move. This happens because the frictional force cannot automatically adjust beyond a certain limit. When the force that we apply exceeds that limit, an unbalanced force that is equal to the difference between the two opposite forces remains. This unbalanced force starts the motion of the table.

The forces that act between the surfaces of two objects in contact with each other, to oppose the relative motion when the objects are moving relative to each other or, to oppose the tendency to move when the objects have a tendency to move relative to each other, are called frictional forces.

Frictional forces exist in the motion of liquids and gasses too, However, in this lesson we discuss only the frictional forces that act between solid bodies.

## 5.2 Static, limiting and dynamic states of frictional forces

Frictional forces can be divided into three categories, depending on the situations they act on a body

They are:

1. The frictional forces that act when there is no relative motion, even though, a force is applied on the body.
2. The frictional forces that act on a body as it just begins to move. This force includes the small additional force that is necessary to give it a velocity.
3. The frictional forces that act on bodies when they are in relative motion.

In order to investigate differences among the three types of frictional forces mentioned above, let us do the following activity.

## Activity 1

**Items required** : A block of wood weighing 60 N, a Newton balance

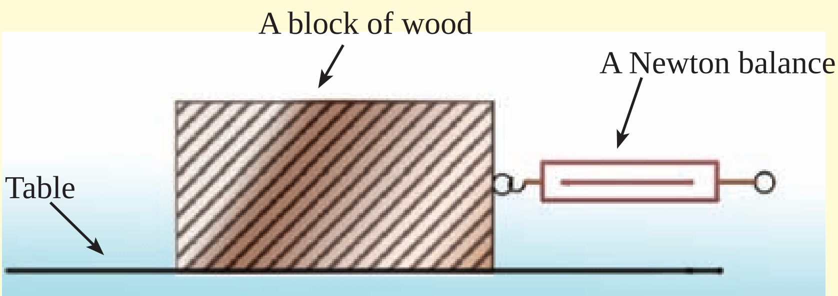



Figure 5.2 – Finding the maximum frictional force exerted on the object

Procedure :

- Fix a small ring to the block of wood and attach the balance to the ring.
- Place the block of wood on a horizontal table and pull the block as shown in Figure 5.2, with a very small force. You would be able to read the magnitude of the applied force from the Newton balance. Initially, the force would be insufficient to move the block.
- Gradually increase the force on the object. When the force is gradually increased, at some point it will just begin to move. Find the force at the moment it just about to move.

The body begins to move because the table surface is not capable of further increasing the frictional force in order to balance the force that you exerted. In other words, the frictional force does not exceed that force. The maximum frictional force exerted by the surface of the table to oppose the motion is equal to the force necessary to just start the motion.

Whenever the force applied on the body is smaller than this maximum frictional force, the surface of the table exerts a frictional force on the body that is equal and opposite to the applied force. This frictional force exerted on the body before the motion starts is called **static friction**.

When the applied force is gradually increased, the static friction acting on the body also increases with it. However, the static frictional force can increase only up to a certain maximum value. When the applied force exceeds this maximum value the frictional force is incapable of increasing further in order to keep the body in equilibrium. Therefore the body begins to move and acquires a small velocity. This maximum frictional force between the surfaces of two bodies in contact with one another is known as the **limiting frictional force** between the two bodies.

The frictional force acting on the body after the body starts to move, is known as **dynamic friction** between the two surfaces. In other words, dynamic friction is the frictional force acting on bodies that are in motion. Dynamic friction is slightly less than the limiting frictional force.

## 5.3 Factors affecting the limiting frictional force

Frictional forces act between objects that are in contact with one another. Therefore, let us now investigate how the frictional forces depend on the nature and area of contact surfaces and the reaction forces perpendicular to the contact surfaces (normal reaction).

Let us first do the following activity in order to investigate how the limiting frictional force depends on the nature of the contact surfaces.

### Activity 2

**Items required** : A block of wood weighing 60 N, a Newton balance, several sheets of sand paper of various roughness

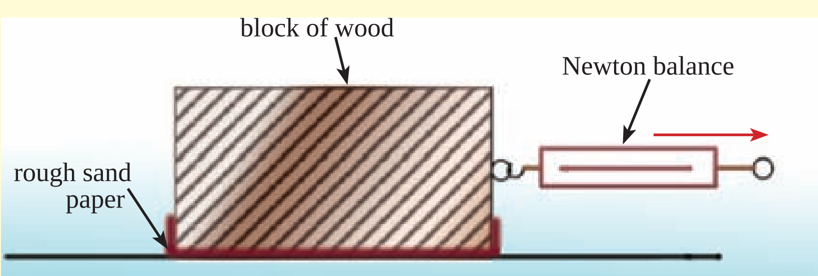



Figure 5.3 – Investigation of the influence of surface roughness on friction

Procedure :

- Fix the block of wood with the sand paper having the lowest roughness with rough side facing out and completely covering the bottom surface.
- Place the block of wood on the table so that the rough surface of the sand paper is in contact with the surface of the table. Next pull the Newton balance attached to the block with a very small horizontal force at first and then increasing the force gradually.
- When the block of wood just begins to move, record the reading of the Newton balance. This is the limiting frictional force.
- Next use a sand paper which is rougher than the first and fix it again to cover the bottom surface of the block, and find the limiting frictional force that is just enough to set the block of wood in motion.
- Repeat the above procedure using several sand papers of increasing roughness and record the limiting frictional force each time.
- Compare the results you obtained. You will observe that the limiting frictional force increases gradually with increasing roughness of the sand paper used to cover the block of wood.

**This activity shows that the limiting frictional force depends on the nature of the surfaces in contact.**

Now let us investigate the dependence of the limiting frictional force on the surface area of the contact surfaces through the following activity.

## Activity 3

**Items required** : A block of wood with a weight of 60 N and different dimensions for length, width and height, a Newton balance, several pieces of sand paper of equal roughness.

Procedure :

- Paste the sand paper on the surfaces of the block of wood which have different areas.
- Next place the surface with the largest area in contact with the table top and find the force that is just enough to move the block (the limiting frictional force) as before.

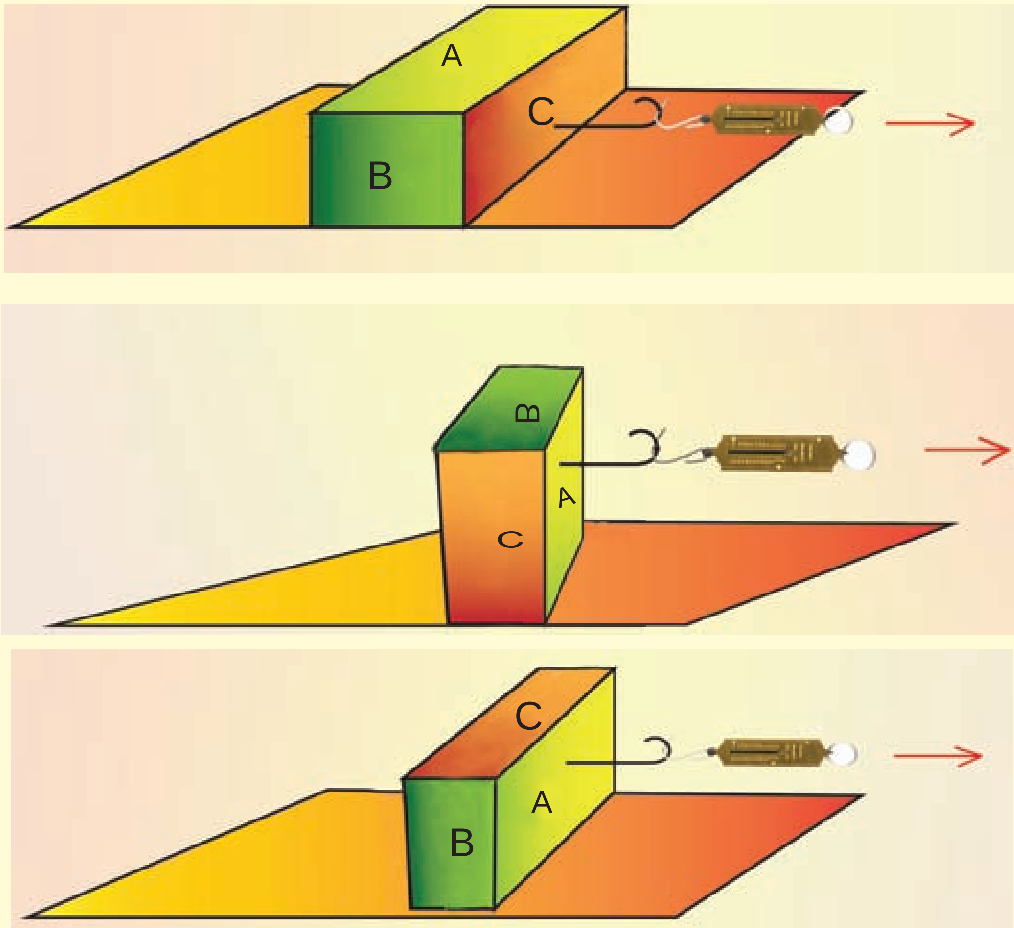



Figure 5.4 – Investigation of the influence of surface area on friction

- Repeat the above step, placing different surfaces of the block in contact with the table as shown in Figure 5.4, to find the limiting frictional force corresponding to each surface.
- You will find that the limiting frictional force is the same for all surfaces of the block of wood in contact with the table. This shows that the limiting frictional force **does not depend** on the surface area.

Our next activity is the investigation of the dependence of the normal reaction between bodies in contact, on the limiting frictional force.

## Activity 4

**Items required**: Three blocks of wood each having a weight of 20 N, a Newton balance

Procedure :

- As in the previous experiment, place one block of wood on the table and find the force required to just move the block. That is the limiting frictional force.
- Next, place another block of wood on the first one and find the limiting frictional force as before.
- Repeat the above step with the third block placed on the other two and record the limiting frictional force.

This experiment can also be done by placing various other objects on the first block of wood instead of the other blocks of wood.

You will notice that the readings obtained for different weights are not the same and that the limiting frictional force increases with increasing weights.

That is, when the weight (W) is increased, the normal reaction exerted on the weight by the table (perpendicular reaction force R) also increases.

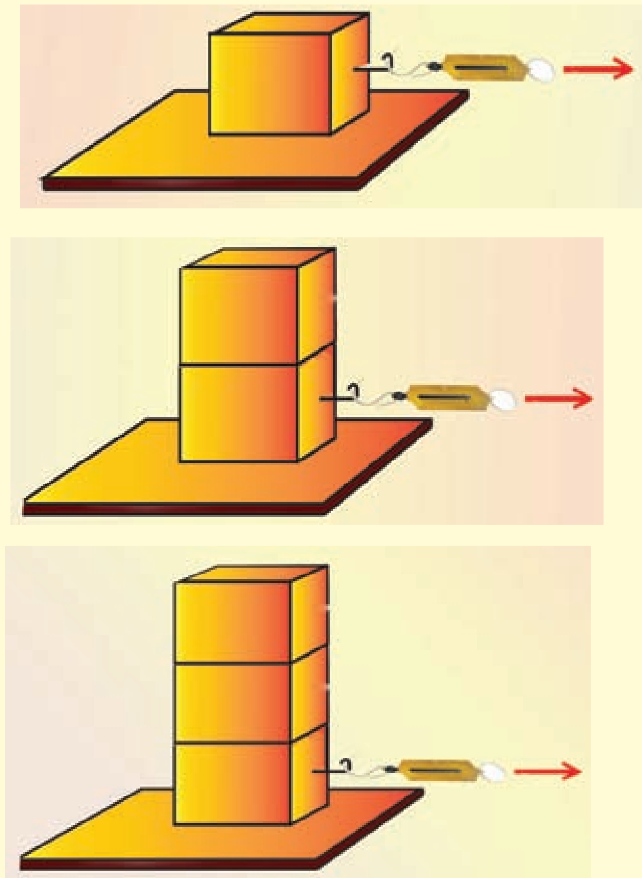


Figure 5.5 – Investigation of the influence of nomal reaction on frictional force

That is, weight of the object = perpendicular reaction force.

**This activity shows that the limiting frictional force increases when the normal reaction between the two forces increases.**

The above activities show that the limiting frictional force depends on the nature of the contact surfaces and the normal reaction between the surfaces while it does not depend on the area of the contact surfaces.

## 5.4 Practical applications of friction

Various parts of most of the machines and instruments that we use daily are in contact with other parts. When we operate these machines and instruments, these parts slide on one another, giving rise to frictional forces. Therefore, when machines are operated, an excessive amount of additional work has to be done against frictional forces, causing a loss of energy, This loss of energy appear as heat, raising the temperature of the object. If we could reduce frictional forces, then we would be able to minimize the energy loss and the rise in temperature.

### Methods of reducing friction

- Reducing the roughness of contact surfaces or polishing them.
- Applying lubricators such as graphite, lubrication oil or grease between the contact surfaces.
- Inserting balls that could roll between the contact surfaces. Such balls can prevent the two contact surfaces from sliding on each other. Ball bearings used to connect most of the rotating parts of vehicles and machines to stationary parts such as axles are fabricated in this manner. A few different types of bearings are shown in Figure 5.6.

Figure 5.6 – Some types of bearings

## Advantages of frictional forces

So far we discussed only some disadvantages of frictional forces and how to minimize them. Sometimes friction is useful to us. A few such examples are given below.

- We can walk on a surface only because of the frictional force exerted by that surface on our feet prevents slipping. If we try to walk on a wet surface or an oily surface, we tend to slip and fall, due to lack of friction.
- Grooves are etched on the surface of tire as shown in figure 5.7 in order to increase the friction between the tire and the road surface. If a sufficient amount of friction is not exerted on the tire, the wheels would tend to skid on the road, causing accidents. Sometimes, when a motor vehicle is travelling on mud or sand, the wheels tend to rotate in the same place, without moving forward because the friction is insufficient for the wheels to move forward. On wet roads a water layer that exists between the road and the tire tends to reduce the friction between the two surfaces causing the vehicles to skid. The purpose of having grooves on the surface of tyres is to allow water to pass through these grooves.

Figure 5.7 – Tires with grooves to increase friction

- Coir ropes are formed by twisting a large number of coir fibers together. Even when a large force is applied on a rope, the fibres do not separate because of the friction among them. It is easier to untie a knot made with a nylon string than a knot made with a coir string. This is because the frictional forces among the coir fibers are stronger than those among the nylon fibers.

- Moving vehicles can be brought to rest by applying brakes because of friction. As shown in figure 5.8, breaks of a bicycle operate by pressing the break-pads which are made of rubber on the wheel rim. The bicycle stops because of the friction between the surfaces of the rubber break-pads and the wheels.

Figure 5.8 – Break system of a bicycle

- In modern motor vehicles, disc-breaks are used to stop the vehicle. Such a break system is shown in figure 5.9. In such systems, the frictional forces caused by pressing the break-pads against a disc attached to the wheel, are used to stop the wheels from rotating.

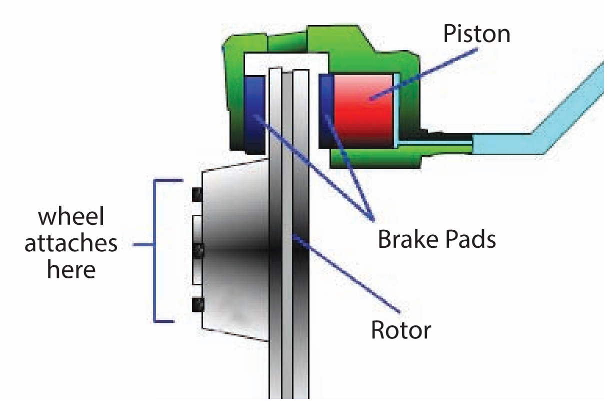



Figure 5.9 - Disk brake system of a car

## Exercise

(1) (i) Briefly state what is meant by friction.

(ii) Briefly explain what is meant by static friction.

(iii) Briefly explain what is meant by limiting friction.

(iv) Under what circumstances does dynamic friction act?

(v) What are the two main factors that limiting friction depends on?

(vi) State a factor on which friction does not depend?

(2) (i) Give two benefits of friction.

(ii) Give two disadvantages of friction.

(iii) It is dangerous to drive vehicles with tires that have worn out grooves on rainy days. Explain why.

(iv) Write down two methods used to reduce friction.

## Summary

- When one of two bodies in contact with one another moves or tries to move relative to the other, the second body exerts a force that tends to stop this relative motion. This phenomenon is known as friction.
- The frictional force that acts before the body begins to move is the static friction. Static friction between the bodies varies with the external force that tries to cause the relative motion.
- The frictional force that acts when the relative motion between the two bodies just starts.
- Limiting friction between two bodies depends on the nature of the contact surfaces and the normal reaction.
- Limiting friction does not depend on the surface areas of the contact surfaces.
- The frictional force acting on a moving body is the dynamic friction.

| Technical terms | | |
|---|---|---|
| Friction | ඝර්ෂණය | உராய்வு |
| Static friction | ස්ථිතික ඝර්ෂණය | நிலையியல் உராய்வு |
| Limiting friction | සීමාකාරී ඝර්ෂණය | எல்லை உராய்வு |
| Dynamic friction | ගතික ඝර්ෂණය | இயக்கவியல் உராய்வு |
| Weight | බර | நிறை |
| Normal Reaction | අභිලම්බ ප්‍රතික්‍රියාව | செவ்வன் மறுதாக்கம் |

Biology

06

# Structure and functions of the plant and animal cell

## 6.1 Basic unit of life

In 1665, Robert Hooke observed a section of a cork using a microscope prepared by him. He discovered a structure like chambers in a beehive and he named them as cells.


**Figure 6.1 Robert Hooke, the microscope and the cells in a section of the cork**

Schleiden, Schwann and Radolf Virchow introduced the cell theory, based on the facts revealed by observing different live tissues through the microscope.

The contents of the cell theory are as follows.

- The structural and functional unit of life is the cell.
- All organisms are made up of one or more cells.
- New cells are formed from pre-existing cells.

## 6.2 Concept of the cell

The cell is the smallest structural unit of the organization of the living body.

The organisms composed of a single cell are called unicellular organisms and those of many cells are called multicellular organisms.
Cells perform different functions in the body.

For example - The transportation of oxygen is done by red blood cells.

Transmission of impulses is done by neurons.

Accordingly, the smallest bio unit that is adapted to perform a particular function is the cell. So it is clear that the structural and functional unit of life is the cell.

The cells differ from one another from their shape, size and function. Except few occasions, mostly cells are not visible to the naked eye. Therefore they have to be observed using the light microscope.

## 6.3 Structure of cells

Let's do the following activities (01 and 02) to study the structure of animal cells and plant cells.

To study the animal cells we will observe cheek cells and for the plant cells, let's take onion epidermal cells, as these cells are easily obtained.

### Activity 01

**Study of animal cells (cheek cells)**

**Materials Required -** Sample of cheek cells, Glass slide, Cover slip, Microscope, Water

**Method**

Wash the mouth and scrape the inner side of the cheek using a yoghurt spoon. Obtain a clean glass slide and put a drop of water and transfer the specimen on to the slide. Cover the specimen using a cover slip without trapping any air bubbles and observe through the light microscope.

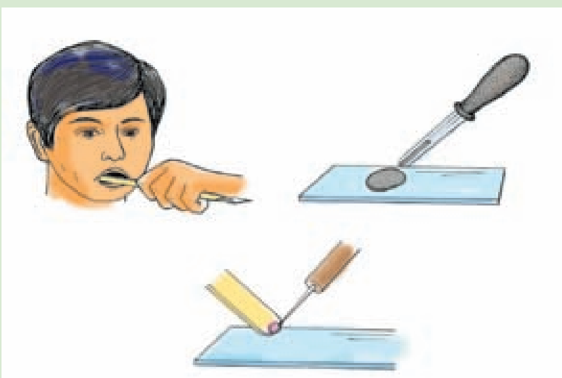
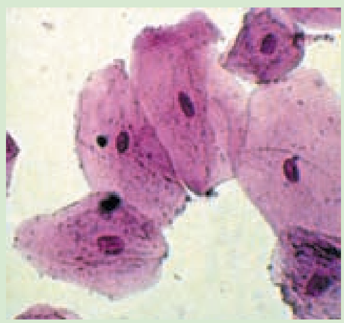


**Figure 6.2 (a)**



**The appearance of stained cheek cells through the light microscope**
**Figure 6.2 (b)**

## Activity 02

**Study of plant cells (onion peel cells)**

**Materials Required -** Onion peel, Watch glass, Glass slide, Cover slip, Paint brush, Microscope, Water

**Method**

Cut an onion and obtain an inner fleshy tissue as shown in the diagram. Remove a peel from inner or outer surface of it and transfer it on to a watch glass containing water. Put a water drop on to a clean glass slide and transfer the specimen on to the slide using a paint brush. Cover it with a cover slip without trapping any air bubbles and observe it through the microscope.

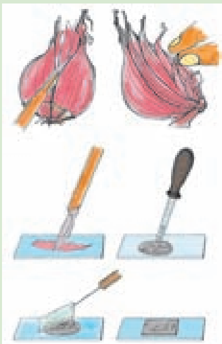
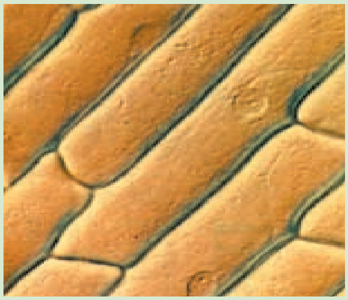


**Figure 6.3 (a)**



**The appearance of stained onion peel cells through the light microscope**
**Figure 6.3 (b)**

## • Typical cell

The small structures present within the cell to perform different functions are known as organelles.The types of organelles and the number of them differ according to the function performed by the cell.

The cell prepared by including all the organelles is known as the typical cell. In the living world such cells do not exist. But cells with a certain number of organelles of the typical cell can be found in living organisms.

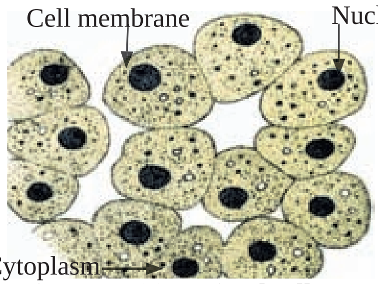



**Figure 6.4 (a) -Animal cells**

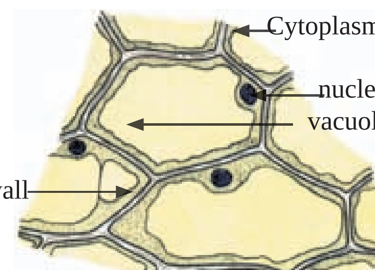



**Figure 6.4 (b) - Plant cells**

**(appearance through a light microscope)**

All animal cells are covered by a plasma membrane or a cell membrane. It is a live semi permeable membrane as well as a selective permeable membrane. There is a centralized nucleus in an animal cell. The cytoplasm is a gelatinous material.

The outer covering of the plant cell is the cell wall . It is made up of cellulose. Inner to the cell wall is the plasma membrane. At the center of plant cell is a large vacuole. Generally there are no such vacuoles in animal cells.

Animal cells as well as plant cells possess different organelles that perform different functions.

Most of the above organelles cannot be observed through the light microscope. Therefore the electron microscope should be used.

Below are the typical plant and animal cells created based on electron microscopic information.

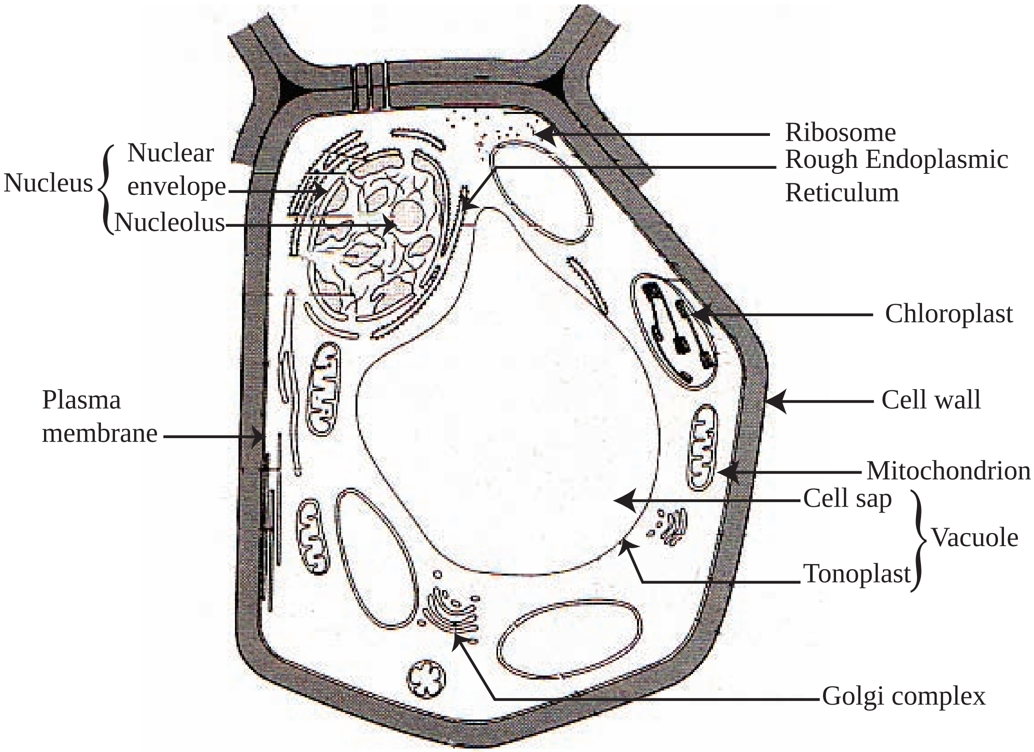



**Figure 6.5 - Typical plant cell created using electron microscopic information**

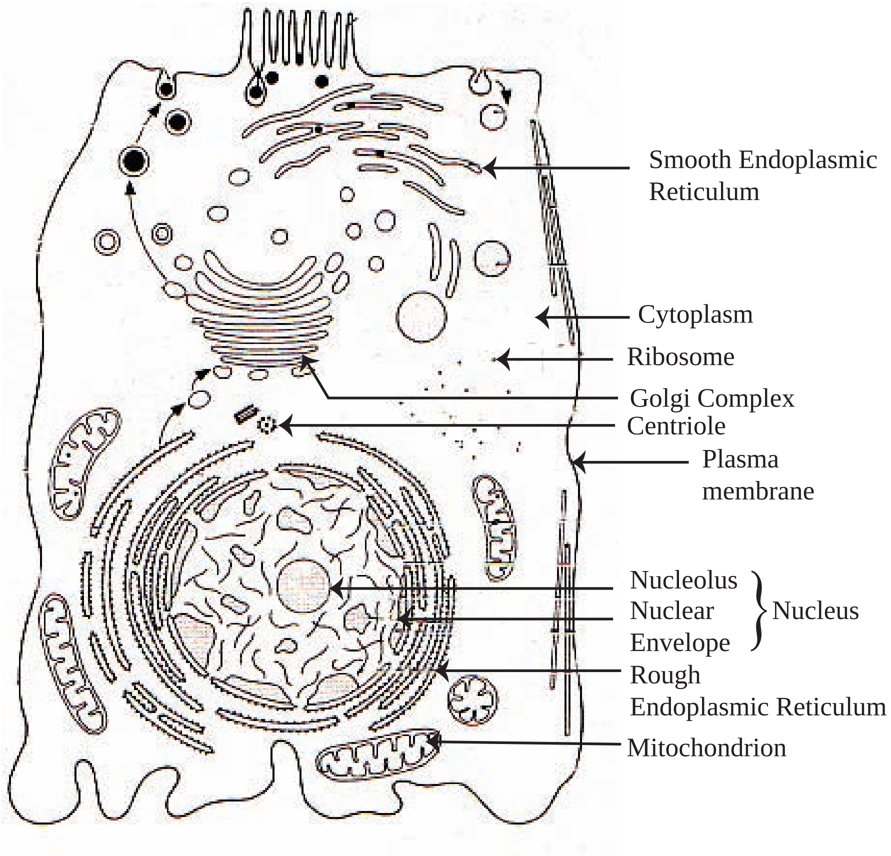



**Figure 6.6** -**Typical animal cell created using electron microscopic information**

There are similarities and differences between animal and plant cells.

The table 6.1 contains the differences between animal and plant cells.

**Table 6.1- Differences between animal cells and plant cells**

| Animal Cell | Plant Cell |
|---|---|
| • Cell wall absent | • Cell wall present |
| • Large content of it contains cytoplasm | • Cytoplasm is pushed towards periphery |
| • A large vacuole is absent. (Some times few small vacuoles may present) | • A large central vacuole or few vacuoles may present |
| • Chloroplasts absent | • Chloroplasts present |

## 6.4 Cell organelles and structures present in a cell

Every organelle and structures present in a cell perform a specific function. Therefore the cell shows division of labour.

- **Cell wall**

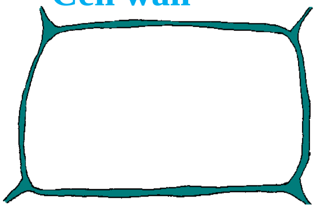


Figure 6.7

The outer most covering of the plant cell is the cell wall. It is a dead structure. The main constituent of it is cellulose. The main functions of the cell wall are , to maintain the shape of the cell, support and protection of the cell.

- **Plasma Membrane (Cell membrane)**

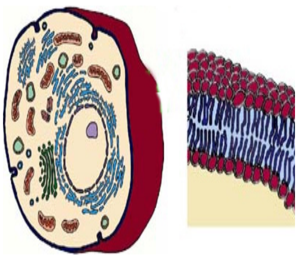


Figure 6.8

Plasma membrane is present interior to the cell wall of plant cells.The boundary of the animal cell is the plasma membrane. It is made up of phospholipids and proteins. Plasma membrane is a semi permeable membrane. The main function of it is to enclose the cell, allow entry of water, ions, some molecules and thereby control the entry and exit of materials into and out of the cell. Plasma membrane is also known as cell membrane.

- **Cytoplasm**

The gelatinous liquid part of the cell excluding organelles is known as the cytoplasm. Inorganic and organic substances are present in it. The functions of the cytoplasm are to maintain a shape to the cell, bear cell organelles and carryout different metabolic processes.

The structures submerged in the cytoplasm are named as organnells. some organelles are surrounded by cell membranes.

Eg.- mitochondrion, nucleus, endoplasmic reticulum, golgi complex.

- **Nucleus**

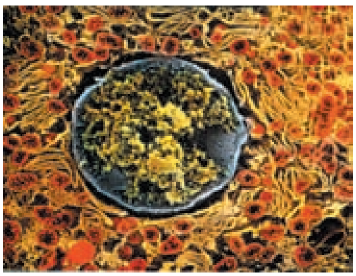


Figure 6.9

Nucleus is the main organelle in a cell. It is surrounded by a nuclear envelope. One or two nucleolus and the chromatin body are present inside the nucleus. During cell division, the chromatin body converts into chromosome. The functions of chromosomes are the storage of genetic material and transfer inherited characters from generation to generation.

The number of chromosomes is specific to a species.

Eg : There are 46 chromosomes in a human being.There are 26 chromosomes in a frog There are 24 chromosomes in a paddy plant.

The main function of the nucleus is the control of life activities of the cell.

## • Mitochondrion

Figure 6.10

It is an oval or rod shaped, membrane bounded organelle. Aerobic respiratory reactions take place within the mitochondrion to release energy. So it is known as the power house of the cell. The energy produced within the mitochondrion is used for the metabolic activities of the cell.

## • Golgi Complex

Figure 6.11

Membrane bounded sacs stacked on top of the other with associated secretory vesicles are collectively known as golgi complex.The functions of golgi complex is the production of secretory substances, packaging and secretion.

## • Ribosome

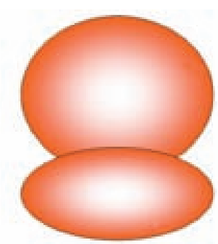


Figure 6.12

They are small organelles without a membrane. It is made up of a large subunit and a small subunit. They can be found freely in the cytoplasm or attached to Endoplasmic Reticulum. The function of ribosome is providing place for the protein synthesis.

## • Endoplasmic reticulum

It is an inter membranous network made up of flat or tubular sacs within the cytoplasm. Endoplasmic reticulum is of two types. They are rough endoplasmic reticulum and smooth endoplasmic reticulum.

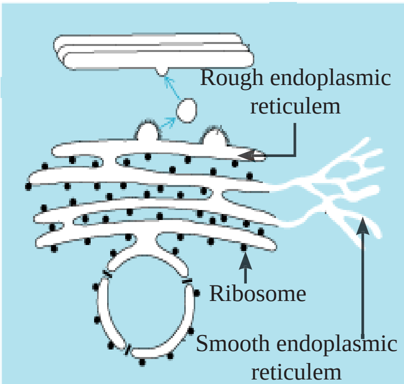


**Figure 6.13**

### Rough endoplasmic reticulum

Endoplasmic reticulum become rough due to ribosomes attahed to the membrane. The function of it is the transportation of proteins within the cell.

### Smooth endoplasmic reticulum

It is a network of tubular sacs without Ribosomes on the membrane. Synthesis of Lipids, steroids and to transport them within the cell are the functions of it.

## • Vacuole

**Figure 6.14**

It is a fluid filled large organelle found in plant cells which is surrounded by a membrane. The membrane that surrounds the vacuole is known as tonoplast. The fluid contained in it is known as the cell sap. Water, sugar, ions and pigments store within the vacuole. Generally no vacuoles are found and sometimes small vacoules may present in animal cells. Contractile vacuoles can be found in unicellular organisms. Maintenance of water balance, support and provision of colour to the cell by the pigments within it are the functions of the vacuole.

### Activity 03

**Materials Required -** permanent slides, electron micrographs of organelles, A microscope

**Method**

- Identify cells and organelles by observing the permanent slides through the light microscope with the help of your science teacher.
- Observe and study the nature of organelles using electron micrographs.

## 6.5 Cell Growth and Cell Division

### • Cell growth

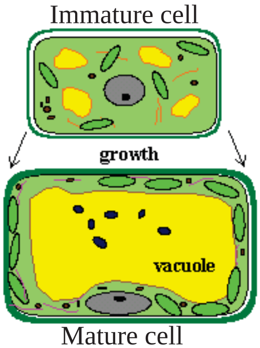


**Figure 6.15**

Growth is a basic feature of organisms. **Growth of a cell is the irreversible increase of size or dry mass.** But a cell has a maximum limit to grow. Beyond that level the cell will not grow, instead it divides.

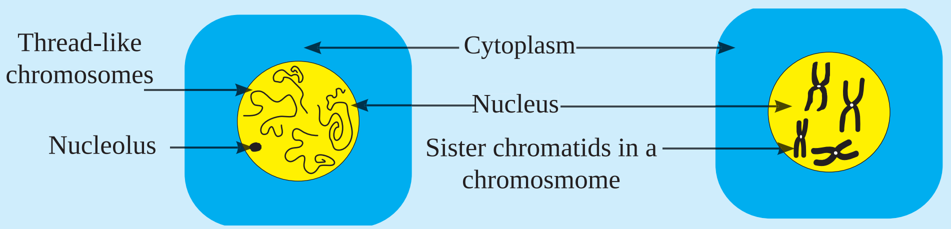
### • Cell division

The cell has the ability to grow and multiply its number. Accordingly a cell can multiply into two, four and eight cells. By multiplication new cells are formed. The cells multiply by cell division.

**The cell division is the process by which new cells are formed by the division of cellular materials.**

To complete the cell division of an eukaryotic cell, first the nucleus should divide and then the cytoplasm.

Chromosomes contain and transfer genetic materials, the inherited characters from generation to generation (Before the division of nucleus). Chromosomes can be seen clearly as in the figures below.



The appearance of chromosomes in an ordinary cell before the division of the nucleus

The appearance of chromosomes in a dividing cell

**Figure 6.16**

The number of chromosomes in an ordinary somatic cell of a species is constant. That is specific to a species.

Example - There are 46 chromosomes in a chromosomal set of human somatic cells. This is comprised of 23 pairs of chromosomes. The same hereditary information is born by each pair of chromosomes.

A pair of chromosomes which contains same hereditary information is called as homologous pair of chromosomes. One of these homologous chromosomes is inherited from father where as the other is from mother.

Accordingly a child inherits 46 chromosomes receiving 23 chromosomes from father and 23 chromosomes from mother.

The cell division takes place in 2 methods.

- Mitosis
- Meiosis

## Mitosis

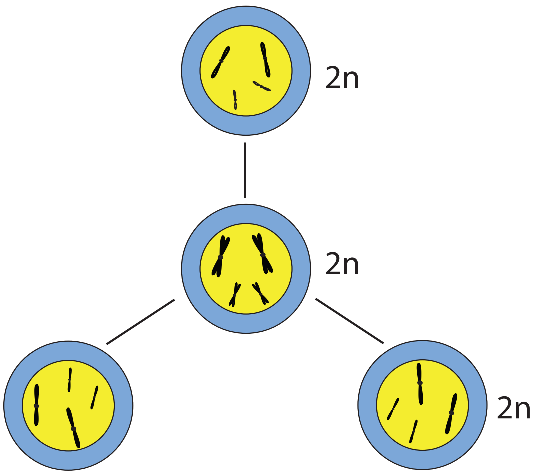



**Figure 6.17**

It is the type of division which multiplies the number of cells by maintaining a constant number of chromosomes in the cells. First the nucleus divides and then the cytoplasm divides to produce two identical daughter cells equal to mother cell.

### Significance of Mitosis

- For the growth of multicellular organisms.
- As an asexual reproduction method.
- Wound healing and cell replacement.

## Meiosis

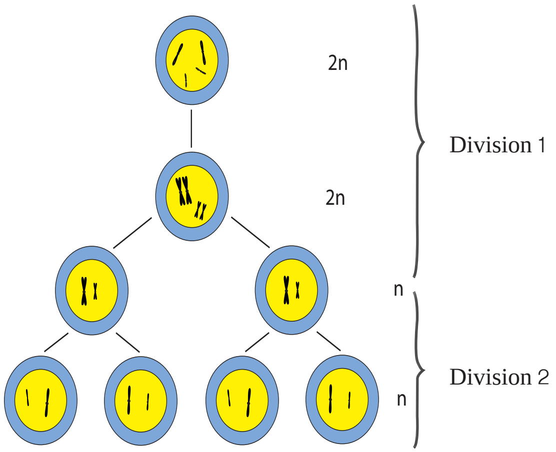


**Figure 6.18**

The cell division that makes the number of chromosomes into half as the parent cell is the **meiosis.** Meiosis takes place during formation of gametes (eggs and sperms) in higher organisms. After the gametes being fused, the number of chromosomes of a species should be maintained, constant. For that the number of chromosomes should be halved during the formation of gametes and become n (haploid).

Eggs and sperms possess only one chromosome of each pair of chromosomal set. (2n $\rightarrow$ n) When these gametes fuse to form the zygote, the chromosomes become n + n $\rightarrow$ 2n again.

Meiosis takes place in 2 stages. The first stage is a meiotic division (reduction division) and the next is a mitosis.

During meiosis, structural changes occur in chromosome. Therefore, new variations or new characters appear in organisms and this is a very important phenomena in evolution.

### Significance of Meiosis

- Maintenance of the constant number of chromosomes from generation to generation.
- Help in evolution due to variations occur in chromosomes.

Differences between Meiosis and Mitosis are mentioned in table 6.2

**Table 6.2- Differences between meiosis and mitosis**

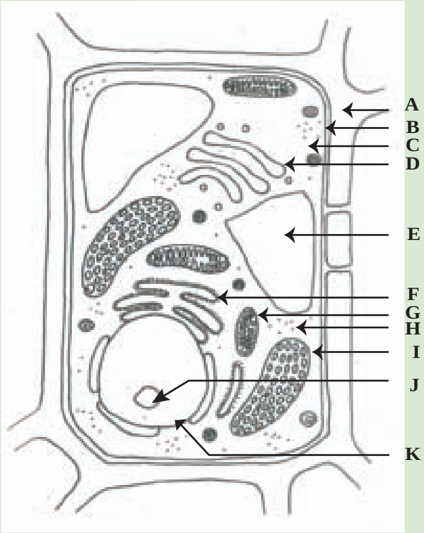
| Meiosis | Mitosis |
|---|---|
| 1. Takes place in two divisions | Only one division |
| 2. Takes place only in diploid cells | Takes place in both diploid and haploid cells |
| 3. Variations occur  Thus changes take place in chromosomes | No variations. The changes in chromosome are rare |
| 4. Four daughter cells result at the end of the division | Two daughter cells result at the end of the division |
| 5. Daughter cell receives half of the chromosomal number of mother cell | Two daughter cells receive the same chromosomal number as the mother cell |
| 6. Daughter cells are different from mother cell | Daughter cells are similar to mother cell |

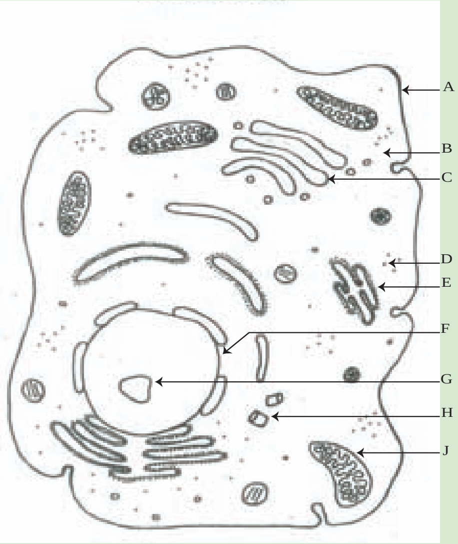
## Summary

- The basic structural unit of the organism is the cell.
- The structural and functional unit of life is the cell.
- New cells are formed from pre-existing cells.
- Different functions are performed by different organelles in the cell.
- All animal cells are surrounded by the plasma membrane. Generally the nucleus is present at the centre of the cell. The area between nucleus and the plasma membrane is the cytoplasm. There are different organelles present in the cytoplasm. Eg :- Mitochondrion, Golgi complex, Endoplasmic reticulum
- Most of the cell organelles are present in both animal and plant cells. But some organelles like cell wall, chloroplast, large central vacuole are present only in plant cells.
- The cellular structures that carry genetic information are the chromosomes in the nucleus.
- The cell growth is the irreversible increase of dry mass or the size of the cell.
- The cell divides at a particular stage during the growth.
- The cell division takes place according to two methods. They are Mitosis and Meiosis.

## Exericises

1.




1.1 Name A,B,C,D,E....... structures and organelles in the above cells.

1.2 Differentiate between a plant cell and an animal cell.

1.3 Mention the functions of the following organelles.

(1) Mitochondrion (2) Golgi complex

(3) Rough endoplasmic reteculum (4) Vacuole

2. Explain the importance of meiosis.

## Technical terms

| | | |
|---|---|---|
| Typical cell | දර්ශීය සෛලය | பொதுமைப்பாடடைந்த கலம் |
| Organelle | ඉන්ද්‍රියිකාව | புன்னங்கம் |
| Chromosomal number | වර්ණදේහ සංඛ්‍යාව | நிறமூர்த்தங்களின் எண்ணிக்கை |
| Cell division | සෛල විභාජනය | கலப்பிரிவு |
| Mitosis | අනූනනය | இழையுருப்பிரிவு |
| Meiosis | ඌනනය | ஒடுங்கற் பிரிவு |

# Quantification of Elements and Compounds

Chemistry 07

## 7.1 Relative Atomic Mass (Ar)

**Assignment – 7.1**

Discuss with the teacher and the students in your class about the units suitable to measure the mass of the following.

- A motor car
- A loaf of bread
- A molecule of carbondioxide
- A brick
- A tablet of medicine
- A helium atom

To measure the mass of items like a motor car, a brick, a loaf bread, a tea spoonful of sugar and a tablet of medicine, units like kilogram, gram and milligram can be used. But if the mass of very small particles such as a carbon dioxide molecule, or a helium atom is given in units like kilogram or gram, the value obtained is extremely small. Even the attogram (ag), the smallest units of mass is too large to indicate the mass of atoms or ions.

$$1 \text{ ag} = 10^{-18} \text{ g}$$

For example, the mass of an atom of the lightest element, hydrogen (H) is $1.674 \times 10^{-24}$ g. That is 0.000000000000000000000001674 g. Masses of some other atoms are given below.

| | |
|---|---|
| Mass of a carbon (C) atom | $= 1.993 \times 10^{-23}$ g |
| Mass of a sodium (Na) atom | $= 3.819 \times 10^{-23}$ g |
| Mass of a chlorine (Cl) atom | $= 5.903 \times 10^{-23}$ g |
| Mass of a potassium (K) atom | $= 6.476 \times 10^{-23}$ g |

It is cumbersome to use this type of small figures in calculations.

For this reason, the mass of a selected atom was taken as a unit and the masses of the other atoms were given relative to it. The mass so expressed is known as the relative atomic mass. The relative atomic mass is not the true mass of an atom of an element. In the past, the mass of an atom of hydrogen, the lightest element was used as the atomic mass unit.

- ## Atomic Mass Unit

The mass of the unit relative to which the masses of other atoms are expressed is called the atomic mass unit.

At present $\frac{1}{12}^{th}$ the mass of $^{12}_{6}C$ isotope is used as the atomic mass unit.

$$\text{Atomic mass unit} = \frac{\text{Mass of the } ^{12}_{6}\text{C isotope}}{12}$$

$$= \frac{1.99 \times 10^{-23}\ \text{g}}{12}$$

$$= 1.66 \times 10^{-24}\ \text{g}$$

**How many times an atom of a given element weighs as much as 1/12 the mass of C - 12 isotope is the relative atomic mass of that element.**

$$\text{Relative atomic mass } (A_r) = \frac{\text{Mass of an atom of the element}}{\frac{1}{12} \times \text{mass of a } ^{12}_{6}\text{C atom}}$$

For example, the true mass of an oxygen atom (O) is $2.66 \times 10^{-23}$ g.

The true mass of a $^{12}_{6}C$ atom is $1.99 \times 10^{-23}$ g. Therefore, the relative atomic mass of oxygen can be found as follows.

$$\text{Relative atomic mass of oxygen (O)} = \frac{\text{Mass of an oxygen atom}}{\frac{1}{12} \times \text{mass of a } ^{12}_{6}\text{C atom}}$$

$$= \frac{2.66 \times 10^{-23}\text{g}}{\frac{1}{12} \times 1.99 \times 10^{-23}\ \text{g}}$$

$$= 16.02$$

According to foregoing calculations, you may understand that the relative atomic mass has no units.

## • Relative Atomic Masses of Some Elements

| Atomic number | Element | Symbol | Relative atomic mass |
|---|---|---|---|
| 1 | Hydrogen | H | 1 |
| 2 | Helium | He | 4 |
| 3 | Lithium | Li | 7 |
| 4 | Beryllium | Be | 9 |
| 5 | Boron | B | 11 |
| 6 | Carbon | C | 12 |
| 7 | Nitrogen | N | 14 |
| 8 | Oxygen | O | 16 |
| 9 | Fluorine | F | 19 |
| 10 | Neon | Ne | 20 |
| 11 | Sodium | Na | 23 |
| 12 | Magnesium | Mg | 24 |
| 13 | Aluminium | Al | 27 |
| 14 | Silicon | Si | 28 |
| 15 | Phosphorus | P | 31 |
| 16 | Sulphur | S | 32 |
| 17 | Chlorine | Cl | 35.5 |
| 18 | Argon | Ar | 40 |
| 19 | Potassium | K | 39 |
| 20 | Calcium | Ca | 40 |

### Worked Examples

01. The mass of a potassium (K) atom is $6.476 \times 10^{-23}$ g. The mass of a ${}^{12}_{6}C$ atom is $1.99 \times 10^{-23}$ g. Find the relative atomic mass of potassium.

$$\text{Relative atomic mass of potassium} = \frac{\text{Mass of potasium atom}}{\frac{1}{12} \times \text{Mass of a } {}^{12}_{6}C \text{ atom}}$$

$$= \frac{6.476 \times 10^{-23}\,g}{\frac{1}{12} \times 1.99 \times 10^{-23}\,g}$$

$$= 39$$

02. The mass of an atom of element A is eight times the mass of ${}^{12}_{6}C$ isotope. Find the relative atomic mass of A.

Relative atomic mass of A $= \dfrac{\text{Mass of an atom of A}}{\frac{1}{12} \times \text{mass of a } {}^{12}_{6}C \text{ atom}}$

Mass of an atom of A $= \text{Mass of a } {}^{12}_{6}C \text{ atom} \times 8$

Relative atomic mass of A $= \left( \dfrac{8 \times \text{Mass of } {}^{12}_{6}C \text{ atom}}{\frac{1}{12} \times \text{mass of a } {}^{12}_{6}C \text{ atom}} \right)$

$= 8 \times 12$

$= 96$

03. Mass of a sodium atom is $3.819 \times 10^{-23}$ g. The value of the atomic mass unit is $1.67 \times 10^{-24}$ g. Find the relative atomic mass of sodium.

Relative atomic mass of sodium $= \dfrac{\text{Mass of a sodium atom}}{\text{Value of the atomic mass unit}}$

$= \dfrac{3.819 \times 10^{-23} \text{g}}{1.66 \times 10^{-24} \text{ g}}$

$= 23.00$

## 7.2 Relative Molecular Mass ($M_r$)

Since many elements are reactive, their atoms do not exist as free atoms. They exist naturally as molecules formed by joining two or more atoms of them. Compounds are composed of molecules formed by the combination of atoms belonging to different elements.

How many times a given molecule of an element or a compound weighs as much as 1/12 the mass of C - 12 isotope is the relative molecular mass of that element or compound.

Relative molecular mass ($M_r$) $= \dfrac{\text{Mass of a molecule of an element or a compound}}{\frac{1}{12} \times \text{Mass of a } {}^{12}_{6}\text{C atom}}$

For instance, the true mass of a carbon dioxide ($CO_2$) molecule is $7.31 \times 10^{-23}$ g. Mass of a carbon atom is $1.99 \times 10^{-23}$ g.

Relative molecular mass of $CO_2$ $= \dfrac{\text{Mass of a molecule of a Carbon dioxide}}{\frac{1}{12} \times \text{mass of a } {}^{12}_{6}\text{C atom}}$

$$= \frac{7.31 \times 10^{-23}\,\text{g}}{\frac{1}{12} \times 1.99 \times 10^{-23}\,\text{g}}$$

$= 44$

As the relative atomic mass, relative molecular mass too does not have a unit.

The mass of a water molecule is ($H_2O$) $2.99 \times 10^{-23}$ g. Atomic mass unit is $1.67 \times 10^{-24}$ g. Find the relative molecular mass of water.

Relative molecular mass of $H_2O$ $= \dfrac{\text{Mass of a } H_2O \text{ molecule}}{\text{Atomic mass unit}}$

$$= \frac{2.99 \times 10^{-23}\,\text{g}}{1.66 \times 10^{-24}\,\text{g}}$$

$= 18$

If the molecular formula of an element or a compound is known, its relative molecular mass can be calculated. This is because the relative molecular mass is equal to the sum of relative atomic masses of the atoms in a molecule.

For example a water molecule has two hydrogen atoms (H) and one oxygen atom (O) bound together. Therefore, the relative molecular mass of water ($H_2O$) is the sum of the relative atomic masses of two hydrogen atoms and an oxygen atom.

Since the relative atomic mass of hydrogen is 1 and oxygen is 16, the relative molecular mass of water can be calculated as follows.

$$H_2O = 2 \times 1 + 16 = 18$$

Relative molecular masses of some elements and compounds are tabulated in Table 7.1.

Table 7.1

| Species | Molecular formula | Relative molecular mass |
|---|---|---|
| 1. Hydrogen | $H_2$ | 2 x 1 = 2 |
| 2. Nitrogen | $N_2$ | 2 x 14 = 28 |
| 3. Oxygen | $O_2$ | 2 x 16 = 32 |
| 4. Carbon dioxide | $CO_2$ | 12 + (2x 16 ) = 44 |
| 5. Glucose | $C_6H_{12}O_6$ | (6x12) + (12x1) + (6x16) = 180 |

**Exercise 01**

Calculate the relative molecular mass of the following compounds.

01. Ammonia ($NH_3$)
Relative atomic masses H - 1 ; N - 14

02. Sulphuric acid ($H_2SO_4$)
Relative atomic masses H - 1 ; O - 16 ; S - 32

03. Sucrose ($C_{12}H_{22}O_{11}$)
Relative atomic masses H - 1 ; C - 12 ; O -16

The ionic compounds such as sodium chloride (NaCl) exist as lattices but not molecules. Its formula is written to indicate the simplest ratio in which $Na^+$ and $Cl^-$ ions are present in the ionic lattice. In such compounds what is calculated as the relative molecular mass is the mass relevant to their empirical formula. It is known as the relative formula mass or formula mass.

Relative atomic mass Na - 23 ; Cl - 35.5

Relative formula mass of sodium chloride (NaCl) = 23 + 35.5

= 58.5

**Exercise 02**

Calculate the relative formula mass of the following compounds.

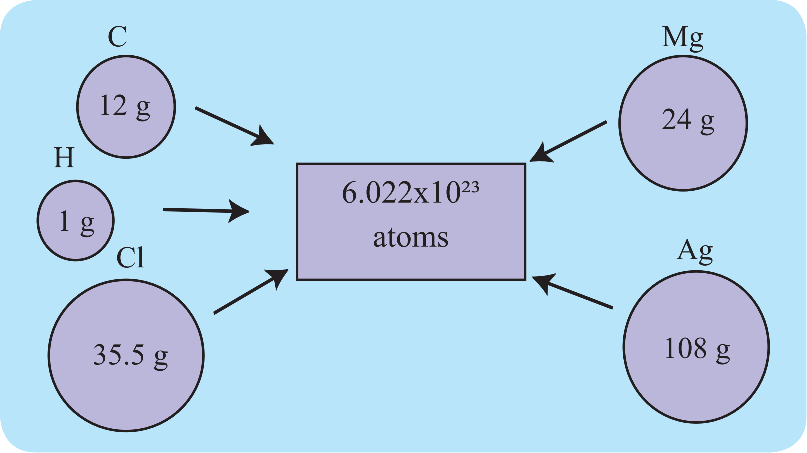
01. Magnesium oxide (MgO)
Relative atomic masses O - 16 ; Mg - 24

02. Calcium carbonate ($CaCO_3$)
Relative atomic masses C - 12 ; O - 16 ; Ca - 40

03. Potassium sulphate ($K_2SO_4$)
Relative atomic masses O - 16 ; S - 32 ; K - 39

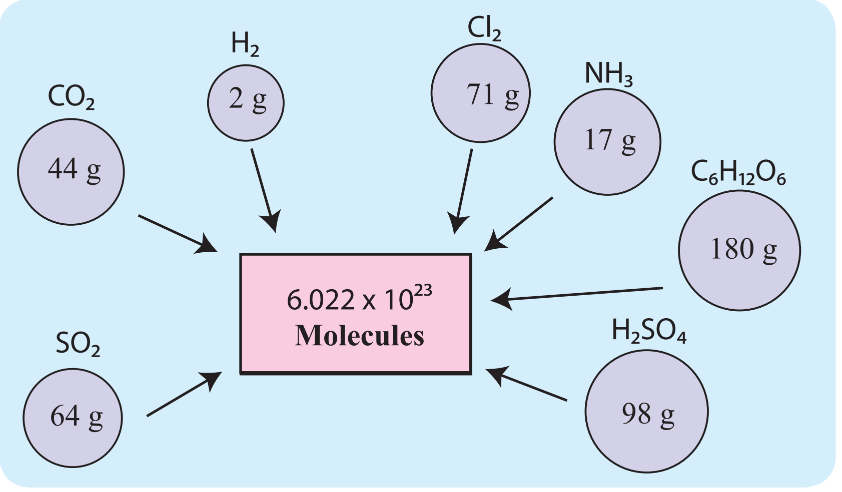
## 7.3 Avogadro constant

When a mass of any element equal to its relative atomic mass is taken in grams, it is seen that it contains the same number of atoms irrespective of the element.




Similarly, it can also be shown that when a mass of any substance equal to its relative molecular mass is taken in grams, it contains the same number of molecules.

After the great scientist Amedeo Avogadro, this constant number is called **Avogadro Constant**.




**The presently accepted value of this constant is** $6.022 \times 10^{23}$ **and it is symbolised as L .**

## 7.4 Mole

In various tasks, measurement of the amount of a substance is a requirement. A dozen of books means 12 books. Similarly 'ream' is used to measure the amount of papers.

In the SI unit system, the unit used to measure the amount of a substance is the mole.

**The mole is the amount of a substance that contains as many basic building units (atoms, molecules, ions) as there are atoms in exactly 12.00 g of C – 12 isotope.**

The number of basic units contained in a mole of any substance is a constant and it is equal to the Avogadro constant or $6.022 \times 10^{23}$.

Thus, the relative atomic mass of any element taken in grams contains one mole of atoms or $6.022 \times 10^{23}$ atoms. The relative molecular mass of any substance taken in grams contains one mole of molecules or $6.022 \times 10^{23}$ molecules.

A mole of an element or a compound that exists as molecules means a mole of molecules of them.

Since mole is a unit that indicates a very large amount, it is not suitable to measure the amount of substances that we come across in day to day life. Therefore, the unit mole is practically used to measure the amounts of things such as atoms, molecules and ions which exist in very large numbers.

The following example illustrates the magnitude of the number representing a mole.

Suppose there are 1000 million children in the world. This in powers of ten is,

$$1000 \text{ million} = 1000 \times 10^6 = 10^9$$

If a mole of lozenges is equally distributed among these children,

$$\text{The number of lozenges each child gets} = \frac{6.022\times10^{23}}{10^9}$$

$$= 6.022\times10^{14}$$

$$= 602200000000000$$

As the number of units belonging to a mole is very large, counting is impossible. Therefore, other methods are used to measure the mole. One method to have a mole of atoms of an element is weighing out its relative atomic mass in grams. For example, the relative atomic mass of sodium is 23.

1 mol of sodium atoms = 23 g of sodium

In order to have a mole of molecules of a given compound, its relative molecular mass has to be weighed out in grams. For instance, the relative molecular mass of glucose ($C_6H_{12}O_6$) is 180.

1 mol of glucose molecules = 180 g of glucose

## • Molar Mass

Molar mass is the mass of a mole of any substance.

Though relative atomic mass and relative molecular mass have no units, grams per mole (g $mol^{-1}$) or kilograms per mole (kg $mol^{-1}$) is the unit of the molar mass.

| | | | |
|---|---|---|---|
| 1. | Relative atomic mass of sodium (Na) | = | 23 |
| | Molar mass of sodium | = | 23g $mol^{-1}$ |

| | | | |
|---|---|---|---|
| 2. | Relative molecular mass of carbon dioxide ($CO_2$) | = | 44 |
| | Molar mass of carbon dioxide | = | 44 g $mol^{-1}$ |
| 3. | Relative formula mass of sodium chloride (NaCl) | = | 58.5 |
| | Molar mass of sodium chloride | = | 58.5 g $mol^{-1}$ |
| 4. | Relative formula mass of calcium carbonate ($CaCO_3$) | = | 100 |
| | Molar mass of calcium carbonate | = | 100 g $mol^{-1}$ |

The following relationship can also be used to find the amount of any given substance (number of moles).

$$\text{Amount of substance (number of moles)} = \frac{\text{Mass of the substance}}{\text{Molar mass of the substance}}$$

$$n = \frac{m}{M}$$

## Worked Examples

01. Find the number of atoms in 4 mol of carbon.

Number of atoms in 1 mol of carbon = $6.022 \times 10^{23}$

Number of atoms in 4 mol of carbon = $6.022 \times 10^{23} \times 4$

= $2.409 \times 10^{24}$

02. Find,

i. the number of molecules;
ii. total number of atoms; and
iii. the number of oxygen atoms
in 5 mol of carbon dioxide.

i. Number of $CO_2$ molecules in 1 mol of carbon dioxide molecules = $6.022 \times 10^{23}$

Number of $CO_2$ molecules in 5 mol of carbon dioxide molecules = $6.022 \times 10^{23} \times 5$

= $30.11 \times 10^{23}$

= $3.011 \times 10^{24}$

ii. Total number of atoms in a carbon dioxide molecule = 3

Total number of atoms in 5 mol of carbon dioxide = $3.011 \times 10^{24} \times 3$

= $9.033 \times 10^{24}$

iii. Number of oxygen atoms in a carbon dioxide molecule = 2

Number of oxygen atoms in 5 mol of carbon dioxide = $3.011 \times 10^{24} \times 2$

= $6.022 \times 10^{24}$

03. Molar mass of carbon is 12 g $mol^{-1}$. Find the amount of carbon in 10 g of carbon.

Amount of carbon in 12 g of carbon = 1 mol

Amount of carbon in 10 g of carbon $= \frac{1\ \text{mol}}{12\ \text{g}} \times 10\ \text{g}$

$= 0.83$ mol

04. Find the number of molecules in 0.1 mol of carbon dioxide.

Number of molecules in 1 mol of carbon dioxide $= 6.022 \times 10^{23}$

Number of molecules in 0.1 mol $= \frac{6.022 \times 10^{23} \times 0.1\ \text{mol}}{1\ \text{mol}}$

$= 6.022 \times 10^{22}$

05. Relative molecular mass of oxygen ($O_2$) is 32. Find the number of oxygen molecules ($O_2$) in 10 g of oxygen.

Number of molecules in 32 g of oxygen $= 6.022 \times 10^{23}$

Number of molecules in 10 g of oxygen $= 6.022 \times 10^{23} \times 10\text{g}/ 32\text{g}$

$= 1.88 \times 10^{23}$

06. Molar mass of water is 18 g $mol^{-1}$. Find the amount of water in 20 g of water.

Amount of water in 18 g of water = 1 mol

Amount of water in 20 g of water $= \frac{1\ \text{mol}}{18\ \text{g}} \times 20\ \text{g}$

$= 1.11$ mol

07. Calculate the amount of carbon dioxide in 22 g of carbon dioxide (Molar mass of carbon dioxide is 44 g $mol^{-1}$).

Amount of carbon dioxide in 44 g of carbon dioxide = 1 mol

Amount of carbon dioxide in 22g of carbon dioxide $= \frac{1\ \text{mol}}{44\ \text{g}} \times 22\ \text{g}$

$= 0.5$ mol

This can also be solved using the formula as follows.

$$n = \frac{m}{M}$$

$$= \frac{22\ g}{44\ g\ mol^{-1}}$$

$$= 0.5\ mol$$

08. Calculate the amount of carbon in 24 g of carbon. Molar mass of carbon is 12 g $mol^{-1}$.

Amount of carbon in 12 g of carbon $= 1\ mol$

Amount of carbon in 24 g of carbon $= \frac{1\ mol}{12\ g} \times 24\ g$

$= 2\ mol$

This can also be solved using the formula as follows.

$$n = \frac{m}{M}$$

$$= \frac{24\ g}{12\ g\ mol^{-1}}$$

$$= 2\ mol$$

## Summary

- Atoms are very small. Therefore their masses are given relative to the mass of a selected atom instead of expressing them in units like grams and kilograms.
- The atomic mass unit is $1/12^{th}$ the mass of C – 12 isotope.
- The relative atomic mass of an element is the mass of an atom of that element relative to $1/12^{th}$ the mass of C – 12 isotope.
- When the relative molecular mass of an element or a compound is taken in grams it contains $6.022 \times 10^{23}$ molecules.
- The international unit (SI Unit) of measuring the quantity of a substance is the mole.
- The mole is the amount of substance which contains as many atoms or molecules as there are atoms in exactly 12 g of C – 12 isotope.
- The number of basic units in a mole of a given substance is a constant. It is equal to the Avogadro Constant ($6.022 \times 10^{23}$).
- Molar mass is the mass of a mole of a given substance. The substance may be composed of atoms or molecules. The unit of molar mass is g $mol^{-1}$
- Amount of moles of a substance $(n) = \dfrac{\text{Mass of that substance (m)}}{\text{Molar mass of that substance (M)}}$

## Exercises

01. Find the relative molecular mass of the following substances.

| | | |
|---|---|---|
| i. | $CH_3OH$ | (Methyl alcohol / Methanol) |
| ii. | $CS_2$ | (Carbon disulphide) |
| iii. | $C_8H_{18}$ | (Octane) |
| iv. | $CH_3COOH$ | (Acetic acid) |
| v. | $C_{12}H_{22}O_{11}$ | (Sucrose) |
| vi. | $CO(NH_2)_2$ | (Urea) |
| vii. | $C_9H_8O_4$ | (Aspirin) |
| viii. | $HNO_3$ | (Nitric acid) |
| ix. | $CCl_4$ | (Carbon tetrachloride) |
| x. | $C_8H_9NO_2$ | ((Paracetamol) |

(R.A.M : H - 1, C - 12, N - 14, O - 16, S - 32, Cl - 35.5)

02. Find the molar mass of the following compounds.

| | | |
|---|---|---|
| i. | $CO_2$ | (Carbon dioxide) |
| ii. | NaCl | (Sodium chloride) |
| iii. | $CaCO_3$ | (Calcium carbonate) |
| iv. | $NH_4Cl$ | (Ammonium chloride) |
| v. | $Mg_3N_2$ | ((Magnesium nitride) |
| vi. | $H_2S$ | (Hydrogen sulphide) |
| vii. | $AlCl_3$ | (Aluminium chloride) |
| viii. | $(NH_4)_2CO_3$ | (Ammonium carbonate) |
| ix. | $CuSO_4$ | (Copper sulphate) |
| x. | $Na_2C_2O_4$ | (Sodium oxalate) |

R.A.M : H - 1, C - 12, N - 14, O - 16, Na - 23, Mg - 24, Al - 27, S - 32, Cl - 35.5,Ca - 40, Cu - 63.5)

03.

i. What is the amount of substance in moles in 12 g of magnesium (Mg) ?

ii. What is the amount of substance in moles in 10 g of calcium carbonate ($CaCO_3$) ?

iii. How many molecules are there in 5 mol of carbon dioxide ($CO_2$) ?

iv. How many water molecules are present in 4 mol of water ($H_2O$) ?

v. What is the mass of 2 mol of urea ($CO(NH_2)_2$) ?

04. How many moles of oxygen atoms (O) does one mole of each of the following compounds contain ?

i. $Al_2O_3$ ii. $CO_2$ iii. $Cl_2O_7$
iv. $CH_3COOH$ v. $Ba_3(PO_4)_2$

## Technical terms

| | | | | |
|---|---|---|---|---|
| Atomic mass unit | - | පරමාණුක ස්කන්ධ ඒකකය | - | அணுத்திணிவு அலகு |
| Relative atomic mass | - | සාපේක්ෂ පරමාණුක ස්කන්ධය | - | சார் அணுத்திணிவு |
| Relative molecular mass | - | සාපේක්ෂ අණුක ස්කන්ධය | - | சார் மூலக்கூற்றுத் திணிவு |
| Avogadro constant | - | ඇවගාඩ්රෝ නියතය | - | அவகாதரோ மாறிலி |
| Mole | - | මවුලය | - | மூல் |
| Molar mass | - | මවුලික ස්කන්ධය | - | மூலர்த்திணிவு |

# Characteristics of organisms

Recall all the information and experiences you have , about organisms. Using that knowledge carry out the below mentioned assignment.

**Assignment 8.1**

**Express your idea about below instances whether they are living or non living.**

1. Hen egg
2. A tissue which is obtained from an organism and stored under special preservation methods
3. A fossil about thousands of years old

How far the living characteristics already known to you could be applied to describe a hen egg? Even after few weeks, if the egg is incubated, a chick with living features will be born.
A tissue removed from an organism can be stored under special preservation methods for a longer time. Once it is bud into another organism using appropriate techniques, it will show living characteristics.

The DNA isolated from a thousand year old fossil can be bud to obtain new organisms with old characteristics using gene technology.

By considering above facts, you can understand that only by observing the external features, one cannot get a confirmation about life.

**Assignment 8.2**

List out the features that can be used to identify living from non living.

The features that you have listed are not always found in all living units. But all living units show one or few living characteristics. You can study in future lessons that living and non living cannot be separated by a clear line in some instances.

The common characteristics of living organisms can be listed out as below.

- Cellular organization
- Nutrition
- Respiration
- Irritability and Co-ordination
- Excretion
- Movement
- Reproduction
- Growth and Development

## 8.1 Cellular organization

The structure of a unicellular organism, is made up of the cytoplasm and organelles enclosed by a plasma membrane. This unicellular unit is an organism which shows living characteristics. When a water sample of a pond or hay extraction is observed using a microscope, unicellular organisms can be observed easily.

*Chlamydomonas*

*Euglena*

*Amoeba*

*Paramecium*

**Figure 8.1 - Appearance of unicellular organisms through light microscope**

In a unicellular organism, organelle level organization can be seen. The origin of a multicellular organism is from a single cell, the zygote which is the product of the fertilization of an egg with a sperm. The below mentioned sketch (Fig 8.2) is just to show the development of embryo of human.

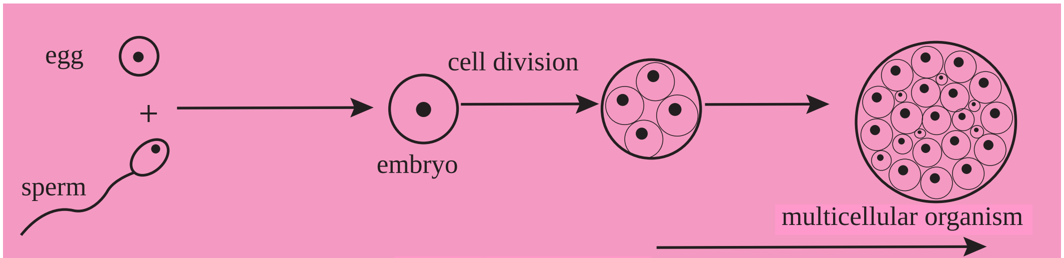


Figure 8.2

The bodies of the multicellular organisms are composed of different types of cells. Those cells are important in different functions.

Diagram 8.3 shows the arrangement of different cells in the plant body and diagram 8.4 shows the arrangement of different cells in the human body.

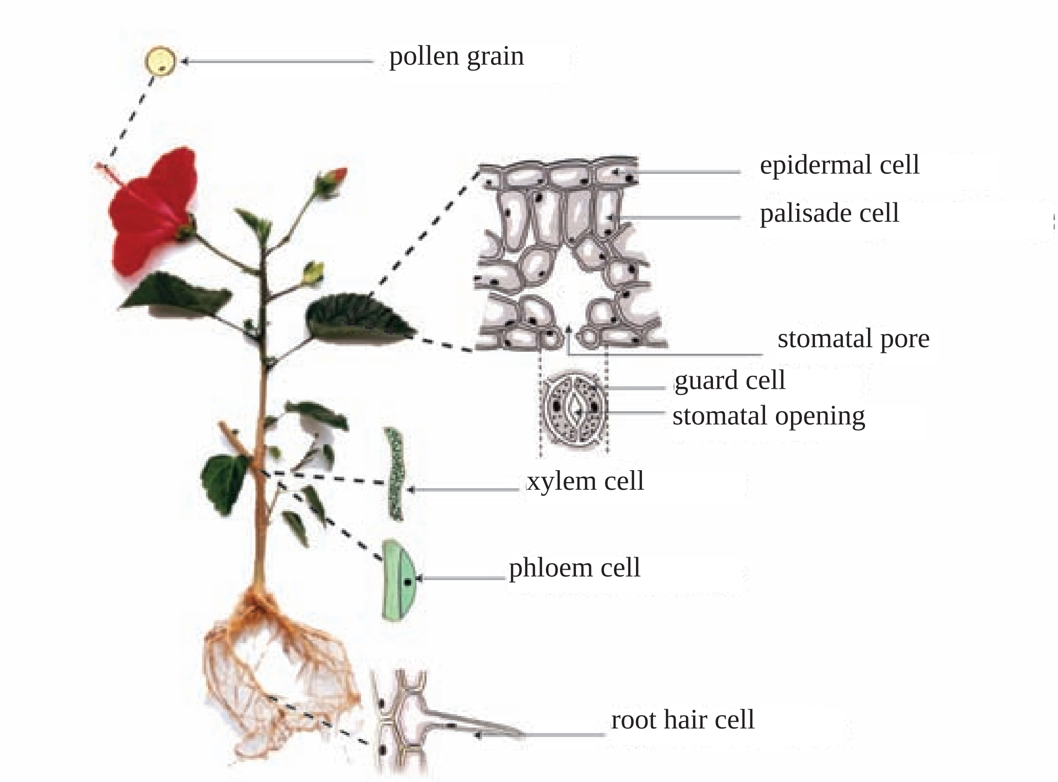


**Figure 8.3 - Organization of different cells in plant body**

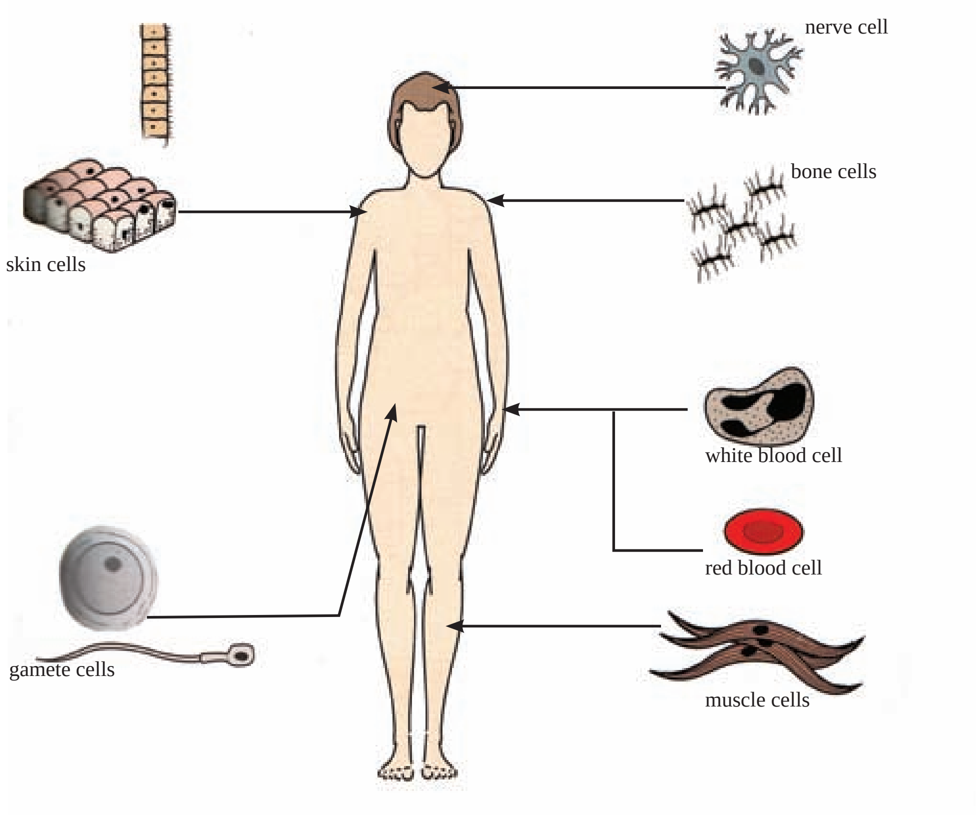



**Figure 8.4 - Organization of different cells in the human body**

A multicellular organism possesses a tissue and a system level organization. The organs of the organism are well developed and designed to carry out relevant functions.
E.g. Tongue, Eye, Heart

## Activity 01

**Materials Required -** Pond water sample or hay extraction, A light microscope, Prepared slides of different cells

**Method**

- Observe a water sample obtained from a pond or a hay extraction under light microscope. Identify micro organisms and illustrate them.
- Observe the prepared slides of different cells in the laboratory and identify them.

The smallest structural and functional unit at living condition is the cell. A group of cells modified to perform a specific function is called a tissue. A collection of tissues form an organ, a collection of organs forms a system, and systems collectively form an organism.

Below chart shows the organisational levels of an organism considering the blood circulatory system.

**Cell**

↓

**Tissue**

↓

**Organ**

↓

**Systems**

↓

**Organism**

**Figure 8.5 - Organisational levels that can be identified in a living being**

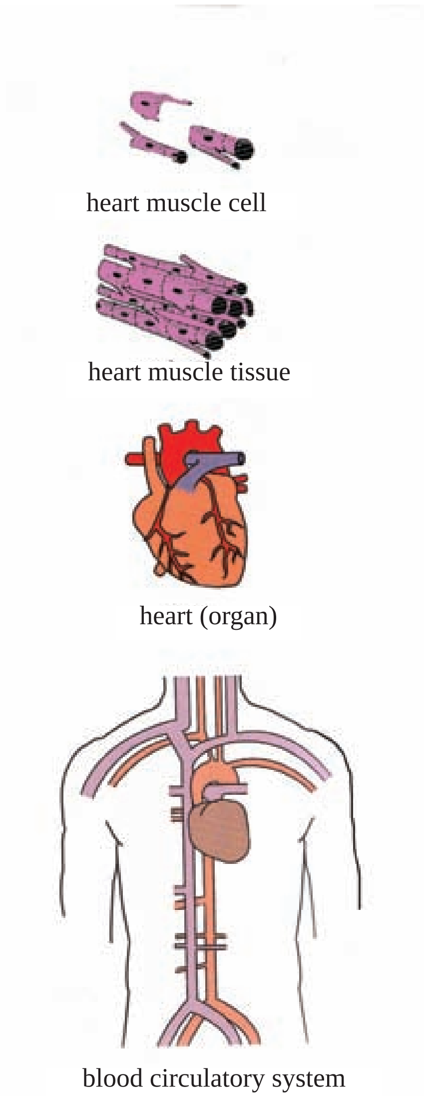



**Figure 8.6 - Blood circulatory system and how it becomes complex from cellular level to system level**

## 8.2 Nutrition

The process by which the energy and the materials are obtained for the maintenance of life is known as nutrition. Energy is needed for the cell growth and to repair the worn out structures. This energy is obtained by nutrients. The Organisms that produce their own food or the nutrients by themselves are known as autotrophic organisms.

Autotrophism can be divided into two categories according to the type of energy they use for food production. If light energy is used they are known as photoautotrophics and if energy is obtained by a chemical reaction they are known as chemoautotrophics. Most of the plants are photoautotrophic. Most bacteria are chemoautotrophic. Production of food inside the chloroplast of plant cells using chlorophyll, which is a specific organic compound, is called photosynthesis.
Photosynthesis can be expressed by the below equation.

$$\text{Carbondioxide} + \text{Water} \xrightarrow[\text{chlorophyll}]{\text{light energy}} \text{Glucose} + \text{Oxygen}$$

$$6CO_2 + 6H_2O \xrightarrow[\text{chlorophyll}]{\text{light energy}} C_6H_{12}O_6 + 6O_2$$

The food produced in the leaves get stored in stems, roots and fruits. Animals are heterotrophic as they utilize food produced by plants or organic compounds with other living origins.

Below food web shows the connection between these modes of nutrition.

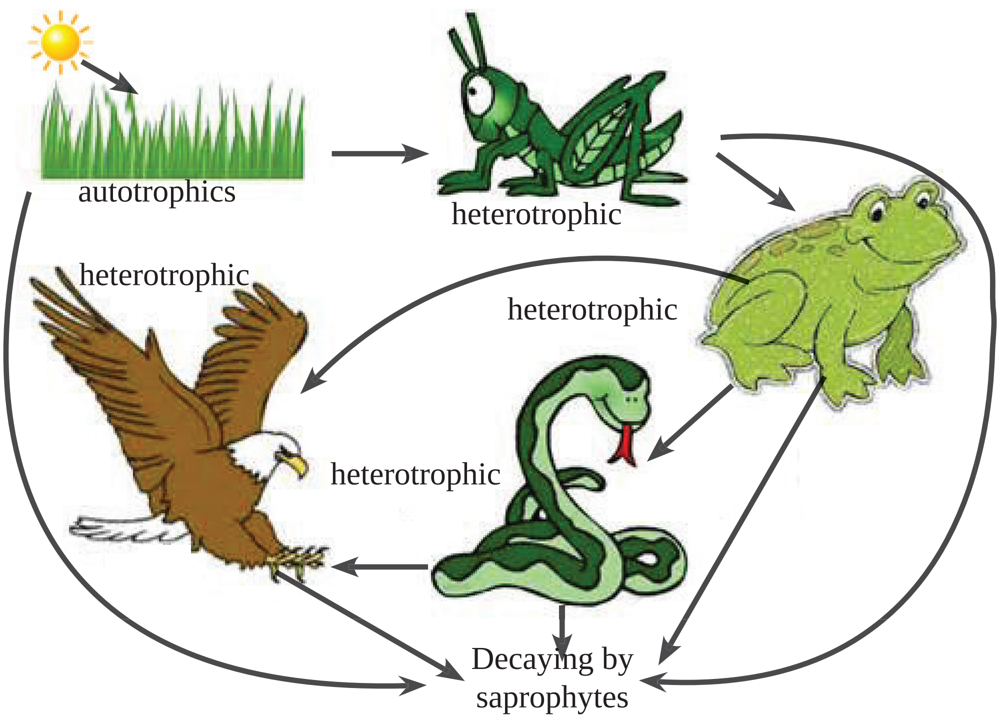



**Figure 8.7 - A Food web**

## 8.3 Respiration

All Organisms need energy for their metabolism. They obtain this energy by breaking down of food inside the cell that they have produced or obtained by other means. **The process by which the stored food is transformed into energy inside the cells is known as cellular respiration.**

Cellular respiration is a series of biochemical reactions. The respiration, which is an important characteristic of life, cannot be observed directly. But it can be observed using respiratory movements of some organisms. That is by inspiration, intake of oxygen for respiration and removal of carbon dioxide, the expiration.

Using the below experiment it can be shown that $CO_2$ is released while $O_2$ is absorbed during respiration.

### Activity 02

**Experiment to show the release of $CO_2$ during respiration**

**Materials Required -** Limewater, KOH, Water, Five equal bottles with corks, L shape aqual size glass tubes, A frog, Suction

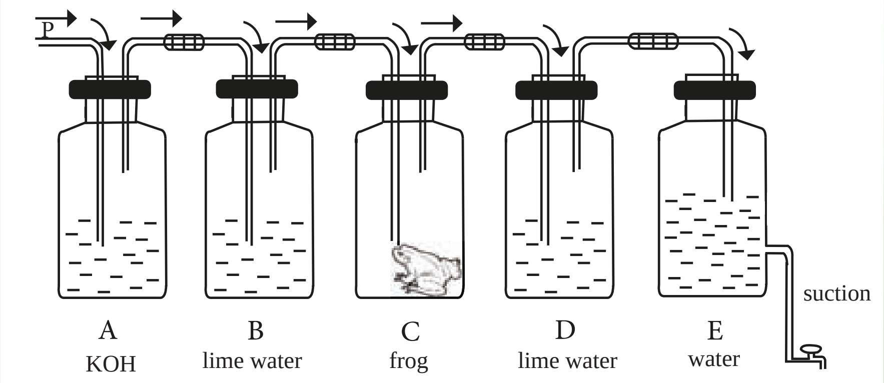



**Figure 8.8- Demonstration of the products of respiration**

**Method**

Arrange the apparatus as shown above and remove water in bottle E.

When water is removed, an air flow occurs from bottle A to bottle E.

The colour of limewater in B does not change as $CO_2$ in air that enters through P dissolves in KOH of vessel A. But after some time the limewater in vessel D turn to milky. It is because of the released $CO_2$ by the frog during respiration. A control experiment can be used without a frog in C. Accordingly it is confirmed that $CO_2$ is released as a byproduct of respiration. This experiment can be conducted again using germinating green gram / paddy/ maize/ bean seeds in vessel C instead of a frog.

Now we will carry out the experiment below to show the absorption of $O_2$ during respiration.

## Activity 03

**Experiment to show absorption of oxygen in respiration**

**Materials Required** - 2 Conical flasks, Glass tubes, Rubber tubes, Small test tube, 2 Beakers, Coloured water, Germinating seeds, KOH

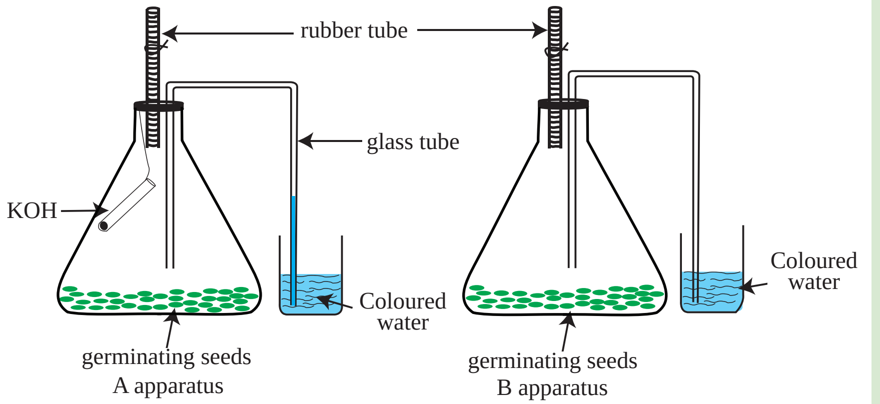



**Figure 8.9- A practical demonstration to show absorption of oxygen in respiration**

**Method**

Close the flask with the cork lid connected to a rubber tube and a U tube as shown in the diagram. After sometime tighten the rubber tube and observe the water level in the U tube.

when the flasks are closed with cork lids air inside is released through the rubber tube and pressure comes to equilibrium. Then rubber tubes are tightened to avoid gas exchange.

$CO_2$ released during respiration of seeds in apparatus A dissolves in KOH. $O_2$ in the flask is absorbed by the seeds for respiration. To fill that gap, (reduction in volume of air) air in the tube flows into the flask. The water column in the glass tube is drawn up. So it is clear that $O_2$ is absorbed for respiration of organisms. No such change in B setup as absorbed volume of $O_2$ is equal to the released volume of $CO_2$.

Two assumptions are made in this experiment.
(i) Volume of $CO_2$ in the flasks is negligible.
(ii) In respiriation, absorbed volume of $O_2$ is equal to the released volume of $CO_2$

**Assignment 8.3**

Observe the respiratory movements and associated movements of organisms given below and write a report on your observation.

01. Frog
02. Tilapia
03. Human
04. Dog
05. Grass hopper

## 8.4 Irritability and Co-ordination

Figure 8.10- Responding towards stimuli

Organisms react according to the changes in the environment. When there is a change in the internal and external environment or a stimulus with a particular strength, organisms respond accordingly. A change which is strong enough to bring about a response is known as a **stimulus**. The stimuli are detected by organs such as eye, ear, nose, tongue and skin. The stimuli are light, sound, chemicals and mechanical or physical vibrations.

The reactions according to the changes in the environment are known as **responses**. Eg: The stimulus is the sound and the response is closing of ears with hands as in the above diagram 8.10.

The ability to respond to stimuli receives from internal or an external environment is known as **irritability**. The communication between different organs during responding to a stimulus is known as co-ordination. Nerves, muscles and hormones are important in co-ordination. Some insects fly towards light, some fly towards dark. Not only animals but also plants respond to stimuli.

**Example :** Leaves of *Mimosa* fold when touched. That means those plant leaves are sensitive to touch. Leaves of Thora, Tamarind and *Sesbania* fold at night. That means these plant leaves are sensitive to light.

## 8.5 Excretion

All organisms obtain materials from the environment and transform them to a beneficial form of energy. At the same time the materials which are not used and the waste materials that are produced during the processes in the body are released to the environment.

The sum of chemical and physiological activities or building up and breaking down of materials within the cell are known as metabolic activities. **Removal of the waste products from the body that are produced during metabolism is known as excretion.**

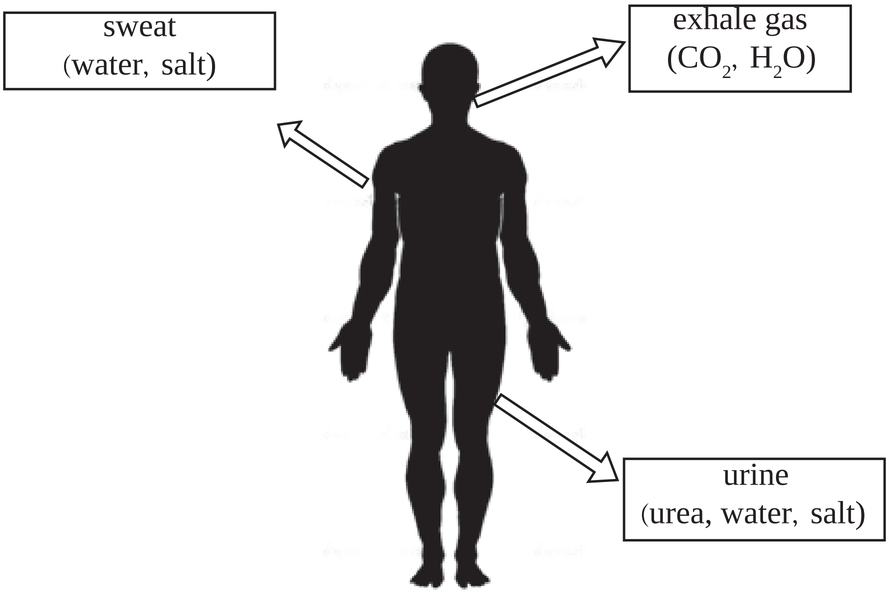



**Figure 8.11- Different ways of excretion of a living being**

The main excretory materials of organisms are urea, salts, $CO_2$ and water. There are organ systems present in the organism body for excretion. Nitrogenous excretion of human mainly takes place by the kidney.

Plants release $CO_2$ during respiration, $O_2$ during photosynthesis through lenticels and stomata of the leaves. That can be referred to as excretion too.

**For extra knowledge.**

- **Anabolism**

  The process of synthesis of complex compounds from simple compounds within the living body. Energy is stored during this process.

- **Catabolism**

  The process of breaking down complex compounds into simple compounds in the body releasing energy is known as Catabolism.

- **Metabolism**

  Summation of bio chemical reactions taking place in the living body or the total of anabolism and catabolism is known as Metabolism.

## 8.6 Movement

Organisms fulfil their requirements (food, protection, reproduction) with the help of movement. During this, the whole organism or a part of the organism is moved. Unicellular organisms use cilia, flagella or pseudopodia for movement.

Multicellular organisms move the whole body or a part of the body with the help of muscles. Most of them possess organs for locomotion.

E.g :- Fins, Wings, Legs

Similarly the organelles within the cell have the ability to move. Movement is a living characteristic of organisms and it is essential for their existence.

You may have observed the growth of a shoot tip of a potted plant towards light which is placed closer to a window. The shoot apex of a plant grows towards light and the root apex towards the gravity.

Organisms move as a response to stimuli. The stimuli may vary.

Examples : Light/darkness, Chemical substances, Gravitational force
Heat/temperature, Vibrations/touch

**Assignment 8.4**

- State different modes of locomotion of mammals and give two examples for each.
- For what purposes do organisms locomote?
- Give examples for different growth movements of plants.

## 8.7 Reproduction

What happens to the existence of the earth, if all the organisms die without producing their own offsprings? If so, the populations become extinct with time, one by one. Therefore before one generation dies, they have to produce their next generation. **Production of a new generation by a unicellular or a multicellular organism for the continuation of their species is known as reproduction.**
Reproduction is of two types. They are sexual and asexual reproduction. During sexual reproduction, gametes of two individuals sperm and an egg of the same species unite to form a zygote. The first cell of the process of producing a new organism is the zygote.
During asexual reproduction, a single organism can produce an identical new offspring without the contribution of another organism.

**Example :** Propagation of new plants by vegetative structures of plants

## 8.8 Growth and Development

The life of multicellular plants or animals starts from a single cell. Tissues which are modified to perform a specific function arise by the division of the above single cell, zygote.
The zygote which is the result of the sexual reproduction of human develops into an embryo within the uterus and later transforms into an offspring. It is useful to study about the above process to understand the growth and development.

Mainly the increase in number of cells by the cell division contributes towards the growth of a multicellular organism. The growth of a unicellular organism is considered as the increase of the size and the volume of the cell. (*Paramecium*, Yeast, *Chlamydomonas*) The cell growth means the irreversible increase of dry mass of the cell. Development means, the increase in the complexity of the cell. Accordingly, growth and development can be expressed in three steps.

1. **Irreversible increase in size of the cell**
2. **Increase in number of cells by cell division**
3. **Cell differentiation**

Auxanometer can be used to show the growth of a plant.

## Activity 04

**Observation of plant growth using auxanometer**

**Materials Required -** A potted plant, An Auxanometer

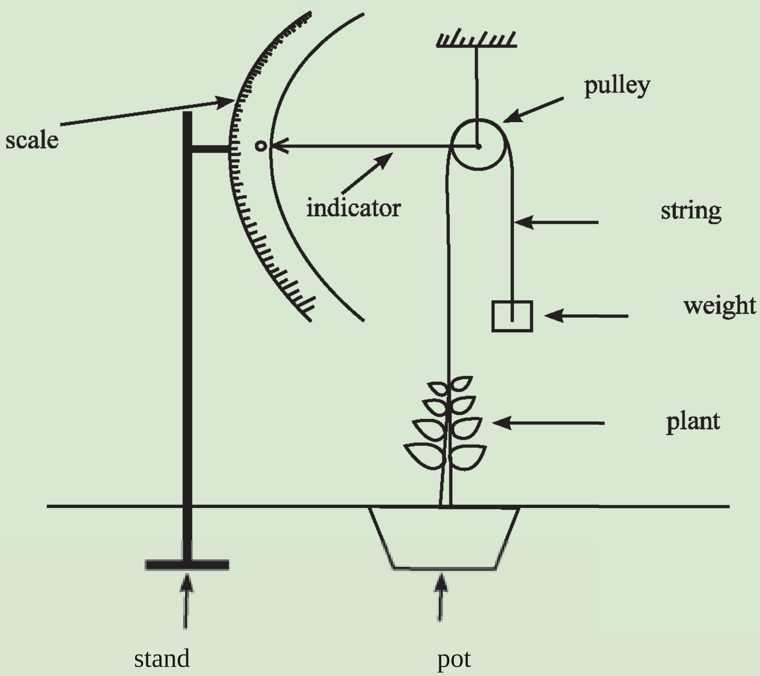



**Figure 8.12- A model of an auxanometer**

**Method**

According to the Figure 8.12 a thread is connected to the shoot apex of a potted plant and it is sent through a pulley and a weight is hung onto it. observe how the indicator moves.

In the above activity the plant grows very slowly, but the indicator shows it in a greater scale.

**Figure 8.13 - Human growth and development**

**Figure 8.14 - Plant growth and development**

According to the above mentioned features, now you can identify living or non living things in the environment.

Observe a white thread like mass on a pile of decomposing garbage. It is the somatic part (growth part) of a fungus. Later it transforms into mushrooms which are structures of sexual reproduction.

You can observe Lichen grows on a coconut trunk, ferns and orchids grow on a wall, mealy bugs on chili or papaw plants, small, fragile white eggs on leaflets of *Sesbania* and identify their living or non living nature.

Sometimes, living or non living nature of some substances cannot be identified easily. Bacteria cells can be dried into a powder. Yeast which is a fungus that is used to make bread is available in the market as a dried powder.

**Assignment 8.5**

Some non living things show, living features in the environment. Formations of rocks by aggregation of soil, growth of crystals are some examples. Waves appear in reservoirs show a movement. Discuss how this movement and growth is different from that of living organisms.

Some living entities cannot be easily identified whether they are living or non-living.

E.g : Virus

## Virus

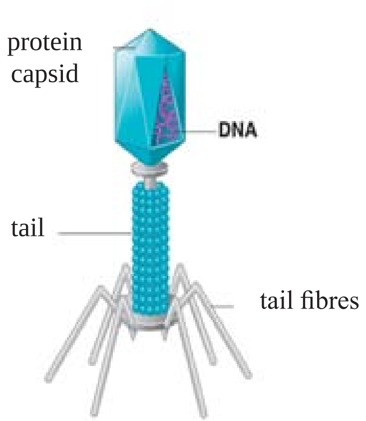



**Figure 8.15- Structure of a virus as a model observed through electron microscope**

They are very small and can be observed only through the electron microscope and are about 1/1000th of the size of a bacteria. They show living or non living features according to their status. A virus is not considered as a cell. They are composed of a nucleic acid enclosed by a protein capsid. The nucleic acid may be DNA or RNA. Viruses with different shapes and sizes have been identified.

Viruses do not possess any organelles for metabolic reactions. A virus becomes active only inside the host cells.

**Fig 8.16- A virus infected cell observed through electron microscope**

**For extra knowledge.**

The only living feature of virus is the reproduction. When a virus reaches an appropriate host it hydrolyzes the cell membrane of the host cell and releases its RNA or DNA into it. The nucleic acid then multiplies within the host cell or produces thousands of viral particles. A virus activity like an organism in this manner can only be seen inside a host cell.

Common plant viral diseases are banana bunchy top disease and curly leaf of chilies. Some animal viral diseases are influenza, common cold, Dengue and AIDS. It is important to prevent those diseases by knowing about them.

Organisms live in environments in which they can maintain their life. Therefore we can protect them by conserving those environments.

## For your attention

You should have the ability to differentiate living from non living after studying the above lesson. You should respect every organism in the environment as they are part of the environment. Spend little time daily to study about the environment. Try to keep a daily record about them. If possible try to keep a environmental diary. Collect relevant information from your teacher.

## Summary

- Cellular organization, Nutrition, Respiration, Irritability and coordination, Excretion, Movement, Reproduction, Growth and Development are characteristics of organisms.

- The basic organizational level of an organism is the cell. Multicellular organisms possess tissues, organs and system level complex organization.

- The process of obtaining energy and material to maintain the life is known as nutrition.

- The cellular respiration is the process by which the end products of digestion combine with oxygen to produce energy inside the cell.

- The ability to respond to the changes in the external or internal environment is known as irritability. The adaptation of the body functions according to those changes is the coordination.

- Removal of waste products of metabolism out of the body is termed excretion.
- Organisms move as a result of coordination.

- Production of new generation for the continuation of their species is termed reproduction.

- The growth is the irreversible increase of dry mass of a cell. During development, cells differentiate to perform a particular function.

- Virus is an acellular form which cannot be differentiated into living or non living.
- All organisms contribute to maintenance and the existence of the environmental balance.

## Exercises

Select the correct answer

(01) Select the correct term for the gap.

Cell $\longrightarrow$ Tissue $\longrightarrow$ $\boxed{\phantom{xxxx}}$ $\longrightarrow$ System

1. Organism 2.Organ 3. Organelle 4. Structure

(02) What is the process that produces energy for cells?

1. Nutrition 2. Reproduction 3. Excretion 4. Respiration

(03) Select the plant that is not photoautotrophic

1. *Acalypha* (Kuppamenia) 2. *Asparagus*
3. *Loranthus* 4. *Cuscuta*

(04) Which organ does not act as an excretory organ ?

1. Kidney 2. Skin 3. Stomach 4. Lungs

(05) Few statements about viruses are given below

A - Virus is a species of organism
B - Virus possess DNA or RNA
C - Virus multiply only within living cells
Correct statements are,

1. A and B 2. B and C 3. C and A 4. All above

(06) What is the term used to explain all the bio chemical reactions take place in living body?

1. Metabolism 2. Co-ordination 3. Respiration 4. Growth

(07) To which group of organisms do Yeast belong?

1. Bacteria 2. Fungi 3. Algae 4. Protozoa

(08) Select the most appropriate term to define a stimulus.

1. Maintenance of a constant internal environment
2. A change takes place in internal and external environment
3. A change in the external or internal environment that is strong enough to bring about a response
4. Co-ordination between different organs during responding

## Technical terms

| | | | | |
|---|---|---|---|---|
| Cellular organization | - | සෛලීය සංවිධානය | - | கலவொழுங்கமைப்பு |
| Nutrition | - | පෝෂණය | - | போசணை |
| Respiration | - | ශ්වසනය | - | சுவாசம் |
| Reproduction | - | ප්‍රජනනය | - | இனப்பெருக்கம் |
| Movement | - | චලනය | - | அசைவு |
| Excretion | - | බහිස්ස්‍රාවය | - | கழிவகற்றல் |
| Sensitivity | - | සංවේදීතාව | - | உணர்ச்சி |
| Irritability | - | උද්දීප්‍යතාව | - | உறுத்துணர்ச்சி |
| Co-ordination | - | සමායෝජනය | - | இயைபாக்கம் |
| Growth and Development | - | වර්ධනය සහ විකසනය | - | வளர்ச்சியும் விருத்தியும் |

Physics

# 09

# Resultant force

## 9.1 The resultant of several forces

Figure 9.1 shows a motor car stalled on the road due to a mechanical fault being pushed by one person in the forward direction. Since the force exerted was not sufficient to move the vehicle, it did not move. Figure 9.2 shows two people trying to push the car. The motor car did not move in this attempt either. In Figure 9.3, three people are shown to push the motor car. In this attempt, the car has moved.

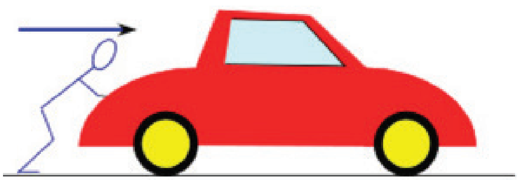


Figure 9.1 – One person pushing a car

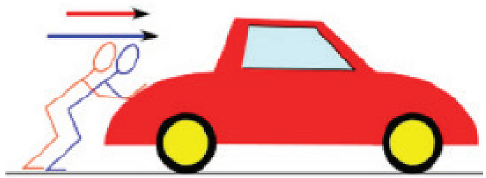


Figure 9.2 – Two persons pushing the car

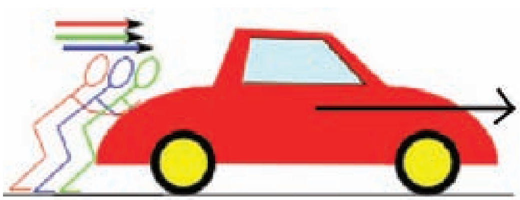


Figure 9.3 – Three persons pushing the car

In order to move the car all the forces have to be applied in the direction that the car needs to be moved.

If many people take part in pushing the car instead of just one person, all the individual forces combine to form a larger force in the same direction and the task becomes easier.

The result of many people exerting forces in the same direction is that all the forces add up to give a larger single force.

**When more than one force is applied, the single force that gives the same result as that of all the contributing forces is known as the resultant force of the individual contributing forces.**

Forces applied on objects can have various directions. In this lesson will discuss about,

(i) the resultant of two collinear forces (forces having the same 'line of action') and

(ii) the resultant of two parallel forces (forces having parallel but different 'line of action')

## 9.2 Resultant of two collinear forces

### Resultant of two collinear forces acting along the same direction

When pulling on fishing nets, the task can be accomplished more easily if a large group of people take part in pulling the net in the same direction. Because all the forces act in the same direction, the fishing net can be successfully pulled. Here, all the forces are applied in the same direction and along the same line.

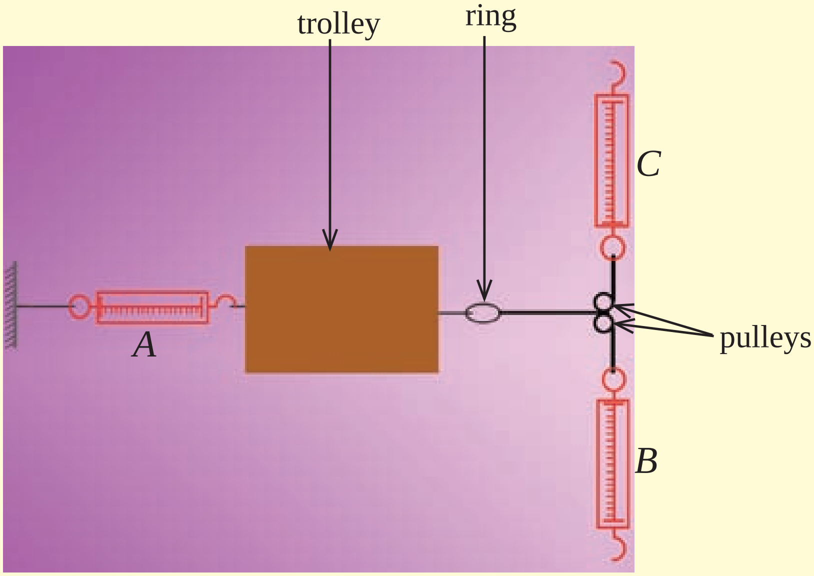
Figure 9.4 – A group of people pulling a fishing net

Now let us investigate a way of finding the resultant of two collinear forces acting along the same direction.

## Activity 1

**Items required** : a trolley, three Newton balances, two pulleys, a ring

Place the trolley on a table and fix the ring to one side of the trolley and attach two strong strings to the ring as shown in Figure 9.5. Pass the two strings over the two pulleys and connect the two Newton balances *B* and *C* to the other ends of the strings. Fix the other end of the trolley to a wall through the third Newton balance *A*.



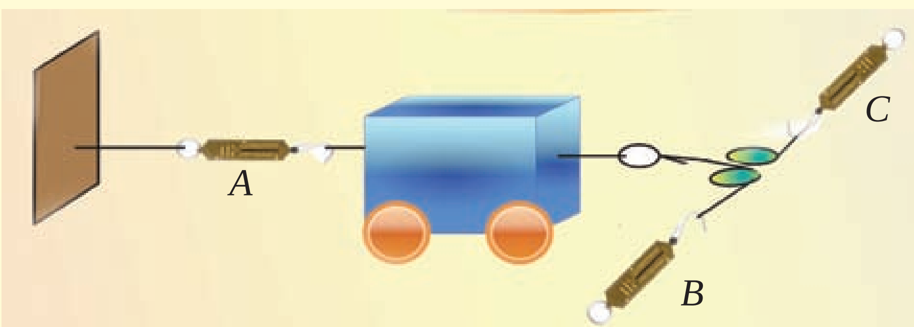




Figure 9.5 - Two forces acting on the trolley in the same direction

- Apply two forces from the two Newton balances *B* and *C*. Record the readings of the balances.
- Record also, the reading of the balance *A*.

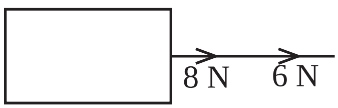
- Find a relationship between the reading on the balance *A* and the readings recorded from *B* and *C* balances.
- Applying different forces from the *B* and *C*, repeat the activity several times and find the relationship between the measurements.

You will observe that the sum of the readings of *B* and *C* is equal to the reading of *A*.

That is, when two collinear forces act along the same direction, the resultant of the two forces is equal to the sum of the two individual forces with a direction in the direction of forces.

## Example 1

Two children are pulling a thread connected to a box placed on a table in the same direction. The force applied by one child is 8 N while that of the other child is 6 N. What is the resultant force with which the children are pulling the box?

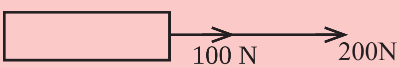


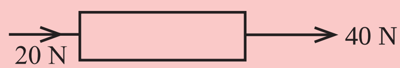

The resultant force applied by both children $= 8\text{ N} + 6\text{ N}$

$= 14\text{ N}$ (To the same direction)

## Exercise 9.1

(1) Find the resultant force in each of following situations.

(i) 


(ii) 


(2) A child is pushing an object placed on a table with a force of 5 N in a certain dierection while another child is pulling it in the same direction with a force of 7 N. What is the resultant of these two forces?

## Resultant of two collinear forces acting along opposite directions

Have you seen the national sport of pulling ropes during the Sinhala new year season? The participants of such competitions form two groups and pull a rope in two directions. The rope will be dragged in the direction of the resultant force which lies in the direction of the larger force.

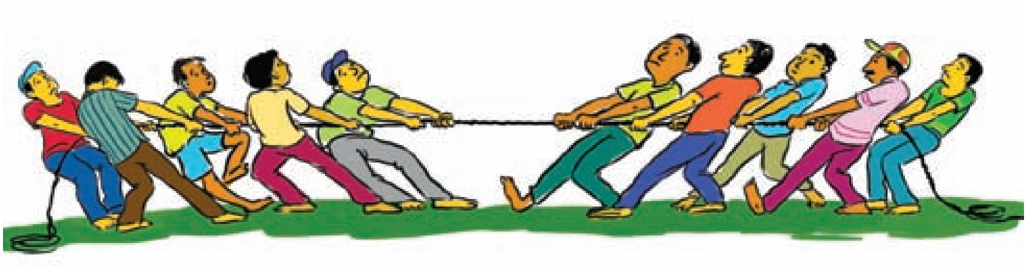


Figure 9.6 – Pulling a rope

When we want to pull an object along a certain direction, the resultant force or the net force of forces applied along that direction is given by the summation of the forces.

The result of applying forces in various directions is a non-utilization of the forces productively.

It is possible to obtain a large net force only if all the contributing forces are applied in the same direction.

It is an experience that in order to drag a heavy object along the floor easily, the object should be pushed from behind and pulled from the front.

Go carts used to carry children can be pulled from the front or pushed from the back in order to move it. If both a pull from the front and a push from the back are given to the go cart, moving the cart would be easier as a large resultant will operate on the cart.

Now let us find the resultant of two collinear forces acting in opposite directions. In order to do it, let us engage in the following activity.

## Activity 2

**Items required** : a trolley, two Newton balances, two smooth pulleys, measuring weights

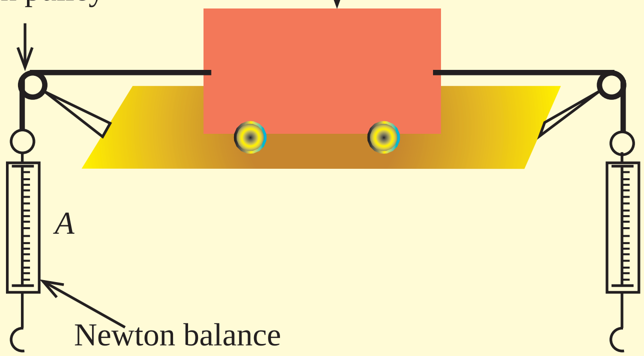



Figure 9.7 - Forces acting in opposite directions on a trolley

- Place the trolley on a table as shown in Figure 9.7 and fix two pieces of string to the two ends of the trolley. Allow the other ends of the pieces of string to pass over the two pulleys and attach two Newton balances *A* and *B*.
- Record your observations on the motion of the trolley after applying a 4 N force on each balance.
- Record your observations on the motion of the trolley after applying a 4 N force on the balance *A* and a 6 N force on balance *B*.
- Repeat the above step applying a 6 N force on the balance *B* and a 6 N force on the balance *A*.

You will observe that the trolley does not move in the first case. The trolley remains in equilibrium under the action of the two equal forces acting on it in opposite directions.

In the second instance, the trolley moves in the direction of the Newton balance *B*. Here, there are two inequal forces acting on the trolley in opposite directions and the trolley moves in the direction of the larger force. The extra force which is applied in the direction of *A* than in the direction of *B* is 2 N. That is, in this instance the resultant is 2 N in the direction of *B*.

In the third instance, the trolley does not move. Here, the resultant is zero since the two forces acting in the opposite directions become equal.

When two collinear forces are exerted on an object in opposite directions, the resultant is given by their difference, with a direction in the direction of the larger force.

### Example 1

What is the magnitude and the direction of the resultant of a force of 5 N pulling an object placed on a table in a certain direction and another force of 2 N pulling it in the opposite direction?

$$\text{Resultant force} = (5\text{ N}) + (-2\text{N})$$
$$= 3\text{ N}$$

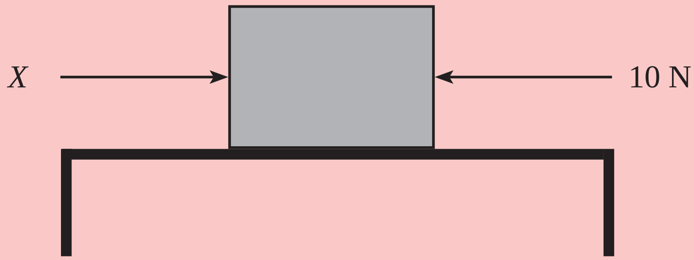
The object will be pulled by a force of 3 N in the direction of the 5 N force.

### Exercise 9.2

(1) The forces applied by two children in order to push a box resting on a horizontal plane is shown in the figure.


Find the resultant of the two forces.

(2) A force of 10 N is applied towards the West, on an object placed on a table. If the object is drawn towards the West with a force of magnitude 5 N, what is the magnitude of the force $X$?



## 9.3 Resultant of two parallel forces

Let us now investigate instances where two parallel forces which are not collinear are in action, and how to find the resultant of these two parallel forces.

Let us consider this example.

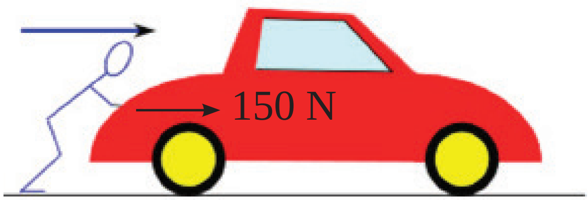



Figure 9.8 – One person trying to push a motor car

One person is trying to push a motor car with a force of 150 N in the direction as shown in Figure 9.8, but it has not moved.

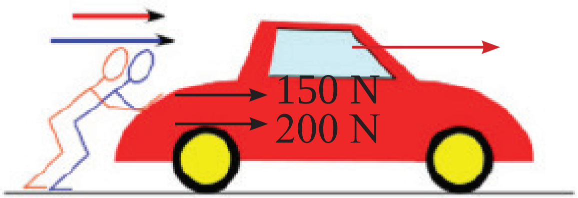



Figure 9.9 – Two persons pushing the car

However, when the assistance of another person pushing the car with a force of 200 N was obtained and the car was pushed by both persons, in the direction shown the car moved. It was because the resultant of the two forces is sufficient for the motion of the car.

Although both these forces were applied in the same direction, they are not collinear. They are two parallel forces acting on two different points of the motor car. However, that when two forces act along the same direction the resultant is the sum of the two forces.

Resultant of the two forces = 150 N + 200 N (since both forces act in the same direction)

= 350 N

To experimentally check that the resultant of two parallel forces are equal to their sum, let us do the following activity.

## Activity 3

**Items required** : a strip of wood with three holes drilled as shwon in the figure, three Newton balances

- Drill three holes *X*, *Y* and *Z* on the strip of wood as shown in the figure below and attach the three Newton balances *A*,*B* and *C*. Pull the three balances keeping the strip of wood to be in a rest position. (Always keep the strip perpendicular to the Newton balances. you may need to apply equal forces on the *A* and *B* balances)

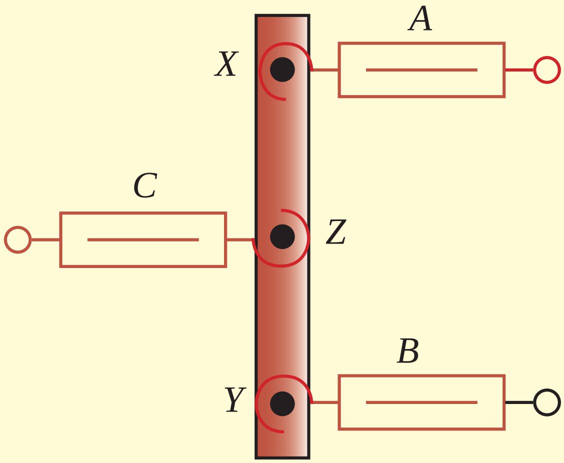


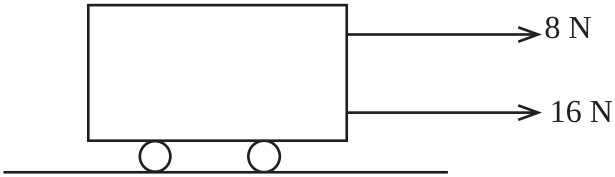

Figure 9.10 - Finding the resultant of two parallel forces

- When the strip of wood is at rest, you would observe that the sum of the readings of the Newton balances *A* and *B* is equal to that of the Newton balance *C*. What is the reason for this? It is because the resultant of the two forces on *A* and *B* is equal to the magnitude of the force on *C*.

In order to find the resultant of two parallel forces acting along the same direction, the two forces must be added.

One of the best uses we can get from a knowledge of resultant force is to make use of a large number of small forces in place of a single large force effectively.

**Example 1**



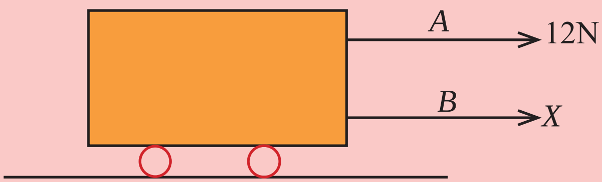

Two strong strings attached to a trolley is pulled by a force of 8 N on one string and a force of 16 N on the other string keeping the two strings parallel. Find the resultant of these two forces.

Resultant of the two forces $= 8\text{ N} + 16\text{ N}$

$= \underline{\underline{24\text{ N}}}$

**Exercise 9.3**

(1) When a trolley placed on a table is pulled by two strings attached to it keeping the two strings parallel to each other, the resultant force is 20 N.




The force exerted on the string $A$ is 12 N. Find the force exerted by the string $B$.

## 9.4 Resultant of two inclined forces

Let us now investigate how to find the resultant of two inclined forces.

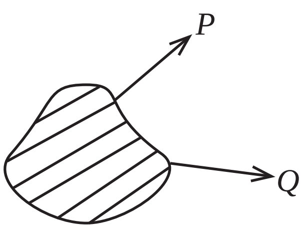
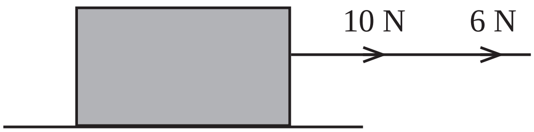



Figure 9.11 – Two inclined forces acting on an object

Two forces $P$ and $Q$ that act with their lines of action inclined to one another is shown in Figure 9.11. When two such forces are applied on an object, the object does not move in either of the directions of $P$ or $Q$. In such an instance, the direction of motion of the object lies in a direction between the two forces.

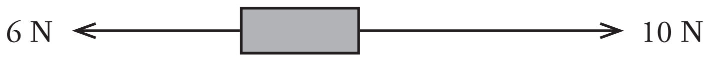
## Miscellaneous exercises

(1) (i)



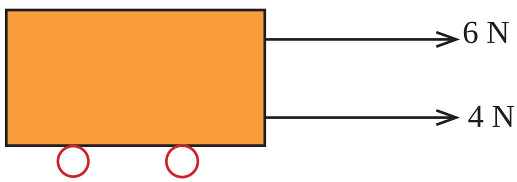

If an object is pulled by two forces 10 N and 6 N along the same direction, what is the resultant of the two forces?

(ii)




If the two forces are applied along two opposite directions, what would be the resultant?

(2) (i) What is the resultant of the two parallel forces shown below?




(ii) (a) What is the force that can be applied in the opposite direction so as to make the resultant zero.

(b) Illustrate it using a figure.

(3) One bull out of a pair of bulls tied to a plough for ploughing a paddy field, exerts a force of 100 N while the other bull exerts a force of 80 N. What is the resultant force that the plough is pulled with?

(4) When an object is held by a Newton balance, the reading was 80 N. If another object of mass 500 g was attached to the Newton balance, what would be the resultant force in Newtons?

(5) If a trolley is being pulled by two forces, one with a magnitude of 20 N along the East and the other with a magnitude of 15 N along the West, in which direction would it move? What is the resultant?

## Summary

- The single force acting in place of many forces (the single force that gives the same result as many forces) is known as the resultant force.
- The magnitude of the resultant of two forces acting in the same direction is the sum of the two forces. Direction of the resultant is the direction of an individual forces.
- If the magnitudes of two collinear forces acting in opposite directions are different, then the magnitude of their resultant is equal to the difference between the two forces and acts in the direction of the larger force.
- The resultant of two inclined forces act in a direction which lies between the two forces.

| Technical terms | | |
|---|---|---|
| Resultant force | සම්ප්‍රයුක්ත බලය | விளையுள் விசை |
| Newton balance | නිව්ටන් තුලාව | நியூற்றன் தராசு |
| Unbalanced force | අසංතුලිත බලය | சமநிலைப்படாத விசை |
| Opposite direction | විරුද්ධ දිශාව | எதிர்த் திசை |

Chemistry 10

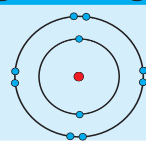
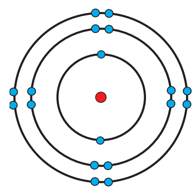
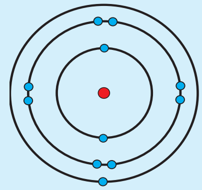
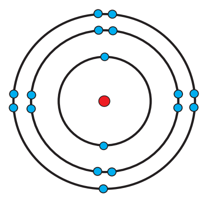
# Chemical Bonds

The English alphabet contains 26 letters. Yet, the combination of them forms a large number of words. There is only a limited number of elements. In spite of that, millions of compounds are formed by their chemical combination.

Though most of the elements form chemical compounds, there are some elements which do not form compounds under normal conditions. Helium, neon and argon are examples. These elements occurring as single atoms in nature exist as gases. They are known as noble gases.

What is the reason why many elements form compounds but not the noble gases? This can be explained by taking into consideration the electronic configuration of elements.

Table10.1

| Element | Electronic configuration | Distribution of electrons among the energy levels |
|---|---|---|
| Neon (Ne) | 2, 8 |  |
| Argon (Ar) | 2, 8, 8 |  |
| Sodium (Na) | 2, 8, 1 |  |
| Chorine (Cl) | 2, 8, 7 |  |

The outermost shell carrying electrons in an atom of an element is known as its valence shell.The valence shell of the atoms of neon and argon has eight electrons each. This electronic structure has been identified as a stable electronic configuration. Because of this stable configuration their reactivity is very low, so they are referred to as noble gases. But, the state of sodium and chlorine atoms is different. In order to have the stable noble gas configuration, a sodium atom has to either lose the electron in the last shell or gain seven electrons. Similarly a chlorine atom can attain the stable electronic configuration by receiving a single electron or by removing seven electrons. In the atoms of these element, electrons in the valence shell reorganise to acquire the stable electronic configuration. That means, loss, gain or sharing of electrons occurs.

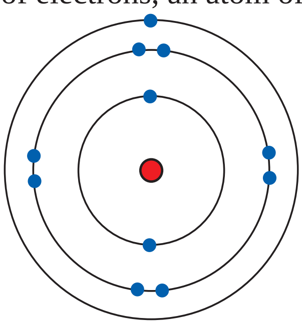
**The attractive forces or binding among the atoms or ions resulted by the rearrangement of electrons in the valence shell for stabilizing the atoms of elements as described above are called chemical bonds.**

According to the way the participating atoms behave when they chemically bind together, the chemical bonds can be divided into two types.

1. Ionic bonds
2. Covalent bonds

## 10.1 Ionic Bonds

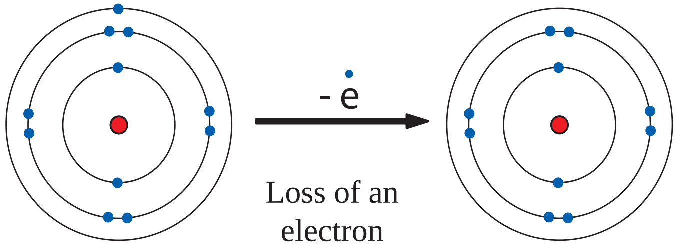
The electronic configuration of the sodium atom is 2, 8, 1. Sodium is an element with low electronegativity. As the number of protons in a sodium atom is equal to the number of electrons, an atom of sodium is electrically neutral (Fig. 10.1).



| | |
|---|---|
| Number of electrons | 11 (-11) |
| Number of protons | 11 (+11) |
| Total charge | 0 |

A sodium atom
Fig. 10.1

The atom after losing its electron in the outer energy level becomes a sodium ion ($Na^+$) with a charge of +1 (Fig.10.2). An atom after receiving a charge is known as an ion. Since this ion has a positive charge it is called a positive ion or a cation. The chemical properties of an ion is different from that of an atom.




| The Na atom | |
|---|---|
| Number of electrons | 11(-11) |
| Electronic configuration | 2, 8, 1 |
| Number of protons | 11(+11) |
| Total charge | 0 |

| The $Na^{+}$ ion | |
|---|---|
| Number of electrons | 10(-10) |
| Electronic configuration | 2, 8, |
| Number of protons | 11(+11) |
| Total charge | +1 |

$$\mathbf{Na} \longrightarrow \mathbf{Na^{+} + e}$$

$$\textbf{Atom} \longrightarrow \textbf{Positive ion} + \mathbf{e}$$

Fig 10.2 Formation of a $Na^{+}$ ion form a Na atom

The electronic configuration of the chlorine atom is 2, 8, 7.Chlorine is an element with a high electronegativity value. Since the opposite charges are equal, a chlorine atom is electrically neutral (Fig.10.3).

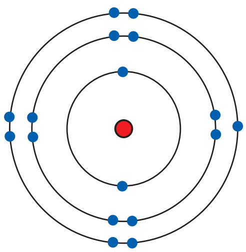
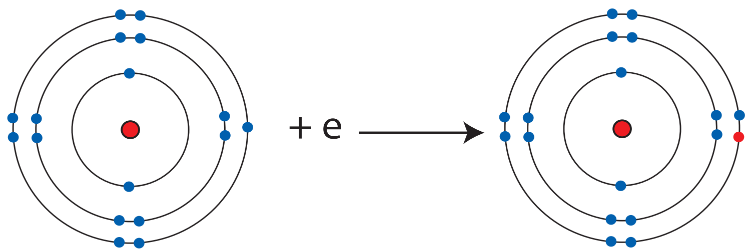


Fig. 10.3 A chlorine atom

| Chlorine atom | |
|---|---|
| Number of electrons | 17 (-17) |
| Electronic configuration | 2, 8, 7 |
| Number of protons | 17 (+17) |
| Total charge | 0 |

Gaining one electron to the outermost energy level, a chlorine atom (Cl) forms the chloride ion ($Cl^{-}$) with a single negative charge (Fig. 10. 4). As this ion is negatively charged it is called a negative ion or an anion.




| The Cl atom | |
|---|---|
| Number of electrons | 17 (--17) |
| Electronic configuration | 2, 8, 7 |
| Number of protons | 17 (+ 17) |
| Total charge | 0 |

| The $Cl^-$ (chloride) ion | |
|---|---|
| Number of electrons | 18 (-- 18) |
| Electronic configuration | 2, 8, 8 |
| Number of protons | 17 (+ 17) |
| Total charge | --1 |

$$Cl + e \longrightarrow Cl^-$$

$$\text{Atom} + e \longrightarrow \text{Negative ion}$$

Fig. 10.4 Formation of a $Cl^-$ ion from a $Cl^-$ atom

Neutral atoms form positively charged ions by losing electrons. Neutral atoms form negatively charged ions by gaining electrons. Some polyatomic groups too bear positive or negative charges (e.g. $NH_4^+$, $SO_4^{2-}$, $NO_3^-$). **An ion is an atom or a group of atoms with an electrical charge.**

Now let us examine how the compound sodium chloride is formed. The sodium ions formed by the sodium atoms by losing electrons and the chloride ion formed by chlorine atoms by gaining electrons are oppositely charged. These ions by virtue of their opposite charges strongly bind together by electrostatic attractive forces to form the compound sodium chloride with ionic bonds. This process is illustrated in Fig. 10.5.

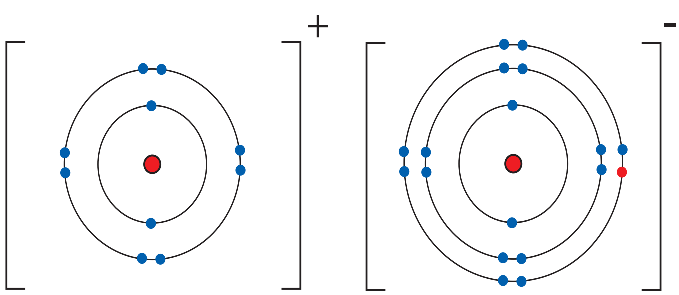


Fig.10.5 Electrostatic attraction between $Na^+$ and $Cl^-$ ions

**The bonds formed due to the strong electrostatic attractions between the positive and negative ions produced by the exchange of electrons among atoms are known as ionic bonds or electrovalent bonds. So, sodium chloride is a compound with ionic bonds. Such compounds are called ionic compounds.**

Fig 10.6 shows how electrons in the outermost energy levels of the atoms reorganize during the formation of sodium chloride.

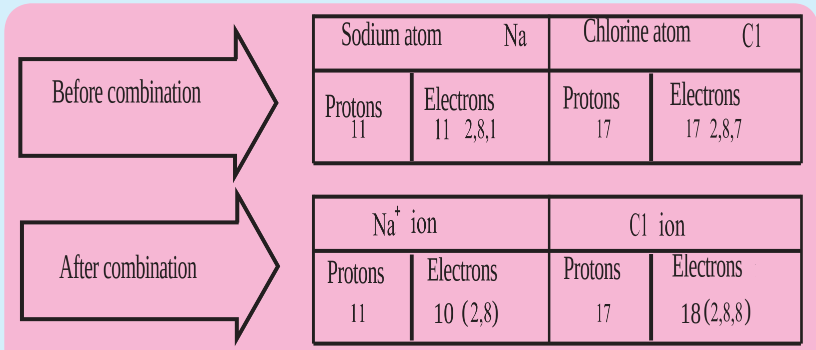
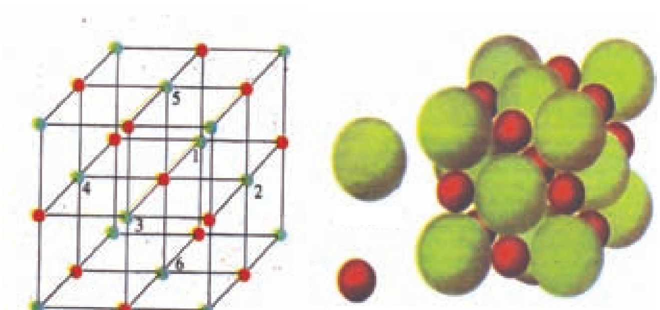



Fig 10.6

The attractions among the ions in the compound sodium chloride is not limited to a single pair of $Na^+$ and $Cl^-$ ions. Owing to the attractions, a large number of positive and negative ions arrange themselves to form a regular three dimensional array where six $Na^+$ ions surround every $Cl^-$ ion and six $Cl^-$ ions surround every $Na^+$ ion. This arrangement gives rise to the crystal lattice of sodium chloride known as an 'ionic lattice' (Fig. 10.7). In all ionic compounds the ions are organised in a three dimensional lattice.



10.7 Ionic lattice of sodium chloride

## • Ionic Compounds

Mostly the ionic bonds are formed between the positive ions produced by the atoms of low electronegativity and the negative ions formed by the atoms of high electronegativity. Table 10.2 presents some examples for such ionic compounds.

Table 10.2

| Compound | Chemical formula |
|---|---|
| Sodium chloride | $NaCl$ |
| Lithium oxide | $Li_2O$ |
| Magnesium sulphide | $MgS$ |
| Calcium chloride | $CaCl_2$ |
| Potassium fluoride | $KF$ |

In addition to the above compounds, ionic bonds are formed during the combination of ionic radicals and ions also. Presents some examples for such compounds.

Table 10.3

| Compound | Chemical formula |
|---|---|
| Copper sulphate | $CuSO_4$ |
| Calcium carbonate | $CaCO_3$ |
| Ammonium chloride | $NH_4Cl$ |
| Ammonium nitrate | $NH_4NO_3$ |

**Assignment – 10 -1**

As was done for sodium chloride, illustrate pictorially how ionic bonds are formed in the ionic compounds lithium oxide ($Li_2O$) and calcium chloride ($CaCl_2$).

**Activity - 10 - 1**

Using coloured clay or plastics balls or any other suitable materials, make a model of the sodium chloride ionic lattice.

## 10.2 Covalent Bonds

Electron sharing between atoms is another method of forming bonds among them. By sharing of electrons like this, the atoms acquire the noble gas configuration. Joining of atoms by sharing electrons between a pair of atoms is referred to as a covalent bond.

Sharing of electrons between atoms of the same kind gives rise to homoatomic molecules.

e.g. hydrogen ($H_2$), fluorine ($F_2$), oxygen ($O_2$), nitrogen ($N_2$)

Sharing of electrons between atoms of different elements gives rise to heteroatomic molecules.

e.g. water ($H_2O$), methane ($CH_4$), ammonia ($NH_3$)

### a). Fluorine molecule

The electronic configuration of a fluorine atom is 2, 7. By sharing a pair of electrons, two fluorine atoms acquire the stable electronic configuration. The result of this is the bonding of two fluorine atoms covalently to form a fluorine molecule (Fig.10.8).

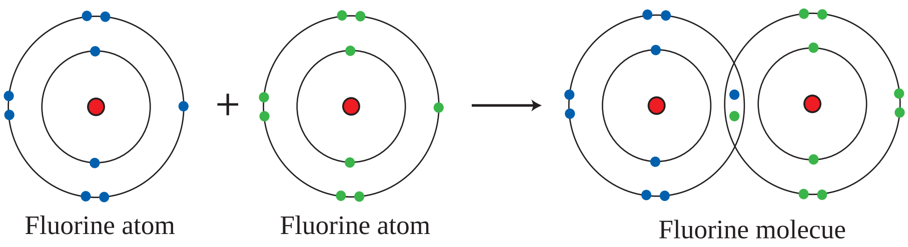



Fig.10.8 Formation of a fluorine molecule

### b). Hydrogen molecule

A hydrogen atom has one electron. Two hydrogen atoms share their electrons between them each acquiring the stable configuration of helium. This gives rise to the hydrogen molecule ($H_2$) in which the two hydrogen atoms are joined by a covalent bond (Fig. 10.9).

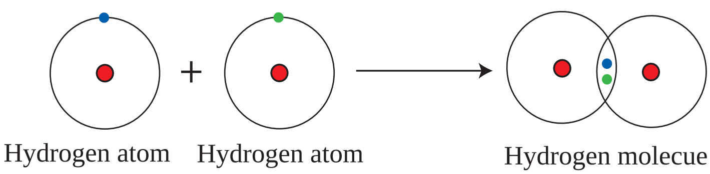



Fig. 10.9 Formation of the hydrogen molecule

## c). Water molecule

The electronic configuration of the oxygen atom is 2, 6. An oxygen atom shares two pairs of electrons with two hydrogen atoms forming two single bonds giving rise to the water ($H_2O$) molecule (Fig.10.10).

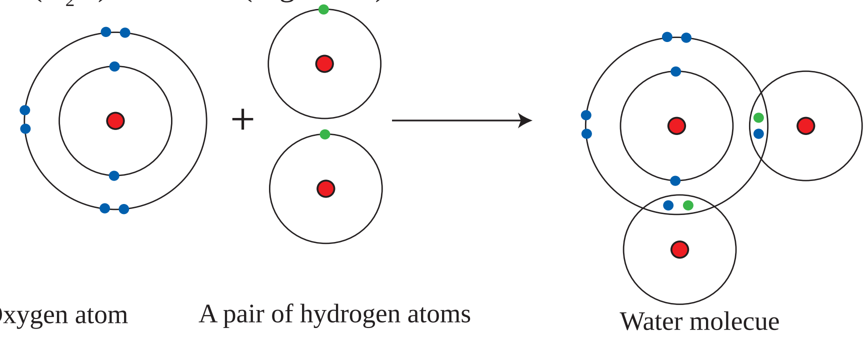



Fig. 10.10 Formation of a water molecule

## d). Ammonia molecule

The electronic configuration of the nitrogen atom is 2, 5. Three hydrogen atoms share three pairs of electrons with a nitrogen atom. This leads to the formation of an ammonia ($NH_3$) molecule which has three single bonds (Fig.10.11).

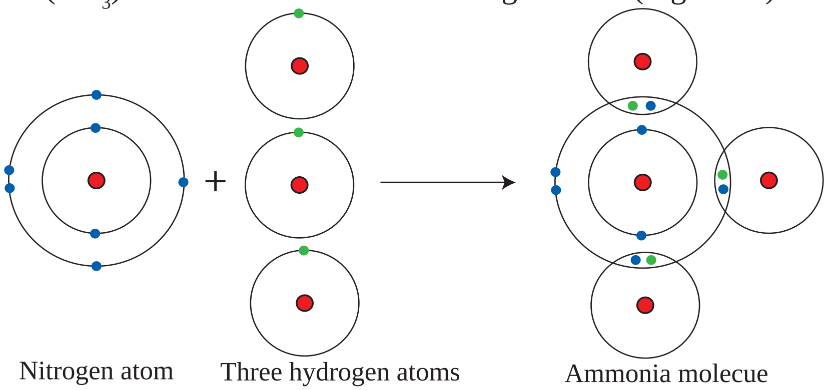



Fig. 10.11 Formation of the ammonia molecule

## e). Methane molecule

The electronic configuration of the carbon atom is 2, 4. Four hydrogen atoms share four electrons with a carbon atom forming a methane molecule ($CH_4$) with four single bonds (Fig. 10.12).

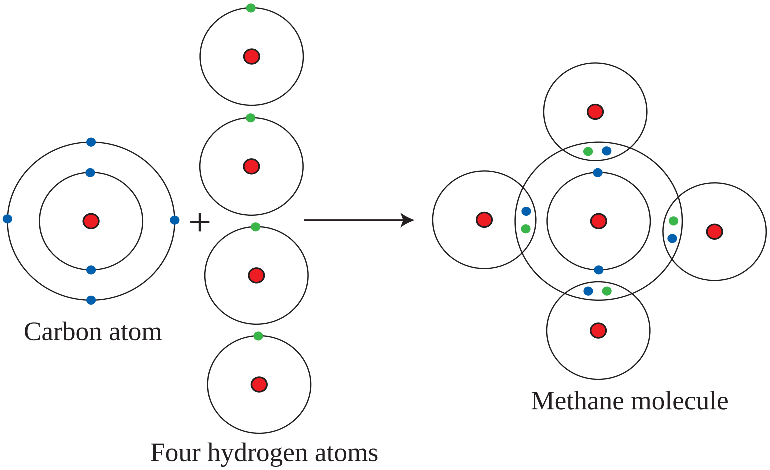



Fig.10.12 Formation of a methane molecule

## f). Hydrogen chloride molecule

The electronic configuration of a chlorine atom is 2, 8, 7. The hydrogen chloride (HCl) molecule is formed by the sharing of a pair of electrons between a chlorine atom and a hydrogen atom (Fig. 10.13).

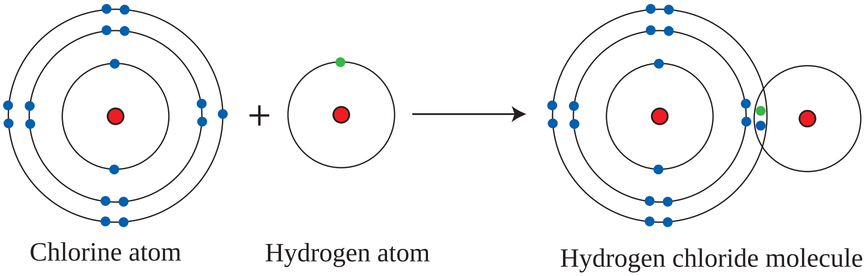



Fig. 10.13 Formation of a hydrogen chloride molecule

## g). Carbon tetrachloride molecule

The electronic configuration of a carbon atom is 2, 4. The electronic configuration of a chlorine atom is 2, 7. The carbon tetrachloride ($CCl_4$) molecule is formed due to the sharing of four pairs of electrons between a carbon atom and four chlorine atoms (Fig.10.14).

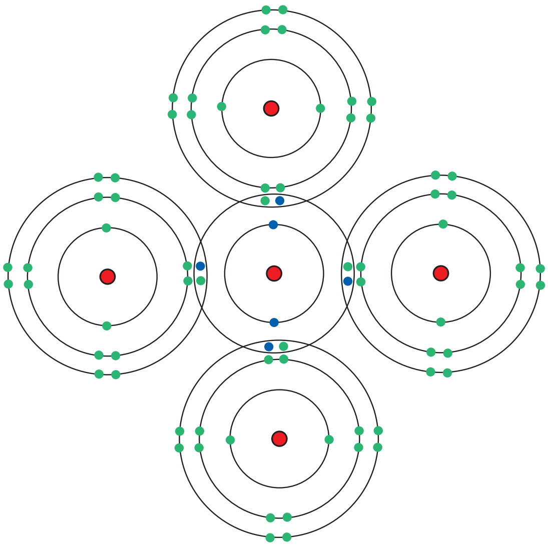


Fig.10.14 Formation of a carbon tetrachloride molecule

## h). Oxygen molecule

The oxygen atom has the electronic configuration 2, 6. When forming the oxygen ($O_2$) molecule, two oxygen atoms share two pairs of electrons between them. Since two pairs of electrons are shared, the bond is known as a double bond (Fig. 10.15).

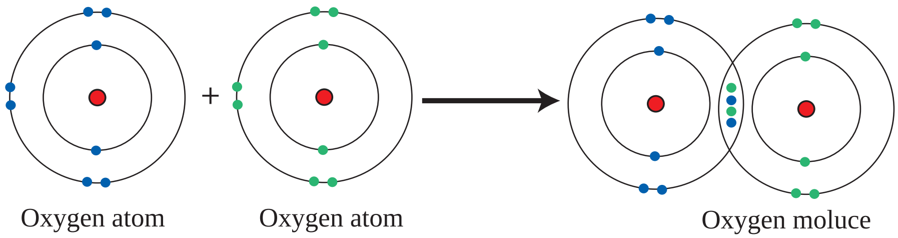



Fig.10.15 Formation of an oxygen molecule

## i). Nitrogen molecule

The electronic configuration of a nitrogen atom is 2, 5. Two nitrogen atoms form a nitrogen ($N_2$) molecule by sharing three pairs of electrons between them. Since three pairs of electrons are shared such a bond is called a triple bond (Fig. 10.16).

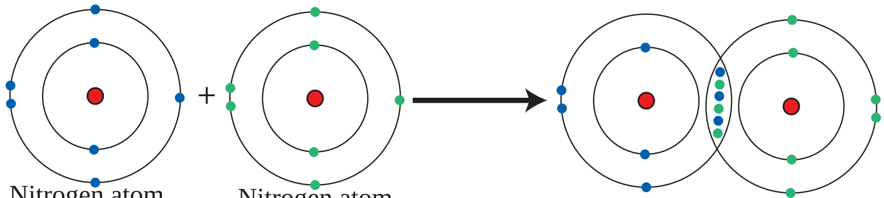



Fig 10.16- Formation of a nitrogen molecule

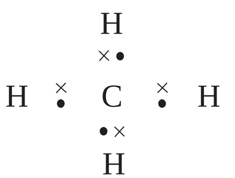
**Activity 01**

**Displaying covalent bonds**

**Requirement** : Styrifoam, beads of various colours, markers, glue

**Method** : Take a styrifoam sheet and draw the molecules a, b, c, d, e, f, g, h, i you studied above. Show creatively the formation of covalent bond using beads for the electrons. Display your work in the class.

## • Dot and cross diagram



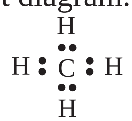

Dot and cross diagram of methane

Always electrons in the valence shells of atoms participate in the formation of covalent bonds. The Lewis dot and cross diagram illurtrates how electrons exist in the covalent bond. In this diagram, electrons of one atom are represented by dots while the electrons of the other atom are shown by crosses. For example, let's take the dot and cross structure of the methane ($CH_4$) molecule. Carbon whose electronic configuration is 2, 4 haz four electrons in its valence shell. These electrons are represented by dots. The electrons of hydrogen atoms which form covalent bonds with carbon are symbolized by the crosses.

## Lewis Structure

Showing covalent bonds of a molecule representing the valence shell electrons of its atoms **only by dots** is called the Lewis dot diagram.

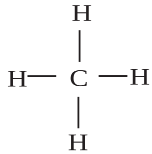

Dot diagram of ammonium



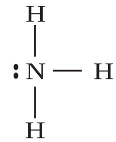

Dot diagram of methane

When a bond electron pair is represented by a short line (-) and a non – bonding lone pair by dots, it is called the Lewis structure.

Lewis structure of $H_2$



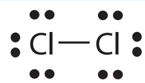
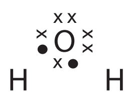
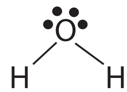
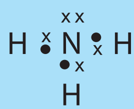
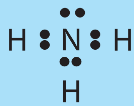
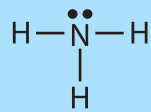
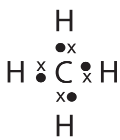
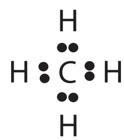
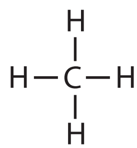
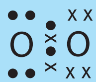
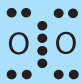
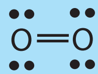
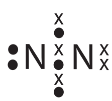
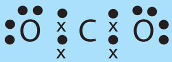
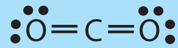
Lewis structure of $CH_4$



Lewis structure of $NH_3$

The electrons represented by dots are known as lone pairs whereas electrons pairs represented by lines are called bond pairs. The dot and cross diagrams, Lewis dot diagrams and Lewis structures of some covalent molecules are given in Table 10.3.

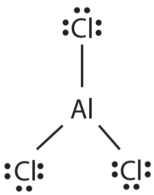
Table 10.3

| Molecule | Lewis dot and cross diagram | Lewis dot diagram | Lewis structure |
|---|---|---|---|
| $Cl_2$ |  |  |  |
| $H_2$ |  |  |  |
| $H_2O$ |  |  |  |
| $NH_3$ |  |  |  |
| $CH_4$ |  |  |  |
| $O_2$ |  |  |  |
| $N_2$ |  |  |  |
| $CO_2$ |  |  |  |

In the ammonia molecules nitrogen atom is the central atom and hydrogen atoms are the peripheral atoms. There are three bond pairs and a single lone pair in the valence shell of the ammonia molecule.

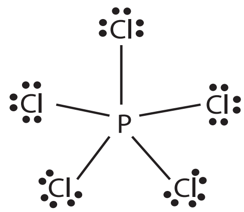
In all the molecules given above, the central atom as well as the peripheral atoms have acquired the noble gas configuration. That means, except in hydrogen, a set of eight electrons is completed in the valence shell of atoms after the formation of the bonds. Those are known as the compounds in which the octet of electrons is complete.

Nevertheless, there are exceptions too. Let's take aluminium chloride ($AlCl_3$) as an example. In this, the electronic configuration of the aluminium atom is 2, 8, 3. The electronic configuration of a chlorine atom is 2, 8, 7. Three chlorine atoms share three pairs of electrons with an aluminium atom to form an $AlCl_3$ molecule.




In this molecule, the valence shell of the aluminium atom contains six electrons. In the case of a chlorine atom, the octet is complete.

In contrast, there are instances where the octet of electrons in the valence shell is expanded. Phosphorus penta chloride ($PCl_5$) is an example. The electronic configuration of phosphorus is 2, 8, 5. The electronic configuration of chlorine is 2, 8, 7. A phosphorus atom and five chlorine atoms share five pairs of electrons to form the $PCl_5$ molecule.Then there are10 electrons around the central phosphorus atom. In each chlorine atom, the octet is completed.

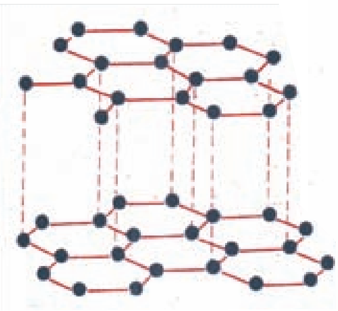



- ## Atomic Lattice

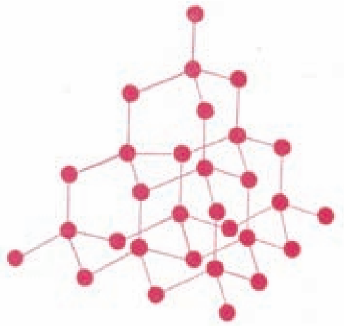
In some elements the atoms are organised as a lattice. Such lattices in which the atoms are covalently bonded are known as atomic lattices. Carbon naturally occurs as two forms of atomic lattices, graphite and diamond. They are known as the allotropic forms of carbon. These two forms differ in the way the carbon atoms form covalent bonds with one another. Generally the melting points and boiling points of covalent compounds are low. But in diamond and graphite, the melting point and boiling point are high due to their atomic lattice structure.

- Graphite

Graphite consists of layers of carbon atoms formed by the joining of one carbon atom with three other carbon atoms by single bonds. These layers are superimposed on one other. The forces holding these layers are weak. Thus one layer can easily slide over the other. Because of this structure, graphite behaves as a lubricant.



Atomic lattice of graphite



Atomic lattice of diamond

## Diamond

Diamond is a three dimensional lattice in which every carbon atom forms four single bonds with four other carbon atoms. Diamond is the hardest substance found in nature.

## 10.3 Polarity of Bonds

Electronegativity is the tendency of an atom to attract electrons of a chemical bond towards itself. It takes different values for different atoms. Then hydrogen molecule is formed by the joining of two hydrogen atoms of equal electronegativity by a covalent bond. The distribution of electrons in the bond pair of this molecule is symmetrical. Therefore, the hydrogen is a non – polar molecule. But when two atoms of different electronegativities are joined by a covalent bond, the attraction imposed by the two atoms on the bond pair is different. Let us take hydrogen fluoride molecule as an example. Since fluorine is more electronegative than hydrogen, the bond pair is more displaced towards the fluorine atom. So, the electron distribution is not symmetrical. Consequently the fluorine atom bears a small negative charge. This is known as polarization. However the molecule HF as a whole is a neutral molecule.

$$H^{\delta^+} — F^{\delta^-}$$

Fig. 10.18 - Polarization of the hydrogen fluoride molecule

When two atoms of unequal electronegativities are joined by a covalent bond, it gets polarized due to asymmetric distribution of electrons. Such bonds are called polar covalent bonds.

In case where two atoms of similar or slightly different electronegativities are joined by a covalent bond, the bonding electrons between those two atoms distribute symmetrically. Such covalent bonds are referred to as non – polar covalent bonds.

In the water molecule, there are four pairs of electrons in the valence shell of its oxygen atom. Of them two pairs are bond pairs and two pairs are lone pairs.

When an O – H bond of a water molecule is considered, the bond pair shifts more towards the more electronegative oxygen atom. Thus the molecule is polarized so that the oxygen atom bears a partial negative charge while the hydrogen atom carries a partial positive charge. Hence water is a compound with polar covalent bonds.

In three dimensional space water molecule is disposed as follows. It assumes an angular shape (Fig. 10.19).

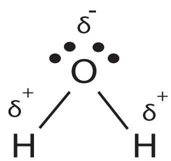


Fig. 10.19 Shape of the water molecule

## 10.4 Intermolecular Bonds

In water molecules the hydrogen atoms which bear a very small positive partial charge forms attractive forces with oxygen atoms bearing a very small negative charge of the neighbouring water molecules. This kind of attractions among the molecules are known as intermolecular forces or intermolecular bonds.

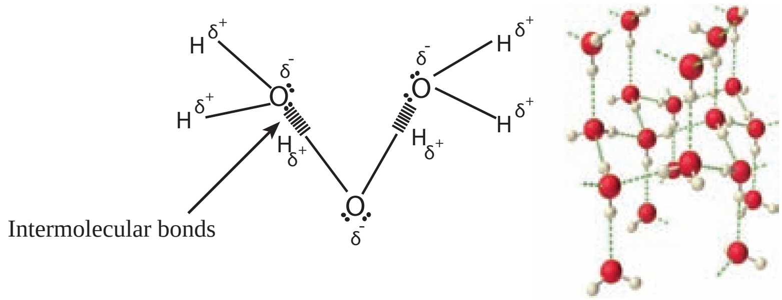



Fig. 10.20 - Intermolecular bonds in water

These intermolecular forces are not as strong as the covalent bonds between the oxygen atoms and the hydrogen atoms in a water molecule. Yet, these intermolecular forces impart many special properties to water.

Because of these intermolecular forces, water exists as a liquid at room temperature. In case that there were no intermolecular forces among the water molecules, water is a gas at room temperature.

Some special properties possessed by water due to attractive forces among the water molecule are as follows.

- High boiling point
- High specific heat capacity
- Having a higher density than that of ice

## 10.5 Properties of Ionic and Covalent Compounds

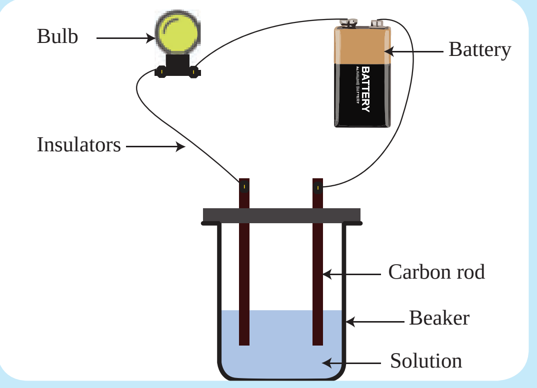
**Activity 3**

**Examining the electrical conductivity of the solutions of ionic and covalent compounds**

**Requirement:** Four beakers, two carbon rods, two bulbs, two batteries (Six dry cells), conducting wires, a salt solution (common salt), sugar solution, copper sulphate solution, distilled water

**Method:**

- Take four equal beakers and label them A, B, C, D.
- Add salt solution to A, copper sulphate solution to B, sugar solution to C and distilled water to D.
- Dip two carbon rods in each solution, complete the circuit as shown in fig. 10.21 and see whether the bulb lights. The carbon rods should be washed well before using in the other solution.




Examining the electrical conductivity of the solution of ionic and covalent compound
Fig. 10.21

The bulb lights in the circuits with common salt and copper sulphate solutions. It doesn't light in the circuits with the sugar solution and distilled water. Common salt and copper sulphate are compounds with ionic bonds. Hence, aqueous solutions of ionic compounds conduct electricity. Sugar and water are covalent compounds. Electricity does not flow through them. Experiment shows that even common salt in the fused state conducts electricity. This confirms that electricity flows through ionic compounds in aqueous solution and fused state. However electricity does not flow through ionic compound in solid state.

## Melting Points and Boiling Points of some Compounds

Table 10.5

| Compound | Melting / $^0$C | Boiling point / $^0$C | Bond type |
|---|---|---|---|
| Sodium chloride | 801 | 1413 | Ionic |
| Potassium chloride | 776 | 1500 | Ionic |
| Water | 0 | 100 | Covalent |
| Ammonia | -78 | -33 | Covalent |
| Oxygen | -218 | -183 | Covalent |
| Ethyl alcohol | -117 | 79 | Covalent |
| Calcium oxide | 2580 | 2850 | Ionic |
| Sulphur dioxide | -73 | -10 | Covalent |

From Table 10.5 it is clear that melting points and boiling points of ionic compound are relatively high. Mostly they exist as solids at room temperature. The above Table also affirms that the melting points and boiling points of covalent compounds are low. Generally they are liquids or gases at room temperature.

### Characteristics of Ionic Compounds

- Ionic compounds are composed of oppositely charged (+ and -) ions.
- Most of the compounds have a solid crystalline form at room temperature.
- They have high melting points and boiling points.
- They conduct electricity in the fused (molten) state and in aqueous solution.
- Most of the ionic compounds are soluble in water.

### Characteristics of Covalent Compounds

01. They mostly exist as molecules composed of several atoms.
02. Most of the covalent compounds are in the liquid or gaseous state at room temperature.
03. Generally the melting points and boiling points of covalent compound are low (However the lattice compounds have high melting points and boiling points).
04. The aqueous solutions of covalent compounds do not conduct electricity.
05. Some covalent compounds are soluble in water.

**For further exploration**

Collect information about the unique characteristics of water caused by the intermolecular forces.

## Summary

- Compounds are formed by bonding two or more atoms of different elements chemically.
- When forming compounds, electrons in the valence shells of atoms rearrange.
- Positive ions are formed by the loss of electrons from an atom; negative ions are formed by the gain of electrons by an atom.
- Electrostatic attractions between the oppositely charged ions are called ionic bonds.
- The bonds formed by sharing of electrons between pairs of atoms are named covalent bonds.
- Solid crystalline ionic lattice of an ionic compounds is formed by the orderly arrangement of ions in space.
- An atomic lattice is created by the orderly arrangement of atoms in space.
- According to the nature of bonding, ionic and covalent compounds show characteristic properties.
- A bond with partial positive and negative charges is called a polar covalent bonds. Water is a compound with polar covalent bonds.
- The attractive forces among the molecules are known as intermolecular forces.
- The intermolecular forces give specific characteristics to compounds.
- Water has special properties due to intermolecular attractions among the water molecules.

## Exercises

01. Define an ion.

02. Write the electronic configurations of the following ions and illustrate them by diagrams.

    (a) $Na^+$ (b) $Mg^{2+}$ (c) $O^{2-}$ (d) $N^{3-}$

03. What is meant by an ionic bond?

04. Illustrate by diagrams how the compound calcium oxide is formed.

05. Draw the dot and cross diagrams of the following molecules.

    (a) Chlorine (b) Oxygen (c) Water

    (d) Methane (e) Ammonia

06. What is meant by a covalent bond?

07. Give two properties of ionic compounds and covalent compounds.

08. Carbon is an element in Group IV. Why carbon has a high melting point and a high boiling point.

09. Explain scientifically why common salt is readily soluble in water.

10. Give reason to the existance of high boiling point, 100 $^{0}C$ to water though it is a covalent compound.

## Technical terms

| | | |
|---|---|---|
| Chemical bonds | රසායනික බන්ධන | இரசாயனப் பிணைப்பு |
| Cation | කැටායනය | கற்றயன் |
| Anion | ඇනායනය | அனயன் |
| Ionic bonds | අයනික බන්ධන | அயன் பிணைப்பு |
| Covalent bonds | සහසංයුජ බන්ධන | பங்கீட்டுவலுப்பிணைப்பு |
| Polarity | ධ්‍රැවීයතාව | முனைவுத்தன்மை |
| Inter molecular bond | අන්තර් අණුක බල | மூலக்கூற்றிடை விசை |
| Hydrogen bond | හයිඩ්‍රජන් බන්ධන | ஐதரசன் பிணைப்பு |

Physics

# Turning effect of a force

# 11

## 11.1 Moment

We have seen that by applying forces on objects, it is possible to push, pull or lift them. Similarly, it is possible to rotate objects by applying forces on them. That is, by applying a force we can rotate or turn an object around a given point. In this lesson, we will focus our attention on the ability of a force to rotate an object around a given point.

Let us do the following activity in order to investigate the factors affecting the rotation of an object.

### Activity 1

Mark four points *A*, *B*, *C*, *D* on the same horizontal level of a door attached to its frame by two hinges. Attach a Newton balance to the point *A* with the aid of a rubber sucker clamp and apply a perpendicular force on the door to open it. Measure the force necessary to slightly move the door using the Newton balance. Repeat this procedure for the other three points *B*, *C* and *D* and record your measurements in Table1 11.1 given below.

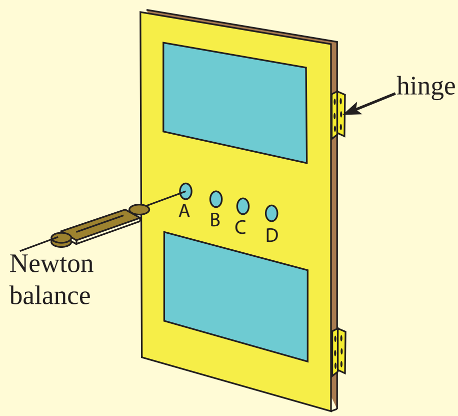



Figure 11.1 – Measuring the force necessary to open the door

Table 11.1

| Point attached to the Newton balance | Perpendicular distance from the rotation axis to the force | Newton balance reading when the door just starts to move | Value of force × perpendicular distance (N m) |
|---|---|---|---|
| *A*<br>*B*<br>*C*<br>*D* | | | |

- At which point was the force required to rotate the door a maximum?
- At which point was the force required to rotate the door a minimum?

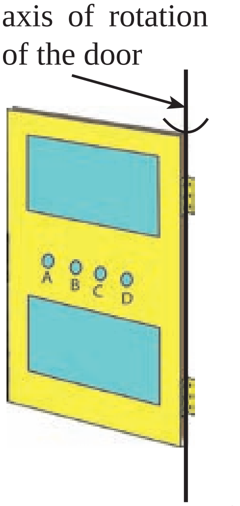


Figure 11.2 – Axis of rotation of the door

Here, the door rotates around an axis passing through the hinges as shown in Figure 11.2. This axis is known as the **axis of rotation** of the door.

It would be clear to you that the force required to rotate the door decreases when the perpendicular distance to the line of action of the force from the rotation axis is increased. It would also be clear to you from your measurements that the force required to rotate the door increases when the perpendicular distance to the line of action of the force from the rotation axis is decreased.

This means that it is easier to open the door when the applied force is further away from the rotation axis, while it is more difficult to open when the applied force is closer to the rotation axis.

It is clear from the above activity that the force required to rotate an object around an axis depends on the perpendicular distance to the force from the axis.

The product of the force and the perpendicular distance to the line of action of the force from the axis of rotation is known as the **moment of the force** around the axis.

In order to subject a body to a motion in a straight line, a force is required. In order to rotate an object around a given axis, what is required is not just a force but a moment. A moment required to rotate an object is created by applying a force at a certain distance from the rotation axis. This tendency for rotation due to the action of a force is known as the turning effect of the force.

Therefore, we can write an equation for the moment due to a force as defined below.

| | | | | |
|---|---|---|---|---|
| Moment due to a force | = | force<br>N | × | perpendicular distance from the rotational axis to the line of force of action<br>m |

The unit of moment of a force is N m.

Since the moment is a tendency for rotation, depending on whether the rotation is clockwise or anticlockwise, the moment too has to be clockwise or anticlockwise.

## • Investigation of the dependence of the moment on the magnitude of the force.

Let us carry out the following activity in order to investigate the dependence of the moment on the magnitude of the force.

### Activity 2

**Items required** : a fairly long stick of wood, two rubber washers, a screw, a drill, a Newton balance, a table or a plank of wood

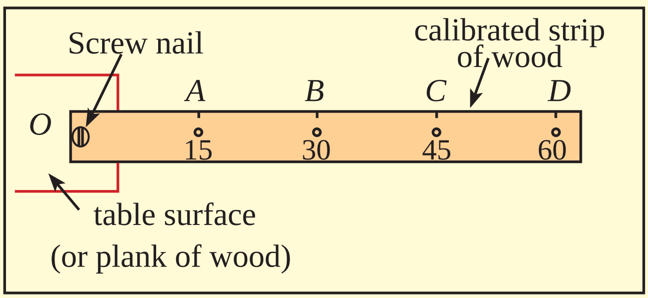



Figure 11.3 – Investigation of the dependence of the moment on the magnitude of the force

- Drill holes at the points *O*, *A*, *B*, *C* and *D* which are spaced 15 cm apart from the adjacent hole as shown in Figure 11.3.
- Next, clamp the stick to the table at the point *O* using the washers and the screw nail.

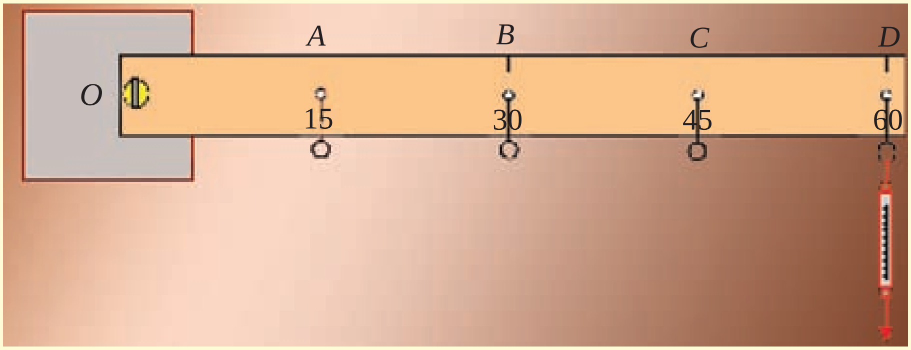



Figure 11.4 - Applying force perpendicular to the stick

- Now attach a loop formed with a piece of wire to each of the holes at *A*, *B*, *C* and *D* on the stick. Attach the Newton balance on the ring at *D* as shown in figure 11.4 and measure the minimum force necessary to barely move the stick, keeping the balance perpendicular to the stick. The axis of rotation in this case is the axis passing from the centre of the nail head down through the nail.
- Next, rotate the nail half a turn to tighten the stick a little more and measure the force required to slightly move the stick.
- Again, rotate the nail half a turn to tighten the stick further and measure the force required to slightly move the stick.
- Tabulate your measurements. What is the result that you have expected ?

Suppose you obtained the results shown in the table below. (You may obtain values different to the values given depending on your set up.)

Table 11.2

| Stage | Force |
|---|---|
| Initial set up | 2 N |
| After tightening the screw by half a turn | 5 N |
| After tightening the screw by a full turn | 9 N |

You will see that the force required to initiate the turning effect increases as the stick is tightened. Since the distance to the line of action of the force is maintained constant this confirms that the moment depends on the magnitude of the force.

## Investigation of the dependence of the moment on the perpendicular distance to the force from the point of suspension.

In order to investigate how the moment depends on the perpendicular distance to the force from the point of suspension, let us do the following activity.

### Activity 3

- As shown in Figure 11.5, insert a loop made from a piece of thread around the stick of wood used in Activity 2 near the point A and hook the balance on the loop. Rotate the screw by one turn to bring it back to its original position. Find the force required to initiate rotating the stick slightly. Suppose this force is $F_1$.

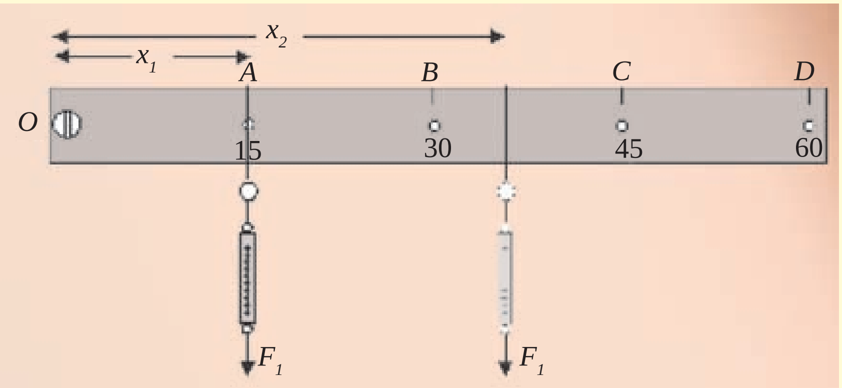



Figure 11.5 - Investigation of the dependence of the moment on the perpendicular distance

- Now rotate the screw by about ¼ th of a turn to tighten it.
- Then, move the loop together with the balance slowly towards *D*, keeping the force $F_1$ constant.
- When the stick begins to move around *O*, measure the distance $x_2$ from *O* to the balance.
- Repeat the procedure, tightening the screw by another ¼ th of a turn and sliding the loop towards *D*, keeping the force ($F_1$) constant and measure the distance $x_3$ from *O* to the balance when the stick begins to rotate around *O*.
- Tabulate your measurements.

What would you expect from your results?

Suppose you obtained the measurements shown in Table 11.3.

Table 11.3

| Stage | Force | Distance to the balance (x) |
|---|---|---|
| Initial set up | 1. 5 N | 15 cm |
| After tightening the screw by quarter of a turn | 1. 5 N | 32 cm |
| After tightening the screw by half a turn | 1. 5 N | 55 cm |

The above results show that when the force necessary to initiate the turning effect is kept constant, perpendicular distance to the Newton balance had to be increased as the strip is tightened

This confirms that the moment of force also depends on the perpendicular distance to the force from the point of suspension.

## Direction of the moment of force and equilibrium of object under the action of the moments of force.

When a force acting on an object, depending on the direction of rotation, moments can be classified as clockwise or anti - clockwise.

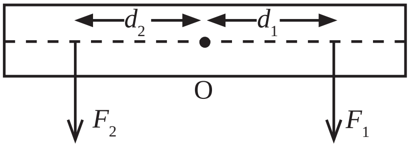


Figure 11.6 - Clockwise and anti - clockwise moments.

Consider two forces $F_1$ and $F_2$ exerted on a stick clamped at the point $O$ as shown in the figure 11.6

clockwise moment $= F_1 \times d_1$

anti - clockwise moment $= F_2 \times d_2$

When the two forces are applied in the same time,

the resultant moment $= F_1 \times d_1 - F_2 \times d_2$

Here, clockwise moment is considered as positive.

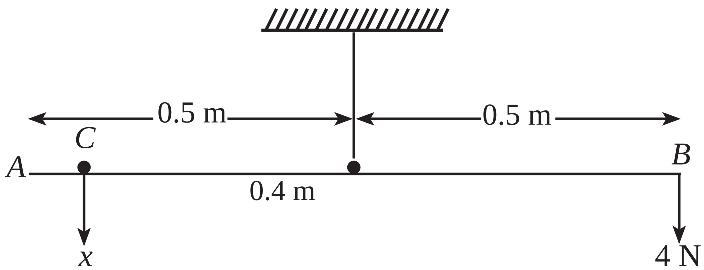
If the opposite moments are equal, (that is $F_1 \times d_1 = F_2 \times d_2$) the object will not rotate, and it will be in equilibrium.

## Example 1

As shown in the following figure a uniform rod *AB* of length 1 m is suspended and balanced at its center.

(i) If a weight of 4 N is now suspended from *B*, find the initial (clockwise) moment.

(ii) If the 4 N weight is kept at *B*, what weight suspended from a point *C* situated 0.4 m from the center would balance the rod again?




(i) Clockwise moment = 4 N × 0.5 m = 2 N m

(ii) Assume that the weight suspended from *C* is *x*.

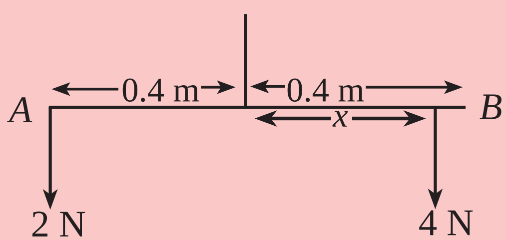
$$\therefore\ x \times 0.4 = 4 \times 0.5$$

$$x = \frac{4 \times 0.5}{0.4}$$

$$= \frac{4 \times 5}{4} = 5\text{ N}$$

### Exercise 11.1

(1) A uniform rod *AB* is 0.8 m long. It was balanced after being suspended from the centre and then a weight of 2 N held at one end. In order to bring the rod back into equilibrium, how far from the balance point on the other side of the rod should a weight of 4 N be held?



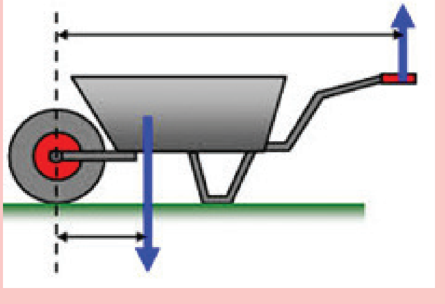
(2) Some examples of using the moment of a force in day to day life is given below.

Describe how the moment acts in each one of them.

1. The use of a spanner to detach a nut.

2. Applying a force on the pedal of a bicycle

3. The use of a wheel barrow



## 11.2 The couple of forces

To rotate an object with a single force that object must be pivoted to a fixed point. It is possible to rotate an object that is not pivoted, with the use of two forces acting in opposite directions.

Consider the case of a strip of wood being pierced at the center and fixed with a screw to a table as shown in the figure. Attach a Newton balance as shown and measure the force ($F$) when the rod begins to rotate slightly.

Next, attach two Newton balances at both ends $A$ and $B$ and measure the force required to slightly rotate the rod. If the force required with one force had been $F$, the force required when two forces are applied in opposite direction would be $F/2$. Note that the two forces act on the same plane (coplaner).

From the above activity, it would be clear to you that when applying forces to rotate or turn an object around a certain axis it is easier to rotate by applying two equal forces in opposite directions.

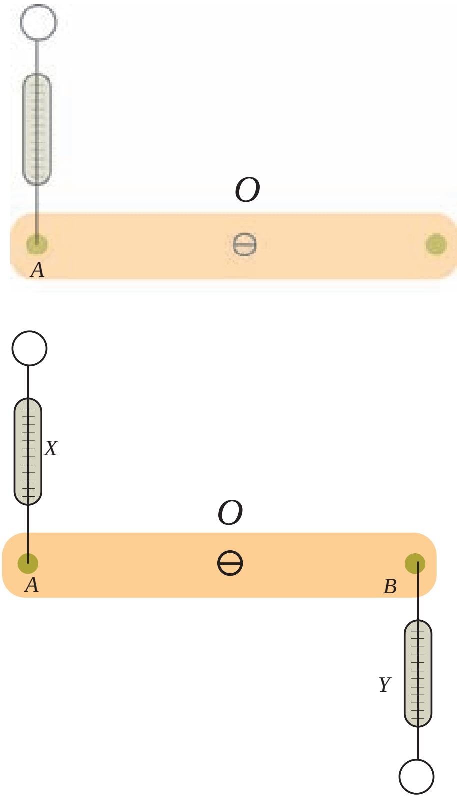



Figure 11.7 - Demonstration of couple of forces

Two coplanar forces of equal magnitudes acting in opposite directions, along two lines of action that are spaced apart are known as a couple of forces.

When a couple of forces is applied on an object, the resultant of the two forces is zero as the two forces of equal magnitude and act in opposite direction. Therefore, a couple of forces does not cause a linear displacement in an object. However, the object rotates around a point between the two forces.

The moment of a force couple is defined as the product between the magnitude of one force and the perpendicular distance between the lines of actions of the two forces.

Moment of a couple of forces = force × perpendicular distance between the lines of action of the two forces (m)
(N)

The unit of the moment of a couple of forces is N m.

Moment of a couple of forces = F x d
Where F = force
d = perpendicular distance between the lines of action of the two forces

If we want to rotate an object by a single force as done by attaching one Newton balance to the point *A* and pulling the object as in the example above, then the object has to be pivoted at a certain point. (What happens here is the formation of a force couple due to the action force we apply and the reaction force generated at the pivot according to Newton's third law.) However, it is possible to rotate even a free object by applying a force couple as done in the example of applying two forces at points *A* and *B* with two Newton balances

## Applications of couple of forces

When opening or closing a tap, a couple of forces acts on the tap head.

Figure 11.8 - tap

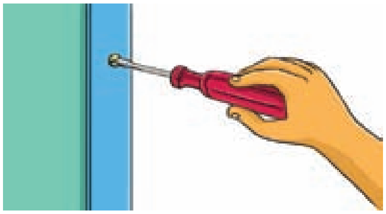


Figure 11.9 – Unscrewing a nail with a screw driver

When unscrewing or tightening nails with a screw driver as shown in Figure 11.9 we apply a couple of forces on the handle of the screw driver.

A steering wheel can be rotated more easily by applying a couple of forces with both hands instead of trying to turn it with only one hand.

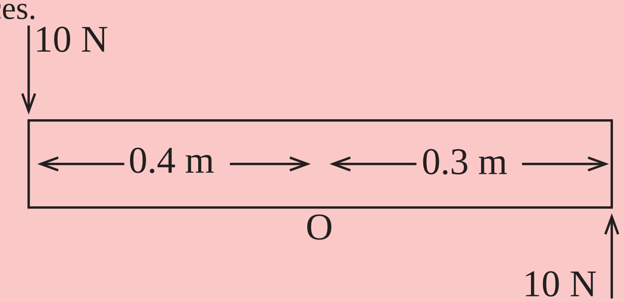
Figure 11.10 - rotating the steering wheel

## Exercise 11.2

(1) Give two examples where force couples are acting.

**for further knowledge**

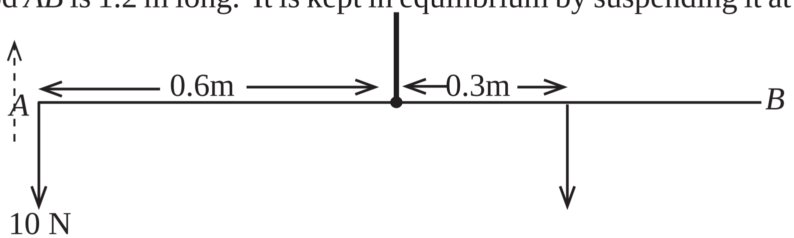
A thin plank of timber which is pivoted at O is shown in the figure. If two forces are applied as shown in the figure, let us find the moment of the cou ple of forces.




moment of the couple of force $= 10N \times 0.7m$
$= 7Nm$

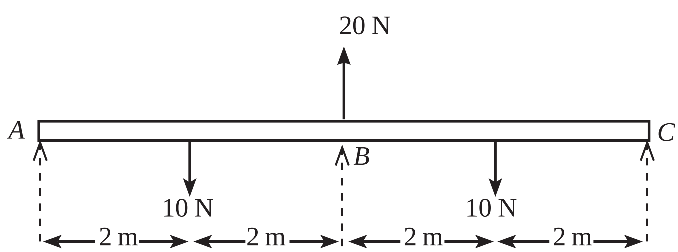
## Miscellaneous exercises

(1) The rod *AB* is 1.2 m long. It is kept in equilibrium by suspending it at the center.




Now, if a weight of 10 N is held at the end A, what force held at a point 0.3 m away from the center of the rod would bring it back to equilibrium?

(2) Determine the sum of moments of the three forces about,
(a) point *A*, (b) point *B*, (c) point *C*



## Summary

- What is meant by the moment of a force is the tendency of an object to rotate as a result of a force acting on it.
- The moment of a force is given by the product between the force and the perpendicular distance to the line of action of the force from a selected axis.

  That is,

  $$\boxed{\text{Moment due to a force} = \text{force} \times \text{perpendicular distance to the line of action of the force from a selected axis.}}$$

- A couple of forces is a pair of two equal forces that are parallel to one another and acting in opposite directions on an object so as to turn or rotate it.
- A couple of forces can rotate an object without causing a linear motion in the object.

## Technical terms

| | | |
|---|---|---|
| Moment of force | බලයෙහි ඝූර්ණය | உந்தம் |
| Turning effect of a force | බලයේ භ්‍රමණ ආවරණය | விசையின் திரும்பல் விளைவு |
| Couple of forces | බල යුග්මය | விசையிணை |

Physics

12

# Equilibrium of Forces

## 12.1 Introduction to equilibrium of forces

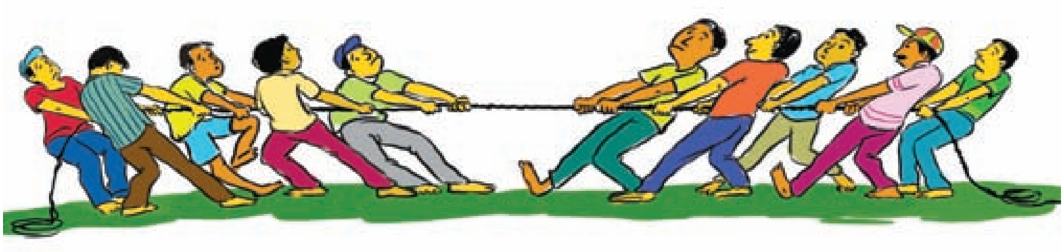


Figure 12.1 – Two groups pulling a rope

In a competition of pulling a rope, two groups pull the rope in two opposite directions. When the force exerted in one direction becomes greater than the force exerted in the other direction, the rope moves in the direction of the larger force. When both groups pull with equal forces, the rope will remain at rest without moving in either direction. The sum of the two forces becomes zero. In this situation the rope is said to be in equilibrium under the action of the forces in the two directions.

Another such instance is shown in Figure 12.2. It shows an object suspended by a spring balance.

Here there are two forces acting on the object. One force is the weight of the object which arises due to the gravitational force. The other is the upward force exerted by the spring of the balance in order to keep the object from falling onto the ground. Under the action of these two forces, the object remains at rest. That is, the object is in equilibrium under the two forces.

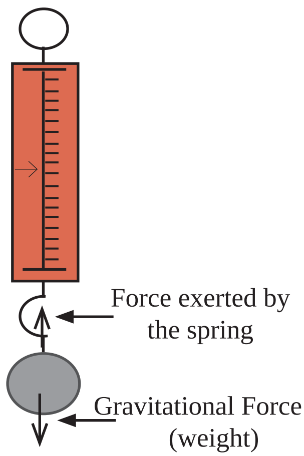



Figure 12.2 - An object suspended by a spring balance

A sphere suspended by a string is shown in Figure 12.3. The weight of the sphere is acting vertically downwards. The sphere remains at rest as the vertically upward force applied by the string, balances the force due to its weight (The force applied by the string is called its tension). In this instance, the sphere remains in equilibrium under the downward force due the weight (W) and the upward force (T) exerted by the string.

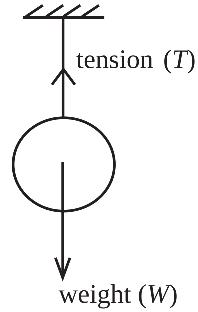


Figure 12.3 – A sphere suspended by a string

In daily life, we come across situations where various forces act on objects quite frequently. Objects can remain in equilibrium under two, three or even many forces.

Here we will consider instances where objects remain in equilibrium under two or three forces.

## 12.2 Equilibrium of a body under two forces

We learnt about the effective force or the resultant force of two collinear forces (forces acting along the same line) acting on a point, in the lesson on resultant force.

In that lesson, you have learnt that, while a certain force is acting on an object, if it is pulled by another force in the opposite direction, the magnitude of the resultant force decreases. When an object is said to be in equilibrium, what is meant is that the resultant force of the two forces acting on the object is zero.

Now let us investigate the factors required to keep an object in equilibrium under two forces acting in opposite directions along the same line.

Let us do activities 1 and 2 for this purpose.

### Activity 1

**Items required** : a ring, two spring balances

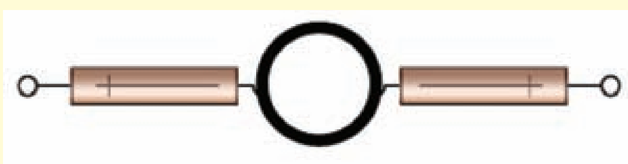


Figure 12.4 - Examine the equilibrium of an object under two forces

- Place the ring horizontally on a table and pull it with the two balances in opposite directions as shown in Figure 12.4. By varying the extent of the pull, apply forces of varying magnitudes on the object. In each attempt, the ring must be kept at rest.

- The ring stays at rest only when it is in equilibrium under the action of the two forces in opposite directions. Every time the ring is in equilibrium, you will observe that the readings of the two spring balances are equal.

That is, at equilibrium, the two forces are equal in magnitudes.

Now try to maintain equilibrium without having the two forces along the same line. You will find that this is impossible. That is, every time the two forces are in equilibrium, they must be aligned along the same line and their directions must be opposite to one another.

## Activity 2

**Items required** : a cubic shaped block of wood, two Newton balances, two rings to fix the balances to the wooden block

- Fix the two rings to the centers of two opposite faces of the block of wood as shown in Figure 12.5.
- Now attach the two Newton balances to the two rings and pull the block of wood along the two directions applying forces of various magnitudes.

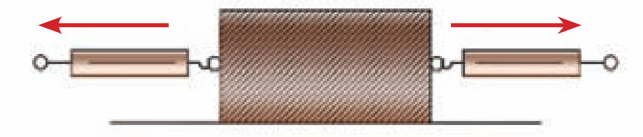


Figure 12.5 – Pulling a block of wood in two directions

You will observe that the block of wood moves in one direction whenever there is a nonzero resultant force and that it remains stationary whenever the resultant force is zero. That is, every time the block of wood is in equilibrium, the two forces acting on it in opposite directions have equal magnitudes.

An object placed on a table is shown in Figure 12.6. Why doesn't the object fall down?

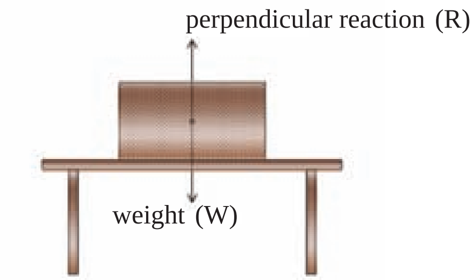



Figure 12.6 – A book in equilibrium on a table

In this case, the weight of the object, acting vertically downwards, is balanced by the perpendicular reaction force exerted vertically upwards by the table. That is, the object is in equilibrium under the action of the two forces mentioned above and the object remains at rest.

If an object suspended by a string as shown in Figure 12.7 remains in equilibrium, the reason is that a force equal to the weight of the object is acting vertically upwards along the string. The force exerted upwards by the string is known as the tention of the string. As the object is held in equilibrium by two forces - its weight and the tension of the string - the object remains at rest.

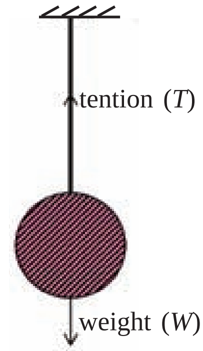



Figure 12.7 - An object suspended by a string

In each of the instances described above, only two forces were acting on the object. In addition, the two forces were equal in magnitude and opposite in direction. Also, their lines of action were the same. That is, for an object to remain in equilibrium, the following conditions must be satisfied.

1. The two forces must have equal magnitudes.
2. The two forces must act along two opposite directions.
3. Both forces must lie along the same line of action.

## 12.3 Equilibrium of a body under three coplanar parallel forces

Figure 12.8 – Bunch of banana suspended on a horizontal rod

A bunch of banana suspended on a light horizontal rod is shown in Figure 12.8. Here, the rod, the two strings used to suspend it and the string used to suspend the bunch of banana are all in the same plane. Also, all three strings are parallel. This is an example of a system in equilibrium under the action of three parallel, coplanar forces. (There are four forces acting in the system if the weight of the rod is considered. However, by a "light rod" we mean a rod whose weight is negligibly small. Therefore, we do not consider that force here.)

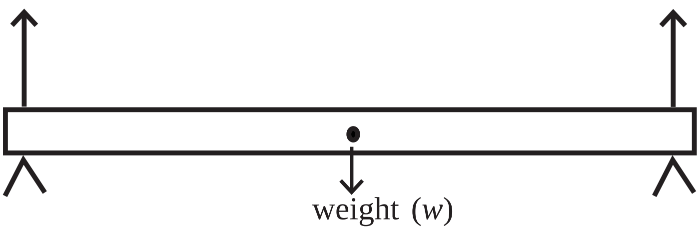



Figure 12.9 - A rod resting on two supports

A rod resting on two supports is shown in Figure 12.9. In this system of forces, the three forces, the weight of the rod and the two perpendicular reaction forces exerted on the rod are coplanar and their lines of action are parallel to one another. Under these forces, the rod is in equilibrium on the two supports.

Now, let us engage in the following activity in order to investigate the factors that affect the equilibrium of three parallel and coplanar forces.

## Activity 3

**Items required** : two spring balances, a meter ruler, two rubber bands.

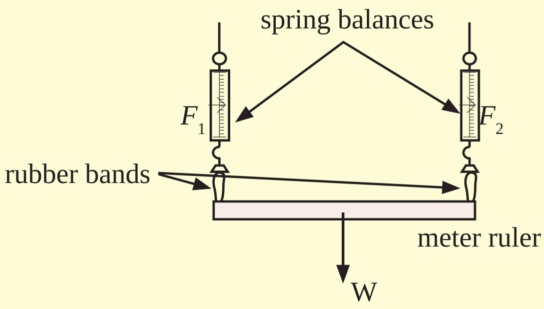



Figure 12.10 - Equilibrium of a meter ruler under three coplanar parallel forces

- Measure the weight of the meter ruler. Next, suspend it at the two ends with the aid of the rubber bands and balances as shown in Figure 12.10 and keep the meter ruler in equilibrium in a horizontal position. Take measurements of the two spring balances. The system is now in equilibrium under the action of three parallel, coplanar forces.
- Investigate the relationship between the measurements of the two spring balances and the weight of the meter ruler. You will notice that the sum of the two readings of the balances is equal to the weight of the meter ruler.
- That is, the sum of the two forces exerted on the meter ruler by the two balances is equal to the weight of the meter ruler.
- See whether it is possible to push the meter ruler in a horizontal plane with a force applied normal to the meter ruler at one end of the ruler and still maintain equilibrium.
- You will understand that every time the meter ruler is in equilibrium, the two balances and the meter ruler are in the same plane.

That is, in order for an object to maintain equilibrium under the action of three parallel forces, the following conditions must be satisfied.

(i) The three forces must be coplanar.
(ii) One force must have a direction opposite to the other two forces.
(iii) The resultant of any two forces must be equal in magnitude and opposite in direction to the third force.

A child sitting on a swing is an example for a system in equilibrium under three parallel forces. The child can remain in equilibrium on the swing, since the sum of the two forces $F_1$ and $F_2$ exerted by the two ropes is equal to the weight of the child as shown in Figure 12.11.

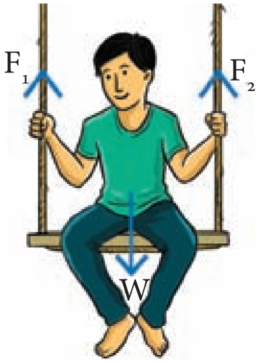



Figure 12.11 - A child sitting on a swing

## 12.4 Equilibrium of a body under three forces that are not parallel

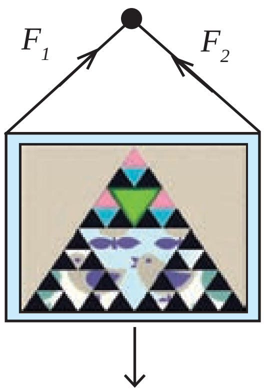



Figure 12.12 - A framed picture hanging on the wall

A framed picture like the one shown in Figure 12.12 remains at rest because the tensions of the two strings ($F_1$ and $F_2$) and the weight of the picture ($W$) are in equilibrium. Although these three forces are coplanar, they are not parallel to one another as in the examples described earlier.

Let us now engage in the following activity to find out the factors necessary to maintain equilibrium in a system of three forces that are coplanar, but not parallel to one another.

## Activity 4

**Items required** : a thin rectangular laminar, a string

You may use a thin sheet of metal or a piece of cardboard as the laminar. Hang your laminar from three points, one at a time as shown in Figure 12.13 and mark the verticle line that goes along the string, on the laminar each time.

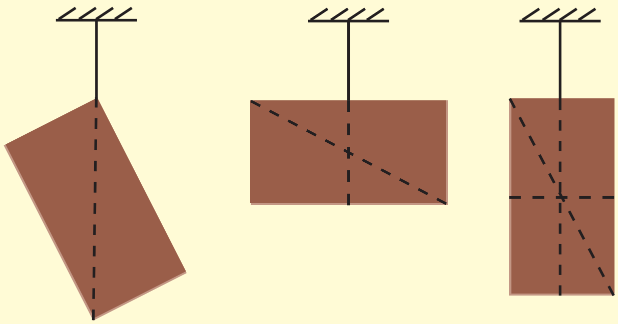


Figure 12.13 - Finding the centre of gravity of the laminar

- The point of intersection of the three lines can be considered as the center of gravity of the laminar.

  Center of gravity is the point at which the whole weight of a body may be considered to act. Therefore, the weight of the laminar acts along the verticle line that goes through its centre of gravity.

- Hang the laminar using two strings connected to it, as the framed picture shown in Figure 12.12 and keep it in equilibrium in a vertical plane.

- Mark the lines of each string on a sheet kept behind the laminar. Mark also, the vertical line passing through the center of gravity.

  All three lines marked above will lie on the same plane and they will pass through a common point.

- Now, keeping the position of one of the three forces fixed, turn the laminar to change the plane of the other forces. You will observe that, the system remains equilibrium only after readjusting the lines of action of the forces so as to have all three forces lying on the same plane.

That is, in order for a system of three non parallel forces to be in equilibrium, the three forces must be coplanar. Also, the lines of action of the three forces must meet at a common point. Furthermore, the resultant of any two of the forces should be equal to the third force in magnitude, and opposite in direction.

So far we have only discussed systems that are in equilibrium under the action of two or three forces. Equilibrium can exist under the action of more than three forces. Figure 12.14 shows a system in equilibrium under five forces.

It shows a plank of wood suspended by four strings attached to the four corners. The plank of wood maintains equilibrium since its weight acting vertically downwards is balanced by the forces of tension exerted by the four strings.

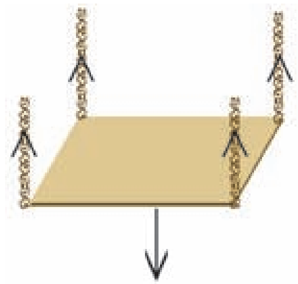


Figure 12.14 - A system in equilibrium under five forces

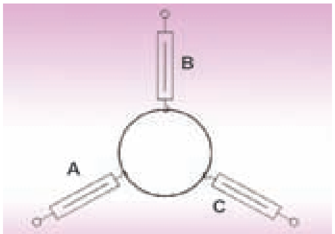
## Miscellaneous exercises

(1) (i) An object on a horizontal plane is pulled along a certain direction with a force of 20 N. In order to bring the object to rest, what is the force that should be applied on it in the direction opposite to the 20 N force?

(ii) What would happen if a force of 25 N is applied on the above object in the opposite direction?

(2) If several people are trying to push a car whose engine is not functioning, in what manner should each one try to exert a force on the car?

(3) If the resultant force of the two forces applied by the spring balances *B* and *C* as shown in the figure below is known, what should be done in order to bring the ring to rest?



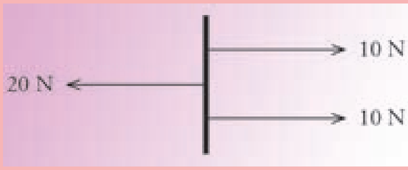

(4) A box is placed on a table. Although the gravitational attraction force is acting downwards on the box, why does it remain at rest without falling down?

(5) What can you say about the nature of the motion of an object on a horizontal table that is pulled in opposite directions with two unequal forces?

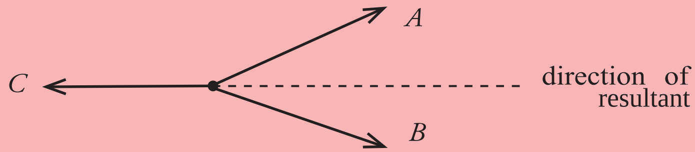
## Summary

- If the magnitudes of two collinear forces applied on an object are equal and they have opposite directions, then the object is in equilibrium.
- An object under three parallel forces is in equilibrium if one force is equal in magnitude to the resultant of the other two forces and it is in the opposite direction.

  eg;




- If an object stays in equilibrium under three forces that are not parallel to one another, when the resultant of any two of the forces is equal in magnitude and opposite in direction to the other force.




When the resultant of the two forces *A* and *B* is applied in the dirction of the force *C*, the three forces will be in equilibrium.

- Even under the action of more than three forces, a system can remain in equilibrium by applying forces appropriately.

## Technical terms

| | | |
|---|---|---|
| Force | බලය | விசை |
| Equilibrium of forces | බල සමතුලිතතාව | விசைகளின் சமநிலை |
| Equilibrium of co-planer forces | ඒකතල බල සමතුලිතතාව | ஒரு தள விசைகளின் சமநிலை |
| Equilibrium of two forces | බල දෙකක සමතුලිතතාව | இரு விசைகளின் சமநிலை |
| Equilibrium of three forces | බල තුනක සමතුලිතතාව | மூன்று விசைகளின் சமநிலை |
| Equilibrium of three parallel forces | සමාන්තර බල තුනක සමතුලිතතාව | மூன்று சமாந்தர விசைகளின் சமநிலை |