3 Metals and Non-Metals

You have studied in the previous class that materials, made up of same kind of particles, are known as **pure substances**. A sample, of a given element, or a given compound, is a 'pure substance'. This is because a given element (/compound) is made up of atoms (/molecules) of the same kind. Different elements/compounds differ from each other in their physical and chemical properties as they are made up of atoms/molecules of different kind.

▶ Classification of Elements

There are about 118 elements known at present. It is difficult to study and describe all the properties of all these elements separately. Hence, elements, showing similar properties, are grouped together and their general characteristics are studied. Such 'grouping' of elements is called **classification of elements**.

The elements have been broadly classified into two categories: **metals** and **non-metals**; this classification is based on the differences in their physical and chemical properties.

Occurrence of Elements

Metals exist in abundance in the earth's crust. Aluminium is the most abundant metal; it is followed by iron. Highly reactive metals, like sodium, potassium, aluminium and zinc, are found in nature in the form of their compounds (like oxides, sulphides and carbonates). Less reactive metals, like gold, silver and platinum, occur in nature in their elemental, or native state.

Many **non-metals** are found in their free state in the atmosphere. Oxygen and nitrogen are two well-known examples of such non-metals. Several non-metals exist in nature in the form of their compounds (like oxides and nitrates). Sulphur exists in the free state as well as in the combined state (as sulphides and sulphates). Carbon exists in its native state as diamond, graphite and fullerene; it also exists in the form of its compounds like carbon dioxide, carbonates and bicarbonates.

Minerals and Ores

A **mineral** is a naturally occuring inorganic substance found deep under the surface of the earth. An **ore** is a mineral from which one or more metals can be extracted profitably. For example, aluminium is extracted from its bauxite ore and iron from its haematite ore. The sequence of processes, used to extract a metal, in its pure form from its ore, is called **metallurgy**. The extraction of a metal, from its ore, generally involves the following steps:

- **Concentration of ore:** It is the process of removal of impurities from the ore.
- **Reduction:** It is the process of 'treating the metal ore' to get the metal in its free state.
- **Refining of metal:** The metal, obtained by reduction, is generally impure. **Refining** is the process of purification of this impure metal.

Let us now study and compare the physical and chemical properties of metals and non-metals.

Physical Properties

1. **Physical state:** All metals (except mercury, which is a liquid) are solid at room temperature. Iron, copper, aluminium, gold and silver are some of the examples of metals.

Non-metals (at room temperature) may exist in solid, liquid or gaseous state. Carbon, sulphur, phosphorus and iodine are a few examples of non-metals which exist in the solid state. Bromine exists as a liquid while chlorine, oxygen and nitrogen are examples of non-metals which exist in the gaseous state.

2. **Melting point and boiling point:** Metals generally have high melting as well as high boiling points. For example, melting point of iron is 1536°C and its boiling point is 3000°C. Some metals, however, have an exceptionally low melting point. For example, the melting point of caesium metal is only 28.7°C.

   Non-metals generally have low melting as well as low boiling points. For example, the melting point of sulphur is 119°C. However, there are exceptions in non-metals also. The melting point of diamond (form of carbon) is very high, i.e. 3723°C.

3. **Density:** Metals generally have a high density. Non-metals generally have a low density. However, there are some exceptions. Sodium and potassium, which are metals, have quite a low density; their density value is less than that of water.

4. **Hardness:** Most metals are very hard. They can withstand quite high pressures without getting distorted. Non-metals are generally not hard; they are brittle and easily break into pieces when hammered.

   Again there are some exceptions. Sodium and potassium are metals but they are so soft that they can be easily cut with a knife or a razor blade. On the other hand, diamond (a non-metal), which is a form of carbon, is the hardest substance known.

Activity 1

Take some crystals of iodine and beat them with a duster. What do you observe? The crystals easily break into small pieces.

5. **Lustre:** Metals have a shining surface. This is known as **metallic lustre**. Non-metals generally have a dull appearance, that is, they are non-lustrous. Iodine is the only non-metal which has a natural lustre.

Do You Know?

On exposure to air for sometime, metals lose their shine. This is because metals react with various gases present in air and get coated with a thin layer of their oxide, carbonate or sulphide.

6. **Malleability:** Metals are malleable, that is, they can be hammered into thin sheets without breaking.

   Non-metals are non-malleable, that is, they cannot be hammered into sheets. They are brittle, and break into pieces on being hammered.

Activity 2

Take a small piece of zinc metal (zinc granule) and strike it gently with a hammer. What do you observe? The zinc piece spreads a little and becomes thinner, but does not break.

7. **Ductility:** Metals can be drawn into thin wires. This property of metals is known as **ductility**. Copper, aluminium and iron wires are commonly used for electrical fittings, making net doors and wire meshes, and so on.

   Non-metals are non-ductile, that is, they cannot be drawn into wires.

Do You Know?

- Gold and silver are highly malleable. Gold can be converted into a foil which is only 2.0×10^{-5} mm thick.
- Gold is the most ductile metal. A two kilometre long wire can be drawn from only one gram of gold.

8. **Tensile strength:** It is the property due to which a substance can bear a lot of strain without breaking. Metals have high tensile strength due to their ductility and malleability. Non-metals generally do not have high tensile strength (except carbon-fibre).

9. **Conductivity:** The ability of a material, to transfer heat energy, or electrical current, from one point to another, is taken as an indicator of its **conductivity**. We generally speak of two types of conductivities: **thermal conductivity** and **electrical conductivity**.

(a) **Thermal Conductivity:** The thermal conductivity, of a material, is a measure of the ease with which heat energy can flow through it.

Activity 3

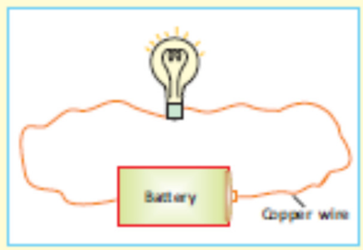
Take some hot water in a beaker and place one end of an iron rod in it. Touch the other end of the rod after sometime. What do you observe? It also becomes hot.

This activity shows that metals can easily conduct heat energy from one point to another. Thus, metals are good thermal conductors. It is due to this property that metals like copper and iron are used for making cooking utensils and water boilers.

(b) **Electrical Conductivity:** The electrical conductivity, of a material, is a measure of the ease with which electric current can flow through it.

Activity 4

Connect two terminals of a battery with the two terminals of a small bulb, using copper wires as shown in the figure. What do you observe? The bulb starts glowing. This shows that copper wires readily conduct electric current from the battery to the bulb.



This activity shows that metals are good conductors of electricity. It is due to this property that metal wires (generally copper wires) are used in electrical fittings.

Non-metals are generally poor conductors of heat and electricity. Most of them are non-conductors or **'insulators'**. However, graphite, which is a form of carbon, is a good conductor of electricity; it is used in batteries.

Do You Know?

Silver is the best conductor of heat and electricity, followed by copper and aluminium. Among metals, mercury is the poorest conductor.

10. **Sonorosity:** When a piece of metal is struck with something hard, a ringing sound is produced. This property of metals is known as **sonorosity**; metals are, therefore, said to be **sonorous**. It is due to this property that metals are used for making bells. Non-metals are non-sonorous.

It is on the basis of these differences in their physical properties that one can distinguish metals from non-metals. These differences in their properties have been summarised in Table 1.

Table 1: Physical Properties of Metals and Non-Metals

Property	Metals	Non-metals
1. Physical state	They are all solids, except mercury (which is a liquid).	They may be solid, liquid or gaseous.
2. Melting and boiling point	They generally have high melting as well as high boiling points.	They generally have low melting as well as low boiling points.
3. Density	They (generally) have a high density.	They (generally) have a low density.
4. Hardness	They are quite hard (with exceptions of sodium and potassium).	They are not hard (except diamond).
5. Lustre	They possess a natural shine.	They generally have a dull appearance.
6. Malleability and ductility	They are malleable and ductile.	They are not malleable and ductile; they are brittle.
7. Tensile strength	They have high tensile strength.	They do not have tensile strength (except carbon fibre).
8. Thermal and electrical conductivity	They are good thermal as well as good electrical conductors.	They are non-conductors or insulators (except graphite).
9. Sonorosity	They are sonorous.	They are not sonorous.

There are some elements which show some properties of metals as well as non-metals. Such elements are called **metalloids**. Silicon (Si), germanium (Ge), arsenic (As) are the well-known examples of metalloids.

Chemical Properties

Metals and non-metals differ from each other in their chemical properties also. Let us compare the chemical properties of metals with those of non-metals.

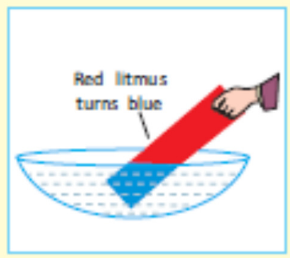
1. Reaction with Oxygen

Activity 5

Hold a magnesium ribbon with a pair of tongs and ignite it. Magnesium ribbon burns with a bright white light and forms a white powder. The white powder formed is magnesium oxide.

$$2Mg(s) + O_2(g) \rightarrow 2MgO(s)$$

Magnesium + Oxygen (from air) → Magnesium oxide (white powder)



Collect this white powder and dissolve it in water. Dip a strip of red litmus paper in this solution. The red litmus turns blue, indicating that the solution is alkaline. This happens because magensium oxide dissolves in water to form magnesium hydroxide (which is an alkali and (hence) turns red litmus blue).

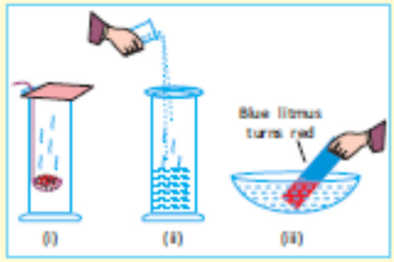
$$MgO(s) + H_2O(l) \rightarrow Mg(OH)_2(aq)$$

Magnesium oxide + Water → Magnesium hydroxide

This activity shows that metals react with oxygen to form metallic oxides which are **basic** in nature. Potassium (K), sodium (Na) and calcium (Ca) are highly reactive metals. They react with the oxygen present in the air, even at room temperature, to form their respective oxides.

Activity 6

Take a small piece of charcoal (a form of carbon) in a deflagrating spoon and ignite it. Put the spoon in a gas jar and cover it with a lid. Remove the spoon from the jar after sometime. Add some water in the jar and cover it again. Mix the contents in the gas jar by shaking it well. Pour the solution in a watch glass and put a strip of blue litmus paper in it. The blue litmus turns red indicating that the solution is acidic. This happens because charcoal (carbon) burns, in presence of oxygen, to form carbon dioxide gas which dissolves in water to form an acid (carbonic acid).



$$\underset{\text{Charcoal}}{C(s)} + \underset{\text{(from air)}}{O_2(g)} \rightarrow \underset{\text{Carbon dioxide}}{CO_2(g)}$$

$$CO_2(g) + H_2O(l) \rightarrow \underset{\text{Carbonic acid}}{H_2CO_3(aq)}$$

The acid, thus, formed turns blue litmus red.

This activity shows that non-metals can react with oxygen to form non-metallic oxides which are **acidic** in nature.

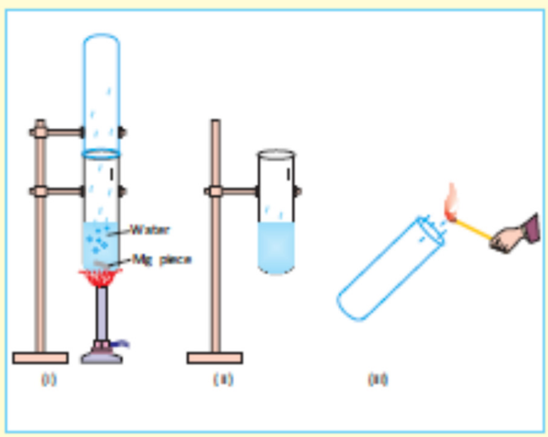
Do You Know?

Aluminium cookers are anodised from inside so that in the pressure of air and water, a protective layer of Al_2O_3 gets formed there. This layer then prevents further oxidation of aluminium.

2. Reaction with Water

Activity 7

Take a piece of magnesium ribbon. Clean its surface by rubbing it with a sand paper to remove the layer of its oxide. Put it in a boiling tube; half fill the tube with water. Invert another boiling tube over the mouth of the first boiling tube and gently warm the lower tube over the flame of a bunsen burner (as shown in the figure).



You will observe the evolution of a gas in the form of bubbles.

Remove the burner. Carefully bring a burning splinter near the mouth of the upper (inverted) boiling tube. It burns with a crackling sound. This happens because magnesium reacts with water on heating and liberates hydrogen gas which burns with a popping sound.

$$\underset{\text{Magnesium}}{Mg(s)} + \underset{\text{Water}}{2H_2O(l)} \xrightarrow{\text{Heat}} \underset{\text{Magnesium hydroxide}}{Mg(OH)_2(aq)} + \underset{\text{Hydrogen}}{H_2(g)}$$

This activity shows that some metals can react with water to liberate hydrogen gas.

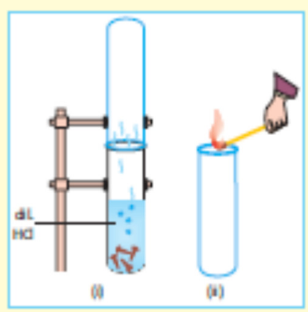
Metals differ in their reactivity towards water. For example, sodium and potassium metals reacts very vigorously with water; this reaction gives out so much heat that the hydrogen evolved catches fire. Therefore, these metals are stored under kerosene, or paraffin wax. Magnesium does not react with cold water but reacts on heating. Zinc reacts with boiling water and iron reacts with steam, indicating that it is very much less reactive. Metals like copper, silver, gold, platinum and mercury do not react with water at all.

Non-metals do not react with water. Therefore, some reactive non-metals are stored in water to prevent their reaction with air. For example, phosphorus is kept in water to prevent its contact with air; it catches fire on reaction with air.

3. Reaction with Acids

Activity 8

Take some iron nails and clean their surface by rubbing them with sand paper. Put them in a test tube and then add some dilute hydrochloric acid to the tube. Invert another test tube over the mouth of the first test tube. You will observe the evolution of a gas in the form of bubbles.



Carefully bring a burning splinter near the mouth of the inverted test tube. It burns with a popping sound which shows the evolution of hydrogen.

Repeat the activity by taking magnesium ribbon and zinc granules; allow them to react with other acids like dilute sulphuric acid.

Compare the observations.

Hydrogen gas is released as per the following reactions:

$Fe(s)$	+	$2HCl(aq)$	$\longrightarrow$	$FeCl_2(aq)$	+	$H_2(g)$
Iron		Hydrochloric acid		Iron chloride		Hydrogen
$Zn(s)$	+	$H_2SO_4(aq)$	$\longrightarrow$	$ZnSO_4(aq)$	+	$H_2(g)$
Zinc		Sulphuric acid		Zinc sulphate		Hydrogen

This activity shows that most metals react with dilute acids to liberate hydrogen gas and form metal salts.

Some metals, like copper and lead, do not react with dilute hydrochloric acid. They react with sulphuric acid and nitric acid but they do not liberate hydrogen gas. Metals, like gold and platinum, do not react with dilute acids.

Non-metals generally do not react with acids. Some non-metals, like sulphur and phosphorus, react with hot concentrated sulphuric acid, or nitric acid, but they do not liberate hydrogen gas.

Do You Know?

Certain food stuffs like citrus fruits, curd, pickles, tamarind, etc., contain acid. They should not be stored in utensils made of iron, copper or aluminium as the acid present in the food stuff reacts with the metal and forms compounds which may be toxic.

4. Reaction with Alkalies

Most metals do not react with alkalis. Aluminium and zinc can, however, react with sodium hydroxide, or potassium hydroxide, to form their salts and liberate hydrogen gas.

Reactivity of Metals

The tendency of an element to react with other substances to form compounds is an indicator of its **reactivity**. The more is the tendency of an element to form compounds, the more is its reactivity.

All metals do not have the same reactivity. Some are more reactive than the others, that is, they have a greater tendency to form compounds. Such metals occur in the form of their compounds in earth's crust. Lesser reactive metals occur in their native state, that is, elemental state. On the basis of experiments, involving the reaction of different metals with a particular substance, metals have been arranged in the decreasing order of their reactivity. The series of metals, arranged in the order of their decreasing reactivity, is called the **reactivity series**. Table 2 (given below) shows the reactivity series.

Table 2: Reactivity Series of Metals

Symbol of the element	Name of the element	Symbol of the element	Name of the element
K	Potassium	Sn	Tin
Na	Sodium	Pb	Lead
Ca	Calcium	Cu	Copper
Mg	Magnesium	Hg	Mercury
Al	Aluminium	Ag	Silver
Zn	Zinc	Au	Gold
Fe	Iron	Pt	Platinum

Potassium is the most reactive metal while platinum is the least reactive.

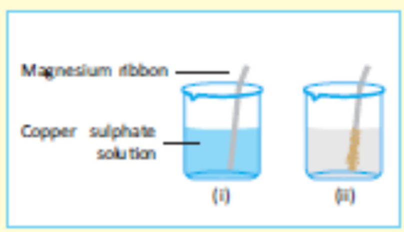
Displacement Reactions

You have already learnt about displacement reactions. Reaction of a metal, with an acid, is an example of a displacement reaction in which the metal displaces hydrogen from the acid. A reaction, in which a more reactive metal displaces a lesser reactive metal from the aqueous solution of its salt, is another example of a displacement reaction.

Let us perform an activity to understand this better.

Activity 9

Take 50 ml of water in a beaker and dissolve a few crystals of copper sulphate in it. A blue coloured solution is obtained. Dip a magnesium ribbon in this solution. You will observe that the blue colour of the solution fades and after sometime, the solution becomes colourless. Also, the magnesium ribbon gets coated with a brown layer.



This happens because magnesium, being more reactive than copper, displaces it from copper sulphate. The magnesium sulphate formed is colourless and the copper metal, that gets deposited on the magnesium ribbon, appears as a brown coating. This displacement reaction can be represented by the following equation:

$Mg(s)$	+	$CuSO_4(aq)$	$\longrightarrow$	$MgSO_4(aq)$	+	$Cu(s)$
Magnesium		Copper sulphate (blue)		Magnesium sulphate (colourless)		Copper

Repeat the activity by taking a solution of silver nitrate and dipping a copper wire in it. Report your observation to the teacher and write the equation for the chemical reaction involved.

Noble Metals

As seen from the reactivity series, platinum is the least reactive metal. It does not react with air, water, acids, bases and most other substances. Another metal, which shows a similar behaviour, is gold. Gold and platinum are called **noble metals**.

Since noble metals are least reactive, they are not chemically affected by the substances around them. Hence, they do not get tarnished, and retain their lustre for a very long time.

Both, these noble metals are also highly ductile and malleable; they can be drawn into extremely thin wires and can be beaten into very thin foils. It is because of these properties that gold and platinum are used for making jewellery. Gold can also be used for plating other metals, like copper and silver. Platinum is used in dentistry and in making scientific instruments.

Pure gold is very soft. Therefore, it cannot be used for making jewellery in its pure form. Hence, for making jewellery, it is often mixed with silver or copper to make it appropriately hard.

The purity of gold is expressed in terms of **carats** (or **karats**). The **carat** number gives the number of parts of gold present in 24 parts of a mixture of gold with the other metals. For example, 22 carat gold means that 22 parts of pure gold is present in 24 parts of a mixture of gold with copper (or silver). This implies that pure gold would be rated as: '24 carat gold'.

Gold jewellery

Uses of Metals, Alloys and Non-Metals

Uses of Common Metals

Metals have been an integral part of our daily life since ancient times. They have played an important part in the development of different civilisations. Even today, metals are used for a variety of purposes in our day-to-day life. The most commonly used metals, in every day life, are iron, copper, aluminium and silver.


Iron

Iron is the most widely used metal. It is used for making cooking vessels, water boilers, stoves, toys, tools, pipes, agricultural implements, chains, wires, nails, bolts, electromagnets, and so on.


Aluminium

Aluminium, being a very light metal, is used for making aircraft bodies. It is also used for making cooking vessels. Its thin foils are used for packaging of food stuffs and medicines.


Copper

Copper is the most widely used metal for making electrical cables and other electrical goods. It is also used for making cooking vessels.


Silver

Silver is used for making jewellery, decoration pieces, tableware, etc. Silver, being highly malleable, can be converted into very thin foils which are used for decorating food items. Silver is a very good conductor of electricity, but it is not commonly used for electrical fittings because it is very expensive. Silver and Gold wires are, however, used for high precision electrical contacts in computers.

Uses of Alloys

Besides being used in their pure form, metals are also often used in the form of their alloys. An **alloy** is a homogenous mixture of two or more metals, or a metal and a non-metal. By adding appropriate amount of other metals, or non-metals, to form the alloys, the properties of a given metal can be (significantly) modified. Alloys are generally stronger, harder and more resistant to corrosion than the (pure) metal itself. Uses of some common alloys are mentioned in Table 3 (given below).

Table 3: Uses of some well-known Alloys

Name of the Alloy	Made From	Used for making
Steel	iron + carbon	construction material, machine parts
Stainless steel	iron + chromium + nickel	cooking utensils and cutlery, surgical implements
Brass	copper + zinc	cooking utensils, decorative statues, nuts and bolts
Bronze	copper + tin	cooking utensils, coins, medals, statues, decorative items
German Silver	copper + zinc + nickel	tableware
Duralumin	aluminium + copper + magnesium + manganese	aircraft bodies, automobile parts, undersea vessels
Alnico	aluminium + nickel + cobalt	magnets
Gun metal	copper + tin + zinc	gun-barrels

Uses of Non-Metals

Some of the common uses, of some of the well-known non-metals, are given below:

1. Nitrogen, in the form of fertilisers, is essential for the growth and development of seeds and plants.
2. Phosphorus is used in matchbox industry and in fertilisers.
3. Iodine is used as an antiseptic.
4. Sulphur is used for making fire crackers, gun powder and sulphuric acid.
5. Oxygen is essential for survival of all living beings.
6. Diamond (a form of carbon) is used in making jewellery, in cutting glass and for grinding of tools.
7. Graphite (also a form of carbon) is used in batteries and in pencils.

Do You Know?

Many metals, and some non-metals, play a vital role in the functioning of the human body. Iron is an essential and important component of haemoglobin; its deficiency can lead to serious complications. Sodium and potassium play an important role in the transmission of (electric) signals, to and from, the brain. Several other metals also play an important role in the human body. Non-metals, like carbon and phosphorus, also play an important role in human body. Phosphorus is present in bones and helps cells obtain energy from food.

Keywords

alloy	a homogenous mixture of two or more metals, or a metal and a non-metal.
conductivity	the ability of a material to transfer heat energy, or electrical current, from one point to another.
ductility	the property of metals due to which they can be drawn into thin wires.
malleability	the property of metals due to which they can be hammered into thin sheets.
metalloid	elements which show (some) properties of metals as well as non-metals.
metallurgy	the sequence of processes used to extract a metal from its ore in its pure form.
mineral	a natural occuring inorganic substance found deep under the surface of earth.
noble metals	those metals which are least reactive and so are not chemically affected by the substances around them.
ore	it is a mineral from which one, or more, metals can be extracted.
reactivity	the tendency of an element to react with other substances to form compounds.

reactivity series	the series of metals arranged in the order of their decreasing reactivity.
sonorosity	the property of metals to produce sound when struck with something hard.
tensile strength	the property, due to which a substance can bear a lot of strain, without breaking.

You Must Know

1. Elements are pure substances made up of atoms of the same kind.
2. Elements are broadly classified into two categories, namely, metals and non-metals.
3. Minerals are substances found deep under the surface of earth.
4. Ore is a mineral from which one, or more, metal can be extracted profitably.
5. All metals are solid at room temperature except mercury; metals (generally) have high melting and boiling points; are malleable, ductile and sonorous; have natural lustre and high tensile strength; and are good conductors of heat and electricity.
6. Non-metals can be solid, liquid or gases at room temperature; generally have low melting and boiling points, are brittle, non-sonorous and are bad conductors of heat and electricity.
7. Metalloids are elements which show (some) properties of both metals and non-metals.
8. Metals react with oxygen to form metallic oxides which are basic in nature.
9. Non-metals react with oxygen to form non-metallic oxides which are acidic in nature.
10. Many metals react with water to liberate hydrogen gas; non-metals do not react with water.
11. Many metals react with dilute acids to form a salt (metal salt); non-metals do not liberate hydrogen gas with acids.
12. A reaction, in which a more reactive metal displaces a lesser reactive metal from the aqueous solution of its salt, is called a displacement reaction.
13. An alloy is a homogenous mixture of one or more metals, or a metal and a non-metal.
14. Metals and non-metals are used in our daily life for a variety of purposes.

Something To Know

A. Fill in the blanks.

1. The property, due to which a metal piece can be hammered into thin sheets, is known as ___________.
2. Bronze is an alloy of ___________ and ___________ .
3. Gold is mixed with ___________ and/or ___________ to make it hard.
4. ___________ is the only non-metal to have a natural lustre.
5. ___________ is a non-metal which catches fire in air.
6. The only metal, which exists in the liquid state at room temperatures, is ___________.

B. Match the following.

1.	Hardest substance	(a)	bromine
2.	Aluminium ore	(b)	graphite
3.	A non-metal, normally, existing in the liquid state	(c)	bauxite
4.	A good electrical conductor	(d)	diamond
5.	A metalloid	(e)	arsenic

C. Tick (✓) the correct option.

1. The two most abundant metals, found in the earth's crust, are—

   ☐ aluminium and copper ☐ aluminium and iron
   ☐ iron and copper ☐ iron and silver

2. The metals, used in making the alloy 'german silver', are—

   ☐ copper + zinc + tin ☐ copper + zinc + nickel
   ☐ copper + nickel + tin ☐ copper + nickel + cobalt

3. When a metal reacts with oxygen, the resulting oxide of the metal—

- [ ] is a neutral oxide
- [ ] turns blue litmus red
- [ ] is a acidic oxide
- [ ] is a basic oxide

4. Out of the metals, gold, silver, copper and aluminium, the one, that is most ductile, is—

- [ ] gold
- [ ] silver
- [ ] aluminium
- [ ] copper

5. Two of the metals, that cannot be stored either in air, or under water, are—

- [ ] sodium and magnesium
- [ ] magnesium and calcium
- [ ] calcium and potassium
- [ ] potassium and sodium

D. Answer the following questions in brief.

1. Name (i) one metal and (ii) one non-metal which normally exists in the liquid state.
2. State the fraction of gold present in an 18 carat gold piece.
3. State the property of copper wires that makes them useful for electrical fittings.
4. Define an alloy.
5. List any two uses of non-metals.

E. Answer the following questions.

1. Write the balanced chemical equations for the following reactions:

   (a) sodium reacts with oxygen

   (b) aluminium reacts with dilute hydrochloric acid
2. Why are gold and platinum suitable for making jewellery?
3. 'Sodium and potassium is stored under kerosene.' Give reason.
4. Why is bronze preferred over copper metal for making statues?

Value Based Question

The chemistry teacher, while teaching her students, explained to them the differences between 'metals' and 'non-metals'. She told them that both of them react with the same gas-oxygen-but their resulting oxides are 'opposite' in nature.

She then went on to say that, in a somewhat similar way, we could use our stay in the school either–

(i) to gain knowledge, learn good manners and develop, and tone up, different skills, or

(ii) to indulge in idle gossip and other frivolous and irrelevant activities.

1. State two of the 'values' that the teacher conveyed to her students.
2. Give one example each of the reaction of a (i) metal, (ii) non-metal, with oxygen to explain the 'opposite nature' of the oxides formed in the two cases.
3. Let the students form two teams: M (Metals) and N (Non-metals); let the two teams form 'pairs' to explain the differences between 'their' properties.

Something To Do

1. **Find out the names of places in India where mines of gold, copper and iron are located. Also, write the names of the places where major steel plants are located.**
2. **The study of extracting metals from their ores is called metallurgy. Centuries ago, India was far ahead in metallurgy. Refer to books in library and find out the history of metallurgy in India.**
3. **Make a list of five articles used at home and school, which are made up of metals or alloys. Write their composition in a tabular form.**

CHAPTER

4 Force and Pressure

We all know that motion is an integral part of our life. In Class-VII we have talked about the details of the motion of an object moving along a straight line. We now know that the motion of an object can be uniform or non-uniform in nature. However, we have not yet looked at the cause of motion. When and why does the speed of an object change with time?

We all know that an object at rest does not start moving on its own. Some 'effort' is needed to make it move. From our everyday experience, we know that we have to push, or pull, a table, a chair, or an almirah, if we wish to change its position in a room. When we push or pull an object, we are exerting a force. A football, at rest, has to be kicked to send it over a distance. We again say that we are exerting a force on it. We, therefore, say that we exert a force when we push, pull, kick or lift a given object.

In all these situations, some kind of external agency (very often a muscular effort) is involved and its effect can be noticed or felt quite easily. It follows that we need an external force to move a body from its rest position, or to stop a moving body.

For example, we can stop a ball rolling down an inclined plane by applying a force against the direction of its motion.

We can thus say that **force** is a push or pull which comes into play when there is an interaction of one object with another object. For example, when we wish to change the position of a study table in our room, we have to push it. The study table does not move due to our presence alone. There has to be an interaction (push/pull) between us and the study table. The study table begins to move in the direction of the applied force.

Activity 1

Given below are some situations involving different objects. Try to identify the action(s) involved. Can the effort be called force? Is there any interaction between the two concerned objects?

S.No.	Description of situation	Action(s)	Effort leads to Force (Yes/No)	Does the effort involve an interaction between two objects? (Yes/No)
1.	Drawing a bucket from a well.			
2.	Opening or closing a table drawer.			
3.	Squeezing wet clothes for drying.			
4.	Pedalling a bicycle.			
5.	Moving a loaded trolley.			
6.	A hockey player taking a penalty corner shot.			

From the above activity, we can infer that a force comes into play only when at least two objects 'interact' with each other.

Thus an interaction of one object with another object can result in a force between the two objects.

Force

We can now say that: A **force** is a push or pull upon an object resulting from its interaction with another object. Whenever there is an interaction between the two objects, some force acts between them; when the interaction ceases, the force between them no longer exists.

Force exists only as a result of some interaction.

A bullock pulling a cart

Do You Know?

Force does not always involve effort by living beings like humans or animals. Force can also be due to many natural causes. We may not be able to 'see' such forces, but can still feel or observe their effects on objects.

Effects of Force

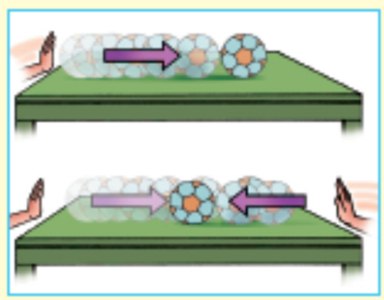
- **Change in the state of motion:**

  A change, in either the speed of an object, or its direction of motion, or both, is described as a change in its state of motion.

Activity 2

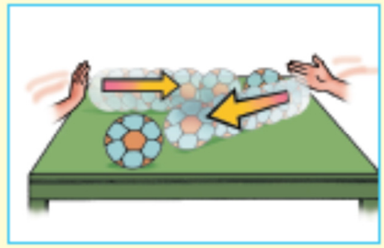
(i) Take a rubber ball and place it on a smooth level surface (like a table top). Gently push the ball; it starts to move. Now, push it harder. What do you observe? Is there any change in its speed? Does it increase or decrease?

(ii) Roll the ball on the table top and now, push against the motion of the ball. What do you observe in this case? The speed of the ball decreases and it can come to rest.



(iii) Next push the ball at an angle to the direction of motion of ball. What do you observe?

Change the angle of your hand with respect to the direction of motion of ball. Does your effort result in a change in direction of motion of ball?



From the above activity, we understand that a force, applied on an object, may change its speed, or direction of motion, or both.

We also realise that—

- if the applied force acts on a body along its direction of motion, the speed of the body will increase.
- if the direction of force, on the body, is opposite to its direction of motion, the speed will decrease.

  (In both the above two cases, the object is supposed to be moving in a straight line).
- if the force acts at an angle to the direction of motion, it can change the speed as well as the direction of motion.

Do You Know?

When a very small body hits a very large body, the forces acting on both the bodies are equal in magnitude but opposite in direction. However, the effect (of force) produced in the small body is very large as compared to the effect of (the equal) force on the larger body.

Our common experience also tells us that many a time the application of force does not result in a change in the state of rest or motion of the body. For example, we do not observe any motion, when we try to push a heavy stone.

A force may not, therefore, always succeed in bringing a change in the state of motion of an object. Sometimes, it only tends to do so.

- **Change in size/shape of an object:**

We know that to make a *chapatti*, we first take same dough and then roll it between the palms to make it spherical. We can also change the shape of an inflated balloon by gently pressing it between our palms. Some of us might have had a chance to observe the potter at work. A potter makes pots of different sizes and shapes from kneaded clay. In all these situations, the changes in size, or shape, or both take place due to the force applied on them.

We can now say that a force may—

- make an object move from rest.
- change the speed of a moving object.
- change the direction of a moving object.
- bring a change in the size, or shape, of an object.
- cause two, or more, or all, of these effects.

Activity 3

Try to analyse these situations:

(i) a batsman hits a cricket ball for a six.

(ii) a goalkeeper saves a goal by kicking the ball away.

Can we say that these actions cause one, or more, of the above stated effects of force? Identify the agent supplying the force in each case. Also, try to identify the number of times the speed of the ball changes.

Do You Know?

An object continues to be in motion, with the same speed and in the same direction, unless acted upon by an unbalanced force. It is a natural tendency of objects to resist any change in their state of rest or motion. This is known as the **Law of Inertia.**

Factors Associated with the Magnitude of Force Needed

We know that harder we kick a football, faster it moves. It means that: 'greater is the applied force, greater is the change in the speed of the object.'

Consider a lighter mass (car) and a heavier mass (loaded truck) parked on a horizontal road. We all know from our experience that a much greater push (force) is needed to move the truck than the car.

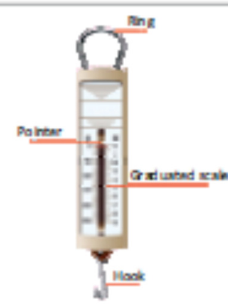
Now, suppose we apply the same force, for the same time, to both the car and the truck. The car picks up a greater speed than the truck in that time.

We thus realise the mass of an object, and the value of the change in its speed (in a given time) are both important parameters that determine the magnitude of the force needed.

Do You Know?

Spring balance is a simple device that can be used for measuring the force acting on an object. It consists of a coiled spring which gets stretched when a force is applied to it. Stretching of the spring is measured by a pointer moving on a graduated scale. The reading on the scale gives the magnitude of the force. The SI unit of force is 1 newton (1N).

The force is said to be 1N if it produces an acceleration of $1 m/s^2$ in a body of mass 1kg.



Spring balance

Force has Both Magnitude and Direction

It is now easy to understand that we need to know both the magnitude of force, and the direction in which it acts, to completely specify it. When we change either the direction, or the magnitude, or both (magnitude and direction) of the applied force, its effect changes.

Do You Know?

The force need not always act in the direction of motion. Depending upon the situation, force may act at any angle to the direction of motion. A force, acting perpendicular to the direction of motion, does not cause any change in speed but can still cause a change in direction.

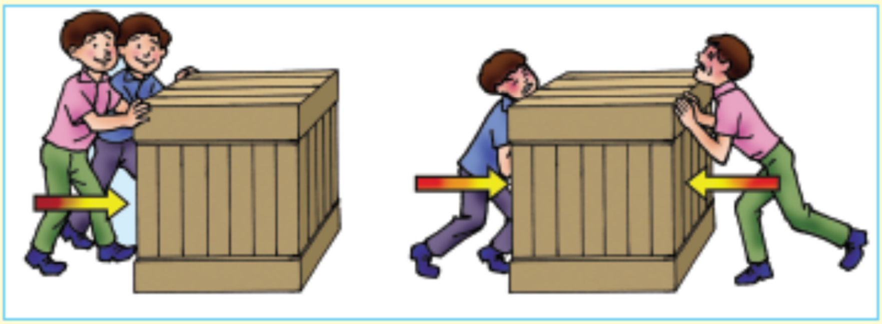
Balanced and Unbalanced Forces

From our experience we know that sometimes more than one force can act on an object. The effect of all these forces on the object, would be due to the net force acting on it. To understand this, let us perform the following activity.

Activity 4

Consider a large 'container' filled with a heavy material. (i) Try to push it, all by yourself, from one corner of the room to another corner. Can you move it? (ii) Take the help of one of your friends. Ask him to push the container in the same direction in which you are pushing it. (iii) Next ask him to push from the opposite direction. What do you observe? In which case does it become easier, or difficult, to move the container?

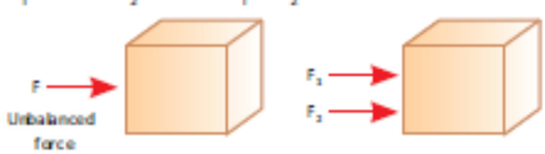
When your friend pushes the container in the same direction, his effort adds to yours, but when he pushes in the opposite direction, his effort tries to cancel your effort. In each case, an unbalanced force can act on the container.



It is the net unbalanced force, acting on an object, that changes its speed or direction of motion, or both. When the two forces, acting on an object, are different, the object undergoes a change in its state of rest or motion. The change caused depends on the net force acting on it. We call a pair of different forces as **unbalanced forces**.

1. **Unbalanced forces, acting in the same direction, combine by addition**

$F_1 \longrightarrow + F_2 \longrightarrow = F_1 + F_2$



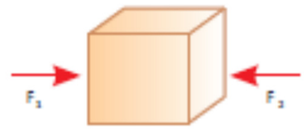
2. **Unbalanced forces, acting in mutually opposite directions, combine by subtraction. The net force is equal to the difference between the two forces and is exerted in the direction of the larger force.**

$(F_1 \longrightarrow) + (F_2 \longleftarrow) = F_2 - F_1$

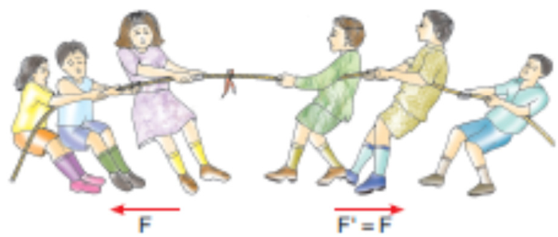
OR

$(F_1 \longleftarrow) + (F_2 \longrightarrow) = F_2 - F_1$

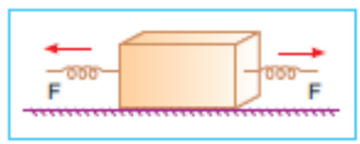
where $F_2 > F_1$



The resultant (net) of unbalanced forces is always non-zero. For example, in a game of tug of war, the weaker team always gets pulled towards the stronger team.



The figure shows a block of wood, lying on a table, that has been tied to two springs. If we pull the block from both sides, with the same force, the block remains stationary. The forces are equal and opposite. The net force is zero. Similarly, in a game of tug of war, when both the teams pull the rope, with equal and opposite forces, the rope remains stationary. The net force again is zero. We call such a pair of forces as **balanced forces**.



Now, try to squeeze a rubber ball between your palms by applying nearly same force from both sides. As the forces applied are equal and opposite, net force is almost zero. It does not move the ball, but can deform it.

We thus conclude that—

- equal and opposite forces (balanced forces) do not change the state of rest or motion of an object. They may, however, cause a change in the size and/or shape of the object.
- unequal (unbalanced) forces may lead to (i) change in state of rest or motion as well as (ii) change in size and/or shape of an object.

Do You Know?

Sir Isaac Newton (1642-1727) was a great physicist and mathematician. Newton wrote two important books – *Principal* and *Opticks*. The first book describes the theory of universal gravitation. The second book contained Newton's ideas on light and colour and his optical researches.

Newton expressed the relations, between the forces acting on a body and its motion, through his famous **Laws of Motion**. Newton's third law of motion finds its technological application in rocket propulsion; this plays a very important role in space exploration.

Sir Isaac Newton

Type of Forces

It is clear now that whenever there is an interaction between different bodies forces come into play. We can classify all forces in two broad categories:

1. **Contact forces**
2. **Non-Contact forces ('action at a distance' forces)**

Contact Forces

We call those forces as contact forces which result when two interacting bodies are in direct physical contact with each other. Some of the examples of contact forces include muscular force, frictional force, air resistance force and so on.

- **Muscular force:** In our daily life, we push, pull or lift many things. The effort (force) is caused by the action of muscles in our body. Animals, like bullocks, horses and camels, have been used for pulling carts. In arctic regions, reindeers are made to pull the sledges that are used as passenger vehicles. In these cases, the muscles of animals apply the force. This force is called **muscular force**. All animals, including human beings, use muscular force for most of their activities.

- **Frictional force:** We know that a ball, rolling along the ground, gradually slows down and finally comes to rest. In order to move a bicycle along a straight level road, we have to keep pedalling it all the time. This is because of the frictional force acting between the two surfaces in contact. The magnitude of the frictional force depends upon the nature of the two surfaces in contact. The direction of the frictional force is (usually) opposite to the direction of motion of the object. We will learn more about the details of the force of friction in the next chapter.

Do You Know?

There is a popular story that one day, when Newton was sitting under an apple tree, an apple fell on his head, and this led him to think about the **force of gravitation**. As in all such legends, this story is almost certainly not true in its details, but the story contains elements of what actually happened. Probably the more correct version of the story is that Newton, upon observing an apple fall from a tree, began to think along the following lines :– The falling apple is getting accelerated; there must be a force acting on the apple. If the force can reach to the top of the highest level of tree might it not reach even further (all the way to moon!). By such reasonings, Newton came to the conclusion that any two objects, in the universe, exert gravitational attraction on each other. This force is directly proportional to the product of their masses and inversly proportional to square of the distance between them. The weight of an object is a measure of the gravitational force exerted on that object by the earth.

Non-Contact Forces ('Action at a distance' forces)

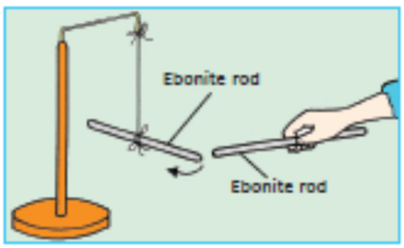
We call those forces as non-contact forces which can cause their effects even when the two interacting bodies are not in direct physical contact with each other. Here they are able to exert a push, or pull, despite their separation. Some examples of non-contact forces are gravitational force, magnetic force and electric force.

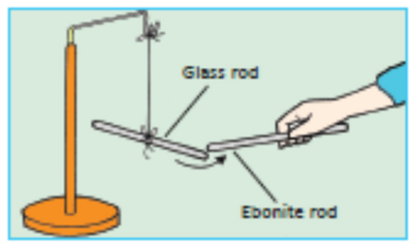
- **Gravitational force:** We know that when we throw a ball upwards, the ball goes up in the air but then falls down again. Ripe fruits, that grow on trees, fall to the ground by themselves. This happens, due to a force, we call as the **gravitational force**.
- **Magnetic force:** We have already learnt in Class-VI that the magnetic property of lodestone was known to mankind since quite early times. Magnets have the well-known property of attracting objects made of iron. Likes poles of two magnets repel and unlike poles of two magnets attract each other. A magnet can exert a force on another magnet without being in contact with it. The force, exerted in this case, is known as a **magnetic force**.

Do You Know?

A single isolated force does not exist by itself. Forces are always pushes or pulls between two objects, so they always occur in pairs. When two objects interact, the force, exerted by one object on the other, is equal and opposite to the force exerted by the second object on the first.

- **Electric force:** We have already learnt in Class-VII that two charged bodies exert a force on each other. When a glass rod is rubbed with a silk cloth, the rod becomes positively charged. Similarly, when an ebonite rod is rubbed with wool, the rod acquires a negative charge. Bring this charged ebonite rod near the suspended (and charged) glass rod. You will find that the suspended glass rod moves towards the charged ebonite rod. From these observations, we observe that like charges repel and unlike charges attract. This attraction, or repulsion, between charges is due to the (non-contact) **electric force** between them.





Activity 5

Some situations have been given in Column 1 of the table given below. Try to analyse these situations and identify the nature and kind of forces that may be involved.

Description of situation	Nature of forces (Contact/Non-Contact or Both)	Kind of forces present (muscular, gravitational, frictional, etc.)
1. Expansion of lungs when we inhale and exhale during breathing.		
2. Two plastic refills rubbed with polyethene and kept near each other.		

3. A rubber band, suspended from a hook, first stretched and then released.		
4. Falling of raindrops.		
5. A rocket fired upwards to launch a satellite in its orbit.		
6. A book lying on the table.		
7. An archer, stretching his bow, while taking aim at the target. He then releases the arrow which begins to move towards the target.		
8. A horse pulling a cart.		

Pressure

We are now familiar with the effects of a force on different objects. Careful observations and analysis reveal that the effect of a force also depends on the surface area over which the force acts. It is a common experience that it is difficult to carry a school bag, when it is tied to narrow thin string; it becomes easier to carry the same school bag when it is tied to 'broad straps'. This implies that if the same force (say, the weight of an object) acts over a smaller area, its effect is felt more. Thus the overall effect of a force depends on (i) its magnitude (ii) the area over which it acts.

We, therefore, need to define a physical quantity that takes both these factors into account. Physicists have now defined such a quantity and named it as **pressure**. It is pressure which is a measure of the effect of force over a given area.

When we apply force in a direction perpendicular to a given surface area, we call it as **thrust**.

The thrust, acting, on a unit area of a surface, is called **pressure**.

$$\text{Pressure} = \frac{\text{Thrust}}{\text{Surface area over which it acts (contact area)}}$$

Do You Know?

In case of solids, the force can be applied in any direction with respect to the surface. However, in case of fluids (liquid/gases) at rest, the force must be applied at right angles to the liquid surface. This is because fluids, at rest, cannot sustain a tangential force. We, therefore, usually speak in terms of pressure in their case.

It follows that the pressure, due to a given force, would vary according to the area over which the force is acting. We can, therefore, increase or decrease pressure, without any change in force, by changing the surface area over which the force acts. To understand this, let us perform an activity.

Do You Know?

Pressure always acts normal to the surface and it is always compressive in nature. We, therefore, need only its magnitude for its complete description.

Activity 6

Take some moulding clay. Spread a thick [3 to 5 cm] layer of this moulding clay on the desk. Place a wooden block on the surface of the moulding clay (length-wise). Now, place a book on it for sometime. Remove the wooden block and book. Measure the depression produced in the moulding clay with the help of a scale.

Repeat the above steps keeping the wooden block (breadth-wise/thickness-wise) on the surface of the moulding clay. What do we observe?

It is the same force that is acting on the clay in all the three cases. However, the effect produced is different because of the difference in the contact area. We, thus, realise that for a given applied force, when the contact area is less, its pressure, on the surface in contact, becomes more.

Applications: The decrease in the pressure of a given force, through an increase in the surface area over which the force acts, finds many applications in our day to day life. We list below some such applications:

1. Buses and trucks usually have double wheels on the rear side.
2. High rise buildings and dams have a wide base.
3. Tanks and bulldozers are fitted with caterpillar tracks rather than wheels.
4. Railway tracks are laid on large sized wooden/iron sleepers.

There are many situations where we need to have a larger pressure due to a given force. In such cases, we decrease the area over which the force acts. For example,

1. It is easier to cut with a sharp knife than with a blunt knife.
2. Nails, pins and spikes have pointed ends so that they can be driven into the surface with minimum effort.

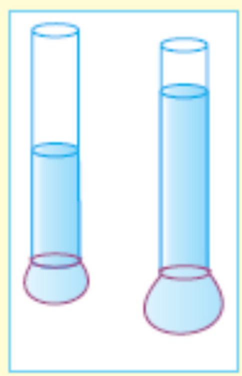
Liquid Pressure

It is easy to observe that a liquid exerts pressure, due to its weight, on the bottom of its container. This is much the same way as a solid does on the surface supporting it.

The pressure, exerted by a stationary liquid (kept in a container) at any point inside the liquid, is known as **hydrostatic (liquid) pressure**.

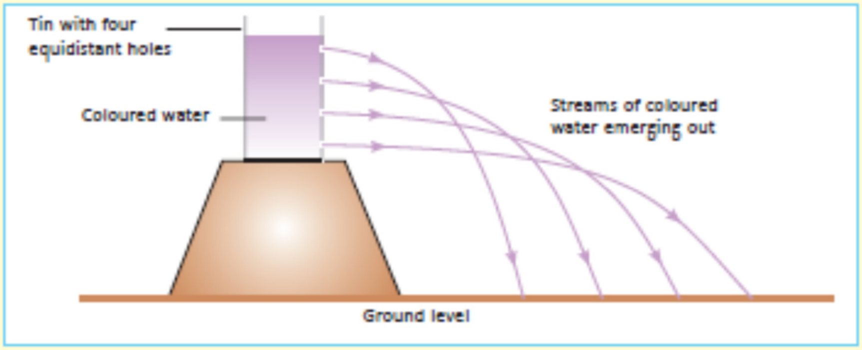
Activity 7

Take a transparent pipe (plastic/glass). The length of the pipe should be 15-20 cm and its diameter may be about 6 cm. Stretch a rubber balloon/sheet over one end of the pipe. Hold the pipe in vertical position as shown in the figure. Now, pour some water in the pipe. What do we observe? The rubber balloon bulges out. Note the height of water column in the pipe. Pour some more water. Observe again the bulge in the rubber balloon. What do we infer? Pressure, exerted by the water column at the bottom of the container, increases with an increase in the height of its column.



Activity 8

Take a tin can, some coloured water, a sharp pin/nail and some cellotape. Make holes with the pin/nail at four different points, along a vertical line in the tin can, as shown in the figure. These holes should be equidistant. Cover the holes with cellotape. Place the can on a stool and fill it with coloured water. Now, remove the tapes from the holes and observe the streams of water coming out of these holes. We observe that the stream, from the lower holes travel a larger distance. Why? What do we infer?



The emerging water goes out farther from the lower holes; this is because the pressure of water increases with an increase in the 'depth' of the hole. Hence the water pressure, at a point, increases with the height of water column above it.

Try repeating the steps of above activity using, say vegetable oil* instead of coloured water. What do we observe? Do the streams of vegetable oil travel the same distance from the same holes?

We thus observe that, for a particular liquid, the pressure, exerted at any point, is directly proportional to the height of liquid column above that point (or depth of that point below the surface); however, this pressure is different for different liquids.

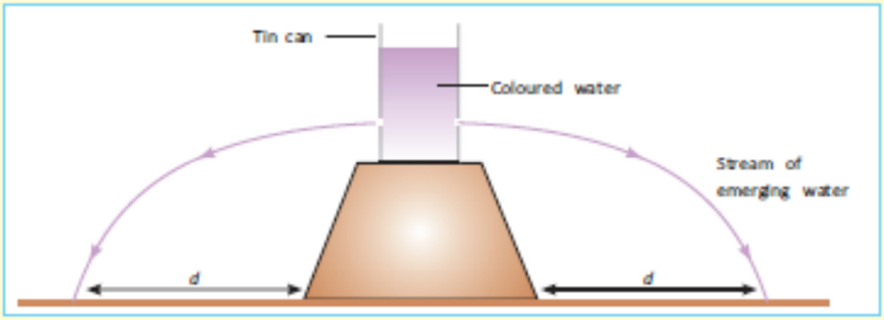
Do You Know?

The pressure, exerted by a given liquid, increases with depth. It is for this reason that submarines are always built with very thick and heavy metals. They have to withstand an enormous water pressure when they go deep down, near to ocean floors.

* We need to have a broad flat container into which the oil oozing out of the holes falls. We should not let the oil spill over on the table top, or the floor.

Activity 9

Make a number of holes at the same level in a tin can using a sharp (pin/nail). Repeat the steps of the earlier activity. When tapes are removed, water is seen to emerge out from all these holes with equal force. Mark the points, on the floor, where the water has fallen**. Join these points to form a closed figure. What do we observe? The closed figure is (nearly) a circle, with the (centre of the) can approximately at its centre. This illustrates that the liquid pressure is transmitted equally in all directions, and is same at a given horizontal level.



Do You Know?

Pressure applied at any point in a liquid is transmitted equally in all directions. Hydraulic jack (used for lifting a car), the car hoist (used for lifting the car for washing at service stations) and hydraulic brakes (used in cars for applying brakes to their wheels) are all based on this principle of 'equality of transmission of pressure' in liquids.

Properties of liquid pressure: Careful observations show that the pressure, exerted by a liquid, has the following characteristics:

- Liquid pressure, on the bottom of the container (due to weight of liquid column), does not depend on the area of the bottom.
- Liquid pressure, at any point inside the liquid, depends upon the density of the liquid and the height of liquid column above that point.

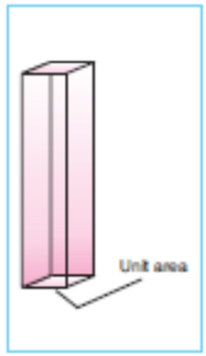
** We should do this activity at a place where the falling water 'does not create a mess/cause any problem'. We, of course, need to 'mop-up' the floor and clean the place after the activity.

- Liquids exert (an equal) pressure on all the walls of the container.
- An external pressure, applied on a liquid in a closed container, is transmitted uniformly throughout the liquid.

Atmospheric Pressure

We all know that there is air all around us. It is the earth's **gravitational pull** that holds this air around us. This envelope of air, around the earth, is known as **atmosphere**. It extends up to nearly 1,000 km above the surface of earth. The weight of this huge mass of air exerts a pressure, at all points and at all objects, on the earth. We call this pressure as the **atmospheric pressure** or **air pressure**.

We now know that pressure is thrust per unit area. We imagine a unit area at a place on earth. Let the height of the atmosphere above that place be H. The weight of an air column, 'contained' in a cylinder, of height (H) having a base of unit area, is the atmospheric pressure at that place.



Why is it that we do not feel this large atmospheric pressure acting on us all the time? We do not normally feel it because there is also a pressure inside our bodies that is almost same as this external air pressure. This internal pressure cancels the effect of this outside pressure and saves us from getting crushed under it.

Do You Know?

You will be surprised to know the amount of weight you are carrying on your shoulders all the time. It is very large (nearly 1,000 kg). It is actually the weight of the air above your shoulders. Taking the (approximate) area of the shoulder as 10 cm × 10 cm, the weight of air in a column of height equal to the (approximate) height (~300 km) of the atmosphere, is approximately 1,000 kg.

Activity 10

Pour some hot water* into a (good quality) plastic bottle, carefully. Close the lid of the bottle. Shake it for half minute. Now, pour out the water and (quickly) close the lid of bottle very tightly. What do we observe? The walls of the bottle are seen to get deformed and may get crushed inwards.

* **Caution:** Always take great care while handling hot water. It must be ensured that it does not cause any burns. You can take the help of your teacher/lab incharge as and when needed.

Why does this happen? The hot water heats up the air in the bottle and causes it to expand. A good part of the air inside the bottle, therefore, escapes out. When the lid is now (quickly) closed, there is less air inside the bottle. The pressure of the outside air, therefore, becomes (considerably) more than the pressure of air inside. It is this (large) difference in pressure, acting inwards, that can deform and crush the bottle.

Variation in Air Pressure

As we move upwards through the atmosphere, the height of air column, above us, would decrease. This would result in a decrease in air pressure at higher altitudes. In fact, when we move towards higher altitudes, breathing can become difficult. Sometimes bleeding from nose may also occur. Most climbers, who attempt to scale high range mountains, (like Mount Everest), need to carry oxygen cylinders with them. For this very reason, aircrafts have 'pressurised cabins'. The air pressure in these is increased to a (sufficient) value that safeguards the passengers and the crew.

Air pressure also varies with temperature and time at a given place. We have already learnt (in Class-VII) that due to uneven heating of earth's surface, air pressure can change rapidly. At a hotter place, the warm air there is lighter than the cooler air in the surrounding regions. Hence air can rush in from (the neighbouring) high pressure surrounding area to this lower pressure area. This phenomenon can result in land breezes, sea breezes, winds and storms.

Importance of Atmospheric Pressure

We make use of atmospheric pressure in our day to day life while performing very many simple tasks. For example:

1. When we drink liquid with a straw, the air pressure inside the straw decreases (due to our sucking). The air pressure, acting on the surface of liquid, then becomes greater than the pressure inside the straw. This forces

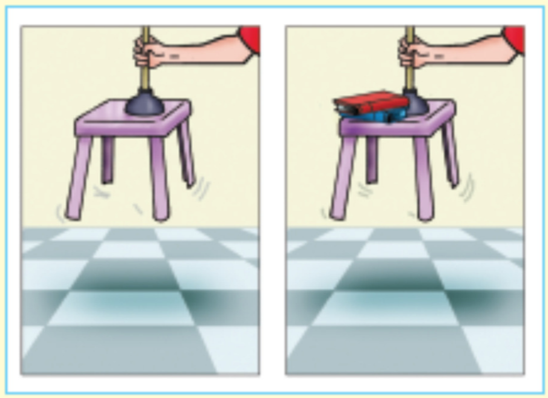
the liquid to move up inside the straw.

The syringe also works in a similar way.

2. We, sometimes, use rubber suckers for installing hooks in a room. When we press the sucker the air between the air sucker and the wall gets forced out. Hence, the air, pressing on it from outside, holds it firmly against the wall. If we wish to pull the sucker off the surface, the force, applied by us, has to be large enough to overcome this effect of the atmospheric pressure.

Activity 11

To get an estimate of the atmospheric pressure using an air sucker.



Take a good quality rubber sucker. Press it hard on the smooth plane surface of a plastic stool and make it stick to the surface. We can now lift the stool by the rubber sucker, (as shown in the figure).

Now, keep some books, one by one, on the top of the stool. What do we observe? Does the sucker still remain stuck to the stool? Add more books till the stool falls down. The weight of the books, at this point, divided by the area of contact (of the sucker), gives us a rough estimate of the atmospheric pressure.

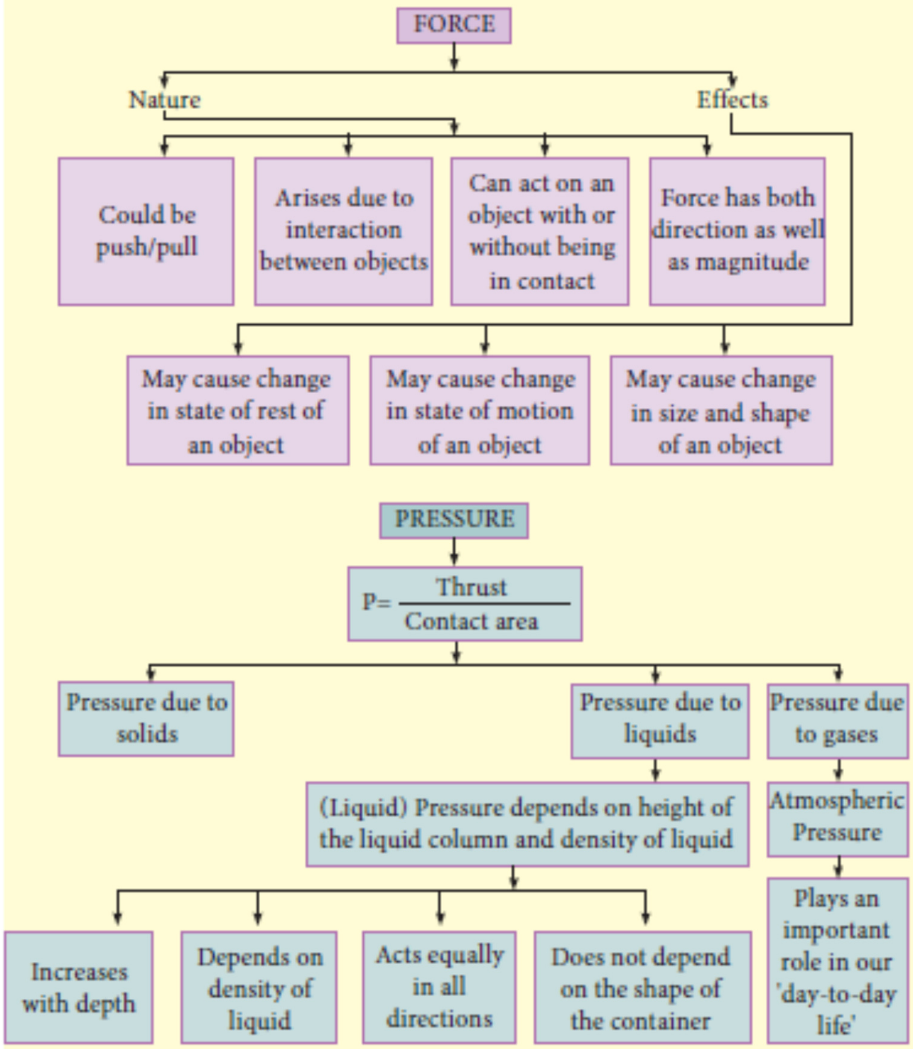
Force and Pressure

Force and pressure are two different concepts. At times, we tend to use these words interchangeably. This needs to be avoided. Let us bring out the differences between the two by making a **Concept Map** (Flowchart).

Activity 12

To make a concept map/flowchart to differentiate between the concept of force and pressure.

CONCEPT MAP



Keywords

atmospheric pressure	it is defined as the force per unit area, exerted on a given surface, by the weight of the air above the surface.
balanced forces	pair of forces that are equal in magnitude but opposite in direction; their resultant force is zero.
contact force	the force which acts only when objects are in physical contact with each other.
electric force	force exerted by a charged body on another charged body.
force	a push or pull upon an object; it results from its interaction with another object.
frictional force	force between two surfaces in contact; it (usually) acts opposite to the direction of motion.
gravitational force	the force of attraction between two objects due to their masses.
hydrostatic pressure	pressure exerted by a stationary liquid.
magnetic force	force of interaction between a magnet and another (suitable) object/magnet.
muscular force	force exerted by the action of muscles in the body of living beings.
non-contact force	the force of interaction which acts on an object without its having any direct physical contact with another body.
pressure	the perpendicular force (thrust) acting per unit area of the surface.
thrust	the force acting on a surface in a direction perpendicular to the surface.
unbalanced forces	unequal forces acting on a given object; their resultant force is non-zero.

You Must Know

1. Force is a push or pull which an object experiences when it interacts with another object.
2. Forces, acting on an object, may cause a change in its state of motion, a change in its speed, a change in its direction of motion; a change in its shape or size; one, or more of these effects, may occur simultaneously.
3. The magnitude of force depends upon the mass of the object and the change produced in its speed, in a given time.
4. Force has both magnitude as well as direction.
5. Forces, applied on an object, along the same direction add to one another; if the forces are applied in opposite directions (on a given object), the net force acting on it is the difference between the forces; this net force acts along the direction of the larger force.
6. Forces, that are equal in magnitude but opposite in direction (such that their resultant force is zero), are called balanced forces.
7. Balanced forces do not cause a change in the state of motion of an object.
8. When the net force, acting on an object is non-zero, the forces, acting on it, are called unbalanced forces.
9. It is unbalanced forces that cause a change in the state of motion of an object.
10. A force can act on an object with, or without, being in contact with it.
11. A contact force is a force acting between two objects (or an object and a surface) that are in physical contact with each other. Muscular force and frictional force are two of the well-known examples of contact forces.
12. A force, which acts on an object without its being in direct physical contact with

another object, is called a non-contact force. Magnetic force, electric force and gravitational force are well-known examples of non-contact forces.

13. Pressure is the perpendicular force (thrust) acting on a unit area of the object.

14. Pressure depends on the magnitude of force and the area over which the force acts. Pressure increases with an increase in the magnitude of force applied; it decreases with an increase in the area on which a given force is exerted.

15. The pressure, exerted by a stationary liquid at any point inside the liquid, is called hydrostatic (liquid) pressure.

16. The properties of liquid pressure are:

    - liquids exert pressure perpendicular to the base (or bottom) of the container; this pressure does not depend upon the area of the bottom.
    - liquid exerts pressure on all the walls of the container.
    - liquid pressure, at a given point, depends upon the density of the liquid and the depth of that point below the surface of the liquid.
    - the liquid pressure increases with increasing depth inside the liquid.
    - at a given depth, the liquid pressure remains the same in all directions.
    - an external pressure, applied on a liquid in a closed container, is transmitted uniformly throughout the liquid.

17. The atmospheric air extends up to many kilometres above the surface of earth. The force per unit area exerted on the surface, by the weight of air above the surface, is known as atmospheric pressure.

18. At high altitudes, the air pressure decreases; hence breathing may become difficult and nose bleeding may occur.

19. Many devices, such as a drinking straw, a syringe and a rubber sucker, all work because of the atmospheric pressure.

Something To Know

A. Fill in the blanks.

1. For a force to come into play, the two concerned bodies must ____________ with each other.
2. To draw water from a well, we have to ____________ the rope.
3. An unbalanced force, acting on a moving object, may change its ____________ and/or its ____________.
4. In the game of cricket, the 'bails' fall when the ball strikes them. This is an example of a/an ____________ force.
5. The force, responsible for raising our body hair, when we try to take off a synthetic (terylene or polyster) shirt in dry weather conditions, is an ____________ force.
6. The atmospheric pressure ____________ as we move towards higher altitudes.

B. State True or False for the following statements.

1. The effect of a force may change by changing the direction of the applied force. ____________
2. A force has to be specified both in terms of its magnitude as well as its direction. ____________
3. Frictional force is an example of a non-contact force. ____________
4. A gas filled balloon moves up. The upward force acting on it is smaller than the force of gravity, i.e. (the downward acting force). ____________
5. We can reduce the pressure of a given force by increasing the area over which the force acts. ____________
6. Inside a bottle filled with water, pressure is least at the bottom and the greatest at the surface of water. ____________

C. Tick (✓) the correct option.

1. When two forces, applied on an object, are equal and opposite, then these forces–

   - ☐ may move the object.
   - ☐ may stop a moving object.
   - ☐ may move the object and also cause a change in its shape.
   - ☐ do not move the object but may cause a change in its shape.

2. The following are the names of some of the well-known forces

   A. gravitational force   B. muscular force

   C. magnetic force   D. frictional force

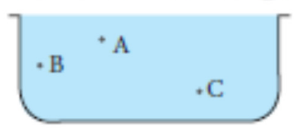
   Out of these, the 'contact forces' are the forces labelled as—

   - ☐ A and B
   - ☐ B and C
   - ☐ B and D
   - ☐ C and D

3. Rohini is pushing a box towards the west direction with a force of magnitude F. To help her move the box faster in the same direction, her friend should—

   - ☐ push the box in the east direction with a force of magnitude 'F'.
   - ☐ pull the box in the west direction with a force of magnitude 'F'.
   - ☐ push the box in the west direction with a force of any magnitude.
   - ☐ push the box in the east direction with a force of any magnitude.

4. A container is filled with water as shown in the figure below.

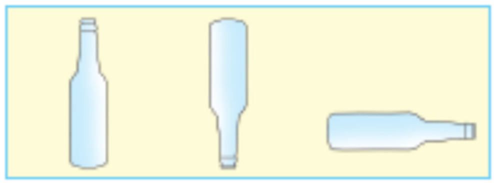


   Which of the following statement is correct about the pressure of water in this container?

   - ☐ pressure at A > pressure at B > pressure at C
   - ☐ pressure at C > pressure at B > pressure at A

- [ ] pressure at A = pressure at B = pressure at C
- [ ] pressure at A < pressure at B > pressure at C

5. An empty metal bottle has to be placed on a table so that it exerts the maximum pressure on the surface of table?



Position A Position B Position C

For this, the bottle need to be placed in the position(s) labelled as—

- [ ] position A
- [ ] position B
- [ ] position C
- [ ] position A and C

6. When we press the bulb of a dropper, with its nozzle kept under water, air in the dropper is seen to escape in the form of bubbles. If we then release the pressure on the bulb, water gets filled in the dropper. The rise of water in the dropper is due to–

- [ ] pressure of water in the container
- [ ] weight of the bulb
- [ ] gravity of the earth
- [ ] atmospheric pressure

7. The length, breadth and height, of a given rectangular box, are 100 cm, 50 cm and 20 cm, respectively. This box is kept on ground in three different ways, one by one. Which of the following statements is the correct statement about the pressure exerted, by this box, on the ground?

- [ ] the pressure exerted is maximum when the 'length' and 'height' sides form the base.
- [ ] the pressure exerted is maximum when the 'length' and 'breadth' sides form the base.
- [ ] the pressure exerted is maximum when the 'breadth' and 'height' sides form the base.
- [ ] the pressure exerted remains the same irrespective of which of its 'sides' form the base.

D. Answer the following questions in brief.

1. In the following situations, identify the agent exerting the force. Also, state the effect of the force in each case.

   (a) Squeezing a piece of lemon between the fingers to extract its juice.

   (b) A person diving into a swimming pool.

   (c) A labourer moving a loaded cart.

   (d) A car coming to rest once its engine is switched off.

   (e) An athelete making a high jump to clear a bar kept at a certain height.

2. An object experiences a net non-zero force. Is it possible for the object to move with a constant speed along a straight line?

3. Distinguish between:

   (a) balanced and unbalanced forces.

   (b) contact and non-contact forces.

4. When we throw a ball upwards, what happens to its speed while it is going up? Give reason for your answer.

5. The figure shows a man with a parachute.

   (a) Name the force which is responsible for his downward motion. Is it a contact force or a non-contact force?

   (b) Will the man come down with the same speed without the parachute? Explain.

6. How would the pressure (exerted by a force on an area) change if—

   (a) the area is doubled keeping the thrust constant?

   (b) thrust is doubled keeping the area constant?

7. When will a diver 'experience a greater pressure'—100 cm below the surface of water or 200 cm below the surface of water? Justify your answer.

E. Answer the following questions.

1. Define force. Is it necessary for the two bodies to be in direct contact for a force to exist between them? Explain with examples.

2. State three effects of a force. Give suitable examples.

3. Give reasons for the following statements–

   (a) 'Snow shoes' are more effective than ordinary shoes for walking on snow.

   (b) Porters place a large round piece of cloth on their heads when they carry heavy loads.

   (c) A sharp knife cuts vegetables and fruits more effectively than a blunt knife.

   (d) School bags are provided with wide straps to carry them.

   (e) It is much easier to burst an inflated balloon with a needle than (directly) with the finger.

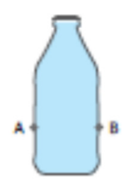
   (f) Mountaineers may suffer from nose bleeding at high altitudes.

   (g) Airplanes have pressurised cabins for passenger safety while flying high in the atmosphere.

4. Two rods, 'A' and 'B', of the same weight and equal length, have different thicknesses. A boy, while playing with them on a beach, held them vertically on the surface of sand as shown in the figure. Which one of them will sink less? Explain.

5. Three holes, A, B and C, are made in an empty can at different levels, one over the other, as shown in the figure. They are (temporarily) closed with an adhesive tape. The can is now filled with water. What will you observe, when the tape (on all of them) is pulled out? Justify your answer.

6. Make two tiny holes, of the same size, at equal heights from the bottom in a plastic bottle. Cover them and fill the bottle with water. Let the 'covers' be now removed. State the 'observations', and the resulting 'conclusions', based on this activity.



7. Discuss, in brief, the variation in atmospheric pressure with altitude. Do changes in temperature also cause a change in atmospheric pressure?

Value Based Question

On coming back from School, Anudit asked his mother to explain to him the concepts related to the addition/subtraction of forces acting along the same line. Mother explained to him the reason for adding such forces when they act along the same direction and of subtracting, one from the other, when they act along mutually opposite directions. She went on to say that, in a similar manner, we get an 'added up and enhanced effect', when we use our strength, hard work and attention, 'all together', for achieving our desired goal.

1. State the 'values', conveyed by Anudit's mother.

2. Write down the magnitude and direction of the net force in the following situations.

   (a) In tug of war, Team A is applying a force of 100 N along the east direction and Team B is applying force of 200 N along the west direction.

   (b) A boy is pushing a box with a force 100 N towards left by overcoming a force of friction that has a magnitude of 50 N.

3. Have a group discussion in which students give examples of 'combined' and 'similarly directed efforts' of a number of individuals, producing enhanced/better 'positive results'.

Something To Do

1. **Design your own barometer to predict weather.**

   (Use an empty jar, a long necked bottle, coloured water and a marker pen.)

   Note the changes in the marked level over a period of few weeks and 'predict weather' on the basis of your observations.

   Hint:

   Higher marked level indicates high air pressure and fine weather, lower marked level indicates low air pressure; this may cause a stormy weather.

2. **How is pressure related to force and area?**

   Design an experiment/activity to explain how this inverse relationship, between pressure (due to a given force) and area, is used in daily life.

3. **Force and pressure are two different concepts though at times we tend to use these two words interchangeably. Collect some pictures, or draw cartoons, to bring out the difference between the two.**

Useful Information

Italian Physicist, Evangelista Torricelli (1608-47) invented the **barometer**. It is an instrument for measuring atmospheric pressure. The common unit, in which atmospheric pressure is usually mentioned, is **one atmosphere**. It is the average pressure, exerted by the atmospheric air, at sea-level; it is equal to the pressure exerted by a column of mercury of height 76 cm at a temperature of 0°C when kept at sea-level.

Barometer

CHAPTER

5 Friction

It is a matter of common experience that when we roll a ball along the ground, the ball does not continue to 'keep on moving' for long. It slows down and finally comes to rest.

Now consider this situation: we are riding a bicycle, and after attaining a good speed, we stop pedalling. The bicycle would be seen to gradually slow down and would stop after covering a certain distance. To make it move with a constant speed, even along a straight level road, we have to 'keep on' pedalling it.

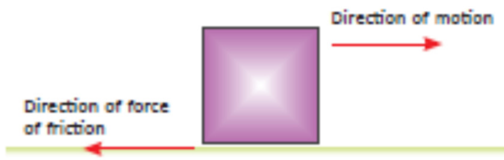
In the last chapter, we learnt that we need an external force to change the speed, or direction of motion, of an object that may be initially at rest or in motion. Why do objects, like the rolled out ball or the moving bicycle, slow down and finally come to rest, after the force acting on them, has been removed? Why does not the object keep on moving with a constant speed along its straight path, after the removal of the applied force?

In terms of our ideas about the effects of force, we can now realise that there must be a force between the rolling ball (or the moving bicycle) and the ground. We call this force as the **force of friction**. This force opposes any relative motion between two objects that are in contact with each other. It is due to the **friction**, between the ground and the surface of ball/wheel of bicycle, that the rolling ball/moving bicycle stops (after moving some distance) when the externally applied force has been removed.

It is clear from above that the force of friction is a contact force.

Friction

We can now say that whenever an object moves, or tends to move over the surface of another object, there is a force acting between the two surfaces in contact. We call this force as the **force of friction,** or simply '**friction**'. We also understand that this force is a contact force and always opposes, or tends to oppose, any relative motion between the two surfaces in contact. The force of friction is always directed along the surfaces in contact, i.e. it acts along the 'tangential direction.'



Activity 1

To explore the relation between the force of friction and nature of the surfaces in contact.

Take four matchboxes (or toy cars), sand paper, a plastic sheet, an aluminium foil, handmade paper, a wooden tray, a plastic tray, a metal tray and a sheet of waxed paper.

Cover the first matchbox with sand paper, the second one with the plastic sheet, the third one with aluminium foil and the fourth one with handmade paper.

Put all the covered matchboxes along a line at one end of a wooden tray. Gradually lift upwards and tilt that end of the wooden tray towards which the matchboxes have been kept. Observe the order in which the matchboxes start moving. Also, observe the order in which they slide down to reach the other end of the wooden tray.

Next cover the wooden tray with a sheet of waxed paper and repeat the above steps. Do you observe any change now?

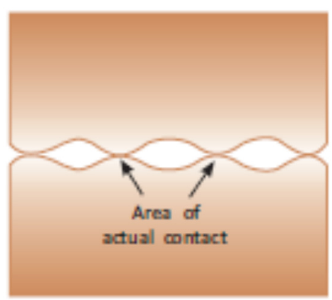
Replace the wooden tray, first with a plastic tray and then with a metallic tray and again repeat the above steps. What do you observe? Over which tray do the matchboxes move with greater ease?

Try to record your observations in a tabular form and discuss your findings with your teacher and friends.

Cause of Friction

The Activity1 (and similar other observations) show that the force of friction depends on the nature of the two surfaces in contact. The more is the roughness of the two surfaces, that are in contact, the more is the force of friction between them. We can, therefore, associate friction with the **roughness of the surfaces in contact**. All surfaces have some roughness on them. Even the surfaces, which appear to be very smooth to the unaided eye, are seen to have a large number of minute irregularities (bumps or depressions), when seen under a powerful microscope. The view of an apparently smooth looking surface, through a powerful microscope, invariably shows it to be uneven (rough) having **ups** (mountains) and **downs** (valleys) in it.

We can now have a simple understanding/ explanation of the **cause of friction**. When two surfaces are put in contact, the irregularities (ups/downs) of one surface get somewhat **interlocked** with the irregularities of the other surface. This may be regarded somewhat similar to the interlocking of the teeth of two saws. We have to apply a force to **unlock** this interlocking of the two surfaces (in contact) and, thereby, to enable them to move with respect to each other.



Cause of sliding friction

It is this interlocking of irregularities that may be viewed as the basic cause of a built-in opposition to any relative motion between the two surfaces in contact. It is this opposition that we observe as the force of friction (or just friction), between them.

Factors Affecting Friction

The force of friction, between two surfaces in contact, depends on the extent of their roughness or smoothness. The force of friction is greater where rougher surfaces are involved. The smoother the surfaces, the smaller is the force of friction between them.

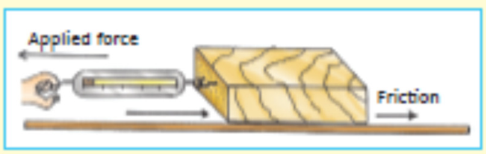
We can, therefore, say: **The force of friction between two surfaces, depends on the nature of the surfaces in contact**.

Do You Know?

When one surface is placed over another surface, humps of their molecules press against each other and get interlocked. The pressure values, at the points of contact are, therefore, high; this results in small 'joints' being formed there due to the strong (adhesive) intermolecular forces between the molecules of the surfaces in contact. These 'joints' have to be broken apart before one surface can slide over the other surface. We usually observe, and talk of, this effect in terms of the more convenient concept of the 'force of friction'.

Activity 2

Tie a string around a wooden block/board. Pull the block by a spring balance as shown in the figure.



Note down the reading on the spring balance, when the block just begins to move. It gives a measure of the force of friction between the surface of the block and the floor.

Now, keep a book on the block. Again pull the block by the spring balance. Note down the reading. Do we observe any difference in the reading of the spring balance in the above two cases?

When a body moves over a horizontal surface, it presses down against the surface by a force equal to its 'weight'. The force of friction increases with increase in the weight of the body. Hence, in the second case, reading on the spring balance would be more.

The force of friction is thus, seen to depend on the magnitude of the force (weight) pressing the two surfaces together.

We can now say that the **force of friction** depends on–

Do You Know?

It is interesting to note that the force of friction between two surfaces does not vary with (i) their apparent area of contact (ii) their speed relative to each other after the start of motion.

1. **nature of the two surfaces in contact**.
2. **force pressing the two surfaces together**.

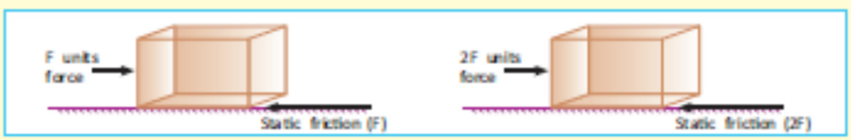
Static and Sliding Friction

We now understand that force of friction is the force exerted by a surface when an object moves across it, or makes an effort to move across it. Hence we can say that there are two types of friction–**static friction** and **sliding friction**. Let us perform some activities that can help us to understand the difference between the two.

Activity 3

Try to push a large box (to make it move across the floor), by applying a small force say 'F' units. What do we find? The box remains at rest. Now, increase the applied force to '2F' units. What do we find now? The box still remains at rest. When an external force acts on the box, the force of friction, known as **static friction**, comes into play and opposes the motion of the box. This static friction balances the force which we exert on the box and the box remains at rest. When applied force is increased to, say '2F', static friction also increases to '2F' and again opposes the motion of the box.

Now, increase the applied force gradually till the box just begins to slide over the horizontal surface (floor).



Self-adjusting nature of static friction

This activity shows that force of static friction increases with an increase of the applied force. In other words, **static friction is a self-adjusting force**. However, it can increase only up to a certain limit. The maximum value of the force of static friction comes into play when the body is just sliding over the horizontal surface; it is called the **limiting force of friction**.

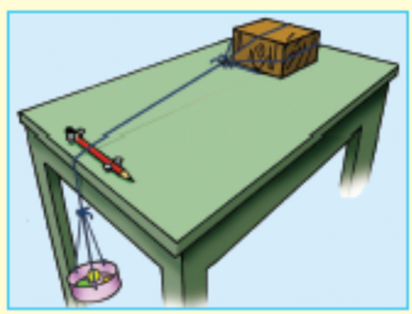
We, thus, conclude that when a force is applied on a body at rest, a force of friction, called **static friction**, comes into play. This static friction opposes the applied force. On increasing the applied force, static friction also increases. However, it can increase only up to a certain maximum value. This maximum value of the force of static friction is called **limiting friction**. When the applied force is increased beyond the limiting friction, the body begins to slide over the surface on which it was resting. After this, it is the force of **sliding (kinetic) friction** that acts between the two surfaces. This force of friction is a little less than the (limiting) force of static friction.

Our day to day experience tells us that it is easier to keep sliding an object (once it has been put in motion) than to make it slide from rest. Let us do an activity to verify this fact.

Activity 4

Take a wooden tray/block. Place it near the one edge of a table top. Keep a cylindrical pencil/rod on the opposite edge of the table top (using drawing pins). Make sure the pencil/rod is free to rotate about its axis (between the drawing pins) as shown in the figure. (You can also use a pulley for this purpose).

Next take the plastic lid of a jar. Make three symmetric holes in it. Put three pieces of string through the holes and tie them together. Next tie them to a longer string from which we can suspend the plastic lid freely. Tie the other end of the longer string to the wooden tray/block such that it passes over the pencil.



Take some marbles (marble chips/very small marbles). Add these marbles in the plastic lid one by one until the wooden tray/block starts just sliding. Note down the number of marbles required. The number of marbles, put in the plastic lid, is an indicator of the magnitude of the limiting force of (static) friction.

Once the wooden tray/block begins to slide, (gently) take out a small marble from the plastic lid. What do we observe? Pick up another such small marble. Does the tray/block stop sliding over the surface of the table top? What happens when we remove a sufficient number of marbles from the plastic lid?

In the first case, when the tray/block just begins to slide, the force of friction is the limiting (or maximum) value of the force of static friction. Once the tray/block begins to slide, the friction, that exists, is sliding friction.

When two/three (small) marbles are (gently) removed from the plastic lid, the tray/block still keeps on sliding and moves to the other end of the table top (with almost the same speed). It shows that sliding friction is (slightly) less than static friction.

Let us now define static friction and sliding friction.

Static friction: We call the force of friction as 'static friction' when it exists between two surfaces (in contact) between which there is no relative motion. In other words, the force of friction, which balances the applied force during the stationary state of a body, is **static friction**.

Sliding friction (or Kinetic friction): We call the force of friction, between two objects, when one of them is sliding over the surface of the other, as the (force of) sliding friction between them. Sliding friction is (a little) smaller than the static friction between the same two surfaces.

A Simple Explanation

We now observe that, for a given pair of surfaces, static friction is (a little) more than sliding friction. Once motion gets started, the friction becomes slightly less than the maximum, or limiting, value of the force of static friction. This can be understood as follows:

We can say that relative motion between two surfaces starts only when the interlockings between their irregularities (ups/downs) have been **unlocked**. Once motion starts the irregularities act just as an obstruction against their relative motion; they are not interlocked now. In other words, **once the motion starts, the 'contact points' on one surface, do not get enough time to lock into the 'contact points' of the other surface.**

Thus, it is easier to keep on moving an object (when it is already in motion) than to start it from rest.

Rolling Friction

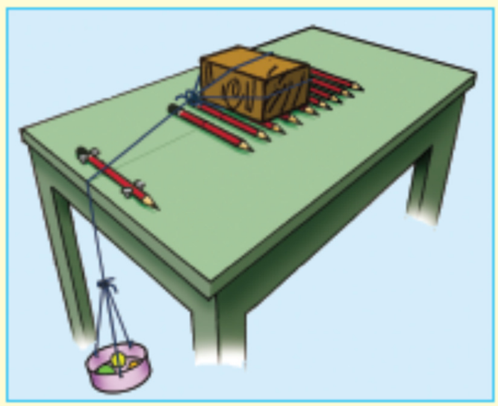
We often see (on bus stands, railway platforms and airports) that even small children are able to carry along their suitcases easily if they are fitted with wheels. Why is it so?

Let us again try the previous activity to understand the reason.

Activity 5

Take a few pencils which are cylindrical in shape. Place them parallel to each other on the table top. Now, place the wooden tray/block over them as shown in the figure.

Repeat the steps of the previous activity. What do we observe? Do we find it easier to move the tray/block in this way than to slide it? Note down the number of marbles required in this case? Observe the difference between the two cases. Do you think that opposition to the motion of the wooden tray/block has been reduced?



We observe that the pencils start rolling as the wooden tray/block moves. Moving the tray/block in this way is much easier than sliding it. Thus, rolling is seen to reduce the friction.

We observe that it is much easier 'to roll', than 'to slide', a body over a given surface. On a railway platform, or bus stop, we often notice that small children can easily pull a suitcase fitted with wheels. It is because of the reduced friction, (associated with rolling), that makes it easy for the child to pull along the suitcase.

It is easy now to appreciate why labourers prefer placing logs under heavy machines/objects while moving them from one place to another place.

Rolling friction is, thus, the force of friction that comes into play when one body rolls over the surface of another body. It is (much) less than the (force of) sliding friction.

We can now conclude that it is more convenient 'to roll' than 'to slide' an object over a given surface. Hence,

Static friction > Sliding friction > Rolling friction

Wheel – A Revolutionary Invention

The realisation, that rolling friction is much less than sliding friction, led man to invent the **wheels**.

The wheel has been considered one of the greatest inventions in the history of mankind. It is much easier to cart a heavy load, put on a trolley with wheels, than to push it. Wheels are used extensively in daily lives for transportation. They save labour and energy to a great extent. This is because of the (very much) reduced friction associated with rolling.

Do You Know?

Proper inflated tyres roll without sliding since rolling friction is less than the sliding friction. Therefore, there is less dissipation of energy against friction. Hence, proper inflated tyres save fuel.

Friction – A Necessary Evil

Friction plays a very important role in our daily life. Many of our daily activities depends on the presence of frictional force. In some cases, friction is useful and necessary. In other cases, friction causes a wastage of energy and damages moving parts of machinery, etc. It is, therefore, harmful and an evil (or nuisance) in such situations.

Friction – A Necessity

Let us first look at some situations where friction becomes a necessity.

1. **Walking on the ground:** It is friction between the ground and our feet (shoes) that enables us to walk. When we walk, we push the ground under

our feet in the backward direction (action); friction then provides the forward reaction and makes us move forward. If friction between our feet and ground were absent, it would not be possible to walk. Have you tried walking on a wet smooth floor or an oily floor? Why do we tend to slip on the wet or oily floor? The water/oil on the floor provides a thin layer in between our feet and the floor. This decreases friction between our feet/shoes and the ground. Our feet are then no longer able to grip the floor firmly and push it backward. We, therefore, tend to slip.

Do You Know?

Sand is thrown on roads when they get covered with snow. This is so because on a road covered with snow, the friction between the tyres of vehicles and the road is very small. This leads to the 'skidding of' the vehicles from the road. Sand is thrown to increase the force of friction to a sufficient value and thus, reduce the chances of skidding of the vehicles.

2. **For rolling:** The friction between the tyres/wheels and the road, is necessary for vehicles to move safely. If there were no friction, the tyres of vehicles will go on spinning at the same place and will not move forward at all. If friction becomes less than a specified value, the wheel/tyre can lose their grip of the road. The vehicle may then skid or turn.

3. **Performing small day to day activities/tasks:** Can you imagine being able to write at all if there were no friction? Whenever we write with pen, or pencil on paper, or with chalk on a blackboard, it is the friction that holds the ink/chalk particles, and makes them stick to the rough surface of paper/blackboard.

We also know from our day to day experience that it is easier to hold an earthen pot, or a paper glass than to hold a (smooth) glass tumbler. Why is it so? It is friction which enables us to hold things safely in our hands. Friction also enables us to keep things along a slope. Imagine everything hurtling down hills and mountains if there were no friction.

We would not be able to fix a nail/screw on the wall/wood, or tie a knot, or light a matchstick, had there been no friction between the surfaces.

Friction – An Evil or Nuisance

We now know that friction is needed for so many activities in our daily life. However, it has many disadvantages too and is unwanted in certain situations. Let us now look at some situations where friction is not desirable.

1. Friction consumes a substantial part of the useful energy available to us. As friction opposes any relative motion between two objects in contact; some of the effort (force/energy) applied to the moving object is wasted in overcoming friction.

Do You Know?

Friction can never be entirely eliminated. We cannot reduce friction to zero by continuously polishing and smoothening surfaces. In fact, friction can go up to very high values for ultrasmooth surfaces. This is because the molecules come very close to each other (in such surfaces) and exert very strong attractive forces on one another. To us, they would appear as a very strong interlocking of the surfaces.

2. Friction is responsible for a lot of wear and tear of moving parts/objects. We must have seen the worn out steps of 'foot over-bridges' (at railway stations) or the worn out soles of old shoes. Have you ever thought about the cause of these observations? It is friction which 'wears out' surfaces rubbing against each other. For this very reason, the moving parts of old machines need replacements.

3. A significant amount of energy, supplied to a machine, gets wasted in the form of heat energy while overcoming the force of friction.

We all have observed that, when we strike a matchstick against a rough surface, it catches fire. Also, when we vigorously rub our palms together for a few minutes, they become warm. This is because friction leads to production of heat. The energy, required to overcome friction is (mainly) converted into heat. While this is welcome for warming up our palms on a winter morning, it becomes a problem between the moving parts of a machine. Excessive heat, produced due to friction, can damage the moving parts of a machine.

Do You Know?

It is interesting to note that force of friction between narrow tyres and road is equal to the force of friction between similar wider tyres and road. This is so because the force of friction is independent of the area of contact. Wider tyres of vehicles spread the weight of vehicle over a large surface area and hence, decrease the wear and tear of the tyres.

Methods of Increasing Friction

We now know that friction is desirable in some situations and undesireable in some other situations. Whenever friction is required, it is increased by making the surfaces rough. Why do you think tyres of vehicles like (cars and bus) have treades on them? Why is the sole of your shoe grooved? The treades and grooves improve their grip on the road. This increases the friction to desired value, and helps us to avoid skidding or slipping.

Sportsmen and players use special types of sport shoes with spikes/cleats (a piece of metal/rubber) on their soles. This helps them to 'get a better grip' on the ground.

Atheletes and other sportpersons, (when they play), often make use of friction. Gymnasts often apply some coarse substance/chalk powder on their hands. By doing so, they increase the friction between their hands and the uneven bars. This gives them a better grip. For the same reason, *Kabaddi* (a game) players rub their hands with soil for having a better grip on their opponents.

Methods of Reducing Friction

We now know that, in very many situations, friction is undesirable and we would want to minimise it.

The following are some common ways used to reduce friction:

Do You Know?

We use polished jewels in watches to hold the axles between them.

1. **Polishing:** When we polish a surface, its roughness (unevenness) decreases. The

surface becomes smooth and friction gets reduced. We also sometimes rub the surfaces with a fine sand paper to reduce their unevenness.

2. **Lubrication:** We all know that when a few drops of oil are poured on the hinges of a door, the door moves much more smoothly. Bicycle and motor mechanics use grease between the moving parts of these machines. In all these cases, we want to reduce friction in order to increase efficiency. Oil-like substances, which help to reduce friction when put on a surface, are called **lubricants**.

Lubricants can be (i) liquids (like oils) (ii) semi-liquids (like grease) (iii) solids (like talcum powder).

When we apply a libricant between the moving parts of a machine, a thin layer of this lubricant is formed between the two surfaces. As the surfaces now do not rub against each other directly, friction is reduced. Interlocking of irregularities between the (now) changed surfaces reduces considerably and movement becomes smooth. Oiling/greasing of machines results in less wear and tear, and hence, less energy wastage. This helps to increase the efficiency of machines.

Sometimes we use solids (in the form of powders) as lubricants. For example, when we play a game of carrom-board, we often sprinkle talcum powder on the carrom-board. By sprinkling talcum powder (on carrom-board), the friction between the 'striker' and the 'board' is very much reduced and the 'striker' moves smoothly on the board.

In some machines, it may not be advisable to use oil as a lubricant. An air cushion between the moving parts is also often used to reduce friction.

Do You Know?

A hovercraft is a vehicle which can travel on both land and water without much friction. It moves on a cushion of air provided by powerful pumps.

Compressed and purified air can also act as a lubricant. It provides an elastic cushion between the moving parts, thus reducing friction. It has the added advantage of preventing dust and dirt from collecting on the moving parts.

It is these properties of air that play a very important role in the smooth ride of a hovercraft.

3. **Ball-bearings:** We know that rolling friction is smaller than sliding friction. Sliding can be replaced by rolling, (in most machines) by use of ball-bearings. For example, we use ball-bearings in shafts of motors, dynamos, axles of vehicles and so on.

Fluid Friction

We now know that whenever a solid object moves over some solid surface (of another object), frictional force (solid friction) comes into play. This opposes the relative motion between the two surfaces in contact.

But what happens when an object moves through air? What do you think? The air also exerts a force of friction even though air itself is very light and thin. We call this friction as **air resistance**; it also opposes the motion of objects through it. Like air, water and other liquids also exert a force of friction when objects move through them.

Thus we can say that **fluids** (collective term for liquids and gases) too exert force of friction (**fluid friction/drag**) on objects moving through them.

The **force of (fluid) friction** on an object, in a fluid, depends on the—

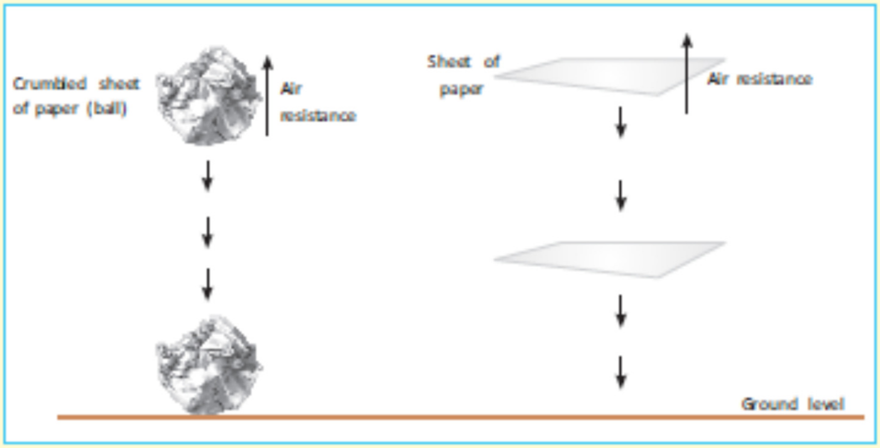
1. **nature of the fluid.**
2. **shape of the moving object (the area of contact).**
3. **speed of the moving object (with respect to the fluid).**

Air resistance, for example, increases with an increase in the speed of the object moving through it.

Activity 6

Take two large sheets of aluminium foil/thick paper that are identical in size and shape. As both the sheets are made of the same material, it can be assumed that they have the same mass. Now, crumble one sheet into a tight ball. Hold both—the ball and the other sheet of foil– head high and drop them both at the same time. What do we observe?

Which piece of foil falls with a greater speed? You will find that the piece, that has been crumbled into a ball, falls with a greater speed. This shows that it experiences much less air resistance. This, in turn, implies that greater the surface area of a body, the more is the resistance that the air offers to its motion. In other words, fluid friction depends on the shape of the object moving through the fluid.



We, thus, realise that fluid friction can be reduced to a great extent by (suitably) adjusting the shapes of bodies.

We also observe that when objects move through fluids with a higher speed, a larger force (due to fluid friction) opposes their motion. They can lose a considerable part of their useful energy to overcome this fluid friction. To minimise this energy loss, the bodies/objects are given special shapes.

In Class-VI, we have already learnt that birds and fishes have to move about in fluids almost all the time. Their bodies must, therefore, have evolved to shapes, which would make them lose less energy in overcoming fluid friction. If we look carefully at the shapes of an aeroplane and a boat we find that the shape of an aeroplane has some similarities to the shape of birds and the shape of a boat is somewhat similar to that of a fish.

Nature, thus, gives many useful ideas to mankind. Scientists often put them to use in designing the shapes of objects. Sports vehicles are often so designed (made more pointed towards front) that air flows smoothly over their surfaces in such a way that every air particle passes a particular point with the same speed and in the same direction. Such a flow is called **streamline flow;** all such special shaped bodies are called **streamlined bodies**. A streamlined flow of air, over the surface of a vehicle, reduces friction (air resistance) and helps it to acquire a faster speed.

Do You Know ?

Look around and you will find that the vehicles, moving on the road, come in a variety of shapes and designs. These different shapes and designs are constantly evolved and developed by car engineers and designers. Their attempts not only make the car look beautiful but also reduce the effects of air friction when they move on the roads. Racing cars, which have to move really fast, are given a very different shape. Their special (streamlined) shapes lower the air resistance to very low values; this enables these cars to move really fast.

Keywords

air resistance	the frictional force exerted by air against a moving object.
ball bearings	small metal balls, that when placed between the moving parts of a machine, help to reduce friction; this results in a very much smoother motion of such parts.
fluid	a substance (like a liquid) that can flow easily; it has no fixed shape. It takes the shape of its container.
fluid friction/ drag	the frictional force, exerted by fluids, against a moving object.
friction	a force that opposes any relative motion between the surfaces of two objects in contact.
limiting force of friction	maximum value of the force of friction between two surfaces (in contact with each other) that comes into play just before the onset of a relative motion between them.
lubricants	a substance which can reduce the force of friction between the two surfaces in contact.
rolling friction	the force of friction resisting the (rolling) motion when a body rolls on a surface.
sliding friction	the friction that acts between an object and a surface when the object is sliding over that surface.
static friction	the self-adjusting (up to a limit) force of friction that exists between a stationary object and the surface on which it has been kept.
streamline flow	a systematic regular flow of a fluid in which all the particles, that pass any given point, follow the same path with the same speed.
streamlined shape	a special shape that lowers the frictional drag between a fluid and an object moving through that fluid.

You Must Know

1. Whenever an object moves, or tends to move, over the surface of another object, an (opposing) force comes into play; this force acts parallel to the surface of contact and opposes any relative motion between the object and the surface. This opposing force is called force of friction or simply friction.
2. Friction is caused by the 'interlocking of irregularities' in the surfaces of the two objects which are in contact with each other.
3. For a given pair of surfaces, friction depends upon the state of smoothness or roughness of those surfaces and on the extent of hardness that presses the two surfaces together.
4. Static friction comes into play when we try to move an object which is at rest. Static friction is a self-adjusting force, but only up to a certain (maximum) limit.
5. The maximum value of the force of static friction is called limiting friction.
6. Sliding (kinetic) friction comes into play when an object is sliding over the surface of another object. Sliding friction is (a little) less than static friction.
7. Rolling friction comes into play when an object rolls over the surface of another object. Rolling friction is much less than sliding friction. This fact led to invention of wheels which, in turn, led to a revolution in transportation.
8. For many of our activities, like walking, writing, holding things, etc, friction is a necessary and important requirement.
9. Friction is quite often undesirable as it reduces the efficiency of machines.
10. Friction can be increased by making the surfaces more rough; it can be decreased by making the surfaces smooth.
11. The soles of the shoes and the tyres of vehicles are 'treaded' to increase friction between them and the ground.
12. Friction can be reduced by polishing the surface, or by putting lubricants on a surface. The use of ball bearings, in machines, also helps to reduce friction.
13. Fluids also exert frictional force on the objects moving through them. This force depends upon the nature of the fluid, the shape of the moving object and the speed of the moving object with respect to the fluid.
14. Fluid friction can be minimised by giving a special shape (called 'streamlined shape') to the objects moving through the fluid.

Something To Know

A. Fill in the blanks.

1. Friction always __________ any relative motion between the two surfaces that are in contact with each other.
2. Static friction is always __________ than sliding friction.
3. Sportsmen use shoes, fitted with spikes, to __________ friction between their shoes and the ground.
4. Sprinkling of talcum powder, on the carrom-board, helps to __________ friction.
5. Frictional force, on an object moving in a fluid, depends on its __________ .
6. The shape of an aeroplane is __________ to reduce, the effects of friction, due to air.

B. State True or False for the following statements.

1. When a body slides over smooth and wet surfaces, the amount of interlocking of irregularities, of the two surfaces in contact, increases. __________
2. If a car moves eastwards, the force of friction acts southwards. __________
3. Friction depends on how hard the two surfaces press against each other. __________
4. The sole of shoes and the tyres of the vehicles are 'treaded' to decrease the effects of friction. __________
5. Lubricants can be liquids, semi-liquids or solids. __________
6. Friction can be increased by using ball bearings between the moving parts of machines. __________

7. Fluid friction can be minimised by giving suitable shapes to the objects moving through the fluid. ____________

C. Tick (✓) the correct option.

1. Suppose your writing desk is tilted to a position where a book kept on it just starts sliding down. The figure, showing the correct direction of frictional force acting on it, is—

2. Two boys are applying oppositely directed, and equal in magnitude, forces on a box as shown in the figure.

In such a case, the force of friction, that would exist between the lower end of the box and the ground, would be called—

- ☐ sliding friction
- ☐ static friction
- ☐ fluid friction
- ☐ rolling friction

3. Four students were asked to arrange the (frictional) forces, due to rolling, static and sliding friction, in an increasing order. Their arrangements are listed below. The correct arrangement is —

- ☐ rolling, static, sliding
- ☐ rolling, sliding, static
- ☐ static, sliding, rolling
- ☐ static, rolling, sliding

4. The energy, 'used up' in overcoming friction, gets converted mainly into—

- [ ] sound energy
- [ ] heat energy
- [ ] light energy
- [ ] chemical energy

5. Rahul rolls a ball on a wooden surface. The ball covers a certain distance before coming to rest. To make the same ball cover a (much) longer distance, before coming to rest, Rahul should—

- [ ] spread a newspaper on the wooden surface.
- [ ] spread a towel on the wooden surface.
- [ ] sprinkle talcum powder on the wooden surface.
- [ ] spread a jute bag on the wooden surface.

6. A block is sliding on a horizontal surface. The force of friction between the two can be increased by—

- [ ] decreasing the area of contact of the block with the surface.
- [ ] applying a layer of some lubricant on the surface.
- [ ] by polishing the surface.
- [ ] by putting a second identical block on top of the given block.

D. Answer the following questions in brief.

1. Define the terms (a) static friction (b) sliding friction.
2. State the meanings of the terms (a) rolling friction (b) fluid friction.
3. State the likely cause of friction.
4. A box is resting on the floor. To move it, a (variable) force is applied as shown in the diagram below.

Box is at rest — Fig (a) | Box is at rest — Fig (b) | Box just begins to slide — Fig (c)

(a) Give the (likely) value of the force of limiting friction.

(b) Why does the box stay at rest in the cases corresponding to Fig (a) and Fig (b)?

(c) Mark the direction of frictional force, and mention the kind of frictional force that comes into play, in each case.

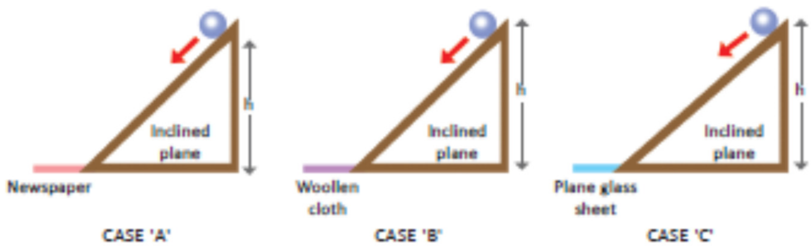
5. Name the kind of frictional friction, that comes into play, when a book, kept on a collection of cylindrical pencils, is moved by pushing it.

6. Why are objects given special shapes when they are moving through fluids? Write the name given to these special shapes?

E. Answer the following questions.

1. Define Force of friction. List the factors affecting the force of friction. Explain with examples.

2. A ball is allowed to roll down an inclined wooden plane from a given height. At the foot of the inclined plane, it moves on a horizontal surface, differently 'covered', one by one, as shown in the following figures.



In which case, is the ball likely to move the longest distance? Give reason for your answer.

3. Explain why sliding friction is slightly less than static friction.

4. Give reasons for the following—

(a) We tend to slip when we step on a banana peel.

(b) It is easier to push a lighter box than a similar heavy box on the same floor.

(c) The force, needed to start a cart, is (somewhat) greater than the force needed to keep it moving with a uniform speed.

(d) Sportsmen use shoes fitted with spikes.

(e) Ball-bearings are used in machines.
(f) Tyres of the vehicles need to be changed regularly.
(g) Machines parts are frequently oiled or greased.
(h) Sport cars, aeroplanes and boats are designed to have a streamlined shape.
(i) Metal chains are wrapped on tyres when they run on icy roads.
(j) Rollers are used for transporting luggage.

5. State and explain, with examples, how friction can help the cause of motion in certain situations.

Value Based Question

Ramit and Kush, both students of Class VIII, would often strongly argue with each other about the different aspects of their day-to-day school life. However, they made a very good 'doubles team' of their school, for the interschool badminton tournaments. When playing together, they would forget all their differences and play as a 'team' to ensure their school's victory.

Their science teacher, who was also their badminton coach, would quote their example. He would explain to his students how the force of friction can be a 'good friend' and 'a source of help' even though it was usually viewed only as a 'trouble maker'.

1. State the values displayed by Ramit and Kush.
2. Give two examples of situations in which the force of friction is a 'source of help'.
3. Stage a play in which different members of two teams give examples to show that the force of friction is (i) a friend (ii) a foe.

Something To Do

1. **Imagine that friction were to suddenly vanish altogether. Write a short story/play on how would our lives be affected.**
2. **List some sports/games where friction is a 'help' or 'a source of trouble'. Discuss your list with your friends with some supporting pictures.**
3. **In the Activity 1 of this Chapter, what is likely to happen if you change the angle which the tray makes with the table top. Does the angle, made by the inclined plane with respect to horizontal, affect the sliding? Discuss your findings with your teacher. Does the angle (at which sliding just starts) depend on the nature of the two surfaces in contact? Find the answer using different materials/toy cars and so on.**