CHAPTER 10

Mass, Weight and Density

You may have often heard the terms 'mass' and 'weight'. Do you know exactly what they mean? What is the difference between them? It is believed that, when Sir Issac Newton, a great scientist, saw an apple falling from the tree, he started to wonder why that happened while the sun, moon and other stars remained overhead in the sky? That led to his understanding of the force of gravity.

As you read further, you will understand the meaning of the terms mass, weight and density and also find the answer to this riddle.

Mass and Weight

Mass is the amount of matter in a body. A truck has more mass than a bicycle. If you try to push a truck, you will not be able to do so. But if you try to push a bicycle, you can probably do it very easily. Mass is measured in **kilograms**. Small masses are measured in **grams** and **milligrams**. Large masses are measured in **tonnes**. The units in which mass is measured are given below.

1 g (gram) = 1000 mg (milligrams)
1 kg (kilogram) = 1000 g (grams)
1 tonne = 1000 kg (kilograms)

All objects on earth are pulled towards it by the force of **gravity**. Weight is a measure of this force of gravity. **The weight of an object is the force with which it is attracted towards the earth.** Like all forces, weight is also measured in **Newtons (N)**. When you 'weigh' something, you are actually measuring this force. A large mass is pulled towards the earth with a greater force than a small one. Therefore, the weight of a car is more than the weight of a bicycle. Weight is measured using a **spring balance.** When you hang an object on the spring balance, the force of gravity acting on the object pulls the spring down. The force of gravity on the moon is less than that on the earth. So, the weight of an object, too, will be less on moon than on the earth.

A mass of 1kg is pulled towards the earth by a force of 9.8 N. So the weight of 1 kg is 9.8 N or **1 kg-wt = 9.8 N.**

If the mass of an object is 2 kg, then gravity pulls it down with a force of $9.8 \times 2 = 19.6$ N. In other words, 2 kg-wt = 19.6 N. The spring balances that we use in school laboratories are marked in kilogram-weight or gram-weight instead of in Newtons.

Activity 1 Using a Spring Balance

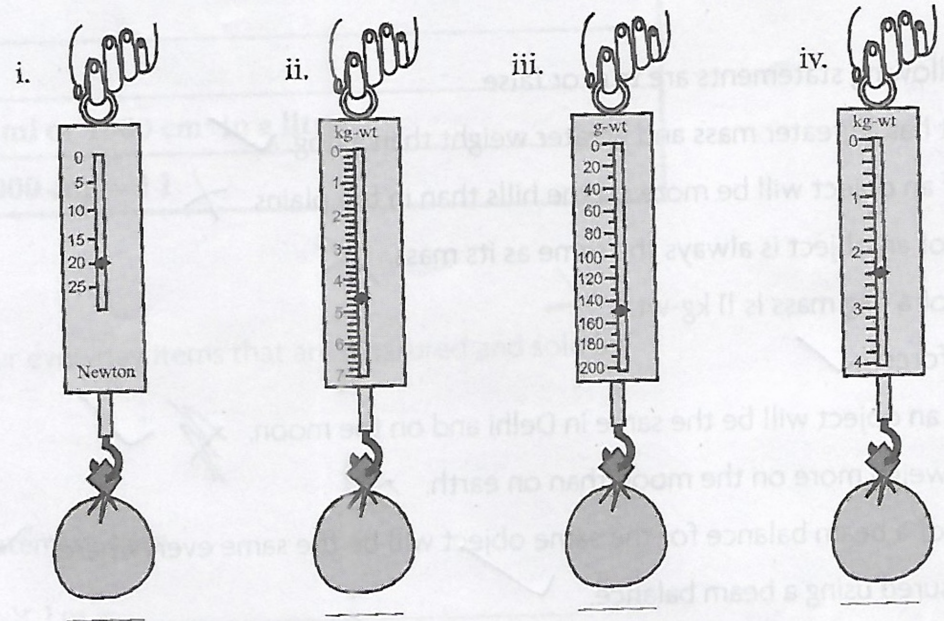
You will need: a spring balance, a stand and several small objects to weigh

Work in groups. In your notebook, make a table and list the objects you have. Hang your spring balance from a stand (if available). Look carefully at your balance. Find out the units in which it can take measurements. Find out how many small divisions are marked between two larger ones. How much does each small division measure?

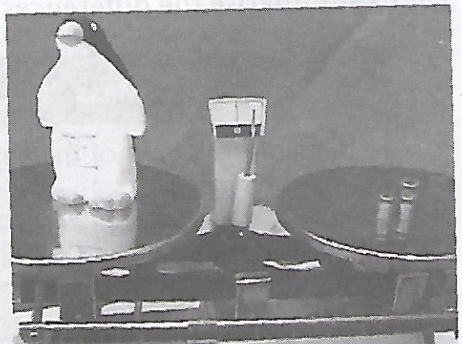
Make sure that your balance shows 'zero' before you start. Ask your teacher to help set the balance otherwise. Now, use your spring balance to weigh the objects you have.

Exercise 1

Look at the pictures given here carefully. Below each picture write the weight of the object.



On the other hand, a **beam balance** compares the force pulling the object with the force pulling a standard mass. If these forces balance each other, it means that the two objects have the same mass. This would be the same, no matter where the balance is used.



▲ beam balance

Exercise 2

Do you see this type of balance in use? Where? Find out the standard masses used for comparison.

Exercise 3

The force of gravity on an object of mass 1 kg is 9.8 N on earth. (Since 9.8 is very close to 10, we can make our calculations easier by using 10 instead of 9.8.) Now complete the following table.

Mass (Kg)	Weight (N)
i. 1	10
ii. 4	40
iii. 48	480
iv. 65	65

Gravity is not the same all over the earth's surface. **The force of gravity goes on decreasing the further the body moves from the centre of the Earth**. On the moon, the pull of gravity is much less than on the earth. The force of gravity on the moon is one-sixth that on the earth.

Exercise 4

Indicate if the following statements are true or false.

i. An elephant has a greater mass and greater weight than a dog.

ii. The mass of an object will be more on the hills than in the plains.

iii. The weight of an object is always the same as its mass.

iv. The weight of a 1 kg mass is 11 kg-wt.

v. Weight is a force.

vi. The mass of an object will be the same in Delhi and on the moon.

vii. A body will weigh more on the moon than on earth.

viii. The reading of a beam balance for the same object will be the same everywhere.

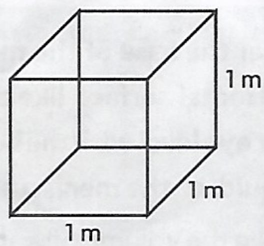
ix. Mass is measured using a beam balance.

x. The mass of 1 kg of sweets on the moon will be 1000 g.

Let us summarise the differences between mass and weight.

Mass	Weight
i. It is the amount of matter in a body.	**i.** It is a measure of the gravitational force acting on an object.
ii. It is measured using a beam balance.	**ii.** It is measured using a spring balance.
iii. It is measured in kg and g.	**iii.** It is measured in Newtons and kg-wt.
iv. It is always the same everywhere.	**iv.** It varies, depending on the force of gravity.

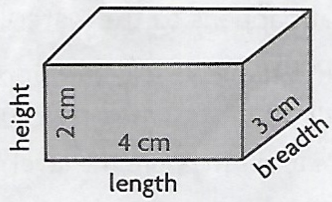
Measuring Volume



Volume is the amount of space occupied by an object. The unit of volume is **1 m³**. This is the space occupied by a cube, each of whose sides is equal to 1 m.

The volume of a rectangular object, such as a box, can be found from the measurements of its length, breadth and height. Its **volume = length × breadth × height**.

Exercise 5



What is the volume of the box shown in the figure?

We can also measure the space or volume occupied by liquids. The units used are given in the follwing table.

The volume of liquids is measured in millilitres (ml) or litres (l).
1 ml = 1 cm³
There are 1000 ml or 1000 cm³ in a litre.
or 1000 ml = 1000 cm³ = 1 l

Exercise 6

Name at least four everyday items that are measured and sold by volume.

Exercise 7

Complete the statement here.

$1 m^3 = 1 m \times 1 m \times 1 m =$ ______________ cm^3

Activity 2 Measuring the Volume of an Irregular Solid

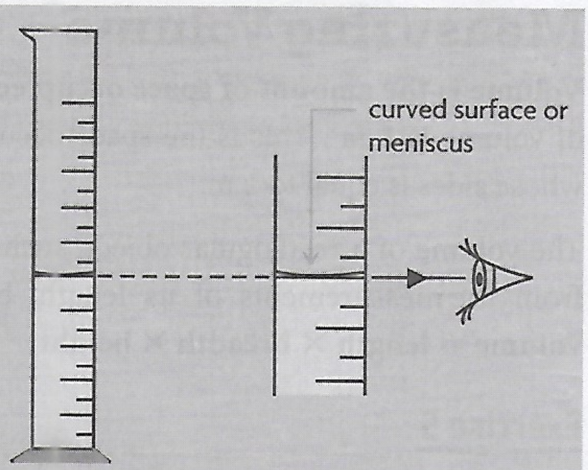
You will need: a measuring cylinder, some water, string, a stone

Pour water into the measuring cylinder. Note the level of water in the cylinder.

In what units is the cylinder marked? What is the smallest amount you can measure?

Is it better to hold the measuring cylinder in your hands or to leave it on the table to note the level of water? Why?

Remember the base of the measuring cylinder should be on a horizontal surface like a table. Also you must read with your eye level with the bottom of the curved surface of the liquid, or the meniscus, as shown in the diagram.



Note down the volume of water in the measuring cylinder.

Tie a string to the stone and lower it into the measuring cylinder.

What happens to the water level? Can you say why this happens?

The level of water rises because the stone takes up space and displaces some water.

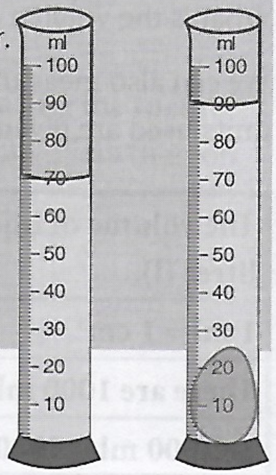
Once again, measure the level of the water in the cylinder. Complete the steps below:

Level of water at start of experiment = ______________________

Level of water + stone = ______________________

Therefore, volume of stone = ______________________

The volume of the stone is equal to the volume of the water it displaces.

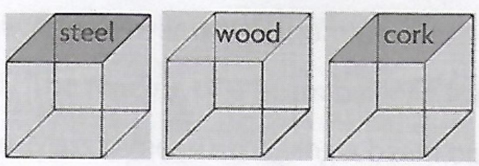


Exercise 8

Study the pictures and find out the volume of the stone. ▶

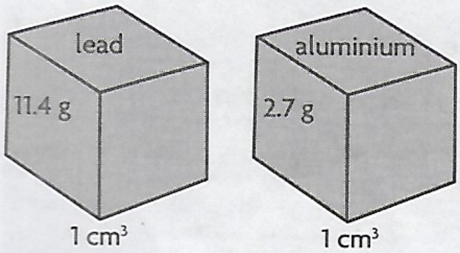
Density

Exercise 9



The picture shows you three cubes of the same size, made of steel, wood and cork. Can you say which one would have the greatest mass?

The three cubes have the same volume. However, you would certainly say that the steel cube has the greatest mass. The wooden cube has a smaller mass than the steel cube; and the cube made of cork would have the smallest mass. More matter is packed into the same space in the steel cube than in the wooden one. Scientists use another term, **density**, which tells you how tightly matter is packed in different substances.



Look at the cube of lead and aluminium blocks shown in the next diagram. Both are solid metals.

The figure shows that a cube of aluminium of volume 1 cm^3 has a mass of 2.7 g, whereas a block of lead of the same volume has a mass of 11.4 g. The lead block has a greater mass packed into the same volume. Thus, lead has a greater density than aluminium.

Density is defined as the mass per unit volume of a substance. In other words, it tells you the mass of 1 cm^3 or 1 m^3 of a substance.

The density of steel is 8 g/cm^3. This means that 1 cm^3 of steel has a mass of 8 g. The density of wood is 0.7 g/cm^3. This means that 1 cm^3 of wood has a mass of only 0.7 g. Which one has more matter packed in the same volume? Of course, steel. Thus, steel has a greater density than wood.

In everyday language, steel is said to be 'heavier' than wood. This does not mean that a steel needle has more mass than a tree trunk. It means that a piece of steel has more mass than a piece of wood of the same volume.

Exercise 10

Complete the following sentences.

i. The density of iron is 7.8 g/cm^3. This means that ______________.

ii. The density of sand is 1600 kg/m^3. This means that the mass of 1 m^3 of sand is ______________.

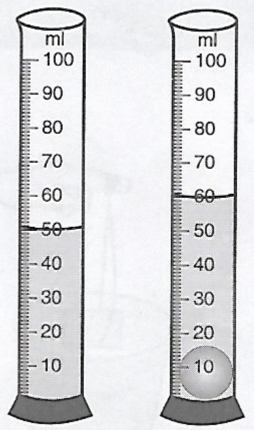
iii. The mass of 1 litre of water is 1000 g or 1 kg. Hence its density is ______________.

iv. 1 cm^3 of gold has a mass of 17.5 g. Its density is ______________.

v. Marble has a density of 2.7 g/cm^3. This means that 1 cm^3 of marble has a mass of __________ g. Thus, 200 cm^3 of marble will have a mass of ______________ g.

vi. 1 ml of milk has a mass of 1.03 g. Thus, the density of milk is ______________.

Exercise 11



Aditya has an iron ball. The mass of the ball is 79 g. He measured the volume of the ball by placing it in a measuring cylinder with water. Study the pictures and calculate the volume of the ball. Then find out its density.

Volume of the ball =

Mass of the ball = 79 g

10 cm^3 of the ball has a mass of 79 g.

1 cm^3 of the ball will have a mass of ______________.

Thus, the density of the iron ball is ______________.

If we know the mass and the volume of a substance, its density can be calculated from: **Density = Mass ÷ Volume**

Exercise 12

In your notebook, calculate the density of the following substances.

i. 193 g of gold has a volume of 10 cm^3.

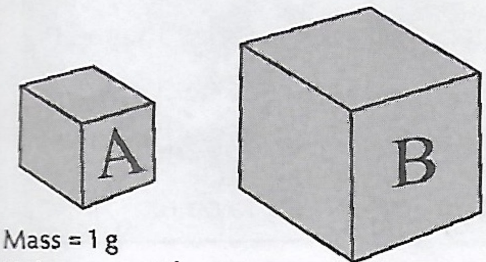
ii. 18 g of cooking oil has a volume of 20 cm^3.

iii. A glass ball has a volume of 5 cm^3 and has a mass of 12.5 g.

iv. An aluminium plate of volume 10 cm^3 has a mass of 27 g.

Exercise 13

Study the pictures and then answer the question that follows.



Mass = 1 g
Volume = 1 cm^3

Mass = 120 g
Volume = 120 cm^3

After looking at the pictures, four students got into an argument and this is what each of them said.

Ravi: No doubt, cube B is of greater density as it is bigger.

Medha: No, cube A has more matter stuffed into such a small space, hence it is denser.

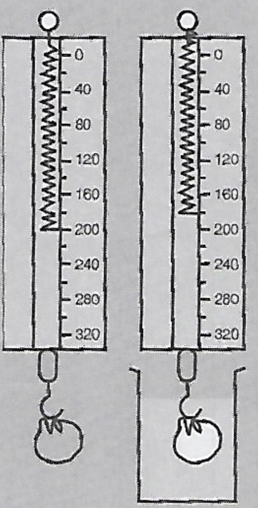
Kavish: It is simple! Both cubes have the same density.

Ramesh: I think it is not possible to find out which one is denser as there isn't enough information.

Who do you think is correct?

Floating and Sinking

Try this out when you are having a bath. Lift a mug full of water from the bottom of a bucket filled with water. Do you notice that as long as you are lifting it under water, it feels quite light. As soon as it comes out of the water, it feels much heavier. Have you ever wondered why objects feel lighter in water than outside it?



Activity 3

You will need: a stone, string, a spring balance, a beaker with water

Tie the string to the stone and hook it to the spring balance. Note down the reading in the spring balance. That will tell you the weight of the stone in air.

Weight of the stone in air = ______________ g-wt

Now, lower the stone into water and note the reading once again.

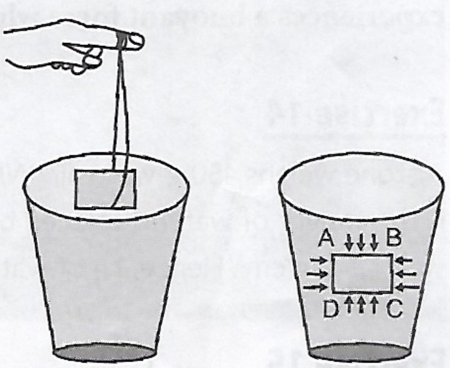
Weight of the stone in water = ______________ g-wt

Did you find that the stone weighed less in water? This happens because water exerts an upward force on the stone. This upward or **buoyant force** makes the immersed stone appear to be lighter than when it was in the air.

Activity 4

Take an empty plastic bottle. Close the mouth of the bottle with an airtight stopper. Put it in a bucket filled with water. You will see that the bottle floats. Push the bottle into the water. Do you feel an upward push? Try to push it deeper down. You will find it difficult to push deeper and deeper. Now, release the bottle. It bounces back to the surface. This indicates that water exerts an upward force on the bottle.

Why does water exert an upward force? The picture here shows you what happens to a brick immersed in a bucket of water. The water pressure inside the bucket increases with depth. At any given level, it acts equally in all directions. Hence, the upward force on DC is more than the downward force on AB. This means there is a resultant upward force acting on the brick ABCD. As long as the brick is under water, it seems to be lighter because of this.



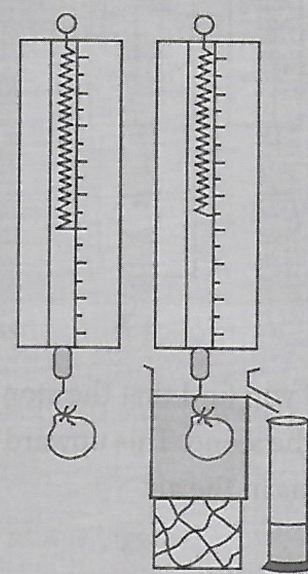
Similarly, in Activity 3, the buoyant force of the water pushes the stone upwards. So it seems as if the stone weighs less when it is in water. If you let go of the string, the stone will sink. The weight of the stone is much more than the buoyant force.

Archimedes Principle

Activity 5 Teacher Demonstration

You will need: a stone tied to a string, a measuring cylinder with water, a spring balance that can measure up to 1 g-wt

The picture shows you how to set up the experiment. Your teacher will show you this activity in class.



Fill in the blanks as you watch the demonstration.

Weight of the stone in air = _____________ g-wt

Weight of the stone in water = _____________ g-wt

Apparent loss in weight = weight in air − weight in water =

_____________ g-wt

The volume of water displaced = _____________ ml

The mass of this water = _____________ g (Density of water = 1 g/cm^3)

The weight of water displaced = _____________ g-wt

Look at the readings noted by you carefully. The weight of water displaced is equal to

____.

You found out that when the stone was immersed in water, **the apparent loss in weight was equal to the weight of water displaced**. The apparent loss in weight of the stone is equal to the upward thrust or the buoyant force. Hence, the buoyant force is equal to the weight of water displaced. This fact was first discovered by Archimedes, a Greek scientist who lived centuries ago.

The Archimedes principle states that when a body is partially or wholly immersed in a liquid, it experiences a buoyant force which is equal to the weight of liquid displaced by it.

Exercise 14

A stone weighs 450 g-wt in air. When fully immersed in water, its weight is found to be 400 g-wt. What is the weight of water displaced by the stone? What is the volume of the stone? (**Hint:** The density of water = 1 g/cm^3. Hence, 1 g of water has a volume of 1 cm^3 or 1 ml.)

Exercise 15

A metal ball weighs 600 g-wt in air and is found to displace 25 ml of water. What is the weight of water displaced? What is the weight of the metal ball in water?

575 g/wt

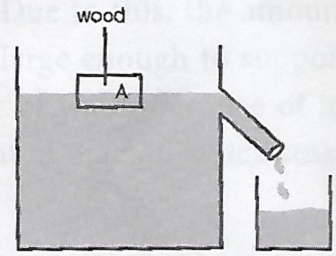
Activity 6

You will need: a piece of wood or cork tied to a string, a spring balance, a beaker with water

First weigh the wood in air. Lower it into water and find out its weight in water.

Weight of wood in air = ____________________

Weight of wood in water = ____________________



Did you find that the wood is floating and the reading in the spring balance is zero when you weighed the wood in water? Let us understand why this is so.

In the diagram shown here, a wooden block A is floating. The buoyant force of the water must be balancing the weight of the block. Not all of the block is under water. The volume of water displaced is less than the volume of the block. However, the weight of water displaced equals the weight of the block. This happens because water is more dense than wood. This can be stated as the **Law of Floatation: A floating body displaces a weight of liquid equal to its own weight.**

Activity 7

You will need: a pan balance, a beaker, an overflow can, some nails, a small wooden block

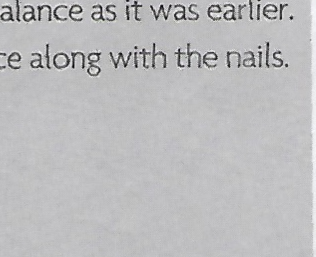
Take a beaker. Put it one pan of a balance. Put enough nails or some other small objects on the other pan to balance the scales. Take an overflow can and fill it with water. When water stops flowing out of its spout, put the beaker under the spout. Take the wooden block. Gently place it in the overflow can. Take care that the block remains away from the spout. Remember that the floating block will not be completely submerged in water. It should float freely and the water it displaces should be collected in the beaker. Return the beaker containing the displaced water to the same side of the balance as it was earlier. Take the wooden block out of the water and put it on the other side of the balance along with the nails.

Are the scales of the pan balanced now?

Is the weight of the block equal to the weight of the water displaced?

Now, try this experiment with some other objects that float on water.

What do you think would happen if, instead of wood, you tried this experiment with a stone or some other object that sinks in water?



Now look at the steel block B. It sinks in water. The buoyant force exerted by water is not enough to make the block float. The buoyant force is less than the weight of the block. The volume of water displaced is equal to the volume of the block. However, water is less dense than steel. Thus, the weight of water displaced is less than the weight of the block. The block is denser than water and sinks in it.

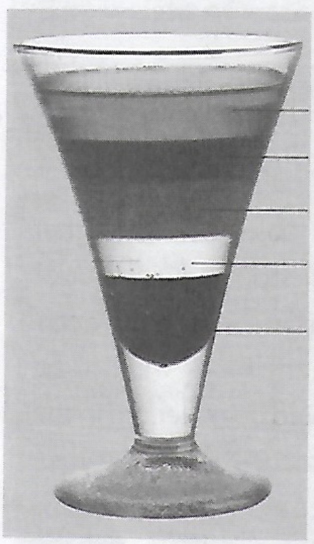
Hence, objects of density less than that of a liquid will float on the liquid. Objects of density greater than that of a liquid will sink in the liquid.

What happens when different immiscible liquids are mixed? For example, when oil and water are mixed, which one floats on top of the other?

Exercise 16

The table below shows the density of some substances. Study the table. Which liquid will float on oil (density of oil = 0.8 g/cm^3)?

Liquid	Density (g/cm^3)
A	1.05
B	0.7
C	0.9
D	1.2



Exercise 17

The picture here shows the arrangement of some immiscible liquids, after all of them were poured into a glass. In which option below are the liquids arranged correctly in order of decreasing density?

i. olive oil, glycerine, sugar syrup
ii. glycerine, water, sugar syrup
iii. sugar syrup, water, surgical spirit
iv. water, glycerine, spirit

Exercise 18

Pratibha poured three immiscible liquids, kerosene (density = 0.7 g/cm^3), water (density = 1 g/cm^3) and glycerine (density = 1.2 g/cm^3), into a beaker. Draw a diagram to show how they would be arranged in the beaker. Next, she dropped a lump of aluminium (density = 2.9 g/cm^3) and a piece of cork (density = 0.4 g/cm^3) into the beaker. Draw a diagram to show where each of them would come to rest.

Exercise 19

A tree trunk floats on water. It weighs 200 kg-wt.

i. What weight of water must the trunk displace?

ii. What mass of water does it displace?

iii. If the density of water is 1000 kg/m^3, what volume of water is displaced by the trunk?

How can huge ships and supertankers made of heavy metal float whereas a small iron nail sinks in water? This is because of the shape of the ship. It has a large volume. Due to this, the amount of water displaced is much larger. This ensures that the buoyant force is large enough to support the weight of the ship. A small iron nail displaces only a small amount of water because of its shape. The buoyant force, therefore, is less and does not support the weight of the nail which sinks immediately.

Activity 8 Buoyancy of Different Liquids

You will need: a drinking straw, some plasticine or modelling clay, three identical beakers, fresh water, salt water, oil, marker pen

Take equal volumes of the three liquids in each beaker. Stick enough plasticine to one end of the straw so that it floats upright in the beaker with fresh water. Carefully mark on the straw the depth to which the straw sinks in water.

Now, float the straw in salt water and note the difference. What does this mean?

Finally, put the straw in oil and note the difference. Why do you think this happens?

In your notebook, draw three diagrams to show how the straw floats in each liquid.

Complete the sentences below to understand what happens.

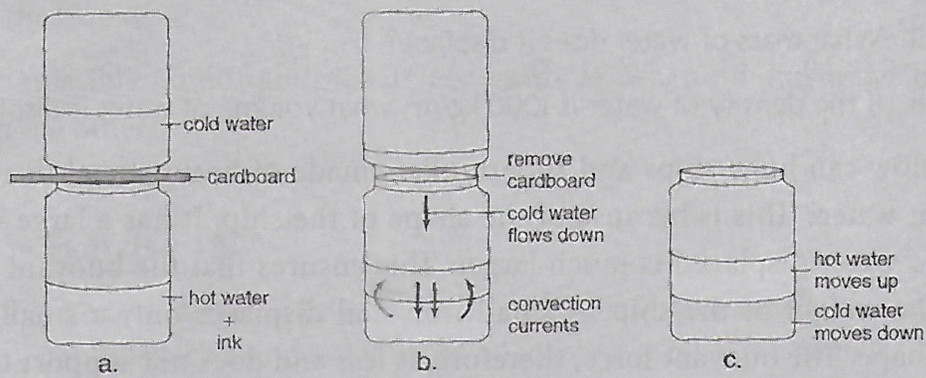
Salt water is ______ (less/more) dense than fresh water. The weight of salt water displaced will be ______ (less/more) than the weight of fresh water displaced. Hence, ________ (salt/fresh) water exerts a greater buoyant force. This explains why the straw rises higher in ________ (salt/fresh) water. The density of oil is ________ (less/more) than that of both ____________ (salt/fresh) water and ____________ (salt/fresh) water. Hence, the upthrust is ________ (most/least) in oil. The straw will be still ________ (higher/lower) in oil than in ____________ (salt/fresh) water.

Exercise 20

Why does the straw float lower in oil than in water?

Activity 9 Which is denser—hot or cold water?

You will need: two identical jam jars, cold and hot water, a few drops of ink, a piece of stiff cardboard (like a thick invitation card)



Fill one jar with hot water and add a few drops of ink to it. Place it on a table. Fill the second jar with cold water. Cover its mouth with the cardboard. Hold the cardboard in place firmly and invert the jar care fully on top of the first jar. Make sure that the mouths of the two jars are exactly in line with each other. Hold the upper jar in place with one hand and with your other hand, pull away the cardboard. Watch what happens. Can you say why?

Repeat the experiment. This time, invert the jar with hot water on top of the jar with cold water. What do you think will happen?

When a liquid in a beaker is heated from below, the warm water at the bottom is less dense than the cold water above it. The cold water sinks to the bottom, while the warm water rises to the top. In this way, currents are set up in the water. These you know are called **convection currents.**

Now try this. Dissolve five teaspoons of salt in cold water. Then pour it into a jam jar. Take cold coloured water in a second jam jar. Cover the mouth of the second jar with thick cardboard and invert the first jar on top of the second. What do you think you will see when you slowly pull away the cardboard?

CHECK IT OUT

***1.** i. 20 N; ii. 4.6 kg-wt; iii. 150 g-wt; iv. 2.4 kg-wt* ***2.** Rice, pulses, spices, vegetables and fruit are usually measured using this kind of balance. The standard masses used for comparison are 5 kg, 2 kg, 1 kg, 500 g, 200 g, 100 g, 50 g. These are usually made of iron.*

3.

Mass (Kg)	Weight (N)
i. 1	**10**
ii. 4	**40**
iii. 48	480
iv. 6.5	65

4. i, v, vi, viii, ix x are true. ii, iii, iv, vii, x are false. **5.** Volume of the box = length × breadth × height = 4 × 3 × 2 = 24 cm^3 **6.** Milk, fruit juices, drinking water, liquid medicines, petrol or diesel are sold by volume. **7.** 1 m^3 = 1 m × 1 m × 1 m = 100 cm × 100 cm × 100 cm = 1000000 cm^3 **8.** Volume of water displaced = 20 ml. Hence, the volume of the stone = 20 cm^3 **9.** The mass of the steel cube is the most. **10.** i. The density of iron is 7.8 g/cm^3. This means that **the mass of 1 cm^3 of iron is 7. 8 g**. ii. The density of sand is 1600 kg/m^3. This means that the mass of 1 m^3 of sand is **1600 kg**. iii. The mass of 1 litre of water is 1000 g or 1 kg. Hence its density is **1000 g/l or 1 kg/l**. iv. 1 cm^3 of gold has a mass of 17.5 g. Its density is **17.5 g/cm^3**. v. Marble has a density of 2.7 g/cm^3. This means that 1 cm^3 of marble has a mass of **2.7** g. Thus, 200 cm^3 of marble will have a mass of **540** g. vi. 1 ml of milk has a mass of 1.03 g. Thus, the density of milk is **1.03 g/ml**.

11. Volume of the ball = **10 cm^3**
1 cm^3 of the ball will have a mass of **7.9 g**
Thus, the density of the iron ball is **7.9 g/cm^3**.

12. i. Mass = 193 g; Volume = 10 cm^3
Density = Mass ÷ Volume = 193 ÷ 10 = **19.3 g/cm^3**
ii. Mass = 18 g; Volume = 20 cm^3
Density = Mass ÷ Volume = 18 ÷ 20 = **0.9 g/cm^3**
iii. Mass = 12.5 g; Volume = 5 cm^3
Density = Mass ÷ Volume = 12.5 ÷ 5 = **2.5 g/cm^3**
iv. Mass = 27 g; Volume = 10 cm^3
Density = Mass ÷ Volume = 27 ÷ 10 = **2.7 g/cm^3**

13. Kavish

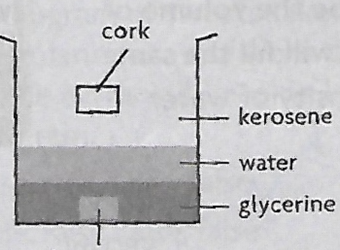
14. Weight of stone in air = 450 g-wt; Weight of stone in water = 400 g-wt, Apparent loss in weight = 50 g-wt
According to Archimedes principle, apparent loss in weight is equal to the weight of water displaced = **50 g-wt**. Thus, the volume of stone = **50 cm^3**.

15. Weight of the metal ball in air = 600 g-wt
Apparent loss in weight of the ball in water = weight of water displaced = **25 g-wt**
Thus, weight of metal ball in water = **575 g-wt**

16. B

17. iii

18.



19. i. Weight of water displaced = 200 kg-wt ii. Mass of water displaced = 200 kg
iii. Volume of water displaced = mass ÷ density = 200 ÷ 1000 = 0.2 m^3 **Activity 8:** Salt water is **more** dense than fresh water. The weight of salt water displaced will be **more** than the weight of