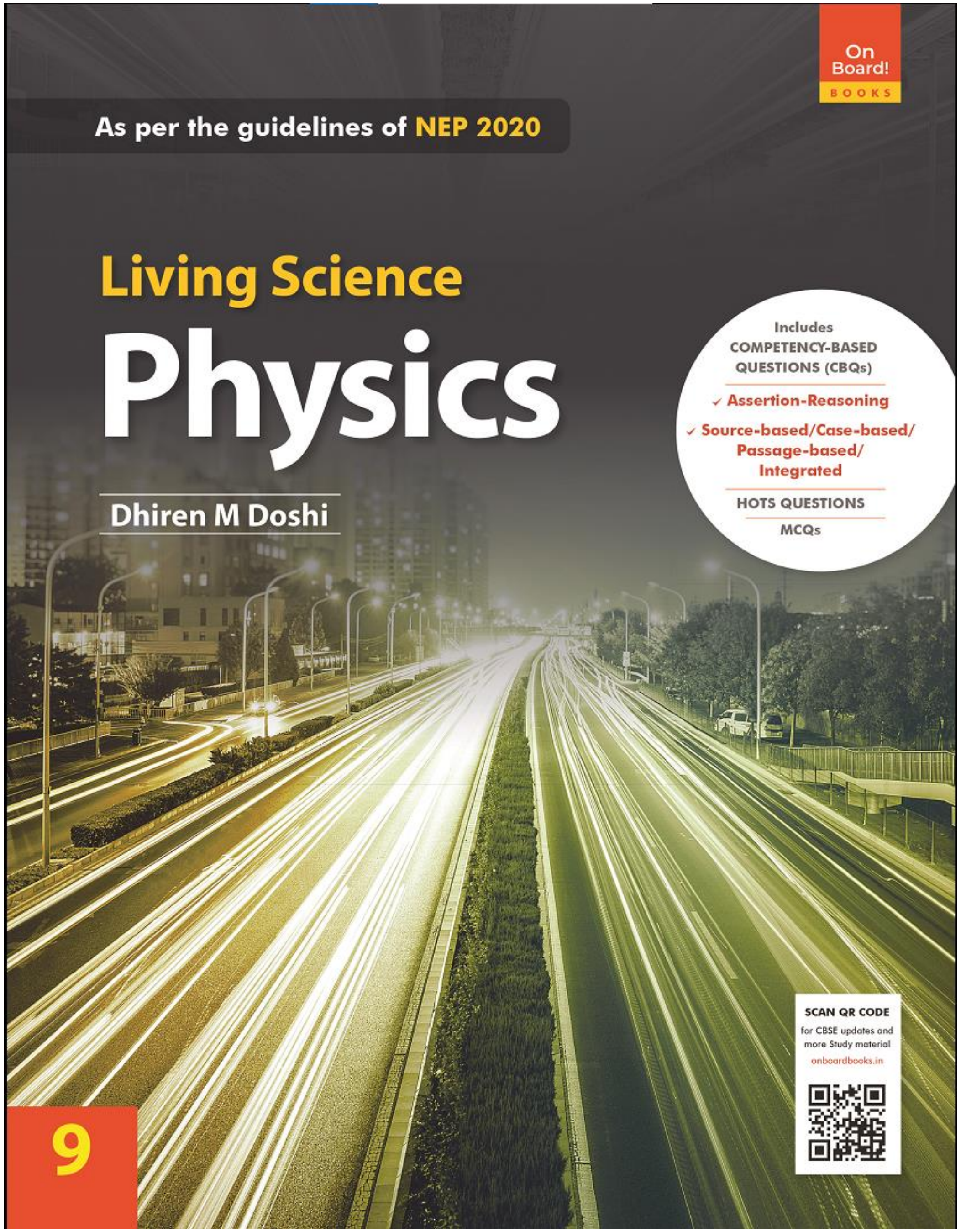
On Board!
BOOKS



CBSE
Living Science
Physics

Class 9

Chapter-4 Floatation

LEARNING OBJECTIVES

Thrust and Pressure

- ❖**Effects of pressure**

Pressure in Liquids

- ❖ **Mathematical expression for pressure exerted by a liquid**

Buoyant Force

- ❖**How does buoyant force help in making objects appear lighter in fluids?**
- ❖**Cause of buoyant force**
- ❖**Characteristic properties of buoyant force**

Archimedes' Principle

Principle of Floatation

Density and Relative Density

What is thrust?

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

Thrust: A Force acting perpendicular to the surface

If we stand on loose sand, we observe that our feet go deep into the sand.

It is because of our body weight. Our weight is the force acting vertically downwards. Here, the **force is acting perpendicular** to the surface of the sand. And this force is called thrust. Other examples of force acting perpendicular to the surface are:

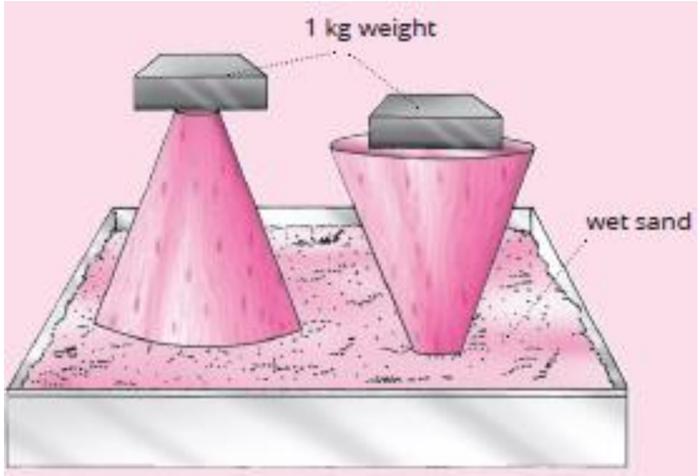
When we press a drawing pin, we apply force in the perpendicular direction.

When we push in the handle of the bicycle pump, we apply force in the perpendicular direction.

Since thrust is a force, its SI unit is the same as that of force, i.e. newton (N). So, the **SI unit of thrust is newton (N).** It is a vector quantity.

The Effect of Thrust

The effect of forces of the same magnitude on different areas is different. In this case, thrust is the same but effects are different. The effect of thrust on sand is larger when the conical wooden piece is made to stand with its narrow end than when kept with its broader end. The depression in the wet sand in case of the narrow end is more than that in case of broader end.



Pressure

The effect of thrust depends on the area on which it acts. It is useful to know the thrust per unit area to feel its effect. **The thrust per unit area is called pressure.** Thus, Pressure = Thrust /Area

The unit of pressure is therefore newton per metre square or N/m^2.

1 Pa (pascal) = 1 N/m^2

1 kPa = 1000 Pa = 1000 N/m^2

Blaise Pascal, in whose honour the SI unit of pressure is named.

Effects of pressure

The effect of force applied on a body is measured by the pressure exerted on it. The higher the pressure exerted on a body, the greater the effect it produces.

We know, Pressure = Thrust / Area

From the above expression, we conclude:

1. Pressure is directly proportional to thrust, i.e. the more the thrust, the more is the pressure and vice versa.

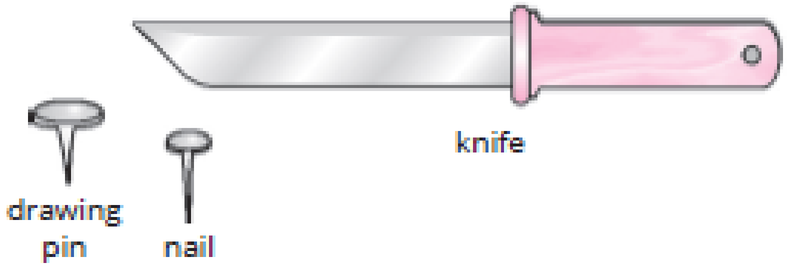
$$\text{Pressure } (P) \propto \text{Thrust}$$

2. Pressure is inversely proportional to the area of contact, i.e. the lesser the area of contact, the more is the pressure and vice versa.

$$\text{Pressure } (P) \propto 1/\text{ Area}$$

Thus, the effect of force is increased by decreasing the area on which it acts.

Drawing pins and nails have pointed ends and cutting edge of knives are sharpened to increase the effect of force.

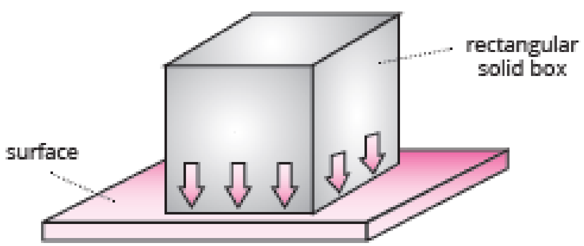


What is a Fluid?

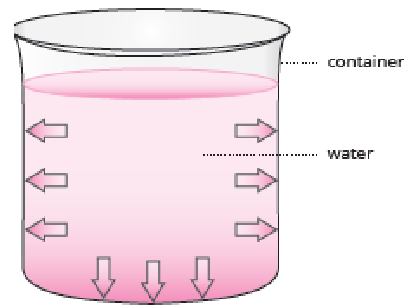
Any substance which has no fixed shape and has the ability to flow is called a fluid. All liquids and gases do not have fixed shape and can flow. Hence they are regarded as fluids.

Pressure exerted by a solid and a fluid

A solid exerts pressure on another surface on account of its weight. Similarly, fluids have weight and they also exert pressure on the base and walls of the container in which they are enclosed.



Pressure exerted by a solid only on account of its weight



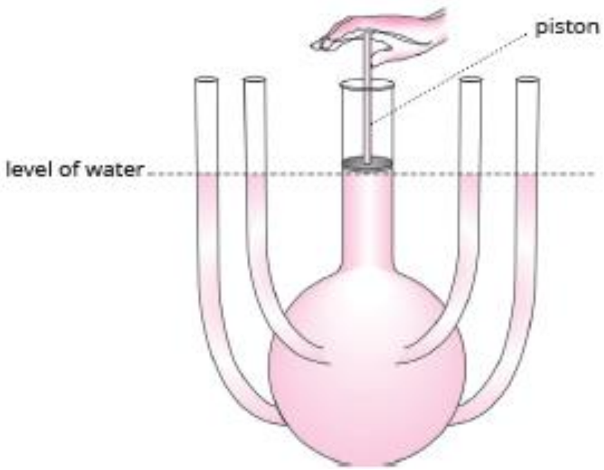
Pressure exerted by water (a fluid) on the base and walls of the container (in which it is enclosed)

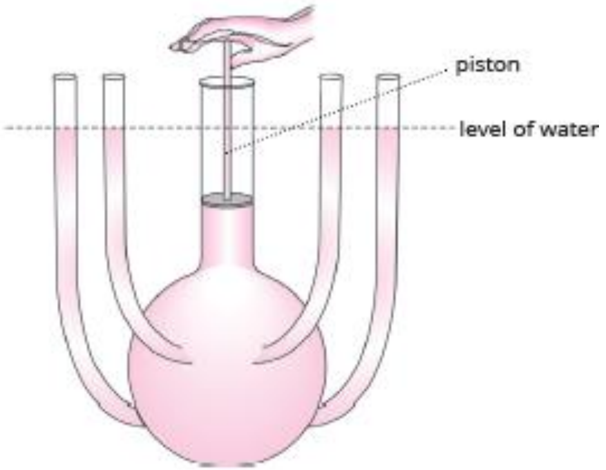
Study Tips: Fluid pressure acts perpendicular to any surface in the fluid no matter how that surface is oriented.

Pressure in Fluids

Like solids, fluids have weight and they also exert pressure on the base and walls of the container in which they are enclosed.

Whenever any pressure is applied anywhere on a confined fluid (liquid or gas), it is transmitted equally in all the directions throughout the fluid





Mathematical expression for pressure exerted by a liquid

Thrust at the base of the cylindrical column of liquid

= Weight of the liquid column

= Mass of the liquid column $\times$ g = $m \times g$

= $(V \times d) \times g$ (since mass $m = V \times d$)

Thrust = $(a \times h) \times d \times g$

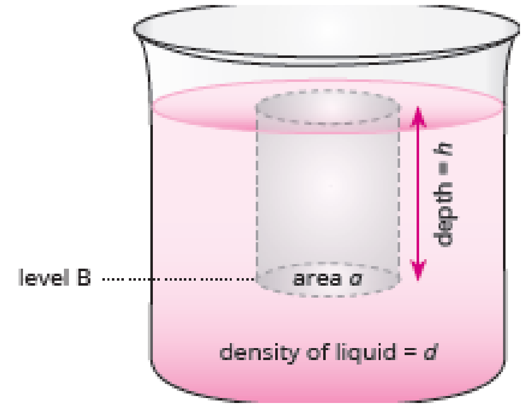
Pressure exerted by the liquid at the depth *h*

= Thrust/ Area

$=(a \times h \times d \times g) / a$

$P = hdg$

Pressure = Height of the liquid column × Density of the liquid × Acceleration due to gravity



Pressure = Volume of liquid displaced × Density of liquid × Acceleration due to gravity

Points to remember

a. Pressure exerted by a liquid contained in a vessel at a point inside it is directly proportional to its depth, density and acceleration due to gravity.

b. All points at the same depth in a liquid are under the same pressure.

c. Pressure due to the liquid at a point on the surface of the liquid is zero as height = 0. So, $hdg = 0$.

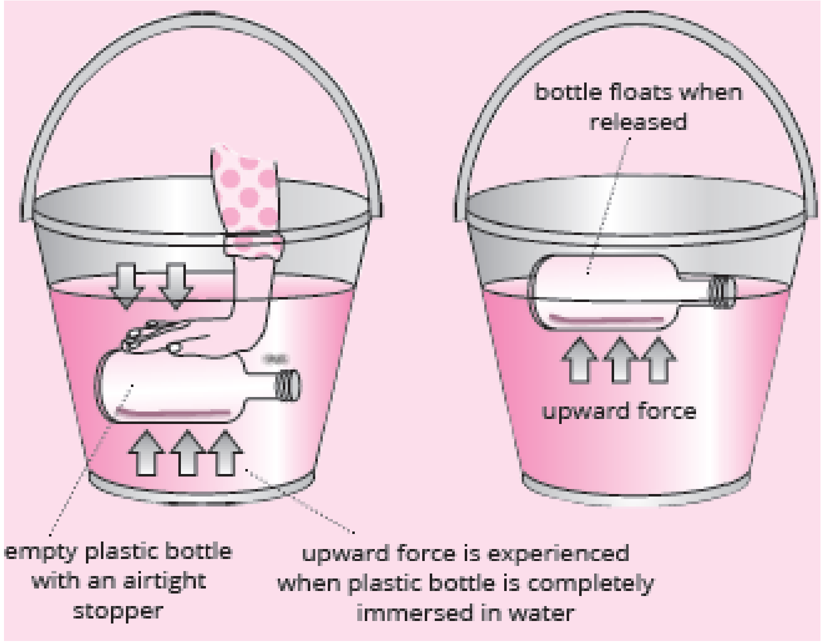
d. Pressure due to the liquid is not affected by the shape and size of the vessel in which it is contained.

Study Tips: The pressure at a point in a fluid depends on the depth of that point and not on any horizontal dimension of the fluid or its container.

Buoyant Force

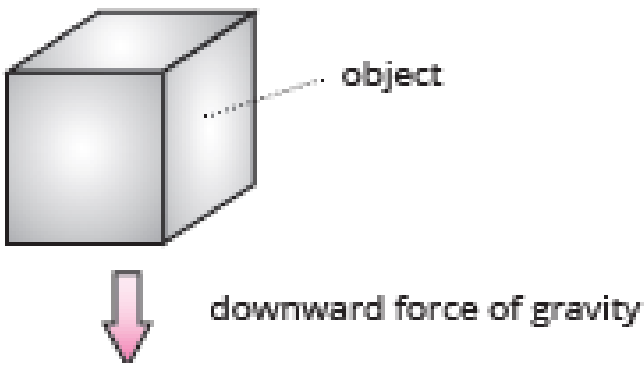
Objects appear to be lighter when submerged in water. This is because water exerts an upward force on them. In fact, every liquid exerts an upward force on the objects immersed in it. This upward force is called buoyant force. It can be defined as follows:

The upward force acting on an object when it is partly or completely immersed in a fluid is called buoyant force or upthrust. The tendency of a fluid to exert an upward force on an object placed in it is called buoyancy. It is due to the buoyant force (upthrust) exerted by water that we are able to swim in water and the ships float on water.

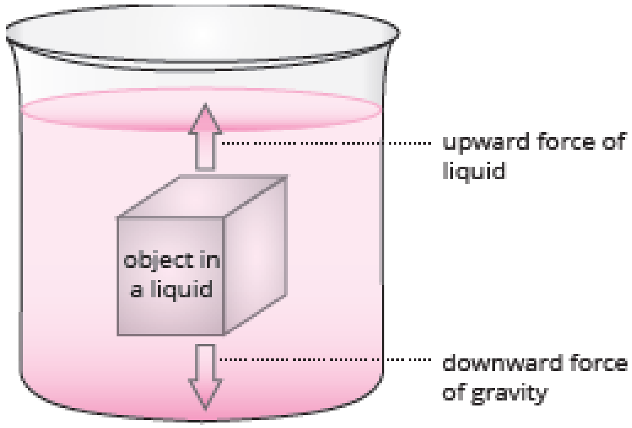


How does buoyant force help in making objects appear lighter in fluids?

The force of gravity pulls the object downwards while the buoyant force of the liquid pushes the object upwards. So, when we lift an object immersed in a liquid, we have to apply a smaller upward force because a part of the upward force required to lift the object is provided by the buoyant force of the liquid. Therefore, the object appears to be lighter as long as it is inside the liquid.



Object lying on the ground appears to be heavy.



Same object immersed in a liquid (say water) appears to be lighter than in air

Characteristic properties of buoyant force

The buoyant force due to a fluid on a body immersed in it depends on the following four factors.

1. The volume of the body immersed in the fluid.

2. The density of the fluid in which the body is immersed.

3. Acceleration due to gravity.

4. Temperature of the fluid.

- Buoyant force (BF) is directly proportional to the volume of the body immersed in the fluid, i.e. BF ∝ volume of the body immersed in the fluid

- BF is directly proportional to the density of the fluid in which the body is immersed, i.e. BF ∝ density of the fluid

- BF is also directly proportional to the acceleration due to gravity, i.e. BF ∝ *g.*

Buoyant force is more on the earth than on the moon. The reason is that acceleration due to gravity on the earth is more than that on the moon. The value of *g* on the moon is 1.63 m/s^2 and that on the earth is 9.8 m/s^2.

- BF is inversely proportional to the temperature of the fluid, i.e. BF ∝ 1/*T*

Archimedes' Principle

According to Archimedes' principle, when a body is partially or completely immersed in a fluid, it experiences an upthrust, which is equal to the weight of the fluid displaced by the immersed part of the body.
In other words,
Buoyant force acting on an object = Weight of the fluid displaced by that object

Applications of Archimedes' principle

1. Archimedes' principle is used in designing ships and submarines.

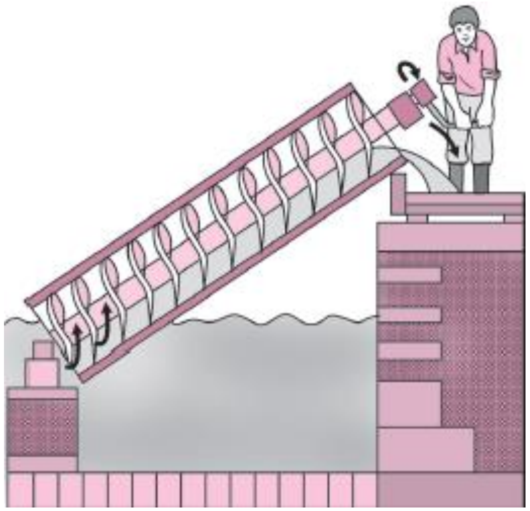
2. Archimedes' principle is used to determine the relative density of a substance.

3. The hydrometers used for determining densities of liquids are based on Archimedes' principle. They are also used to find the relative density of a liquid directly without any calculation.

4. Lactometers which are used to determine the purity of a sample of milk are based on Archimedes' principle. A lactometer measures the relative density of milk. Addition of water in milk (milk adulteration) reduces the density of milk.

Archimedes' screw

Archimedes' screw has a large spiral fitted inside a cylinder. One end of the cylinder is placed in water and then it is turned. This pulls the water up the cylinder and out at the top of the cylinder. Archimedes devised it to pump water from the hold of a large ship and later it was used in land irrigation. Even now, it is used in many parts of the world for this purpose.

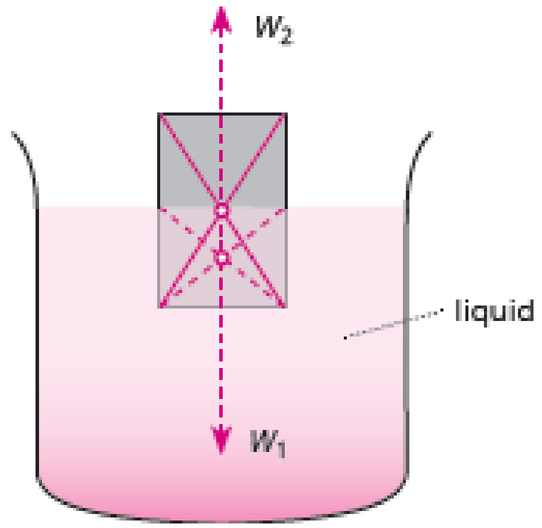


Principle of Floatation

When a body is immersed in a liquid, the following two forces act on the body:

1. The weight (W_1) of the body, which acts vertically downwards. This force has a tendency to sink the body (due to the force of gravity) in the liquid.

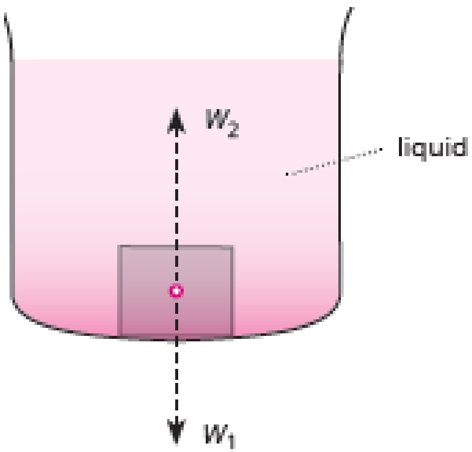
2. The upthrust (W_2) of the liquid, which acts vertically upwards. The upthrust (or buoyant force) is equal to the weight of the liquid displaced by the immersed part of the body. This force has a tendency to push the body out of the given liquid



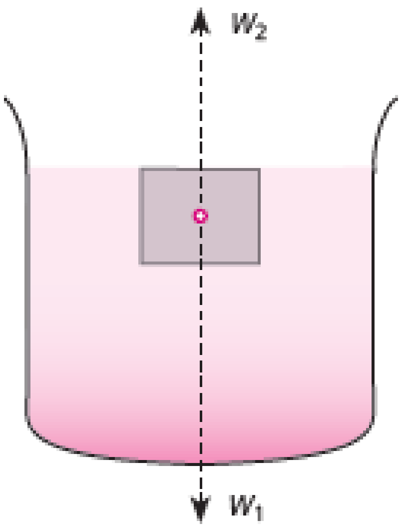
Two forces acting on a floating body

A **body placed in a liquid will float in the liquid if the weight of the liquid displaced by the body's immersed part is equal to its (body's) weight.** This is called the **principle of floatation** or the **law of floatation.**

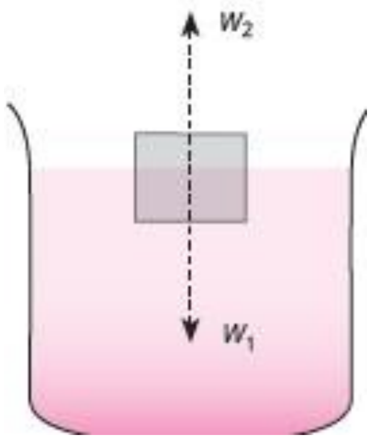
With respect to the above two forces, when a solid is placed in a liquid, three situations can arise.



CASE I: When the weight of the body is greater than the buoyant force, i.e. $W1 > W2$ then the body will sink in the liquid.
It means the body will sink in a liquid if its density is more than that of the liquid.



CASE II: When the weight of the body is equal to the buoyant force, i.e. $W1 = W2$, then the body will float just below the surface of the liquid and its apparent weight will be zero ($W1 – W2 = 0$). The body will be in a weightless condition. It means the body will just float in a liquid if its density is equal to the density of the liquid.



CASE III: When the weight of a body is less than the buoyant force, i.e. $W1 < W2$, then the body will float partially above the surface of the liquid. It means the body will float partially above the surface of the liquid if its density is less than the density of the liquid.

Characteristics of a floating body

1. The weight of the body is equal to the weight o the liquid displaced by the immersed part of the body.

2. In the floating position, the apparent weight of the body will be zero and it will be in a weightless condition.

Floatation of iron ships

An iron nail sinks in water while a ship made of iron does not sink and keeps floating. The density of iron is greater than that of water. Therefore, if we place an iron nail on the surface of water, the weight of the nail is greater than the weight of water displaced by it, so it sinks. On the other hand, a ship made of iron does not sink because it is made hollow from inside which causes the average density of the ship to become less than that of water. So, a ship floats on water. Therefore, even when a small part of a ship is submerged, the weight of the water displaced by it becomes equal to the weight of the entire ship. So, the iron ship keeps floating.

Floatation of icebergs

The density of ice (0.917 g/cm3) is less than the density of water (1 g/cm3). Therefore, huge masses of ice known as icebergs are able to float on water.

It has been found that an iceberg floats in sea water with 11/12th part of its volume below the water surface and 1/12th part of its volume above the water surface. Icebergs are extremely dangerous for ships as the ships may hit the underwater icebergs due to their non-visibility and could sink into the sea.

Floatation of balloons

The principle of floatation applies to gases also. When lighter gases like hydrogen or helium (whose densities are much lesser than air) are filled in a balloon, the weight of the air displaced by the inflated balloon becomes more than the weight of the gas-filled balloon. Since the upthrust on the balloon is more than its weight, it experiences a net upward force and hence it rises up.

Floatation of man

The average density of the human body with empty lungs is 1.07 g/cm3, while with lungs filled with air is 1.00 g/cm3. In the Dead Sea in Jordan, the density of water is 1.16 g/cm3. Therefore, the water of this sea offers a greater buoyant force. So the chances of drowning in the Dead Sea are very less. A man can easily swim with his shoulders above the sea water all the time.

Floatation of fish

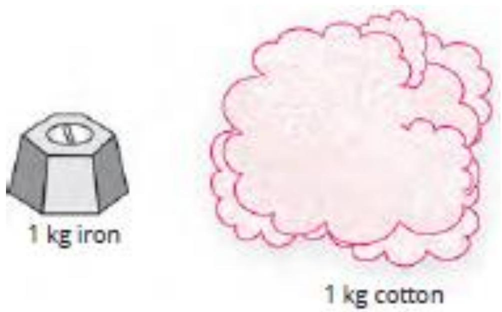
Many species of fish have a compressible organ called **swim-bladder.** It enables the fish to change the volume of its body and hence its average density.

1. When air diffuses from the fish's body fluids into its bladder, the volume of the fish increases. As a result the upthrust increases and the average density of the fish becomes less than that of water. This causes the fish to rise up.

2. When the fish has to come down, it empties its bladder. Thus, air from the bladder diffuses out which causes the volume of the fish to decrease. This reduces the upthrust and the fish comes down.

Density

Iron and cotton wool, each having the same mass occupy different volumes. Iron occupies less volume as compared to cotton wool having the same mass. This is because substances differ from one another in their densities. The density of iron is more than that of cotton.



Substances differ in their densities.

Density of a substance is defined as its mass per unit volume, i.e.
Density (*d*) = Mass (*m*) /Volume (*V*)
Its unit in the CGS system is g/cm^3 and in the SI system is kg/m^3.

Density and floatation

a. If the density of the body is more than the density of water, it will sink in water.

b. If the density of the body is equal to the density of water, it will remain submerged completely at any level in the water.

c. If the density of the body is less than the density of water, it will float on the surface of water.

Relative Density

The relative density of a substance is defined as the ratio of density of the substance to the density of water at 4 ° C. Thus,

Relative Density (R.D.) = Density of the substance / Density of water

$$\text{R.D.} = \frac{\text{Mass of the substance}}{\text{Volume of the substance}} \times \frac{\text{Mass of water}}{\text{Volume of water}}$$

Taking equal volumes of the given substance and water, we get

R.D. = Mass of the substance / Mass of equal volume of water

Thus, **the relative density of a substance is the ratio of the mass of the substance to the mass of an equal volume of water at 4 ° C.**

Points to Remember

Thus, we conclude:

1. The relative density of a substance tells us by how much its mass is more (or less) when compared to an equal volume of water.

2. If the relative density of a substance is more than 1, the substance will be heavier than water and hence will sink in water. The relative density of iron is 7.8, which indicates that it will sink in water.

3. If the relative density of a substance is less than 1, the substance will be lighter than water and hence will float in water. The relative density of wood is 0.8, which conveys that it will float in water.

4. Since **relative density is a pure ratio of two similar quantities (masses), it has no units,** and is a pure number.

SUMMARY

1. Fluid: Any substance which has no fixed shape and has the ability to flow is called a fluid. All liquids and gases do not have fixed shape and can flow. Hence they are regarded as fluids.

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

3. Pressure: Thrust per unit area is called pressure.

4. Buoyant force: The upward force acting on an object when partly or completely immersed in a fluid is called bouyant force.

5. Archimedes' Principle: When a body is partially or completely immersed in a fluid, it experiences an upthrust which is equal to the weight of the fluid displaced by the immersed part of the body.

6. Law of floatation: When a solid floats in a fluid, then the weight of the floating body is equal to the weight of the liquid displaced by the immersed part of the solid.

7. Relative density: Relative density is defined as the ratio of the density of the substance to the density of water at 4 °C.