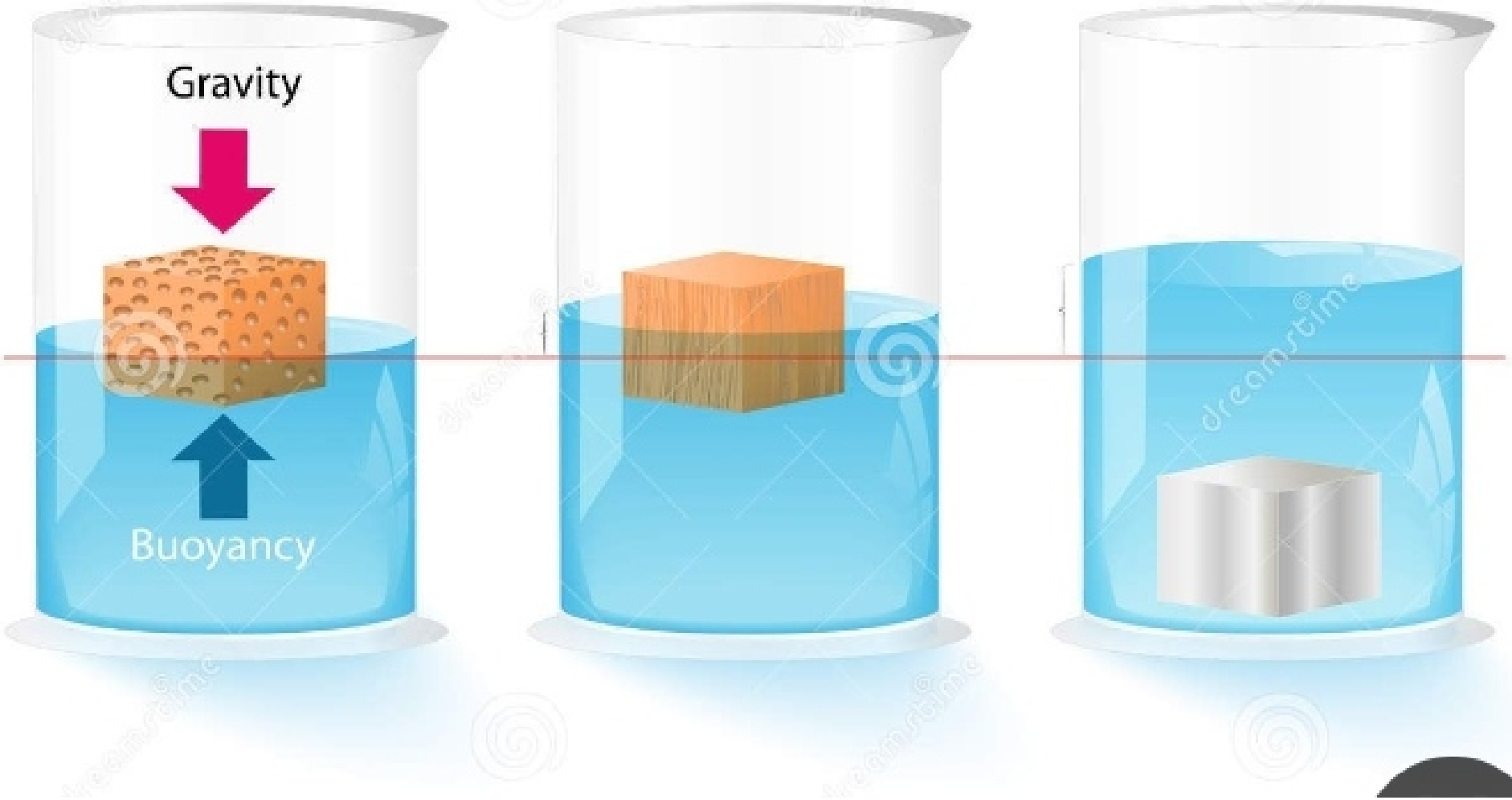
ARCHIMEDES PRINCIPLE



Archimedes Principle

When we go swimming, we feel a little weightless in the water. The reason for this is that liquids exert an upward force to objects submerged in them. This is known as thrust and is a consequence of the difference in pressure a liquid exerts at different heights. As we submerge an object (considering it is fully submerged) deeper into a liquid, the pressure exerted by the liquid keeps on increasing but the thrust force remains the same.

Archimedes' principle states that:

> The upward buoyant force that is exerted on a body immersed in a fluid, whether partially or fully submerged, is equal to the weight of the fluid that the body displaces and acts in the upward direction at the center of mass of the displaced fluid.

The value of thrust force is given by the Archimedes law which was discovered by Archimedes of Syracuse of Greece. When an object is partially or fully immersed in a liquid,the apparent loss of weight is equal to the weight of liquid displaced by it.

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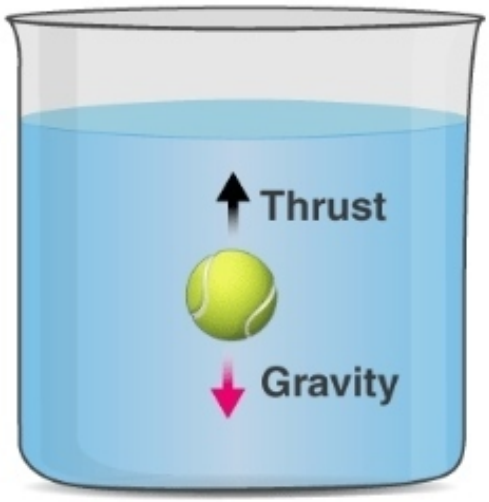

If you look at the figure, the weight due to gravity is opposed by the thrust provided by the fluid. The object inside the liquid only feels the total force acting on it as the weight. Because the actual gravitational force is decreased by the liquid's upthrust, the object feels as though its weight is reduced. The apparent weight is thus given by:

Apparent weight= Weight of object (in air) – Thrust force (buoyancy)

Archimedes principle tells us that this loss of weight is equal to the weight of liquid the object displaces. If the object has a volume of V, then it displaces a volume V of the liquid when it is fully submerged. If only a part of the volume is submerged, the object can only displace that much of liquid.

Archimedes Principle Formula

In simple form, the Archimedes law states that the buoyant force on an object is equal to the weight of the fluid displaced by the object. Mathematically written as:

$$F_b = \rho \times g \times V$$

Where,

- F_b is the buoyant force
- ρ is the density the fluid
- V is the submerged volume
- g is the acceleration due to gravity

Archimedes Principle Derivation

The mass of the liquid displaced is.

$$Mass = Density \times Volume = \rho \times V$$

This is because density (ρ) is defined as

$$Density, \rho = \frac{Mass}{Volume} = \frac{M}{V}$$

Thus the weight of that displaced liquid is:

$$Weight = Mass \times Acceleration\ due\ to\ gravity$$

$$W = M \times g = \rho \times V \times g$$

Thus from Archimedes principle, we can write:

Apparent loss of weight = weight of water displaced = ρ×V×g

Thus the Thrust force is,

$$Thrust = \rho \times V \times g$$

Where,

- ρ is the density of liquid
- V is the volume of liquid displaced

The thrust force is also called the buoyant force because it is responsible for objects to float. Thus, this equation is also called the law of buoyancy.

Archimedes Principle Applications

Following are the applications of Archimedes principle:

Submarine:

The reason why submarines are always under water is because they have a component called ballast tank which allows the water to enter making the submarine be in its position under water as the weight of the submarine is greater than the buoyant force.

Hot-air balloon:

The reason why hot-air balloon rises and floats in mid-air because the buoyant force of the hot-air balloon is less than the surrounding air. When the buoyant force of the hot-air balloon is more, it starts to descend. This is done by varying the quantity of hot air in the balloon.

Hydrometer:

A hydrometer is an instrument used for measuring the relative density of liquids. Hydrometer consists of lead shots which makes them float vertically on the liquid. The lower the hydrometer sinks, lesser is the density of the liquid.

Archimedes Principle Experiment

You can try an Archimedes principle experiment at home.

- Take a mug filled with water to the brim and place it in an empty bowl.
- Now take any solid object you like and measure its weight using a spring balance. Note this down.
- Keep the object attached to the spring balance and submerge it in the water. Just make sure the spring balance is not submerged

- Now, note down the weight shown by the spring balance. You will notice that it is less. Some water will be displaced into the bowl.
- Collect this water and weigh it. You will find that the weight of the water will be exactly equal to the loss of weight of the object!

Q1. Calculate the resulting force, if a steel ball of radius 6 cm is immersed in water. Assume the density of lead is 7900 kg.m^{-3}.

Ans: Given,

Radius of steel ball = 6 cm = 0.06 m

Volume of steel ball, V = $\frac{4}{3}\pi r^3$

V = $\frac{4}{3}\pi 0.06^3$

$\therefore$V = 9.05 × 10^{-4} m^3

Density of water, ρ = 1000 kg.m^{-3}

Acceleration due to gravity, $g = 9.8\ m.s^{-2}$

From Archimedes principle formula,

$$F_b = \rho \times g \times V$$

$$F_b = (1000\ kg.m^{-3})(9.8\ m.s^{-2})(9.05 \times 10^{-4}\ m^3)$$

$$\therefore F_b = 8.87N$$

Q.2. Calculate the buoyant force acting on it, if a stone of mass 250 g is thrown in water?

Answer:

Known: m (Mass of stone) = 0.25 kg,
The buoyant force is given by

$F = mg$
$= 0.25 \times\times 9.8$
$= 2.45$ N.

Thus, 2.45 N of upward force is being applied to the stone.

Q.3 . Calculate the buoyant force, if a floating body is 95% submerged in water. Density of water is 1000 kg.m^{-3}.

Home-Work