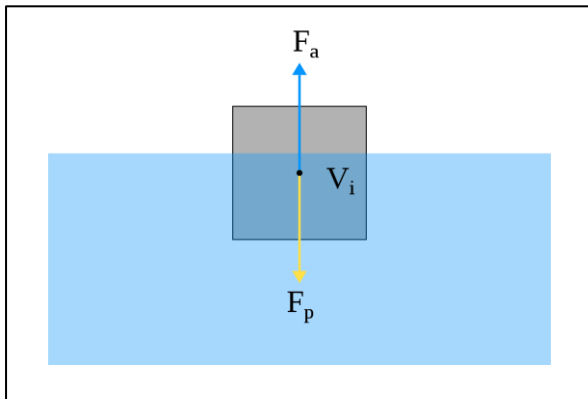




# Archimedes' principle



## Key words

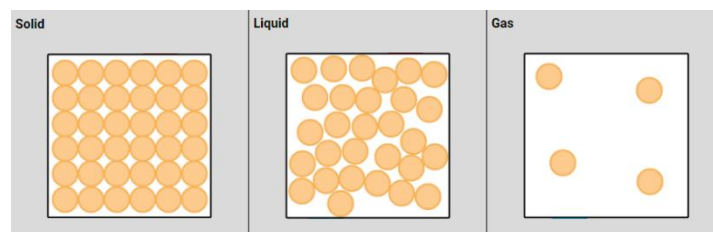
- Engineering, Mathematics
- Archimedes' principle
- Mass and volume
- Density

## The science behind

In this experiment we can see that when the different liquids are mixed in water some of them sink, or float over the water. The same happens with the different small things put in the water. This is because of their different density.

**Density** is a characteristic property of a substance.

The mass of atoms, their size, and how they are arranged, determine the density of a substance.



The density of a substance is the relation between the mass of the substance and how much space it takes up (volume). It is a measure of the amount of mass per unit volume. In order to calculate density, you need to know the mass and volume of the item.

The formula for calculating density is:

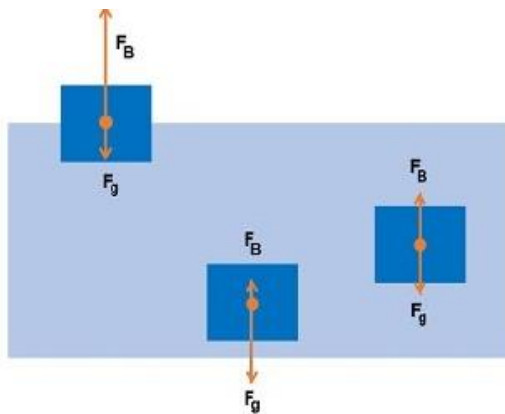
$$\text{density} = \text{mass/volume} \quad \rho = m/V$$

Objects with the same volume but different mass have different densities



**Buoyant force** is an upward force that opposes the downward force of gravity. The magnitude of the buoyant force determines whether an object will sink, float, or rise when submerged in a fluid. The term **buoyant force** refers to the upward-directed force that a fluid (either a liquid or a gas) exerts on an object that is partially or completely immersed in the fluid.

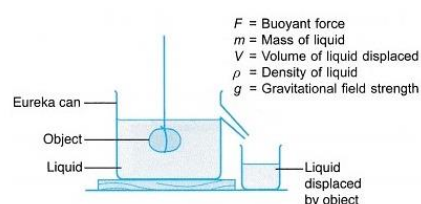
- An object will sink if the gravitational force acting on it is greater than the buoyant force
- An object will float if the gravitational force acting on it is equal to the buoyant force
- An object will rise if the gravitational force acting on it is less than the buoyant force



**Archimedes' principle** states that the buoyant force exerted on an object that is submerged partially or completely in a fluid is equal to the weight of the fluid that is displaced by the object.

- **$F = \rho g V$** , where:
  - **$\rho$**  is the density of the fluid,
  - **$g$**  is acceleration due to gravity,
  - **$V$**  is the volume of fluid that is displaced by the object.

$V$  is only equals the volume of the object if it is completely submerged.



Buoyant force = Weight of liquid displaced



## Everyday life

Each substance has its own density because of the atoms and molecules it is made from. Density is how much matter is contained within a volume. A dense object weighs more than a less dense object that is the same size. An object less dense than water will float on it; one with greater density will sink.

Buoyancy is the force that enables boats and beach balls to float on water.

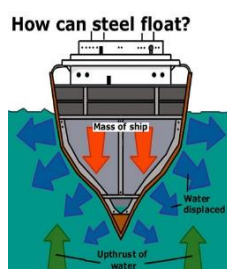
Buoyant force also explains why we can lift objects underwater more easily than on land.

### Why do steel ships float?

It's obvious that a piece of steel will sink in water, yet ships made of steel float. There must be some other factor that comes into play to explain this. Applying Archimedes' principle to the problem the upthrust of the water must be greater than the mass of the ship, so somehow a great mass of water has to be displaced. This is done by shaping the hull of the ship in such a way that as the ship sinks into the water it displaces more and more liquid until a balance is reached between the mass of water displaced and mass of the ship. This general principle applies to any object made from a material that is denser than the liquid it is in.

### How do submarines float and sink?

Using Archimedes' Principle, it is clear that a change in mass of an object affects how much liquid has to be displaced.





In submarines, this is controlled by ballast tanks. When the tanks are empty, the submarine has less mass, and it floats like a normal ship. As water is allowed into the tanks, the mass of the submarine increases, the downward gravitational force on the submarine increases and the submarine begins to sink. Careful balancing of the water ballast enables the craft to stay at any chosen depth.

### What about balloons?

Hot air balloon



Archimedes' principle applies to any fluid so it works for a balloon in air too. If a balloon is filled with a gas which is less dense than air, it will float. In a hot air balloon, the air trapped in the canopy is less dense than the surrounding air so again the balloon will rise.

The Greek mathematician and philosopher Archimedes first discovered buoyancy in the 3rd century B.C. while puzzling over a problem posed to him by King Hiero II of Syracuse. King Hiero suspected that his gold crown, made in the shape of a wreath, was not actually made of pure gold, but rather a mixture of gold and silver. Archimedes observed that the silver mass caused more water to flow out of the vessel than the gold one. Next, he observed that his "gold" crown caused more water to flow out of the vessel than the pure gold object he had created, even though the two crowns were of the same weight. Thus, Archimedes demonstrated that his crown indeed contained silver. Prior to the discovery of buoyancy, it was believed that an object's shape determined whether it would float.