

Density, pressure and pressure in liquids

Physics grades 9-10 (GCSE · IGCSE · O Level · Class 9-10) · Lesson

Quick answer: Density is mass per unit volume, $\rho = m \div V$. Pressure is force per unit area, $p = F \div A$, measured in pascals. In a liquid, the pressure at depth h is $p = \rho g h$, so it grows with depth and depends on the liquid's density, not on the container's shape.

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How do you calculate density?

A kilogram of feathers and a kilogram of iron have the same mass, but the iron takes up far less space. Density measures how much mass is packed into a given volume.

Definition

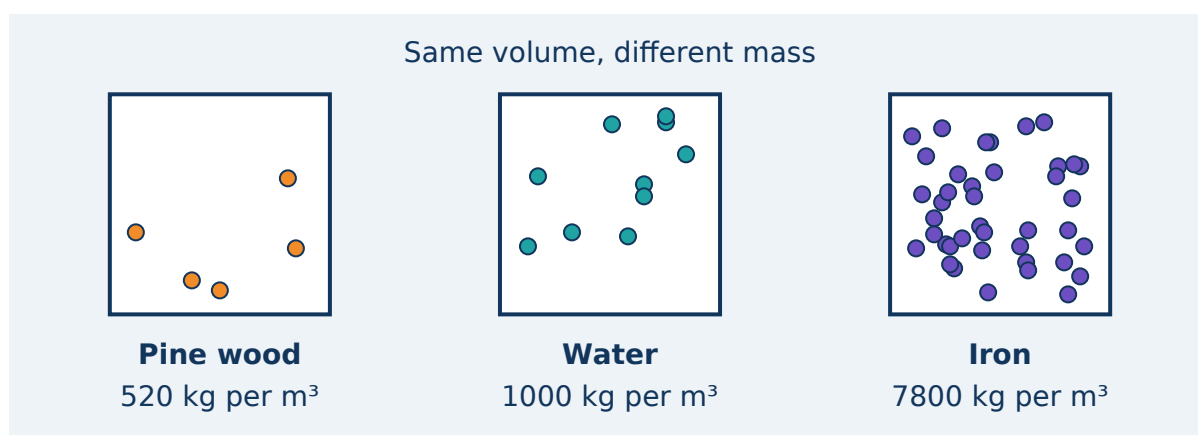
Density is the mass per unit volume of a substance. It tells you how tightly its particles are packed.

Formula

$$\rho = m \div V$$

ρ (rho) = density in kg/m^3 (or g/cm^3), m = mass in kg (or g), V = volume in m^3 (or cm^3).

$$1 \text{ g/cm}^3 = 1000 \text{ kg/m}^3.$$



Equal volumes of different materials have different masses. The dots are only an illustration of how closely packed the particles are.

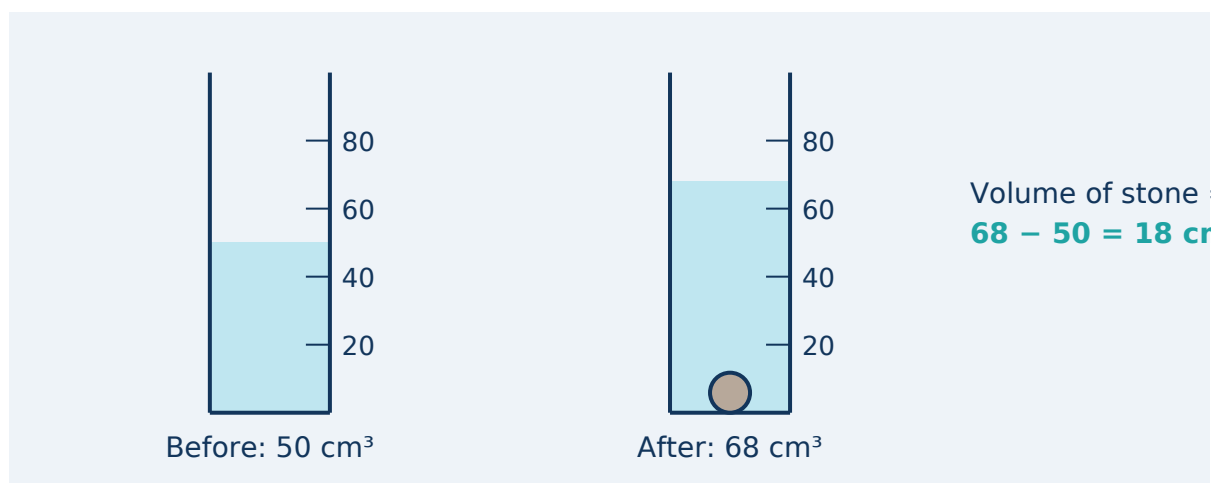
Worked example 1

A clay brick has a mass of 2.1 kg and measures $0.20 \text{ m} \times 0.10 \text{ m} \times 0.050 \text{ m}$.

$$V = 0.20 \times 0.10 \times 0.050 = 1.0 \times 10^{-3} \text{ m}^3.$$

$$\rho = m \div V = 2.1 \div 1.0 \times 10^{-3} = \mathbf{2100 \text{ kg/m}^3}.$$

For an irregular solid, find the volume by **displacement**. Lower the object into a measuring cylinder of water. The rise in the water level is the volume of the object.



Finding the volume of an irregular solid by displacement of water.

Worked example 2

The pebble in the figure has a mass of 46.8 g.

$$V = 68 - 50 = 18 \text{ cm}^3.$$

$$\rho = 46.8 \div 18 = \mathbf{2.6 \text{ g/cm}^3} \text{ (2600 kg/m}^3\text{)}.$$

Material	Density (kg/m ³)	Density (g/cm ³)
Air	1.2	0.0012
Cork	240	0.24
Ice	920	0.92
Water	1000	1.00
Sea water	1030	1.03
Iron	7800	7.8
Mercury	13 600	13.6

An object floats in a fluid if its average density is less than that of the fluid, and sinks if it is greater. Ice (920 kg/m³) floats on water (1000 kg/m³).

What is pressure and how do you calculate it?

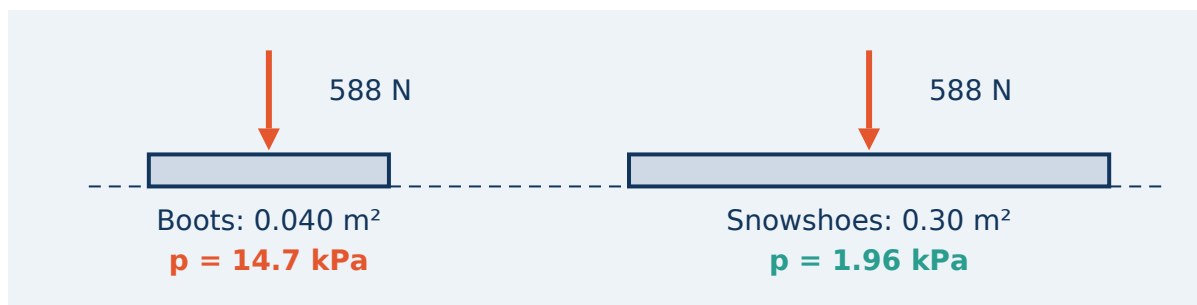
Pressure shows how concentrated a force is. A sharp knife cuts easily because the edge has a tiny area. Pressure is measured in pascals (Pa), where 1 Pa = 1 N/m².

Formula

$$p = F \div A$$

p = pressure in pascals (Pa), F = force in newtons (N) acting at right angles to the surface, A = area in square metres (m²).

$$1 \text{ kPa} = 1000 \text{ Pa}.$$



The same force spread over a larger area gives a much smaller pressure.

Worked example 3

A person of mass 60 kg has a weight of $60 \times 9.8 = 588$ N. Boots have a total contact area of 0.040 m².

$p = F \div A = 588 \div 0.040 = 14\,700$ Pa = **14.7 kPa**.

On snowshoes of area 0.30 m²: $p = 588 \div 0.30 = \mathbf{1960}$ Pa, so she does not sink.

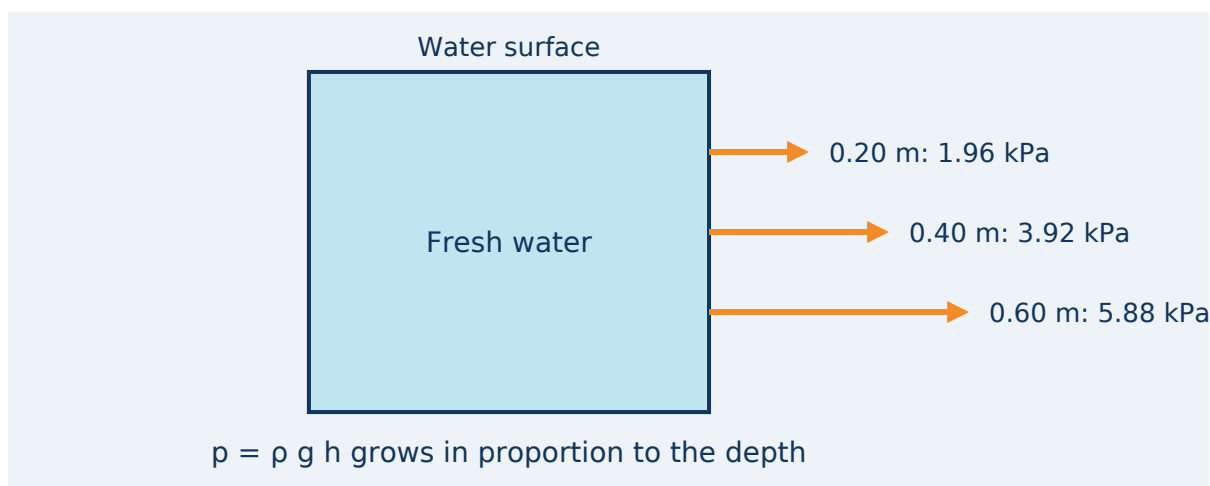
How does pressure change in a liquid?

A liquid pushes on every surface it touches, in all directions. The deeper you go, the more liquid is above you, so the pressure increases. The pressure depends on the depth, the density of the liquid and g , but not on the shape of the container.

Formula

$$p = \rho \times g \times h$$

p = pressure due to the liquid in Pa, ρ = density of the liquid in kg/m³, $g = 9.8$ N/kg, h = depth below the surface in m.



Pressure in a liquid increases with depth.

Worked example 4

A diver in the sea ($\rho = 1030$ kg/m³) is 12 m below the surface.

$p = \rho g h = 1030 \times 9.8 \times 12 = 121\,128$ Pa, so about **1.2×10^5 Pa** due to the water.

The atmosphere adds about 1.0×10^5 Pa, so the total is about 2.2×10^5 Pa.

Common mistake

Students put the mass instead of the weight into $p = F \div A$, or use g/cm^3 with kg/m^3 in the same equation. Always change to N, m^2 and kg/m^3 first. Also, liquid pressure depends on depth only, not on how much water is in the container.

Lina's tip

Write the units on every number and cancel them like fractions. If a pressure comes out in N instead of N/m^2 , or a density in kg instead of kg/m^3 , the equation was used wrongly.

Key points to remember

- Density: $\rho = m \div V$; $1 \text{ g/cm}^3 = 1000 \text{ kg/m}^3$; water is 1000 kg/m^3 .
- An object floats if its average density is less than the fluid's density.
- Pressure: $p = F \div A$, in pascals ($1 \text{ Pa} = 1 \text{ N/m}^2$).
- Pressure in a liquid: $p = \rho g h$, with $g = 9.8 \text{ N/kg}$.
- Volume of an irregular solid = rise in water level (displacement).

Density, pressure and pressure in liquids: frequently asked questions

What is the formula for density?

Density = mass $\div$ volume, written $\rho = m \div V$. In SI units mass is in kg, volume in m^3 and density in kg/m^3 . Water has a density of 1000 kg/m^3 , which is 1.00 g/cm^3 .

Why does a ship made of steel float?

The hull encloses a large volume of air, so the average density of the whole ship is less than that of water. An object floats if its average density is lower than the density of the fluid.

Why do sharp knives and drawing pins work?

A small contact area gives a large pressure for the same force, because $p = F \div A$. The point concentrates your push on a tiny area, so it can pierce the surface.

Does the shape of a container affect the pressure at the bottom?

No. In a liquid $p = \rho g h$ depends only on the density of the liquid, g and the depth. A wide and a narrow tank filled to the same depth have the same pressure at the base.

How do you measure the volume of an irregular object?

Lower it into water in a measuring cylinder and read the level before and after. The rise in the water level is the volume. Use a displacement can if the object is too big for the cylinder.