Teacher guide: density simulation

Quick reference

The density simulation relates mass, volume and density (ρ = m / V) using nine real materials and a custom one. Everything happens on the macroscopic scale: volumes are given in litres and masses in kilograms, density is read as the mass of a 1 L cube and masses are compared on a two-pan balance. Its main use is in ESO 2 (Year 9 in the UK, 8th grade in the US), with applications in ESO 3 and ESO 4.

Item	Details
Link	simulaciencia.es/en/simulations/densidad/
Year groups	ESO 2 (main use), ESO 3, ESO 4; occasional review in Bachillerato 1
Subject	Physics and Chemistry
Suggested time	15–20 minutes of explanation with the simulation projected
Equipment	Projector or interactive whiteboard; runs in the browser, also on phones and tablets, with nothing to install
Prior knowledge	The ideas of mass and volume, the units kg and L, simple division
Accessibility	Dark, light and high-contrast themes (gear button). The sliders can be moved with the keyboard (arrow keys, Page Up / Page Down, Home and End)

How the simulation works

The simulation has two modes, “One object” and “Compare”, chosen at the top of the left-hand panel. Both show the block of material and a bar at the bottom that places the density on a scale from 0 to 14 kg/L, with the water line marked.

Units. Volume is given in litres (L), mass in kilograms (kg) and density in kg/L. Since 1 kg/L = 1 g/cm³, densities have the same numbers as in g/cm³ (water 1.00, iron 7.87), and the reference is easy to remember: one litre of water has a mass of one kilogram.

Mode	What the teacher controls	What it shows
One object, real material	Material (cork, wood, ice, water, PET plastic, aluminium, iron, copper, lead) and sample volume, from 0.1 to 10 L, or its mass	The mass changes with the volume and the density does not. It shows the mass of 1 L, the calculation with numbers and whether it floats or sinks in water
One object, “Custom”	Mass (0.1–20 kg) and volume (0.1–20 L) separately	The density that results from that quotient, with its buoyancy in water
Compare, same volume	Shared volume (0.1–10 L) and the materials of A and B	Two identical blocks on the pans of a balance, which tips towards the one with more mass. The panel says which one is denser
Compare, same mass	Shared mass (0.1–10 kg) and the materials of A and B	Two blocks of different sizes and the balance level

Five elements support the explanation:

- **The formula with numbers.** The panel writes out the quotient with the current values, for example 1.2 kg / 2 L = 0.600 kg/L for wood. It lets you check the calculation out loud.
- **The 1 L cube.** In “One object”, next to the density there is a one-litre cube of the material with its mass: 1 kg for water, 7.87 kg for iron. It is density read as “how many kilograms there are in each litre”.
- **Linked mass and volume sliders.** With a real material you can move either the volume or the mass: when one moves, the other changes and the density stays the same.
- **The two-pan balance.** In “Compare”, the blocks sit on the pans. With the same volume, the balance tips towards the denser material; with the same mass, it stays level even though the blocks are very different in size. Water goes in a glass that counts as tared.
- **The flotation indicator.** It always compares with water: below 1 kg/L the object floats, above it sinks, and at around 1 it is neutrally buoyant.

The “Key concepts” drop-down in the panel summarises mass, density as an intensive property, what the balance compares and the equivalences 1 L = 1 dm^3 = 1000 cm^3 and 1 kg/L = 1 g/cm^3 = 1000 kg/m^3.

Use in each year group

In ESO 2 the simulation is used to introduce density; in ESO 3, to work with it as a derived quantity and with unit conversions; in ESO 4, as the basis for Archimedes' principle. The curriculum content quoted is from the LOMLOE Physics and Chemistry curriculum of the Community of Madrid (Spain), in our own translation.

ESO 2: introducing density

Ages 13–14 · Year 9 in the UK · 8th grade in the US

Curriculum content. Block A: “Measuring quantities. Indirect measurements. International System of Units. Simple unit conversions” and “the laboratory and virtual environments”. Block B: “Matter and its properties. Introduction to the kinetic-molecular theory. States of matter”.

Objectives. Distinguish mass, volume and density. Calculate density as an indirect measurement. Recognise that density belongs to the material and not to the size of the object. Predict whether a material floats in water.

Teaching sequence (15–20 min).

1. Compare mode, same volume, wood versus iron (this is what appears when you open “Compare”). Before looking, ask which way the balance will tip if the two blocks are the same size. Show the masses with 1 L of each: 0.6 kg versus 7.87 kg.
2. Go back to “One object” with iron and then with wood, and point to the 1 L cube: 7.87 kg versus 0.6 kg. Define density as “how much mass there is in each litre”.
3. Switch to One object with water. Move the volume from 0.1 to 10 L: the mass goes up (1 L, 1 kg; 2 L, 2 kg…) and the density stays at 1.00 kg/L. Repeat with aluminium, this time moving the mass slider. Conclude that density does not depend on the size of the sample.
4. Read the formula with numbers in the panel and write it on the board: $\rho = m / V$, in kg/L.
5. Go through cork, wood, ice and plastic, looking at the flotation indicator and the water line on the bottom bar. Finish with ice (0.92 kg/L), which floats on liquid water.
6. Compare, same mass, cork versus lead: the balance stays level even though one block is much bigger. Ask why they take up such different amounts of space.

ESO 3: density as a derived quantity

Ages 14–15 · Year 10 in the UK · 9th grade in the US

Curriculum content. Block A: “Derived quantities. International System of Units. Unit conversion. Conversion factors. Scientific notation. Significant figures” and “Recording data and results using tables, graphs and mathematical expressions”. Block B: “Kinetic-molecular model of matter” and “Atomic mass and molecular mass”.

Objectives. Treat density as the quotient of two fundamental quantities. Convert kg/L to g/cm³ and to kg/m³ using conversion factors. Interpret the linear relationship between the mass and the volume of the same material.

Teaching sequence (15–20 min).

1. One object with aluminium. Note on the board the mass for 1, 2, 4 and 8 L (2.7, 5.4, 10.8 and 21.6 kg) and show that it doubles when the volume doubles. Draw the m–V graph: a straight line through the origin whose gradient is the density.
2. Repeat two points with cork and with lead on the same graph: each material has its own line, and the steepest one belongs to the densest material.
3. Convert 2.70 kg/L to kg/m³ (1 m³ = 1000 L) and to g/cm³ with conversion factors and check it against the equivalence in “Key concepts”.
4. Custom mode: set 5 kg and 2 L and obtain 2.500 kg/L. Discuss how many significant figures it makes sense to give.
5. Compare, same mass, cork versus lead: the balance is level. Explain why the cork block is so much larger: V = m / ρ.

ESO 4: density and flotation

Ages 15–16 · Year 11 in the UK · 10th grade in the US

Curriculum content. Block D: “Main forces in everyday surroundings: recognising weight, the normal force, friction, tension and upthrust” and “Forces and pressure in fluids [...] Archimedes' principle”. Block B: “Atomic and molecular mass. The concept of the mole”.

Objectives. Relate the condition for flotation to the comparison between the density of the object and that of the fluid. Explain density in terms of the mass of the particles and how closely packed they are, beyond what the simulation shows.

Teaching sequence (15–20 min).

1. Review ρ = m / V in 3 minutes with One object mode.
2. With Custom, adjust mass and volume until ρ ≈ 1 kg/L and show the “neutrally buoyant in water” state. Introduce upthrust: a submerged object displaces its own volume of water, and it floats or sinks depending on whether it weighs less or more than that water.
3. Compare, same volume, ice versus water: the balance tips only slightly towards the water (0.92 kg versus 1 kg with 1 L of each). Explain why ice floats and why only a small part of an iceberg shows above the surface (0.92 / 1.00).
4. Point out that the simulation only compares with water. Ask out loud what would happen to iron in mercury (13.6 kg/L) or ice in alcohol (0.79 kg/L), where it sinks, and link to the Archimedes simulation, which does let you change the liquid.

5. Away from the simulation, use lead versus aluminium to discuss that density depends on the mass of each atom and not only on how many there are: lead has about $3.3 \cdot 10^{22}$ atoms/cm³, fewer than aluminium ($6.0 \cdot 10^{22}$), and it is denser because each atom is much heavier.

Bachillerato 1: occasional review

Ages 16–17 · Year 12 in the UK · 11th grade in the US

There is no specific content on density. The simulation can be used for review when dealing with “The concept of the mole. Atomic mass [...] Molar mass” or “The metallic bond. Structure and properties”: from the molar mass and density of iron, copper and lead, students calculate how many atoms there are in the 1 L cube shown by the simulation.

Misconceptions it helps to address

The simulation mainly tackles the confusion between density, mass and size. Each row gives a common prior idea and how to break it down with the simulation.

Students' idea	Correct idea	How to show it
“Heavy things sink and light things float”	Floating depends on density, not on mass	Custom with 15 kg and 20 L: ρ = 0.75 kg/L and it floats. Then 1 kg and 0.5 L: ρ = 2.0 kg/L and it sinks
“A bigger piece is denser”	Density is intensive: it does not change when you cut the object	One object with iron: move the volume from 0.1 to 10 L and see that ρ stays at 7.87 kg/L
“Density and mass are the same thing”, “dense means heavy”	Mass is the total amount of matter; density is matter per unit volume	Compare, same mass, cork versus lead: equal mass and very different volumes
“Big objects weigh more”	For the same volume, the mass depends on the material	Compare, same volume, wood versus iron
“Ice floats because it has air inside”	Ice is less dense than liquid water	Compare, same volume, ice versus water: the balance tips towards the water, because the ice has less mass
“If the balance is level, the two objects are the same”	A balance compares masses, not volumes or materials	Compare, same mass, cork versus lead: level with blocks of very different sizes
“Materials that float have no mass” or “cork weighs nothing”	Every object made of matter has mass	One object with cork at 10 L: 1.8 kg

Simplifications worth knowing

The simulation puts the idea “more density, more mass in each litre” first, and to do so it simplifies the drawing and the measurement. It is worth knowing about these liberties so as not to reinforce wrong ideas by accident.

1. **Macroscopic scale only.** There are no particles. Mixing the structure of cork, molecules and atoms in a single picture, or painting particles in the colour of the material, encourages misconceptions. To explain density with the particle model, it is better to do it separately, for example with the changes of state simulation.

2. **The size of the block is not proportional to the volume in "One object".** The block grows on a logarithmic scale so that the change is noticeable over the whole slider. In Compare, same mass, the real proportion between the two blocks is respected, up to a difference in side length of about 6.7 times.
3. **Idealised balance.** The tilt grows with the relative difference in mass and reaches a stop, like the pointer of a real balance. Differences below 0.5 % look level. The water glass counts as tared, and air buoyancy is ignored.
4. **Linked mass and volume.** With a real material, both sliders move together in steps of 0.1 L: each step adds ρ · 0.1 kg to the mass.
5. **2D cross-section.** The blocks are drawn as a flat section.
6. **Fixed densities.** Each material has a single value, with no effect of temperature or pressure. Wood (0.60 kg/L) and plastic (PET, 1.38 kg/L) vary a great deal depending on the type, and water is exactly 1.00 kg/L.
7. **It only compares with water.** The flotation indicator always uses fresh water and treats any density between 0.995 and 1.005 kg/L as "neutrally buoyant". It does not take hollow objects into account, such as a steel ship, where what matters is the average density of the whole.

Student activity worksheet

The activity worksheet follows a predict, observe and explain structure. Each activity links to the simulation already set up, so it works in the computer room, with tablets or as homework. It downloads in Word and LibreOffice formats so it can be adapted.

Year group	Activities	Suggested time
ESO 2 (Year 9)	Before you start, activities 1 to 6, Apply what you have learnt, Review your ideas and Self-assessment	One 50–55 minute lesson, or two if the problems are done in class
ESO 3 (Year 10)	Before you start, activities 2, 4 and 6, Apply what you have learnt and Going further	One lesson
ESO 4 (Year 11)	Activities 3, 5 and 6 as revision before Archimedes' principle	20–25 minutes

The "Before you start" table collects five of the prior ideas from the misconceptions table. It is best not to correct it at the beginning: students come back to it in "Review your ideas", and the contrast between prediction and observation is what makes the idea change.

Answers

Section	Answer
Before you start	All false. a) For the same size, the mass depends on the material (activity 1). b) Floating depends on density, not on mass (activity 6). c) Density does not depend on size (activity 2). d) The cork takes up 63 times more space (activity 4). e) Ice is less dense than liquid water (activity 5)
Activity 1	Wood 0.6 kg; iron 7.87 kg; aluminium 2.7 kg; cork 0.18 kg. The balance tips towards the iron. For the same volume, each material has a different mass: it depends on the material
Activity 2	2.7, 5.4, 10.8 and 21.6 kg. m / V = 2.7 kg/L every time. When the volume doubles, the mass doubles and the density does not change. "The density of a material is the mass there is in each litre (unit of volume). It does not depend on the size of the object."

Section	Answer
Activity 3	Cork 0.18, wood 0.60 and ice 0.92 float; PET 1.38, aluminium 2.70 and iron 7.87 sink. The materials less dense than water float; the boundary is 1 kg/L, the density of water
Activity 4	The balance stays level because it compares masses, and both are 1 kg. Cork 5.56 L; lead 0.0882 L. 5.56 / 0.0882 ≈ 63 times (also 11.34 / 0.18 = 63). Lead is much denser: the same mass fits into less volume
Activity 5	Ice 0.92 kg and 0.92 kg/L; water 1 kg and 1.00 kg/L. Ice floats because it is less dense than liquid water, not because it has air in it: the block in the simulation is solid ice
Activity 6	ρ = 15 kg / 10 L = 1.5 kg/L: it sinks. At 15 L it is neutrally buoyant (1.00 kg/L); it floats from 15.1 L upwards (0.993 kg/L). It is false: what decides is the density. Examples: a large log, an iceberg, a ship (here what counts is the average density of the hull and the air it encloses)
Apply what you have learnt	1) ρ = 1.84 kg / 2 L = 0.92 kg/L; it stays on top of the water. 2) ρ = 8.1 kg / 3 L = 2.7 kg/L: aluminium. 3) m = ρ · V = 8.96 kg/L · 5 L = 44.8 kg. 4) V = m / ρ = 3 kg / 0.60 kg/L = 5 L
Going further	1) Three straight lines through the origin; the steepest is lead, because the gradient is the density. 2) 2.70 kg/L · (1000 g / 1 kg) · (1 L / 1000 cm^3) = 2.70 g/cm^3; 2.70 kg/L · (1000 L / 1 m^3) = 2700 kg/m^3

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