Teacher guide: lab practical “Density of a solid”

Quick reference

A simulated lab practical in which students are given an unknown sample, weigh it on an electronic balance, measure its volume by displacement in a measuring cylinder, calculate its density and identify the material from a table. It is not an explanation projected for the class but a practical that each student or pair carries out: the simulation never gives the volume, which has to be read off the scale, and procedural mistakes have the same consequences as in the lab. Its main use is in ESO 2 (Year 9 in the UK, 8th grade in the US), with applications in ESO 3.

Item	Details
Link	simulaciencia.es/en/simulations/practica-densidad
Student lab sheet	simulaciencia.es/en/lab-sheets/practica-densidad, in Word and LibreOffice to adapt it, and in PDF
Year groups	ESO 2 (main use), ESO 3; review in ESO 4 before Archimedes’ principle
Subject	Physics and Chemistry
Suggested time	One 50-minute lesson: 15 minutes at the guided level and 20 at the open level with the lab sheet
Grouping	Individually or in pairs, with a computer, tablet or phone per group
Equipment	A browser, with nothing to install. The lab sheet, printed or digital, for the open level
Prior knowledge	Mass and volume, mL and cm³, division with decimals
Accessibility	Dark, light and high-contrast themes (gear button). It can be used with a mouse, a finger or the keyboard, and “Describe the scale” says which marks the water is between

How the practical works

On the bench there is an electronic balance reading to 0.1 g, a measuring cylinder, a wash bottle, a magnifier and the sample on its tray. Everything is dragged with the mouse or a finger. The ON and TARE buttons are on the balance itself, and EMPTY is on the base of the measuring cylinder.

Two levels

Level	What students do	What the simulation checks
Guided (step by step)	They follow eight numbered steps and record their measurements in an on-screen lab notebook. At the end they choose the material from a table of densities	Each reading and each calculation as it is entered, and whether the chosen material is correct. At the end it gives the percentage error and suggests repeating with the same sample
Open (with a lab sheet)	They follow the student lab sheet, choose the measuring cylinder (50, 100 or 250 mL), record their measurements and do the calculations on the sheet	Nothing. It only sets out the instruments and the sample number. The teacher marks the work with the key in this guide

The eight steps of the guided level are: switch on and tare the balance; weigh the sample; pour about 50 mL of water into the cylinder; read the initial volume; lower the sample to the water and let go of it; read the final volume; calculate the volume of the sample and its density; and find the material in the table.

What to know about the measurement

- **The volume never appears in writing.** It has to be read off the scale with the magnifier, which enlarges the meniscus. Its yellow line marks eye level and is placed on the bottom of the meniscus. The mass, on the other hand, is read on the balance display, as in the lab.
- **The measuring cylinder starts empty.** It is filled by bringing the spout of the wash bottle over its mouth.
- **The samples are drawn to scale.** The rise in the water level is the volume of the sample. All of them sink and all of them are painted the same matt colour, so that their appearance does not give away the material.
- **Each sample number is always the same material,** but its mass and volume are random every time you start (from 11 to 25 cm^3). So each student has their own numbers, and repeating with the same sample shows that the mass changes and the density does not.
- **When the practical opens, a random sample appears.** Another can be chosen from the drop-down list or with “Random sample”.

Mistakes with consequences

Procedural mistakes are not punished arbitrarily: each one spoils the measurement for a physical reason that can be explained in class.

Mistake	What happens in the simulation
Weighing without taring	The empty balance reads a few tenths of a gram, which are added to the mass of the sample. At the guided level, the recorded mass is not accepted
Switching on or taring the balance with the sample on it	The balance zeroes itself with the sample on it, does not show its mass and a warning appears
Dropping the sample from the top of the cylinder	It falls, water splashes out and you have to start again
Pouring in so much water that it overflows when the sample goes in	The water spills and you have to start again
Leaving the water above the top mark	There is no scale to read and you have to start again
Weighing the sample after taking it out of the water	It has water stuck to it, the balance reads too much and you have to start again
Choosing a cylinder the sample does not fit into (open level)	The sample does not go through the mouth and a warning asks for a wider cylinder. Only samples 5, 6, 12, 15, 22, 29 and 30 fit in the 50 mL cylinder

Handing out the practical ready set up

The address of the practical accepts three parameters, which can be combined and pasted into Google Classroom, Moodle or Teams:

Parameter	Effect	Example
`nivel=libre`	Opens the open level	simulaciencia.es/en/simulations/practica-densidad/?nivel=libre

Parameter	Effect	Example
`muestra=N`	Starts with sample N (from 1 to 30)	.../practica-densidad/?nivel=libre&muestra=7
`probeta=50`, `100` or `250`	At the open level, starts with that measuring cylinder	.../practica-densidad/?nivel=libre&probeta=250

Key to the samples

For marking the open level. Mass and volume change on every attempt, so the procedure and the calculation are marked with each student's own data, and the material with this table.

Material	Density (g/cm³)	Samples
PVC	1.40	3, 12, 21, 26
Magnesium	1.74	9, 16, 22, 28
Teflon	2.20	5, 14, 24, 29
Aluminium	2.70	1, 7, 15
Titanium	4.51	8, 18, 23, 30
Iron	7.87	2, 10, 17, 25
Copper	8.96	4, 11, 19, 27
Lead	11.34	6, 13, 20

There are 30 samples, one per student in a class of 30. Samples 5, 6, 12, 15, 22, 29 and 30 are the narrowest and also fit in the 50 mL cylinder. The table of densities that students see is the same as in this key, and any two neighbouring materials differ by at least 13 %: with a good reading on the 100 mL cylinder, the calculated density always leads to the right material.

Use in each year group

In ESO 2 the practical is used to learn the procedure and density as a characteristic property; in ESO 3, to work on the precision of instruments and on error. The curriculum content quoted is from the LOMLOE Physics and Chemistry curriculum of the Community of Madrid (Spain), in our own translation.

ESO 2: measuring a density and identifying a substance

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".

Objectives. Follow a lab procedure in the right order. Tare a balance and read a measuring cylinder with the eyes level with the meniscus. Measure the volume of an irregular solid by displacement. Calculate density as an indirect measurement and use it to identify a material. Check that density does not depend on the size of the sample.

Suggested lesson (50 min).

1. **Opening question (5 min).** “Which has more mass, a kilo of lead or a kilo of straw?” and then “how would you find out what metal an unlabelled piece is made of?”. Collect prior ideas about mass, volume and density.
2. **Guided level, in pairs (15 min).** Each pair with whatever sample comes up. This is for learning how to handle the equipment and the order of the steps. At the end, the simulation suggests repeating with the same sample: it will have a different mass and volume.
3. **Open level with the lab sheet (20 min).** Give each student (or each pair) a different sample number with the `muestra=N` parameter. There are 30, one per student, and each material appears in three or four of them, so several will have the same material (for example, samples 1, 7 and 15 are aluminium).
4. **Whole-class discussion (10 min).** On the board, a table with sample, mass, volume, density and material. Pairs with the same material compare: different masses and volumes, the same density. This settles the central idea that density belongs to the material and not to its size.

ESO 3: precision of measurement and error

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”.

Objectives. Relate the precision of an instrument to the error in the measurement. Choose the right measuring cylinder before measuring. Calculate the percentage error. Express density in g/cm³ and in kg/m³ using conversion factors.

Suggested lesson (50 min).

1. **Review with the guided level (10 min).** One sample per pair, to recall the procedure.
2. **Planning (5 min).** Before measuring at the open level, answer the planning questions on the lab sheet: which cylinder to choose and why, why the sample is weighed before it gets wet and how much water is needed.
3. **The same sample with three cylinders (20 min).** Measure the volume with the 50, 100 and 250 mL cylinders (with a narrow sample: 5, 6, 12, 15, 22, 29 or 30). Repeat each reading with different amounts of water and take the mean. With the 250 mL cylinder each mark is 2 mL: for a volume of about 15 cm³ that is already more than 10 %.
4. **Error and units (15 min).** Calculate the percentage error with the density from the table and check that it comes mainly from the measuring cylinder, not the balance (0.1 g in a mass of tens of grams is less than 1 %). Convert the density to kg/m³.

ESO 4: review before flotation

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

As an activity before Archimedes’ principle, at the open level and in about 20 minutes. With data from the whole class for one material, students can plot a mass–volume graph: it is a straight line through the origin whose gradient is the density. The random size of the samples fits this activity exactly. Afterwards, the question “what if the sample floated?” leads on to the Archimedes simulation.

Assessment

At the open level, mass and volume change on every attempt, so there is no single numerical answer. The key gives the material and its density; everything else is marked with each student's data. A simple rubric:

Criterion	What to look for
Procedure	Correct order: tare, weigh dry, fill and immerse carefully. If they had to start again because of a mistake, they explain what it was and why it spoils the measurement
Measurement	Readings with their unit and the precision of the instrument: mass to 0.1 g and volume to the division of the measuring cylinder
Calculation	$V = Vf - Vi$ and $\rho = m / V$ done correctly with their own data and with units
Identification	Correct material according to the key and percentage error correctly calculated
Conclusion	Explains where the error comes from and why density can be used to identify the material

Misconceptions it helps to address

Students' idea	Correct idea	How to show it
"A bigger piece is denser"	Density does not depend on the size of the sample	Repeat with the same sample, which comes out a different size, or compare two samples of the same material in the class discussion
"Heavier things are denser", "dense means heavy"	Density is the mass of each cm^3, not the total mass	In the class table, a large aluminium sample can have more mass than a small iron one and be much less dense
"The water that rises is the water the sample weighs"	The rise in the water is the volume of the sample, not its mass	Before immersing, predict how far the water will rise. The samples are drawn to scale
"You can read the measuring cylinder from anywhere"	It is read with the eyes level with the water, at the bottom of the meniscus	The magnifier and its yellow line. Ask students to explain what would happen if they looked from above
"If the balance shows something, that is the value"	The empty balance must be zeroed before weighing	Switch the balance on: without taring it already reads a few tenths. Switch it on with the sample on it: the simulation gives a warning
"An error means you made a mistake"	Every measurement has an uncertainty that depends on the instrument	Measure the same sample with the 50, 100 and 250 mL cylinders
"It doesn't matter whether you weigh it before or after putting it in water"	A wet sample has water stuck to it, which also has mass	Weigh it after taking it out of the cylinder: the balance reads too much and you have to start again

Simplifications worth knowing

1. **The sample is lowered by hand.** In the lab you tilt the measuring cylinder and let the sample slide down the side. Here it is enough to lower it to the water before letting go, because it is easier to handle.
2. **Only solids that sink.** The displacement method as it stands does not work for a solid that floats, dissolves or absorbs water. This is a deliberate choice: no sample floats.

3. **Closed table of densities.** There are eight materials, chosen so that they can be told apart with a good reading. Real materials vary: there are many aluminium and iron alloys and several types of PVC.
4. **No temperature.** Densities are at 20 °C and do not change. The water does not evaporate or leave bubbles stuck to the sample.
5. **Ideal balance.** If it is tared properly, it reads exactly the mass of the sample rounded to 0.1 g, with no fluctuation and no buoyancy from the air.
6. **Only one possible reading.** The scale is drawn without defects, and at the guided level only the mark closest to the water is accepted.
7. **Samples of uniform colour.** They are painted on purpose so that the colour does not give away the material. In the lab, colour and shine also give clues.

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