**Physics: 8. Density and Flotation**

***Please remember to photocopy 4 pages onto one sheet by going A3→A4 and using back to back on the photocopier***

**Syllabus**

**OP2** Measure mass and volume of a variety of solids and liquids and hence determine their densities.

**OP3** Investigate flotation for a variety of solids and liquids in water and other liquids, and relate the results of this investigation to their densities.

**Student Notes**

**Before studying this chapter you should first revise Chapter 1: *Measurement and Units***

**Introduction: Why do we have the concept called ‘density’ in the first place?**

Which is heavier; paper or iron?

Iron, right?

Well not necessarily; what about if the sample of iron was the size of a thumb-tack but the paper was like your textbook? Now the paper is heavier!

Well obviously it’s not a fair test – there’s too much paper.

For the comparison to be a fair test there should be the same *amount* of both materials. Or more specifically they should have the same *volume*. Now weigh both and see which is heavier.

Strictly speaking we should be looking at the object’s *mass* rather than its *weight*. The difference between *mass* and *weight* is something we deal with in the *Forces* chapter).

It’s not always convenient to have the same volume of two materials in order to see which has the greater mass. However there is a neat mathematical trick which allows us to get past that obstacle. If we divide the mass of the object by its volume then we get an answer for how much the mass of one metre cubed would weigh. We call this number the density of the object. Now we are in a position to compare the masses of different materials.

So to measure density we simply use the following formula:

The unit of density is the kg/m3 (pronounced “**kilogram per metre cubed**”) or **g/cm3**

**Density and Flotation**

**One reason we need to know an object’s density is to establish whether or not it will float in a liquid.**

**A solid will float in a liquid if the density of the solid is less than the density of the liquid**

e.g. plastics will float on water (or even iron cannonballs on mercury – see the YouTube clip).

**Predict, Observe, Explain**

Try floating an orange in a glass of water – what happens?

Try floating a *peeled* orange in a glass of water – now what happens?

Try floating a segment of a peeled orange in a glass of water – what happens?

Try floating an orange in a glass of diet and regular sprite – what happens?

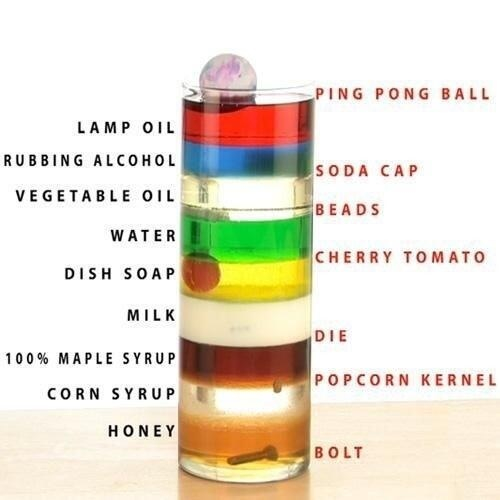
Why?

**Put a carrot into water – it sinks. Why?**

**Take the carrot out and cut it into pieces. What will happen if the pieces are put into the water?**

**A less dense liquid will float on top of a more dense liquid**

e.g. oil will float on water.

****

**Experiments**

**Measure mass and volume of a variety of solids and liquids and hence determine their densities**

1. To measure the density of a regularly-shaped block
2. To measure the density of an irregularly-shaped small stone
3. To measure the density of an irregularly-shaped large stone
4. To measure the density of a liquid

**Did you know?**Saturn is the only planet that floats; you should have a rubber Saturn instead of a rubber ducky in your bath!

**Summary of all the experiments**



**In each case to calculate the density we simply use the formula:**

****

**To measure the density of a regularly-shaped block**

*To find the mass* - weigh it on an electronic balance.

*To find the volume*:

Volume = length × width × height

In this case the volume is 5 × 2 × 1 = 10 cm3.

****

**To measure the density of an irregularly-shaped small stone**

*To find the mass* - weigh it on an electronic balance.

*To find the volume*:

Drop the stone into a graduated cylinder containing water and note the new volume.

To get the volume of the stone simply subtract the two readings.

In this case the volume = 90 – 75 = 15 cm3.

**To measure the density of an irregularly-shaped large stone**

*To find the mass* - weigh it on an electronic balance.

*To find the volume:*

Fill an overflow can up to the top and place an empty graduated cylinder under the spout.

Carefully drop the stone in (using a string so there is no splash).

Note the level of water in the overflow can.

****

**To measure the density of a liquid**

*To find the mass:*

Weigh an empty graduated cylinder, and then weigh the graduated cylinder after pouring water into it.

Then subtract the two readings.

*To find the volume* simply note the level of water in the graduated cylinder.

**Exam Questions:**

1. [2008 OL]

|  |
| --- |
| MASS  VOLUME |

1. Complete the equation in the box below using the words on the right.

Density =

1. If the mass of a stone is 20 g and the volume of the stone is 10 cm3, find the density of the stone.

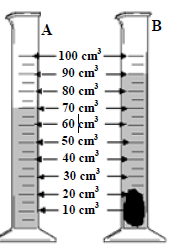


1. [2007 OL]

A block of metal has the measurements shown on the right.

The mass of the metal block is 21 g.

1. Calculate the volume of the block.
2. Calculate the density of the block.



1. [2011 OL]

A student set up the equipment shown to measure the volume of an irregular shaped object e.g. a stone.

When the stone was carefully dropped into the graduated cylinder containing water, arrangement B resulted.

1. Calculated the volume of the stone from the information shown.
2. If the mass of the stone was 40 g, calculate the density of the stone.
3. What is the unit of density?



1. [2009 OL]

The mass of a metal block is 14.7 g. It has a volume of 7 cm3.

1. Name the instrument you would use in the laboratory to find the mass of the block.
2. Calculate the density of the block.
3. What is the unit of density?
4. [2009]

A pupil measured the volume of a potato using the items of laboratory equipment, labelled A and B as shown in the diagram.

1. Name the items labelled A and B.
2. The potato had mass 175 g and volume 125 cm3.

Calculate the density of the potato.

Give the units of density with your answer.

1. Why did the potato sink in the water?
2. [2011]

The photo shows a hot air balloon.

Why does the balloon rise when the air inside is heated?

1. [2010]

Why do icebergs float on water?

1. [2007]

Ice floats on water but ice sinks in ethanol (an alcohol).

Use this information to compare the *density* of *ice* with

1. the *density* of *water*;
2. the *density* of *ethanol*.

**Exam Solutions**

1. Density = Mass/Volume
2. Density of the stone = 20/10 = 2 g/cm3
3. Volume = 5×1×2 = 10 cm3
4. Density = 21/10 = 2.1 g/cm3
5. Volume = 90 – 70 = 20 cm3
6. Density = mass/volume = 40/20 = 2 g/cm3
7. g/cm3
8. Electronic balance / weighing scales
9. Density = 14.7÷7 = 2.1
10. Unit = g/cm3
11. Item A is an overflow can

Item B is a graduated cylinder

1. Density = 175/125 = 1.4 g/cm3
2. Because it is denser than water
3. Because the air expands and becomes less dense / air outside denser
4. They have a lower density than water.
5. Ice is less dense than water
6. Ice is more dense than ethanol

**Extra Questions: Density**

1. What is meant by the term ‘density’?
2. Draw a diagram of the apparatus used to measure the density of a regularly-shaped object.
3. Draw a diagram of the apparatus used to measure the density of an irregular-shaped object.
4. Draw a diagram of the apparatus used to measure the density of a liquid.
5. A stone has a mass of 120 g and a volume of 20 cm3, what is the density of the stone?
6. What is the density of an object which has a mass of 20 kg and whose volume is 4 m3?
7. A student measured the density of a number of substances. The results are shown in the table below. Identify two substances that would float in paraffin oil.

|  |  |
| --- | --- |
| Substance | Density (g/cm3) |
| Cork | 0.3 |
| Polystyrene | 0.03 |
| Water | 1.0 |
| Paraffin Oil | 0.7 |
| Rubber | 1.1 |

**Experiment: To measure the density of a regular-shaped object (wooden block)**

**Questions**:

1. Was there any point in repeating the experiment with the third block?
2. Look at your results for density – are they about the same?
3. Isn’t this strange since we used different sized blocks?

How could this be?

1. If you have worked out the answer to Question 4 then you will know that your answers for density should be exactly the same each time. Are they?
2. If not why not?
3. Does this mean your experiment is wrong?
4. Can you think of anything you could do to make your results more convincing?
5. What was the point in getting an average of the three results?

**To measure the density of water**

**Questions**

1. Was there any point in repeating the experiment the third time?
2. Look at your results for density – are they about the same?
3. Isn’t this strange since we used different amounts of water each time?

How could this be?

1. If you have worked out the answer to Question 4 then you will know that your answers for density should be *exactly* the same each time. Are they?
2. If not why not?
3. Does this mean your experiment is wrong?
4. Can you think of anything you could do to make your results more convincing?
5. What was the point in getting an average of the three results?
6. The fact that science experiments don’t give perfect answers is a very important concept for society.
7. Can you think why?

**To measure the density of a small irregular–shaped object (using a graduated cylinder)**

**Questions**

1. Why use thread when it would be easier to just drop the stone in?
2. Why is it important that the stone is lowered gently?
3. Was there any point in repeating the experiment with the third stone?
4. Look at your results for density – are they about the same?
5. Isn’t this strange since we used different sized stones?

How could this be?

1. If you have worked out the answer to Question 4 then you will know that your answers for density should be *exactly* the same each time. Are they?
2. If not why not?
3. Does this mean your experiment is wrong?
4. Can you think of anything you could do to make your results more convincing?
5. What was the point in getting an average of the three results?

**To measure the density of a large irregular–shaped object using an overflow can*.***

**Questions**

1. Why use thread when it would be easier to just drop the stone in?
2. Why is it important that the stone is lowered gently?
3. Was there any point in repeating the experiment with the third stone?
4. Look at your results for density – are they about the same?
5. Isn’t this strange since we used different sized stones?

How could this be?

1. If you have worked out the answer to Question 4 then you will know that your answers for density should be *exactly* the same each time. Are they?
2. If not why not?
3. Does this mean your experiment is wrong?
4. Can you think of anything you could do to make your results more convincing?
5. What was the point in getting an average of the three results?
6. The fact that science experiments don’t give perfect answers is a very important concept for society.
7. Can you think why?

**Teaching *Mass, Volume and Density***

**Syllabus**

**OP2**

Measure mass and volume of a variety of solids and liquids and hence determine their densities

**OP3**

Investigate flotation for a variety of solids and liquids in water and other liquids, and relate the results of this investigation to their densities

**OP2:**

**Measure mass and volume of a variety of solids and liquids and hence determine their densities**

**Teaching density**

See the introduction in the notes above

**The experiment**

I assume students have already calculated the mass and volume of various objects from first year but a quick revision would be very worthwhile.

See the pages at the bottom of this section for a proposed template and associated higher order questions.

**Repeat with different samples**

One of the most important lessons here is that different samples of the same material have the same density, so in each of the following experiments ensure that the students repeat their procedure for different samples (of the same material).The fact that the syllabus doesn’t expect students to do this is merely a reflection of the incompetence of the syllabus committee and should be ignored.

This will necessitate gathering up *a lot* of wooden blocks and similar-type stones (small and large) in advance.

**Sample size**

A second very important lesson can also be tied into this; when students repeat with a different size sample they are unlikely to get exactly the same density (indeed the fact that the two results are almost the same may surprise many). We can still conclude that because the densities of all objects are approximately the same that it is okay to generalise. No experiment in Physics (or Science) will give exact answers. This should be used as an opportunity to discuss the role of experimental error in Science.

So how could we make the results even more convincing?

Answer: use a greater sample size.

So Science is actually all about probability, not certainty!

This concept is one of the most important in all of Science (so no, it’s not on the syllabus either).

**Planning the experiment in advance**

The emphasis in the revised syllabus is to give some thought beforehand to planning the experiment instead of diving straight in without knowing how to go from one step to the next, or indeed what the experiment is about.

To avoid this the students should have to show in advance that they know what to do.

This is what the ‘planning’ aspect is trying to get at.

**Density and Flotation**

When results are finally collected for the timber, stone and water they can be used as part of a discussion on density and flotation. Hopefully students will guess the relationship themselves with a little guidance (or group discussions).

**The write-up:**

**Procedure**

Students may now be using booklets which tell them exactly what they should write for each step. Nevertheless you should emphasise that with the procedure the most important aspect is detailing how you obtained values for each of the variables (in this case mass and volume), and then detailing how you used these to get a final answer.

They should also ask themselves as they go along whether their colleagues would be able to repeat the experiment based on their account.

**Results**

Whenever possible all results should be presented neatly in a table.

The layout of the table is a task in itself and should be dealt with in advance.

Syllabus: Investigate flotation for a variety of solids and liquids in water and other liquids, and relate the results of this investigation to their densities

**1.1 Demos**

* An egg will sink in tap-water but will float in salt-water.
* A can of diet coke will float in tap-water but a can of regular coke will sink.
* Assuming that the extra mass is due to sugar, how could you find out how much extra sugar is in the regular coke?
* A peeled orange will sink in tap-water while an unpeeled orange will float.

Get a glass of fizzy water (ideally transparent, e.g. Sprite) and drop in some raisins or peanuts.

The raisins initially sink, but then slowly rise to the top, only to start sinking again. The process repeats for up to an hour.

What’s going on?

Ask them to go into groups and observe then explain what’s going on.

Bubbles of CO2 form on the raisins and as a result the raisins float until at the top the bubble is released (why?) and the raisins sink.

Link to dissolved oxygen used by fish.

Link also to the traditional lava lamp.

**Class Activity**

Get an empty small plastic bottle and keep putting water in it (through trial and error) so that it just floats.

What is it about this amount of water that makes it just the right amount?

Encourage comments to try and tease out misconceptions and then bring them around to mass and volume.

Now we wish to compare this to the mass and volume of water which they have already calculated.