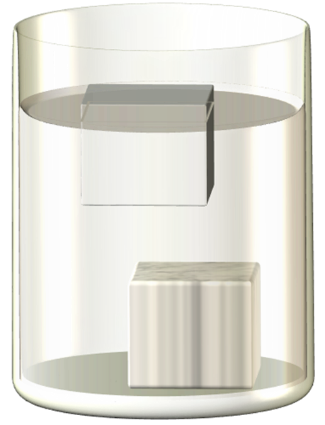
**Particle anomaly**

Ice floats in water and a piece of rock sinks.

**To do**

Draw particle diagrams for the rock and water and ice.

Particles in rock

Particles in water

Particles in ice

**To answer**

1. Why does rock have a higher density than water?

…………………………………………………………………………………………………………………………………………………….

…………………………………………………………………………………………………………………………………………………….

…………………………………………………………………………………………………………………………………………………….

1. Why does ice have a lower density than water?

…………………………………………………………………………………………………………………………………………………….

…………………………………………………………………………………………………………………………………………………….

…………………………………………………………………………………………………………………………………………………….

1. What is wrong with the particle diagram that shows the particles in ice?

…………………………………………………………………………………………………………………………………………………….

…………………………………………………………………………………………………………………………………………………….

…………………………………………………………………………………………………………………………………………………….

*Physics > Big idea PMA: Matter > Topic PMA4: Particle explanations > Key concept PMA4.1: Density*

|  |
| --- |
| **Response activity** |
| **Particle anomaly** |

**Overview**

|  |  |
| --- | --- |
| Learning focus: | Density, the mass of material in 1m3 or in 1cm3, is dependent on both the mass of its particles and their spatial arrangement. |
| Observable learning outcome: | Explain why the density of water in its solid state is less than the density of water in its liquid state. |
| Activity type: | Application and practice |
| Key words: | Particle, mass, volume, density |

This activity can help develop students’ understanding by addressing the sticking-points revealed by the following diagnostic question:

* Diagnostic question: Cold water

**What does the research say?**

An understanding of particles is not necessary to understand density, but to understand *why* the density of one material is different to the density of another, students need to use the particle model. They also need to understand that even sub-microscopic particles have a mass and volume (Smith, Snir and Grosslight, 1992). Smith et al. (1997) found that although these concepts are often assumed when density is taught, 27% of 12- to 13-year-olds (n=30) do not hold them. In their study they found that giving students opportunity to address these concepts directly led to a more robust understanding of density.

The particle model of matter can represent how closely particles are packed together, which together with the mass of each particle explains the density of a material. Density is a joint function of mass of particles and their spatial arrangement, which is affected by temperature and pressure. An understanding of particles provides students with powerful tools for thinking about changes of density. (Smith et al., 1992)

In a very large study of students in the United States, called Project 2061, the American Association for the Advancement of Science (AAAS) found that 14% of students age 14-18 held the misunderstandings that the identity of the molecules of a substance change during a phase change. 14% also thought that particles change weight/mass during a phase change.

Students need opportunity to test out and consolidate their understanding of density in a range of different situations. When a class of (n=36) 15- to 16-year-olds were shown a block of ice floating on water and asked to draw diagrams to represent particles in the ice and the water, their drawings showed particles closer together in ice than in water (Mortimer and Machado, 2000). Only when asked whether ice was more or less dense than water did some realise their error. This example illustrates the truism that in solving a physics problem it is always good practice to consider whether or not the final answer is reasonable.

**Ways to use this activity**

This activity gives students the opportunity to practise applying their understanding and to clarify their thinking through discussion. To support this, students should answer the questions in pairs or small groups.

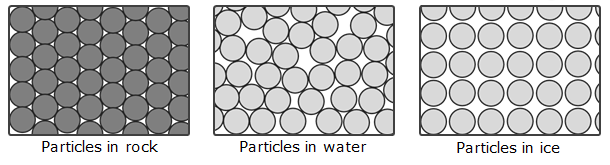
Listening to individual groups as they work often highlights any difficulties they might have. These can often be overcome, through a whole class clarification or redirection part way through the activity.

Asking students to share their answer is a useful check. After a group has fed back, it might be helpful to model an even better answer. You could do this, for example, by asking another group to add to, or clarify, the first observation. Then ask another group to sum up the important part of the observation, and so on.

*Differentiation*

If some students are working with a teaching assistant, then a list of prompt questions for the teaching assistant could help to make this activity more purposeful.

**Expected answers**



1. Rock has a higher density than water because it has more mass in a particular volume. Particles of rock are different to the particles in water and each one may have more mass than a particle of water. The particles in rock may also be closer together than the particles in water.
2. Ice has a lower density than water because it has less mass in a particular volume. The particles in ice and water are the same, so the particles in ice must be packed less tightly together.
3. The particle diagram for ice shows gaps between the particles. In a solid each particle should be touching the particles next to it. In order to keep some gaps between particles of ice and to make them touch, particles in the diagram need to be drawn in a different shape. Water particles are in reality shaped more like a banana than a ball.

**Acknowledgments**

Developed by Peter Fairhurst (UYSEG), based on the work of Mortimer and Machado (2000).

Images: Peter Fairhurst (UYSEG).

**References**

AAAS. *Science Assessment Topic: Atoms, Molecules and States of Matter* [Online]. Available at: <http://assessment.aaas.org/> [Accessed July 2020.

Mortimer, E. F. and Machado, A. H. (2000). Anomalies and Conflicts in Classroom Discourse. *Science Education,* 84(4)**,** 429-444.

Smith, C., et al. (1997). Teaching for understanding: a study of students' preinstruction theories of matter and a comparison of the effectiveness of two approaches to teaching about matter and density. *Cognition and Instruction,* 15(3)**,** 317-393.

Smith, C., Snir, J. and Grosslight, L. (1992). Using conceptual models to facilitate conceptual change: the case of weight-density differentiation. *Cognition and Instruction,* 9(3)**,** 221-283.