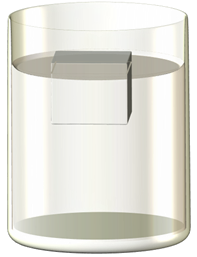
**Cold water**



Ice floats on water.

**a.** What do you think about the density of ice?

*Put a tick (✓) in the box next to the best answer.*

|  |  |  |
| --- | --- | --- |
| **A** | Ice has a lower density than water. |  |
|  |  |  |
| **B** | Ice has the same density as water. |  |
|  |  |  |
| **C** | Ice has a higher density than water. |  |

**b.** Which **two** statements best explain your last answer?

*Put a tick (✓) next to* ***one*** *of these three answers …*

|  |  |  |
| --- | --- | --- |
| **A** | The particles in ice and water are identical. |  |
|  |  |  |
| **B** | The particles in ice have more mass than those in water. |  |
|  |  |  |
| **C** | The particles in ice have less mass than those in water. |  |

+

*…* ***and*** *put a tick (✓) next to* ***one*** *of these three answers.*

|  |  |  |
| --- | --- | --- |
| **D** | There are more particles in 1cm3 of ice than in 1cm3 of water. |  |
|  |  |  |
| **E** | There are fewer particles in 1cm3 of ice than in 1cm3 of water. |  |
|  |  |  |
| **F** | The number of particles in 1cm3 of ice is the same as in 1cm3 of water. |  |

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

|  |
| --- |
| **Diagnostic question** |
| **Cold water** |

**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. |
| Question type: | Two-tier multiple choice |
| Key words: | Particle, mass, volume, density |

**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 question**

Students should complete the questions individually. This could be a pencil and paper exercise, or you could use an electronic ‘voting system’ or mini white boards and the PowerPoint presentation. The follow on question will give you insights into how they are thinking and highlight specific misconceptions that some may hold.

If there is a range of answers, you may choose to respond through structured class discussion. Ask one student to explain why they gave the answer they did; ask another student to explain why they agree with them; ask another to explain why they disagree, and so on. This sort of discussion gives students the opportunity to explore their thinking and for you to really understand their learning needs.

*Differentiation*

You may choose to read the questions to the class, so that everyone can focus on the science. In some situations it may be more appropriate for a teaching assistant to read for one or two students.

**Expected answers**

a. A

b. A and E

**How to respond - what next?**

Most, if not all, students are likely to answer *part a* correctly. It is misunderstandings in the reasons they give for their answer that often need addressing.

A minority of students may continue to hold the misconception that particles in ice and water are different to each other.

It is common for students to apply a general understanding of particle arrangements in solids and liquids to this situation and assume particles in ice are more closely packed than those in water (option D). From this error logic leads to the wrong conclusion that the mass of particles in ice must be less than those in water (option C).

It is also relatively common for students who say that ice has a smaller density than water, to also state that particles in ice and water are identical and that there are more particles in 1cm3 of ice than a similar volume of water. These statement do not fit into a coherent framework and students are likely to be relying on ‘facts’ they have learnt.

If students have misunderstandings about explaining why the density of water in its solid state is less than the density of water in its liquid state, it can help to model the process of thinking through the new situation logically, by applying scientific understanding. Careful questioning should elicit the understanding that observation shows that, whilst the particles in ice and water are identical, ice is less dense than water. This leads to the explanation that the particles in ice cannot be as tightly packed as they are in water. This conclusion contradicts the general understanding of particles in solids and liquids and suggests there must be some new information that is necessary to fully understand the phenomenon.

The particle model represents particles as spheres and this is a limitation of the model because many molecules are not this shape. Particles of water can, for example, be thought of as roughly banana shaped. In both its liquid and solid states water molecules are all in contact with adjacent molecules, but in the solid state they align and are held in place in a more open structure that explains the lower than expected density of ice.

The following BEST ‘response activity’ could be used in follow-up to this diagnostic question:

* Response activity: Particle anomaly

**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.