**Diamond conductor**

Diamond is made from carbon atoms.

It is a non-metal.

The carbon atoms are bonded together to make a giant structure.

The forces holding the carbon atoms in place are very strong.

Metals are good thermal conductors.

**a.** What sort of thermal conductor do you think diamond is?

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

|  |  |  |
| --- | --- | --- |
| **A** | A poor thermal conductor. |  |
|  |  |  |
| **B** | A good thermal conductor. |  |
|  |  |  |
| **C** | A *very* good thermal conductor. |  |

Each statement below correctly describes diamond.

**b.** Which one do you think is the *best* reason for your last answer?

*Put a tick (✓) in the box next to the one you think.*

|  |  |  |
| --- | --- | --- |
| **A** | Diamond is a non-metal. |  |
|  |  |  |
| **B** | There are no free electrons in diamond. |  |
|  |  |  |
| **C** | The forces holding the carbon atoms in place are very strong. |  |
|  |  |  |
| **D** | Diamond has a giant structure. |  |

*Physics > Big idea PMA: Matter > Topic PMA3: Energy of moving particles > Key concept PMA3.1: Transfer of energy by conduction*

|  |
| --- |
| **Diagnostic question** |
| **Hot iron** |

**Overview**

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| --- | --- |
| Learning focus: | Energy is transferred through a solid away from regions of higher temperature as its particles are caused to vibrate more vigorously. |
| Observable learning outcome: | Explain why some non-metals are better thermal conductors than metals. |
| Question type: | Two-tier multiple choice |
| Key words: | Non-metal, giant structure, rigid, free-electron, thermal conductor |

|  |  |
| --- | --- |
| **B** | **Bridging**  This diagnostic question probes understanding of ideas that are usually taught at age 16-19, to build a bridge to later stages of learning. |

**What does the research say?**

Diamonds are sometimes described as ‘ice’ because they feel very cold to the touch. This is because they are excellent thermal conductors. At room temperature the thermal conductivity of diamond is approximately three times higher than that of copper (Engineering ToolBox, 2003).

Engel Clough and Driver (1985) found that almost all 12- to 16-year-olds understood that ‘heat’ travelled through metals. This understanding may lead some students to believe that all non-metals are poor thermal conductors.

**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.** **C** A *very* good thermal conductor

**b**. **C** The forces holding the carbon atoms in place are very strong.

**How to respond - what next?**

The information provided in the question may lead some students to understand that diamond is an excellent thermal conductor because very strong forces hold each carbon atom very tightly to four others. This means that when one is made to vibrate faster by heating, the vibration can be transferred through the structure very quickly.

N.B. Diamond is a not a good conductor of electricity because it has no freely moving outer electrons.

Some students may misunderstand all non-metals to be poor thermal conductors (answers A, A or A, B).

Answer D, for part b, does improve thermal conduction but it is the rigid bonds (answer C) that are necessary for good conduction in a giant structure.

If students have misunderstandings about why some non-metals are better thermal conductors than metals, it can to review understanding of *both mechanisms* of thermal conduction. Careful questioning should elicit the understanding that all solids are thermal conductors to some extent because in all solids vibrating particles can transfer some vibration to their neighbouring particles. And that the effectiveness of how well they can do this depends on strength of the forces in the bonds between them. Metals have freely moving outer electrons that provide a second form of thermal conduction, which is *usually* more effective than the former mechanism.

It may also help to model thermal conduction in diamond, in order to compare it to conduction in other non-metals on a sub-microscopic scale. This can be done using a line of students as particles linking arms to represent bonds between them. In a diamond structure the bonds are strong and there is very little movement between particles. In most non-metals the bonds are much looser and vibrations take longer to pass along the line.

Asking students to write down (or draw) individual explanations can help consolidate understanding and can be a quick check for persisting misunderstanding.

**Acknowledgments**

Developed by Peter Fairhurst (UYSEG).

Images: Peter Fairhurst (UYSEG).

**References**

Engineering ToolBox, (2003). *Thermal Conductivity of selected Materials and Gases*. [online] Available at: https://www.engineeringtoolbox.com/thermal-conductivity-d\_429.html [Accessed 1 July 2020].

Engel Clough, E. and Driver, R. (1985). Secondary students' conceptions of the conduction of heat: bringing together scientific and personal views. *Physics Education,* 20**,** 176-182.