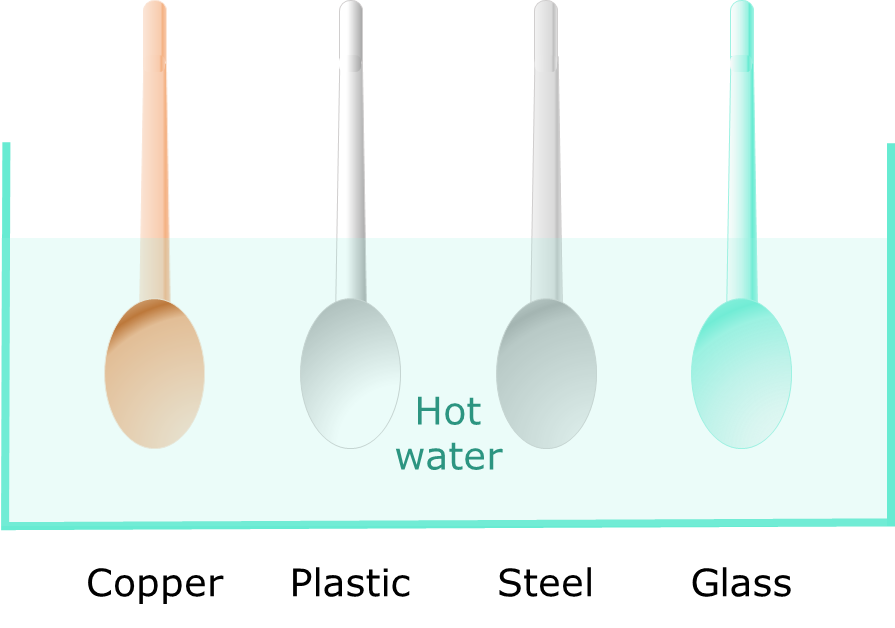
**Fast conduction**

These four spoons are all placed in hot water at the same time.



These statements are about the speed of thermal conduction.

*For each statement, tick (✓)* ***one*** *column to show what you think.*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | | I am **sure** this is right | I think this is right | I think this is wrong | I am **sure** this is wrong |
| **A** | The tops of the metal spoons become hotter before the tops of the other spoons. |  |  |  |  |
| **B** | Outer electrons from metal atoms can move easily through metal. |  |  |  |  |
| **C** | The outer electrons from metal atoms carry heat through a metal. |  |  |  |  |

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

|  |
| --- |
| **Diagnostic question** |
| **Fast conduction** |

**Overview**

|  |  |
| --- | --- |
| 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 metals are good thermal conductors. |
| Question type: | Confidence grid |
| Key words: | Thermal conduction, free electron, heat, energy, particle, vibrate |

**What does the research say?**

The notion that heat and cold are material substances that can flow from one place to another seem to be both common and persistent (Engel Clough and Driver, 1985; Hatzikraniotis et al., 2010; Thomaz et al., 1995). Engel Clough and Driver (1985) found that almost all 12- to 16-year-olds understood that ‘heat’ travelled through metals, but often described heat flowing rather than the actual mechanism. Hatzikraniotis et al. (2010) reported that the majority of 13- to 14-year-olds (n=24) described thermal conduction as the flow of hot particles. In their study in Portugal, Thomaz et al. (1995) similarly found that before teaching, 42% of 14- to 15-year-olds (n=79) wrongly thought of ‘heat’ (or ‘cold’) as a substance.

Metals are good thermal conductors because the outer electrons of metal atoms can move freely in-between metal ions. In thinking about how these outer electrons make metals good thermal conductors Pathare and Pradhan (2010) found some second year undergraduate physics students wrongly thought the heating of one end of a metal rod *released* more electrons from atoms to flow along it.

**Ways to use this question**

Students should complete the confidence grid 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.

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**

Statements A and B are right; and statement C is wrong.

**How to respond - what next?**

Most, if not all, students will recognise that metals are good conductors and are likely to realise that the tops of the metal spoons become hotter before the tops of the others. They may not however understand the mechanism that makes metals good thermal conductors.

In the earlier BEST key concept PMA1.3: Thermal conduction, the importance of explaining the more rapid conduction in metals in terms of the movement of outer electrons from metal atoms that can move freely in-between metal ions (Millar, 2011) was made clear. However, the nature of these electrons is likely to be as source of misunderstanding. Some students are likely to imagine that a metal is made up of atoms that release electrons when they are heated, and these ‘freed’ electrons can then move through the metal. Instead, a metal consists of positive ions and the outer electrons from metal atoms that are separate from the ions and always free to move between the ions. Heating increases the speed of motion of these electrons so that they move more quickly through the metal and pass on their movement to ions via collisions.

Statement C is wrong as it suggests the freely moving outer electrons become hotter and move through the metal taking their ‘heat’ with them. An electron cannot become ‘hotter’ but it can move more quickly. As faster moving outer electrons move through the metal their collisions with ions make the ions vibrate more vigorously. It is the more vigorous movement of metal ions that can be detected as hotness.

If students have misunderstandings about why metals are good thermal conductors, it can help to model the two mechanisms for thermal conduction: firstly as more vigorous vibrations are transmitted particle to particle; and secondly as freely moving outer electrons pass on vibrations in metals. These two mechanisms should be compared and students given the opportunity to explain each one in their own words. Focused small group discussions can support the social construction of a scientific understanding through dialogue. Giving students the opportunity to explain their thinking individually in writing or with diagrams can consolidate these ideas and provides a quick check on each students understanding.

The following BEST ‘response activities’ could be used to support these strategies in follow-up to this diagnostic question:

* Response activity: Free electron model
* Response activity: Along the line

**Acknowledgments**

Developed by Peter Fairhurst (UYSEG).

Images: Peter Fairhurst (UYSEG).

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