**Handlebars**

On a cold day the metal on a bike feels very cold.

The plastic grips on the handlebars do not feel so cold.



Why does the metal handlebar feel colder than the plastic grips?

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

|  |  |  |
| --- | --- | --- |
| **A** | Metal is a better thermal conductor than plastic. |  |
|  |  |  |
| **B** | Metal absorbs the cold better than plastic. |  |
|  |  |  |
| **C** | Metal is smoother and more shiny than plastic. |  |
|  |  |  |
| **D** | Metal lets the heat out more easily than plastic. |  |
|  |  |  |
| **E** | Plastic has a higher temperature than metal. |  |

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

|  |
| --- |
| **Diagnostic question** |
| **Handlebars** |

**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 different objects in thermal equilibrium feel hotter or cooler to touch. |
| Question type: | Simple multiple choice |
| Key words: | Thermal equilibrium, temperature, absorb |

**What does the research say?**

It is common for students to *not accept* that different objects are at the same temperature as each other if they are left in contact with the same surroundings for a long time (Thomaz et al., 1995; Hatzikraniotis et al., 2010). Hatzikraniotis et al. (2010) found that just over 40% of 13- to 14-year-olds (n=24) did not understand that objects in thermal equilibrium all have the same temperature. Understanding the concept of thermal equilibrium is central to understanding other heat and temperature concepts (Thomaz et al., 1995).

Students may link their perceived temperature of an object to whether it feels warm or cold to the touch, for example that metal is colder than plastic when both are at room temperature (Engel Clough and Driver, 1985; Thomaz et al., 1995). In a study of 12- to 16-year-olds (n=84), Engel Clough and Driver (1985) found just 6% were able to explain correctly why metal spoons felt colder to the touch than plastic spoons at the same temperature. 25% said it was because metals let ‘heat’ in or out more easily and 5% that they attracted or absorbed coldness. Pathare and Pradhan (2010) found that this idea persisted even amongst a few undergraduate physics students.

When asked to explain why the metal parts of handlebars felt colder than plastic parts in cold, frosty weather, Engle Clough and Driver (1985) found that 23% of 12- to 16-year-olds (n=84) explained this using the misunderstanding that metals attract or absorb cold more easily. ‘The direction of conduction of heat in relation to the human body appears to influence thinking; quite simply students find it difficult to think of conduction of heat when they feel cold’ (Engel Clough and Driver, 1985).

McLure, Won and Treagust (2020) found that a thinking frames approach to understanding the concept of why conduction away from the body caused object to feel cold was particularly successful, and significantly improved students understanding both immediately and in the longer term. The thinking frames approach used predict, explain; observe, explain activities to engage students in focussed small group discussions, in order to support the construction of a scientific understanding.

**Ways to use this question**

Students should complete the question 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 answers to the question will show you whether students understood the concept sufficiently well to apply it correctly.

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** Metal is a better thermal conductor than plastic.

**How to respond - what next?**

In a study, in which Engel Clough and Driver (1985) asked this as an open-ended question to eighty-four 12- to 16-year-old students, the following responses were reported:

|  |  |
| --- | --- |
| Different substances feel different because they have different thermal conductivities. | 6% |
| Metal attracts/absorbs/conducts coldness. | 23% |
| Conductivities of different materials depend on some observable property such as colour, thickness or smoothness etc. | 17% |
| Metals let heat in or out more easily. | 14% |
| Mixed and other uncodeable responses. | 40% |

Of the students in the study, none of the 12-, or 14-year-olds were able to give a scientifically-acceptable explanation and only five out of twenty-four 16-year-olds gave one.

In this BEST multiple-choice question, answer A is correct because when the hand heats the metal, the metal’s good thermal conductivity allows energy to transfer quickly from the hand. Metal ions made to vibrate more quickly by the hand very quickly transfer vibrations on to metal ions throughout the metal. The vigour of the vibrations of the metal ions in contact with the hand do not increase enough to raise their temperature sufficiently to feel warm to the touch.

The lower thermal conductivity of the plastic grips mean the heating from the hand can increase the temperature much more locally so, at the point of contact, the plastic grips feel warm. The rest of the plastic grips are at the same temperature as the metal handlebars, so answer E is not the best answer. (Answer E also implies that in the cold, plastic has a higher temperature because of its inherent properties.)

It is quite likely that when students apply their understanding to a challenging context, such as this, they revert to earlier misunderstandings.

If students have misunderstandings about why different objects in thermal equilibrium feel hotter or cooler to touch, it can help to discuss with students the temperature of their own hands and the temperature to the object that they are touching in order to help them to think about the situation in a scientific way. The temperature of the palm of a hand touching a cold handlebar is likely to be around 30oC, which is much warmer than the handlebar.

Focused small group discussions can then support the social construction of a scientific understanding through dialogue. The following BEST ‘response activities’ use this strategy in a way that McLure, Won and Treagust (2020) found to be particularly successful in helping students understand the concept of why conduction away from the body causes an object to feel cool. They could be used in follow-up to this diagnostic question:

* Response activity: Thermal equilibrium
* Response activity: Melting ice

**Acknowledgments**

Developed by Peter Fairhurst (UYSEG), from an idea by Engel Clough and Driver (1985).

Images: by Wokandapix from Pixabay

**References**

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.

Hatzikraniotis, E., et al. (2010). Students' design of experiments: an inquiry module on the conduction of heat. *Physics Education,* 45 (4)**,** 335-344.

McLure, F., Won, M. and Treagust, D. F. (2020). Teaching thermal physics to year 9 students: The Thinking Frames Approach. *Physics Education,* 53**,** 11.

Pathare, S. R. and Pradhan, H. C. (2010). Students' misconceptions about heat transfer mechanisms and elementary kinetic theory. *Physics Education,* 45**,** 629-634.

Thomaz, M. F., et al. (1995). An attempt to overcome alternative conceptions related to heat and temperature. *Physics Education,* 30 (1)**,** 19-26.