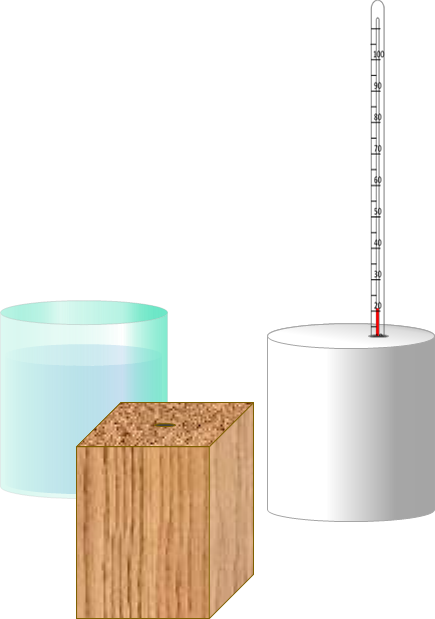
**Thermal equilibrium**



Glass of water

Block of wood

Block of metal

These materials have been left in the laboratory overnight.

Feel each material with your hand.

Put them in order, from the one that feels the warmest to the one that feels the coldest.

**Predict**

Which material do you think has the highest temperature and which one the lowest temperature?

Do you think these are higher or lower than the temperature of the room?

**Explain**

What are the reasons you think the temperatures will be like this?

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| --- |
| **Measure the temperature of each material and of the room.** |

**Observe**

Record the temperature of each material and the temperature of the room.

**Explain**

Were your prediction and explanation correct?

Try to improve your first explanation to explain what happens more clearly.

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

|  |
| --- |
| **Response activity** |
| **Thermal equilibrium** |

**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. |
| Activity type: | Predict, explain; observe, explain (PEOE) |
| Key words: | Thermal equilibrium, temperature |

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

* Diagnostic question: Warm and cold
* Diagnostic question: Handlebars
* Diagnostic question: Cold spoons

**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 activity**

Students should complete this activity in pairs or small groups, and the focus should be on the discussions. It is through the discussions that students can check their understanding and rehearse their explanations.

To begin, each group should discuss the activity and use their scientific understanding, firstly to predict *what* they think will happen, and then to explain *why* they think they are going to be right. If students in any group cannot agree, you may be able to direct them with some careful questioning.

Students now carry out the practical, or watch a demonstration. You will need to decide whether it is better for each group to carry out the practical and risk some unexpected observations, or to demonstrate the activity so that everyone *observes* the same thing.

*As each material needs be left at room temperature for several hours it may be easiest to complete this activity as a demonstration.*

After the practical each group should be given the opportunity to change, or improve their explanation. A good way to review your students’ thinking might be through a structured class discussion. You could ask several groups for their *explanations* and put these on the whiteboard. Then ask other groups to suggest which explanation is the most accurate and the most clearly expressed, and through careful questioning work up a clear ‘class explanation’.

A useful follow up is for individual students to then write down explanations in their own words – without reference to the class explanation on the board (i.e. cover it up).

*Differentiation*

The quality of the discussions can be improved with a careful selection of groups; or by allocating specific roles to students in the each group. For example, you may choose to select a student with strong prior knowledge as a scribe, and forbid them from contributing any of their own answers. They may question the others and only write down what they have been told. This strategy encourages contributions from more members of each group.

**Equipment**

For the class:

* Beaker of water (500 ml)
* Metal block with a hole for a thermometer (a specific heat capacity block)
* Wooden block with a hole for a thermometer
* x4 thermometers (calibrated against each other) that fit into the holes in each block

**Technician notes**

Standard laboratory thermometers may differ in their measurements by one or even two degrees C. It is important for this activity to select four thermometers that all read exactly the same value at room temperature.

**Health and safety**

Practical work should be carried out in accordance with local health and safety requirements, guidance from manufacturers and suppliers, and guidance available from CLEAPSS.

**Expected answers**

All three materials and the room have the same temperature. As they materials have been in the same room for a long time, they will have had time to reach thermal equilibrium with each other and with the room.

The wood feels warmer than the metal or the water because it is a poor thermal conductor. This means that when we touch it, the wood in contact with our fingers can quickly heat up and feel warm whilst the rest of the wood remains at room temperature. Metal is a good thermal conductor and energy is transferred quickly throughout the metal away from where we are touching it. This means that the metal in contact with our fingers remains at (roughly) room temperature, as does the rest of the metal block.

If a material is initially hotter than the room then vibrating particles in its surface will cause the particles in the air to move more quickly and they themselves will move less quickly. In this way energy will be transferred from a hot object to the room until they are both at the same temperature.

If a material is initially cooler than the room the reverse process will happen and the object will warm up until its temperature is the same as the room.

**Acknowledgments**

Developed by Peter Fairhurst (UYSEG), from an idea by Thomaz et al. (1995).

Images: Peter Fairhurst (UYSEG).

**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.