

Key concept (age 14-16)

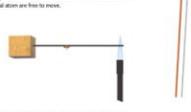
PMA3.1: Transfer of energy by conduction

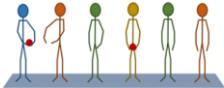
Learning focus	Energy is transferred through a solid away from regions of higher temperature as its particles are caused to vibrate more vigorously.				
As students' conceptual understanding progresses they can:					
	Describe how the sensation of hotness is caused by vibrating particles. P	Describe the mechanism of thermal conduction that can occur in all solids. P	Explain why metals are good thermal conductors.	Explain why different objects in thermal equilibrium feel hotter or cooler to touch.	Explain why some non-metals are better thermal conductors than metals. B
Diagnostic questions	Hot blocks	Heating spoons	Fast conduction	Warm and cold	Diamond conductor
	Hot iron			Handlebars	
				Cold spoons	
Response activities	Feel the heat		Free electron model	Thermal equilibrium	
		Along the line		Melting ice	

Key:

P Prior understanding from earlier stages of learning

B Bridge to later stages of learning

<p>Hot blocks</p> <p>Touching hot metal can hurt. The hot metal can damage the cells in your skin.</p>  <p>a. If you touched one of these blocks of metal for ten seconds, which would burn you the most? Put a tick (✓) next to the best answer.</p> <p>60°C 70°C 80°C</p> <p>A B C</p> <p>Do not try this yourself!</p> <p>b. What is the best reason for your last answer? Put a tick (✓) in the box next to the best answer.</p> <p>A More heat particles flow from the block. <input type="checkbox"/></p> <p>B More energy flows from the block. <input type="checkbox"/></p> <p>C There are more particles in this block that are vibrating. <input type="checkbox"/></p> <p>D The particles in this block are vibrating more quickly. <input type="checkbox"/></p> <p><small>Developed by the University of York Science Education Group and the Salters' Institute. This document may have been edited. Download the original from www.BestEvidenceScienceTeaching.org. © University of York Science Education Group. Distributed under a Creative Commons Attribution-NonCommercial (CC BY-NC) license.</small></p>	<p>Hot iron</p> <p>Touching hot iron in the wrong place can hurt. The hot metal can't cut damage the cells in your skin.</p>  <p>Do not try this yourself!</p> <p>a. If you touched the hot metal on an iron, what length of time would damage your skin the most? Put a tick (✓) in the box next to the best answer.</p> <p>A 1 second. <input type="checkbox"/></p> <p>B 3 seconds. <input type="checkbox"/></p> <p>C 5 seconds. <input type="checkbox"/></p> <p>D The same damage for 1, 2 or 3 seconds. <input type="checkbox"/></p> <p>b. What is the best reason for your last answer? Put a tick (✓) in the box next to the best answer.</p> <p>A More energy flows from the metal. <input type="checkbox"/></p> <p>B More heat particles flow from the metal. <input type="checkbox"/></p> <p>C Particles in the metal are vibrating against the skin for longer. <input type="checkbox"/></p> <p>D Particles in the metal are vibrating the same each time. <input type="checkbox"/></p> <p><small>Developed by the University of York Science Education Group and the Salters' Institute. This document may have been edited. Download the original from www.BestEvidenceScienceTeaching.org. © University of York Science Education Group. Distributed under a Creative Commons Attribution-NonCommercial (CC BY-NC) license.</small></p>	<p>Heating spoons</p> <p>Energy can be transferred through a spoon by thermal conduction. These spoons are made from different materials. Thermal conduction is faster in some materials and slower in others.</p>  <p>Wood Plastic Metal Glass</p> <p>These statements are linked to thermal conduction in different materials. For each statement, tick (✓) or put a cross (✗) in the box to show what you think.</p> <table border="1"> <thead> <tr> <th></th> <th>I am sure this is right</th> <th>I think this is wrong</th> <th>I am sure this is wrong</th> </tr> </thead> <tbody> <tr> <td>A Temperature of a material increases as it fills with heat.</td> <td><input type="checkbox"/></td> <td><input type="checkbox"/></td> <td><input type="checkbox"/></td> </tr> <tr> <td>B Particles in a spoon with bigger vibrations make the particles next to them vibrate more vigorously.</td> <td><input type="checkbox"/></td> <td><input type="checkbox"/></td> <td><input type="checkbox"/></td> </tr> <tr> <td>C There is an thermal conduction through a plastic spoon (plastic is an insulator).</td> <td><input type="checkbox"/></td> <td><input type="checkbox"/></td> <td><input type="checkbox"/></td> </tr> <tr> <td>D Our skin can detect the vibrations of particles that are too small to see under a microscope.</td> <td><input type="checkbox"/></td> <td><input type="checkbox"/></td> <td><input type="checkbox"/></td> </tr> </tbody> </table> <p><small>Developed by the University of York Science Education Group and the Salters' Institute. 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Distributed under a Creative Commons Attribution-NonCommercial (CC BY-NC) license.</small></p>		I am sure this is right	I think this is wrong	I am sure this is wrong	A Temperature of a material increases as it fills with heat.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	B Particles in a spoon with bigger vibrations make the particles next to them vibrate more vigorously.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	C There is an thermal conduction through a plastic spoon (plastic is an insulator).	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	D Our skin can detect the vibrations of particles that are too small to see under a microscope.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<p>Fast conduction</p> <p>These four spoons are all placed in hot water at the same time.</p>  <p>Copper Plastic Steel Glass</p> <p>These statements are about the speed of thermal conduction. For each statement, tick (✓) or put a cross (✗) in the box to show what you think.</p> <table border="1"> <thead> <tr> <th></th> <th>I am sure this is right</th> <th>I think this is wrong</th> <th>I am sure this is wrong</th> </tr> </thead> <tbody> <tr> <td>A The top of the metal spoons become hotter before the top of the other spoons.</td> <td><input type="checkbox"/></td> <td><input type="checkbox"/></td> <td><input type="checkbox"/></td> </tr> <tr> <td>B Some electrons (called free electrons) can move easily through metal.</td> <td><input type="checkbox"/></td> <td><input type="checkbox"/></td> <td><input type="checkbox"/></td> </tr> <tr> <td>C Free electrons carry heat through a metal.</td> <td><input type="checkbox"/></td> <td><input type="checkbox"/></td> <td><input type="checkbox"/></td> </tr> </tbody> </table> <p><small>Developed by the University of York Science Education Group and the Salters' Institute. This document may have been edited. 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For each statement about heat, tick (✓) or put a cross (✗) in the box to show what you think.</p> <table border="1"> <thead> <tr> <th></th> <th>I am sure this is right</th> <th>I think this is wrong</th> <th>I am sure this is wrong</th> </tr> </thead> <tbody> <tr> <td>A The glass feels cooler than the metal.</td> <td><input type="checkbox"/></td> <td><input type="checkbox"/></td> <td><input type="checkbox"/></td> </tr> <tr> <td>B The orange has a higher temperature than the metal.</td> <td><input type="checkbox"/></td> <td><input type="checkbox"/></td> <td><input type="checkbox"/></td> </tr> <tr> <td>C The temperature of each object is the same.</td> <td><input type="checkbox"/></td> <td><input type="checkbox"/></td> <td><input type="checkbox"/></td> </tr> </tbody> </table> <p><small>Developed by the University of York Science Education Group and the Salters' Institute. This document may have been edited. 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<p>Handlebars</p> <p>On a cold day the metal on a bike feels very cold. The plastic grips on the handlebars do not feel so cold.</p>  <p>Why does the metal handlebar feel colder than the plastic grips? Put a tick (✓) in the box next to the best answer.</p> <p>A Metal is a better thermal conductor than plastic. <input type="checkbox"/></p> <p>B Metal absorbs less heat better than plastic. <input type="checkbox"/></p> <p>C Metal is smoother and more easily than plastic. <input type="checkbox"/></p> <p>D Metal lets the heat out more easily than plastic. <input type="checkbox"/></p> <p>E Plastic has a higher temperature than metal. <input type="checkbox"/></p> <p><small>Developed by the University of York Science Education Group and the Salters' Institute. This document may have been edited. Download the original from www.BestEvidenceScienceTeaching.org. © University of York Science Education Group. Distributed under a Creative Commons Attribution-NonCommercial (CC BY-NC) license.</small></p>	<p>Cold spoons</p> <p>These two spoons have been dipped into some very cold water. They have been kept in the water for a long time.</p>  <p>Plastic Metal</p> <p>These statements are about the spoons. For each statement about them, tick (✓) or put a cross (✗) in the box to show what you think.</p> <table border="1"> <thead> <tr> <th></th> <th>I am sure this is right</th> <th>I think this is wrong</th> <th>I am sure this is wrong</th> </tr> </thead> <tbody> <tr> <td>A The metal spoon feels colder.</td> <td><input type="checkbox"/></td> <td><input type="checkbox"/></td> <td><input type="checkbox"/></td> </tr> <tr> <td>B The plastic spoon has a higher temperature.</td> <td><input type="checkbox"/></td> <td><input type="checkbox"/></td> <td><input type="checkbox"/></td> </tr> </tbody> </table> <p><small>Developed by the University of York Science Education Group and the Salters' Institute. 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Put a tick (✓) in the box next to the best answer.</p> <p>A A poor thermal conductor. <input type="checkbox"/></p> <p>B A good thermal conductor. <input type="checkbox"/></p> <p>C A very good thermal conductor. <input type="checkbox"/></p> <p>Each statement below correctly describes diamond.</p> <p>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.</p> <p>A Diamond is a non-metal. <input type="checkbox"/></p> <p>B There are no free electrons in diamond. <input type="checkbox"/></p> <p>C The forces holding the carbon atoms in place are very strong. <input type="checkbox"/></p> <p>D Diamond has a giant structure. <input type="checkbox"/></p> <p><small>Developed by the University of York Science Education Group and the Salters' Institute. This document may have been edited. Download the original from www.BestEvidenceScienceTeaching.org. © University of York Science Education Group. Distributed under a Creative Commons Attribution-NonCommercial (CC BY-NC) license.</small></p>	<p>Feel the heat</p> <p>Lucia has a plastic case for her phone. She has noticed that her plastic case sometimes feels very warm.</p>  <p>Lucia is discussing with her friends why the plastic case of her phone sometimes feels very warm.</p> <p>Lucia: Heat moves through the plastic when the phone gets hot.</p> <p>Muhammad: Lucia is feeling the warmth of his own hand. Plastic is an insulator.</p> <p>Rafiq: The phone is heating the plastic and making its particles vibrate more vigorously.</p> <p>Prithvi: All the particles in the plastic are connected because plastic is a solid.</p> <p>Oliver: Heat isn't something that can flow. We feel warmth when particles in the plastic vibrate a bit.</p> <p>To answer:</p> <p>1. Who is right about why the plastic case sometimes feels very warm? Explain your answer.</p> <p>2. Who is wrong about why the plastic case sometimes feels very warm? What would you say to help them understand?</p> <p><small>Developed by the University of York Science Education Group and the Salters' Institute. This document may have been edited. Download the original from www.BestEvidenceScienceTeaching.org. © University of York Science Education Group. Distributed under a Creative Commons Attribution-NonCommercial (CC BY-NC) license.</small></p>	<p>Free electron model</p> <p>Metals are good thermal conductors because the outer electrons of each metal atom are free to move.</p>  <p>Explain why metals are good thermal conductors. Put one statement of each row to explain how.</p> <table border="1"> <tbody> <tr> <td>1</td> <td>In a metal, the outer electrons of each metal atom are free to move.</td> <td>They move about freely in the metal.</td> <td>They each orbit a metal ion.</td> </tr> <tr> <td>2</td> <td>When metal is heated some metal ions are made to vibrate more vigorously. They vibrate against other ions, forcing more and more to vibrate faster.</td> <td>They also cause the outer electrons to move around more quickly.</td> <td>They also cause the outer electrons to vibrate faster.</td> </tr> <tr> <td>3</td> <td>They also cause the outer electrons to vibrate faster.</td> <td>These electrons flow readily ions throughout the metal to vibrate faster.</td> <td></td> </tr> <tr> <td>4</td> <td>These electrons flow readily ions throughout the metal to vibrate faster.</td> <td></td> <td></td> </tr> <tr> <td>5</td> <td>This greatly speeds up thermal conduction in a metal.</td> <td></td> <td></td> </tr> </tbody> </table> <p><small>Developed by the University of York Science Education Group and the Salters' Institute. This document may have been edited. Download the original from www.BestEvidenceScienceTeaching.org. © University of York Science Education Group. 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Along the line	Thermal equilibrium	Melting ice
<p>BEST STUDENT WORKSHEET</p> <p>Along the line</p> <p>Some students are modelling thermal conduction in metal. They want to show how the freely moving outer electrons from metal atoms enable a metal to conduct quickly.</p>  <p>To answer</p> <ol style="list-style-type: none"> State three ways in which this is a good representation of thermal conduction in metal. State three ways in which this is not an accurate representation of thermal conduction in metal. Describe a better model to show thermal conduction in a metal. <p><small>Developed by the University of York Science Education Group and the Salters' Institute. This document may have been edited. Download the original from www.BestEvidenceScienceTeaching.org. © University of York Science Education Group. Distributed under a Creative Commons Attribution-NonCommercial (CC BY-NC) license.</small></p>	<p>BEST STUDENT WORKSHEET</p> <p>Thermal equilibrium</p> <p>These materials have been left in the laboratory overnight.</p> <p>Feel each material with your hand.</p> <p>Are there any other, from the one that feels the warmest to the one that feels the coldest.</p>  <p>Predict</p> <p>Which material do you think has the highest temperature and which one the lowest temperature? Do you think there are higher or lower than the temperature of the room?</p> <p>Explain</p> <p>What are the reasons you think the temperatures will be like that?</p> <p>Measure the temperature of each material and of the room.</p> <p>Observe</p> <p>Record the temperature of each material and the temperature of the room.</p> <p>Explain</p> <p>Write your prediction and explanation correct. Try to improve your first explanation to explain what happens more clearly.</p> <p><small>Developed by the University of York Science Education Group and the Salters' Institute. This document may have been edited. Download the original from www.BestEvidenceScienceTeaching.org. © University of York Science Education Group. Distributed under a Creative Commons Attribution-NonCommercial (CC BY-NC) license.</small></p>	<p>BEST STUDENT WORKSHEET</p> <p>Thermal equilibrium</p> <p>Two pieces of ice are taken out of the freezer at the same time.</p> <p>They are the same size as each other.</p> <p>One is placed on a piece of wood, the other on a piece of metal.</p> <p>They are left to melt to each other.</p>  <p>Predict</p> <p>How quickly do you think each piece of ice will melt? Which will melt the most quickly?</p> <p>Explain</p> <p>Why do you think the pieces of ice will melt like that?</p> <p>Observe the ice at intervals of ten minutes through the lesson.</p> <p>Observe</p> <p>Record a description of each ice cube at intervals of ten minutes.</p> <p>Explain</p> <p>Write your prediction and explanation correct. Try to improve your first explanation to explain what happens more clearly.</p> <p><small>Developed by the University of York Science Education Group and the Salters' Institute. This document may have been edited. Download the original from www.BestEvidenceScienceTeaching.org. © University of York Science Education Group. Distributed under a Creative Commons Attribution-NonCommercial (CC BY-NC) license.</small></p>
<p>Critique a representation</p>	<p>Predict, explain; observe, explain (PEOE)</p>	<p>Predict, explain; observe, explain (PEOE)</p>