Cambridge Assessment International Education

Teaching Pack

Heat conduction in metal rods

Cambridge O Level

Physics 5054

Version 2.0

Cambridge Pathway

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Introduction

This pack will help you to develop your learners' experimental skills as defined by assessment objective 3 (AO3 Experimental skill and investigations) in the course syllabus.

Important note
Our *Teaching Packs* have been written by **classroom teachers** to help you deliver topics and skills that can be challenging. Use these materials to supplement your teaching and engage your learners. You can also use them to help you create lesson plans for other experiments.

This content is designed to give you and your learners the chance to explore practical skills. It is not intended as specific practice for Paper 5 (Practical Test) or Paper 6 (Alternative to the Practical Test).

There are two options for practising experimental skills. If you have laboratory facilities, this pack will support you with the logistics of running the experiment. If you have limited access to experimental equipment and/or chemicals, the pack will help you to deliver a virtual experiment.

This is one of a range of *Teaching Packs*. Each pack is based on one experiment with a focus on specific experimental techniques. The packs can be used in any order to suit your teaching sequence.

The structure is as follows:

Briefing lesson (1 hour*)
This lesson introduces the focus experimental skills to be developed. It also introduces any content needed for your learners to understand the experiment being carried out in the *Lab lesson*.

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Lab lesson (1 hour*)	
Option 1 – run the experiment	**Option 2 – virtual experiment**
This lesson allows the experiment to be run with your learners, providing an opportunity to practice the experiment skills introduced in the *Briefing lesson*.	This lesson allows your learners to complete a virtual experiment, providing an opportunity to practice the experiment skills introduced in the *Briefing lesson*.

↓

Debriefing lesson (1 hour*)
This lesson consolidates and builds on the progress learners have made. In some cases, it will also provide the opportunity to practise extended writing skills.

**the timings given here are guides; you may need to adapt the lessons to suit your circumstances.*

In this *Teaching Pack* you will find the lesson plans, worksheets for learners and teacher resource sheets you will need to successfully complete this experiment.

Experiment: Heat conduction in metal rods

This *Teaching Pack* focuses on measuring relative rates of thermal conductivity.

Conductivity is one of the three methods by which thermal energy is transferred from one place to another. It only occurs in solids. In this experiment you will investigate the relative conductivities of different metals, and consider the practical applications of such knowledge.

This experiment has links to the following syllabus content (see syllabus for detail):

- 9.1 Conduction

The experiment covers the following experimental skills, adapted from **AO3: Experimental skills and investigation** (see syllabus for assessment objectives):

- make and record observations
- interpretation of experimental results
- plan experiments and investigations, including equipment selection.

Prior knowledge

Knowledge from the following syllabus topics is useful for this experiment.

- 9.1 Conduction
- 11.3 Molecular model

Going forward

The knowledge and skills gained from this experiment can be used when you teach learners about the other modes of thermal energy transfer.

Briefing lesson: Making observations

Resources	• Access to the internet and a projector • Worksheets A, B and C
Learning objectives	By the end of the lesson: • ***all*** learners should know what an observation is and be able to describe conduction • ***most*** learners should be able to distinguish between and observation and a deduction, and explain how conduction occurs • ***some*** learners will understand the importance of accurate observation, and will be able to explain why conduction only occurs in solids.

Timings	Activity
15 min	**Starter/Introduction** Show your learners the video clip on the webpage shown below. This should demonstrate the need for careful observation. **www.awarenesstest.co.uk/** You can have a discussion with learners after watching the video. In the discussion, you should make the importance of observation clear. In a scientific experiment learners must understand what they are observing and how they should record this information.
10 min 10 min 5 min	**Main lesson** Give your learners Worksheet A. They should work through the questions independently to begin with. After three minutes each learner should share their thoughts with a partner. You should then take feedback from each pair so that the whole class can share their ideas (think, pair, share). All of your learners should have the same answer to the first question, but answers to the others may differ. This is not a problem, as long as they can justify their thinking. Give your learners Worksheet B which they should use to demonstrate their understanding of the three types of thermal energy transfer. This work should be consolidated by using one of the two activities below depending on your learner's ability: • able learners should write their own definitions for each of the energy transfer types • less able learners can complete the matching exercise on Worksheet C.
10 min 10 min	**Plenary** Organise your learners into groups of three or four. Each group should devise an experiment to exemplify the three types of energy transfer. Groups should then share their experiment with a neighbouring team. Every learner should identify one strength and one area for improvement for the experiment they were shown by the other group.

Lab lesson: Option 1 – run the experiment

Resources	• Teacher notes • Teacher walkthrough video • Worksheets D, E, F, G, H and J • Equipment as outlined in the notes

Learning objectives	By the end of the lesson: • ***all*** learners should be able to describe an experiment to investigate the conductivity of a range of metals • ***most*** learners should be able to carry out an experiment to investigate the conductivity of a range of metals • ***some*** learners will be able to plan and carry out an experiment to investigate the conductivity of a range of metals.

Timings	Activity
5 min	**Starter/Introduction** Show images of or describe two different saucepans, one with a metal handle, and one with a non-metal handle. Ask your learners to explain which is better for cooking and why.
10 min	**Main lesson** Show the class the available equipment. They can work in pairs to suggest how it could be used to measure thermal conductivity. Your learners can use Worksheet D if they need some help. There are three levels of support on the worksheet and it can be folded or cut up as required.
10 min	Following their discussions and your feedback, ask learners to design a method to carry out their investigation. They can use Worksheet E (more able) or Worksheet F (less able) to help them. Worksheet G gives you a completed method to refer to as you circulate the classroom and check your learners' work.
5 min	Your learners will need a table of results. They can draw this themselves, or there is an example on Worksheet J.
20 min	Ask your learners collect the equipment and set up the experiment following the diagram on Worksheet H. Make sure you draw their attention to the specific things they should be aware of, for example, the handling of hot metal rods. They should then follow the method on Worksheet G and make careful note of the results as the experiment progresses. **Safety** Circulate the classroom at all times during the experiments so that you can make sure that your learners are safe and that the data they are collecting is accurate.
10 min	**Plenary** The individual groups should feedback to the rest of the class which metal they found was the best thermal conductor, and which was the worst.

Teacher notes

Watch the teacher walkthrough video and read these notes.

Each group will require:

- Bunsen burner
- Metal rods
- Heat resistant plate
- Petroleum jelly
- Stopwatch
- Tripod
- Drawing pins

Safety

The information in the table below is a summary of the key points you should consider before undertaking this experiment with your learners.

It is your responsibility to carry out an appropriate risk assessment for this experiment.

Substance	Hazard	First aid
—	Burns	Flood burnt area with water for at least 10 minutes. For serious injuries see a doctor.

Teacher method

This is your version of the method. The learner method is on Worksheet G.

Before you begin
Plan how you will group your learners during the experiment.

Think about:
- the number of groups you will need (group size 2–4 learners)
- the amount of equipment required
- the physical spacing of the learners to minimise the risk of being burnt.

Experiment
Circulate during the experiment in case learners encounter any difficulties.

Steps	Notes
1. Learners should collect all the equipment they need from the front of the class.	
2. Learners should place the heat resistant mat onto the tripod.	
3. To one end of each of the metal rods, learners should add a small amount of petroleum jelly.	*Remind learners that the amount of petroleum jelly on the end of each rod should be approximately the same.*
4. The rods should be arranged in a fan shape on top of the heat resistant mat.	*Both ends of the rods should be clear of the heat resistant mat.*
5. A drawing pin should be added onto the end of each rod using the petroleum jelly.	
6. Learners should light their burners and place onto a gentle blue flame.	*Watch learners carefully to ensure they do not overheat the rods.*
7. As the Bunsen is placed under the ends of the rods without the drawing pins attached – the timer should be started immediately.	*Care must be taken not to overheat the rods as some of the softer metals may melt.*
8. As each pin drops, learners should record the time at which this happens.	

Clean-up
After the experiment learners should:
- only handle the metal rods if they have had sufficient time to cool
- handle any hot materials with protective equipment
- return the equipment to where you have indicated.

Lab lesson: Option 2 – virtual experiment

Resources	• Virtual experiment video • Worksheets E, F, G, H, I and J
Learning objectives	By the end of the lesson: • ***all*** learners should be able to describe an experiment to investigate the conductivity of a range of metals • ***most*** learners should be able, with help, to plan an experiment to investigate the conductivity of a range of metals • ***some*** learners will be able to plan an experiment to investigate the conductivity of a range of metals

Timings	Activity
5 min	**Starter/Introduction** Show images of or describe two different saucepans, one with a metal handle, and one with a non-metal handle. Ask your learners to explain which is better for cooking and why.
10 min	**Main lesson** Use Worksheet I, to show your learners what equipment is available. They should work in pairs to suggest how the equipment could be used to measure thermal conductivity. You can give learners Worksheet D to help if they need it. There are three levels of support on the worksheet and it can be folded or cut up as required.
15 min	Once your learners have shared their ideas and you have given them some feedback, they can use Worksheet E, (more able) or Worksheet F, (less able) to help them write up their experimental method.
5 min	Worksheet G has a completed method to help you to check learners' suggestions. Worksheet H shows a diagram of the experimental set-up. Make sure that your learners have a table of results on which to record their results. There is an example on Worksheet J if they need it.
10 min	Show your learners the first part of the virtual experiment video, and ask them to compare the method used to their own (the video will stop at the appropriate place). They should note the differences, and for each one decide which method is best by justifying their opinion.
10 min	Learners should now watch until the second pause point on the video, recording each result as it appears on screen.
10 min	**Plenary** Ask learners to work in pairs and consider the answers to the following questions: • Why metals are good conductors (what is the role of electrons in the atom)? • What materials are poor conductors of heat? Why? Learners can now watch the end of the video.

Debriefing lesson: Evaluating methods

Resources	Please look at the starter, and choose what equipment is appropriate for your school. The italicised resources are a suggestion. • *Kettle or similar* • *Cup* • *Tea leaves/tea bags* • *Milk* • *Sugar* • *Spoon* • Worksheet K
Learning objectives	By the end of the lesson: • ***all*** learners should be able to evaluate a method • ***most*** learners should be able to construct success criteria for method evaluation • ***some*** learners will be able to evaluate results

Timings	Activity
10 min	**Starter/Introduction** Ask your learners to quickly write a method for an everyday activity, for example, making a hot drink (in this example, a cup of tea). Choose one of their methods that is not very specific and follow it exactly so that the cup of tea is made incorrectly. For example, if the quantity of water is not specified, either too much or too little can be put in the cup, and the same with the quantities of tea, sugar and milk (this is meant to be fun). Your learners should be able to identify where the method was lacking, and suggest how to rectify it.
20 min	**Main lesson** Using classroom discussion, elicit from your learners what a variable is. Encourage them to identify which variables should remain constant in the experiment. These are the control variables. In this experiment, they include the length and diameter of the rods, the amount of petroleum jelly, the mass of drawing pin etc. Your learners should then identify the only thing that they have changed – the independent variable, i.e. the material the rod is made of. Able learners should be able to explain the importance of only having one independent variable. If there is more than one, then it is difficult to identify which is causing the changes observed. Ask the class to identify what they are measuring, or finding out – the dependent variable – which in this case is the time taken for the pin to drop. By having these discussions, your learners should now be able to identify the key components of a successful method. Ask them to share these as you collate them on the board. These should provide the success criteria against which learners can judge their methods. *Continues on next page …*

Timings	Activity
	Using these criteria, your learners should improve their methods from the last lesson. They can swap books to peer assess against the agreed criteria you have noted. Given what your learners know about accurate methods, they should now consider whether the results from heating the metal rods are reliable? In this case we cannot know if the results are reliable – ask your learners why this might be (the experiment would need to have a minimum of three repeats to establish reliability).
	Learners look at Worksheet K to consider how repeats are used to increase the reliability of results. You should make them aware that: • anomalies should be disregarded • mean averages should be calculated • the closer the values obtained to the mean average, the more reliable the result.
	**Plenary** Learners should record an evaluation of the method they used and how they could make the experiment more reliable. They should explain how improved reliability would make the conclusions more valid.

Worksheets and answers

	Worksheets	Answers
For use in the *Briefing lesson*:		
A: Thinking scientifically	**14**	**25**
B: Energy transfer	**15**	**26**
C: Match the key words	**16**	**27**
For use in *Lab lesson: Option 1*:		
D: Planning an experiment	**17**	—
E: Writing a method	**18**	—
F: Writing a method with support	**19**	—
G: Method	**20**	—
H: Equipment set-up	**21**	—
J: Results	**23**	—
For use in *Lab lesson: Option 2*:		
E: Writing a method	**18**	—
F: Writing a method with support	**19**	—
H: Equipment set-up	**21**	—
I: Images of equipment	**22**	—
J: Results	**23**	—
For use in the *Debriefing lesson*:		
K: Reliability of results	**24**	**28**

Worksheet A: Thinking scientifically

Look at the picture and answer the questions below:

1. What do you see in this picture? (Observations)
2. What do you think about this picture? (Deductions)
3. What do you think will happen next? (Hypothesis/Prediction)
4. What are the reasons for your hypothesis? (Scientific thinking)

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Worksheet B: Energy transfer

Complete the table below as fully as you can

	Identify and describe the energy transfer in the picture	Which is the most important? Why?
	…… …… …… ……	…… …… …… ……
	…… …… …… ……	…… …… …… ……
	…… …… …… ……	…… …… …… ……

Worksheet C: Match the key words

Match the key word to the correct definition

Convection	Thermal energy moves through a solid by causing atoms to vibrate and gain kinetic energy. They pass this energy onto the neighbouring atoms, and so they also vibrate. The more the atoms vibrate, the hotter the solid becomes.
Conduction	Infra-red radiation is emitted by a hot object. These waves can travel through a vacuum and move at the speed of light.
Radiation	A heat source causes liquids or gases to become less dense, and so they move upwards. As they move away from the heat source, they lose their thermal energy, become denser and move downwards.

Worksheet D: Planning an experiment

Use the suggestions below to help you think about how you might use the equipment you have been shown to measure thermal conductivity.

Each column offers different levels of support.

Low-level support	Mid-level support	High-level support
How would we know if the rods were good conductors?	Hint: What happens to petroleum jelly when it gets hot?	If you stuck a drawing pin onto the end of a rod, what would happen if the rod got hot?
Problem: It is difficult to accurately measure the temperature of the metal rod.	What do you think the drawing pins might be for?	Hint: The better the thermal conductor the quicker the thermal energy will travel.
Given that we cannot measure its temperature, how else might we get an idea of how thermal energy is travelling along the rod?	What might you want to measure with the timer?	What might you want to measure with the timer?

Worksheet E: Writing a method

Use the space below to record your method.

An investigation into the thermal conductivity of different metals

Equipment	Method
……	……
……	……
……	……
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……	……
……	……
……	……
……	……
……	……
……	……
……	……

Don’t forget to consider safety precautions

Worksheet F: Writing a method with support

Use the space below to record your method.

An investigation into the thermal conductivity of different metals

Equipment	Method
…… …… …… …… …… …… …… …… …… …… …… …… ……	Think about these questions: 1. What will you do with the metal rods and petroleum jelly? 2. Where will you put the metal rods? Why? 3. What are you using the Bunsen burner for? 4. What are you using the timer for? 5. How will you make sure the experiment is safe? …… …… …… …… …… …… …… …… …… ……

Worksheet G: Method

1. Collect all of your equipment from the front of the class.
2. Place the heat resistant mat onto the tripod.
3. To one end of each of the metal rods, add a small amount of petroleum jelly.

Make sure you add the same amount of petroleum jelly to the end of each rod.

4. Lay the metal rods onto the heat resistant mat making sure that the ends do not touch the mat.

*Check the equipment set up on **Worksheet H** if you are not sure.*

5. Check that the rods are spread out like a fan. All of the ends of the rods without petroleum jelly should be close together and the ends with petroleum jelly should be spread out.

*Check the equipment set up on **Worksheet H** if you are not sure.*

6. Stick one drawing pin to the end of each metal rod using the petroleum jelly to hold it into position.

Make sure that the amount of petroleum jelly you use is the same for each metal rod.

7. Light the Bunsen burner and put it on a gentle blue flame.
8. Place the Bunsen burner under the ends of the metal rods without the drawing pins.

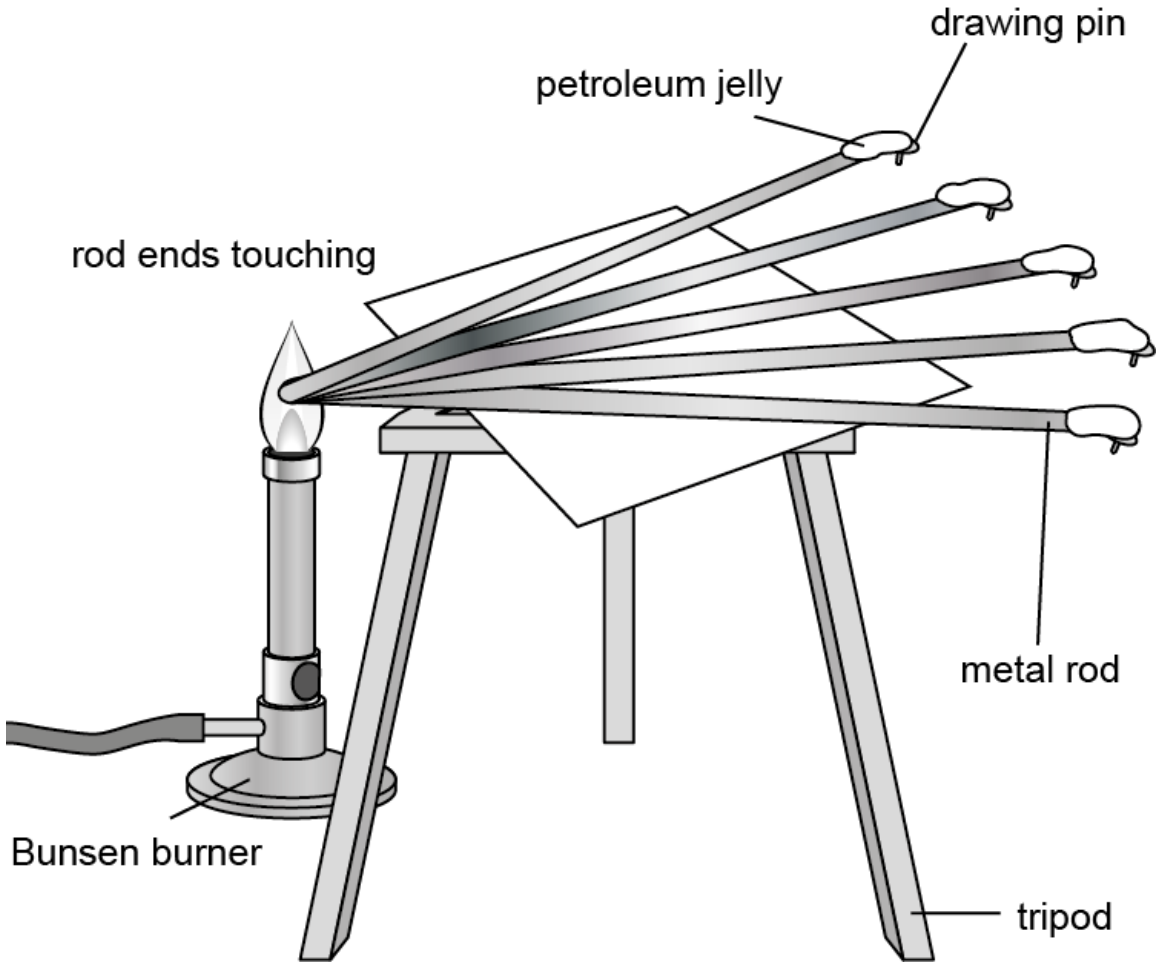
Only heat the metal rods gently to make sure the softer metals do not melt.

9. Immediately start the timer.
10. Use your results table to record how long it takes the pins to drop off each of the metal rods.

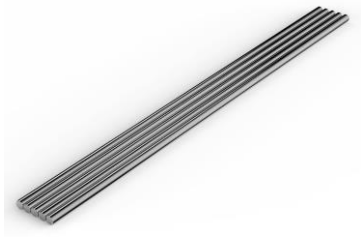
Worksheet H: Equipment set-up

Make sure that you follow the diagram carefully.

Take particular care with any hot materials. Do not heat the rods strongly.



Worksheet I: Images of equipment

		
Bunsen burner	**metal rods**	**drawing pins**
		
heat resistant mat	**petroleum jelly**	**stop clock**
		
	tripod	

Worksheet J: Results

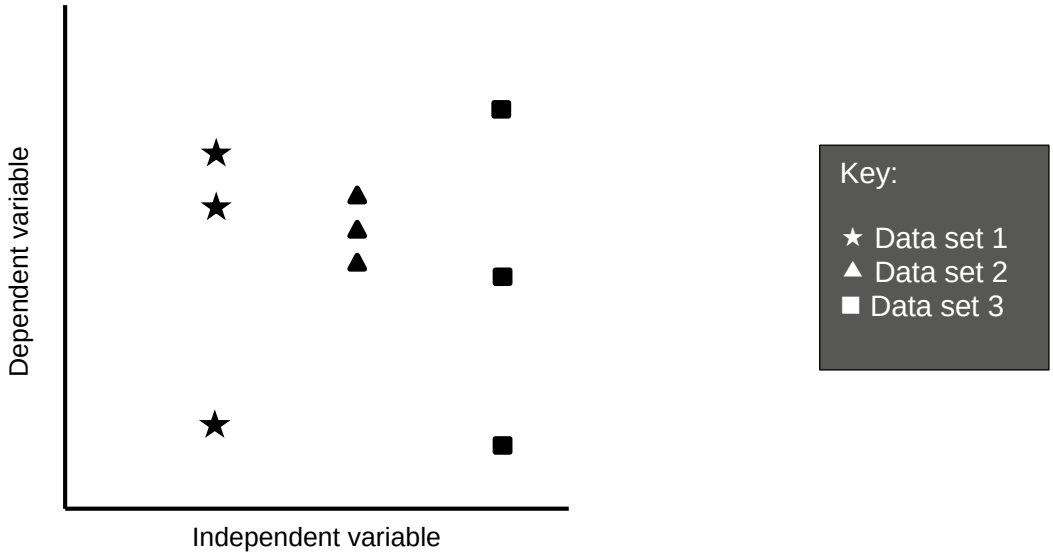
Use this table to record in seconds how long it took each drawing pin to fall off the end of the metal rods.

Type of metal	Time taken for drawing pin to fall off / seconds
……	……
……	……
……	……
……	……
……	……
……	……
……	……
……	……
……	……

Worksheet K: Reliability of results

The sketch graph below shows the results from three experiments.

Look at the data and try to answer the questions below.



On the graph there is only one set of reliable results.

1. Which data set is the reliable one? Why?

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2. What makes the other data sets less reliable?

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Worksheet A: Answers

Look at the picture and answer the questions below:

1. What do you see in this picture? (Observations)
2. What do you think about this picture? (Deductions)
3. What do you think will happen next? (Hypothesis/Prediction)
4. What are the reasons for your hypothesis? (Scientific thinking)

1. *Polar bear, ice floes, icebergs of different sizes, sea water*

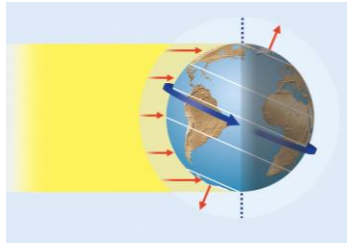
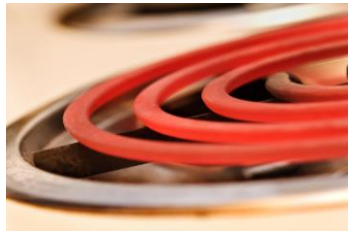
2. *There may be climate change issues, it is summer, the polar bears may be a family group – they are usually solitary.*

3. *They may avoid the water and follow the ice floe; they could swim across to other ice; they may be looking for prey.*

4. *If it is a family group they will need food; the polar bears have no choice but to swim between floes in the summer.*

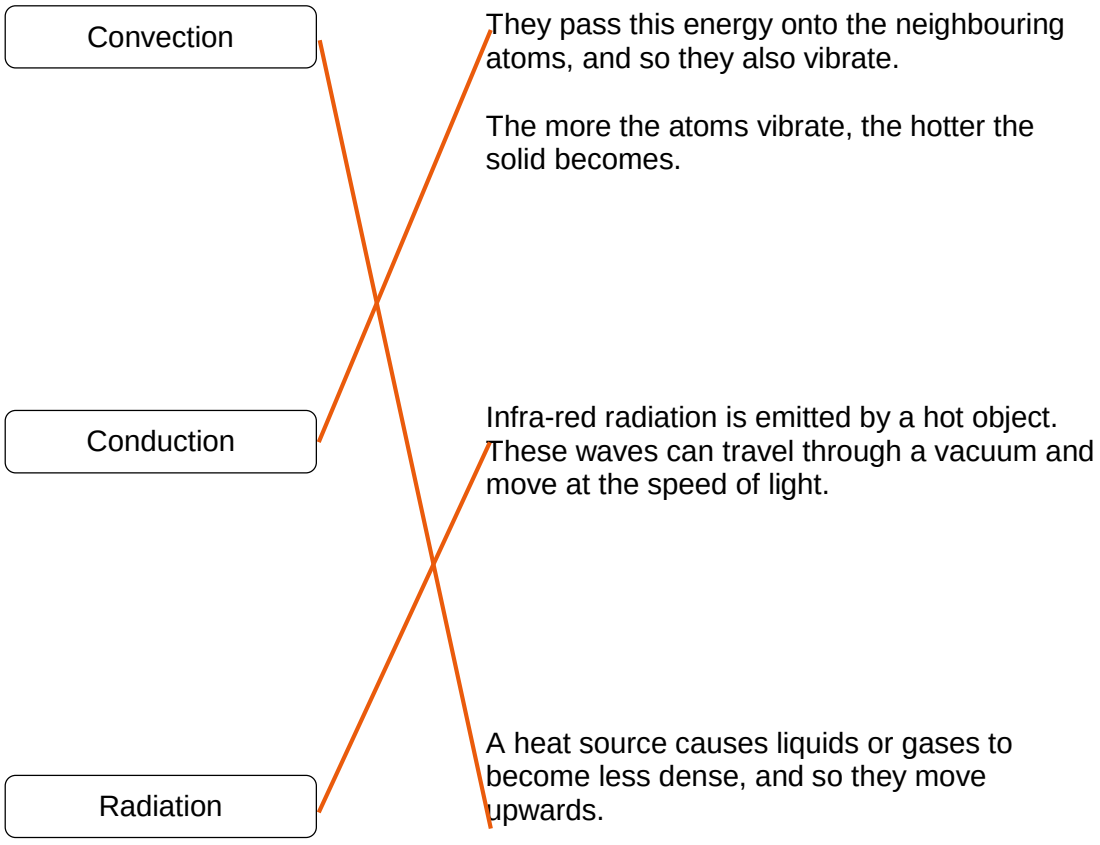
Worksheet B: Answers

Complete the table below as fully as you can

	Indentify and describe the energy transfer in the picture	Which is the most important? Why?
	The water movement in the pan represents convection. The warm water becomes less dense and rises. As it moves away from the heat source it cools, and so becomes more dense and sinks again. This sets up a convection current.	
	The energy from the Sun is heating the Earth due to radiation. This is when thermal energy is transferred as an electromagnetic wave. No particles are needed.	Learners can chose any of the types of energy transfer as the most important, as long as they can justify their answer.
	The hob respresents conduction. This is the transmission of thermal energy through solids caused by increased kinetic energy of the particles. This kinetic energy is passed from particle to particle, transferring the thermal energy through the solid.	

Worksheet C: Answers

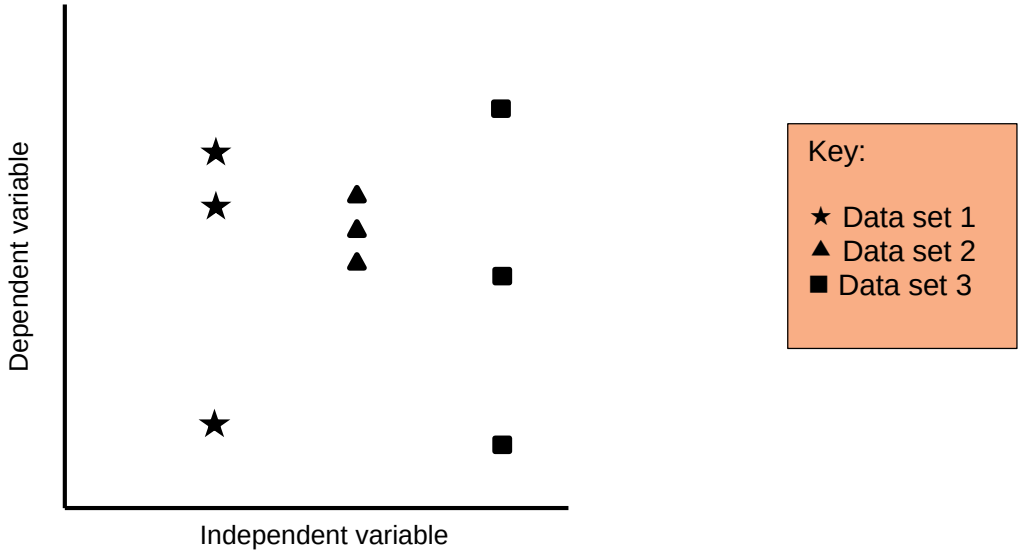
Match the key word to the correct definition



Worksheet K: Answers

The sketch graph below shows the results from three experiments.

Look at the data and try to answer the questions below.



On the graph there is only one set of reliable results.

1. Which data set is the reliable one? Why?

   The triangles represent the most reliable data set, as all of the repeats appear close together.

2. What makes the other data sets less reliable?

   The stars have an anomalous result and the squares are too widely distributed.

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