Teaching Pack

Finding specific latent heat using electrical methods

Cambridge International AS & A Level Physics 9702

Contents

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Introduction

This pack will help you to develop your learners' experimental skills as defined by assessment objective 3 (AO3 Experimental skills and investigations) in the course syllabus.
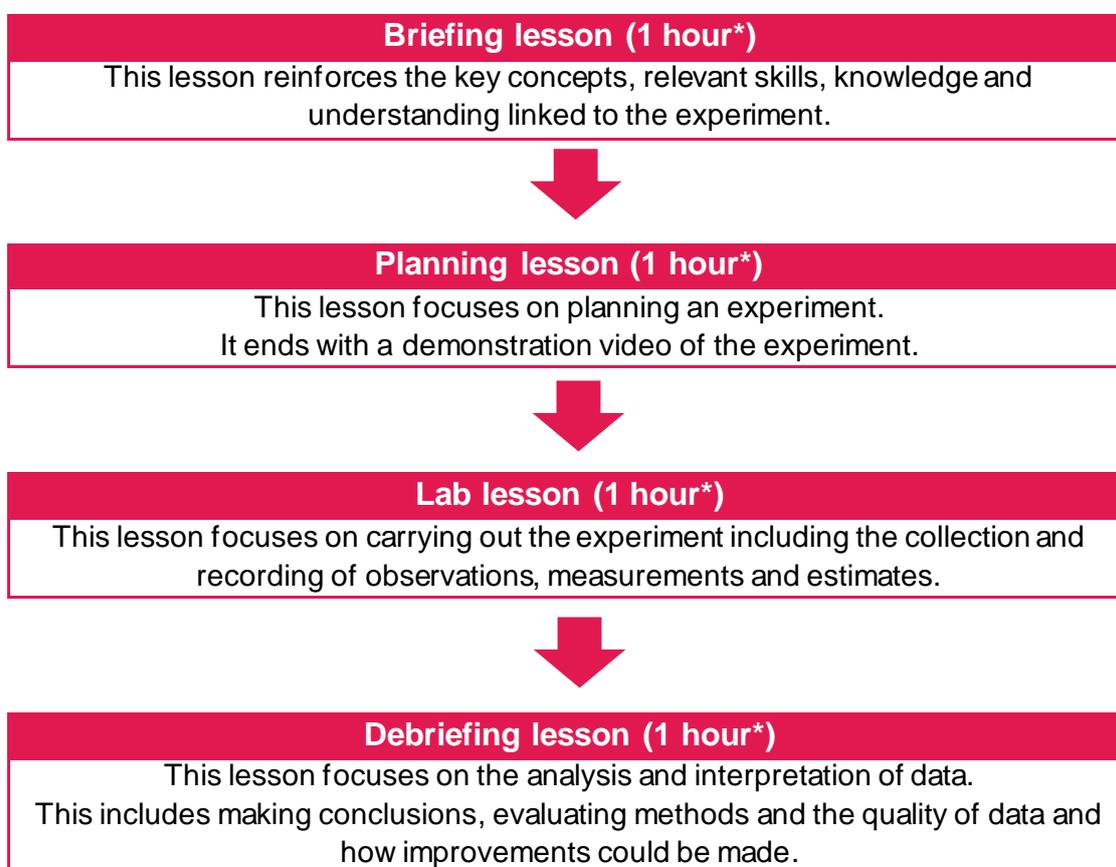
> **Important note**
> Our *Teaching Packs* have been written by **classroom teachers** to help you deliver topics and skills that can be challenging. Use these materials to supplement your teaching and engage your learners. You can also use them to help you create lesson plans for other experiments.
>
> *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 3 (Advanced Practical Skills) or Paper 5 (Planning, Analysis and Evaluation).*

This is one of a range of *Teaching Packs* and each pack is based on one experiment. The packs can be used in any order to suit your teaching sequence.

The structure is as follows:

Briefing lesson (1 hour*)
This lesson reinforces the key concepts, relevant skills, knowledge and understanding linked to the experiment.

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Planning lesson (1 hour*)
This lesson focuses on planning an experiment.
It ends with a demonstration video of the experiment.

↓

Lab lesson (1 hour*)
This lesson focuses on carrying out the experiment including the collection and recording of observations, measurements and estimates.

↓

Debriefing lesson (1 hour*)
This lesson focuses on the analysis and interpretation of data.
This includes making conclusions, evaluating methods and the quality of data and how improvements could be made.

the timings are a guide only; you may need to adapt the lessons to suit your circumstances.

In this pack you will find lesson plans, worksheets and teacher resource sheets.

Experiment: Finding specific latent heat

This *Teaching Pack* focuses on an experiment to investigate the specific latent heat of fusion of ice.

The amount of thermal energy required to convert one kilogram of a substance from the solid phase to the liquid phase, whilst maintaining a constant temperature, is known as the specific latent heat of fusion. In this experiment, an immersion heater will be used to determine the specific latent heat of fusion of ice.

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

- 14.3 Specific heat capacity and specific latent heat

The experiment covers the following experimental skills, as listed in **AO3: Experimental skills and investigations:**

- plan experiments and investigations
- collect, record and present observations, measurements and estimates
- analyse and interpret data to reach conclusions
- evaluate methods and quality of data and suggest improvements.

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

- 14.1 Thermal equilibrium
- 14.2 Temperature scales
- 9.1 Electric current
- 9.2 Potential difference and power
- 10.1 Practical circuits

Briefing lesson: Thermal physics

Resources	• Worksheet A

Learning objectives	By the end of the lesson: • *all* learners should be able to calculate the specific latent heat using relevant values. • *most* learners should be able to define specific latent heat. • *some* learners will be able to explain how the specific latent heat of a substance is relevant in everyday examples.

Timings	Activity
10 min	**Starter / Introduction** Why does an ice cube melt when left in a room if there is no electrical heater provided? Direct learners to discuss what causes the ice cube to melt and how this process can be slowed down or sped up. Use this to introduce the key concepts of thermal equilibrium and temperature.
40 min	**Main lesson** Define temperature and how it affects the flow of heat energy between different substances. Discuss everyday examples such as a person warming up the seat they sit on, a hot water bottle warming up a person and an open door cooling a room. Ensure learners understand how thermal energy is transferred and that energy always flows according to the temperature difference. Define specific heat capacity and specific latent heat. Discuss the differences between the two. Discuss water as a substance with a high specific heat capacity and how this affects its properties and uses. Examples may include its role in moderating the Earth's climate, as a coolant in a car or as a sustained heat source in a hot water bottle. Discuss how substances at the same temperature but with different specific heat capacities will store different amounts of energy. An everyday example of this is when eating hot food such as a jam pudding. The pudding and the jam are the same temperature, but the jam will store more energy and burn our mouths if eaten too hastily. Practise calculations involving specific latent heat using **Worksheet A**.
10 min	**Plenary** It's a hot day and you want to cool down lots of cans of drinks for your friends at a summer event. Do you place the cans in water at 0 °C or ice water at 0 °C? Does it matter? Explain the difference the ice makes. Alternatively, discuss why a steam burn may be more painful than a water burn.

Planning lesson: Specific latent heat

Resources	• No specific equipment is required

Learning objectives	By the end of the lesson:
	• *all* learners should produce a method to follow for the lab lesson.
	• *most* learners should be able to explain how calculation of the electrical energy will allow for the calculation of specific latent heat.
	• *some* learners will be able to explain the importance of the control.

Timings	Activity
10 min	**Starter / Introduction** Introduce the experimental task and recap the definition and equation for specific latent heat. Ask learners to identify the variables they would need to measure to find the specific latent heat of a substance. Direct them to identify some of equipment that could be used to carry out this task.
35 min	**Main lesson** Direct learners to write a full method for the experiment. Depending on the confidence of your learners, this activity can be supported more or less by the teacher. A brief recap of electrical energy may be needed at this point. Your learners should consider: • Measurements that need to be taken and what equipment should be used. • Set up of the equipment. Learners should draw a diagram of this, as well as a circuit diagram. • Sources of error and how to limit these. Learners can share their methods through open discussion with their peers. Learners should then review and improve their methods as necessary.
5 min	**Video** Show the learners the master video.
10 min	**Plenary** Ask learners to evaluate their method based on the video and make any changes. Discuss: • Why is it important for there to be a control in this experiment? • Why must we wait for the drip rates to match after the experiment before taking measurements of mass? • What other sources of error are there in this experiment? Ask learners to discuss obvious sources of error based on observation of the video. This can be played again with the sound off so that learners can point out difficulties they expect to encounter when carrying out the experiment next lesson.

Lab lesson: Specific latent heat of water

Resources	• Equipment as listed in the Teacher notes

Learning objectives	By the end of the lesson: • *all* learners should follow their method to collect results. • *most* learners should be able to discuss how the results relate to each other via a free body force diagram. • *some* learners will consider how to minimise potential sources of error during the experiment.

Timings	Activity
10 min	**Starter / Introduction** Recap the following through questioning of learners: • how to set up the circuit and immersion heater • outline of method • the importance of matching the drip rate • safety hazards e.g. take care with hot equipment.
40 min	**Main lesson** Ask learners to set up the experiment and follow their method to collect and record measurements. Encourage the learners to note observations throughout. Assist learners with set up as needed. They may need help setting up the circuit and/or ensuring the drip rate is constant. **Safety** Circulate the classroom at all times during the experiment so that you can make sure that your learners are safe and that the data they are collecting is accurate.
10 min	**Plenary** Ask the learners to tidy up their work space and return all equipment to you. They can then spend some time discussing their findings and issues they encountered in preparation for the next lesson.

Teacher notes

Watch the Specific latent heat video (teacher version) and read these notes.

Each group will require:
- access to water
- crushed ice (enough to fill two funnels)
- top pan balance
- funnel x2
- beaker x2
- retort stand, boss and clamp x2
- voltmeter
- ammeter
- connecting cables
- DC power supply
- immersion heater x2
- stopwatch

Safety

This experiment uses an immersion heater. Care must be taken when moving around the room with hot equipment.

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

Hazard	First aid
Burns from the hot immersion heater.	In case of accidents with hot equipment, follow the advice below along with any safety guidance and procedures for your own centre. Cool the burn with cool or lukewarm running water for 20 minute immediately after the injury.

Experiment set-up
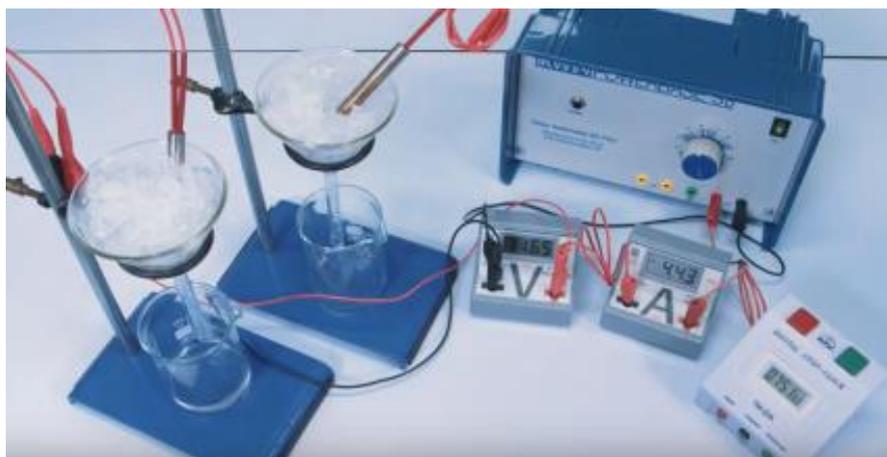
Circuit diagram
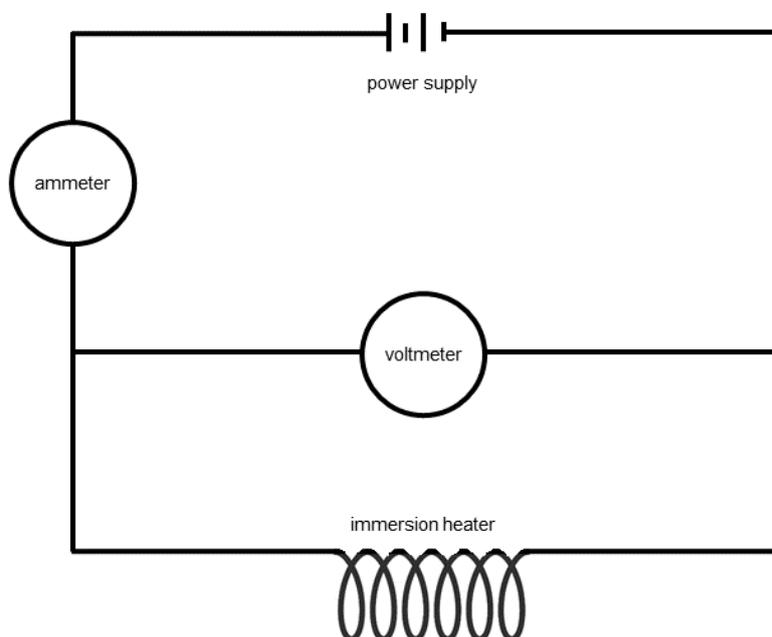
Teacher method

This is your version of the method for this experiment that accompanies the *Teacher walkthrough* video.

Do not share this method with learners.

Before you begin

Plan how you will group your learners during the experiment session.

Think about:
- the number of groups you will need (group size 2–3 learners)
- the amount of equipment/ice required

Experiment

Walk around the learners during the experiment in case they encounter any difficulties.

Steps	Notes
1. Learners should collect the equipment they require from the front of the class.	
2. They should find a space in the classroom where the equipment can be assembled safely.	
3. Make sure your learners have set up their circuit correctly.	*Remind learners to check that the ammeter and voltmeter are connected correctly.*
4. Learners should match the drip rate before turning on the circuit and starting the stopwatch.	*Learners may need to be reminded to ensure the beakers are empty when they start the experiment.*
5. Learners time how long the immersion heater is on for and record the voltage and current.	
6. Learners should record the values of mass once the drip rate is matched again.	
7. Make sure your learners have recorded all of the relevant data ready to carry out calculations of electrical energy and specific latent heat.	

Clean-up

After the experiment learners should:
- tidy up their work space and return all equipment to you.

Debriefing lesson: Specific latent heat of fusion

Resources	● Worksheet B

Learning objectives	By the end of the lesson: ● ***all*** learners should calculate the specific latent heat from their results. ● ***most*** learners should be able to explain the importance of the control. ● ***some*** learners will be able to explain how the sources of error for the experiment affect the results.

Timings	Activity
10 min	**Starter / Introduction** Ask your learners for sources of error and limitations of the experiment. Possible prompts: ● Why does the immersion heater have to be fully immersed in the ice? ● Why is it better to use crushed ice in this experiment rather than ice cubes? ● How can you ensure that ice falls from the funnel directly into the beaker? ● What was the absolute error in the measurements taken? Were these errors significant? ● What was difficult or limiting about the experiment?
10 min	**Analysis** Learners should begin the analysis of their results from the previous lesson by carrying out calculations of electrical energy, mass and specific latent heat.
10 min	**Interpretation** Using the calculations they have carried out of the specific latent heat, learners should now compare their results to the accepted value of ice's specific latent heat of fusion to establish whether their result is accurate. Learners can go on to consider: ● What do the results suggest? ● Are there any alternative interpretations? ● What conclusions can we come to?
10 min	**Evaluation** Learners should calculate the error in their measurements. They should consider the absolute error in each measurement, the percentage error in each measurement and any compound errors. Give your learners **Worksheet B** if learners need support with their calculations.

Debriefing lesson: *continued*

Timings	Activity
10 min	**Quality of data** Ask learners to discuss, and subsequently make notes, on the quality of data. Learners should consider the following: • The control is used to account for the heat energy given to the ice by the air in the room. However, waiting for the drip rate to match means that the immersion heater cannot be preheated before starting the experiment. How does this affect results? • Were there any systematic errors and how did these affect the recorded data? • Were there any obvious random errors in measurements? • What modifications to the experimental arrangement or procedure could be made that would improve the accuracy of the experiment? Ensure that these modifications are achievable in the context of your school laboratory. Can you relate improvements to the sources of uncertainty you have already identified? • Could you extend the investigation to answer a new question?
10 min	**Plenary** Ask learners to discuss the following points to summarise their findings: • Results. What conclusions can be drawn? Discuss the quality of data and relate this to the percentage error in the results. • Improvements. If they ran the experiment again, what would the learners do differently? How would these changes affect the results and the error in the results? • The precision and the accuracy of the experiment. How can we judge the precision and the accuracy of the experiment? Was it possible to take repeats of the same scenario?

Worksheets and answers

	Worksheet	Answers
For use in *Briefing lesson*:		
A: Specific latent heat calculations	**15**	**17**
For use in *Evaluation lesson*:		
B: Calculating the error in a measurement	**16**	**–**

Worksheet A: Specific latent heat

This worksheet reinforces the key concepts, relevant skills, knowledge and understanding linked to the experiment.

The table below lists four substances and their values of specific latent heats to two significant figures.

Substance	Specific heat capacity for substance at 293K / $Jkg^{-1}K^{-1}$	Specific latent heat of fusion / Jkg^{-1}	Specific latent heat of vaporisation / Jkg^{-1}
Lead	130	23 000	870 000
Oxygen	920	14 000	210 000
Silicon	710	1 800 000	13 000 000
Water	4200	330 000	2 300 000

Section 1:

(a) Identify and explain which substance heats fastest.
(b) Identify and explain which substance requires the most energy to become a gas.
(c) Explain why the specific latent heat of vaporisation is much larger than the specific latent heat of fusion.
(d) Identify and explain which substance you would use as a coolant.

Section 2:

(a) Calculate the energy required to heat 1.0 kg of oxygen from 15°C to 45°C.
(b) Calculate the final temperature of a 200 g lead block at 10°C when given 900 J of thermal energy.
(c) Identify the mystery substance using the table above by calculating the specific heat capacity. The mystery substance has a mass of 400 g and its temperature changes 21°C when given 6 kJ of thermal energy.
(d) Calculate the time taken to heat a 1800 kW kettle containing 1 litre of water to boiling. The kettle contains water at 16°C.
(e) Calculate the energy required to melt 200 g of ice at 0°C without producing a temperature rise.
(f) Calculate the energy required to heat and then melt 50g of lead initially at 25°C. The melting point of lead is 328°C.

Worksheet B: Calculating the error in a measurement 📄

Absolute error is defined as the range / 2.

So for the values: 7.2   7.4   7.3   7.0   7.1

The range = largest value − the smallest value

> Range = 7.4 − 7.0 = 0.4

> Absolute error = 0.4 / 2 = 0.2

However, we must also consider the error in our instruments. Error in the instrument is defined as the smallest division. For example, the smallest division on a metre rule is $\pm$ 1 mm. If the error in the instrument is bigger than the range / 2, we must use this as the **absolute error** instead.

Percentage error for a value is calculated from the absolute error. We divide the absolute error by the value and multiply by 100 to get a percentage:

$$\%\Delta A = \frac{\Delta A}{A} \times 100\% \qquad \text{where } \Delta A = \text{Absolute error and } A = \text{Value}$$

When calculating the percentage error of a value such as F where F = m $\times$ a and m and a are measured variables, the percentage error in m and a must be calculated as above and then used to calculate the percentage error of F. This is known as **compound error**.

The percentage error is calculated by adding the percentage errors of all the values in the equation. Constants can be ignored when calculating compound percentage error.

> Example: $A = BC$

> What is the percentage error in A? Simply add the percentage error of B and C.

$$\%\Delta A = \%\Delta B + \%\Delta C$$

Worksheet A: Answers

The table below lists four substances and their values of specific latent heats to two significant figures.

Substance	Specifc heat capacity for substance at 293K / Jkg⁻¹K⁻¹	Specific latent heat of fusion / Jkg⁻¹	Specific latent heat of vaporisation / Jkg⁻¹
Lead	130	23 000	870 000
Oxygen	920	14 000	210 000
Silicon	710	1 800 000	13 000 000
Water	4200	330 000	2 300 000

Section 1:

(a) Lead heats fastest because it has the lowest specific heat capacity. This means that for every joule of thermal energy provided, it will experience the largest temperature rise per unit mass in comparison to the other substances.

(b) Silicon requires the most energy to become a gas. It has the highest specific latent heat of vaporisation. This means that it requires the most energy per unit mass to change state from liquid to gas.

(c) The specific latent heat of vaporisation is much larger than the specific latent heat of fusion because more energy is required to change state from liquid to gas than solid to liquid.

(d) Water should be used as a coolant out of the options because it can absorb the most energy relative to its temperature rise. It has a very high specific heat capacity.

Section 2:

(a) 27 600 J

(b) 45°C.

(c) 714 Jkg⁻¹K⁻¹

(d) 196 s

(e) 66 kJ

(f) 3120 J