PEARSON

# PHYSICS QUEENSLAND

2nd EDITION

## UNITS 1 & 2

Doug Bail



QCE 2025 Physics SYLLABUS

## Skills and Assessment

# Contents

# Contents

# How to use this book

The *Pearson Physics Queensland Skills and Assessment Book* Units 1 & 2 2nd edition takes an intuitive, self-paced approach to science education that ensures every student has opportunities to practise, apply and extend their learning through a range of supportive and challenging activities.

This resource has been developed by highly experienced and expert author teams, with lead Queensland specialists who have a working understand what teachers are looking for with teaching and learning across the new QCE.

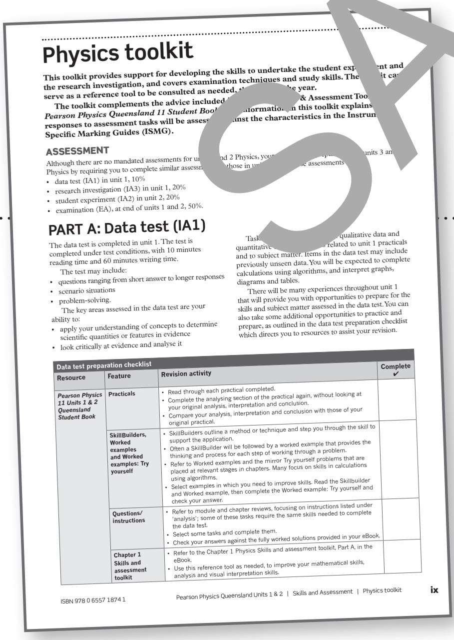
Fully written to the new QCE Year 11 & 12 syllabus, the *Skills and Assessment Book* is organised by units. The **unit opener** outlines the Unit Objectives.

The *Skills and Assessment Book* is further organised into topics. Each topic addresses all of the subject matter and mandatory practicals, from the syllabus.

All activities complement material in the *Pearson Physics Queensland Student Book* Units 1 & 2 for a complete teaching, learning and assessment program, facilitating the integration of practice and rich learning activities. The resource has been designed so it may be used independently of the Student Book, providing flexibility in when and how to engage with it.

## Toolkit

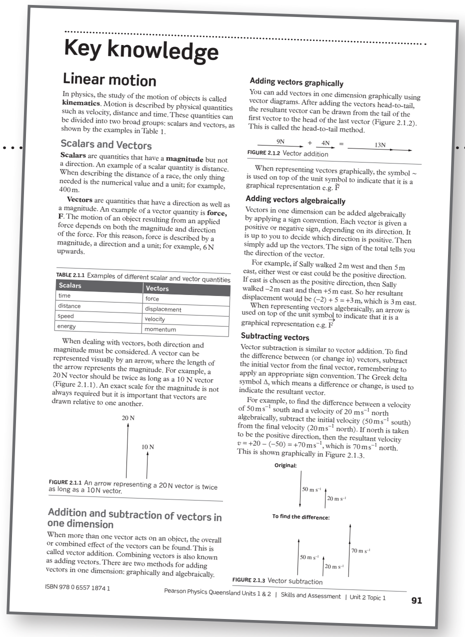
A complementary Toolkit supports the development of the skills and techniques needed to undertake practical investigations, the data test, student experiment and research investigation, and it covers study skills. It also includes checklists and helpful hints to assist in fulfilling all assessment requirements. Key terms are indicated in bold text and are supported with a contextual definition in the Glossary of your Student Book. Alternatively, your teacher may print a copy of the Glossary for you from the Teacher Support for this product to assist in comprehension.


Physics toolkit

PART A: Data test (IA1)

## Key knowledge

Each topic begins with a key knowledge section. Key knowledge consists of a set of succinct summary notes and that cover the subject matter for each topic of the syllabus. This section is highly illustrative and written in a straightforward style to assist students of all abilities in focusing on the salient points. Key terms are bolded for ease of navigation and are reflected in the Student Book Glossary. The key knowledge also serves as a ready reference when completing worksheets and practical activities, and it provides a handy set of revision and study notes.

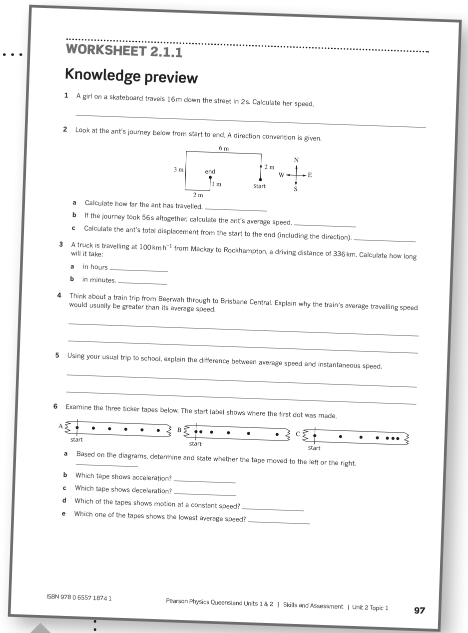

Key knowledge

Linear motion

## Worksheets

A diverse offering of instructive and self-contained worksheets is included in each topic. Common to all topics are the initial 'Knowledge preview' worksheets to activate prior knowledge; a 'Literacy review' worksheet to explicitly build language and the application of scientific terminology; and finally a 'Thinking about my learning' worksheet, which encourages students to reflect on their learning and identify areas for improvement. Other worksheets, with their range of activities and tasks, focus on the application of subject matter to assist in the consolidation of learning and the making of connections between subject matter.

Worksheets may be used for formative assessment and are clearly aligned to the syllabus. A range of questions building from foundation to challenging are included in the worksheets which are written to reflect the Marzano & Kendall taxonomy instructional verbs.


WORKSHEET 2.1.1

Knowledge preview

1 A girl on a skateboard travels 16 m down the street in 2 s. Calculate her speed.

2 Look at the ant's journey below from start to end. A direction convention is given.

a Calculate how far the ant has travelled.
b If the journey took 56 s altogether, calculate the ant's average speed.
c Calculate the ant's total displacement from the start to the end (including the direction).

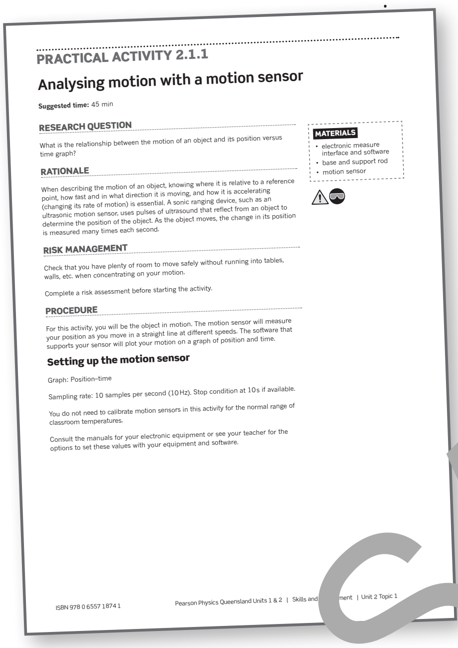
3 A truck is travelling at 100 km h⁻¹ from Mackay to Rockhampton, a driving distance of 336 km. Calculate how long will it take:
a in hours
b in minutes.

4 Think about a train trip from Beerwah through to Brisbane Central. Explain why the train's average travelling speed would usually be greater than its average speed.

5 Using your usual trip to school, explain the difference between average speed and instantaneous speed.

6 Examine the three ticker tapes below. The start label shows where the first dot was made.
a Based on the diagrams, determine and state whether the tape moved to the left or the right.
b Which tape shows acceleration?
c Which tape shows deceleration?
d Which of the tapes shows motion at a constant speed?
e Which one of the tapes shows the lowest average speed?

ISBN 978 0 6557 1874 1 Pearson Physics Queensland Units 1 & 2 | Skills and Assessment | Unit 2 Topic 1 97


PRACTICAL ACTIVITY 2.1.1

Analysing motion with a motion sensor

Suggested time: 45 min

RESEARCH QUESTION
What is the relationship between the motion of an object and its position versus time graph?

MATERIALS
• electronic measure interface and software
• base and support rod
• motion sensor

RATIONALE
When describing the motion of an object, knowing where it is relative to a reference point, how fast and in what direction it is moving, and how it is accelerating (changing its rate of motion) is essential. A sonic ranging device, such as an ultrasonic motion sensor, uses pulses of ultrasound that reflect from an object to determine the position of the object. As the object moves, the change in its position is measured many times each second.

RISK MANAGEMENT
Check that you have plenty of room to move safely without running into tables, walls, etc. when concentrating on your motion.
Complete a risk assessment before starting the activity.

PROCEDURE
For this activity, you will be the object in motion. The motion sensor will measure your position as you move in a straight line at different speeds. The software that supports your sensor will plot your motion on a graph of position and time.

Setting up the motion sensor
Graph: Position–time
Sampling rate: 10 samples per second (10 Hz). Stop condition at 10 s if available.
You do not need to calibrate motion sensors in this activity for the normal range of classroom temperatures.
Consult the manuals for your electronic equipment or see your teacher for the options to set these values with your equipment and software.

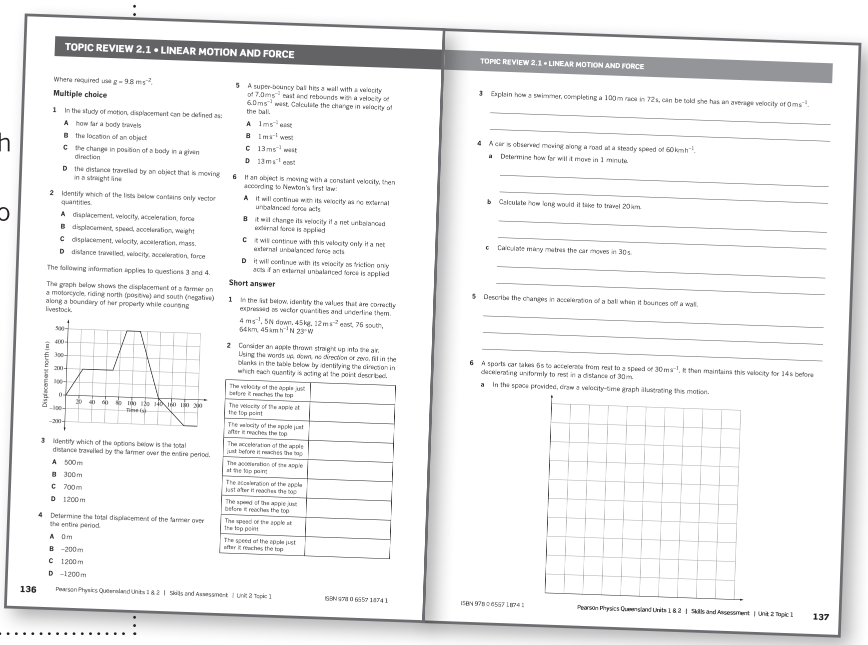
ISBN 978 0 6557 1874 1 Pearson Physics Queensland Units 1 & 2 | Skills and Assessment | Unit 2 Topic 1

## Practical activities

Practical activities take a highly scaffolded approach from beginning to completion and give students the opportunity to complete practical work related to the various subject matter covered in the syllabus. Practical activities include a rich assortment of tasks that maximise learning opportunities whilst also building experience in skill application to perform calculations and analysis of data, necessary for the Data Test. They feature every mandatory practical in the syllabus, as well as many suggested practicals. Like the worksheets, a range of questions building from foundation to challenging are included which are written to reflect the Marzano & Kendall taxonomy instructional verbs.

## Topic review questions

Each topic concludes with a comprehensive set of question items consisting of multiple-choice and short-answer responses written in an exam style. This provides students with exposure to and the opportunity to practise drawing together subject matter and skills to respond to examination style assessment.


TOPIC REVIEW 2.1 • LINEAR MOTION AND FORCE

Where required use $g = 9.8\ m\ s^{-2}$.

Multiple choice

1 In the study of motion, displacement can be defined as:
A how far a body travels
B the location of an object
C the change in position of a body in a given direction
D the distance travelled by an object that is moving in a straight line

2 Identify which of the lists below contains only vector quantities.
A displacement, velocity, acceleration, force
B displacement, speed, acceleration, weight
C displacement, velocity, acceleration, mass
D distance travelled, velocity, acceleration, force

The following information applies to questions 3 and 4.
The graph below shows the displacement of a farmer on a motorcycle, riding north (positive) and south (negative) along a boundary of her property while counting livestock.

3 Identify which of the options below is the total distance travelled by the farmer over the entire period.
A 500 m
B 300 m
C 700 m
D 1200 m

4 Determine the total displacement of the farmer over the entire period.
A 0 m
B −200 m
C 1200 m
D −1200 m

5 A super-bouncy ball hits a wall with a velocity of $7.0\ m\ s^{-1}$ east and rebounds with a velocity of $6.0\ m\ s^{-1}$ west. Calculate the change in velocity of the ball.
A $1\ m\ s^{-1}$ east
B $1\ m\ s^{-1}$ west
C $13\ m\ s^{-1}$ west
D $13\ m\ s^{-1}$ east

6 If an object is moving with a constant velocity, then according to Newton's first law:
A it will continue with its velocity as no external unbalanced force acts
B it will change its velocity if a net unbalanced external force is applied
C it will continue with this velocity only if a net external unbalanced force acts
D it will continue with its velocity as friction only acts if an external unbalanced force is applied

Short answer

1 In the list below, identify the values that are correctly expressed as vector quantities and underline them.
$4\ m\ s^{-1}$, 5 N down, 45 kg, $12\ m\ s^{-2}$ east, 76 south, 64 km, $45\ km\ h^{-1}$ N 23°W

2 Consider an apple thrown straight up into the air. Using the words up, down, no direction or zero, fill in the blanks in the table below by identifying the direction in which each quantity is acting at the point described.

| | |
|---|---|
| The velocity of the apple just before it reaches the top | |
| The velocity of the apple at the top point | |
| The velocity of the apple just after it reaches the top | |
| The acceleration of the apple just before it reaches the top | |
| The acceleration of the apple at the top point | |
| The acceleration of the apple just after it reaches the top | |
| The speed of the apple just before it reaches the top | |
| The speed of the apple at the top point | |
| The speed of the apple just after it reaches the top | |

136 Pearson Physics Queensland Units 1 & 2 | Skills and Assessment | Unit 2 Topic 1 ISBN 978 0 6557 1874 1

TOPIC REVIEW 2.1 • LINEAR MOTION AND FORCE

3 Explain how a swimmer, completing a 100 m race in 72 s, can be told she has an average velocity of $0\ m\ s^{-1}$.

4 A car is observed moving along a road at a steady speed of $60\ km\ h^{-1}$.
a Determine how far will it move in 1 minute.
b Calculate how long would it take to travel 20 km.
c Calculate many metres the car moves in 30 s.

5 Describe the changes in acceleration of a ball when it bounces off a wall.

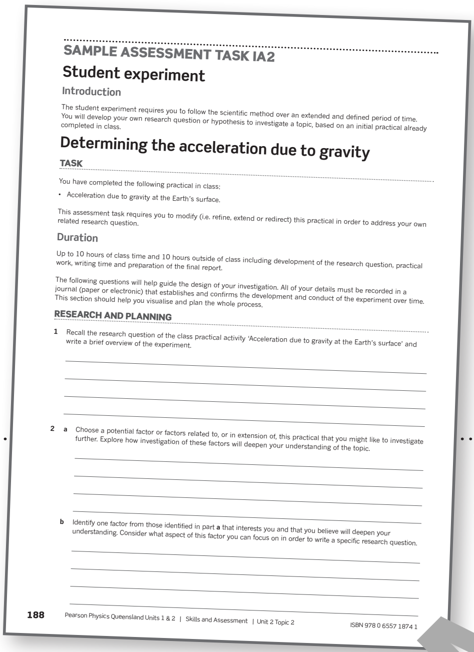
6 A sports car takes 6 s to accelerate from rest to a speed of $30\ m\ s^{-1}$. It then maintains this velocity for 14 s before decelerating uniformly to rest in a distance of 30 m.
a In the space provided, draw a velocity–time graph illustrating this motion.

ISBN 978 0 6557 1874 1 Pearson Physics Queensland Units 1 & 2 | Skills and Assessment | Unit 2 Topic 1 137

 ISBN 978 0 6557 1874 1

## Sample assessment tasks

**Sample Assessment Tasks** for the **Data Test, Student Experiment** and **Research Investigation** provide opportunities for students to practise responding to these assessment tasks. The activities are designed to support students by guiding and scaffolding them through each aspect of these assessments.


SAMPLE ASSESSMENT TASK IA2

Student experiment

Introduction

The student experiment requires you to follow the scientific method over an extended and defined period of time. You will develop your own research question or hypothesis to investigate a topic, based on an initial practical already completed in class.

Determining the acceleration due to gravity

TASK

You have completed the following practical in class:

- Acceleration due to gravity at the Earth's surface.

This assessment task requires you to modify (i.e. refine, extend or redirect) this practical in order to address your own related research question.

Duration

Up to 10 hours of class time and 10 hours outside of class including development of the research question, practical work, writing time and preparation of the final report.

The following questions will help guide the design of your investigation. All of your details must be recorded in a journal (paper or electronic) that establishes and confirms the development and conduct of the experiment over time. This section should help you visualise and plan the whole process.

RESEARCH AND PLANNING

1 Recall the research question of the class practical activity 'Acceleration due to gravity at the Earth's surface' and write a brief overview of the experiment.

2 a Choose a potential factor or factors related to, or in extension of, this practical that you might like to investigate further. Explore how investigation of these factors will deepen your understanding of the topic.

b Identify one factor from those identified in part **a** that interests you and that you believe will deepen your understanding. Consider what aspect of this factor you can focus on in order to write a specific research question.

188 Pearson Physics Queensland Units 1 & 2 | Skills and Assessment | Unit 2 Topic 2 ISBN 978 0 6557 1874 1

## Icons and features

Every mandatory practical is supported by a complimentary SPARKlab alternative practical.

The **safety icon** highlights significant hazards, indicating caution is needed.

The **safety glasses icon** highlights that protective eyewear is to be worn during the practical activity.



## Rate my learning

This innovative feature assists students to reflect on their learning and appears at the end of worksheets, practical activities and sample assessment tasks. It provides students with the opportunity for self-reflection and self-assessment, encouraging them to look ahead to how they can continue to improve, and identify areas of focus for further skill and subject matter development. This tool is based on Marzano and Kendall's taxonomy.

| | | | | | |
|---|---|---|---|---|---|
| **RATE MY LEARNING** | • I get it.<br>• I can apply/teach it. | • I get it.<br>• I can show I get it. | • I almost get it.<br>• I might need help. | • I get some of it.<br>• I need help. | • I don't get it.<br>• I need lots of help. |

## Teacher support

Fully worked solutions, suggested answers and responses to sample assessment tasks, as well as practical activity support including full **risk assessments, expected results** and **handy hints** are provided for teachers through the teacher support subscription.

# Physics toolkit

**This toolkit provides support for developing the skills to undertake the student experiment and the research investigation, and covers examination techniques and study skills. The toolkit can serve as a reference tool to be consulted as needed, throughout the year.**

**The toolkit complements the advice included in Chapter 1 Skills & Assessment Toolkit of *Pearson Physics 11 Units 1 & 2 Queensland Student Book*. The information in this toolkit explains how responses to assessment tasks will be assessed against the characteristics in the Instrument Specific Marking Guides (ISMG).**

## ASSESSMENT

Although there are no mandated assessments for units 1 and 2 Physics, your teacher may prepare you for units 3 and 4 Physics by requiring you to complete similar assessments to those in units 3 & 4. These assessments are:

- data test (IA1) in unit 1, 10%
- research investigation (IA3) in unit 1, 20%
- student experiment (IA2) in unit 2, 20%
- examination (EA), at end of units 1 and 2, 50%.

# PART A: Data test (IA1)

The data test is completed in unit 1. The test is completed under test conditions, with 10 minutes reading time and 60 minutes writing time.

The test may include:

- questions ranging from short answer to longer responses
- scenario situations
- problem-solving.

The key areas assessed in the data test are your ability to:

- apply your understanding of concepts to determine scientific quantities or features in evidence
- look critically at evidence and analyse it.

Tasks in the data test use both qualitative data and quantitative data. This data is related to unit 1 practicals and to subject matter. Items in the data test may include previously unseen data. You will be expected to complete calculations using algorithms, and interpret graphs, diagrams and tables.

There will be many experiences throughout unit 1 that will provide you with opportunities to prepare for the skills and subject matter assessed in the data test. You can also take some additional opportunities to practice and prepare, as outlined in the data test preparation checklist which directs you to resources to assist your revision.



**Data test preparation checklist**

| Resource | Feature | Revision activity | Complete ✔ |
|---|---|---|---|
| ***Pearson Physics 11 Units 1 & 2 Queensland Student Book*** | **Practicals** | • Read through each practical completed.<br>• Complete the analysing section of the practical again, without looking at your original analysis, interpretation and conclusion.<br>• Compare your analysis, interpretation and conclusion with those of your original practical. | |
| | **SkillBuilders, Worked examples and Try yourself** | • SkillBuilders outline a method or technique and step you through the skill to support the application.<br>• Often a SkillBuilder will be followed by a worked example that provides the thinking and process for each step of working through a problem.<br>• Refer to Worked examples and the mirror Try yourself problems that are placed at relevant stages in chapters. Many focus on skills in calculations using algorithms.<br>• Select examples in which you need to improve skills. Read the Skillbuilder and Worked example, then complete the Worked example: Try yourself and check your answer. | |
| | **Questions/ instructions** | • Refer to module and chapter reviews, focusing on instructions listed under 'analysis'; some of these tasks require the same skills needed to complete the data test.<br>• Select some tasks and complete them.<br>• Check your answers against the fully worked solutions provided in your eBook. | |
| | **Chapter 1 Skills and assessment toolkit** | • Refer to the Chapter 1 Physics Skills and assessment toolkit, Part A, in the eBook.<br>• Use this reference tool as needed, to improve your mathematical skills, analysis and visual interpretation skills. | |

| Resource | Feature | Revision activity | Complete ✔ |
|---|---|---|---|
| ***Pearson Physics Queensland 11 Skills and Assessment Book*** | **Mandatory practicals and suggested practicals** | • See suggestions and support practicals; these include working with data. | |
| | **Topic review** | • Refer to the topic review tasks for samples of the style of items on the data test. | |
| | **Practice data test** | • Complete the practice sample assessment task—the data test on page 80.<br>• Complete the data test under exam conditions. | |

# PART B: Student experiment (IA2)

The student experiment uses practical investigation methodology, including a research question developed by the student, the collection of primary data, and then the analysis and synthesis of that data.

The research question developed must:

- relate back to a practical related to the subject matter.

## CONDUCTING THE STUDENT EXPERIMENT

A great deal of preparation is needed before starting the experiment and much thought throughout the internal assessment task. Use the Student experiment checklist as a guide.

Refer to Pearson Physics 11 Units 1 & 2 Queensland Student Book, Chapter 1 ebook:

- Part A covers Scientific skills such as mathematical basics, representations in graphics, tables and graphs, data analysis.
- Part B covers all aspects of the student experiment and includes a sample student report.



**Student experiment checklist**

| Task | | Activity | Due date | Complete ✔ |
|---|---|---|---|---|
| **Form** ideas and develop the experiment question | Initial practical | • Identify the practical to be modified for your experiment | | |
| | Background | • Commence a journal to record all aspects of the assessment task<br>• Research relevant background information | | |
| | Variables | • Understand the data of original experiment<br>• Identify the dependent and independent variables of original experiment | | |
| | Modification | • Modify the original experiment<br>• Develop a new research question<br>• Write a statement of the aim that covers what the scientist wants to show, verify or find out in the experiment; this may be expressed as a statement or question, and may be one or two sentences.<br>• The statement is often written as 'To investigate the effect of … on … ' or 'To investigate if a correlation exists between … and …'<br>• Identify the dependant and independent variables and check they can be measured to provide data | | |
| | Justification | • Justify/provide rationale for the modification for the new experiment question | | |

 ISBN 978 0 6557 1874 1

| | | | | |
|---|---|---|---|---|
| **Find** the procedure and data | Procedure | • Plan the method to be followed for the experiment | | |
| | Materials | • Make a list of all equipment, chemicals and materials used<br>• Include quantities (chemicals) and sizes (equipment) | | |
| | Risk management | • Identify risk management strategies and potential dangers by completing the Risk Assessment Form on page xii | | |
| | The experiment | • Conduct the experiment<br>• Collect sufficient and relevant data to answer the research question<br>• Record all measurements taken during the experiment as well as observations | | |
| | Results | • Observations may be recorded as text, diagrams, photos or videos<br>• Process data and present it clearly correctly<br>• Most common records of primary data are tables with titles and units<br>• Most common records of processed data are tables, graphs and can<br>• include calculations<br>• Check for errors and mistakes in data collected; take steps to reduce these | | |
| **Analyse** the evidence | Organise data collected | • Process the data using mathematical techniques and graphs<br>• Identify the trends, patterns or relationships | | |
| **Interpret** and **evaluate** the evidence | Work with data collected; relate back to the experiment question | • Draw conclusion/s from the evidence that addresses the experiment question<br>• Include the interpretation of results<br>• Identify the uncertainties and limitations of the evidence<br>• Evaluate the reliability and validity of the experimental process<br>• Provide suggestions to improve and/or extend the experiment<br>• Evaluate the method used<br>• Comment on whether results relate to the experiment question<br>• Provide suggestions for improvements and extensions to the experiment | | |
| The report | Presentation format | • Decide on the presentation format; written or multi modal<br>• Check length requirements for your selected format | | |
| | Communication | • Communicate ideas in scientific language and representations<br>• Include in-text citations and reference list<br>• Write using your own words to avoid plagiarising<br>• Ensure length requirements are not exceeded. | | |

# UNIT 1 Thermal, nuclear and electrical physics

TOPIC 1 **Heating processes**

TOPIC 2 **Ionising radiation and nuclear reactions**

TOPIC 3 **Electrical circuits**

## Unit 1 objectives

Students will:

- describe ideas and findings about heating processes, ionising radiation and nuclear reactions, and electrical circuits
- apply understanding of heating processes, ionising radiation and nuclear reactions, and electrical circuits
- analyse data about heating processes, ionising radiation and nuclear reactions, and electrical circuits
- interpret evidence about heating processes, ionising radiation and nuclear reactions, and electrical circuits
- evaluate processes, claims and conclusions about heating processes, ionising radiation and nuclear reactions, and electrical circuits
- investigate phenomena associated with heating processes, ionising radiation and nuclear reactions, and electrical circuits

TOPIC

# 1 Heating processes

- ☐ Worksheet 1.1.1 Knowledge preview

## KINETIC PARTICLE MODEL AND HEAT FLOW

- ☐ Worksheet 1.1.2 Kinetic particle model
- ☐ Practical activity 1.1.2 Finding the relationship between temperature and heat

## TEMPERATURE AND SPECIFIC HEAT CAPACITY

- ☐ Worksheet 1.1.3 Temperature scales
- ☐ Worksheet 1.1.4 Specific heat capacity
- ☐ Practical activity 1.1.3 Determining the specific heat capacity of a substance

## PHASE CHANGES AND SPECIFIC LATENT HEAT

- ☐ Worksheet 1.1.5 The role of oceans and air in the Earth's climate balance
- ☐ Practical activity 1.1.4 Specific latent heat of fusion

## ENERGY CONSERVATION IN CALORIMETRY

- ☐ Worksheet 1.1.6 Thermal equilibrium in mixtures

## ENERGY IN SYSTEMS—MECHANICAL WORK AND EFFICIENCY

- ☐ Practical activity 1.1.5 Energy transfer and heat

- ☐ Worksheet 1.1.7 Literacy review
- ☐ Worksheet 1.1.8 Thinking about my learning
- ☐ **Topic Review 1.[illegible]**




ISBN 978 0 6557 1874 1

# Key knowledge

## Kinetic particle model and specific heat capacity

The **kinetic particle model** proposes that all matter is made of atoms or molecules (particles) that are in constant motion. Matter can exist in four phases or states—solid, liquid, gas and plasma. **Thermal energy** is the **internal energy** (the total **kinetic energy** and **potential energy** of the particles within a substance) present in a system due to its temperature.

**Temperature** describes 'how hot something is'. It is a measure of the internal energy of an object or system and the property that determines the direction in which thermal energy is transferred to or from the object.

**Heat** is the transfer of thermal energy from one object to another. This process, known as heating, only transfers thermal energy from a hotter substance to a colder substance. If an object has become hotter, then it has gained heat energy. Conversely, if an object has become colder, it has lost heat energy.

### HEAT TRANSFERS

The three ways in which heat is transferred are conduction, convection and radiation.

#### Conduction

**Conduction** is heat transfer within a material or between materials without the overall transfer of the substance itself. All materials conduct heat, but this process is most significant in solids. Materials that conduct heat well, such as metals and glass, are called good thermal conductors. Materials that conduct heat poorly, such as wool and wood, are called thermal insulators. Whether a material is a good conductor depends on the method of conduction.

- Heat transfer by molecular collisions alone occurs in poor to very poor conductors.
- Heat transfer by molecular collisions and free electrons occurs in good to very good conductors.

The rate of conduction depends on the temperature difference between two materials, the thickness of the material, the surface area and the nature of the material.

#### Convection

**Convection** is the transfer of heat within a liquid or a gas as a result of the physical movement of matter. Unlike the other two types of heat transfer, it involves the mass movement of particles within a system. A convection current forms when there is warm fluid rising and cool fluid falling, caused by a difference in density. This movement mixes the particles with high and low kinetic energies until thermal equilibrium is reached. An example of convection is thermal air currents in the atmosphere, which are used by glider pilots to gain altitude.

#### Radiation

Radiation is the transfer of thermal energy from one place to another by means of **electromagnetic waves**. Any object with a temperature greater than **absolute zero** emits thermal energy by radiation. An example of where **radiation** can be felt is sitting around a fire, as heat can be felt without touching the fire.

### TEMPERATURE

Temperature is related to the average kinetic energy of the particles in a substance. The faster the particles move (or vibrate), the higher the kinetic energy of the substance and the greater the temperature. Temperature is measured in degrees Celsius (°C) or kelvin (K). Absolute zero is simply 'zero kelvin' (0 K) and is approximately equal to −273°C.

> ℹ To convert from Celsius to kelvin, add 273.
>
> To convert from kelvin to Celsius, subtract 273.

### SPECIFIC HEAT CAPACITY

When heat is transferred to or from a system or object, the temperature change depends upon the amount of energy transferred, the mass of the material(s) and the **specific heat capacity** of the material(s).

The specific heat capacity is the amount of energy that must be added to raise the temperature of one kilogram by one kelvin, and is a constant particular to each substance. Each substance has a different specific heat capacity in different states (solid, liquid or gas). A high specific heat capacity means that a substance will absorb or release thermal energy at a slow rate. Substances with a low specific heat capacity absorb or release thermal energy quickly.

> ℹ $Q = mc\Delta T$
>
> where:
>
> $Q$ is the heat energy transferred (J)
> $m$ is the mass of material being heated (kg)
> $\Delta T$ is the change in temperature (°C or K)
> $c$ is the specific heat capacity of the material ($\text{J kg}^{-1}\,\text{K}^{-1}$).

Table 1.1.1 lists the specific heat capacities for some common substances.

**TABLE 1.1.1** Approximate specific heat capacities of common substances.

| Material | $c$ (J kg$^{-1}$ K$^{-1}$) |
|---|---|
| human body | 3500 |
| methylated spirits | 2500 |
| air | 1000 |
| aluminium | 900 |
| glass | 840 |
| iron | 440 |
| copper | 390 |
| ice (water) | 2100 |
| liquid water | 4200 |
| steam (water) | 2000 |

# Phase changes and energy conservation

## ENERGY AND CHANGE OF STATE

The kinetic particle mode says that temperature is the measure of the average kinetic energy of a substance. This means if the temperature of a substance increases, so too does the kinetic energy of its system. When a solid material undergoes a change of state (also called a phase change), energy is needed to overcome the attractive forces between the particles so that they can separate. It is important to understand that the addition of thermal energy does not increase the kinetic energy of the particles during a change of state, so the temperature does not increase. This is shown at the 'ice melting' and 'water boiling' stages in Figure 1.1.1. As the internal energy of a system contains both kinetic and potential energy, during this phase change it is the potential energy that is increasing, which is what separates the particles and causes the change of state.

## SPECIFIC LATENT HEAT

The **specific latent heat** of a substance is the energy required to change the state of 1 kg of a substance at a constant temperature. There are two types of specific latent heat: latent heat of fusion and latent heat of vaporisation.

In general, for any substance, the energy required (or released) in a change of state is:

> $Q = mL$
>
> where:
>
> $Q$ is the energy transferred (J)
> $m$ is the mass (kg)
> $L$ is the specific latent heat (J kg$^{-1}$).

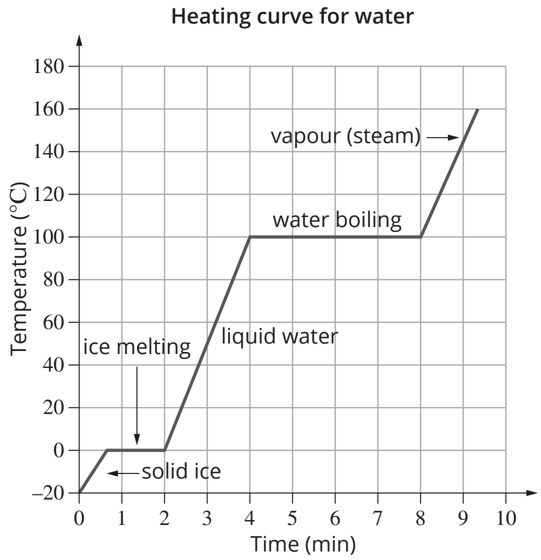



**FIGURE 1.1.1** A heating curve for water, showing the constant temperatures during changes of state.

The latent heat of fusion, $L_{fusion}$, is the energy required to change 1 kg of a material between the solid and liquid states. The latent heat of vaporisation, $L_{vapour}$, is the energy required to change 1 kg of a material between the liquid and gaseous states. The latent heat of fusion of a substance will be different to (and usually less than) the latent heat of vaporisation for that substance. Table 1.1.2 shows the latent heats of fusion and vaporisation for some common substances.

**TABLE 1.1.2** The specific latent heats of fusion and vaporisation for some common substances.

| Substance | Melting point (°C) | $L_{fusion}$ (J kg$^{-1}$) | Boiling point (°C) | $L_{vapour}$ (J kg$^{-1}$) |
|---|---|---|---|---|
| water | 0 | $3.34 \times 10^5$ | 100 | $22.5 \times 10^5$ |
| oxygen | –219 | $0.14 \times 10^5$ | –183 | $2.2 \times 10^5$ |
| lead | 327 | $0.25 \times 10^5$ | 1750 | $9.0 \times 10^5$ |
| ethanol | –114 | $1.05 \times 10^5$ | 78 | $8.7 \times 10^5$ |
| silver | 961 | $0.88 \times 10^5$ | 2193 | $23.0 \times 10^5$ |

## CALORIMETRY

When you heat an object, thermal energy is transferred from a hotter substance to a colder substance so that the entire system has no loss in energy. Heat is given the symbol $Q$. Because heat describes energy, it is measured in joules (J). If no thermal energy flows between objects that are in contact with other, they are said to be in thermal equilibrium, that is, they have the same temperature (i.e. the average kinetic energy in both systems is the same).

### Conservation of energy

The zeroth law of thermodynamics states that if objects A and B are both in thermal equilibrium with object C, then objects A and B are in thermal equilibrium with each other. A, B and C must be at the same temperature. A thermometer works by using the zeroth law; when you



 ISBN 978 0 6557 1874 1

are in contact with a thermometer, your body heat is transferred to it until you and the thermometer have the same temperature.

Conservation of energy states that in a closed system the heat lost by one substance must be equal to the heat gained by the other substance, i.e.

$$Q_{lost} = Q_{gained}$$

## Solving heating problems

Problems involving thermal energy often require calculations of both latent and specific heat as substances change temperature and state during heating and/or cooling. These problems can involve a number of steps, and the process can at first seem quite complex. It can help to use a simple flow diagram to show each step and the form of heating or cooling involved (Figure 1.1.2).

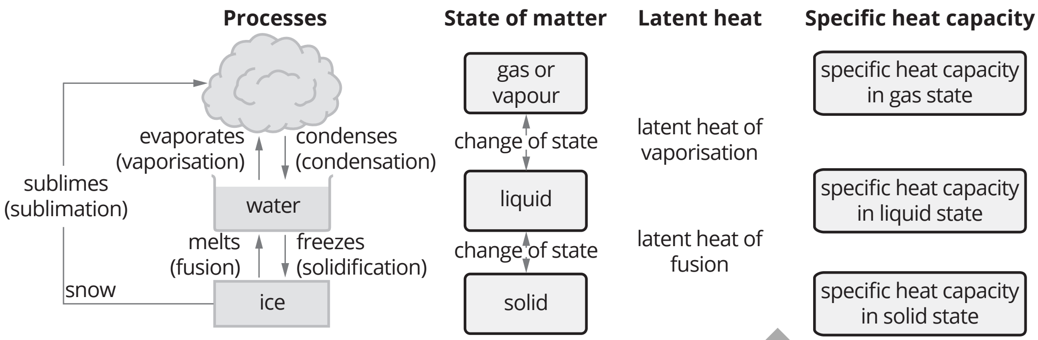



**FIGURE 1.1.2** Flow diagram for solving heating and/or cooling problems involving changes of state

The following worked example illustrates this process as water is heated through two changes of state.

Calculate the heat required in MJ to convert 5 kg of ice at –20°C into steam at 100°C.

| Thinking | Working |
|---|---|
| Four steps are involved in this process:<br>ice at –20°C to ice at 0°C<br>ice at 0°C to water at 0°C<br>water at 0°C to water at 100°C<br>water at 100°C to steam at 100°C<br>Identify $L$ and $c$ for each step and calculate the energy required for each step separately. | From Table 1.1.1:<br>$c_{ice} = 2100\ \text{J kg}^{-1}\ \text{K}^{-1}$<br>$c_{water} = 4200\ \text{J kg}^{-1}\ \text{K}^{-1}$<br>From Table 1.1.2:<br>$L_{fusion}$ (water) $= 3.34 \times 10^5\ \text{J kg}^{-1}$<br>$L_{vapour}$ (water) $= 22.5 \times 10^5\ \text{J kg}^{-1}$ |
| For ice at –20°C being heated to ice at 0°C, use the equation for the specific heat:<br>$Q = cm\Delta T$<br>$\Delta T = 20°C$, $m = 5$ kg, $c = 2100\ \text{J kg}^{-1}\ \text{K}^{-1}$ | $Q_1 = cm\Delta T$<br>$= 2100 \times 5 \times 20$<br>$= 210\,000$ J<br>$= 0.21$ MJ |
| For ice at 0°C changing state to water at 0°C, use the equation for the latent heat of fusion:<br>$Q = mL_{fusion}$<br>$L_{fusion} = 3.34 \times 10^5\ \text{J kg}^{-1}$, $m = 5$ kg | $Q_2 = mL_{fusion}$<br>$= 5 \times 3.34 \times 10^5\ \text{J kg}^{-1}$<br>$= 1.67 \times 10^6$ J<br>$= 1.67$ MJ |
| For water at 0°C being heated to water at 100°C, use the equation for specific heat:<br>$Q = cm\Delta T$<br>$\Delta T = 100°C$, $m = 5$ kg, $c = 4200\ \text{J kg}^{-1}\ \text{K}^{-1}$ | $Q_3 = cm\Delta T$<br>$= 4200 \times 5 \times 100$<br>$= 2.1 \times 10^6$ J<br>$= 2.1$ MJ |
| For water at 100°C changing state to steam at 100°C, use the equation for latent heat of vaporisation:<br>$Q = mL_{vapour}$<br>$L_{vapour} = 22.5 \times 10^5\ \text{J kg}^{-1}$, $m = 5$ kg | $Q_4 = mL_{vapour}$<br>$= 5 \times 22.5 \times 10^5\ \text{J kg}^{-1}$<br>$= 11.25 \times 10^6$ J<br>$= 11.25$ MJ |
| Total heat, $Q_{total} = Q_1 + Q_2 + Q_3 + Q_4$ | $Q_{total} = 0.21 + 1.67 + 2.1 + 11.25 = 15.2$ MJ |



Note that most of the energy required is used in converting the liquid water to steam.

## MECHANICAL WORK AND EFFICIENCY

The first law of **thermodynamics** states that energy simply changes from one form to another and the total energy in a system is constant. In other words, energy cannot be created or destroyed: this is the **law of conversation of energy**. If a system has thermal energy it then has the capacity to do mechanical work. For example, the steam engine is used to convert heat energy into mechanical work by using steam to push a piston. Any change in the internal energy ($\Delta U$) of a system is equal to the energy added by heating ($+Q$) or removed by cooling ($-Q$), minus the work done on ($-W$) or by ($+W$) the system: $\Delta U = Q + W$.

In any mechanical system, energy transfers and transformations will always result in some heat loss to the environment so that the amount of useable energy is reduced.

Energy efficiency, $\eta$, is the rate of useful work performed to the total energy expended or heat taken in, and is given by:

$$\eta = \frac{\text{energy output}}{\text{energy input}} \times 100\%$$

# WORKSHEET 1.1.1

## Knowledge preview

**1** State the temperature, in Celsius and in Fahrenheit, of melting ice. ______

**2** For each of the changes of state given in the table below, identify the correct process from the following list and write it in the process column: **condensation, transformation, freezing, boiling, combustion, melting**.

| Change of state | Process |
|---|---|
| gas changes to liquid | |
| liquid changes to solid | |
| liquid changes to gas | |

**3** Each situation below involves heat transfer. Identify and explain which of the three methods of heat transfer (conduction, convention or radiation) is involved.

- **a** Lighter-coloured clothes keep you cooler in summer. ______
- **b** A drinks cooler is made from polystyrene foam. ______
- **c** The air near the ceiling of a room is warmer than near the floor. ______
- **d** A saucepan has a plastic handle. ______
- **e** You walk in bare feet on the sand at a beach. ______
- **f** A wall feels warm when the sun is shining on it. ______
- **g** Water is boiled in an electric kettle. ______
- **h** You feel cold when diving into the ocean. ______



**4** Recall how heat transfers by circling the correct alternative in each statement below.

- **a** Heat always flows from an object of lower/higher temperature to one of lower/higher temperature.
- **b** Insulators are good/poor conductors of heat.
- **c** Gases are good/poor conductors of heat.
- **d** On a warm day, a house is warmer upstairs because of conduction/convection currents.

**5** Describe how heat travels along a metal rod when it is heated at one end. ______

______

**6** Two identical bathtubs are filled to the same level with water. The particles in bathtub 1 move with greater speed than the particles in bathtub 2.

- **a** State in which bathtub the water will be at a higher temperature. ______
- **b** State which bathtub has more heat energy. ______
- **c** As the water cools, each bathtub loses heat energy. List three places this heat energy could go.

______


ISBN 978 0 6557 1874 1

# WORKSHEET 1.1.7

## Literacy review

Complete the following paragraphs relating to thermodynamics using the word list supplied for each paragraph. Not every word will be used, and some may be used more than once.

**1**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| kinetic | potential | kelvin | Celsius | Fahrenheit | temperature | heat | energy |

Two common temperature scales used in science are the ____________ and ____________ scales. ____________ is related to the average ____________ energy of the particles in a material. ____________ energy depends upon the mass and ____________ of particles.

**2**

| | | | | |
|---|---|---|---|---|
| kinetic energy | thermal energy | cold | hot | transfer |

The word 'heat' is loosely used in common language. However, in science it specifically relates to the ____________ of ____________ from one material to another. Sometimes the term 'heat' is used interchangeably with the term '____________'. ____________ is in fact the total amount of energy contained in a material. Heat is transferred from a ____________ object to a ____________ object.

**3** Complete the following paragraph relating to specific and latent heat from the word list provided.

| | | | | | | |
|---|---|---|---|---|---|---|
| phase | specific heat capacity | phase | transferred | temperature | latent | energy |

When heat is ____________ to or from a system or object, the ____________ change depends upon the amount of ____________ transferred, the mass of the material and the ________________________ of the material. When a solid material changes state, ____________ is needed to separate the particles by overcoming the attractive forces between the particles. This is known as a ____________ change. The energy required to do so is referred to as ____________, or hidden, heat.

**4** Define each of the following means of heat transfer. Refer to Key knowledge on page 3, your student book or another suitable source.

Conduction:

______________________________________________________________

Convection:

______________________________________________________________

Radiation:

______________________________________________________________

**5** The following paragraph explains the application of latent heat of vaporisation to variation in climate. Complete the paragraph, referring to the Key knowledge section on page 3.

The transfer of ____________ during a ____________ change between liquid water and water vapour has a profound effect on our environment. The temperature doesn't cool much at night in regions of ____________ humidity. However, the temperature in deserts (____________ humidity) quickly drops after the sun goes down. This is because regions of high humidity have lots of ____________ ____________ in the air. ____________ ____________ condensing back into a liquid releases ____________ to the air.

| RATE MY LEARNING | • I get it.<br>• I can apply/teach it. | • I get it.<br>• I can show I get it. | • I almost get it.<br>• I might need help. | • I get some of it.<br>• I need help. | • I don't get it.<br>• I need lots of help. |
|---|---|---|---|---|---|




ISBN 978 0 6557 1874 1

# WORKSHEET 1.1.8

# Thinking about my learning

On completion of Topic 1 Heating processes, you should be able to describe, explain and apply the relevant scientific ideas. You should be able to work with data: to interpret, analyse and evaluate it.

Consider how aware you are of how you learn. Consider how much control you take for your own learning.

**1** Think about the different methods or learning strategies you used in this topic. Different learning strategies suit different situations and different people. Some common learning strategies include:

| | |
|---|---|
| • memory devices such as lists<br>• studying and discussing concepts in a group<br>• restating information in your own words<br>• using charts such as flow charts and concept maps to represent information and show relationships | • relating concepts to your own experiences<br>• summarising notes<br>• teaching someone else<br>• frequently rereading class notes<br>• highlighting key points in notes<br>• making flash cards |

**a** List four learning strategies you used during this topic on the table below and describe a situation when each learning strategy was used.

**b** Place a cross along the scale on the right of the table, to indicate how effective each strategy was for you.

| Learning strategy/situation when used | Effectiveness of learning strategy for my learning |
|---|---|
| | **Not effective** This strategy was not very helpful for my understanding and learning. ⟷ **Very effective** This strategy was very helpful for my understanding and learning. |
| | **Not effective** This strategy was not very helpful for my understanding and learning. ⟷ **Very effective** This strategy was very helpful for my understanding and learning. |



**2** Describe two concepts you learned and one skill you developed or improved during this topic.

Two concepts I learned: ______________________________

______________________________

______________________________

______________________________

One skill I developed: ______________________________

______________________________

ISBN 978 0 6557 1874 1

# PRACTICAL ACTIVITY 1.1.4

# Specific latent heat of fusion

**Suggested duration:** 40 minutes

## RESEARCH QUESTION

What is the latent heat of fusion of water?

## RATIONALE

Heat is the energy that is transferred from one substance to another as a result of a difference in their temperature. In addition to changing the temperature of a substance, heat can also break intermolecular bonds, causing the substance to change phase. When this happens, no energy goes into changing the temperature of the substance; it is all used to alter the intermolecular bonds within the substance. The heat energy required for a substance to change phase from a solid to a liquid is given by:

$$\Delta Q = mL_{\text{fusion}}$$

where:

$\Delta Q$ is the change in energy (J)

$m$ is the mass of the substance changing phase (kg)

$L_{\text{fusion}}$ is the latent heat of fusion of the substance ($J\,kg^{-1}$)

The latent heat of a substance is the amount of energy required to turn it from a solid to a liquid. Therefore, the latent heat of fusion of water can be found by investigating the heat energy needed to melt ice.

**MATERIALS**

- data-collection system and temperature sensor (or thermometer and stopwatch)
- 600 mL beaker
- calorimetry cup
- balance (one needed per class)
- hotplate
- stirring rod (temperature sensor can be used instead) or stir station
- 300 mL water
- 3 or 4 ice cubes
- paper towel
- electronic balance (one or more per class)



## RISK MANAGEMENT

- Keep water away from sensitive electronic equipment.
- Be careful using the hotplate. Always be aware that it is on, and be conscious of any loose clothing or papers that could accidently melt or catch fire if left in contact with the hotplate.

Before you commence this practical activity, conduct a risk assessment. Complete the template in your Skills and Assessment book or download from your eBook.

## PROCEDURE

1 Heat 300 mL of water to approximately 40°C in the beaker on the hotplate.

2 If you are using a data-collection system, start a new experiment, connect the temperature sensor to the data-collection system, and choose a digital display of temperature.

3 Carefully measure the mass of the calorimetry cup, and record this value in the table in the Results section.

4 Fill the calorimetry cup three-quarters full with hot water (at approximately 40°C), then quickly, but accurately, measure the mass of the filled cup, and record this in the table in the Results section.

5 Insert the thermometer or temperature sensor into the calorimetry cup and allow the temperature to stabilise. Record the initial temperature (as accurately as possible with your equipment) in the table in the Results section. Include an estimate of the uncertainty.

 ISBN 978 0 6557 1874 1

# TOPIC REVIEW 1.1 • HEATING PROCESSES

## Multiple choice

**1** Identify which of the following is *not* a method of heat transfer.

**A** radiation

**B** insulation

**C** convection

**D** conduction

**2** A vacuum flask, or Thermos®, has a reflective coating of aluminium on the internal surface. This 'silvered' surface reduces heat transfer by:

**A** radiation

**B** convection

**C** conduction

**D** all of the above

**3** Identify which of the following is the best example of heat transfer by conduction.

**A** heat transfer from the Sun to the Earth

**B** heat transfer from the bottom of the ocean to the top

**C** heat transfer from the Earth's crust to the layer below (the mantle)

**D** heat transfer from the Earth's surface to the upper atmosphere

**4** Water is poured into a stainless-steel pot, which is heated over a gas flame. As the water at the bottom of the pan is heated, begins to rise to the surface. The order of heat transfer during this entire process is:

**A** conduction, convection, radiation

**B** convection, conduction, radiation

**C** radiation, convection, conduction

**D** radiation, conduction, convection



## Short answer

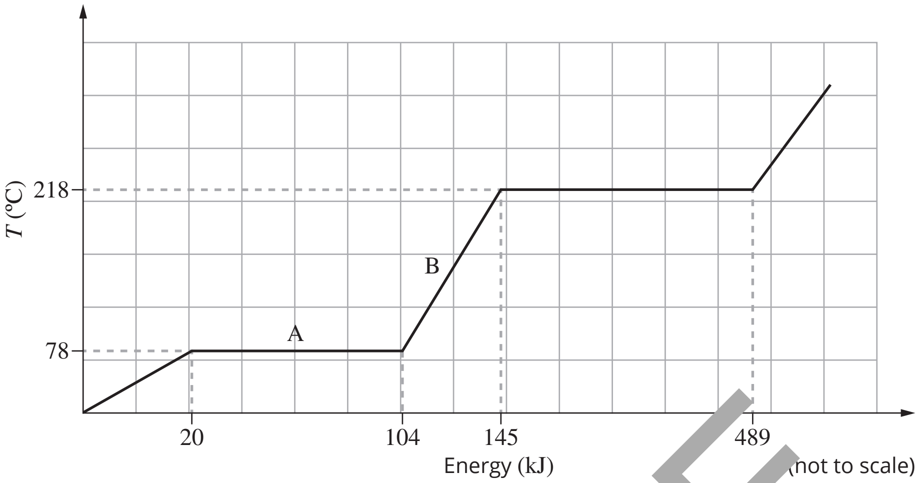
**5** If the particles within two objects have the same average kinetic energy, explain whether the two objects will be at the same temperature.

**6** A thermometer is supplied with no markings. Describe the process you would go through to produce a calibrated scale. State whether your scale would be arbitrary or absolute.

**7** Calculate how much energy, in joules, is needed to raise the temperature of 100 kg of water from a room temperature of 20.0°C to a comfortable bath temperature of 35.0°C. (Assume no losses to the surrounding environment.)

**8** Energy must be supplied to ice for it to melt. The temperature of the resulting water is no higher than the temperature of the original ice. Explain.

**9** A 200 g sample of naphthalene is heated carefully in a closed glass vessel in which all the fumes can be safely contained and the energy inputs can be accurately measured. The heating curve below was produced as a result of the measurements.




**a** Recall the states of matter of the naphthalene in sections A and B.

**b** Use the information on the graph to complete parts i to iv, calculating the following values for naphthalene:

**i** specific heat capacity as a solid

**ii** specific heat capacity as a liquid

**iii** specific latent heat of fusion

**iv** specific latent heat of vaporisation.



**10** A flat plate solar collector consists of an insulated box with a transparent cover, black-painted copper pipes, and a black absorber plate. Evaluate and explain the function of each component in terms of heat transfer and efficiency.

| RATE MY LEARNING | • I get it.<br>• I can apply/teach it. | • I get it.<br>• I can show I get it. | • I almost get it.<br>• I might need help. | • I get some of it.<br>• I need help. | • I don't get it.<br>• I need lots of help. |
|---|---|---|---|---|---|

 ISBN 978 0 6557 1874 1

# SAMPLE ASSESSMENT TASK IA1

# Data test

**Duration**: 10 minutes reading time and 45 minutes to complete the test.

## Task

The data test requires you to apply a range of cognitions to respond to scientific data. The test may be held in a set timeframe under exam conditions.

Each dataset will enable you to analyse and interpret data to apply your understanding of thermal, nuclear and electrical physics.

You will be required to complete multiple-choice and short-answer questions, calculations and interpretation of graphs to a total of approximately 300–450 words. (Total 60 marks)

Complete all parts of each question.

## Data set 1—Specific heat capacity of a metal (22 marks)



In an experiment to determine the specific heat capacity of an unknown metal, a cube of the metal was heated by immersing it in a hot water bath for about 5 minutes. The temperature of the water bath was measured and recorded using a temperature sensor. The metal sample was then quickly transferred to a calorimeter containing water at room temperature. The temperature of the water was monitored until the temperature stopped changing. This temperature was recorded as the final temperature for both the water and the metal sample and the results, including estimates of the uncertainty, were recorded in Table 1 below.

The specific heat capacity of water is 4200 J kg K

The mass of the calorimeter cup was measured as 0.03[illegible] kg on a digital balance.

The mass of the calorimeter cup and water was measured as 0.195 kg.

The mass of the metal was measured as 0.[illegible] kg.

**TABLE 1** Mass and temperature data

| Sample | $T_{final}$ (°C) | Uncertainty $T_{final}$ (°C) | $T_{initial}$ (°C) | Uncertainty $T_{initial}$ (°C) |
|---|---|---|---|---|
| Water | 24.8 | ±0.1 | 23.9 | ±0.1 |
| Metal | 24.8 | ±0.1 | 96.4 | ±0.1 |

**1** Define the specific heat capacity of a substance. (1 mark)

**2** Explain the difference between the specific heat capacity and heat capacity of a substance. (2 marks)

**3** State how the uncertainty in a digital measurement is used to calculate the uncertainty in the measurement of the mass of the calorimeter, and the mass of the metal. (1 mark)

ISBN 978 0 6557 1874 1

# SAMPLE ASSESSMENT TASK IA3

# Research investigation

**Suggested duration:** Approximately 10 hours

## Introduction

The research investigation requires you to gather secondary evidence on a research question over an extended and defined period of time. You will develop your own research question to investigate, based on a claim (provided by your teacher) related to the course.

## Nuclear energy generation and applications—evaluating a claim

### BACKGROUND

From the late 19th century through to the 20th century, experimental discoveries revolutionised the accepted understanding of matter on an atomic scale. The work of Thompson, Rutherford, Bohr, de Broglie, Heisenberg and others led to such an understanding that scientists were able to split the nucleus of an atom, generating an enormous amount of energy for a relatively small mass. In many parts of the world, nuclear energy is used for generating electricity for daily living. Australia has one reactor used for scientific research and the production of radioisotopes for medicine. This is the OPAL Research Reactor located at the Australian Nuclear Science and Technology Organisation (ANSTO) at Lucas Heights in Sydney.

### SAMPLE TASK

In this task you will evaluate a claim about nuclear power generation and/or its applications. You need to consider a variety of claims and select one for research.

Topics for this research task could be related to the following:

- Advances in scientists' understanding of the properties of nuclear radiation have influenced medical treatment and imaging.
- The use of scientific knowledge to predict beneficial and/or harmful or unintended consequences, for example, choosing appropriate radioisotopes for medical imaging or carefully storing nuclear waste.
- The possibility of nuclear fission-based power production replacing fossil fuels to generate electricity.
- The health and environmental risks associated with the use of nuclear fission must be considered along with the environmental and cost benefits of lowering fossil-fuel consumption.
- An understanding of nuclear processes has led to the use of new analytical tools (e.g. radiometric dating) to understand past events.



Evaluating a claim requires you to consider different claims and select one for research.

Your research will include the following steps:

| | |
|---|---|
| Research and planning<br>(Forming and describing the inquiry activity) | Develop a research question from the claim.<br>Include a rationale and background. |
| Scientific arguments and evidence<br>(Finding valid and reliable evidence for the inquiry activity) | Your research will involve gathering data from scientific resources.<br>You will include references to these resources in your final report. |
| Analysing and interpreting | Analyse and interpret the evidence to answer your research question. |
| Evaluating | You will discuss the quality of the evidence and extrapolate from credible evidence to the claim.<br>You will suggest improvements to the investigation that are relevant to the claim. |

In the first place, it will be necessary to develop a question in relation to the claim you have decided to investigate. Your research will involve gathering relevant data from scientific resources which you will interpret and analyse. You will use the scientific evidenceto draw conclusions and complete your evaluation.

A sample task and template has been included to guide you through the process.


ISBN 978 0 6557 1874 1