PEARSON

PHYSICS

QUEENSLAND

SKILLS AND ASSESSMENT

11

UNITS 1 & 2

Doug Bail

QCE 2019 SYLLABUS

Contents

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How to use this book

The *Pearson Physics 11 Queensland Skills and Assessment Book* 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.

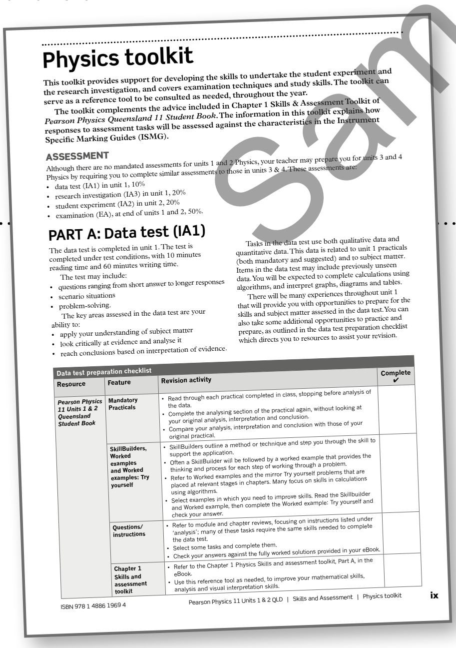
This resource has been developed by highly experienced and expert author teams, with lead Queensland specialists who have a working understand what teachers are looking for with teaching and learning across the new QCE.

Fully written to the new QCE year 11 & 12 syllabus, the Skills & 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 11 Queensland Student Book* 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 Books, 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

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 Queensland 11 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 subject matter
- look critically at evidence and analyse it
- reach conclusions based on interpretation of evidence.

Tasks in the data test use both qualitative data and quantitative data. This data is related to unit 1 practicals (both mandatory and suggested) 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	Mandatory Practicals	• Read through each practical completed in class, stopping before analysis of the data. • Complete the analysing section of the practical again, without looking at your original analysis, interpretation and conclusion. • Compare your analysis, interpretation and conclusion with those of your original practical.	
	SkillBuilders, Worked examples and Worked examples: Try yourself	• SkillBuilders outline a method or technique and step you through the skill to support the application. • Often a SkillBuilder will be followed by a worked example that provides the thinking and process for each step of working through a problem. • 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. • 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'; many of these tasks require the same skills needed to complete the data test. • Select some tasks and complete them. • 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. • Use this reference tool as needed, to improve your mathematical skills, analysis and visual interpretation skills.	

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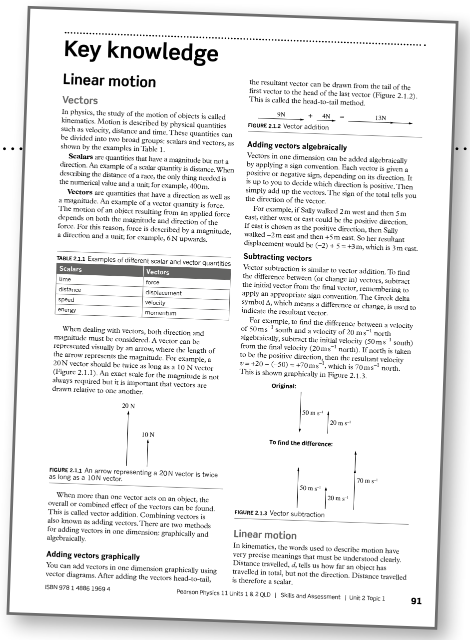
Key knowledge

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

Vectors

In physics, the study of the motion of objects is called kinematics. Motion is described by physical quantities such as velocity, distance and time. These quantities can be divided into two broad groups: scalars and vectors, as shown by the examples in Table 1.

Scalars are quantities that have a magnitude but not a direction. An example of a scalar quantity is distance. When describing the distance of a race, the only thing needed is the numerical value and a unit; for example, 400 m.

Vectors are quantities that have a direction as well as a magnitude. An example of a vector quantity is force. The motion of an object resulting from an applied force depends on both the magnitude and direction of the force. For this reason, force is described by a magnitude, a direction and a unit; for example, 6 N upwards.

TABLE 2.1.1 Examples of different scalar and vector quantities

Scalars	Vectors
time	force
distance	displacement
speed	velocity
energy	momentum

When dealing with vectors, both direction and magnitude must be considered. A vector can be represented visually by an arrow, where the length of the arrow represents the magnitude. For example, a 20 N vector should be twice as long as a 10 N vector (Figure 2.1.1). An exact scale for the magnitude is not always required but it is important that vectors are drawn relative to one another.

FIGURE 2.1.1 An arrow representing a 20 N vector is twice as long as a 10 N vector.

When more than one vector acts on an object, the overall or combined effect of the vectors can be found. This is called vector addition. Combining vectors is also known as adding vectors. There are two methods for adding vectors in one dimension: graphically and algebraically.

Adding vectors graphically

You can add vectors in one dimension graphically using vector diagrams. After adding the vectors head-to-tail, the resultant vector can be drawn from the tail of the first vector to the head of the last vector (Figure 2.1.2). This is called the head-to-tail method.

FIGURE 2.1.2 Vector addition

Adding vectors algebraically

Vectors in one dimension can be added algebraically by applying a sign convention. Each vector is given a positive or negative sign, depending on its direction. It is up to you to decide which direction is positive. Then simply add up the vectors. The sign of the total tells you the direction of the vector.

For example, if Sally walked 2 m west and then 5 m east, either west or east could be the positive direction. If east is chosen as the positive direction, then Sally walked −2 m east and then +5 m east. So her resultant displacement would be (−2) + 5 = +3 m, which is 3 m east.

Subtracting vectors

Vector subtraction is similar to vector addition. To find the difference between (or change in) vectors, subtract the initial vector from the final vector, remembering to apply an appropriate sign convention. The Greek delta symbol Δ, which means a difference or change, is used to indicate the resultant vector.

For example, to find the difference between a velocity of 50 $m\,s^{-1}$ south and a velocity of 20 $m\,s^{-1}$ north algebraically, subtract the initial velocity (50 $m\,s^{-1}$ south) from the final velocity (20 $m\,s^{-1}$ north). If north is taken to be the positive direction, then the resultant velocity $v = +20 - (-50) = +70\,m\,s^{-1}$, which is 70 $m\,s^{-1}$ north. This is shown graphically in Figure 2.1.3.

FIGURE 2.1.3 Vector subtraction

Linear motion

In kinematics, the words used to describe motion have very precise meanings that must be understood clearly. Distance travelled, *d*, tells us how far an object has travelled in total, but not the direction. Distance travelled is therefore a scalar.

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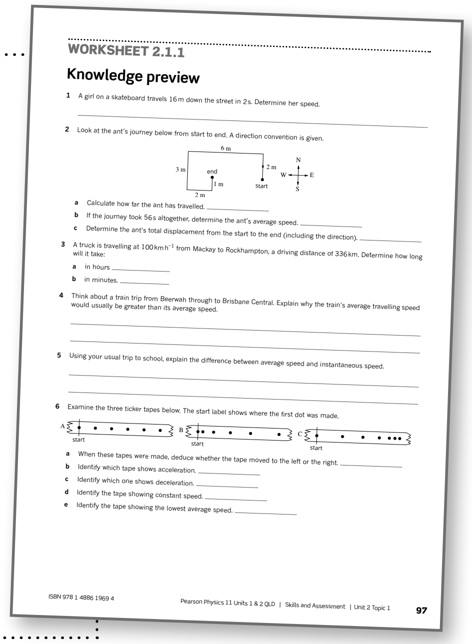
Worksheets

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. Determine 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, determine the ant's average speed.

c Determine 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. Determine 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 When these tapes were made, deduce whether the tape moved to the left or the right.

b Identify which tape shows acceleration.

c Identify which one shows deceleration.

d Identify the tape showing constant speed.

e Identify the tape showing the lowest average speed.

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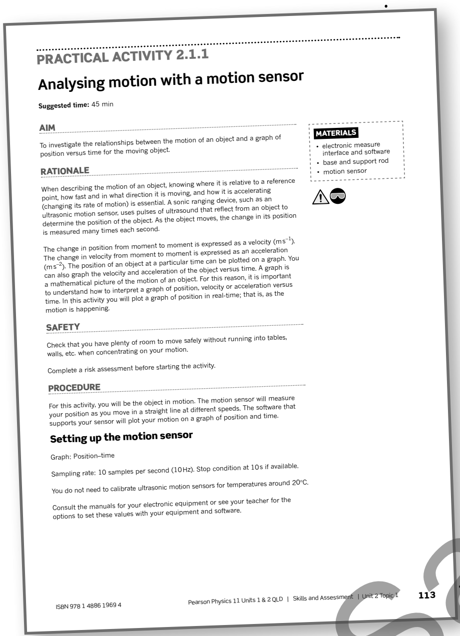
PRACTICAL ACTIVITY 2.1.1

Analysing motion with a motion sensor

Suggested time: 45 min

AIM

To investigate the relationships between the motion of an object and a graph of position versus time for the moving object.

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

RATIONALE

SAFETY

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

Setting up the motion sensor

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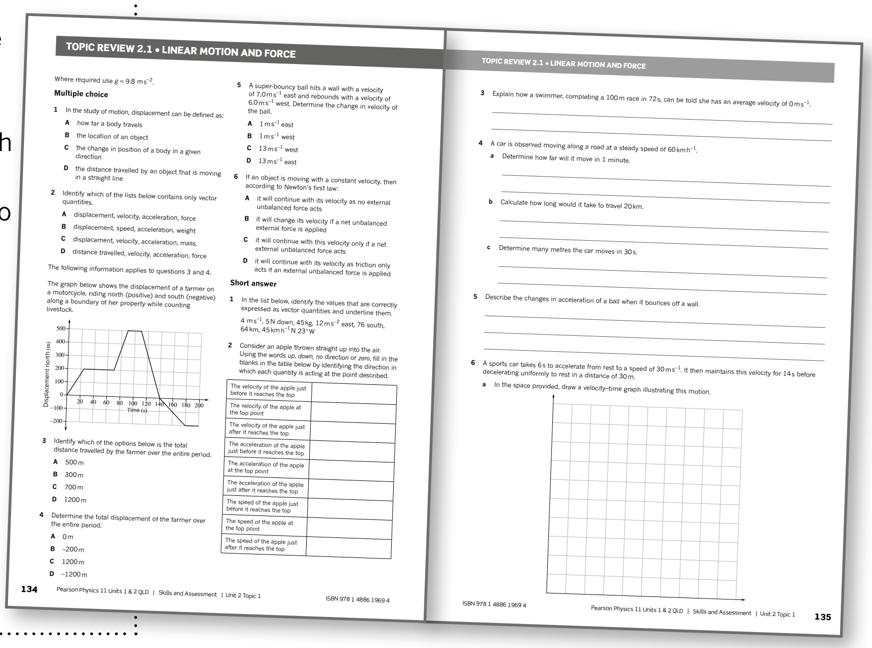
Practical activities

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

Multiple choice

Short answer

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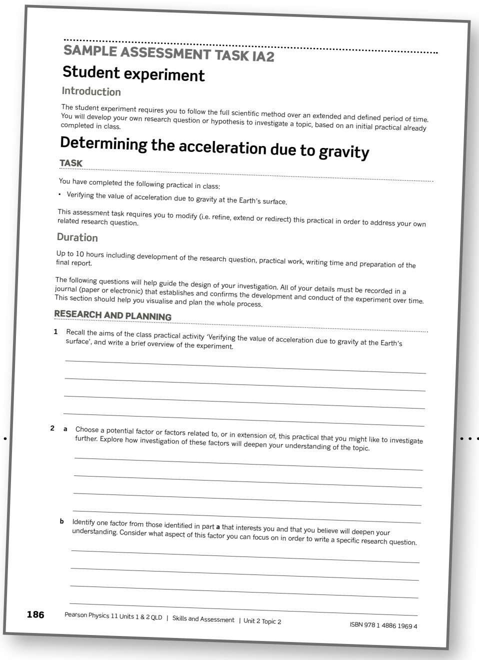
Sample assessment tasks

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 full 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:

- Verifying the value of 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 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 aims of the class practical activity 'Verifying the value of 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.

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Icons and features

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

The *Pearson Physics Skills and Assessment Book* icons in the Student Book, indicate the best time to engage with an activity for practice, application and revision.

The type of activity is indicated as follows:

Worksheet (WS) — WS 3.1.1

Topic review (TR) — TR 1.2

Mandatory practical (MP) — MP 4

Practical activity (PA) — PA 3.2.1

Sample Assessment Task (SAT) — SAT IA1

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

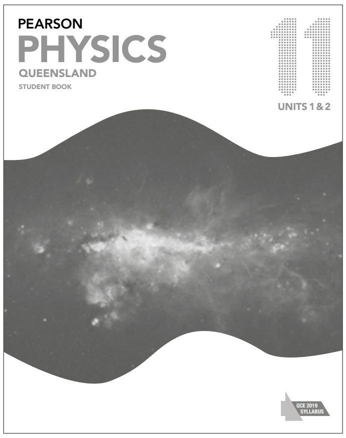
This innovative feature assists students to reflect on their learning and appears at the end of worksheets, practical activities and sample assessment tasks. It provides students with the opportunity for self-reflection and self-assessment, encouraging them to look ahead to how they can continue to improve, 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. • I can apply/teach it.	• I get it. • I can show I get it.	• I almost get it. • I might need help.	• I get some of it. • I need help.	• I don't get it. • 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.

Series overview

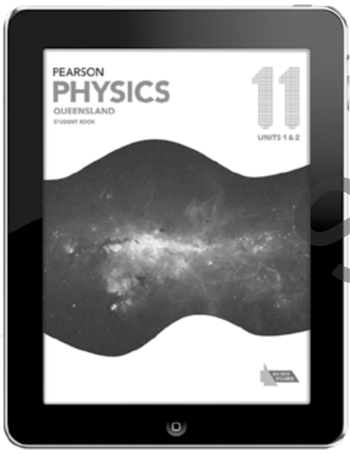


Student Book

Pearson Physics 11 Units 1 & 2 Queensland has been developed by experienced Queensland teachers to address all the requirements of the new QCE Physics 2019 Syllabus. The series features the very latest developments and applications of Physics, literacy and instructional design to ensure the content and concepts are fully accessible to all students.

Skills and Assessment Book

The *Pearson Physics 11 Skills and Assessment Book* gives students the edge in preparing for all forms of assessment. Specifically prepared to provide opportunities to consolidate, develop and apply subject matter and science inquiry skills, this resource features a toolkit, key knowledge summaries, worksheets, practical activities and guidance, assessment practice and exam-style topic review sets.



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Pearson Reader+ lets you use your Student Book online or offline, anywhere and anytime, on any device. Pearson Reader+ retains the look and integrity of the printed book.

Teacher Support

Pearson Physics 11 Units 1 & 2 Queensland Teacher Support provides:

- complete answers, fully worked solutions or suggested answers to all *Student Book and Skills and Assessment Book* tasks
- mandatory practical expected results, common mistakes, suggested answers and full safety notes and risk assessments
- teaching, learning and assessment programs

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TOPIC

1 Heating processes

- ☐ Worksheet 1.1.1 Knowledge preview—thinking about matter

KINETIC PARTICLE MODEL AND HEAT FLOW

- ☐ Worksheet 1.1.2 Heating it up
- ☐ **Mandatory practical 1 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
- ☐ **Mandatory practical 2 Determining the specific heat capacity of a substance with a focus on error propagation**

PHASE CHANGES AND SPECIFIC LATENT HEAT

- ☐ Worksheet 1.1.5 Climate in the balance—the role of oceans and air
- ☐ Practical activity 1.1.2 Latent heat of fusion

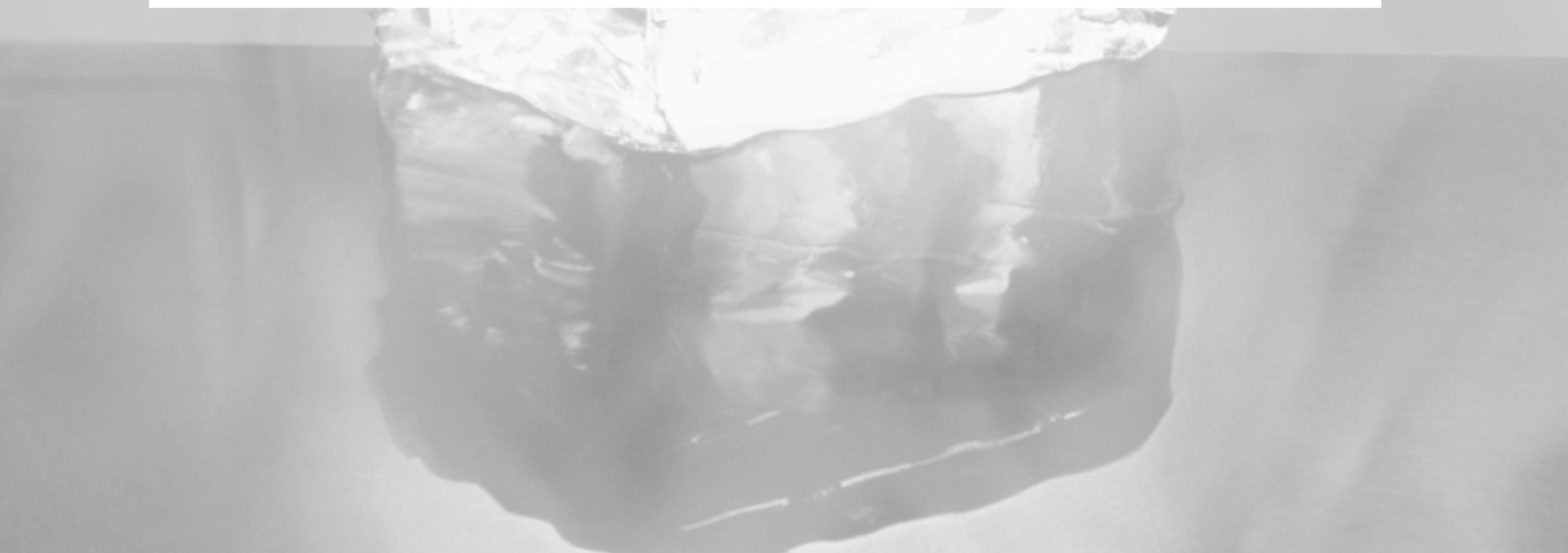
ENERGY CONSERVATION IN CALORIMETRY

- ☐ Worksheet 1.1.6 Thermal equilibrium—working with mixtures

ENERGY IN SYSTEMS—MECHANICAL WORK AND EFFICIENCY

- ☐ Practical activity 1.1.1 Energy transfer and heat

- ☐ Worksheet 1.1.7 Literacy review
- ☐ Worksheet 1.1.8 Thinking about my learning
- ☐ **Topic Review 1.1**



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Key knowledge

Kinetic particle model and heat flow

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 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. 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 AND SPECIFIC HEAT CAPACITY

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 equal to −273.15°C.

> To convert from Celsius to kelvin, add 273.15.
>
> To convert from kelvin to Celsius, subtract 273.15.

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.

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

The **kinetic theory** 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.

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}).

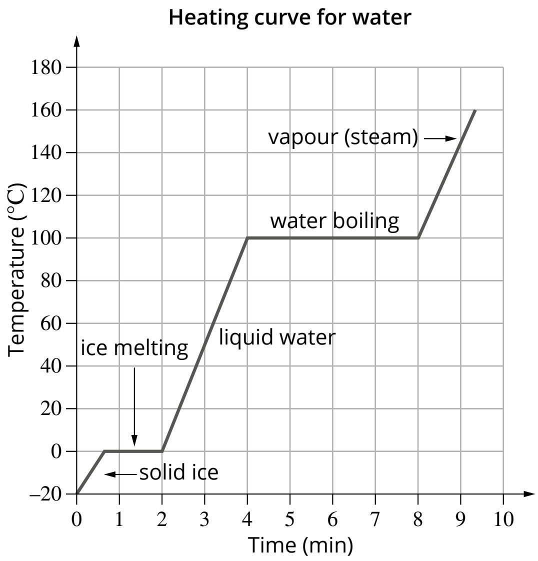

FIGURE 1.1.1 A heating curve for water, showing the constant temperatures during changes of state.

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 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	3.34×10^5	100	22.5×10^5
oxygen	–219	0.14×10^5	–183	2.2×10^5
lead	327	0.25×10^5	1750	9.0×10^5
ethanol	–114	1.05×10^5	78	8.7×10^5
silver	961	0.88×10^5	2193	23.0×10^5

ENERGY CONSERVATION IN 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).

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

 ISBN 978 1 4886 1969 4

zeroth law; when you 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.

$$Q_{\text{lost}} = Q_{\text{gained}}$$

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).

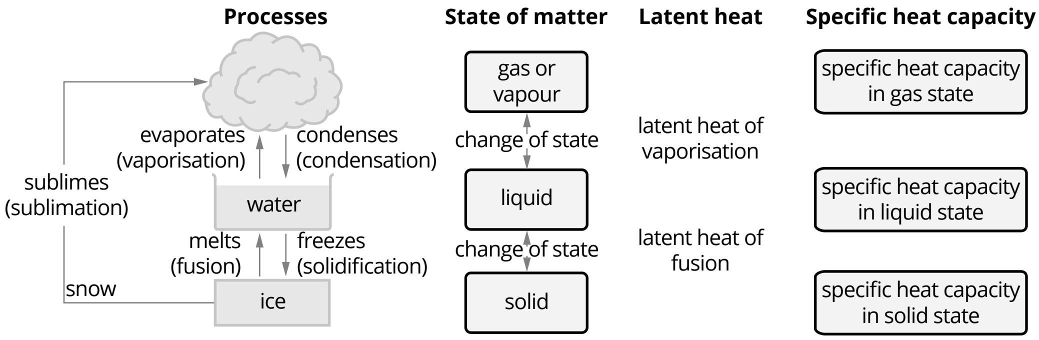

FIGURE 1.1.2 Flow diagram for solving heating and/or cooling problems involving changes of state

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

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

ENERGY IN SYSTEMS—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 (ΔU) 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, η, is the rate of useful work performed to the total energy expended or heat taken in, and is given by:

$$\eta = \frac{\text{energy output}}{\text{energy input}} \times \frac{100}{1}\ \%$$

WORKSHEET 1.1.1

Knowledge preview—thinking about matter

1 Recall the comparative wavelength of each of the following radiation types and use that information to re-order them by increasing wavelength: **green light, infrared, radio, ultraviolet, blue light, red light, X-rays, microwaves**.

2 State the temperature, in Celsius and in Fahrenheit, of melting ice.

3 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	

4 Of the three methods of heat transfer (conduction, convection and radiation), recall the one that describes each situation in the table below.

Situation	Method
Lighter-coloured clothes keep you cooler in summer.	
A drinks cooler is made from polystyrene foam.	
The air near the ceiling of a room is warmer than near the floor.	
A saucepan has a plastic handle.	

5 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.

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

7 Heat transfer can occur by conduction, convection or radiation. Identify the main method of heat transfer in each situation below.

a You walk in bare feet on the sand at a beach.

b A wall feels warm when the sun is shining on it.

c Water is boiled in an electric kettle.

d You feel cold when diving into the ocean.

8 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.

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WORKSHEET 1.1.2

Heating it up

Our understanding of the behaviour of matter depends on what is called the kinetic particle model.

1 Complete the table for the features of the kinetic model that correctly describe water in the three common states of matter.

State of matter	Ice	Water	Water vapour
distance between particles (large or small)			
attraction between particles (negligible or strong)			
free movement of particles (no or yes)			

2 State which substances, according to the kinetic particle model, are made of particles.

3 According to the kinetic particle model, describe the behaviour of particles in gases.

4 Try the following activity and observe the movement of the different coloured objects as the water comes to the boil. Watch the coloured objects as they move around.

You'll need:

- clear beaker or glass-lidded saucepan
- quantity of beads or peas of one colour
- 3–4 beads of a different colour (or corn kernels)
- heat source such as a heat pad or hotplate.

Do this:

- Partly fill the saucepan or container with water and drop in a good quantity of beads or peas.
- Add the different-coloured beads or corn kernels. These will be what you will track.
- Bring the water to the boil.

a Describe the motion of the coloured objects in the container of water.

b Describe any changes in the tracks of the beads that you recorded as the water gained energy and came closer to boiling.

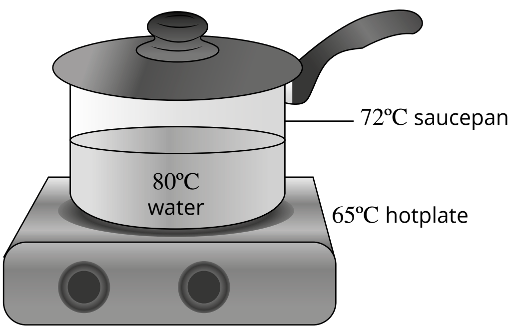
c Explain what made the beads move. Consider the energy changes in the water in your answer.

d The internal energy of the water is the sum of the energies of all of its particles. State the change in the total internal energy of the water as it is heated as an equation.

5 The diagram below shows a hotplate, saucepan and water some time after the hotplate was turned off. The temperatures of each of the materials are shown.

a Show the direction in which heat energy will move by drawing one or more arrows.

b Explain why you think heat energy will move in this direction.



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

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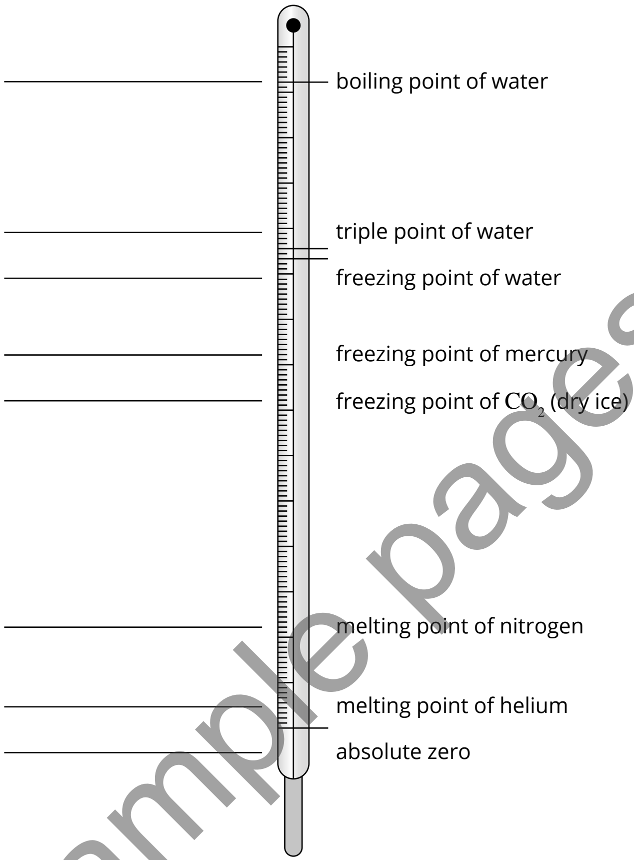
WORKSHEET 1.1.3

Temperature scales

The diagram below shows a temperature scale with several key points labelled. Assume that standard sea-level pressure applies.

1 Alongside each labelled key point, write the corresponding temperature in kelvin (K) and the equivalent temperature in degrees Celsius (°C). You may need to do a little research to find some of the temperatures.



2 The triple point of water has particular significance in determining one of the temperature scales. Define the triple point of water and explain its significance in determining a temperature scale.

3 A temperature of –100 K has no meaning. Explain why this is the case.

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

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WORKSHEET 1.1.4

Specific heat capacity

A student performed an experiment to measure the specific heat capacity of lead. A 2.5 cm cube of lead with a density of 11.34 g cm^{-3} was placed in a beaker of boiling water and left to come to thermal equilibrium at 98.6°C. The temperature was measured using a digital thermometer.

1 The student was expecting the temperature of the boiling water to be 100°C. Explain why the thermometer did not reach 100°C.

The student also had a polystyrene calorimeter holding 100 mL of tap water at a temperature of 20.5°C. The lead cube was removed from the boiling water with tongs and quickly placed in the calorimeter. The lid was returned to the calorimeter, which was then gently shaken about for 3 or 4 minutes until its temperature stabilised at 24.0°C.

2 Complete the specific heat calculation below. (c_{water} = 4.2 kJ kg^{-1} K^{-1})

$$\Delta Q_{lead} + \Delta Q_{water} = 0$$
$$m_{lead}c_{lead}\Delta T_{lead} + m_{water}c_{water}\Delta T_{water} = 0$$

3 The answer obtained is lower than the accepted value of 0.1256 kJ kg^{-1} K^{-1}. Explain why this is the case.

4 The student had heard that the rate of cooling of an object depended on its surface area. She thought that she could try to verify this by means of a similar experiment. She asked some of the metalwork students to take some of the same-sized cubes of lead and hammer them into bricks, cylinders and a sphere. They returned with the objects listed in the table below. Calculate the surface area of each of these objects. Use the formulae given on the left.

sphere: $SA = \pi d^2$
brick: $SA = 2(hl + lw + hw)$
cylinder: $SA = \pi d\left(h + \frac{1}{2}d\right)$

Object	Dimensions (cm)	Surface area (cm^2)	Time (s)	
sphere	$d = 2.3$		25.2	
brick 1	3.0 × 3.0 × 0.7		15.2	
brick 2	4.1 × 3.1 × 0.5		11.8	
cylinder 1	$h = 2.0$, $d = 2.0$		21.8	
cylinder 2	$h = 1.1$, $d = 2.7$		19.0	

She then repeated the experiment above with the same initial conditions. However, this time she placed a small perforated platform in the bottom of the calorimeter so that the water could circulate easily. The time it took to raise the temperature of the water by 1.0°C was recorded. These times appear in the table above.

5 If the rate of cooling of the lead is proportional to the surface area, determine the relationship between the warming time (t) and the surface area (SA). Describe what is significant about the product $t \times SA$. Use the last column of the table to test your hypothesis.

6 State, in your own words, whether the data confirms that the rate of cooling is proportional to the surface area.

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

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PRACTICAL ACTIVITY 1.1.1

Energy transfer and heat

Suggested duration: 20 minutes

AIM

To investigate the transfer of mechanical energy and its effect on temperature.

RATIONALE

The kinetic particle model proposes that all matter is made of atoms or molecules (particles) that are in constant motion. Thermal energy is the internal (total kinetic and potential energy of the particles within a substance) energy 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 then 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. For example, if an object has become hotter, then it has gained heat energy. Conversely, if the object has become colder, then it has lost energy.

Joule’s ‘mechanical equivalent of heat’ experiment quantified the relationship between work and temperature change.

MATERIALS

- digital thermometer and stopwatch or temperature sensor and data-collection system (recommended)
- small can (a used fruit or bean can with the top removed and then rinsed is ideal)
- water at room temperature
- approximately 50–60 cm of rough twine, bailing twine, string or similar
- insulating gloves
- insulating mat or heat mat

SAFETY

Be careful of sharp edges. Use a can with a rolled edge or one that retains a rolled edge when the top is removed.

Avoid slipping on any spilled water. Mop it up as soon as possible.

Complete a risk assessment before starting the activity.

PROCEDURE

This activity requires two people working together for the practical elements and a third as the data collector.

1 If using a temperature sensor, set up the data-collection system as recommended by the manufacturer. Set up a graph of temperature versus time. Record the manufacturer’s estimate of the uncertainty of the thermometer or sensor in the Analysing section.

2 Fill the can about two-thirds to three-quarters full of water. Wrap the twine right around the can once and leave both ends free to move. The ends should be roughly equal in length so that they can be easily held on to.

3 Sit the temperature sensor or digital thermometer in the can and sit the can on the insulating mat. Allow it to rest for a while until the water is at room temperature. Let the can, water and sensor rest until they are at roughly room temperature.

Explain why it’s important to allow the equipment to come to room temperature.

The next step requires co-operation between all prac partners. You may want to practice or carry out the activity more than once.

4 Each person in the group should now take their assigned role:

A Put on the insulating gloves and steady both can and temperature sensor so they aren’t easily moved but the twine is free to move.

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B Take both ends of the twine, one in each hand ready to pull then backwards and forwards as quickly as possible. The looped twine should move backwards and forwards around the can.

C Check that the stopwatch is zeroed or the data-collection system is ready to start. Note and record the starting temperature.

5 Person C should start recording. Person B then, as quickly as reasonably possible without spilling the water, pulls the twine backwards and forwards around the can. Person A should carefully steady the can and support the temperature sensor, keeping it in the water.

6 Keep the twine moving for around 30–40 s. Stop moving the twine and record the time taken and the final temperature in the spaces provided.

7 Calculate the rate of temperature change. Calculate the percentage uncertainty in the final result.

8 You may want swap around and repeat the experiment. Once done, clean up, ensuring any spilt water is mopped up and all surfaces left dry.

ANALYSING

uncertainty in temperature measurement: ± ______ °C

uncertainty in time measurement: ± ______ s

initial temperature: ______ ± ______ °C

final temperature: ______ ± ______ °C

change in temperature, ΔT: ______ ± ______ °C

mass of can: ______ ± ______ kg

mass of water and can: ______ ± ______ kg

mass of water, m: ______ ± ______ kg

energy transferred, $W = \Delta U = cm\Delta T$ = ______ J ± ______ %

CONCLUSIONS

1 Comment on your results. Discuss whether your results support the transfer of energy and describe the process by which energy is being transferred to the water.

2 Evaluate your methods of measurement. Discuss changes to the method that could improve the reliability of the result.

3 Conduct an appraisal of the method, including the roles of the insulating gloves and heat pad.

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

PRACTICAL ACTIVITY 1.1.2

Latent heat of fusion

Suggested duration: 40 minutes

AIM

To determine 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:

ΔQ is the change in energy (J)

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

L_{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. Like the specific heat of a substance, the latent heat of fusion depends on the type of substance and its ability to absorb heat while it changes phase.

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)

SAFETY

- 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 Analysing 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 Analysing 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 Analysing section. Include an estimate of the uncertainty.

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6 Dry off 3 or 4 ice cubes with the paper towel and then place the ice cubes into the cup, stirring slowly until the ice completely melts. Continue stirring for an additional minute to ensure that the water has reached equilibrium. Record the final temperature of the water in the cup in the table.

7 Remove the thermometer or temperature sensor from the calorimetry cup and use the balance to measure the total mass of the cup, initial water and melted ice. Record this value in the table along with the uncertainty in each measurement.

ANALYSING

Item	Value	Uncertainty
mass of calorimetry cup	kg	± kg
mass of calorimeter and initial water	kg	± kg
mass of initial water, m_{water}	kg	± kg
mass of cup, initial water and melted ice	kg	± kg
mass of ice, m_{ice}	kg	± kg
initial temperature of water in the cup, $T_{initial}$	°C	± °C
final temperature of water in the cup, T_{final}	°C	± °C
initial temperature of ice	°C	± °C
temperature of melted ice	°C	± °C
temperature change of water	°C	± °C
temperature change of melted ice	°C	± °C

1 Identify the sign (positive or negative) of the temperature change calculated. Identify what the sign signifies.

2 Assuming that the specific heat capacity of water, c, is $4200\,J\,kg^{-1}\,K^{-1}$, use the values from the above table to find the heat energy transferred from the water initially in the cup.

3 Using the values calculated in the table, determine how much of the heat transferred out of the water in the cup went into warming the melted ice to the final temperature.

4 If the energy needed to warm the melted ice does not account for all the heat transferred from the water, deduce where the additional heat went. Using the results of your previous calculations, determine the amount of additional energy lost by the water that did not go into warming the melted ice.

5 Assume instead that all of the remaining energy can be attributed to the melting ice. Using the mass of the ice, calculate the latent heat of fusion of water including the calculated uncertainty in the value.

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6 If the theoretical value for the latent heat of fusion for water is $3.34 \times 10^5\,\mathrm{J\,kg^{-1}}$, calculate the percentage difference between the experimentally determined value and the theoretical value? Use the following formula:

$$\text{percentage difference} = \frac{\text{theoretical value} - \text{experimental value}}{\text{theoretical value}} \times 100\%$$

CONCLUSIONS

1 Compare the experimentally determined value for the latent heat of fusion for water with the accepted theoretical value. Comment on the reliability of your answer with reference to the calculated percentage difference and your calculated uncertainty in the final value.

EVALUATION

1 Explain why the ice cubes were dried before you placed them in the beaker.

2 Identify the source of the heat energy that melted the ice.

3 Discuss assumptions were made in this experiment about the initial temperature of the ice.

4 Identify other assumptions that were made about energy transfer in conducting this experiment and assess their likely effect on your final result.

5 Keeping these assumptions in mind discuss improvements to the procedure which could lead to a more reliable experimental result.

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

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MANDATORY PRACTICAL 1

Finding the relationship between temperature and heat

AIM

To examine the relationship between temperature and heat

RATIONALE

Heat is defined as energy that is transferred between two or more objects by way of thermal interaction (conduction, radiation, or convection). The heat energy in an object is a representation of the total kinetic energy of all the particles that make up the object.

Temperature is a physical measurement of how 'hot' or 'cold' a substance is based on the average kinetic energy of particles in the substance. The amount of heat energy in an object is related to temperature, but temperature by itself is not a measure of the thermal energy (heat) in an object. Identical thermometers in two pots of water on a hotplate will show different temperatures even if the pots have been on the hotplate for the same time if the amount of water in each pot is different

Suggested duration: 45 minutes

MATERIALS

- digital thermometer or temperature sensor and data-collection system (use 2 or a quad temperature sensor for concurrent measurement)
- electronic balance (1 per classroom)
- 2 × 100 mL beakers such as Pyrex or calorimeter
- hotplate or heating coil
- 250 mL water
- stopwatch (not required with data-collection system)
- heat glove or oven mitt
- retort stand and clamp (two required if measuring concurrently)

SAFETY

- Do not directly touch hot items like the hotplate, beaker and water.
- Keep the boiling water away from other electrical equipment such as computers.
- Wear a lab coat, goggles and gloves as recommended by your teacher.

Complete a risk assessment before starting the activity.

PROCEDURE

1 Using the electronic balance, measure and record the mass of each of the beakers in the space provided in the Analysing section. Turn the hotplate on so it is preheated. If the plate has a temperature control set it to a maximum of around 80°C. There's no need for higher temperatures in this experiment.

2 Fill one beaker with around 40 mL of water and the other with 60 mL.

3 Measure and record the mass of each of the beakers, including the water.

4 Carefully place the beaker on the hotplate. Use the retort stand and clamp to secure the digital thermometer or temperature sensor so that the tip of the thermometer can be submerged in the liquid without touching the wall or bottom of the beaker containing 40 mL of water.

5 Using the options in your data-collection system, or using a stopwatch, note and record the temperature of the water at 30 s intervals in Table 1 of the Analysing section for a total time of 5 minutes. You may want to print out the data from your data-collection system and paste it over the table if the option is available.

Note: *if you have two thermometers or temperature sensors, you can save time by recording both beakers concurrently.*

6 Stop recording data and turn off the hotplate after the 5 minute heating period.

7 Using the heat glove or oven mitt, carefully remove the first beaker and repeat steps 1 and 2 for the beaker containing 60 mL of water. Record your data in Table 1.

ANALYSING

List the variables in this experiment:

Independent: ______________________________

Dependent: ______________________________

Controlled: ______________________________

Mass of beaker in test 1 ________ g

Mass of beaker and water in test 1 ________ g

Mass of beaker in test 2 ________ g

Mass of beaker and water in test 2 ________ g

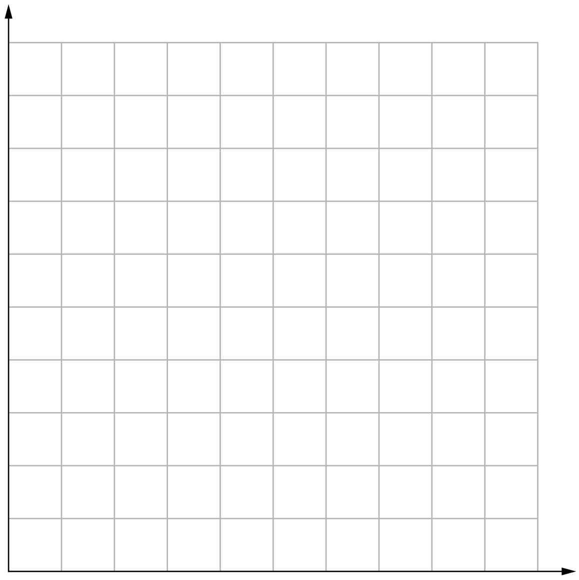
TABLE 1 Time for heating

Time (s)	Temperature 1 (°C)	Temperature 2 (°C)
0		
30		
60		
90		
120		
150		
180		
210		
240		
270		
300		
330		
360		
390		

1 Calculate the mass of the water for each test.

____

2 Plot the data for each test on the same set of axes in the graph space below, with time on the horizontal axis and temperature on the vertical axis. Label the axes, include units and add a title for your graph. If you're using a data-collection system you may prefer to print out your graph and stick it in the space provided.



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3 Draw a line of best fit for each graph and calculate the gradient for each line.

4 Assess how the gradient and temperature change for test 1 (40 mL of water) compares with test 2 (60 mL of water).

5 Considering your answer to the previous question, explain why the final temperature of test 1 is higher than that for test 2.

CONCLUSIONS

1 The aim of the experiment was to determine the relationship between temperature and heat. Summarise your findings including the relationship between time and temperature for each of the tests.

2 Considering your analysis and conclusion, appraise the experimental method you followed as a means of determining the relationship between heating time and temperature of the water.

3 Devise an alternative method by which the experiment could be improved.

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

WORKSHEET 1.2.5

Literacy review—the terminology of ionising radiation

Complete the following table by defining each term, taking care to clearly distinguish each term from similar-sounding terms. You will find similar-sounding terms grouped together rather than being listed alphabetically.

Term	Definition
alpha particle	
beta-negative particle	
gamma ray	
decay series	
electron gun	
energy levels of atoms	
fissile	
fission	
fusion	
half-life	
atomic number	
mass number	
nucleons	
neutron	
neutrino	
antineutrino	
nuclide	
thermal neutron	

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