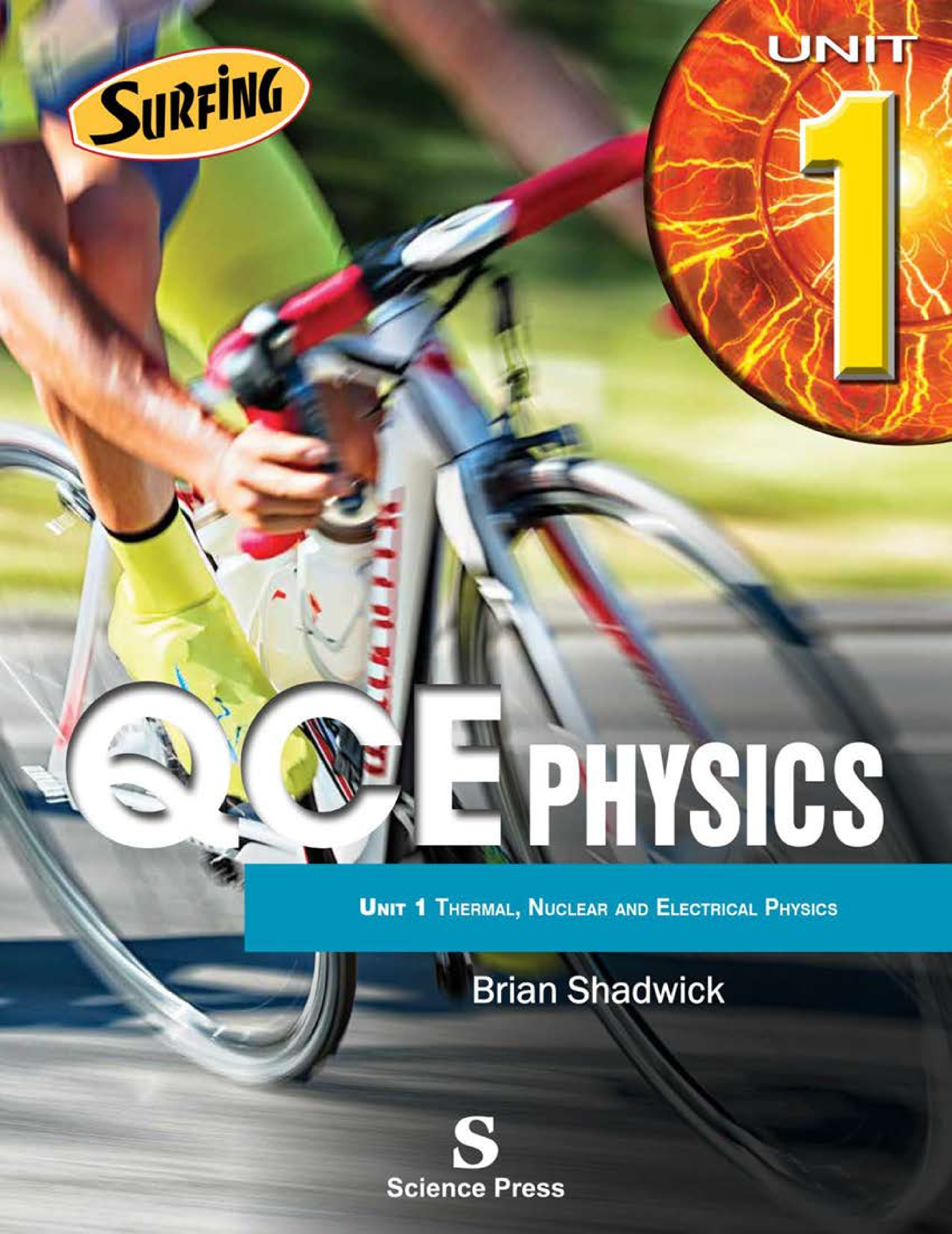

SURFING

UNIT 1

QCE PHYSICS

UNIT 1 THERMAL, NUCLEAR AND ELECTRICAL PHYSICS

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Science Press

First published 2019

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Contents

Topic 1 Heating Processes

Use $T_K = T_C + 273$ to convert temperature measurements between Celsius and Kelvin.

Describe the kinetic particle model of matter.

Explain heat transfers in terms of conduction, convection and radiation.

Conduct an experiment that obtains data to be plotted on a scatter graph (with correct title and symbols, units and labels on the axes), analysed by calculating the equation of a linear trend line, interpreted to draw a conclusion, and reported on using scientific conventions and language.

Use digital and other measuring devices to collect data, ensuring measurements are recorded using the correct symbol, SI unit, number of significant figures and associated measurement uncertainty (absolute and percentage).

Define and distinguish between thermal energy, temperature, kinetic energy, heat and internal energy.

Define thermal equilibrium in terms of the temperature and average kinetic energy of the particles in each of the systems.

Define specific heat capacity and the concept of proportionality.

Solve problems involving specific heat capacity.

Conduct an experiment that determines the specific heat capacity of a substance, ensuring that measurement uncertainties associated with mass and temperature are propagated. Where the mean is calculated (in this, and future experiments), determine the percentage and/or absolute uncertainty of the mean.

Explain why the temperature of the system remains the same during the process of state change; explain it in terms of the internal energy of a system and the kinetic particle model of matter.

Explain that a change in temperature is due to the addition or removal of energy from a system (without phase change).

Interpret tabulated and graphical data of heat added to a substance and its subsequent temperature change (without phase change).

Define specific latent heat.

Solve problems involving specific latent heat.

Explain that energy transfers and transformations in mechanical systems always result in some heat loss to the environment, so that the amount of usable energy is reduced.

Define efficiency.

Solve problems involving finding the efficiency of heat transfers.

Explain the process in which thermal energy is transferred between two systems until thermal equilibrium is achieved, and recognise this as the Zeroth law of thermodynamics.

Solve problems involving specific heat capacity, specific latent heat and thermal equilibrium.

SCIENCE AS A HUMAN ENDEAVOUR

The Human Endeavour subject matter will not be assessed in the external examination, but could be used in the development of claims and research questions for a research investigation. The material contained within the book should be considered only as a start for any research task you undertake in these areas.

SCIENCE AS A HUMAN ENDEAVOUR:
You could explore the development of temperature scales, e.g. Fahrenheit, Celsius and Kelvin.

SCIENCE AS A HUMAN ENDEAVOUR:
You could use the concepts of energy transfers and efficiency to consider the economic and ethical implications of this science on the choice of solar panel, building design, or flooring insulation.

SCIENCE AS A HUMAN ENDEAVOUR:
Energy security and sustainability – emerging energy sources: The science of heating processes is of key importance to the development of efficient and cost effective technologies that use sustainable and renewable energy sources.

SCIENCE AS A HUMAN ENDEAVOUR:
Energy balance of Earth: Predicting global temperatures and human induced climate change is greatly aided by new technologies and an understanding of heating processes.

SCIENCE AS A HUMAN ENDEAVOUR:
Development of thermodynamics: The need to increase the efficiency of early steam engines led to further technological advancements (e.g. the internal combustion engine) and scientific advancements (e.g. an understanding of, and mathematical articulation of, the relationship between heating processes and mechanical work).

Topic 2 Ionising Radiation and Nuclear Reactions

Describe the nuclear model of the atom characterised by a small nucleus surrounded by electrons.

Explain why protons in the nucleus repel each other.

Define the strong nuclear force.

Explain the stability of a nuclide in terms of the operation of the strong nuclear force over very short distances, electrostatic repulsion, and the relative number of protons and neutrons in the nucleus.

Explain natural radioactive decay in terms of stability.

Define alpha radiation, beta positive radiation, beta negative radiation and gamma radiation.

Describe alpha, beta positive, beta negative and gamma radiation, including the properties of penetrating ability, charge, mass and ionisation ability.

Explain how an excess of protons, neutrons or mass in a nucleus can result in alpha, beta positive and beta negative decay.

Solve problems involving balancing nuclear equations.

Represent spontaneous alpha, beta positive and beta negative decay using decay using decay equations,

e.g. ${}^{238}_{92}\mathrm{U} \rightarrow {}^{234}_{90}\mathrm{Th} + {}^{4}_{2}\mathrm{U} + \gamma$

${}^{60}_{27}\mathrm{Co} \rightarrow {}^{60}_{28}\mathrm{Ni} + 10{}^{-1}_{0}\mathrm{e} + v_{\mathrm{n}} + \gamma$

${}^{102}_{50}\mathrm{Sn} \rightarrow {}^{102}_{49}\mathrm{Ni} + 10{}^{-1}_{0}\mathrm{e} + v_{\mathrm{n}} + \gamma$

Explain how a radionuclide will, through a series of spontaneous decays, become a stable nuclide.

Define half-life.

Solve radioactive decay problems involving whole numbers of half-lives.

Describe energy in terms of electron volts (eV) and joules (J).

Define mass defect, binding energy and binding energy per nucleon.

Define nuclear fission.

Define nuclear fusion.

Explain that more energy is released per nucleon in nuclear fusion than in nuclear fission because a greater percentage of the mass is transformed into energy.

Explain a neutron induced nuclear fission reaction, including references to extra neutrons produced from many of these reactions.

Define artificial transmutation.

Distinguish between artificial transmutations and natural radioactive decay.

Explain a fission chain reaction.

Recall Einstein’s mass-energy equivalence relationship.

Solve problems involving Einstein’s mass-energy equivalence relationship.

Research nuclear safety, considering the suitability of using the sources of information in terms of their credibility.

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SCIENCE AS A HUMAN ENDEAVOUR:
You could know that the development of models of the atom often required a wide range of evidence from multiple individuals and across disciplines.

SCIENCE AS A HUMAN ENDEAVOUR:
You could explore how advances in scientists’ understanding of the properties of nuclear radiation have influenced medical treatment and imaging.

SCIENCE AS A HUMAN ENDEAVOUR:
You could explore how the use of scientific knowledge to predict beneficial and/or harmful or unintended consequences, e.g. choosing appropriate radioisotopes for medical imaging, carefully storing nuclear waste.

SCIENCE AS A HUMAN ENDEAVOUR:
You could explore how scientific knowledge of radioactive decay can enable scientists to offer valid explanations and make reliable predictions in radiometric dating of materials.

You could explore the possibility of nuclear fission based power production replacing fossil fuels to generate electricity.

SCIENCE AS A HUMAN ENDEAVOUR:
Radioisotopes and radiometric dating: An understanding of nuclear processes has led to the use of new analytical tools (e.g. radiometric dating) to understand past events.

Harnessing nuclear power: 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.

SCIENCE AS A HUMAN ENDEAVOUR:
Nuclear fusion in stars: Energy production in stars was attributed to gravity until the knowledge of nuclear reactions led to the understanding that energy production in stars is due to nuclear fusion.

Topic 3 Electrical Circuits

Recall that electric charge can be positive or negative.

Recall the law of conservation of electric charge.

Define electric current in a circuit.

Recall that electric current is carried by discrete electric charge carriers.

Solve problems involving electric current, electric charge and time.

Define electrical potential difference in a circuit.

Recall that the energy available to electric charges moving in an electrical circuit is measured using electrical potential difference.

Explain why electric charge separation produces an electrical potential difference (no calculations required to demonstrate this).

Solve problems involving electrical potential difference.

Define resistance.

Compare and contrast ohmic and non-ohmic resistors.

Mandatory practical: Conduct an experiment that measures electric current through, and electrical potential difference across an ohmic resistor in order to find resistance.

Interpret graphical representations of electrical potential difference versus electric current data to find resistance using the gradient and its uncertainty.

Recall resistor, voltmeter, ammeter, cell, battery, switch and bulb circuit diagram symbols.

Recognise series and parallel connections of components in electrical circuits.

Design simple series, parallel and series/parallel circuits.

Explain that the energy inputs in a circuit equal the sum of energy outputs from loads in the circuit and recognise this as Kirchhoff's voltage law.

Recall that electric charge is conserved at all points in an electrical circuit and recognise this as Kirchhoff's current law.

Recall and solve problems using Ohm's law.
Interpret graphical representations of electrical potential difference versus electric current data to find resistance using the gradient and its uncertainty.

Define power dissipation over resistors in a circuit.

Solve problems involving power.

Solve problems involving electrical potential difference, electric current, resistance and power.

SCIENCE AS A HUMAN ENDEAVOUR

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SCIENCE AS A HUMAN ENDEAVOUR:
You could explore how ‘conventional current’ has been accepted as the international convention; consistent use now ensures clear communication of ideas and findings across the globe.

SCIENCE AS A HUMAN ENDEAVOUR:
Increases in the use of household electrical devices during extreme weather (heat in Australian summers or cold in European winters) creates supply problems causing brownouts and power failures.

SCIENCE AS A HUMAN ENDEAVOUR:
Electrical energy in the home: Developing new household electrical devices, improving the efficiency of existing devices and ensuring consistency of electrical standards all require international cooperation between scientists, engineers and manufacturers.

SCIENCE AS A HUMAN ENDEAVOUR:
Powering the digital age: Computers, smart phones and the internet have changed the world, but none would be possible without a reliable supply of electricity.

SCIENCE AS A HUMAN ENDEAVOUR:
Electric lighting: Concerns about sustainable energy usage and global warming have led to international research and development to improve the energy efficiency of electric lighting.

Introduction

This book covers the Physics content specified in the Queensland Certificate of Education Physics Syllabus. Sample data has been included for suggested experiments to give you practice to reinforce practical work in class.

Each book in the *Surfing* series contains a summary, with occasional more detailed sections, of all the mandatory parts of the syllabus, along with questions and answers.

All types of questions – multiple choice, short response, structured response and free response – are provided. Questions are written in exam style so that you will become familiar with the concepts of the topic and answering questions in the required way.

Answers to all questions are included.

A topic test at the end of each topic contains an extensive set of summary questions. These cover every aspect of the topic, and are useful for revision and exam practice.

Words To Watch

account, account for State reasons for, report on, give an account of, narrate a series of events or transactions.

analyse Interpret data to reach conclusions.

annotate Add brief notes to a diagram or graph.

apply Put to use in a particular situation.

assess Make a judgement about the value of something.

calculate Find a numerical answer.

clarify Make clear or plain.

classify Arrange into classes, groups or categories.

comment Give a judgement based on a given statement or result of a calculation.

compare Estimate, measure or note how things are similar or different.

construct Represent or develop in graphical form.

contrast Show how things are different or opposite.

create Originate or bring into existence.

deduce Reach a conclusion from given information.

define Give the precise meaning of a word, phrase or physical quantity.

demonstrate Show by example.

derive Manipulate a mathematical relationship(s) to give a new equation or relationship.

describe Give a detailed account.

design Produce a plan, simulation or model.

determine Find the only possible answer.

discuss Talk or write about a topic, taking into account different issues or ideas.

distinguish Give differences between two or more different items.

draw Represent by means of pencil lines.

estimate Find an approximate value for an unknown quantity.

evaluate Assess the implications and limitations.

examine Inquire into.

explain Make something clear or easy to understand.

extract Choose relevant and/or appropriate details.

extrapolate Infer from what is known.

hypothesise Suggest an explanation for a group of facts or phenomena.

identify Recognise and name.

interpret Draw meaning from.

investigate Plan, inquire into and draw conclusions about.

justify Support an argument or conclusion.

label Add labels to a diagram.

list Give a sequence of names or other brief answers.

measure Find a value for a quantity.

outline Give a brief account or summary.

plan Use strategies to develop a series of steps or processes.

predict Give an expected result.

propose Put forward a plan or suggestion for consideration or action.

recall Present remembered ideas, facts or experiences.

relate Tell or report about happenings, events or circumstances.

represent Use words, images or symbols to convey meaning.

select Choose in preference to another or others.

sequence Arrange in order.

show Give the steps in a calculation or derivation.

sketch Make a quick, rough drawing of something.

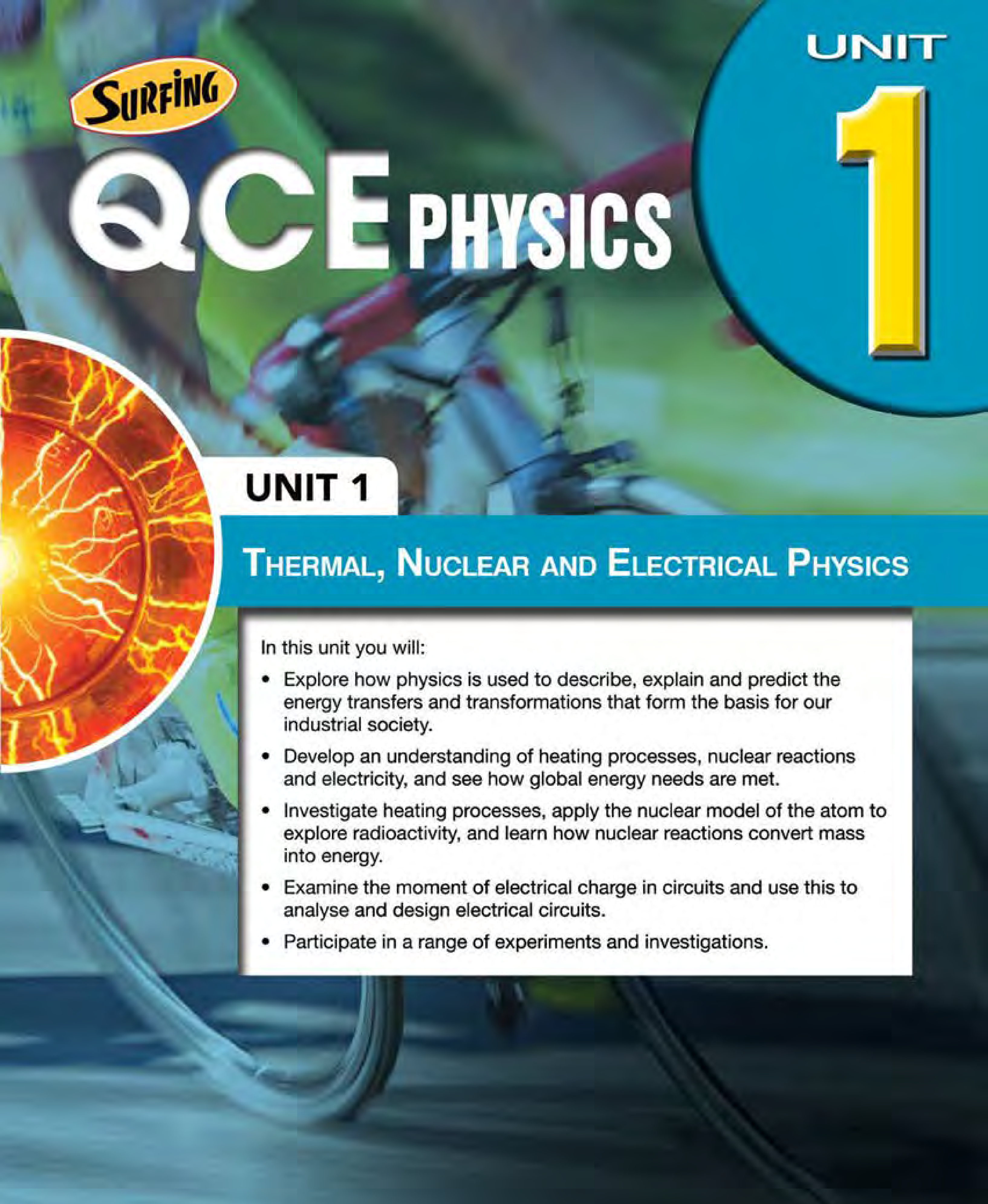
solve Work out the answer to a problem.

state Give a specific name, value or other brief answer.

suggest Put forward an idea for consideration.

summarise Give a brief statement of the main points.

synthesise Combine various elements to make a whole.



SURFING QCE PHYSICS

UNIT 1

UNIT 1

THERMAL, NUCLEAR AND ELECTRICAL PHYSICS

In this unit you will:

- Explore how physics is used to describe, explain and predict the energy transfers and transformations that form the basis for our industrial society.
- Develop an understanding of heating processes, nuclear reactions and electricity, and see how global energy needs are met.
- Investigate heating processes, apply the nuclear model of the atom to explore radioactivity, and learn how nuclear reactions convert mass into energy.
- Examine the moment of electrical charge in circuits and use this to analyse and design electrical circuits.
- Participate in a range of experiments and investigations.

SURFING QCE PHYSICS

UNIT 1

TOPIC 1

HEATING PROCESSES

In this topic you will:

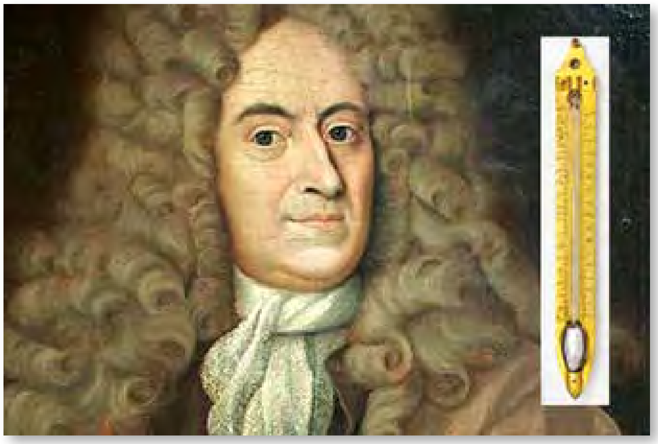
- Learn about the kinetic particle model.
- Investigate temperature and specific heat capacity.
- Conduct experiments involving temperature and measuring devices to obtain data.
- Explore phase changes and specific latent heat.
- Solve problems involving energy conservation in calorimetry.
- Develop an understanding of energy in systems, mechanical work and efficiency of heat transfers.

Use $T_K = T_C + 273$ to convert temperature measurements between Celsius and Kelvin.

1 Major Temperature Scales

In 1597, the Italian physicist Galileo Galilei (1564-1642) invented his ‘thermoscope’, a device to indicate that the temperature of something was changing. He had noticed that the volume of water in a tube expanded and contracted with temperature change and used this idea in his device. The thermoscope had no measurements on it, it only indicated change.

In 1724 Dutch-German-Polish physicist Daniel Fahrenheit (1686-1736) developed a mercury thermoscope and in 1724 added to it the temperature scale we know as the Fahrenheit scale (not so often used these days). On this scale Fahrenheit set the freezing point of water at 32°F and the body temperature of a healthy male at 98.6°F. From this he extrapolated the boiling point of water to 212°F.


Daniel Fahrenheit (1686-1736).

In 1742 Anders Celsius developed his ‘centigrade’ temperature scale based on the freezing point of water at 0° and the boiling point at 100°C. This scale was renamed the Celsius scale in his honour following his death in 1744.

In 1854, William Thomson, the first Baron Kelvin, an Irish-Scottish physicist (1824-1907), produced another temperature scale that was based on the developing science of the behaviour of gases as temperature and pressure changed. Thomson knew from work by gas chemists that the volume of a gas at constant pressure was *directly proportional* to its temperature, and he used this linear relationship to calculate the temperature where pressure would equal zero. The only fixed reference point on the Kelvin scale was absolute zero, which represented the temperature where no kinetic energy remained in any substance. Based on the developing mathematics of the gas laws, on Kelvin’s scale, every degree rise in temperature represented an equal gain in energy.

The absolute zero on the Kelvin scale, equivalent to −273°C represents the temperature at which all molecular motion ceases. The Kelvin scale is more widely used by scientists than the Celsius scale, because it is based on an absolute value which has specific meaning in particle physics. It does not require use of negative numbers, which simplifies calculations.

The equations we use to convert between these scales are given below.

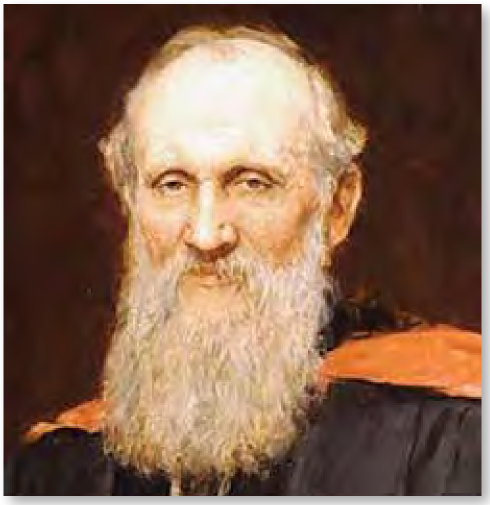
Temperature conversion

$$K = C + 273$$

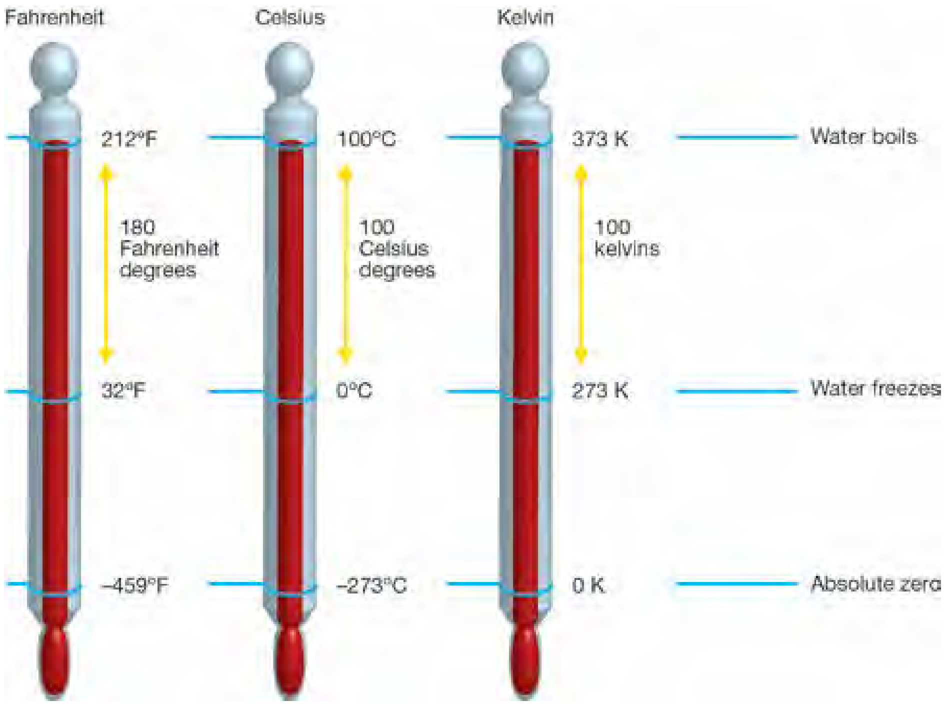
$$C = \frac{5}{9}(F - 32)$$

$$F = \frac{9}{5}C + 32$$


Anders Celsius (1701-1744).


Lord Kelvin (1824-1907).

Relationship between Fahrenheit, Celsius and Kelvin temperature scales



QUESTIONS

1. Fahrenheit's second fixed point on his scale was body temperature at 98.6°F. What is the temperature in Celsius degrees and kelvins?
2. The title of the science fiction book 'Fahrenheit 451' by Ray Bradbury, published in 1953 refers to the temperature that book paper burns, or 451°F. What is this temperature in Celsius degrees?
3. The average surface temperature on Mars is −63°C. What is the temperature in Fahrenheit degrees and kelvins?
4. Oxygen has a boiling point of 90.19 K. What is the temperature in Celsius degrees?
5. Pure iron melts at 1535°C. What is the temperature in kelvins?
6. Which temperature is hotter: 17°C or 58°F or 287 K?
7. A general rule of thumb used by pilots is for every 1000 feet of altitude, the temperature falls 3.5°F. If the temperature at sea level is 78°F, what would you expect the temperature to be at 10 000 feet in Celsius degrees?
8. The surface temperature of the Sun is about 5778 K. What is this in Celsius degrees?
9. Complete the following table.

	Fahrenheit temperature (°F)	Celsius temperature (°C)	Kelvin temperature (K)
(a)	0		
(b)		0	
(c)			0
(d)	100		
(e)		100	
(f)			100
(g)	80		
(h)		60	
(i)			40
(j)		25	

Describe the kinetic particle model of matter.

2 The Kinetic Theory Of Matter

To understand why solids, liquids and gases behave differently, scientists have developed a theory called the **kinetic theory** or the **particle theory of matter**. We can use this theory to explain why the properties of the states of matter are so different. There are three main ideas in the kinetic theory of matter as outlined below.

The kinetic theory

- All matter is made up of small particles.
- These particles are always moving except at absolute zero which is defined as the temperature at which all particle motion ceases.
- The particles are held together by forces which vary in strength.

Our concept of the temperature of matter is also tied to our understanding of the kinetic theory as follows.

> **Temperature** is a measure of the average kinetic energy of the particles of matter.

It is important to remember that the ideas in the kinetic theory represent a **model** only.

- The particles of matter are too small to be seen, so we are not describing what they do from observations of the particles themselves. We deduce their behaviour from the properties of matter.
- We use the kinetic theory to explain and predict the behaviour of matter.
- Any model in science is only as good as its ability to explain and predict accurately, and so far, the kinetic theory model has worked extremely well.
- If we discover properties of matter that we cannot explain using the kinetic theory, then we will need to rethink the theory, perhaps modifying it so that these new properties are also explained.

QUESTIONS

1. Complete the sentences about the kinetic theory by writing one word in each space.

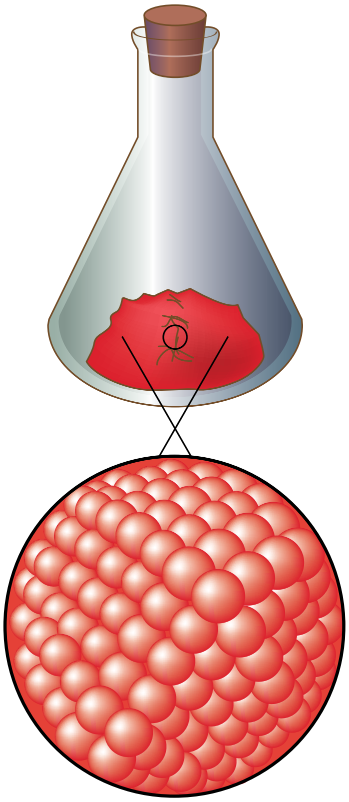
   (a) Particles in .... are held .... by strong ....

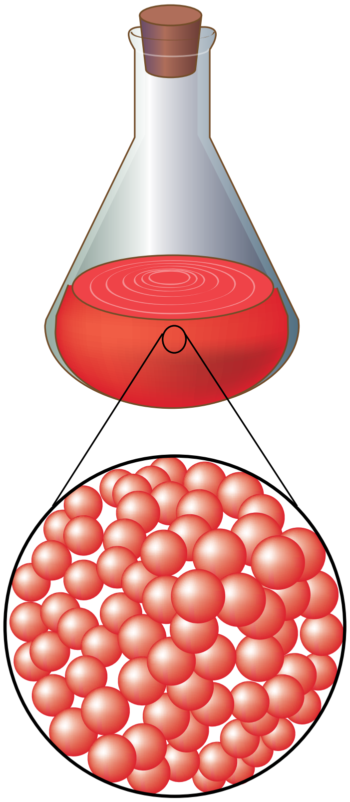
   (b) The particles in solids cannot move .... because they are .... in .... positions.

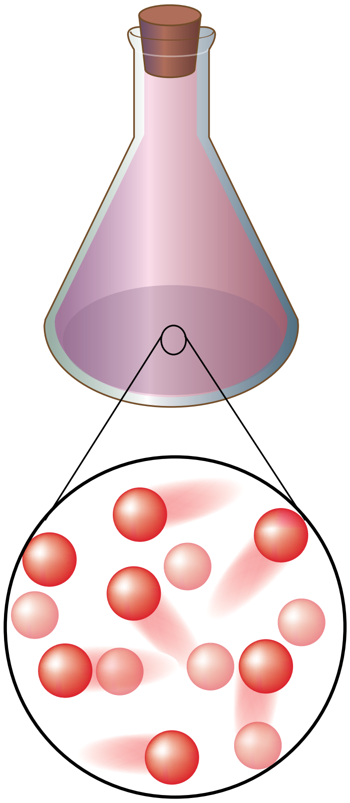
   (c) In liquids, the .... are not held together as .... as in solids, so they can .... over one another. This is why liquids can be ....

   (d) In gases particles are .... held together and are therefore .... to move in any .... This is why gases .... readily and always completely .... their containers.

2. We often use diagrams to help us understand kinetic theory. In these diagrams each circle or square, or triangle, or whatever shape is used, represents one particle of matter.
Complete the labels on the diagrams shown to firstly identify which state of matter each represents, and then describe the properties of the particles that make up each state. One has been done for you as a guide.







Solids		
	• Particles are close together. • Particles are held less tightly than in solids. • Particles are not free to move, but • Particles can roll over one another.	

Answers

Topic 1 Heating Processes

1 Major Temperature Scales

1. 37°C and 310 K
2. 232.78°C
3. −81.4°F and 210 K
4. −182.81°C
5. 1808 K
6. 17°C which is 62.6°F and 290 K
7. 6.1°C
8. 5505°C
9.

	Fahrenheit temperature (°F)	Celsius temperature (°C)	Kelvin temperature (K)
(a)	0	–17.8	255.2
(b)	32	0	273
(c)	–459.4	–273	0
(d)	100	37.78	310.78
(e)	212	100	373
(f)	–279.4	–173	100
(g)	80	26.67	299.67
(h)	140	60	333
(i)	–387.4	–233	40
(j)	77	25	298

2 The Kinetic Theory Of Matter

1. (a) solids, together, forces
   (b) freely, held, fixed
   (c) particles, strongly, slide, poured
   (d) not, free, direction, diffuse, fill
2.

Solids	Liquids	Gases
• Particles are close together. • Particles are held tightly together. • Particles are not free to move. • Particles can only vibrate in their fixed positions.	• Particles are close together. • Particles are held less tightly than in solids. • Particles are not free to move, but • Particles can roll over one another.	• Particles are much further apart. • Particles are not held together. • Particles are free to move. • Particle collisions with container walls cause gas pressure.

3 Temperature and the Kinetic Theory

1. Kinetic energy is given by the equation $E_K = \frac{1}{2}mv^2$. If the motion of particles is zero, i.e. $v = o$, then their kinetic energy will be zero, and therefore by definition, the temperature of the matter will be zero. This is defined as an absolute zero, because particles cannot go slower than stationary! When matter is cooled, particles lose energy and slow down. When they slow down so that all motion stops we have reached absolute zero.
2. (a) (B) It is the coldest, so according to the concept of temperature as a measure of average kinetic energy of particles, they are all water particles. They all have the same mass, so the speed of the ice particles will be the slowest.
   (b) If the steam is at 100°C , then the particles in A and D will have the highest temperature and therefore the highest kinetic energy. However, if the steam is hotter than 100°C, then its particles will have the most kinetic energy.
   (c) B < C < A < (or perhaps equal to) D
   (d) Steam particles move more freely than water particles and are not held to other steam particles, so they can penetrate pores in our skin much more effectively and give a deeper burn.
3. Heat energy from the Sun will conduct through the can and heat up the gas particles inside. This will increase their rate of movement and the number of collisions they make with the wall of the can. The pressure may build up enough to break the seams in the material of the can. The can 'explodes' apart.
4. Friction between the tyres and the road makes the tyres, and the air in them hotter. Pressure builds up inside the tyre and this can cause a blow out and an accident if the pressure is not lowered before the trip starts.
5. (a) Particles in Y have been drawn moving faster, and the balloon has been drawn expanded so it would seem they are colliding more often and with more energy with the balloon walls than the particles in X.
   (b) The temperature of the balloon has been increased.
   (c) As the balloon is heated, the particles move faster making more collisions per second with the walls. This increases the pressure and the balloon expands.

4 Kinetic Theory and Properties Of Matter

1. C
2. B
3. B
4. D
5. C
6. A
7. D
8. A
9. D
10. B
11. D
12. C
13. (a) Because the particles in wood (as in any solid) are as close together as they can be.
    (b) Because the particles in rocks (as in any solid) are held together in fixed positions by strong forces.
    (c) The particles in the gaseous petrol are not held together and are free to move so they spread out (diffuse) quickly.
    (d) Particles in liquids slide over one another and are not held as tightly as in solids, so they can spread out into the holes in the paper towel.
    (e) Particles in the liquid ink slide over one another and are not held together strongly, so they can diffuse into the water
    (f) The particles in the metal are held together by stronger forces than the particles in the wood.
    (g) In tearing one sheet of paper you are breaking the forces between one layer of paper particles which is easy to do, but in trying to tear a phone book in half there are hundreds of pages and too many forces for you to be able to overcome them.
    (h) Particles in gases are not held together by forces and so are free to move through spaces between particles. Particles in liquids are held together by forces which enable them to slide over one another but have to push other particles out of the way and diffuse more slowly than gas particles.
    (i) Particles in liquids can slide over one another and so spread out across the bottom of their container and take whatever shape it is.
    (j) Forces between glue and paper particles are stronger than forces between glue particles.
    (k) Compressed air is air in which the particles have been forced into a much smaller volume. They collide with each other and their container producing a high pressure. When connected to a car tyre where the pressure is lower (due to fewer particles not as close together), collisions between the compressed air particles pushes them into the tyre to equalise the pressures.
    (l) Compressed hairspray has particles which have been forced into a much smaller volume. They collide with each other and their container producing a high pressure. When the button is pushed down it provides an outlet to a region where the pressure is lower (due to fewer particles not as close together). Collisions between the particles from the compressed spray push them into the air to equalise the pressures.