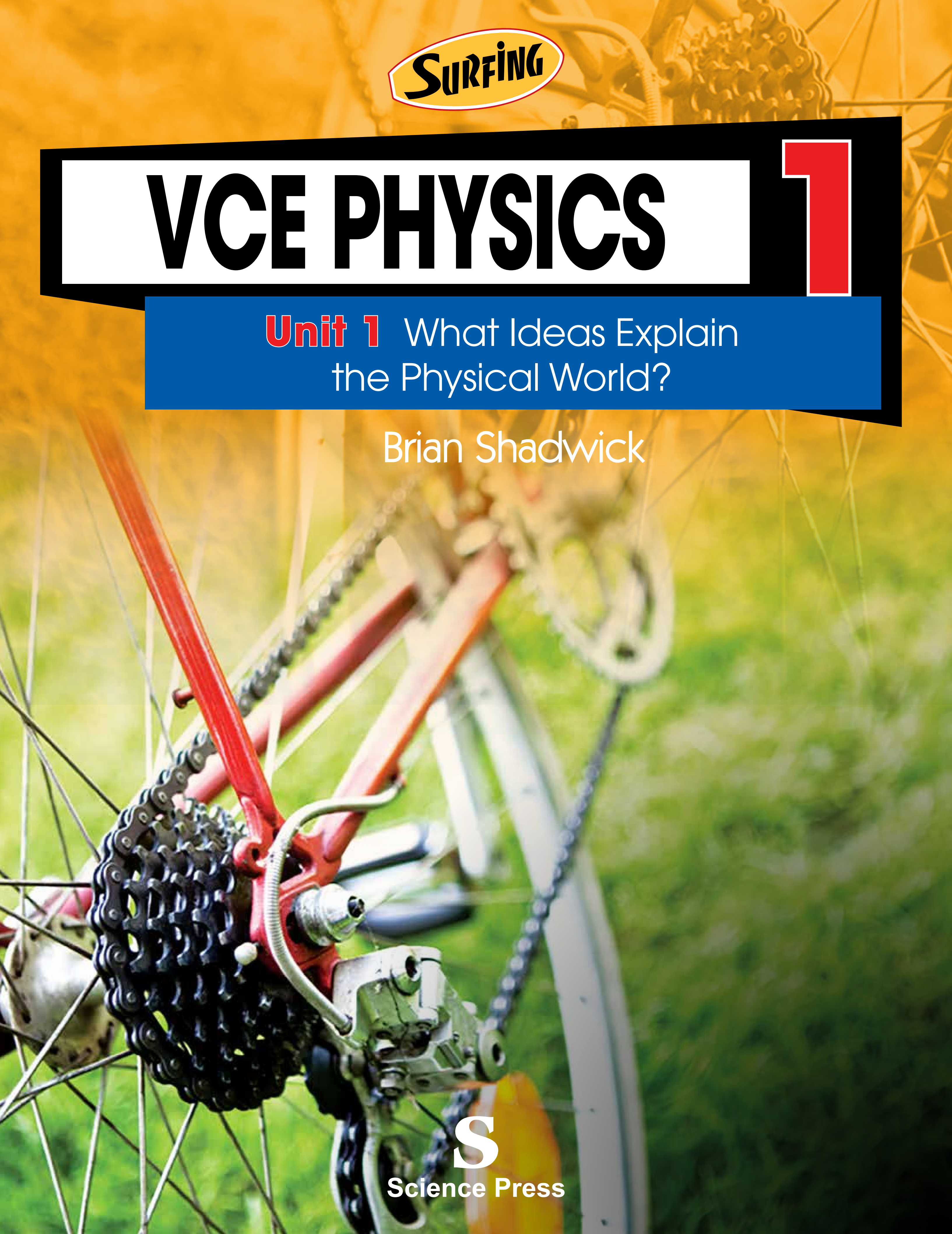


Surfing

VCE PHYSICS 1

Unit 1 What Ideas Explain the Physical World?

Brian Shadwick

Science Press

Science Press
Bag 7023 Marrickville NSW 1475 Australia
Tel: (02) 9516 1122 Fax: (02) 9550 1915
sales@sciencepress.com.au
www.sciencepress.com.au

Contents

What is Matter and How Is It Formed?

Introduction

This book covers the Physics content specified in the Victorian Certificate of Education Physics Study Design. 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 the book 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

VCE PHYSICS 1

Area of Study 1

How Can Thermal Effects Be Explained

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 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.

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.

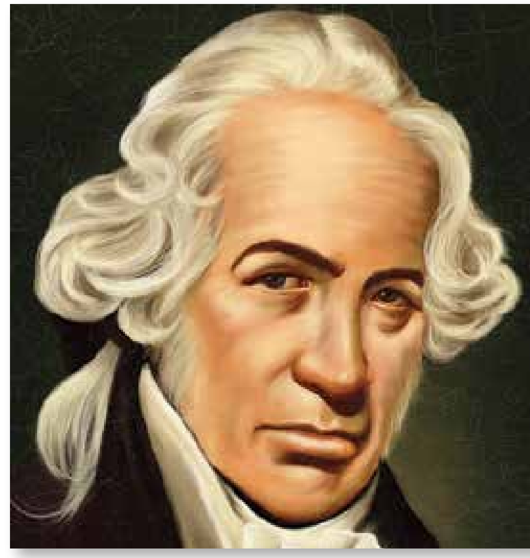
The equations we use to convert between these scales are given below.

Temperature conversion

$$K = C + 273$$

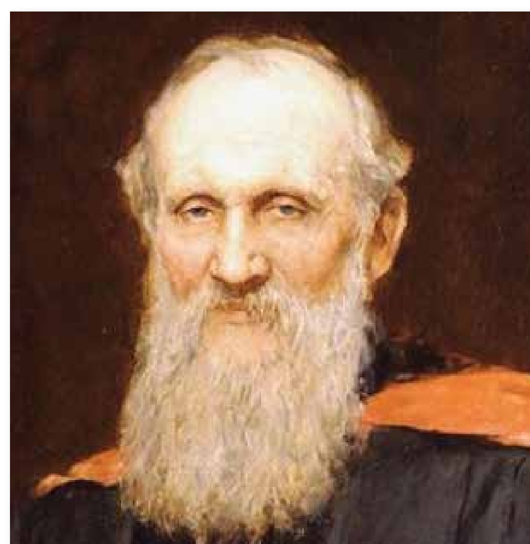
$$C = \frac{5}{9}(F - 32)$$

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



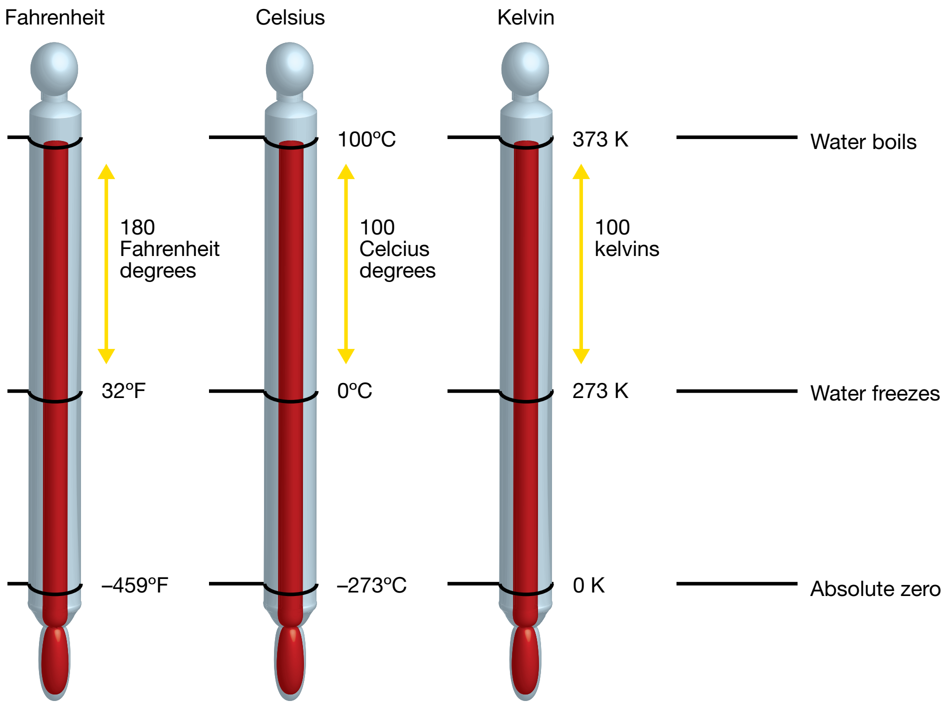
Daniel Fahrenheit (1686-1736)

Anders Celcius (1701-1744)



William Kelvin (1824-1902)

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	

2 Temperature and the Kinetic Theory – Revision

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.

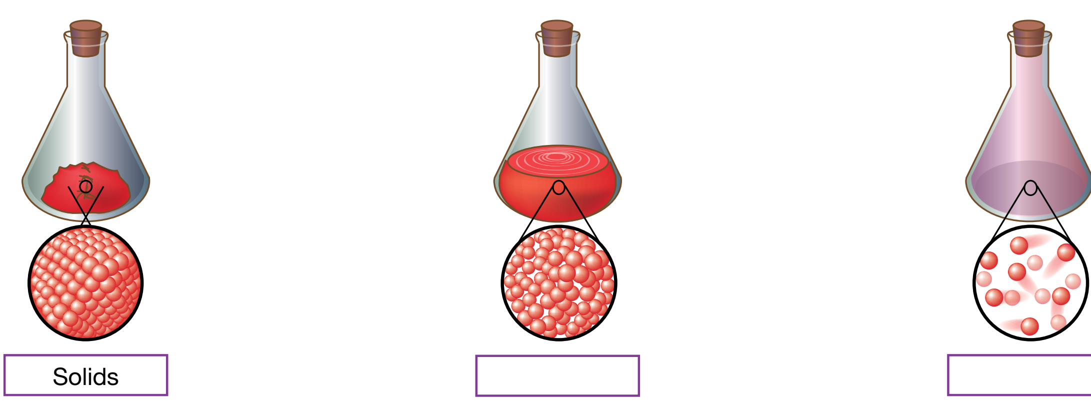
Temperature is a measure of the average kinetic energy of the particles of matter.

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.



- 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.

3. Why are gases easier to compress than liquids?
(A) They are less dense.
(B) Their particles are held together less tightly.
(C) Their particles are further apart.
(D) Their particles move randomly.

4. What is a consequence of the particles in liquids being able to roll over one another?
(A) They cannot be compressed.
(B) They can be poured.
(C) They diffuse quickly.
(D) They expand when heated.

5. What causes particles of matter to move faster?
(A) Weaker forces between them.
(B) Heating the matter.
(C) Cooling the matter.
(D) Shaking the matter.

6. What happens to the particles of matter when it expands?
(A) They get larger and occupy more space.
(B) They get hotter and increase in volume.
(C) They break the forces holding them together and spread out into a larger volume.
(D) They move faster, collide more violently, and need more room to move in.

7. Between which particles would you expect the forces to be strongest?
(A) Between air particles.
(B) Between water particles.
(C) Between ice particles.
(D) Between lemonade particles.

9. Considering what you know about lipstick, which statement is correct?
(A) Forces between lipstick particles and lip particles are stronger than those between lipstick particles.
(B) Forces between lipstick particles are stronger than those between lipstick and lip particles.
(C) Forces between lipstick particles are equal to those between lipstick and lip particles.
(D) Forces between lipstick particles are equal to those between lip particles.

10. Which is *not* an example of diffusion?
(A) Pool chlorine tablets slowly dissolving into the pool water.
(B) Noticing the perfume your friend is wearing.
(C) Volcanic gases spreading throughout the atmosphere.
(D) Biro smudging when your hand rubs over it.

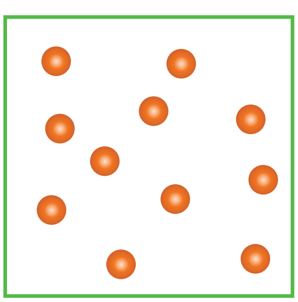
11. Which particles will have the greatest energy?
(A) Water liquid particles at 50°C.
(B) Water vapour particles at 50°C.
(C) Water liquid particles at 60°C.
(D) Water vapour particles at 60°C.

12. Why do gases diffuse more quickly than liquids?
(A) They are less dense.
(B) Their particles are not held together.
(C) Their particles are smaller.
(D) Their particles move more quickly.

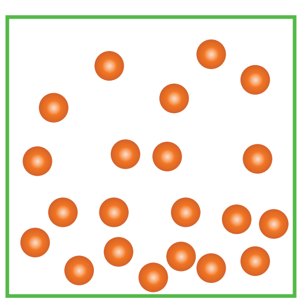
13. Why can't solids and liquids be compressed?
(A) Their particles are held together too strongly.
(B) Their particles are not held together.
(C) Their particles are in fixed positions.
(D) Their particles are as close together as they can be.

8. Which diagram correctly shows the particles of a gas in a closed container?

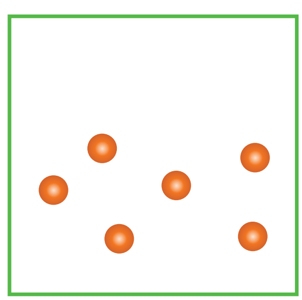
(A)



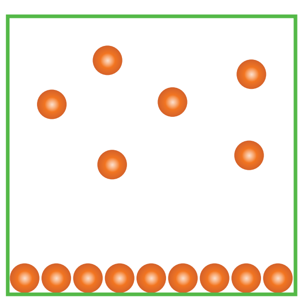
(B)



(C)



(D)



14. Use the kinetic theory in the same way as the examples above to explain each of the following facts.

	Fact	Kinetic theory explanation
(a)	Wood cannot be compressed.	
(b)	Rocks do not diffuse.	
(c)	Petrol fumes can be smelt at a service station.	
(d)	Spilt juice soaks into a paper towel.	
(e)	Drops of ink will spread through a glass of water.	
(f)	A metal bar is stronger than a wooden rod the same size.	
(g)	You can tear one sheet of paper in half easily, but cannot tear a phone book in half.	
(h)	Gases diffuse faster than liquids.	
(i)	Liquids take the shape of their container.	
(j)	Glue from a glue stick is easy to rub onto paper.	
(k)	Compressed air pumps are used to pump up car tyres.	
(l)	Hairspray cans spray the hairspray out when the button is pushed down.	
(m)	Car windows can fog over on the inside on a cloudy day.	
(n)	You should not leave a spray can of oil in the sun while you barbecues.	

3 Temperature and the Kinetic Theory

An important idea in the kinetic theory of matter is the concept of temperature, and what happens to the particles of matter when matter is heated or cooled.

Temperature

- Temperature is a measure of how fast the particles of matter are moving.
- Temperature is a measure of the average kinetic energy of the particles of matter.

When matter is heated its particles absorb energy and move faster.

When matter is cooled its particles lose energy and slow down.

Note: Gas particles have more energy due to their state than liquid particles at the same temperature. Similarly, liquid particles have more energy than solid particles at the same temperature. In both cases this is due to the extra energy they have because the particles move more freely.

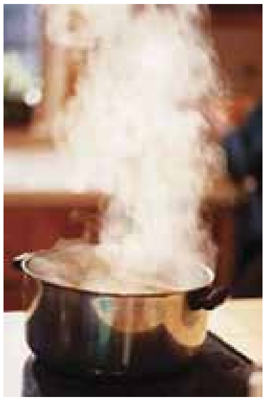
QUESTIONS

1. Accepting that what we know as temperature or heat energy is a measure of the average kinetic energy of motion of the particles of matter, explain how this leads to the idea of an absolute zero temperature.
2. Consider the four different pictures of water below.

(A) Boiling water

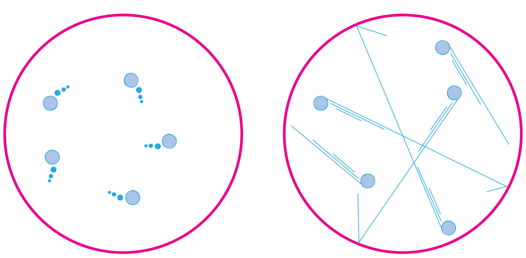
(B) Iceblocks

(C) Shower water



(D) Steam

   (a) In which picture will the water particles be moving most slowly? Justify your answer.
   (b) In which picture will the particles have the most kinetic energy? Justify your answer.
   (c) Rank the particles in the four states of water in order from slowest to fastest.
   (d) Steam at 100°C will actually cause more severe burns to a person than water at 100°C. Suggest an hypothesis as to why this is so.
3. Explain, in terms of the motion of particles, why an aerosol spray can left in the sun could explode.
4. Before going on a long journey in summer, car owners are encouraged to let some of the air out of their tyres. Explain why this could make the journey safer.
5. The diagram shows the particles of matter in the same balloon before and after something happened.



   (a) What inference can you make about the particles in the balloon in Y compared to X?
   (b) Infer from this what has happened to the balloon.
   (c) Explain, in terms of the kinetic theory, why this happened.

4 The Laws of Thermodynamics

In science we define the randomness or disorder in any system as its **entropy**. The less the entropy of a system, the more structured or ordered it is. So crystalline ice has small entropy and gaseous water has high entropy due to the random nature of the motion of its particles.

The thermal properties of materials are summarised in the laws of thermodynamics, stated in simple form as

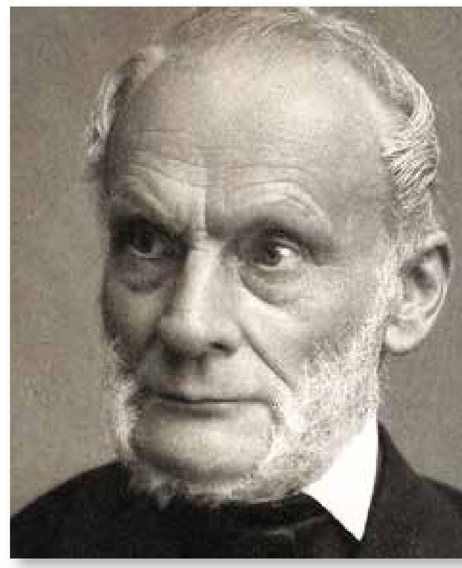
> **Zeroth law of thermodynamics:** If two bodies are in thermal equilibrium with a third body, then they are also in thermal equilibrium with each other. Even more simply, if two bodies are in thermal equilibrium, then there is no detectable flow of heat energy from one to the other.
>
> **First law of thermodynamics:** Energy can neither be created nor destroyed, but can be changed from one form to another. You would know this more generally as the law of conservation of energy.

Investigations into the nature of heat and work began with the invention of the first engines used to extract water from mines. Improvements to such engines to increase their efficiency and power output came first from mechanics and then from the developing theory and mathematics as knowledge of the physics involved improved.

The development of laws of thermodynamics was by way of experimental trial and error over a period of about 50 years. The main problem was to find a connection between thermal energy with the energy involves in chemical processes and work done by engines.

The first explicit statement of the first law of thermodynamics, by Rudolf Clausius in 1850, referred to the internal energy of a system and any work done as follows.

> **First law of thermodynamics:** In a thermodynamic process involving a closed system, the change in the internal energy of the system is equal to the difference between the heat energy accumulated by the system and the work done by it.



Rudolf Claudius (1822-1888)

The idea of internal energy was interesting because it was not a quantity that could be measured. Only a change in the amount of internal energy, as indicated by work done, could be determined as governed by the law of conservation of energy. In its simplest form we can take the internal energy of a system as being the potential and kinetic energies associated with the random motion of the particles within the system.

> The **internal energy** of a system is the total of the potential and kinetic energies associated with the random motion of the particles in the system.

In each repetition of a cyclic process within a system, the work done by the system plus the heat energy leaving the system must equal the heat that enters the system. In a repetitive process in which the system does work on its surroundings, there will always be heat taken into the system and heat given out by the system, and the difference is the heat converted by the system into work.

If we take U = the change in the internal energy of a system and
Q = quantity of heat energy entering the system and
W = the work done by the system

Then it follows from the law of conservation of energy:

$$\boxed{\begin{array}{c} U = Q - W \\ Q = U + W \end{array}}$$

QUESTIONS

1. In a certain process, 600 J of work is done on the system which gives off 250 J of heat. What is the change in internal energy for the process?
   (A) 250 J
   (B) 350 J
   (C) 600 J
   (D) 850 J
2. Which statement best describes what happens to the internal energy of a system when it absorbs heat energy?
   (A) The temperature of the system increases.
   (B) The temperature of the system decreases.
   (C) The internal energy of the system will increase.
   (D) The internal energy of the system will decrease.
3. Which statement about a system which does work is correct?
   (A) Its internal energy will decrease because work involves using energy.
   (B) Its internal energy will decrease because work involves the absorption of energy.
   (C) Its internal energy will increase because work involves using energy.
   (D) Its internal energy will increase because work involves the absorption of energy.
4. Which statement about a system which does work is correct?
   (A) The change in internal energy of the system is equal to the heat added plus the work done by the system.
   (B) The change in internal energy of the system is equal to the heat lost by the system minus the work done by the system.
   (C) The change in internal energy of the system is equal to the heat lost plus the work done by the system.
   (D) The change in internal energy of the system is equal to the heat added to the system minus the work done by the system.
5. As water heats up from 280 K to 310 K, the internal energy of the water will:
   (A) Increase.
   (B) Decrease.
   (C) Increase then decrease.
   (D) Stay the same.
6. In a process, 6000 J of heat is added to a system while the system does work. The internal energy of the system decreases by 4000 J. How much work does the system do?
   (A) 2000 J
   (B) 4000 J
   (C) 6000 J
   (D) 10 000 J
7. In a process, 675 J of heat is added to a system while 300 J of work is done on the system. What is the change in the internal energy of the system?
   (A) 300 J
   (B) 375 J
   (C) 675 J
   (D) 975 J
8. In a process, 5000 J of heat is added to a system while 9000 J of work is done by the system. What is the change in the internal energy of the system?
   (A) −4000 J
   (B) 4000 J
   (C) 5000 J
   (D) 14 000 J
9. What is our concept of temperature?
   (A) The highest amount of kinetic energy the particles in a substance have.
   (B) The average potential energy of the particles in a substance.
   (C) The average kinetic energy of the particles in a substance.
   (D) The amount of heat a substance has.
10. Which of the following is the best definition of energy?
   (A) The ability of a system to do work.
   (B) The movement of an object with application of force.
   (C) The average energy change in a system.
   (D) The amount of heat change in a system.
11. If the internal energy of a container of water increases, what happens to the particles within the water?
   (A) They move more slowly.
   (B) They move more quickly.
   (C) They will evaporate.
   (D) Their temperature will increase.

Answers

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)	−405.4	−243	40
(j)	77	25	298

2 Temperature and the Kinetic Theory – Revision

1. (a) solids, together, forces
   (b) freely, held, fixed
   (c) particles, strongly, roll, 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. C
4. B
5. B
6. D
7. C
8. A
9. A
10. D
11. D
12. B
13. A
14. (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.
    (m) Particles of water moisture in our breath hit the colder glass of the window, slow down and change state to form water liquid.
    (n) Heat energy from the sun will transfer into the can, make the particles of the compressed propellant inside the can move faster (it gets warmer), they collide more energetically with each other and the can causing pressure to build up inside the can to the point where it can burst the can.

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 The Laws of Thermodynamics

1. B
2. C
3. A
4. D
5. A
6. D
7. D
8. A
9. C
10. A
11. B

5 Work Done and Internal Heat Energy

1. Pa m^3 = N m^{-2} m^3 = kg m s^{-2}. m^{-2}. m^3 = kg m^2 s^{-2} = joule
2. Work done = $P\Delta V = 2 \times 10^5 \times \dfrac{3}{1000} = 600$ Pa m^3 = 600 J
3. (a) Because the volume of the gas does not change, no work has been done on the gas.
   (b) $W = P\Delta V = 150 \times 10^3 \times \dfrac{(9.3-6.8)}{1000} = 375$ J
4. (a) Work done needs to be estimated by 'counting grid squares' = about 0.76 J
   $W = 20$ squares $= 20 \times (20 \times 10^3) \times (2 \times 10^{-3})$ = about 800 J
   (b) $Q = mc\Delta T$; $0.8 = 0.04 \times 2.5 \times \Delta T$; $\Delta T = 8$°C
5. $W = P\Delta V = 110 \times 10^3 \times (1.7 - 1.2) \times 10^{-3} = 55$ J
6. (a) The work done by the gas against the piston.
   (b) W = area $= (1 \times 10^5) \times (20 \times 10^{-3}) = 2000$ J
   (c) $W = 2000$ J
   (d) As it expands its temperature will fall. As it is compressed back to its initial volume, the temperature will rise to its initial level.

6 Heat Conduction

1. (a) good
   (b) freely
   (c) conduction
   (d) insulators
   (e) insulators
2. (a) For example: copper, tin, zinc, lead, iron (any metal).
   (b) For example: wood, wool, concrete, glass, ceramic (any non-metal, except some types of carbon).
3. The metal in the spoon conducts the heat energy from the hot water well. The plastic is an insulator and so does not conduct the heat.
4. Heat energy from the engine transfers into the water (it circulates to keep the engine cooler) and then the heat energy conducts into the metal cap on the radiator.
5. (a) The diagrams are showing how heat energy conducts along a heat conductor as particles absorb energy from the Bunsen flame, vibrate more rapidly and bump into particles next to them more violently, transferring energy to them progressively along the rod.
   (b) Particles in non-metals are held together more strongly than those in metals and therefore cannot vibrate as violently in order to transfer energy via the collisions they have with adjacent particles.

6. 1 Metals and metal alloys allow heat energy to transfer through them. (g)
   2 For this reason they are known as heat conductors. (a)
   3 Non-metallic substances do not readily allow heat energy to pass through them. (h)
   4 These substances are called heat insulators. (c)
   5 Conduction of heat occurs because any applied energy causes the particles of the metal to vibrate more violently. (d)
   6 This increased vibration causes these particles to bump into the particles next to them and cause these to vibrate more as well. (b)
   7 Gradually the heat energy is passed through the metal from particle to particle. (f)
   8 In addition to resulting in conduction of heat, the increased vibrations cause the metal to expand. (i)
   9 This happens because the particles need more space in which to vibrate. (e)

7 Heat Convection

1. (a) energy, fluids
   (b) fluids, fixed, positions
   (c) slide, past, free, held
   (d) particles, circular
   (e) expand, dense
   (f) more
2. As the fluid is heated, the particles near the source of heat move faster, collide more violently, and because they are not held together, spread out. The fluid becomes less dense and rises upwards, making way for cooler, more dense fluid to move near the source of heat and repeat the process. As the warmer, less dense fluid rises upwards, it loses energy, the particles slow down, move closer together, and the fluid becomes more dense. The denser fluid moves downwards towards the source of energy to take the place of less dense material moving upwards.
3. Particles in solids are held in fixed positions. They are unable to move away from these positions, so when heated, they simply vibrate faster and collide more violently with their neighbours causing heat conduction and expansion but not convection (unless enough energy is added to melt the solid … but then we have a liquid).
4. Particles in gases are free to move and can therefore move about more readily than particles in liquids. Gases can therefore transfer heat energy by convection faster and more efficiently than particles in liquids.
5.