上海光華學院剑橋國際中心(光華剑橋)
Guanghua Cambridge International School

Cambridge IGCSE/G1 PHYSICS

Structured Questions

Volume IGCSE/G1

I Force, Motion, Energy
II Thermal Physics
III Waves

Cambridge IGCSE/G1 PHYSICS

Structured Questions

Grading Table

Topic	HW #	Max	Earned	Penalties	Grade	Comment
	1					
	2					
	3					
	4					
	5					
	6					
	7					
	8					
	9					
	10					
	11					
	12					
	13					
	14					
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	17					
	18					
	19					
	20					
	21					
	22					
	23					
	24					

Preface

This book covers the entire syllabus of CIE Physics for IGCSE level.The main task of this book is to help you to test your understanding and prepare for the examinations.

This book has been written specifically for a student of Cambridge's 0625 syllabus by an experienced team with examiners who are very familiar with the syllabus and examinations.

All of the questions are chosen from past papers. When tacking questions, it is a good idea to make a first attempt without referring to your textbook or to your notes. This will help to reveal any gap in your understanding. By sorting out any problems at early stage you will progress faster.

We hope that this book will help you to succeed in examinations and we also hope you will learn from the past to take physics to ever greater heights.

Changes for the 2023-2025 Syllabus

Note that many of the questions in thei book have been taken from past syllabuses which, on occasion, might contain subject material removed from later incanations of the syllabus. These questions have not been removed from this book; rather, they have been marked with an open left bracket, as shown in the example below.

1 A thermocouple is used to measure the temperature of the inner wall of a pottery kiln.

(a) In the space below, draw a labelled diagram of a thermocouple that could be used for this purpose.

[2]

Questions marked as such, can be igored, insofar as the 2023-2025 examinations are concerned.

Contents

Part I
Force, Motion, Energy

Chapter 1. Making measurements

1.1 Physical quantities and measurement techniques

Core

1. Describe the use of rulers and measuring cylinders to find a length or a volume
2. Describe how to measure a variety of time intervals using clocks and digital timers
3. Determine an average value for a small distance and for a short interval of time by measuring multiples (including the period of oscillation of a pendulum)

1.4 Density

Core

1. Define density as mass per unit volume; recall and use the equation

   $$\rho = \frac{m}{V}$$

2. Describe how to determine the density of a liquid, of a regularly shaped solid and of an irregularly shaped solid which sinks in a liquid (volume by displacement), including appropriate calculations
3. Determine whether an object floats based on density data

Supplement

4. Determine whether one liquid will float on another liquid based on density data given that the liquids do not mix

1.1 Measuring length

1 Fig 1.1 shows part of a measuring instrument.

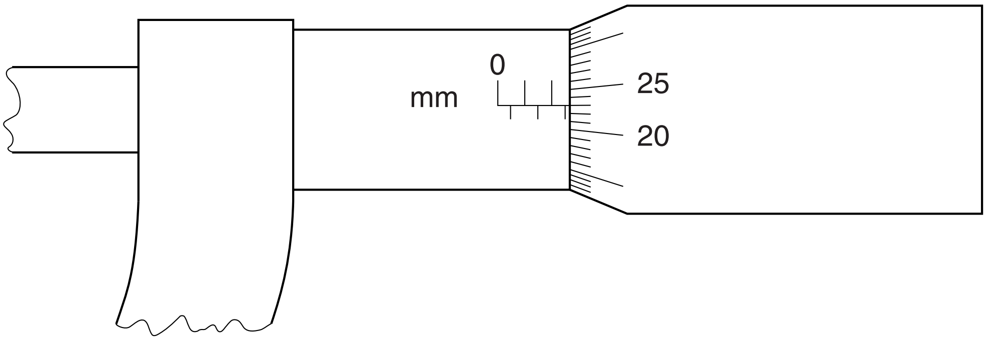


Fig. 1.1

(a) State the name of this instrument.

.... [1]

(b) Record the reading shown in Fig. 1.1.

.... [1]

(c) Describe how you would find the thickness of a sheet of paper used in a magazine.

....

....

....

....

....

.... [3]

[Total: 5]

1-2 A piece of string wraps around a cylinder 8 times.

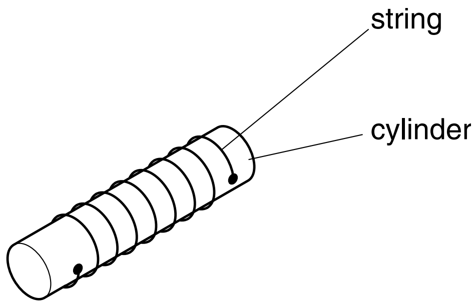


Fig. 1.1

Fig.1.2 shows the string laid along a 30 cm ruler.

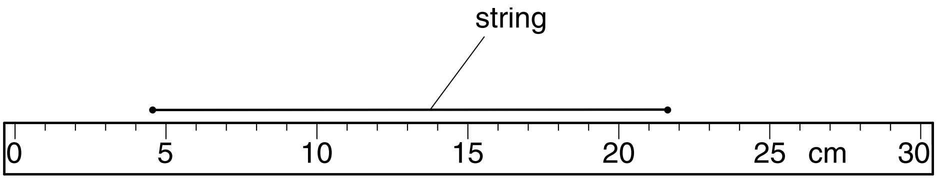


Fig. 1.2

(a) How long is the string?

length of string = ... cm [2]

(b) Calculate the circumference (distance once round) the cylinder.

circumference of cylinder = ... cm [2]

[Total: 4]

2 A laboratory technician has ten pieces of plastic, all cut from the same thin sheet.

The technician wishes to find the thickness of a piece of plastic as accurately as possible.

(a) Name the instrument that should be used.

.... [1]

(b) Describe how the instrument should be used to find the thickness.

....

....

....

....

....

....

....

....

....

.... [3]

[Total: 4]

1.2 Measuring density

1 A student is given the following apparatus in order to find the density of a piece of rock.

100 g mass
metre ruler
suitable pivot on which the rule will balance
measuring cylinder that is big enough for the piece of rock to fit inside
cotton
water

The rock has a mass of approximately 90 g.

(a) **(i)** In the space below, draw a labelled diagram of apparatus from this list set up so that the student is able to find the mass of the piece of rock.

(ii) State the readings the student should take and how these would be used to find the mass of the rock.

....

....

....
[5]

(b) Describe how the volume of the rock could be found.

....

....

....[2]

(c) The mass of the rock is 88 g and its volume is 24 cm^3.
Calculate the density of the rock.

density of rock = ... [2]

2 A scientist needs to find the density of a sample of rock whilst down a mine. He has only a spring balance, a measuring cylinder, some water and some thread.

(a) In the space below, draw two labelled diagrams, one to show the spring balance being used and the other to show the measuring cylinder being used with a suitable rock sample. [2]

(b) The spring balance is calibrated in newtons. State how the mass of the rock sample may be found from the reading of the spring balance.

....[1]

(c) State the readings that would be taken from the measuring cylinder.

....

....[1]

(d) State how the volume of the rock would be found from the readings.

....[1]

(e) State in words the formula that would be used to find the density of the sample.

density =

[1]

3 The list below gives the approximate densities of various metals.

gold	19 g/cm^3
lead	11 g/cm^3
copper	9 g/cm^3
iron	8 g/cm^3

At an antiques market, a collector buys what is advertised as a small ancient gold statue. When the collector tests it in the laboratory, he finds its mass is 600 g and its volume is 65 cm^3.

(a) In the space below, describe how the volume of the statue could be measured. You may draw diagrams if you wish.

[3]

(b) Use the figures given above to decide whether the statue was really made of gold. Show your working.

Was the statue made of gold? (Tick one box.)

yes	
no	

[3]

[Total: 6]

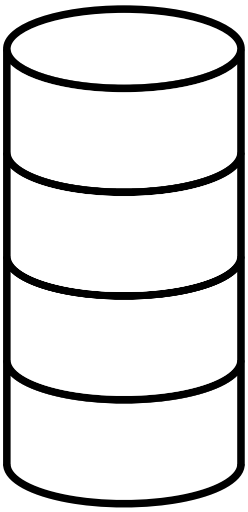
3-2 Four different liquids are poured into a 100 cm^3 measuring cylinder 10 cm in height. Each liquid has a different density and colour.

(a) Fill in the missing values below.

liquid colour	liquid	mass / g	volume / cm^3	density / g/cm^3
clear	ethanol	_____	20.00	0.79
red	gylcerin	20.00	_____	1.26
green	olive oil	25.90	25.80	_____
blue	turpentine	30.00	35.30	_____

[4]

(b) Using data from (a), write down the colour of the liquid you expect to find in each layer, noting the expected thickness, in cm, in the space to the right of the diagram.



[2]

[Total: 6]

1.3 Measuring time

1 An engineering machine has a piston which is going up and down approximately 75 times per minute.

Describe carefully how a stopwatch may be used to find accurately the time for one up-and-down cycle of the piston.

....

....

....

....

....

....

....

....

.... [4]

[Total: 4]

2 A weight attached to one end of a short length of string is swinging from side to side. The highest points in the swing are A and B, as shown in Fig. 1.1.

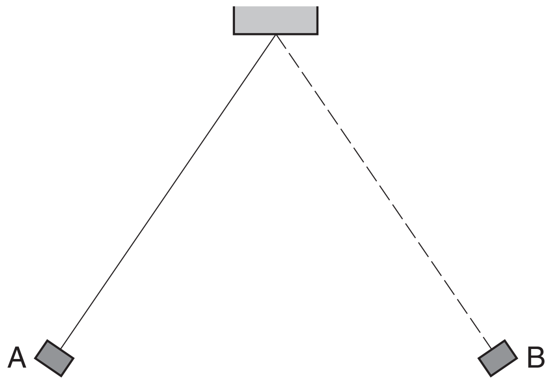


Fig. 1.1

(a) With reference to Fig. 1.1, state what is meant by the amplitude of the oscillations.

.... [2]

(b) Describe how the amplitude of the oscillations could be measured.

....

....

....

....

.... [3]

[Total: 5]

3 The period of the vertical oscillations of a mass hanging from a spring is known to be constant.

(a) A student times single oscillations with a stopwatch. In 10 separate measurements, the stopwatch readings were:

1.8 s, 1.9 s, 1.7 s, 1.9 s, 1.8 s, 1.8 s, 1.9 s, 1.7 s, 1.8 s, 1.8 s.

What is the best value obtainable from these readings for the time of one oscillation? Explain how you arrive at your answer.

best value = ...

explanation ....

....

.... [1]

(b) Describe how, using the same stopwatch, the student can find the period of oscillation more accurately.

....

....

....

....

....

....

.... [4]

[Total: 5]

Chapter 2. Describing motion

1.2 Motion

Core

1 Define speed as distance travelled per unit time; recall and use the equation

$$v = \frac{s}{t}$$

2 Define velocity as speed in a given direction

3 Recall and use the equation

$$\text{average speed} = \frac{\text{total distance travelled}}{\text{total time taken}}$$

4 Sketch, plot and interpret distance–time and speed–time graphs

5 Determine, qualitatively, from given data or the shape of a distance–time graph or speed–time graph when an object is:

(a) at rest

(b) moving with constant speed

(c) accelerating

(d) decelerating

6 Calculate speed from the gradient of a straight-line section of a distance–time graph

7 Calculate the area under a speed–time graph to determine the distance travelled for motion with constant speed or constant acceleration

8 State that the acceleration of free fall g for an object near to the surface of the Earth is approximately constant and is approximately $9.8\,m/s^2$

Supplement

9 Define acceleration as change in velocity per unit time; recall and use the equation

$$a = \frac{\Delta v}{\Delta t}$$

10 Determine from given data or the shape of a speed–time graph when an object is moving with:

(a) constant acceleration

(b) changing acceleration

11 Calculate acceleration from the gradient of a speed–time graph

12 Know that a deceleration is a negative acceleration and use this in calculations

13 Describe the motion of objects falling in a uniform gravitational field with and without air/liquid resistance (including reference to terminal velocity)

2.1 Understanding speed

1 **(a)** Complete the table below to identify the physical quantities as scalars or vectors.

physical quantity	scalar or vector
speed	
velocity	
distance	
force	
kinetic energy	

[3]

(b) Fig. 1.1 shows the path of a football as it is kicked along the ground between three players. The distances between the players are shown on Fig. 1.1.

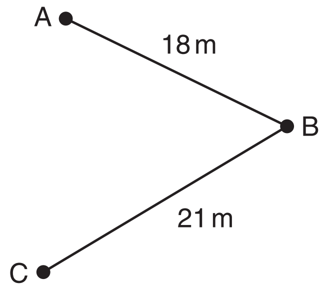


Fig. 1.1

The ball takes 1.2 s to travel from player A to player B.

(i) Calculate the average speed of the ball between A and B.

average speed = ...[2]

(ii) Player B kicks the ball to player C.
It travels with the same average speed.
Calculate the time taken for the ball to travel from B to C.

time = ...[2]

(iii) Suggest why the speed of the ball might change during its motion from A to B.

....

....[1]

(iv) Discuss whether the average velocities, from A to B and from B to C, are the same.

....

....

....[1]

[Total: 9]

2 A person is standing on the top of a cliff, throwing stones into the sea below.

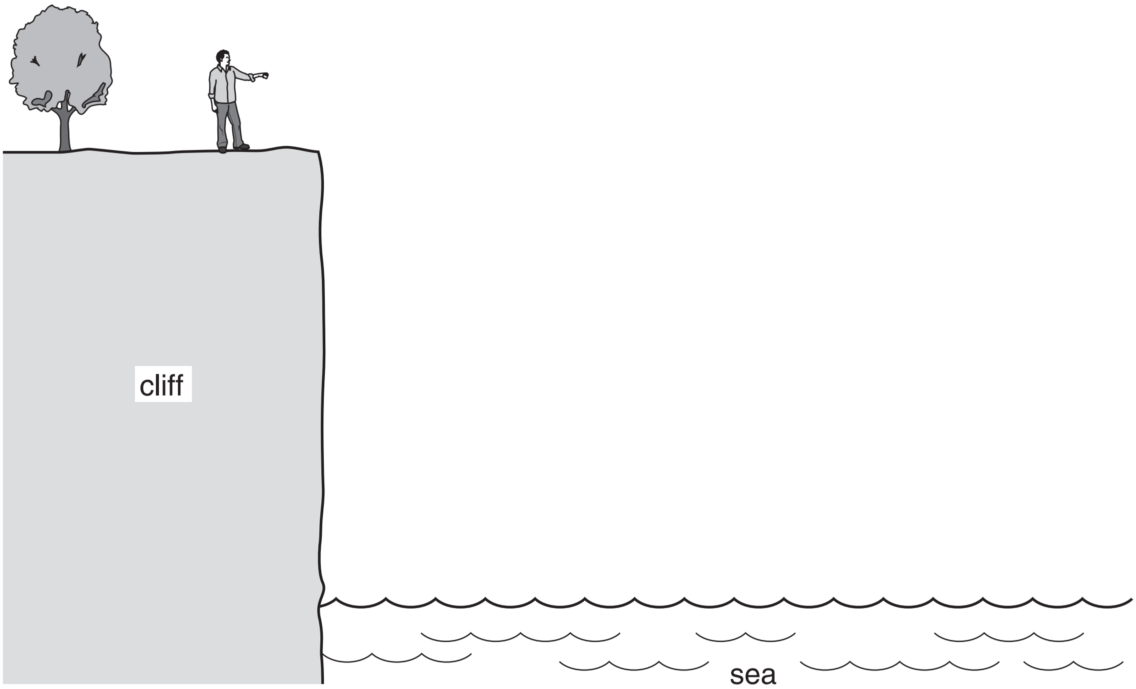


Fig. 2.1

(a) The person throws a stone horizontally.

(i) On Fig. 2.1, draw a line to show the path which the stone might take between leaving the person's hand and hitting the sea.

(ii) On the line you have drawn, at a point halfway to the sea, mark the stone and the direction of the force on the stone.

[3]

(b) Later, the person drops a small stone and a large stone vertically from the edge of the cliff.

Comment on the times taken for the two stones to hit the water.

....

....

....

....[2]

(c) 800 m from the point where the person is standing, a navy ship is having target practice.

The person finds that if a stone is dropped vertically at the same time as the spurt of smoke from the ship's gun is seen, the stone hits the water at the same time as the sound from the gun is heard.

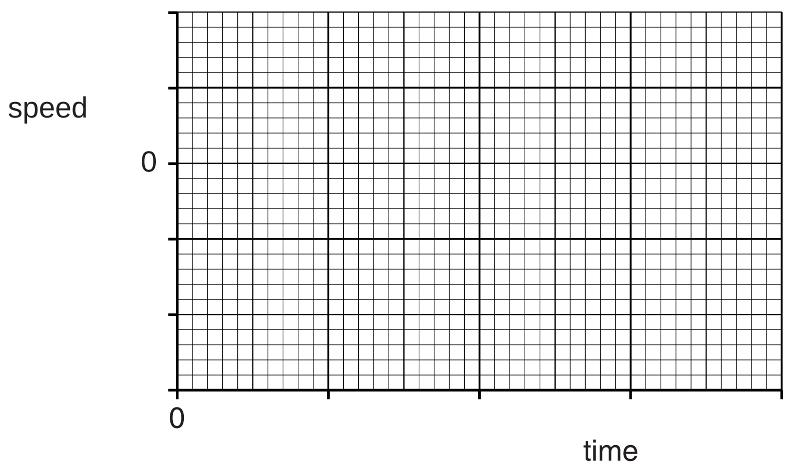
Sound travels at 320 m/s in that region.

Calculate the velocity with which the stone hits the water.

velocity = ...[4]

(d) Sketch a graph of both the horizontal and vertical components of the velocity of the small stone as a function of time starting from the time the stone is thrown.

Only the general shape and sign of the curves can be drawn.You should ignore air resistance.



[3]

[Total 12

3 Fig. 1.1 is a distance/time graph showing the motion of an object.

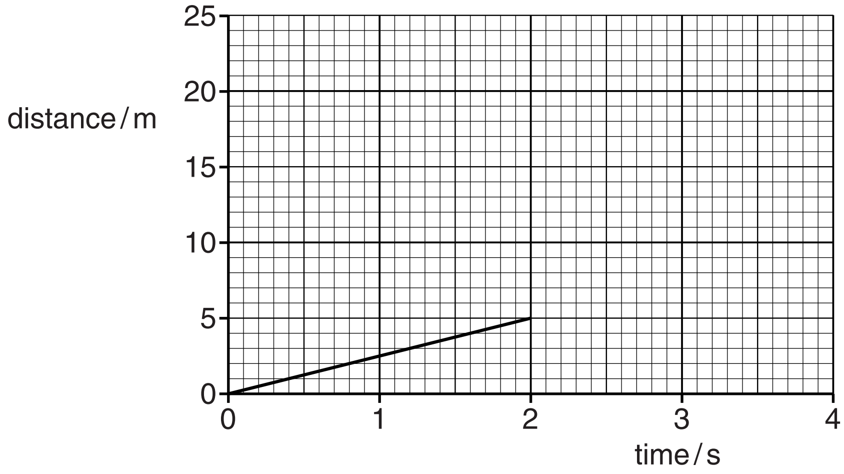


Fig. 1.1

(a) **(i)** Describe the motion shown for the first 2 s, calculating any relevant quantity.

....

.... [2]

(ii) After 2 s the object accelerates.

On Fig. 1.1, sketch a possible shape of the graph for the next 2 s. [1]

(b) Describe how a distance/time graph shows an object that is stationary.

....

.... [1]

(c) Fig. 1.2 shows the axes for a speed / time graph.

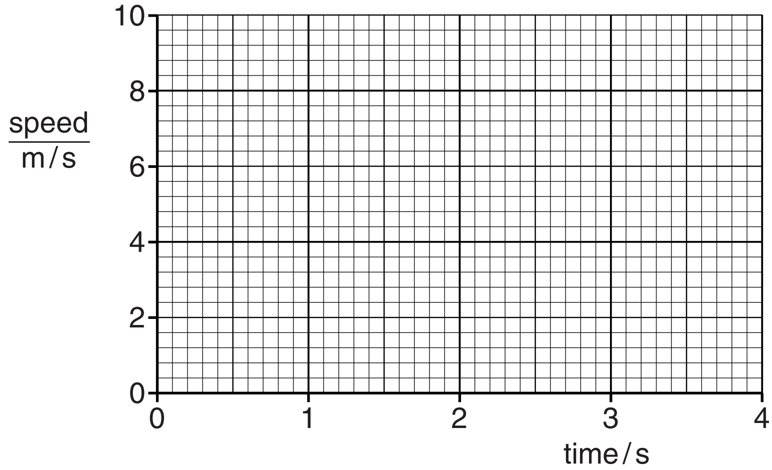


Fig. 1.2

On Fig. 1.2, draw

(i) the graph of the motion for the first 2 s as shown in Fig. 1.1,

(ii) an extension of the graph for the next 2 s, showing the object accelerating at 2 m / s^2.
[3]

(d) Describe how a speed / time graph shows an object that is stationary.

....

.... [2]

[Total: 9]

2.2 Uniformly accelerated motion

1 The speed of a cyclist reduces uniformly from 2.5 m/s to 1.0 m/s in 12 s.

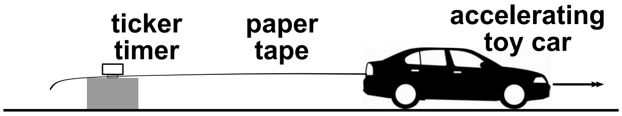
(a) Calculate the deceleration of the cyclist.

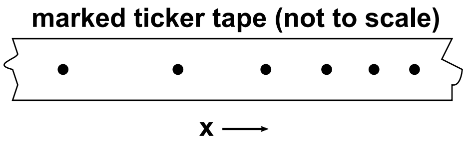
deceleration = ...[3]

(b) Calculate the distance travelled by the cyclist in this time.

distance = ...[2]

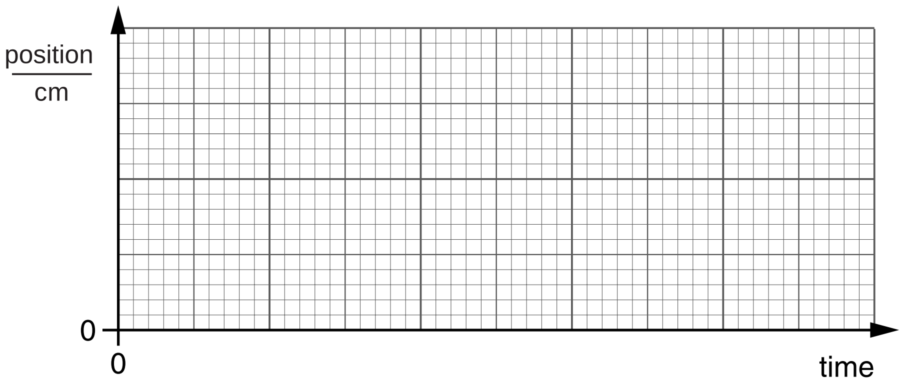
2 A toy car accelerates uniformly from rest. Attached to the car is a paper ticker tape that is marked by a ticker timer at evenly spaced time intervals. Times and locations of the ticker marks are shown in the table below.





t / s	x / cm
0.0	0.00
0.1	1.2
0.2	5.0
0.3	11.3
0.4	19.8
0.5	32.0

(a) Plot a graph of the position of the car as a function of time.



[2]

(b) (i) Which feature of a position versus time graph gives the speed of an object?

.... [1]

(ii) From the above graph, approximate the speed of the car at both t = 0.2 s and t = 0.4 s. Be sure to show all your work.

v_2 = ...[2]

v_4 = ...[1]

(c) Calculate an estimate of the acceleration of the car, stating all assumptions, and showing all work.

[3]

[Total: 9]

2.3 The speed-time graph

1 A small rubber ball falls vertically, hits the ground and rebounds vertically upwards.
Fig.1 is the speed-time graph for the ball.

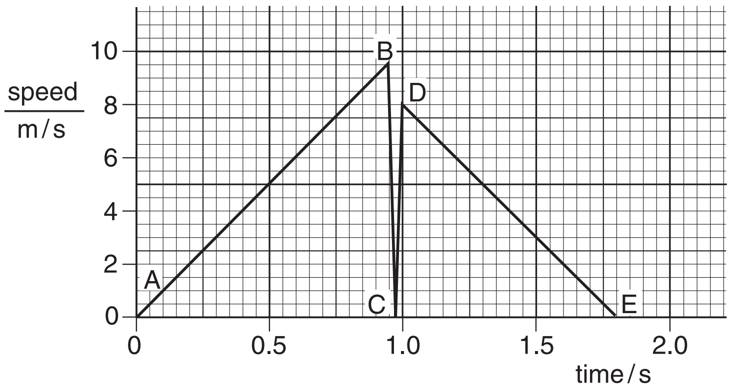


Fig. 1

(a) Using information from the graph, describe the following parts of the motion of the ball.

(i) part AB

....

....

....

(ii) part DE

....

....

....
[3]

(b) Explain what is happening to the ball along the part of the graph from B through C to D.

....

....

.... [2]

(c) Whilst the ball is in contact with the ground, what is the

(i) overall change in speed,

change in speed = ...

(ii) overall change in velocity?

change in velocity = ...
[2]

(d) Use your answer to **(c)** to explain the difference between speed and velocity.

....

....

.... [2]

(e) Use the graph to calculate the distance travelled by the ball between D and E.

distance travelled = ...[2]

(f) Use the graph to calculate the deceleration of the ball between D and E.

deceleration = ...[2]

2 Fig. 1.1 shows the speed-time graph for a bus during tests.

At time $t = 0$, the driver starts to brake.

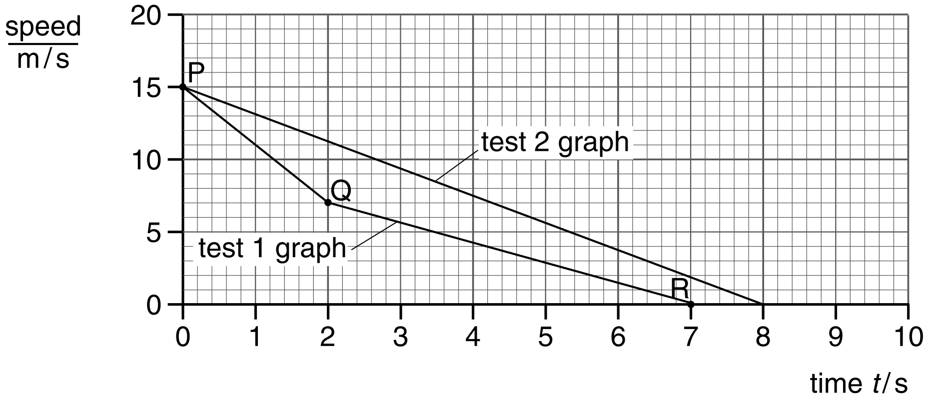


Fig. 1.1

(a) For test 1,

(i) determine how long the bus takes to stop,

....

(ii) state which part of the graph shows the greatest deceleration,

....

(iii) use the graph to determine how far the bus travels in the first 2 seconds.

distance = ...
[4]

(b) For test 2, a device was fitted to the bus. The device changed the deceleration.

(i) State two ways in which the deceleration during test 2 is different from that during test 1.

1 ....

2 ....

(ii) Calculate the value of the deceleration in test 2.

deceleration = ...
[4]

(c) Fig. 1.2 shows a sketch graph of the magnitude of the acceleration for the bus when it is travelling around a circular track at constant speed.

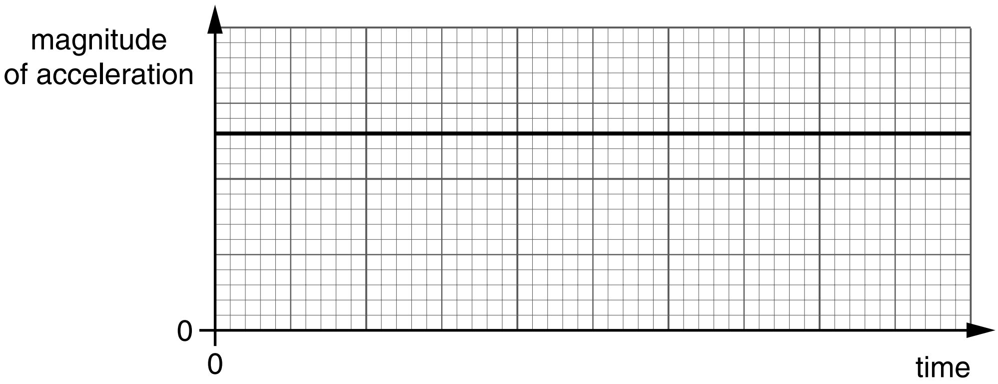


Fig. 1.2

(i) Use the graph to show that there is a force of constant magnitude acting on the bus.

....

....

(ii) State the direction of this force.

....

[3]

3 Fig. 1.1 shows a cycle track.

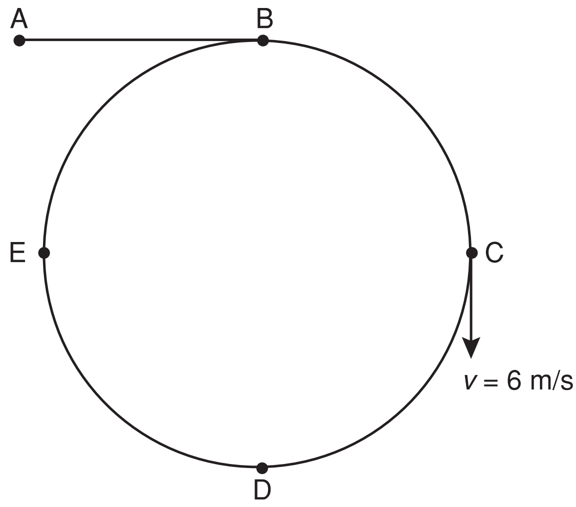


Fig. 1.1

A cyclist starts at A and follows the path ABCDEB.

The speed-time graph is shown in Fig. 1.2.

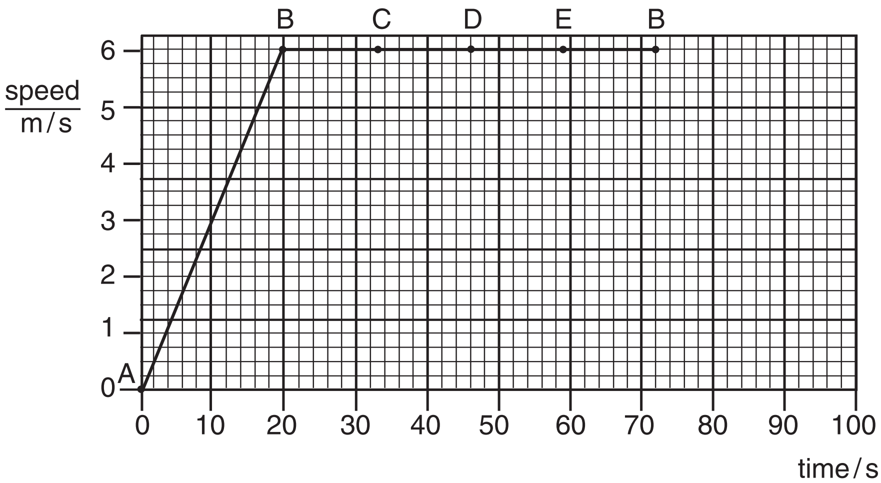


Fig. 1.2

(a) Use information from Fig. 1.1 and Fig. 1.2 to describe the motion of the cyclist

(i) along AB,

....

(ii) along BCDEB.

....

....
[4]

(b) The velocity *v* of the cyclist at C is shown in Fig. 1.1.

State one similarity and one difference between the velocity at C and the velocity at E.

similarity ....

difference ....[2]

(c) Calculate

(i) the distance along the cycle track from A to B,

distance = …………………

(ii) the circumference of the circular part of the track.

circumference = …………………
[4]

4 Fig. 1.1 shows the path of one drop of water in the jet from a powerful hose.

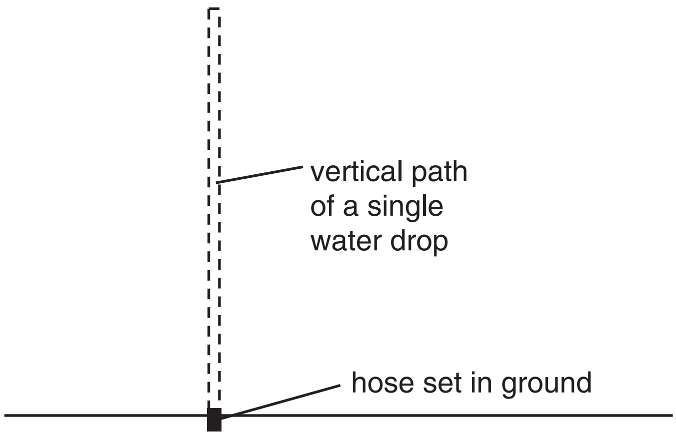


Fig. 1.1

Fig. 1.2 is a graph of speed against time for the water drop shown in Fig. 1.1.

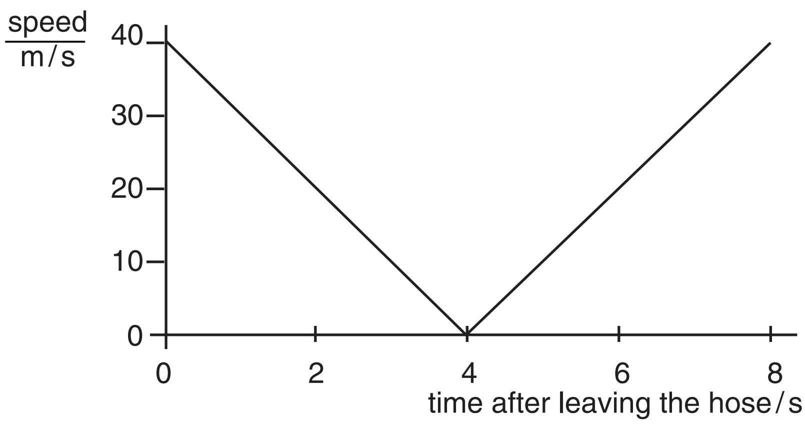


Fig. 1.2

(a) Describe the movement of the water drop in the first 4 s after leaving the hose.

....

....

....[2]

(b) Use Fig. 1.2 to find

(i) the speed of the water leaving the hose,

speed = …………………...

(ii) the time when the speed of the water is least.

time = ……………………..

[2]

(c) Use values from Fig. 1.2 to calculate the acceleration of the drop as it falls back towards the ground. Show your working.

acceleration = ……………………...[3]

(d) Calculate the greatest distance above the ground reached by the drop.

distance = ……………………...[3]

5 **(a)** A stone falls from the top of a building and hits the ground at a speed of 32 m/s.
The air resistance-force on the stone is very small and may be neglected.

(i) Calculate the time of fall.

time = ...

(ii) On Fig. 1.1, draw the speed-time graph for the falling stone.

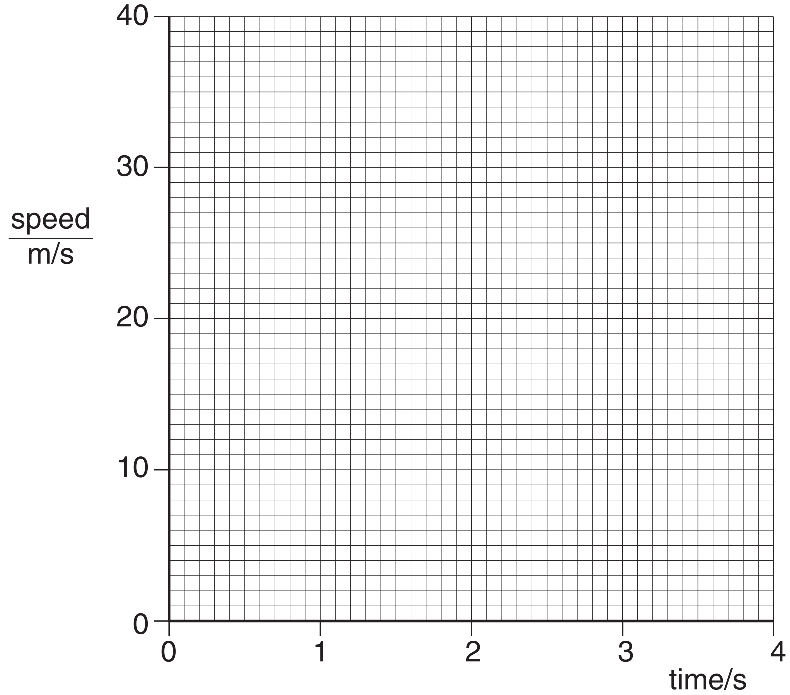


Fig. 1.1

(iii) The weight of the stone is 24 N.
Calculate the mass of the stone.

mass = ...

[5]

(b) A student used a suitable measuring cylinder and a spring balance to find the density of a sample of the stone.

(i) Describe how the measuring cylinder is used, and state the readings that are taken.

....

....

....

....

(ii) Describe how the spring balance is used, and state the reading that is taken.

....

....

(iii) Write down an equation from which the density of the stone is calculated.

....

(iv) The student then wishes to find the density of cork. Suggest how the apparatus and the method would need to be changed.

....

....

....

[6]

6 Fig. 1.1 shows a model car moving clockwise around a horizontal circular track.

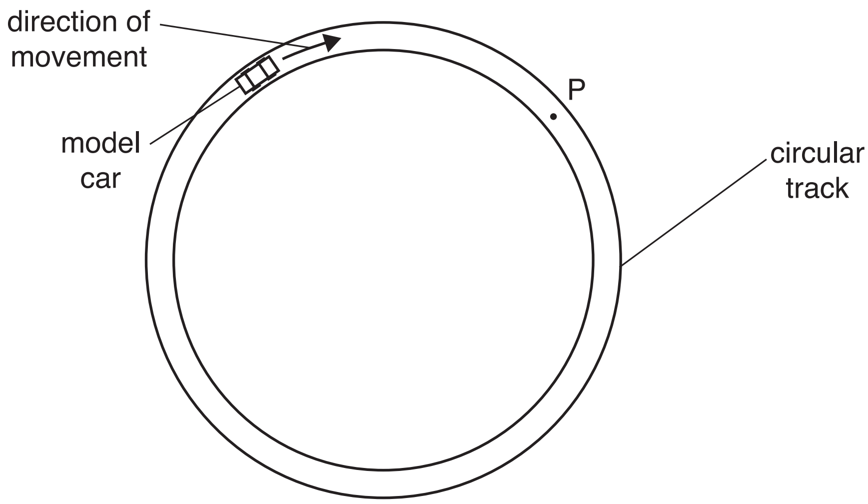


Fig. 1.1

(a) A force acts on the car to keep it moving in a circle.

(i) Draw an arrow on Fig. 1.1 to show the direction of this force. [1]

(ii) The speed of the car increases. State what happens to the magnitude of this force.

.... [1]

(b) (i) The car travels too quickly and leaves the track at P. On Fig. 1.1, draw an arrow to show the direction of travel after it has left the track. [1]

(ii) In terms of the forces acting on the car, suggest why it left the track at P.

....

....

.... [2]

(c) The car, starting from rest, completes one lap of the track in 10 s. Its motion is shown graphically in Fig. 1.2.

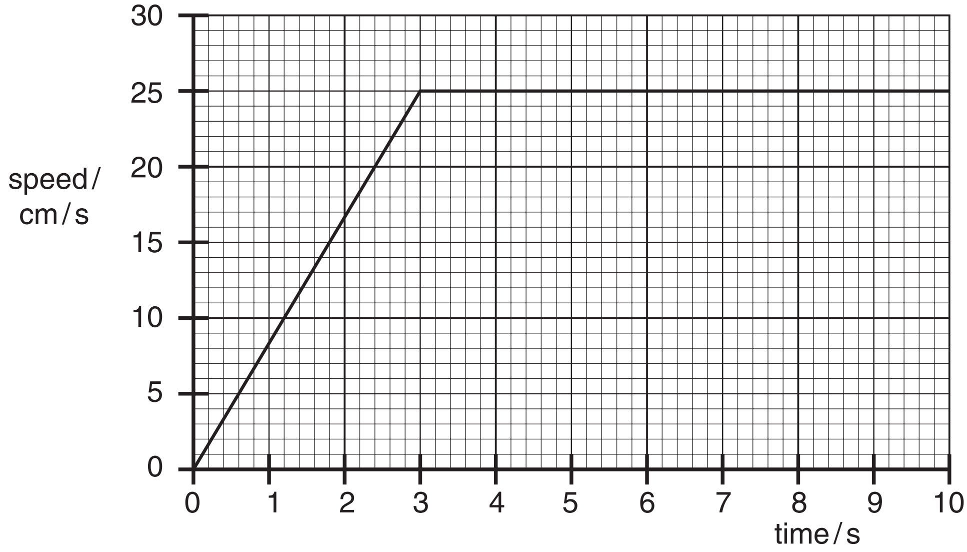


Fig. 1.2

(i) Describe the motion between 3.0 s and 10.0 s after the car has started.

.... [1]

(ii) Use Fig. 1.2 to calculate the circumference of the track.

circumference = ... [2]

(iii) Calculate the increase in speed per second during the time 0 to 3.0 s.

increase in speed per second = ... [2]

[Total: 10]

7 Fig. 1.1 shows the speed/time graph for a car travelling along a straight road.

The graph shows how the speed of the car changes as the car passes through a small town.

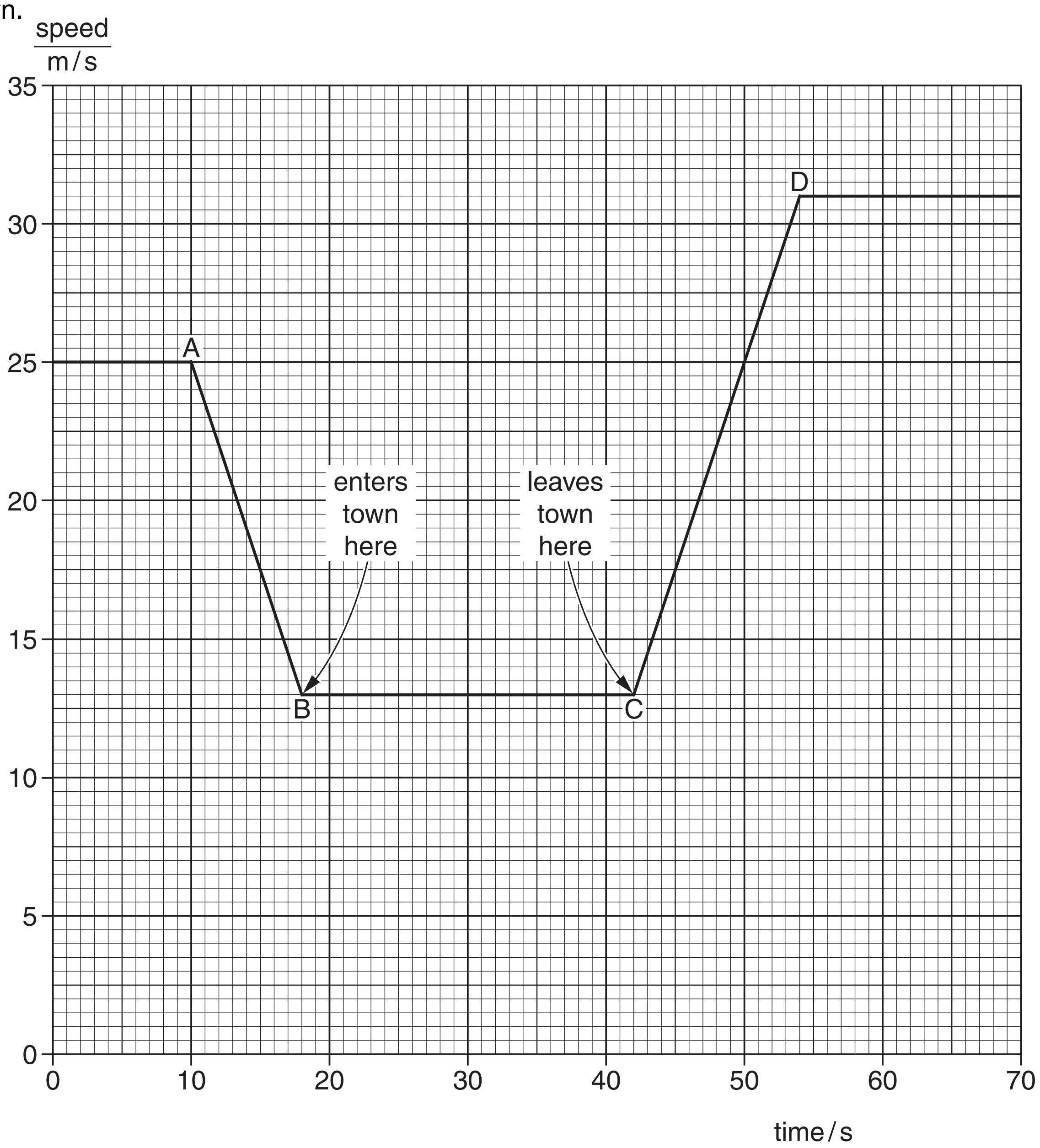


Fig. 1.1

(a) Describe what happens to the speed of the car

(i) between A and B, ...

(ii) between B and C, ...

(iii) between C and D. ....

[1]

(b) Calculate the distance between the start of the town and the end of the town.

distance = ... [3]

(c) Calculate the acceleration of the car between C and D.

acceleration = ... [3]

(d) State how the graph shows that the deceleration of the car has the same numerical value as its acceleration.

....

.... [1]

[Total: 8]

8 **(a)** Define *acceleration*. Explain any symbols in your definition.

....

....[1]

(b) Fig. 1.1 shows a graph of speed against time for a train. After 100 s the train stops at a station.

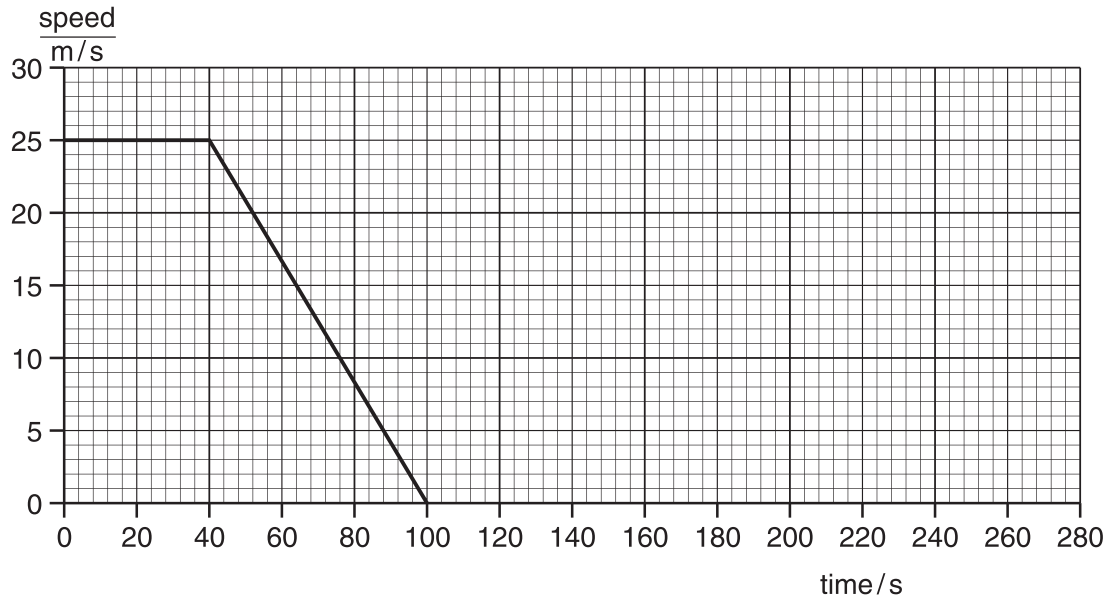


Fig. 1.1

(i) For the time interval between 40 s and 100 s, calculate the distance travelled by the train.

distance = ...[2]

(ii) The train stops for 80 s, then accelerates to 30 m/s with an acceleration of 0.60 m/s^2. It then travels at constant speed.

Complete the graph for the interval 100 s to 280 s, showing your calculations in the space below.

[5]

[Total: 8]

2.4 The distance-time graph

1 A girl rides her bicycle along a straight level road. Fig. 2.1 shows a graph of her distance moved against time.

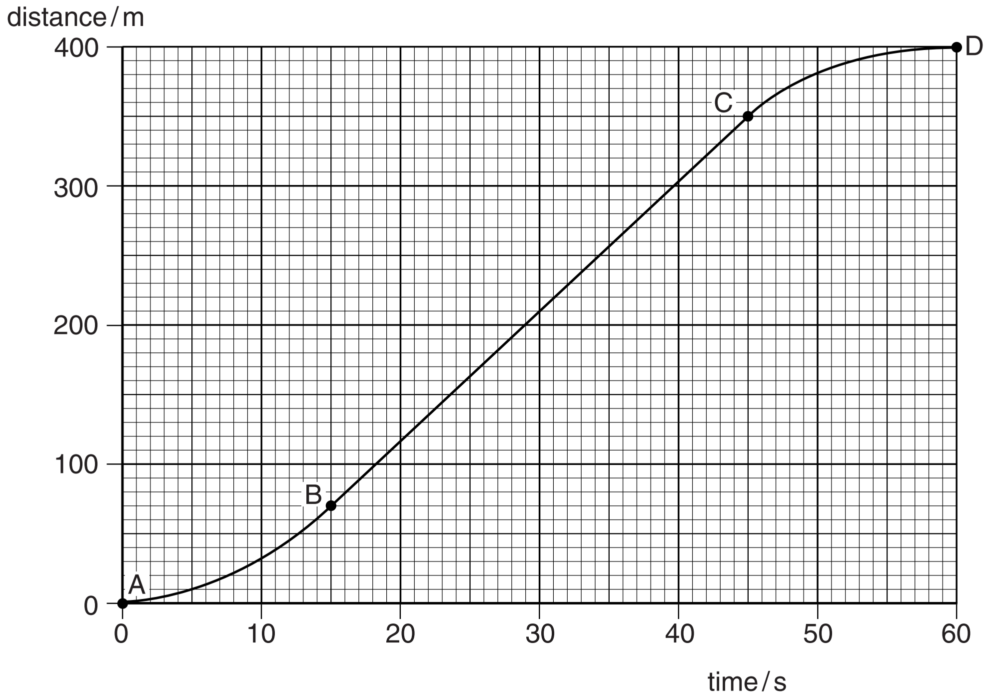


Fig. 2.1

(a) Describe her motion

(i) from A to B, ...

(ii) from B to C, ...

(iii) from C to D. ....
[3]

(b) Calculate

(i) her average speed from A to D,

average speed = ... [2]

(ii) her maximum speed.

maximum speed = ... [3]

[Total: 8]

Chapter 3. Forces and motion

1.3 Mass and weight

Core

1 State that mass is a measure of the quantity of matter in an object at rest relative to the observer

2 State that weight is a gravitational force on an object that has mass

3 Define gravitational field strength as force per unit mass; recall and use the equation

$$g = \frac{W}{m}$$

and know that this is equivalent to the acceleration of free fall

4 Know that weights (and masses) may be compared using a balance

Supplement

5 Describe, and use the concept of, weight as the effect of a gravitational field on a mass

1.5 Forces

1.5.1 Effects of forces

Core

3 Determine the resultant of two or more forces acting along the same straight line

4 Know that an object either remains at rest or continues in a straight line at constant speed unless acted on by a resultant force

5 State that a resultant force may change the velocity of an object by changing its direction of motion or its speed

6 Describe solid friction as the force between two surfaces that may impede motion and produce heating

7 Know that friction (drag) acts on an object moving through a liquid

8 Know that friction (drag) acts on an object moving through a gas (e.g. air resistance)

Supplement

11 Recall and use the equation $F = ma$ and know that the force and the acceleration are in the same direction

12 Describe, qualitatively, motion in a circular path due to a force perpendicular to the motion as:

(a) speed increases if force increases, with mass and radius constant

(b) radius decreases if force increases, with mass and speed constant

(c) an increased mass requires an increased force to keep speed and radius constant

($F = \dfrac{mv^2}{r}$ is **not** required)

1.1 Physical quantities and measurement techniques

Supplement

4 Understand that a scalar quantity has magnitude (size) only and that a vector quantity has magnitude and direction

5 Know that the following quantities are scalars: distance, speed, time, mass, energy and temperature

6 Know that the following quantities are vectors: force, weight, velocity, acceleration, momentum, electric field strength and gravitational field strength

7 Determine, by calculation or graphically, the resultant of two vectors at right angles, limited to forces or velocities only

1.6 Momentum

Core

Supplement

1 Define momentum as mass × velocity; recall and use the equation

$p = mv$

2 Define impulse as force × time for which force acts; recall and use the equation

impulse $= F\Delta t = \Delta(mv)$

3 Apply the principle of the conservation of momentum to solve simple problems in one dimension

4 Define resultant force as the change in momentum per unit time; recall and use the equation

$F = \dfrac{\Delta p}{\Delta t}$

3.1 Mass and weight

1 **(a)** State what is meant by the terms

(i) *weight,* ....

.... [1]

(ii) *mass,* ....

.... [1]

(iii) *density.* ....

.... [1]

(b) A student is given a spring balance that has a scale in newtons. The student is told that the acceleration of free-fall is $10\,m/s^2$.

(i) Describe how the student could find the mass of an irregular solid object.

....

....

.... [2]

(ii) Describe how the student could go on to find the density of the object.

....

....

....

.... [2]

(c) Fig. 1.1 shows three forces acting on an object of mass 0.5 kg. All three forces act through the centre of mass of the object.

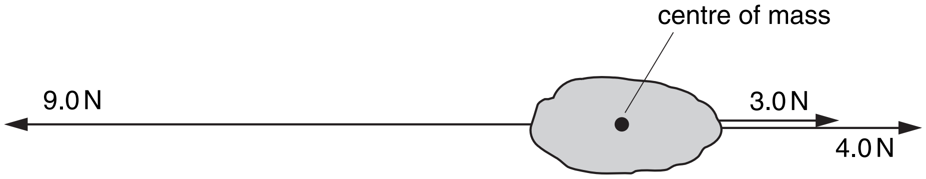


Fig. 1.1

Calculate

(i) the magnitude and direction of the resultant force on the object,

magnitude = ……………… direction .... [2]

(ii) the magnitude of the acceleration of the object.

acceleration =…………………… [2]

[Total 11

2 The apparatus shown in Fig. 5.1 is used to demonstrate how a coin and a piece of paper fall when they are released from rest.

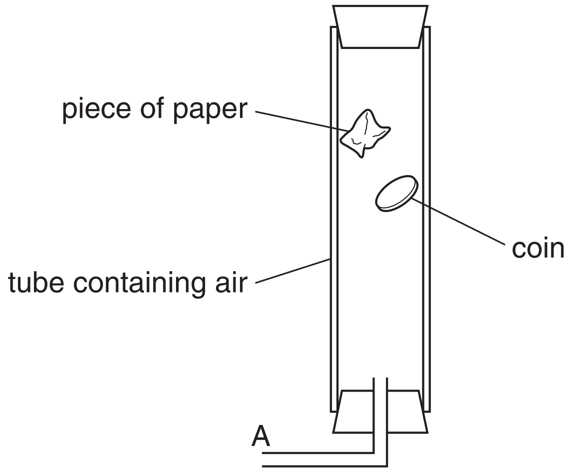


Fig. 5.1

(a) At the positions shown in Fig. 5.1, the paper is descending at constant speed but the coin still accelerates.

In terms of the forces acting, explain these observations.

paper ....

....

....

coin ....

....

.... [4]

(b) A vacuum pump is now connected at A and the air in the tube is pumped out.

The paper and coin are again made to fall from rest.

State one difference that would be observed, compared with what was observed when air was present.

....

.... [1]

[Total: 5]

3 An astronaut has a mass of 65 kg on Earth, where the gravitational field strength is 10 N/kg.

(a) Calculate the astronaut's weight on Earth.

weight on Earth = ...[2]

(b) Complete the following sentence.

The astronaut's weight on Earth is the .... force

between the astronaut and .... [1]

(c) The astronaut undertakes a Moon landing. On the Moon the gravitational field strength is 1.6 N/kg.

(i) State the astronaut's mass on the Moon.

mass = ...

(ii) Calculate the weight of the astronaut on the Moon.

weight on Moon = ...
[2]

[Total: 5]

3.2 Newton's second law of motion

1 A mass of 3.0 kg accelerates at 2.0 m/s^2 in a straight line.

(a) State why the velocity and the acceleration are both described as vector quantities.

....

.... [1]

(b) Calculate the force required to accelerate the mass.

force = ………………. [2]

(c) The mass hits a wall.
The average force exerted on the wall during the impact is 120 N.
The area of the mass in contact with the wall at impact is 0.050 m^2.
Calculate the average pressure that the mass exerts on the wall during the impact.

pressure = ………………. [2]

2 A bus travels from one bus stop to the next. The journey has three distinct parts. Stated in order they are

uniform acceleration from rest for 8.0 s,
uniform speed for 12 s,
non-uniform deceleration for 5.0 s.

Fig. 1.1 shows only the deceleration of the bus.

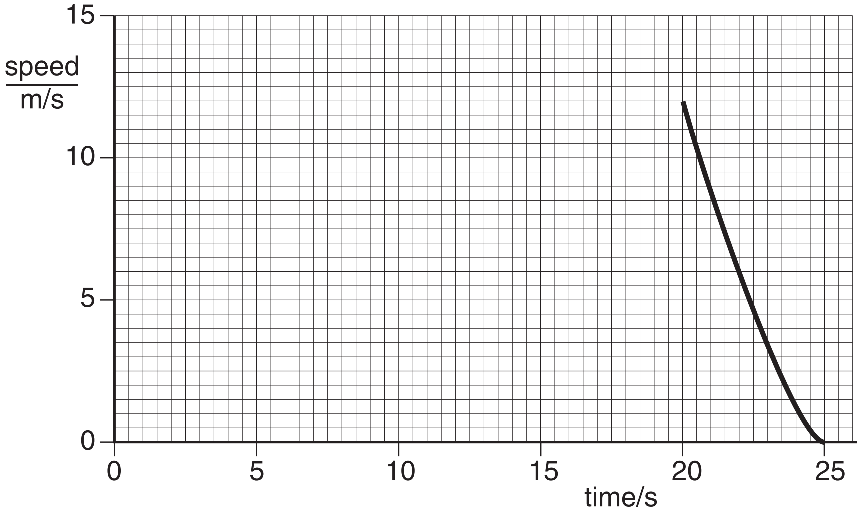


Fig. 1.1

(a) On Fig. 1.1, complete the graph to show the first two parts of the journey. [3]

(b) Calculate the acceleration of the bus 4.0 s after leaving the first bus stop.

acceleration = ...[2]

(c) Use the graph to estimate the distance the bus travels between 20 s and 25 s.

estimated distance = ...[2]

(d) On leaving the second bus stop, the uniform acceleration of the bus is 1.2 m/s^2. The mass of the bus and passengers is 4000 kg.
Calculate the accelerating force that acts on the bus.

force = ...[2]

(e) The acceleration of the bus from the second bus stop is less than that from the first bus stop.
Suggest two reasons for this.

1. ....

....

2. ....

....[2]

3 Fig. 1.1 shows apparatus used to find a relationship between the force applied to a trolley and the acceleration caused by the force.

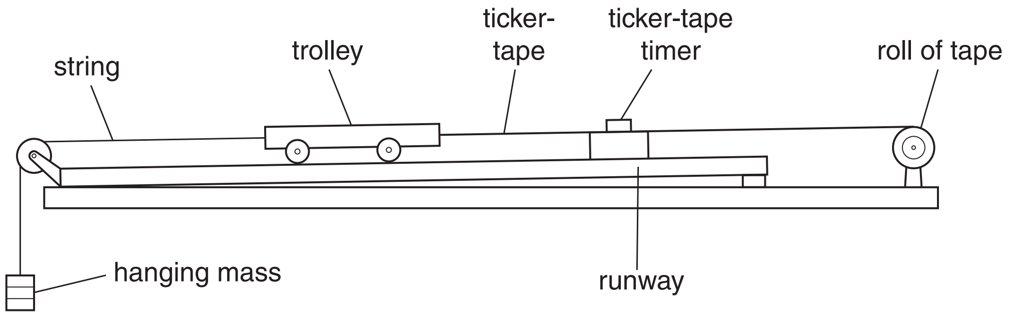


Fig. 1.1

For each mass, hung as shown, the acceleration of the trolley is determined from the tape. Some of the results are given in the table below.

weight of the hanging mass/N	acceleration of the trolley m/s^2
0.20	0.25
0.40	0.50
0.70	
0.80	1.0

(a) **(i)** Explain why the trolley accelerates.

....

.... [2]

(ii) Suggest why the runway has a slight slope as shown.

....

.... [1]

(b) Calculate the mass of the trolley, assuming that the accelerating force is equal to the weight of the hanging mass.

mass = ... [2]

(c) Calculate the value missing from the table. Show your working.

value = ... [2]

(d) In one experiment, the hanging mass has a weight of 0.4 N and the trolley starts from rest.

Use data from the table to calculate

(i) the speed of the trolley after 1.2 s,

speed = ... [2]

(ii) the distance travelled by the trolley in 1.2 s.

distance = ... [2]

[Total: 11]

4 **(a)** A truck of mass 12 kg is rolling down a very slight incline as shown in Fig. 1.1.

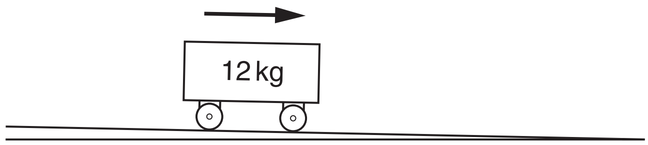


Fig. 1.1

The truck travels at constant speed.

Explain why, although the truck is on an incline, it nevertheless does not accelerate.

....

.... [1]

(b) The slope of the incline is increased. As a result of this, the truck now accelerates.

(i) Explain why there is now acceleration.

....

.... [1]

(ii) Write down an equation linking the resultant force on the truck and the acceleration of the truck.

[1]

(iii) The truck's acceleration is 2.0 m/s^2.

Calculate the resultant force on the truck.

resultant force = ... [2]

(c) The friction force up the slope in **(b)(iii)** was 14.0 N.

By suitable lubrication, the friction force is now almost totally removed.

(i) Calculate the new acceleration of the truck.

acceleration = ... [3]

(ii) The lubricated truck travels down the incline, starting from rest at the top of the incline. It takes 2.5 s to reach the bottom of the incline.

Calculate its speed as it reaches the bottom of the incline.

speed = ... [2]

(d) The incline is reduced to the original value and the lubricated truck is placed on it.

Describe the motion of the truck when it is released.

....

....

....

.... [1]

[Total: 11]

5 **(a)** A force acting on an object causes the object to accelerate.

In which direction is the acceleration?

.... [1]

(b) Any object moving in a circle has a force acting on it towards the centre of the circle.

What does this force do to the object?

.... [1]

(c) A woman of mass 60 kg is standing in a lift at a shopping centre.

(i) The lift is at rest.

1. State the value of the weight of the woman.

.... [1]

2. State the value of the force exerted on the woman by the floor of the lift.

.... [1]

(ii) Calculate the force required to accelerate a mass of 60 kg at 2.5 m/s^2.

force = ... [2]

(iii) The lift accelerates upwards at 2.5 m/s^2.

Calculate the force exerted on the woman by the floor when the lift is accelerating.

force = ... [1]

(iv) The lift reaches a steady upward speed.

State the value of the force exerted on the woman by the floor at this steady speed.

.... [1]

[Total: 8]

6 Fig. 4.1 illustrates an object on a string being whirled anticlockwise in a vertical circle.

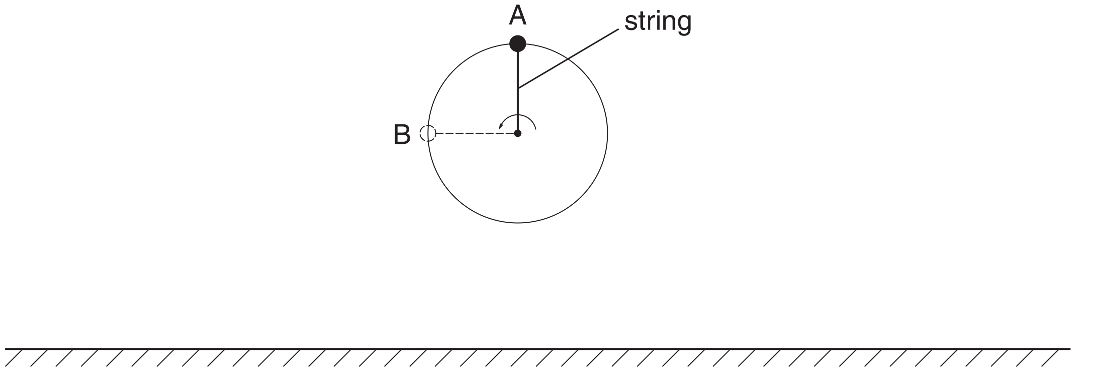


Fig. 4.1

The lowest point of the circle is a small distance above the ground. The diagram shows the object at the top A of the circle, and at B, when it is at the same height as the centre of the circle.

(a) On Fig. 4.1, mark clearly

(i) the force of the string on the object

1. at A,

2. at B. [2]

(ii) the path the object would take until it hit the ground, if the string broke

1. at A,

2. at B. [3]

(b) The mass of the object is 0.05 kg. At A, the tension in the string is 3.6 N.

(i) Calculate the weight of the object.

weight = ... [1]

(ii) Calculate the total force on the object at A.

total force = ... [2]

[Total: 8]

7 Two students make the statements about acceleration that are given below.

Student A: For a given mass the acceleration of an object is proportional to the resultant force applied to the object.

Student B: For a given force the acceleration of an object is proportional to the mass of the object.

(a) One statement is correct and one is incorrect.

Re-write the incorrect statement, making changes so that it is now correct.

For a given .... the acceleration of an object is ....

.... [1]

(b) State the equation which links acceleration *a*, resultant force *F* and mass *m*.

[1]

(c) Describe what happens to the motion of a moving object when

(i) there is no resultant force acting on it,

.... [1]

(ii) a resultant force is applied to it in the opposite direction to the motion,

.... [1]

(iii) a resultant force is applied to it in a perpendicular direction to the motion.

.... [1]

[Total: 5]

8 A car travels around a circular track at constant speed.

(a) Why is it incorrect to describe the circular motion as having constant velocity?

.... [1]

(b) A force is required to maintain the circular motion.

(i) Explain why a force is required.

....

....

.... [2]

(ii) In which direction does this force act?

.... [1]

(iii) Suggest what provides this force.

.... [1]

[Total: 5]

9 A hillside is covered with snow. A skier is travelling down the hill.

Fig. 1.1

The table below gives the values of the acceleration of the skier at various heights above the bottom of the hill.

height / m	350	250	150	50
$\frac{\text{acceleration}}{\text{m/s}^2}$	7.4	3.6	1.2	0

(a) On Fig. 1.2, plot the values given in the table, using dots in circles.

Draw the best curve for these points. [2]

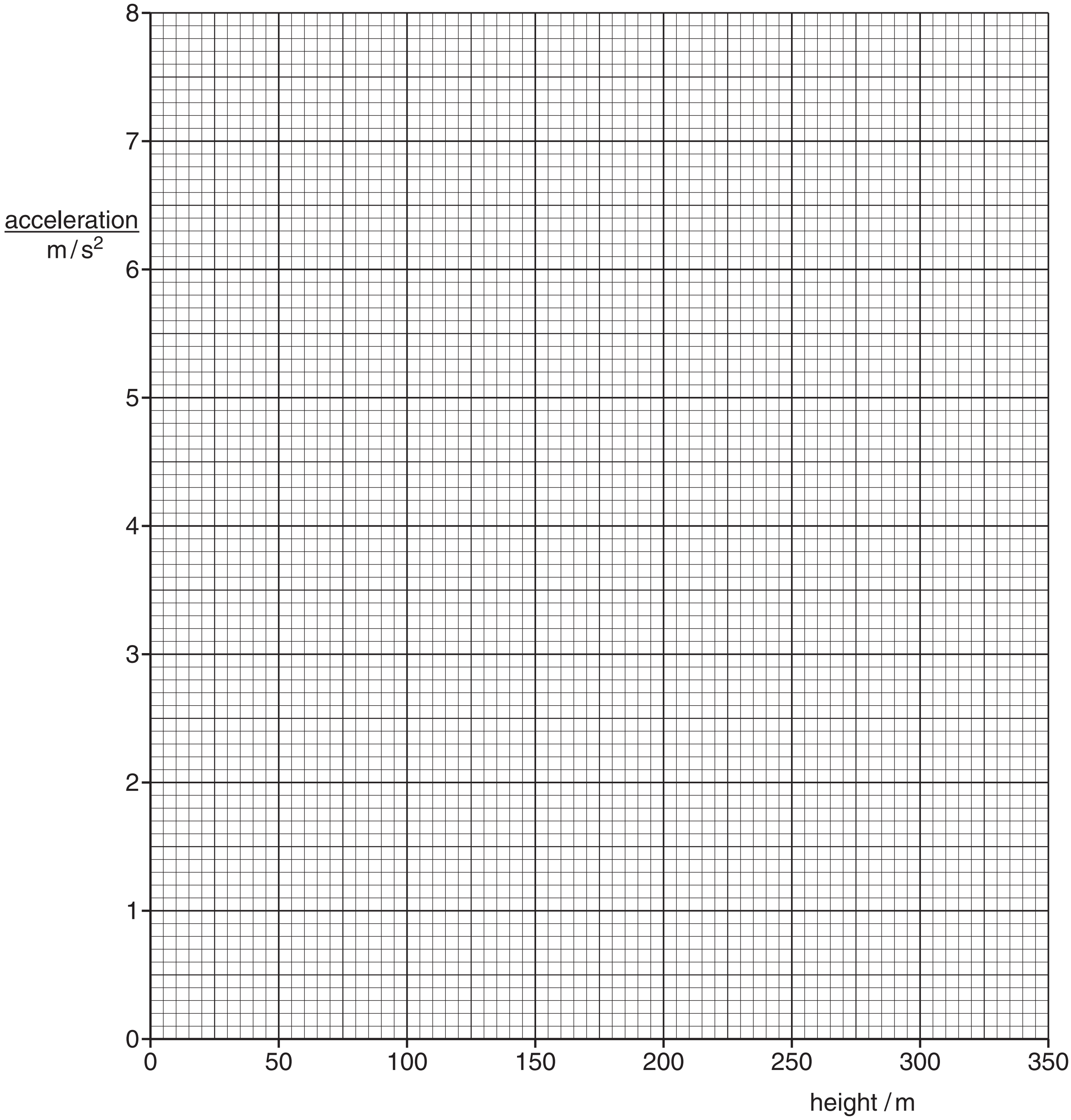


Fig. 1.2

(b) Describe what is happening, during the descent, to

(i) the acceleration of the skier,

....

....

.... [1]

(ii) the speed of the skier.

....

....

.... [1]

(c) The acceleration becomes zero before the skier reaches the bottom of the hill.

Use ideas about forces to suggest why this happens.

....

.... [1]

(d) Below a height of 50 m, further measurements show that the acceleration of the skier has a negative value.

What does this mean is happening to the speed of the skier in the last 50 m?

....

.... [1]

(e) The skier has a mass of 60 kg.

Calculate the resultant force on the skier at a height of 250 m.

resultant force = ... [3]

[Total: 9]

10 A young athlete has a mass of 42 kg. On a day when there is no wind, she runs a 100 m race in 14.2 s. A sketch graph (not to scale) showing her speed during the race is given in Fig. 1.1.

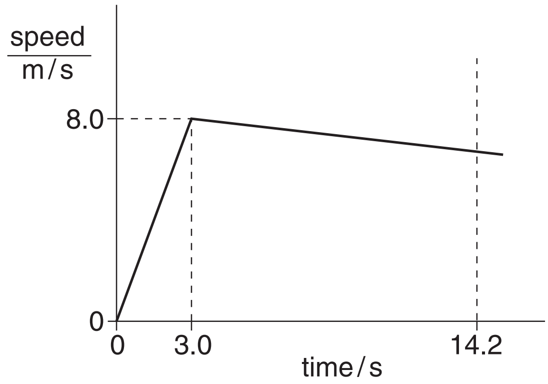


Fig. 1.1

(a) Calculate

(i) the acceleration of the athlete during the first 3.0 s of the race,

acceleration = ... [2]

(ii) the accelerating force on the athlete during the first 3.0 s of the race,

force = ... [2]

(iii) the speed with which she crosses the finishing line.

speed = ... [3]

(b) Suggest two differences that might be seen in the graph if there had been a strong wind opposing the runners in the race.

1. ....

....

2. ....

.... [2]

[Total: 9]

11 In a laboratory, an experiment is carried out to measure the acceleration of a trolley on a horizontal table, when pulled by a horizontal force.

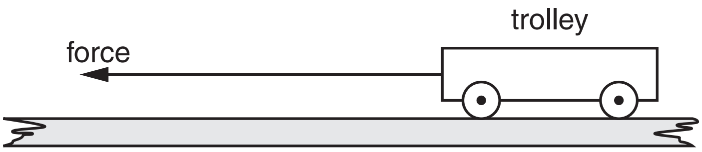


Fig. 1.1

The measurements are repeated for a series of different forces, with the results shown in the table below.

force / N	4.0	6.0	10.0	14.0
acceleration / m/s^2	0.50	0.85	1.55	2.25

(a) On Fig. 1.2, plot these points and draw the best straight line for your points. [2]

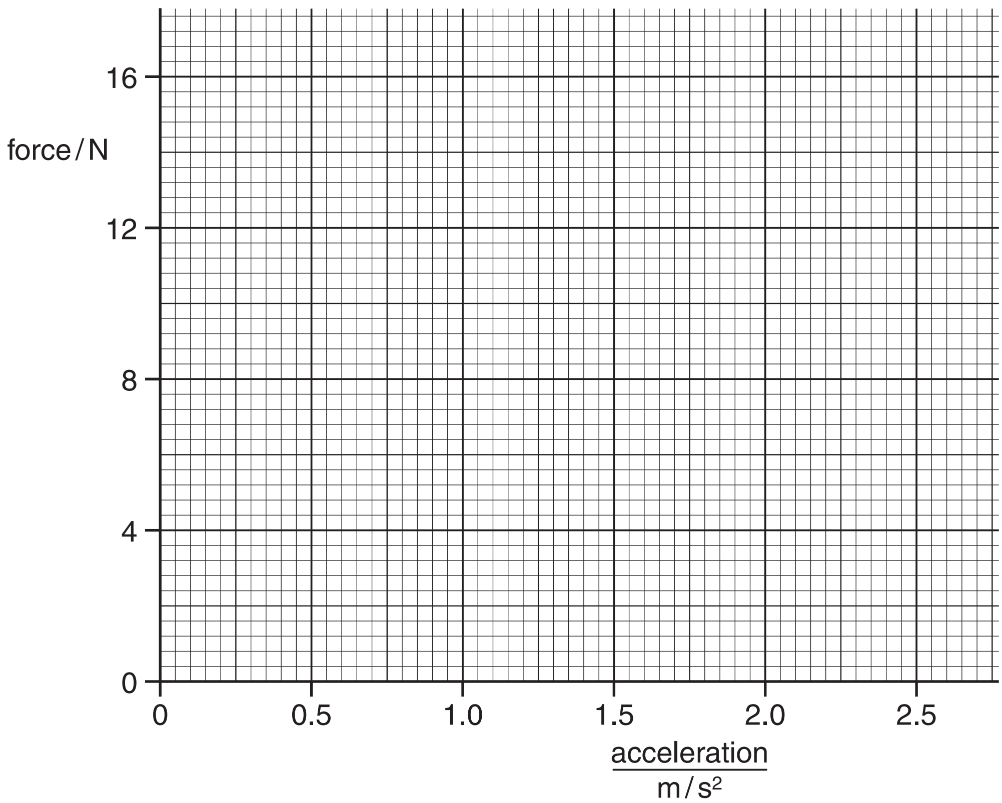


Fig. 1.2

(b) The graph shows that below a certain force there is no acceleration.

(i) Find the value of this force. ....[1]

(ii) A force smaller than that in **(b)(i)** is applied to the stationary trolley. Suggest what happens to the trolley, if anything.

....[1]

(c) Show that the gradient of your graph is about 5.7.

gradient = ...[1]

(d) **(i)** State the equation that links resultant force F, mass m and acceleration a.

[1]

(ii) Use your gradient from **(c)** to find the mass of the trolley.

mass = ...[2]

(e) On Fig. 1.3, sketch a speed/time graph for a trolley with constant acceleration.

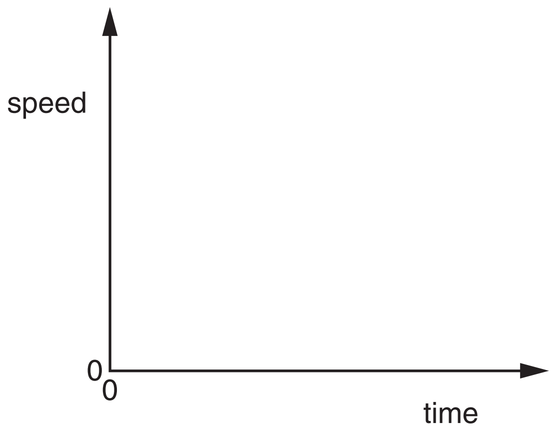


Fig. 1.3

[1]

[Total: 9]

12 Fig. 1.1 shows the graph of speed v against time t for a train as it travels from one station to the next.

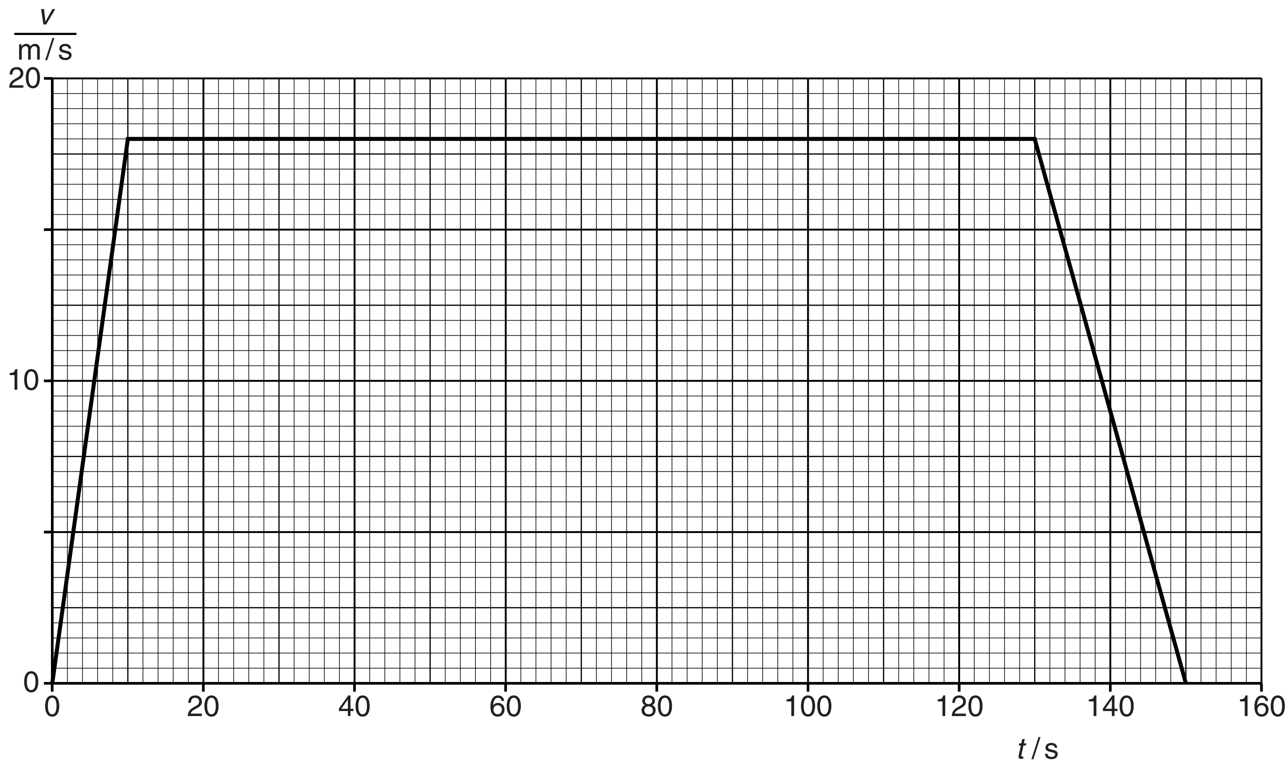


Fig. 1.1

(a) Use Fig. 1.1 to calculate

(i) the distance between the two stations,

distance = ... [4]

(ii) the acceleration of the train in the first 10 s.

acceleration = ... [2]

(b) The mass of the train is 1.1×10^5 kg.

Calculate the resultant force acting on the train in the first 10 s.

resultant force = ... [2]

(c) The force generated by the engine of the train is called the driving force.

Write down, in words, an equation relating the driving force to any other forces acting on the train during the period $t = 10$ s to $t = 130$ s.

.... [1]

[Total: 9]

13 Fig. 2.1 is a head-on view of an airliner flying at constant speed in a circular horizontal path. The centre of the circle is to the left of the diagram.

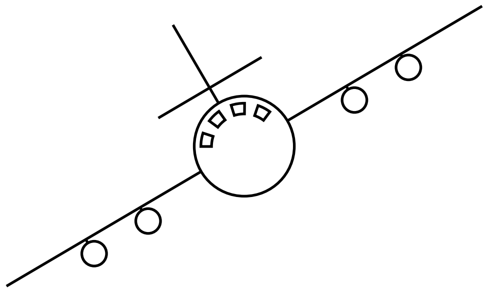


Fig. 2.1

(a) On Fig. 2.1, draw the resultant force acting on the airliner. Explain your answer.

....

....

.... [3]

(b) The weight of the airliner is 1.20×10^6 N and there is an aerodynamic lift force of 1.39×10^6 N acting at 30° to the left of the vertical.

By drawing a scale vector diagram, or otherwise, show that the resultant of these two forces is in the same direction as the resultant force you drew in **(a)**.

[3]

(c) The speed is constant as the airliner flies in this circular path.

State and explain what is happening to the velocity.

....

....

....

.... [2]

[Total: 8]

14 Fig. 2.1 shows a dummy of mass 70 kg used in a crash test to investigate the safety of a new car.

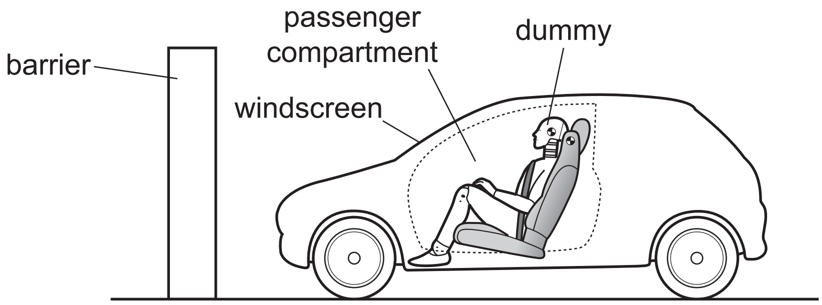


Fig. 2.1

The car approaches a solid barrier at 50 km/hr. It crashes into the barrier and stops suddenly.

(a) **(i)** Calculate the momentum of the dummy immediately before the crash.

momentum = ... [2]

(ii) Determine the impulse that must be applied to the dummy to bring it to rest.

impulse = ... [1]

(b) In the crash test, the passenger compartment comes to rest in 0.30s.

Calculate the deceleration of the passenger compartment.

deceleration = ... [2]

(c) The seat belt and air bag bring the dummy to rest so that it does not hit the windscreen. The dummy has an average deceleration of 25 m/s^2.

Calculate the average resultant force applied to the dummy, of mass 70 kg.

force = ... [2]

(d) The deceleration of the dummy is less than the deceleration of the passenger compartment.

Explain why this is of benefit for the safety of a passenger.

....

....

....

....

....

.... [2]

[Total: 9]

15 Fig.2.1 shows two cars, A and B, before they collide. In the rear carrying space of car B is a one cubic metre container filled with water.

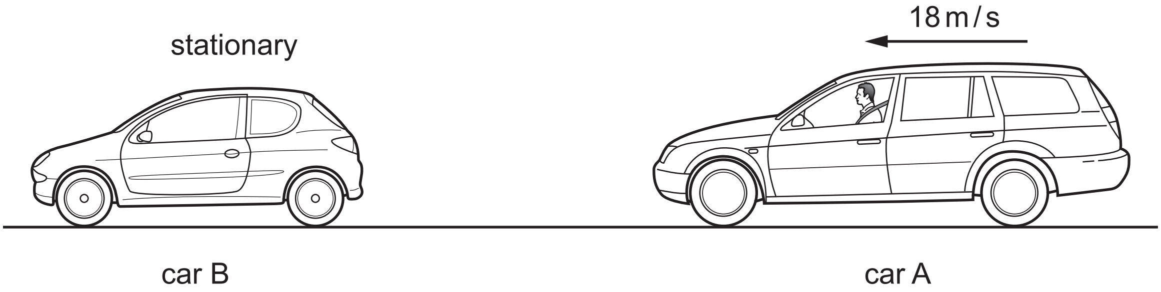


Fig. 2.1

Car B, of mass 1200 kg, is stationary. Car A, of mass 2000 kg, is travelling towards car B at 18 m/s.

(a) Calculate the momentum of car A.

momentum = ... [2]

(b) The cars collide and car B experiences an impulse. Car A continues to move in the same direction, with a momentum of 21 000 kg m / s.

(i) Calculate the momentum of car B immediately after the collision.

momentum = ... [1]

(ii) Determine the average impulse experienced by car B during the collision.

impulse = ... [1]

(iii) The cars are in contact for 0.20 s.

Calculate the average resultant force experienced by car B during the collision.

force = ... [2]

(c) A modern car is designed so that, during a collision, the front section of the car is crushed and the time of contact increases.

Explain the benefit of increasing the time of contact for the people in the car.

....

....

....

.... [2]

[Total: 8]

3.3 Object falling in air

1 A solid plastic sphere falls towards the Earth.

Fig. 1.1 is the speed-time graph of the fall up to the point where the sphere hits the Earth's surface.

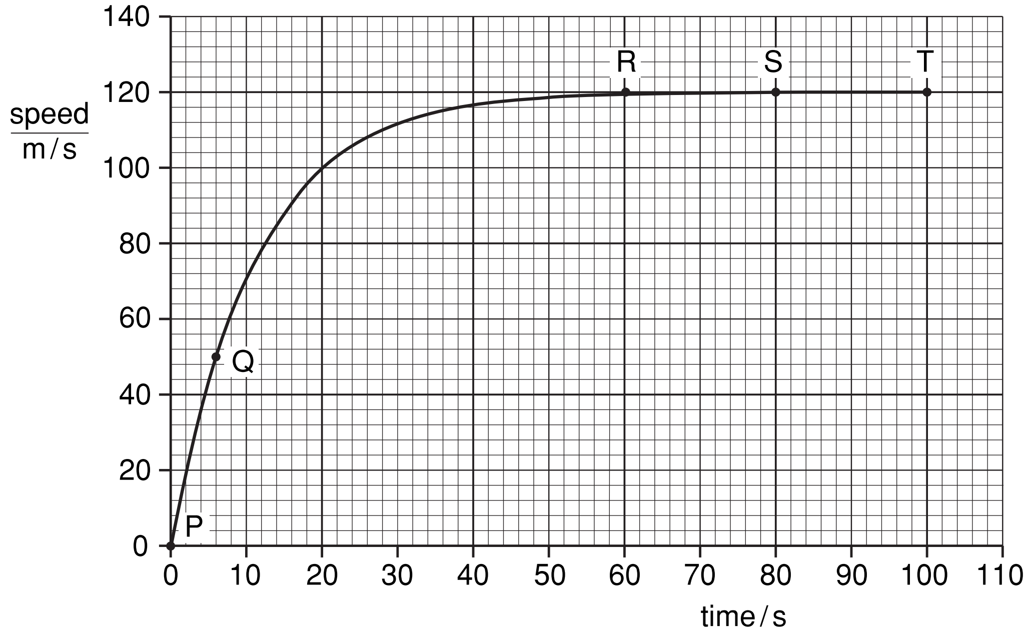


Fig. 1.1

(a) Describe in detail the motion of the sphere shown by the graph.

....

....

....

....

.... [3]

(b) On Fig. 1.2, draw arrows to show the directions of the forces acting on the sphere when it is at the position shown by point S on the graph. Label your arrows with the names of the forces. [2]

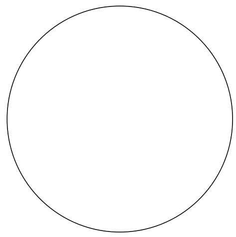


Fig. 1.2

(c) Explain why the sphere is moving with constant speed at S.

....

....

.... [2]

(d) Use the graph to calculate the approximate distance that the sphere falls

(i) between R and T,

distance = ………………. [2]

(ii) between P and Q.

distance = ………………. [2]

2 A large plastic ball is dropped from the top of a tall building.

Fig. 1.1 shows the speed-time graph for the falling ball until it hits the ground.

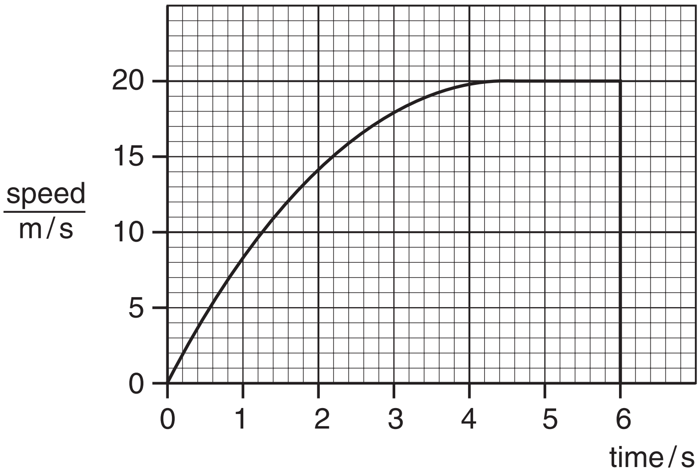


Fig. 1.1

(a) From the graph estimate,

(i) the time during which the ball is travelling with terminal velocity,

time = ... [1]

(ii) the time during which the ball is accelerating,

time = ... [1]

(iii) the distance fallen while the ball is travelling with terminal velocity,

distance = ... [2]

(iv) the height of the building.

height = ... [2]

(b) Explain, in terms of the forces acting on the ball, why

(i) the acceleration of the ball decreases,

....

....

....

.... [3]

(ii) the ball reaches terminal velocity.

....

.... [2]

[Total: 11]

3 Fig. 1.1 shows the speed-time graphs for two falling balls.

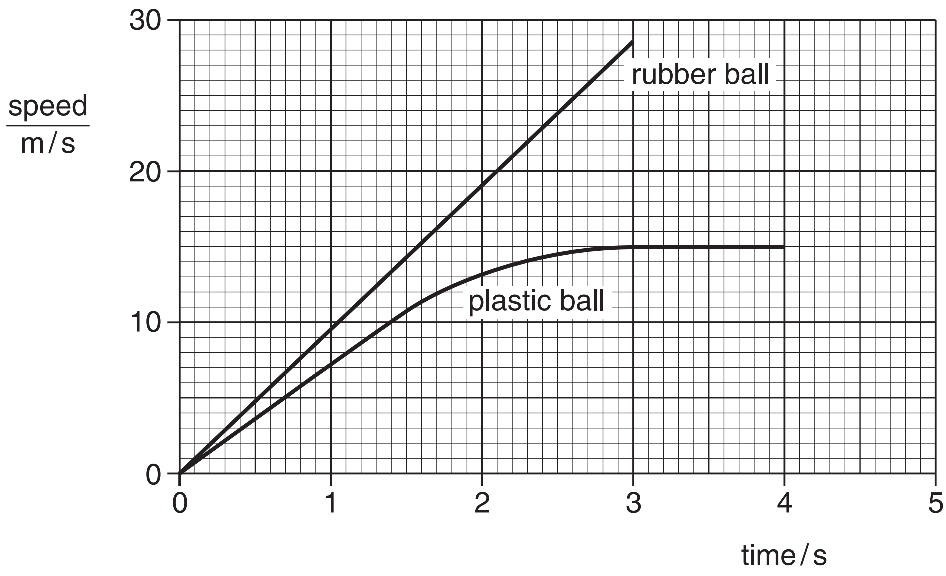


Fig. 1.1

Both balls fall from the same height above the ground.

(a) Use the graphs to find

(i) the average acceleration of the falling rubber ball during the first 3.0 s,

acceleration = ... [2]

(ii) the distance fallen by the rubber ball during the first 3.0 s,

distance = ... [2]

(iii) the terminal velocity of the plastic ball.

terminal velocity = ... [1]

(b) Both balls have the same mass but the volume of the plastic ball is much greater than that of the rubber ball. Explain, in terms of the forces acting on each ball, why the plastic ball reaches a terminal velocity but the rubber ball does not.

....

....

....

....

....

.... [3]

(c) The rubber ball has a mass of 50 g. Calculate the gravitational force acting on the rubber ball.

force = ... [2]

[Total: 10]

4 Fig. 1.1 shows the axes for a speed-time graph.

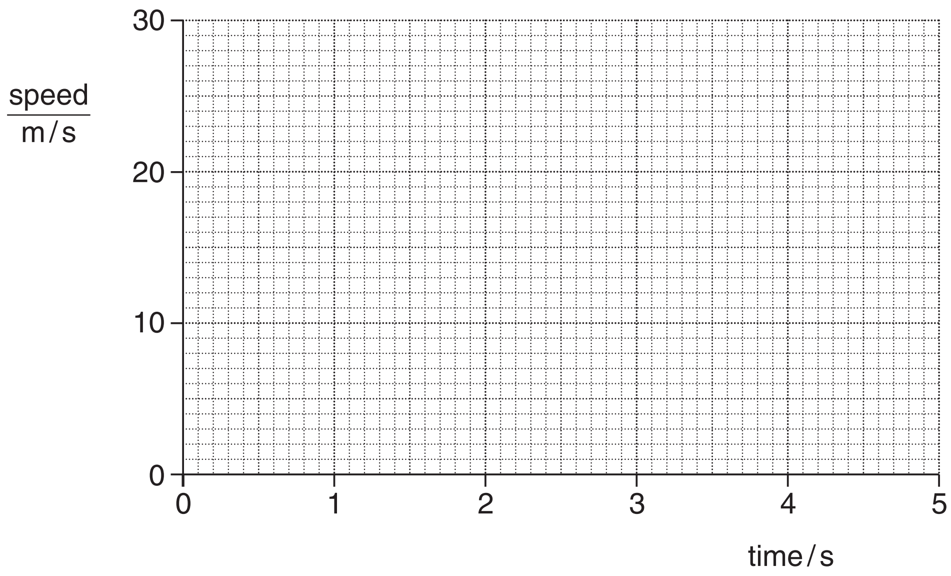


Fig. 1.1

(a) An object A falls freely from rest with the acceleration due to gravity (g = 9.81 m/s^2)
It is not affected by air resistance.

On Fig. 1.1, draw the graph of the motion of object A. [1]

(b) Using your graph, or an alternative method, calculate the distance fallen in the first 2 s by object A in part **(a)**.

distance fallen = ... [2]

(c) A second object B falls through the air from rest, but is affected by air resistance. It reaches a terminal velocity of 14 m/s.

On Fig. 1.1, draw a possible graph for object B, including the region where it is travelling at terminal velocity. [1]

(d) (i) Suggest a possible difference between objects A and B that could lead to B reaching a terminal velocity.

....

....

.... [1]

(ii) Explain, in terms of the forces on B, why B reaches a terminal velocity.

....

....

....

....

.... [2]

(e) Object A experiences a gravitational force of 2.0 N.

(i) State the value of the weight of A.

weight = ... [1]

(ii) Calculate the mass of A.

mass = ... [1]

(f) Object A is floating in equilibrium on a liquid.

State the value of the upward force of the liquid on A.

upward force = ... [1]

[Total: 10]

5 **(a)** Fig. 3.1 shows a skier descending a hillside. Fig. 3.2 shows the speed/time graph of his motion.

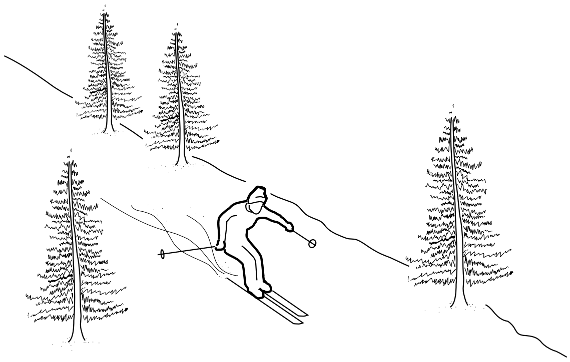


Fig. 3.1

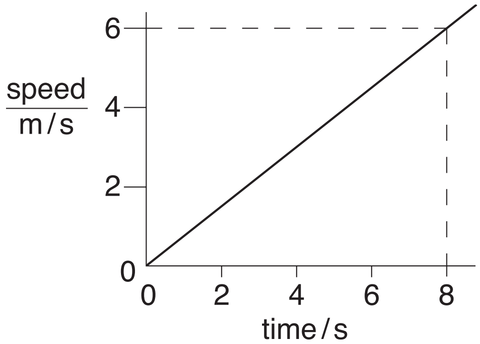


Fig. 3.2

(i) How can you tell that the acceleration of the skier is constant during the 8 s shown on the graph?

.... [1]

(ii) Calculate the acceleration of the skier.

acceleration = ... [2]

(b) Another skier starts from rest at the top of the slope. As his speed increases the friction force on the skier increases.

(i) State the effect of this increasing friction force on the acceleration.

.... [1]

(ii) Eventually the speed of the skier becomes constant.

What can be said about the friction force when the speed is constant?

.... [2]

(iii) 1. On the axes of Fig. 3.3, sketch a possible speed/time graph for the motion of the second skier.

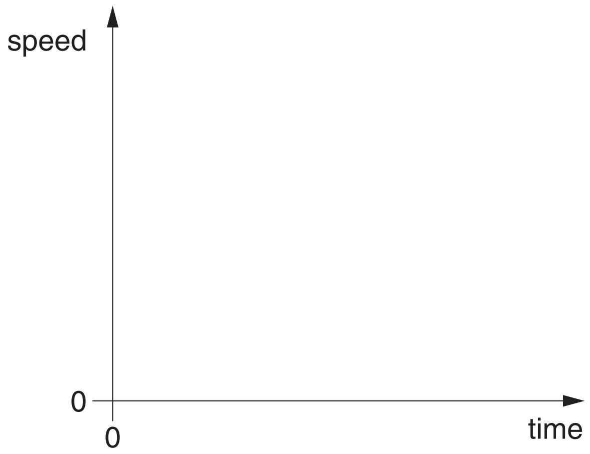


Fig. 3.3

2. On your graph, mark with the letter A a region where the acceleration is not constant. Mark with the letter B the region where the speed is constant. [4]

[Total: 10]

6 A free-fall parachutist jumps out of an aeroplane, but doesn't open his parachute until after some time has elapsed.

Fig. 3.1 shows the graph of his speed during the fall.

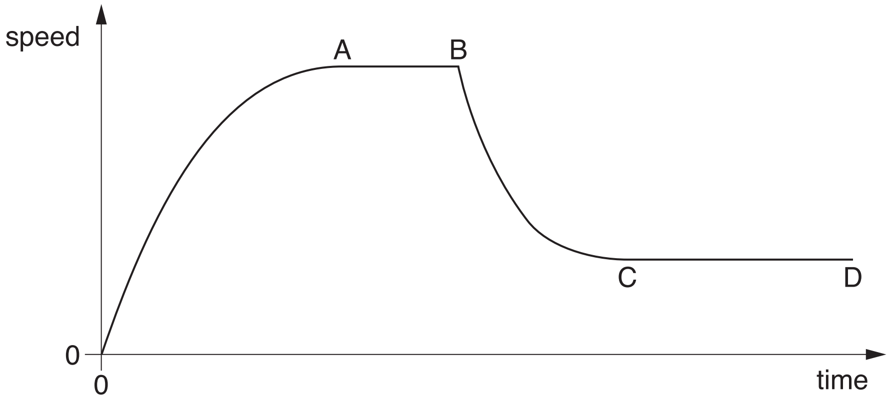


Fig. 3.1

(a) What is the value of the acceleration of the parachutist immediately after he has jumped from the aeroplane?

.... [1]

(b) How can you tell that the acceleration decreases until point A on the graph is reached?

....

.... [1]

(c) State why the acceleration of the parachutist decreases until point A on the graph.

....

....

....

.... [2]

(d) Consider section AB of the graph.

(i) State what is happening to the parachutist's speed in this section.

.... [1]

(ii) What can be said about the forces on the parachutist during this section?

....

.... [1]

(e) At which point did the parachutist open his parachute?

.... [1]

(f) Explain why the speed decreases from B to C.

....

....

.... [2]

[Total: 9]

7 A brick is dropped from the top of a very tall building as it is being constructed.

Fig. 1.1 is the speed/time graph for the brick as it falls to the ground.

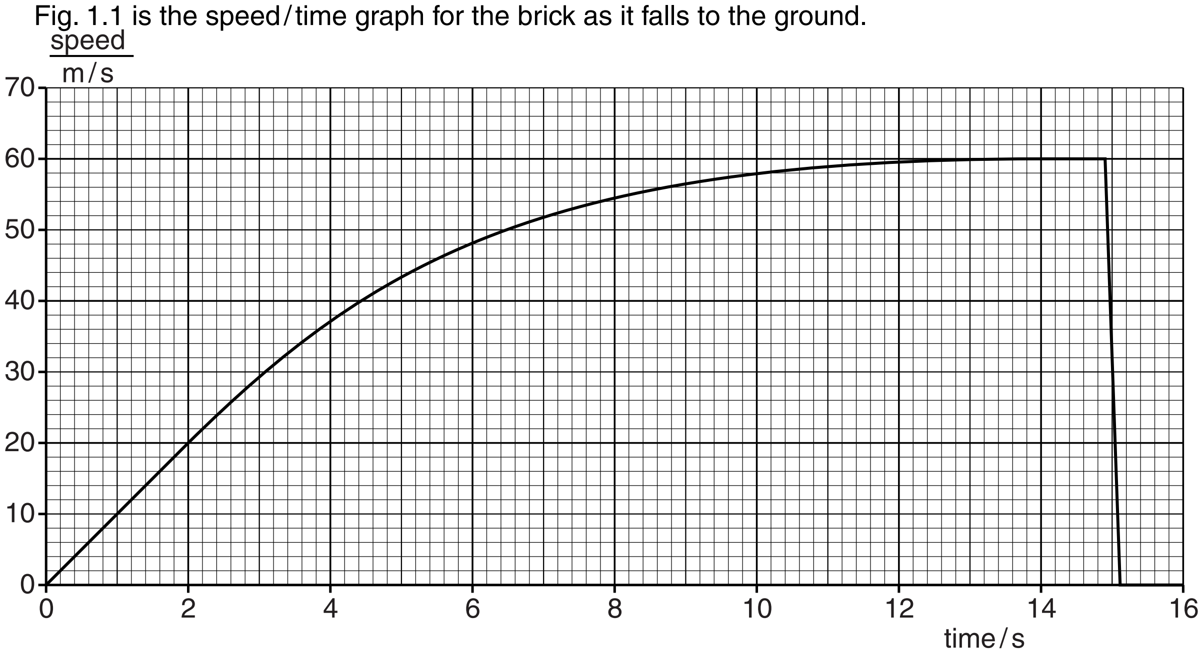


Fig. 1.1

(a) State a time at which the acceleration of the brick is

(i) zero,

time = ... [1]

(ii) constant but not zero,

time = ... [1]

(iii) not constant.

time = ... [1]

(b) Explain in terms of the forces acting on the brick why, between 0 and 14.0 s, its speed varies in the way shown by the graph.

....

....

....

....

.... [4]

(c) State the direction of the resultant force acting on the brick at time 15.0 s.

.... [1]

[Total: 8]

3.4 Scalars and vectors

1 A student sets up the apparatus shown in Fig. 2.1 in order to find the resultant of the two tensions T_1 and T_2 acting at P. When the tensions T_1, T_2 and T_3 are balanced, the angles between T_1 and the vertical and T_2 and the vertical are as marked on Fig. 2.1.

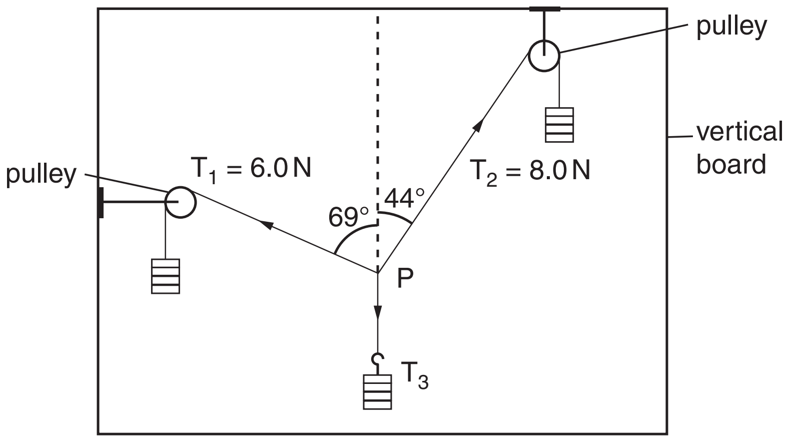


Fig. 2.1

In the space below, draw a scale diagram of the forces T_1 and T_2. Use the diagram to find the resultant of the two forces.

State

(a) the scale used, scale = ...

(b) the value of the resultant, value = ...

(c) the direction of the resultant. direction = ...

[6]

2 **(a)** In an accident, a truck goes off the road and into a ditch. Two breakdown vehicles A and B are used to pull the truck out of the ditch, as shown in Fig. 4.1.

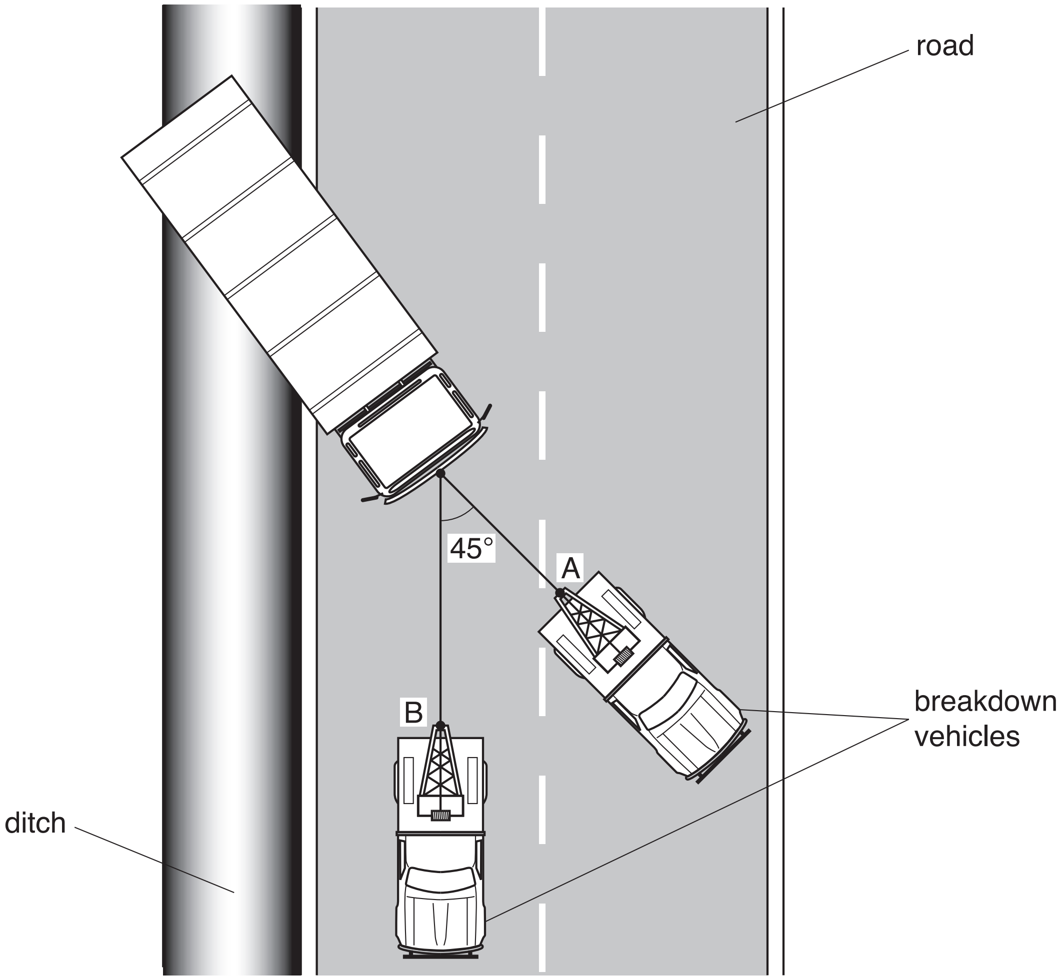


Fig. 4.1

At one point in the rescue operation, breakdown vehicle A is exerting a force of 4000 N and breakdown vehicle B is exerting a force of 2000 N.

(i) Using a scale of 1 cm = 500 N, make a scale drawing to show the resultant force on the truck.

[4]

(ii) Use your diagram to find the magnitude and direction of the resultant force on the truck.

magnitude of resultant force = ...

direction of resultant force = ... to direction of road [2]

(b) **(i)** State why the resultant force is an example of a vector quantity.

.... [1]

(ii) Give an example of a vector quantity that is not a force.

.... [1]

[Total: 8]

3 An object of weight *W* is suspended by two ropes from a beam, as shown in Fig. 1.1.

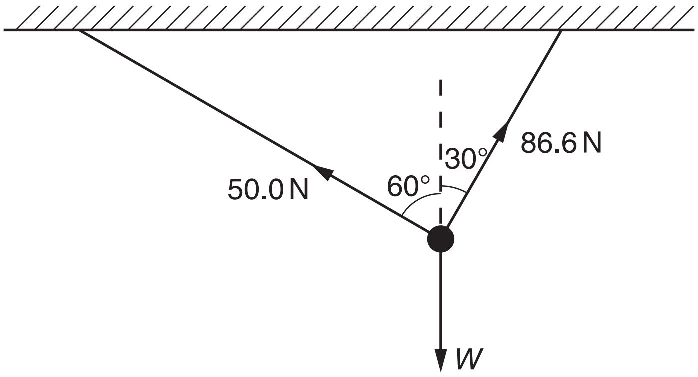


Fig. 1.1

The tensions in the ropes are 50.0 N and 86.6 N, as shown.

(a) In the space below, draw a scale diagram to find the resultant of the two tensions.

Use a scale of 1.0 cm = 10 N.

Clearly label the resultant. [3]

(b) From your diagram, find the value of the resultant.

resultant = ... [1]

(c) State the direction in which the resultant is acting.

.... [1]

(d) State the value of *W*. *W* = ... [1]

[Total: 6]

4 **(a)** **(i)** State the difference between a scalar quantity and a vector quantity.

....

....

(ii) State one example of a vector quantity.

....
[2]

(b) Fig. 3.1 shows the top of a flagpole.

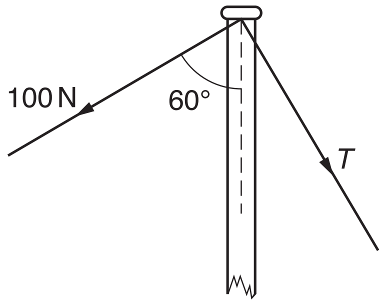


Fig. 3.1

The flagpole is held vertical by two ropes. The first of these ropes has a tension in it of 100 N and is at an angle of 60° to the flagpole. The other rope has a tension *T*, as shown.

The resultant force is down the pole and of magnitude 200 N.

In the space below, using a scale of 1 cm = 20 N, draw a scale drawing to find the value of the tension *T*. Clearly label 100 N, 200 N and *T* on your drawing.

tension *T* = ...[3]

[Total: 5]

5 **(a)** State the factors which completely describe a vector quantity.

....

.... [1]

(b) An aeroplane is flying towards the east in still air at 92 m/s. A wind starts to blow at 24 m/s towards the north.

Draw a vector diagram to find the resultant velocity of the aeroplane. Use a scale of 1.0 cm = 10 m/s.

resultant speed = ...

angle between resultant and easterly direction = ...

[5]

[Total: 6]

Chapter 4. Turing effects of forces

1.5.2 Turning effect of forces

Core

1 Describe the moment of a force as a measure of its turning effect and give everyday examples

2 Define the moment of a force as moment = force × perpendicular distance from the pivot; recall and use this equation

3 Apply the principle of moments to situations with one force each side of the pivot, including balancing of a beam

4 State that, when there is no resultant force and no resultant moment, an object is in equilibrium

Supplement

5 Apply the principle of moments to other situations, including those with more than one force each side of the pivot

6 Describe an experiment to demonstrate that there is no resultant moment on an object in equilibrium

1.5.3 Centre of gravity

Core

1 State what is meant by centre of gravity

2 Describe an experiment to determine the position of the centre of gravity of an irregularly shaped plane lamina

3 Describe, qualitatively, the effect of the position of the centre of gravity on the stability of simple objects

Supplement

1. Fig. 3.1 shows a simple see-saw. One child A sits near to end X and another child B sits near to end Y. The feet of the children do not touch the ground when the see-saw is balanced.

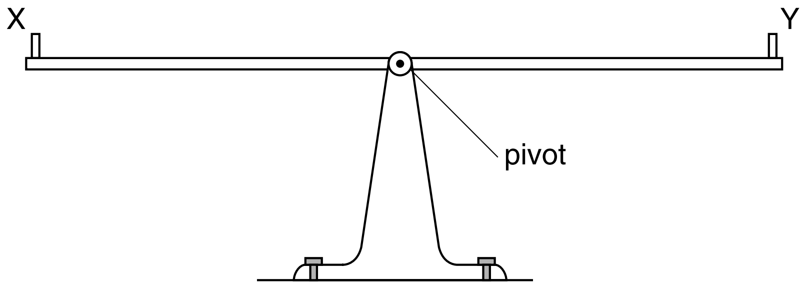


Fig. 3.1

(a) Child A has a mass of 18.0 kg and child B has a mass of 20.0 kg.

Without calculation, indicate where the children could sit so that the see-saw balances horizontally. You may draw on Fig. 3.1 if you wish.

....

....

.... [2]

(b) State the relationship between the moment caused by child A and that caused by child B.

....

.... [1]

(c) Child A is 2.50 m from the pivot. Calculate the distance of child B from the pivot.

distance = ... [2]

2. Fig. 2.1 shows apparatus for investigating moments of forces.

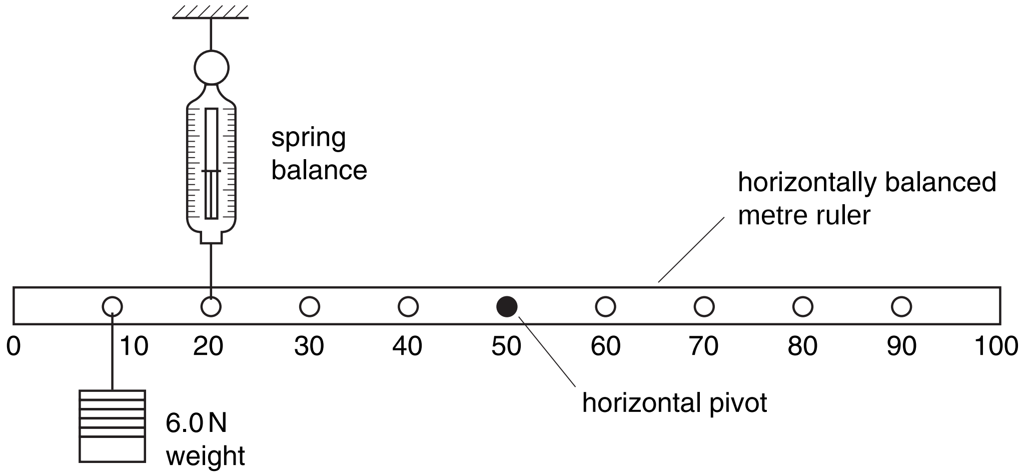


Fig. 2.1

The uniform metre ruler shown in Fig. 2.1 is in equilibrium.

(a) Write down two conditions for the metre ruler to be in equilibrium.

condition 1 ....

....

....

condition 2 ....

....

.... [2]

(b) Show that the value of the reading on the spring balance is 8.0 N. [2]

(c) The weight of the uniform metre ruler is 1.5N.

Calculate the force exerted by the pivot on the metre ruler.

magnitude of force = ...

direction of force .... [2]

3. Fig. 2.1 shows a steam safety valve. When the pressure gets too high, the steam lifts the weight W and allows steam to escape.

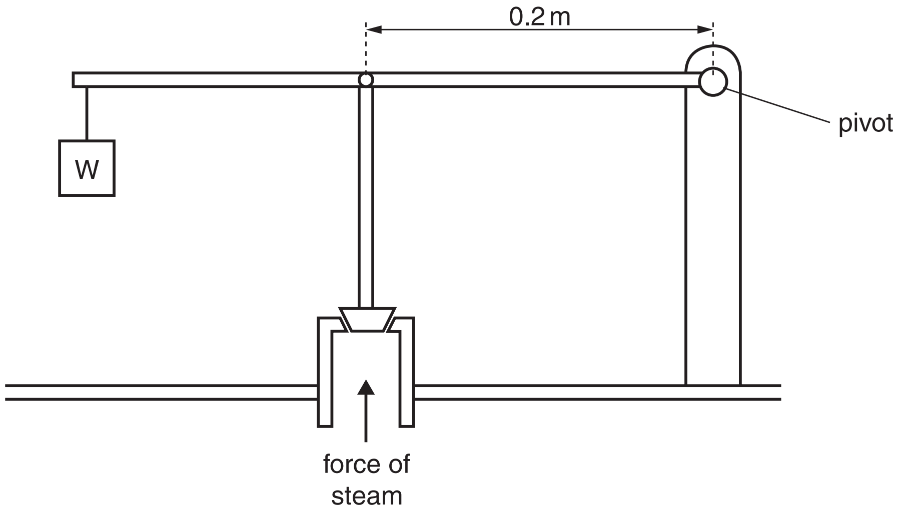


Fig. 2.1

(a) Explain, in terms of moments of forces, how the valve works.

....

....

....

.... [2]

(b) The moment of weight W about the pivot is 12 N m. The perpendicular distance of the line of action of the force of the steam on the valve from the pivot is 0.2 m.

The area of the piston is 0.0003 m^2.

Calculate

(i) the minimum steam force needed for the steam to escape,

force = ... [2]

(ii) the minimum steam pressure for the steam to escape.

pressure = ... [2]

[Total: 6]

4. **(a)** An elastic spring of original length 3.0 cm is extended to a total length of 5.0 cm by a force of 8.0 N.

Assuming the limit of proportionality of the spring has not been reached, calculate the force needed to extend it to a total length of 6.0 cm.

force = ... [3]

(b) Fig. 3.1 shows the arrangement for an experiment on moments.

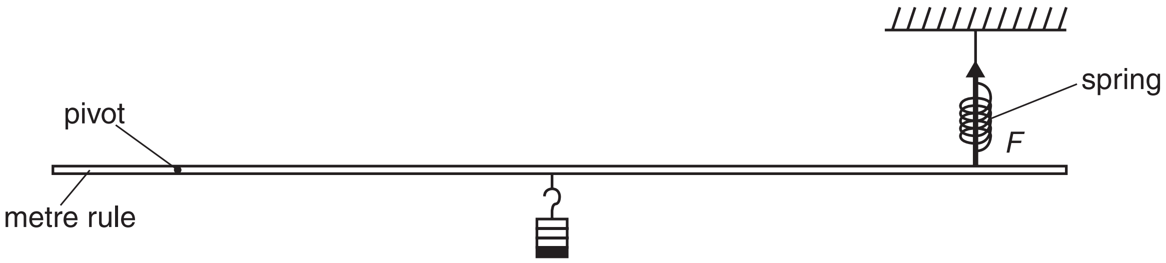


Fig. 3.1

The spring exerts a force *F* on the metre rule.

(i) On Fig. 3.1, mark another quantity which must be measured to find the moment of the force *F*. [1]

(ii) State how the moment of the force *F* is calculated.

....

.... [1]

[Total: 5]

5. Fig. 2.1 shows a circular metal disc of mass 200 g, freely pivoted at its centre.

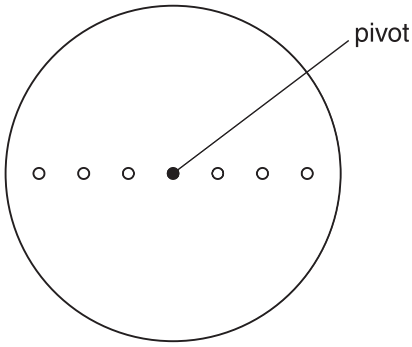


Fig. 2.1

Masses of 100 g, 200 g, 300 g, 400 g, 500 g and 600 g are available, but only one of each value. These may be hung with string from any of the holes. There are three small holes on each side of the centre, one at 4.0 cm from the pivot, one at 8.0 cm from the pivot and one at 12.0 cm from the pivot.

The apparatus is to be used to show that there is no net moment of force acting on a body when it is in equilibrium.

(a) On Fig. 2.1, draw in **two different** value masses hanging from appropriate holes. The values of the masses should be chosen so that there is no net moment. Alongside the masses chosen, write down their values. [2]

(b) Explain how you would test that your chosen masses give no net moment to the disc.

....

....

....

.... [1]

(c) Calculate the moments about the pivot due to the two masses chosen.

moment due to first mass = ...

moment due to second mass = ...
[2]

(d) Calculate the force on the pivot when the two masses chosen are hanging from the disc.

force = ... [2]

[Total: 7]

6. **(a)** A uniform metre ruler is pivoted at its centre, which is also the position of its centre of gravity.

Three loads, 2.0 N, *F* and 3.0 N are positioned on the ruler at the 20 cm, 30 cm and 90 cm marks respectively, as shown in Fig. 3.1.

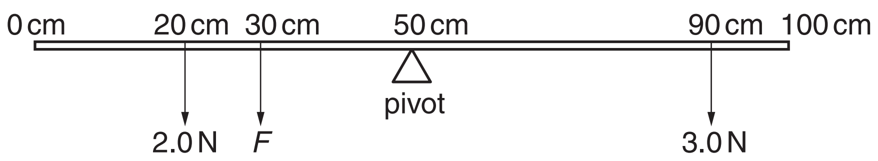


Fig. 3.1

(i) Calculate the moment of the 3.0 N load about the pivot.

moment = ... [1]

(ii) Calculate the moment of the 2.0 N load about the pivot.

moment = ... [1]

(iii) The force *F* maintains the metre ruler in equilibrium on the pivot.

Calculate the value of *F*.

F = ... [3]

(b) The weight of the metre ruler is 1.2 N and can be considered to act at the 50 cm mark.

All the weights in **(a)** are removed. The pivot is positioned under the 30 cm mark and the 2.0 N load is placed on the rule as shown in Fig. 3.2.

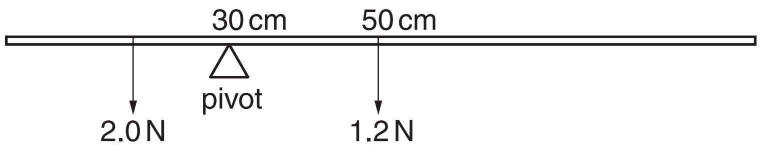


Fig. 3.2

The position of the 2.0 N load is adjusted until the metre rule is again in equilibrium.

Determine the position of the 2.0 N load.

2.0 N load is at the .... cm mark [3]

[Total: 8]

7. **(a)** A loose uniform wooden floorboard weighs 160 N and rests symmetrically on four supports P, Q, R and S.

The supports are 0.50 m apart, as shown in Fig. 2.1.

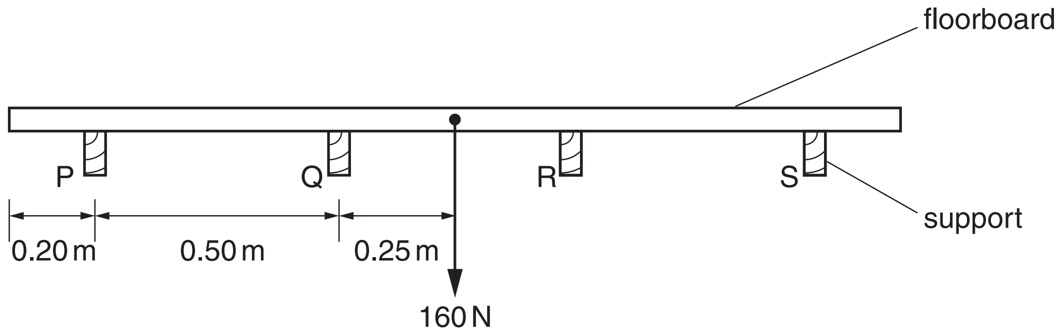


Fig. 2.1

Calculate the force exerted on the floorboard by each of the supports, and state the direction of these forces. One value is already given for you.

force exerted by P = ...

force exerted by Q = 40 N

force exerted by R = ...

force exerted by S = ...

direction = ... [2]

(b) A workman of weight W stands on the end of the floorboard described in **(a)**.

This just causes the floorboard to tip up, as shown in Fig. 2.2.

The supports are each 0.060 m thick.

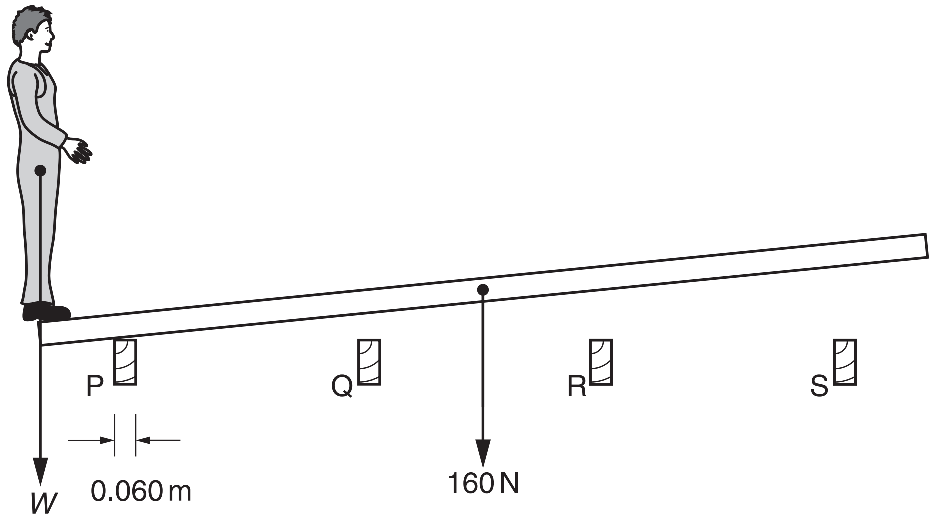


Fig. 2.2

(i) Calculate the weight W of the workman.

weight W = ... [3]

(ii) Calculate the force that each of the supports now exerts on the floorboard.

force exerted by P = ...

force exerted by Q = ...

force exerted by R = ...

force exerted by S = ... [2]

[Total: 7]

8. **(a)** Complete the following statement:

The moment of a force about a point is ....

multiplied by ....[1]

(b) Fig. 3.1 shows a uniform iron bar B of weight 30 N and length 1.40 m. The bar is being used to lift one edge of a concrete slab S. A stone, placed 0.20 m from one end of B, acts as a pivot. A force of 40 N pushing down at the other end of B is just enough to lift the slab and hold it as shown.

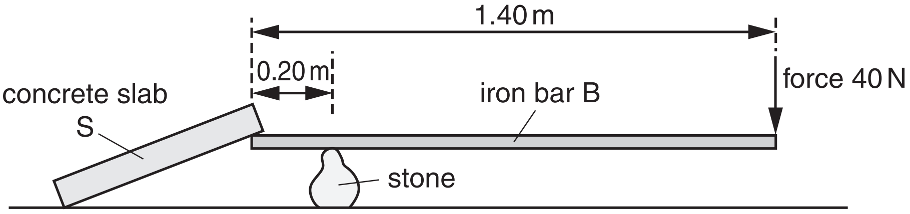


Fig. 3.1

(i) On Fig. 3.1, draw an arrow to show the weight of bar B acting from its centre of mass. [1]

(ii) State the distance *d* of the centre of mass of bar B from the pivot.

d = ...[1]

(iii) Calculate the total clockwise moment, about the pivot, of the forces acting on bar B.

total clockwise moment = ...[3]

(iv) Calculate the downward force which the slab S exerts on the end of bar B.

force = ...[2]

(v) Suggest a change to the arrangement in Fig. 3.1 that would reduce the force required to lift the slab.

....

....[1]

[Total: 9]

9. **(a)** State the two conditions required for the equilibrium of a body acted upon by a number of forces.

1. ....

....

2. ....

....[2]

(b) Fig. 3.1 shows a diagram of an arm with the hand holding a weight of 120 N.

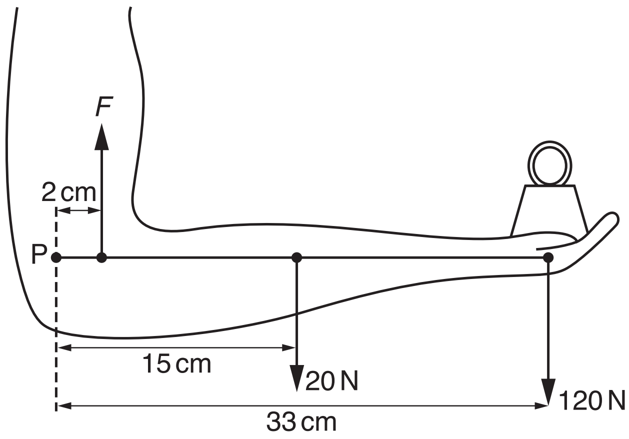


Fig. 3.1

The 20 N force is the weight of the forearm, acting at its centre of mass. *F* is the force in the muscle of the upper arm. P is the point in the elbow about which the arm pivots. The distances of the forces from point P are shown.

(i) By taking moments about point P, calculate the force *F*.

force *F* = ...[3]

(ii) A force acts on the forearm at point P. Calculate this force and state its direction.

force = ...

direction = ...[2]

[Total: 7]

10. Fig. 2.1 shows a mobile bird sculpture that has been created by an artist.

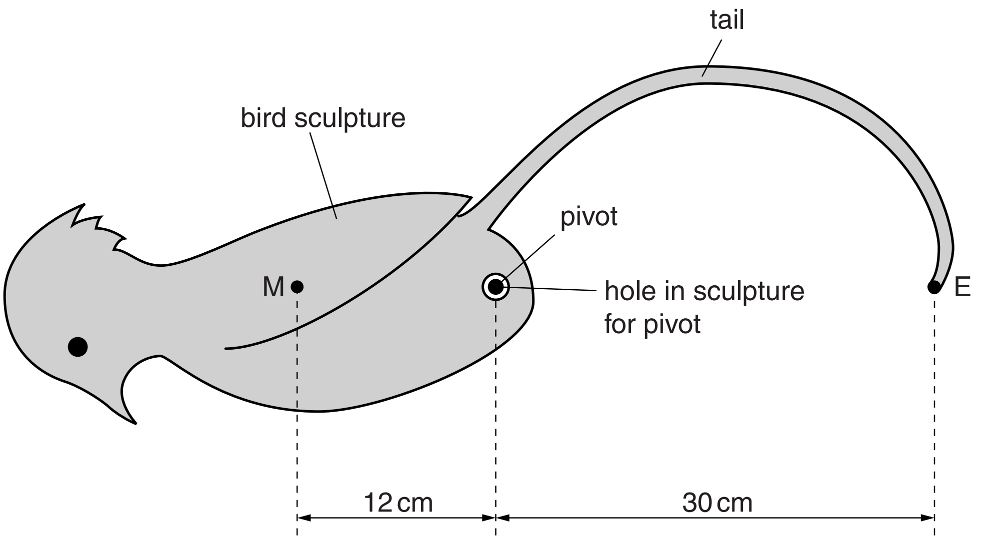


Fig. 2.1

M is the centre of gravity of the bird sculpture, including its tail (but not including the counter-weight that will be added later). The mass of the bird and tail is 1.5 kg.

The bird sculpture is placed on a pivot.

The artist adds the counter-weight at the end E of the tail so that the bird remains stationary in the position shown.

(a) Calculate the mass of the counter-weight.

mass = ... [2]

(b) The centre of gravity of the sculpture with counter-weight is at the pivot.

Calculate the upward force acting at the pivot.

force = ... [1]

(c) The sculpture is rotated clockwise to the position shown in Fig. 2.2. It is held still, then carefully released.

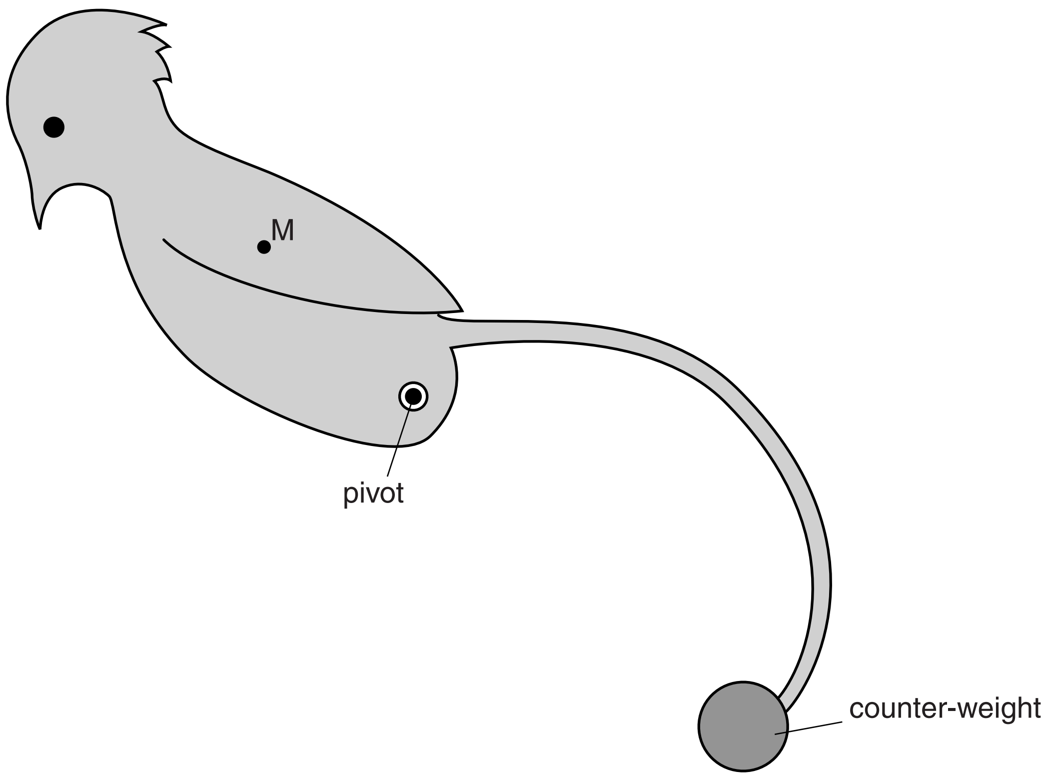


Fig. 2.2

(i) State whether the sculpture will stay in that position, rotate further clockwise or rotate back anticlockwise.

....

....

(ii) Explain your answer to **(i)**.

....

....

....

....
[3]

[Total: 6]

11. **(a)** A stationary body is acted upon by a number of forces. State the two conditions which must apply for the body to remain at rest.

1. ....

2. ....

[2]

(b) Fig. 3.1 shows a device used for compressing crushed material.

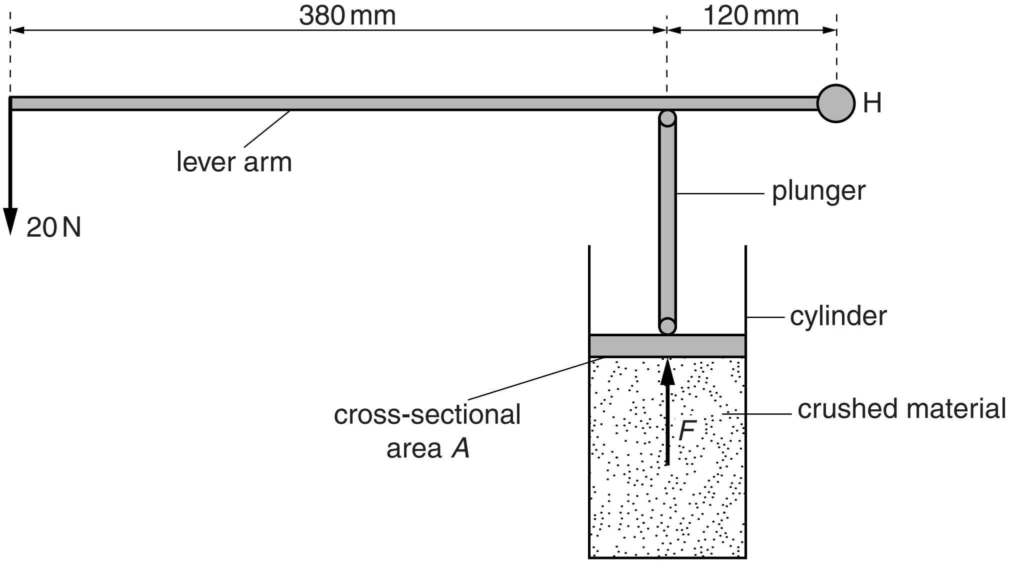


Fig. 3.1

The lever arm rotates about the hinge H at its right-hand end. A force of 20 N acts downwards on the left-hand end of the lever arm. The force F of the crushed material on the plunger acts upwards. Ignore the weight of the lever arm.

(i) Use the clockwise and anticlockwise moments about H to calculate the upward force F which the crushed material exerts on the plunger. The distances are shown on Fig. 3.1.

force F = ... [3]

(ii) The cross-sectional area A of the plunger in contact with the crushed material is $0.0036\,m^2$. Calculate the pressure exerted on the crushed material by the plunger.

pressure = ... [2]

Chapter 5. Forces and matter

1.5 Forces

1.5.1 Effects of forces

Core

1 Know that forces may produce changes in the size and shape of an object

2 Sketch, plot and interpret load–extension graphs for an elastic solid and describe the associated experimental procedures

Supplement

9 Define the spring constant as force per unit extension; recall and use the equation

$$k = \frac{F}{x}$$

10 Define and use the term 'limit of proportionality' for a load–extension graph and identify this point on the graph (an understanding of the elastic limit is **not** required)

1.8 Pressure

Core

1 Define pressure as force per unit area; recall and use the equation

$$p = \frac{F}{A}$$

2 Describe how pressure varies with force and area in the context of everyday examples

3 Describe, qualitatively, how the pressure beneath the surface of a liquid changes with depth and density of the liquid

Supplement

4 Recall and use the equation for the change in pressure beneath the surface of a liquid

$$\Delta p = \rho g \Delta h$$

5.1 [Hooke's law]

1 Fig. 1.1 shows apparatus that may be used to compare the strengths of two springs of the same size, but made from different materials.

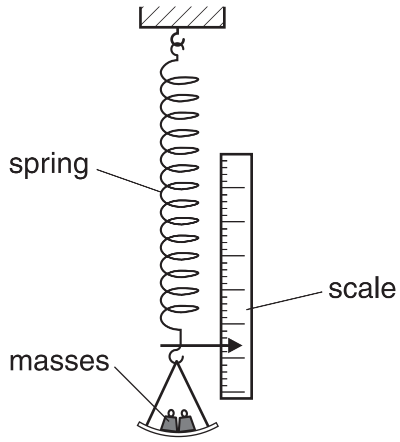


Fig. 1.1

(a) (i) Explain how the masses produce a force to stretch the spring.

....

(ii) Explain why this force, like all forces, is a vector quantity.

....

....

[2]

(b) Fig. 1.2 shows the graphs obtained when the two springs are stretched.

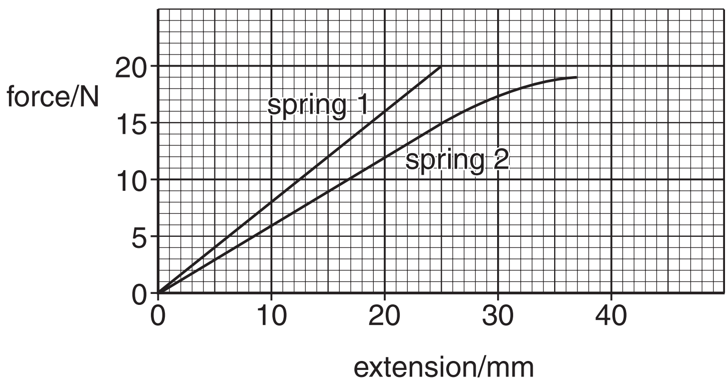


Fig. 1.2

(i) State which spring is more difficult to extend. Quote values from the graphs to support your answer.

....

....

....

....

(ii) On the graph of spring 2, mark a point P at the limit of proportionality. Explain your choice of point P.

....

....

....

(iii) Use the graphs to find the difference in the extensions of the two springs when a force of 15 N is applied to each one.

difference in extensions = ...

(c) **(i)** Explain what is meant by an elastic solid.

.... [1]

(ii) Discuss why springs are often used to model elastic materials

....

.... [2]

Total: [9]

2 A large spring is repeatedly stretched by an athlete to increase the strength of his arms. Fig. 3.1 is a table showing the force required to stretch the spring.

extension of spring / m	0.096	0.192	0.288	0.384
force exerted to produce extension / N	250	500	750	1000

Fig. 3.1

(a) **(i)** State Hooke's law.

....

....[1]

(ii) Use the results in Fig.3.1 to show that the spring exhibits linearity.

[1]

(b) Another athlete using a different spring exerts an **average** force of 400 N to enable her to extend the spring by 0.210 m.

(i) Calculate the work done by this athlete in extending the spring once.

work done = …………………

(ii) She is able to extend the spring by this amount and to release it 24 times in 60 s. Calculate the power used by this athlete while doing this exercise.

power = …………………
[4]

3 In an experiment, forces are applied to a spring as shown in Fig. 2.1a. The results of this experiment are shown in Fig. 2.1b.

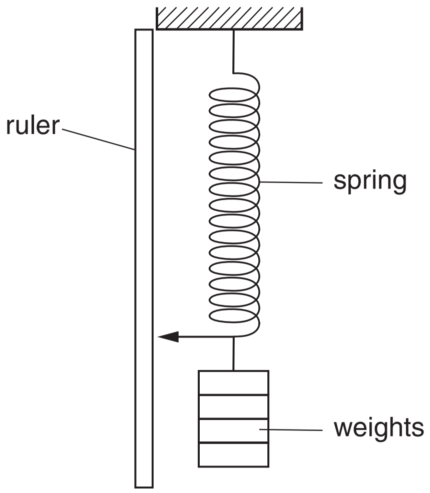


Fig. 2.1a

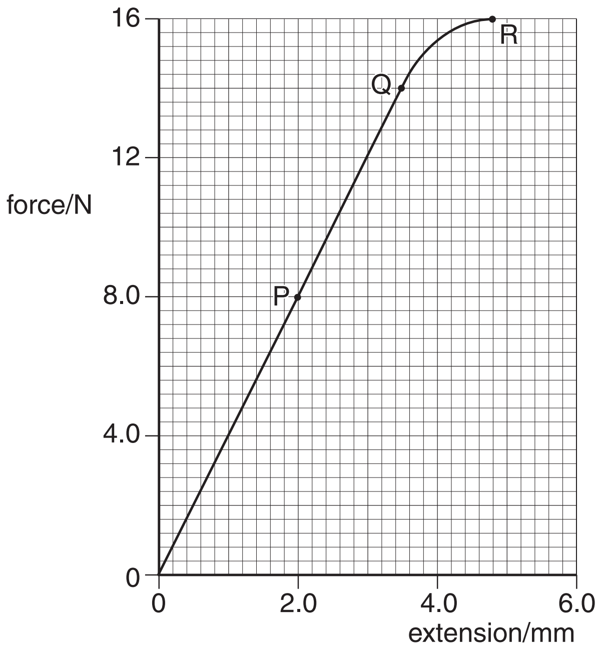


Fig. 2.1b

(a) What is the name given to the point marked Q on Fig. 2.1b?

....[1]

(b) For the part OP of the graph, the spring obeys a linear relation.
State what this means.

....

....[1]

(c) The spring is stretched until the force and extension are shown by the point R on the graph. Compare how the spring stretches, as shown by the part of the graph OQ, with that shown by QR.

....

....[1]

(d) The part OP of the graph shows the spring stretching according to the expression

$$F = kx.$$

Use values from the graph to calculate the value of k.

k =..................................[2]

4 A student investigated the stretching of a spring by hanging various weights from it and measuring the corresponding extensions. The results are shown below.

weight / N	0	1	2	3	4	5
extension / mm	0	21	40	51	82	103

(a) On Fig. 3.1, plot the points from these results. Do not draw a line through the points yet. [2]

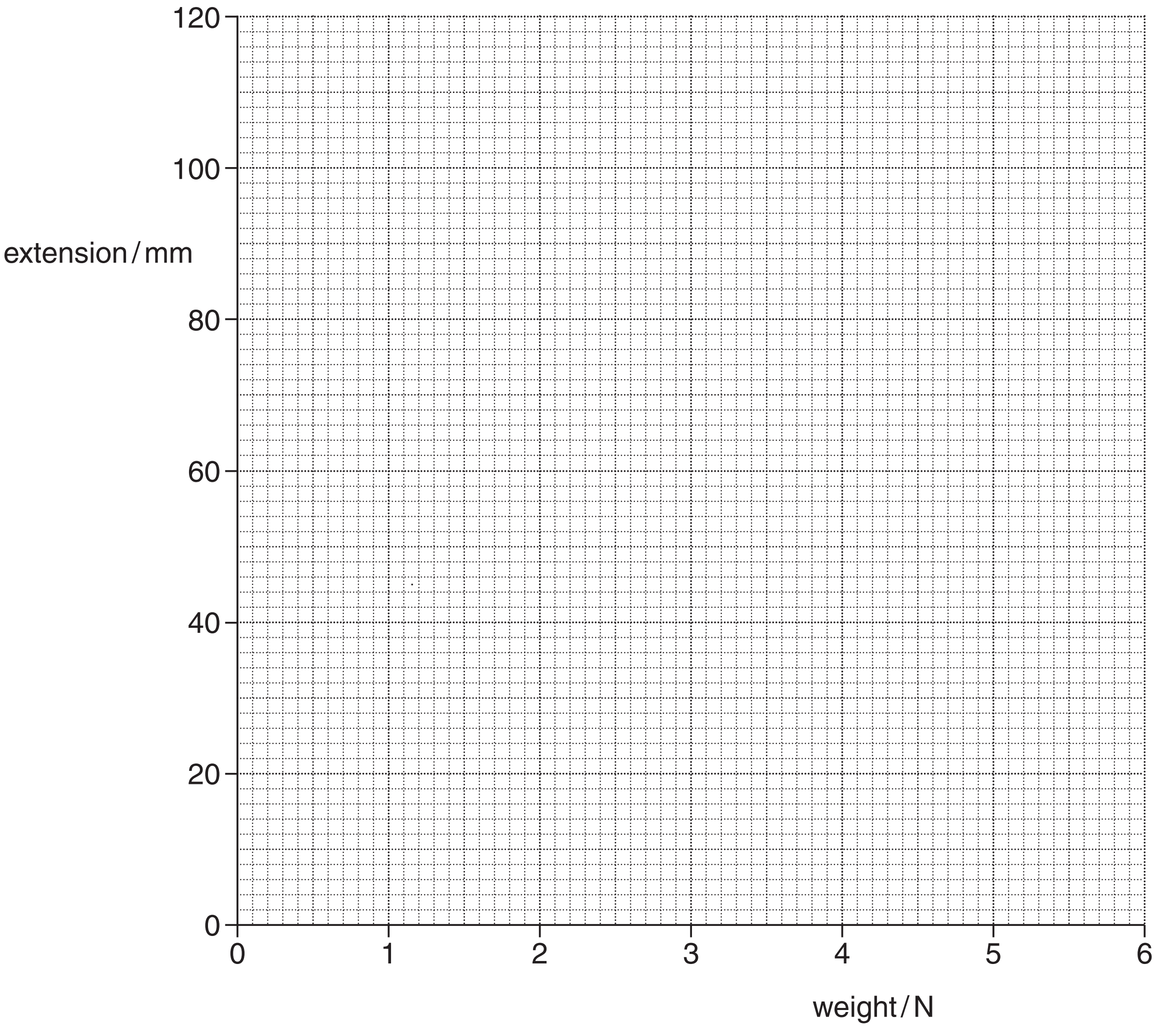


Fig. 3.1

(b) The student appears to have made an error in recording one of the results.

Which result is this?

.... [1]

(c) Ignoring the incorrect result, draw the best straight line through the remaining points. [1]

(d) State and explain whether or not this spring exhibits elastic behaviour.

....

....

....

....

.... [2]

(e) Describe how the graph might be shaped if the student continued to add several more weights to the spring.

....

....

....

.... [1]

(f) The student estimates that if he hangs a 45 N load on the spring, the extension will be 920 mm.

Explain why this estimate may be unrealistic.

....

....

....

.... [1]

[Total: 8]

5 Four students, A, B, C and D, each have a spring. They measure the lengths of their springs when the springs are stretched by different loads.

Their results are shown in Fig. 2.1.

	student A	student B	student C	student D
load / N	spring length / cm	spring length / cm	spring length / cm	spring length / cm
0.5	6.7	9.2	9.1	10.0
1.0	7.7	10.0	9.9	11.1
1.5	8.7	10.8	10.7	12.2
2.0	9.7	11.6	11.5	13.3
2.5	10.7	12.6	12.3	14.4
3.0	11.7	13.8	13.1	15.5
3.5	12.7	15.2	13.9	16.6
4.0	13.7	16.8	14.7	17.7

Fig. 2.1

(a) **(i)** State which student had loaded the spring beyond the limit of proportionality.

.... [1]

(ii) Explain how you obtained your answer to **(a)(i)**.

....

....

.... [2]

(b) For the spring used by student A, calculate

(i) the extra extension caused by each additional 0.5 N,

extra extension = ... [1]

(ii) the unloaded length of the spring.

unloaded length = ... [1]

(c) Student A obtains a second spring that is identical to his first spring. He hangs the two springs side by side, as shown in Fig. 2.2.

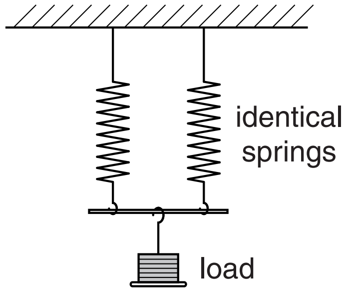


Fig. 2.2

Use the table to calculate the length of each of the springs when a load of 2.5 N is hung as shown in Fig. 2.2. Show your working.

length = ... [2]

[Total: 7]

6 A bucket is full of oil. The total mass of the bucket of oil is 5.4 kg and the gravitational field strength is 9.81 N / kg.

(a) Calculate the total weight of the bucket of oil.

weight = ... [1]

(b) The bucket of oil is hung from a spring of unstretched length 20 cm. The limit of proportionality of the spring is not exceeded and its length increases to 35 cm.

(i) State what is meant by the *limit of proportionality*.

....

.... [1]

(ii) The oil is poured into a measuring tank. The empty bucket stretches the spring to a length of 25 cm.

Calculate

1. the force that stretches the spring to a length of 25 cm,

force = ... [3]

2. the mass of the oil in the measuring tank.

mass = ... [2]

(iii) The volume of the oil in the measuring tank is 0.0045 m^3. Calculate the density of the oil.

density = ... [2]

(c) Explain, in terms of their molecules, why the density of the oil is greater than that of air.

....

.... [1]

[Total: 10]

5.2 Pressure

1 Fig. 3.1 shows a hydraulic lift in a car repair workshop.

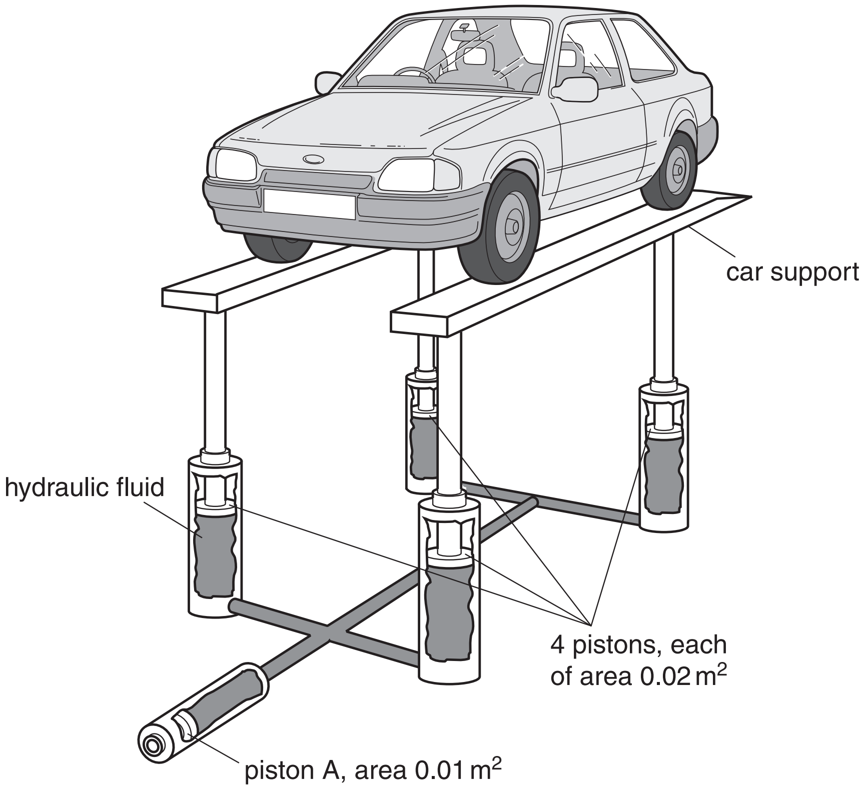


Fig. 3.1

The hydraulic fluid transmits the pressure, caused by piston A, equally to each of the four pistons holding up the car supports. The pressure throughout the fluid is the same.

A force of 1000 N on piston A is just enough to raise the car.

(a) Using values from Fig. 3.1, find

(i) the pressure caused by piston A on the fluid,

pressure = ... [2]

(ii) the total upward force caused by the fluid.

force = ... [3]

(b) The weight of each of the two car supports is 1000 N.

Calculate the mass of the car.

mass = ... [2]

[Total: 7]

2 The front views of two cars are shown in Fig. 5.1, to the same scale.

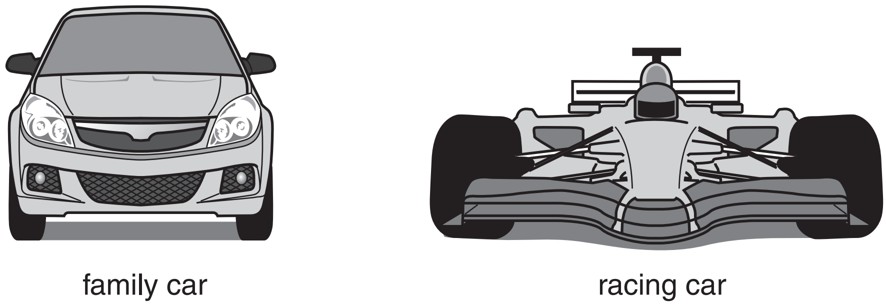


Fig. 5.1

(a) Suggest which car has the greater stability, and give two reasons.

car ....

reason 1 ....

....

reason 2 ....

.... [2]

(b) The cars have the same weight.

Study Fig. 5.1 and suggest why the stationary racing car exerts less pressure on the ground.

....

.... [1]

(c) The family car's tyres each have an area of 0.012 m^2 in contact with the ground.

The weight of the car and its contents is 9600 N.

Calculate the pressure exerted by the car on the ground.

pressure = ... [2]

[Total: 5]

3 A soldier wears boots, each having an area of 0.016 m^2 in contact with the ground.

The soldier weighs 720 N.

(a) (i) Write down the equation that is used to find the pressure exerted by the soldier on the ground.

(ii) Calculate the pressure exerted by the soldier when he is standing to attention, with both boots on the ground.

pressure = ...
[2]

(b) The soldier is crossing a sandy desert.

Explain, stating the relevant Physics, why this soldier is at an advantage over another soldier who has the same weight but smaller feet.

....

....

....

....[2]

(c) The soldier's unit is sent to a cold country, and on one occasion he has to cross a frozen lake.

Suggest one way that the soldier can reduce the risk of the ice breaking under his weight.

....

....

....[1]

[Total: 5]

4 Fig. 4.1 represents part of the hydraulic braking system of a car.

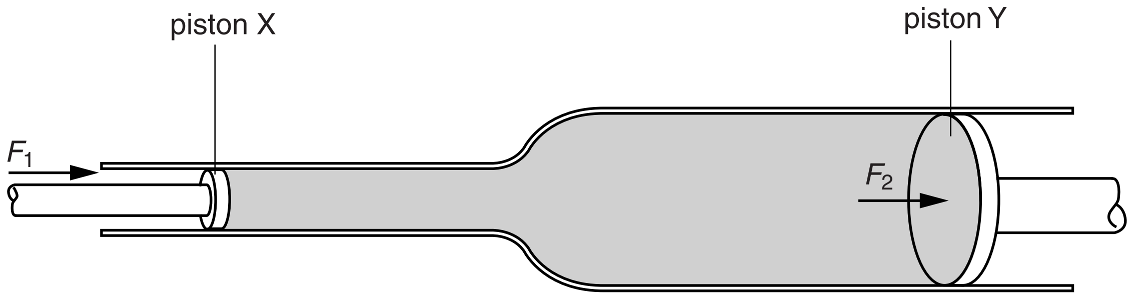


Fig. 4.1

The force F_1 of the driver's foot on the brake pedal moves piston X. The space between pistons X and Y is filled with oil which cannot be compressed. The force F_2 exerted by the oil moves piston Y. This force is applied to the brake mechanism in the wheels of the car.

The area of cross-section of piston X is 4.8 cm^2.

(a) The force F_1 is 90 N. Calculate the pressure exerted on the oil by piston X.

pressure = ... [2]

(b) The pressure on piston Y is the same as the pressure applied by piston X. Explain why the force F_2 is greater than the force F_1.

....

.... [1]

(c) Piston Y moves a smaller distance than piston X. Explain why.

....

....

.... [2]

(d) Suggest why the braking system does not work properly if the oil contains bubbles of air.

....

....

.... [2]

[Total: 7]

5.3 Pressure in liquid

1 Fig. 2.1 shows a diver 50 m below the surface of the water.

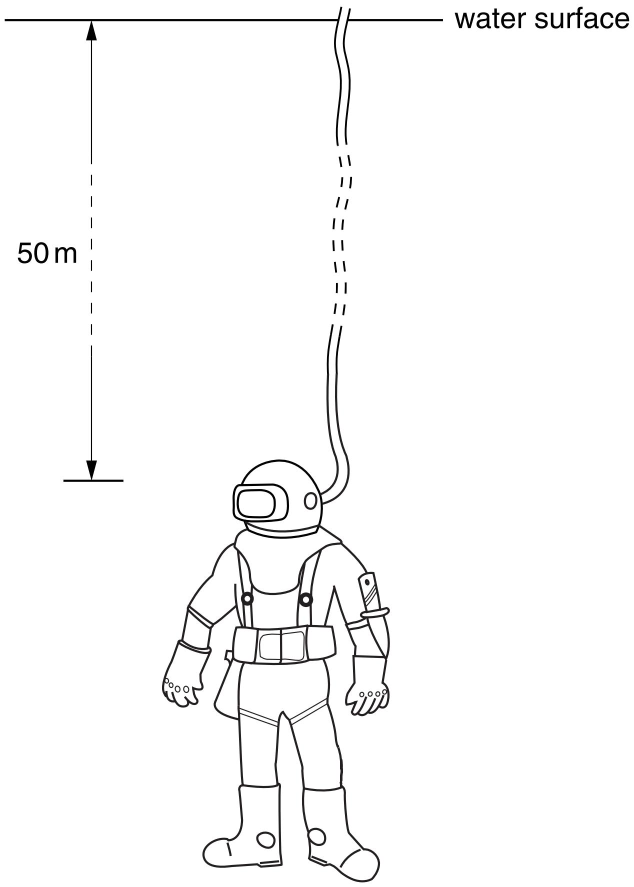


Fig. 2.1

(a) The density of water is 1000 kg/m^3 and the acceleration of free fall is 9.81 m/s^2. Calculate the pressure that the water exerts on the diver.

pressure = ... [3]

(b) The window in the diver's helmet is 150 mm wide and 70 mm from top to bottom.

Calculate the force that the water exerts on this window.

force = ... [3]

2 Fig. 2.1 shows a reservoir that stores water.

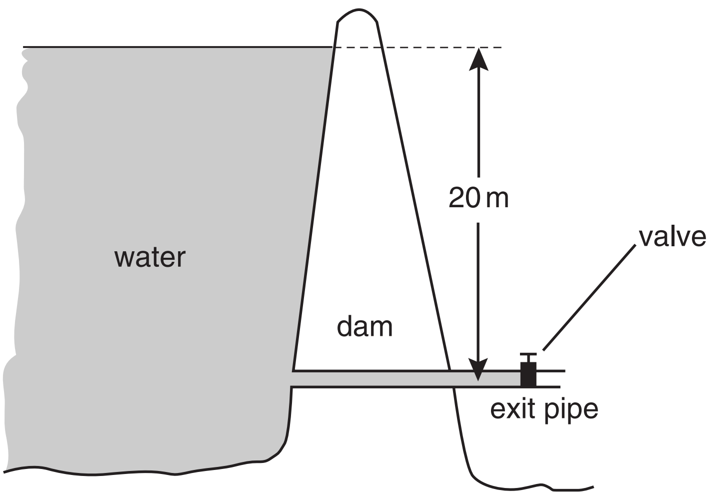


Fig. 2.1

(a) The valve in the exit pipe is closed. The density of water is 1000 kg/m^3 and the acceleration of free fall is 10 m/s^2.
Calculate the pressure of the water acting on the closed valve in the exit pipe.

pressure = ……………………...[2]

(b) The cross-sectional area of the pipe is 0.5 m^2.
Calculate the force exerted by the water on the closed valve.

force = ……………………...[2]

(c) The valve is then opened and water, originally at the surface of the reservoir, finally flows out of the exit pipe. State the energy transformation of this water between the surface of the reservoir and the open end of the pipe.

....

....[2]

3 **(a)** A submarine descends to a depth of 70 m below the surface of water.

The density of the water is 1050 kg/m^3. Atmospheric pressure is 100 kPa.

Calculate

(i) the increase in pressure as it descends from the surface to a depth of 70 m,

increase in pressure = ... [2]

(ii) the total pressure on the submarine at a depth of 70 m.

total pressure = ... [1]

(b) On another dive, the submarine experiences a total pressure of 6.5×10^5 Pa. A hatch cover on the submarine has an area of 2.5 m^2.

Calculate the force on the outside of the cover.

force = ... [2]

(c) The submarine undergoes tests in fresh water of density 1000 kg/m^3.

Explain why the pressure on the submarine is less at the same depth.

....

.... [1]

[Total: 6]

4 **(a)** A man squeezes a pin between his thumb and finger, as shown in Fig. 6.1.

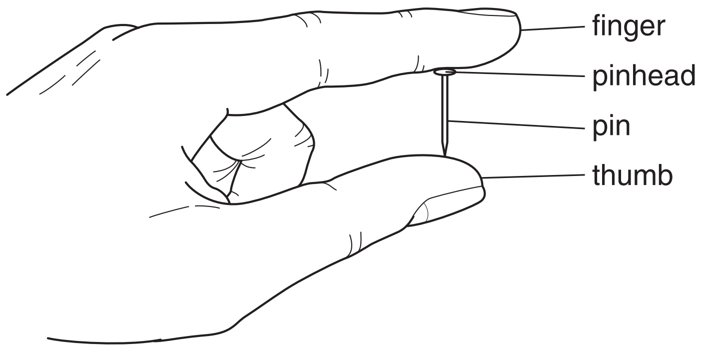


Fig. 6.1

The finger exerts a force of 84 N on the pinhead.

The pinhead has an area of $6.0 \times 10^{-5}\,m^2$.

(i) Calculate the pressure exerted by the finger on the pinhead.

pressure = ... [2]

(ii) State the value of the force exerted by the pin on the thumb.

.... [1]

(iii) Explain why the pin causes more pain in the man's thumb than in his finger.

....

.... [2]

(b) The density of the water in a swimming pool is 1000 kg/m^3. The pool is 3 m deep.

(i) Calculate the pressure of the water at the bottom of the pool.

pressure = ... [2]

(ii) Another pool has the same depth of water, but has twice the area.

State the pressure of the water at the bottom of this pool.

pressure = ... [1]

[Total: 8]

5 During a period of hot weather, the atmospheric pressure on the pond in Fig. 3.1 remains constant. Water evaporates from the pond, so that the depth *h* decreases.

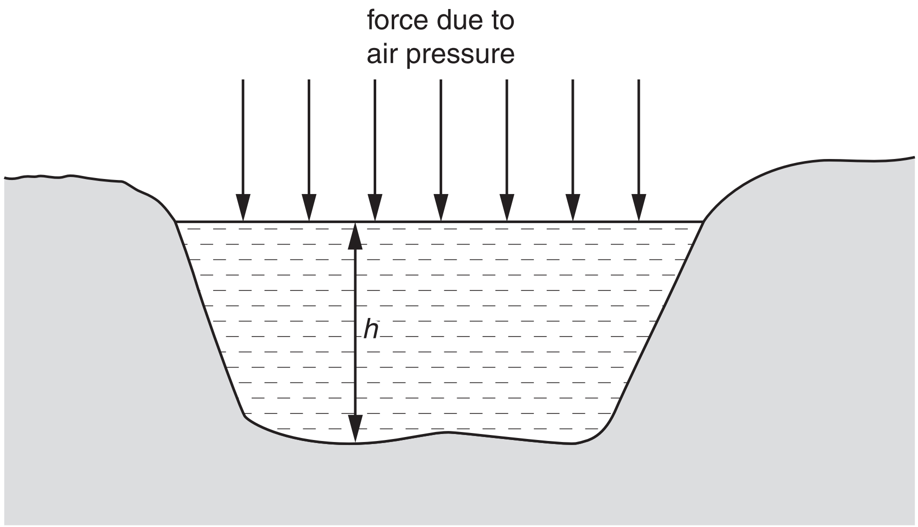


Fig. 3.1

(a) Study the diagram and state, giving your reason, what happens during this hot period to

(i) the force of the air on the surface of the pond,

....

....[1]

(ii) the pressure at the bottom of the pond.

....

....[1]

(b) On a certain day, the pond is 12 m deep.

(i) Water has a density of 1000 kg/m^3.

Calculate the pressure at the bottom of the pond due to the water.

pressure due to the water = ...[2]

(ii) Atmospheric pressure on that day is 1.0×10^5 Pa.

Calculate the total pressure at the bottom of the pond.

total pressure = ...[1]

(iii) A bubble of gas is released from the mud at the bottom of the pond. Its initial volume is $0.5\,cm^3$.

Ignoring any temperature differences in the water, calculate the volume of the bubble as it reaches the surface.

volume = ...[2]

(iv) In fact, the temperature of the water is greater at the top than at the bottom of the pond.

Comment on the bubble volume you have calculated in **(b)(iii)**.

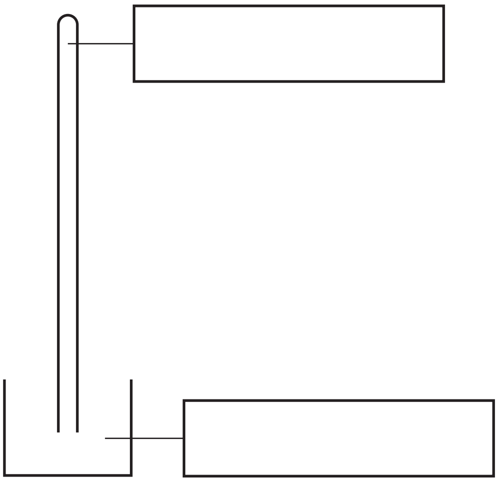
....

....

....[1]

[Total: 8]

6 **(a)** Complete Fig. 4.1 to show a simple mercury barometer. Insert the correct labels in the boxes. Label with the letter *h* the measurement required to calculate the pressure of the atmosphere.



[3]

Fig. 4.1

(b) The value of *h* taken using this barometer is 0.73 m. The density of mercury is 13 600 kg/m^3. Calculate the value of the atmospheric pressure suggested by this measurement. Use g = 10 m/s^2.

atmospheric pressure = ...[2]

(c) Standard atmospheric pressure is 0.76 m of mercury. Suggest a reason why the value of *h* in **(b)** is lower than this.

....

....[1]

[Total: 6]

7 Fig. 3.1 shows a house brick of dimensions 21.0 cm × 10.0 cm × 7.00 cm.

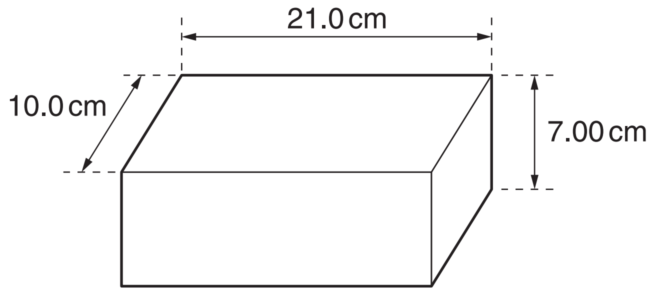


Fig. 3.1

The brick is held under water with its largest surfaces horizontal. The density of water is 1000 kg / m^3.

(a) Calculate the difference in pressure between the top and the bottom surfaces of the brick.

pressure difference = ... [2]

(b) Use your value from **(a)** to calculate the upward force exerted on the brick by the water.

upward force = ... [2]

(c) The mass of the brick is 3.09 kg. Calculate the acceleration of the brick when it is released.

acceleration = ... [3]

[Total: 7]

8 A diver is at a depth of 25 m beneath the surface of a lake. He carries a cylinder of high-pressure air on his back.

(a) **(i)** Explain how the air molecules exert a pressure on the inside surface of the cylinder.

....

....

....

.... [3]

(ii) The diver gradually uses up the air in the cylinder. Explain why the pressure falls.

....

....

.... [1]

(b) The density of the water in the lake is 1000 kg/m^3 and the atmospheric pressure at the surface is 1.0×10^5 Pa.

Calculate the total pressure 25 m beneath the surface of the lake.

total pressure = ... [3]

[Total: 7]

Chapter 6. Energy transformation and energy transfer

1.7 Energy, work and power

1.7.1 Energy

Core

1 State that energy may be stored as kinetic, gravitational potential, chemical, elastic (strain), nuclear, electrostatic and internal (thermal)

2 Describe how energy is transferred between stores during events and processes, including examples of transfer by forces (mechanical work done), electrical currents (electrical work done), heating, and by electromagnetic, sound and other waves

3 Know the principle of the conservation of energy and apply this principle to simple examples including the interpretation of simple flow diagrams

Supplement

4 Recall and use the equation for kinetic energy

$E_k = \frac{1}{2}mv^2$

5 Recall and use the equation for the change in gravitational potential energy

$\Delta E_p = mg\Delta h$

6 Know the principle of the conservation of energy and apply this principle to complex examples involving multiple stages, including the interpretation of Sankey diagrams

1 Fig. 2.1 shows a simple pendulum that swings backwards and forwards between P and Q.

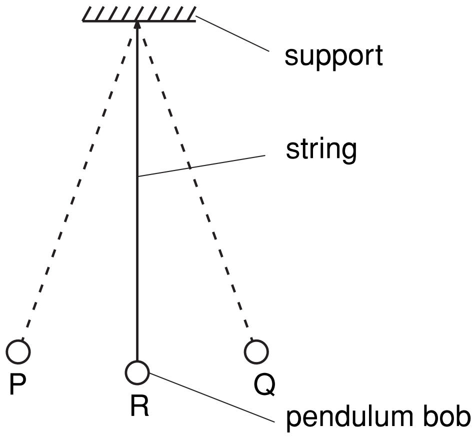


Fig. 2.1

(a) The time taken for the pendulum to swing from P to Q is approximately 0.5 s.

Describe how you would determine this time as accurately as possible.

....

....

.... [2]

(b) (i) State the two vertical forces acting on the pendulum bob when it is at position R.

1. ....

2. .... [1]

(ii) The pendulum bob moves along the arc of a circle. State the direction of the resultant of the two forces in **(i)**.

.... [1]

(c) The mass of the bob is 0.2 kg. During the swing it moves so that P is 0.05 m higher than R.

Calculate the increase in potential energy of the pendulum bob between R and P.

increase in potential energy = ………………. [2]

2 Fig. 3.1 shows a pond that is kept at a constant depth by a pressure-operated valve in the base.

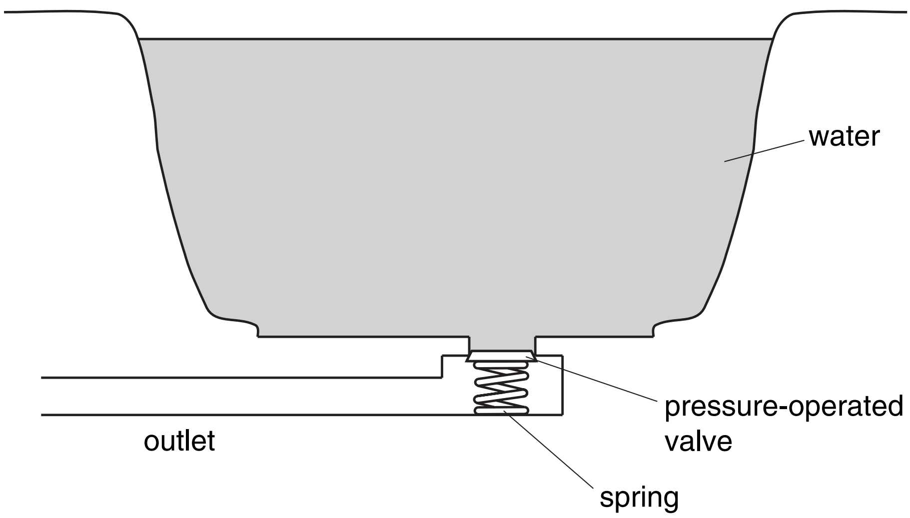


Fig. 3.1

(a) The pond is kept at a depth of 2.0 m. The density of water is 1000 kg/m^3.

Calculate the water pressure on the valve.

pressure =…………………….. [2]

(b) The force required to open the valve is 50 N. The valve will open when the water depth reaches 2.0 m.

Calculate the area of the valve.

area = ……………………….. [2]

(c) The water supply is turned off and the valve is held open so that water drains out through the valve.

State the energy changes of the water that occur as the depth of the water drops from 2.0 m to zero.

....

.... [2]

3 Fig. 3.1 shows water falling over a dam.

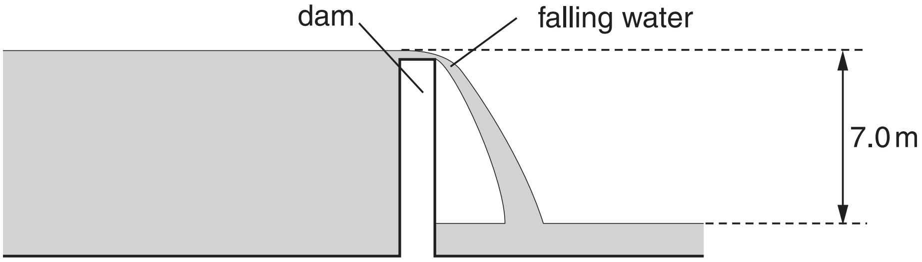


Fig. 3.1

(a) The vertical height that the water falls is 7.0 m.
Calculate the potential energy change of 1.0 kg of water during the fall.

ΔE_p = ...[2]

(b) Assuming all this potential energy loss is changed to kinetic energy of the water, calculate the speed of the water, in the vertical direction, at the end of the fall.

speed = ...[3]

(c) The vertical speed of the water is less than that calculated in **(b)**. Suggest one reason for this.

....

....[1]

4 Fig. 2.1 shows a track for a model car.

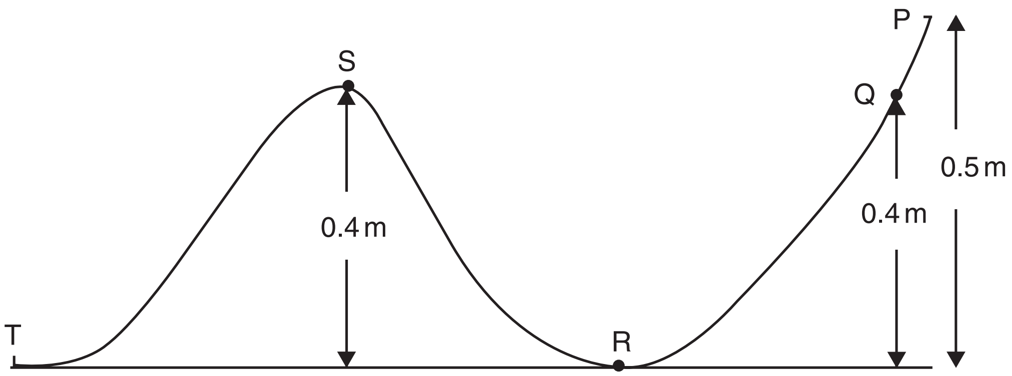


Fig. 2.1

The car has no power supply, but can run down a sloping track due to its weight.

(a) The car is released at Q. It comes to rest just before it reaches S and rolls back.

(i) Describe the motion of the car after it starts rolling back and until it eventually comes to rest.

....

....

.... [2]

(ii) Explain in terms of energy transformations why the car, starting at Q, cannot pass S.

....

....

.... [1]

(b) A second car, of mass 0.12 kg, is released from P. It continues until it runs off the track at T.

Calculate the maximum speed that the car could have at T assuming friction in the car is negligible.

speed = ... [3]

[Total: 6]

5 A cyclist rides up and then back down the hill shown in Fig. 3.1.

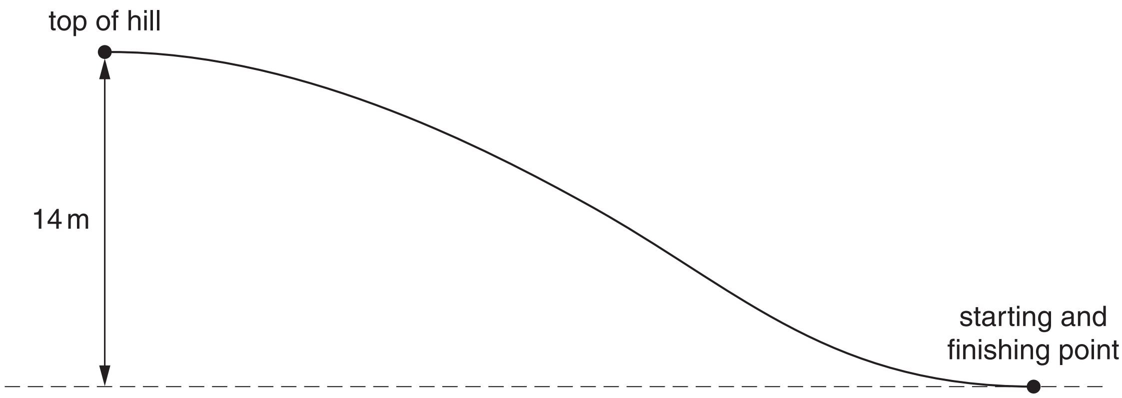


Fig. 3.1

The cyclist and her bicycle have a combined mass of 90 kg. She pedals up to the top and then stops. She turns around and rides back to the bottom without pedalling or using her brakes.

(a) Calculate the potential energy gained by the cyclist and her bicycle when she has reached the top of the hill.

ΔE_p = ...[2]

(b) Calculate the maximum speed she could have when she arrives back at the starting point.

speed = ... [3]

(c) Explain why her actual speed will be less than that calculated in **(b)**.

....

....

.... [1]

[Total: 6]

6 A wind turbine has blades, which sweep out an area of diameter 25 m.

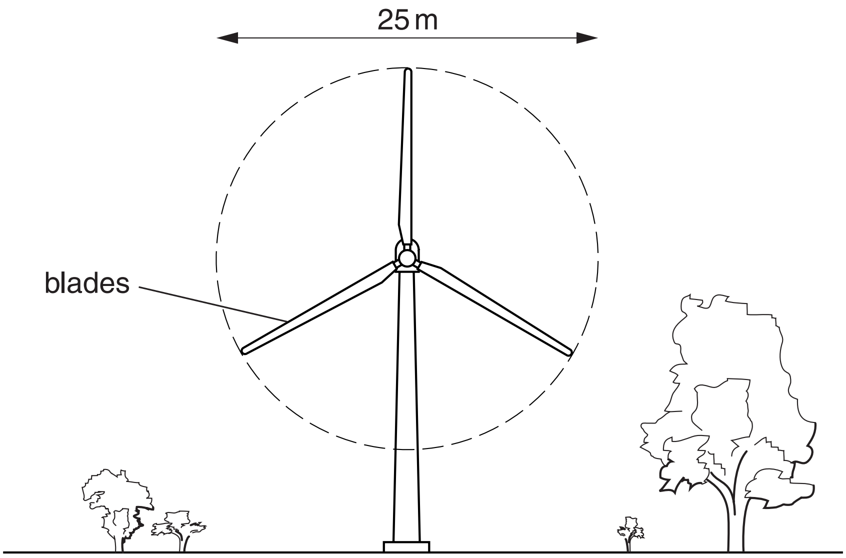


Fig. 5.1

(a) The wind is blowing directly towards the wind turbine at a speed of 12 m/s. At this wind speed, 7500 kg of air passes every second through the circular area swept out by the blades.

(i) Calculate the kinetic energy of the air travelling at 12 m/s, which passes through the circular area in 1 second.

kinetic energy = ... [3]

(ii) The turbine converts 10% of the kinetic energy of the wind to electrical energy.

Calculate the electrical power output of the turbine. State any equation that you use.

power = ... [3]

(b) On another day, the wind speed is half that in **(a)**.

(i) Calculate the mass of air passing through the circular area per second on this day.

mass = ... [1]

(ii) Calculate the power output of the wind turbine on the second day as a fraction of that on the first day.

fraction = ... [3]

(b) Construct two Sankey diagrams, to scale, illustrating the above process, one detailing energy stores, the other, energy transfers.

[4]

[Total: 14]

7 A ball player bounces a ball of mass 0.60 kg. Its centre of gravity moves down through a distance of 0.90 m, as shown in Fig. 1.1. Ignore air resistance throughout this question.

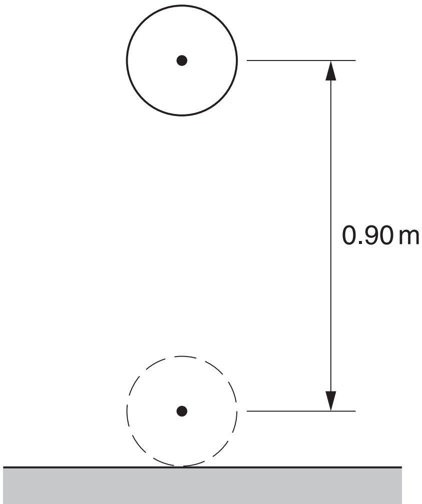


Fig. 1.1

(a) Calculate the decrease in gravitational potential energy of the ball as it moves down through the 0.90 m. Also write the change in gravitational potential energy.

decrease in PE = ... [1]

ΔE_p = ... [1]

(b) The ball hits the ground at 7.0 m/s.

Calculate the initial energy given to the ball by the player.

energy given = ... [3]

(c) On another occasion, the player throws the ball into the air, to a height of 4.0 m above the ground. The ball then falls to the ground.

During the impact, 22% of the ball's energy is lost.

(i) Suggest one reason why energy is lost during bouncing.

....

.... [1]

(ii) Calculate the height to which the ball rises after the bounce.

[2]

(iii) An observer who sees the ball bounce says, "That ball should be slightly warmer after that bounce."

Explain why the observer's statement is true.

....

....

.... [1]

[Total: 9]

8 A bob of mass of 0.15 kg is tied at the end of a cord to form a simple pendulum 0.70 m long.

The upper end of the cord is fixed to a support and the pendulum hangs vertically. A peg is fixed 0.50 m vertically below the support, as shown in Fig. 2.1.

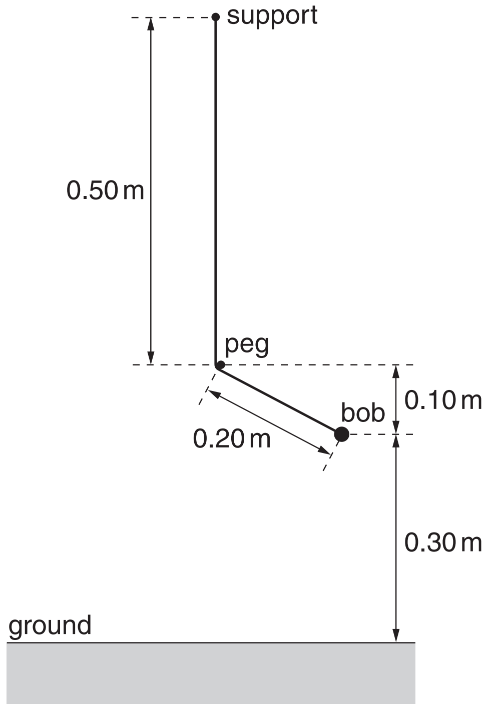


Fig. 2.1

The mass is pulled to the right, until it is in the position shown in Fig. 2.1.

Ignore air resistance throughout this question.

(a) Calculate the gravitational potential energy of the bob, relative to the ground, when the bob is in the position shown in Fig. 2.1.

gravitational potential energy = ... [2]

(b) The bob is released and swings to the left.

(i) Calculate the maximum kinetic energy of the bob.

kinetic energy = ... [4]

(ii) Calculate the maximum velocity of the bob.

velocity = ... [2]

(iii) As the pendulum swings to the left of vertical, state the maximum height above the ground that is reached by the bob.

.... [1]

(iv) On Fig. 2.1, use your ruler to draw carefully the pendulum when the bob is at its maximum height on the left. [3]

[Total: 12]

9 A boy drops a ball of mass 0.50 kg. The ball falls a distance of 1.1 m, as shown in Fig. 6.1. Ignore air resistance throughout this question.

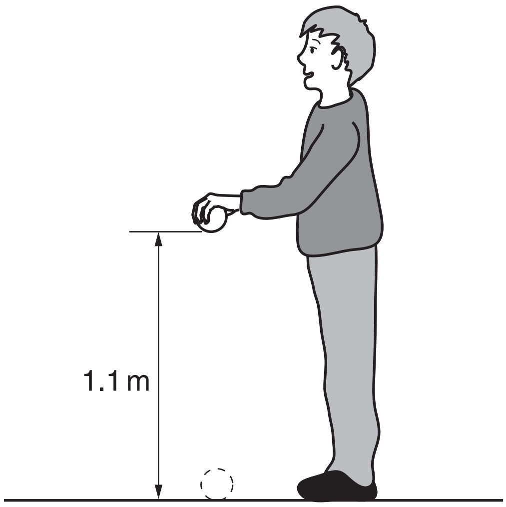


Fig. 6.1

(a) Calculate the decrease in gravitational potential energy of the ball as it falls through the 1.1 m.

decrease in potential energy = ... [2]

(b) The ball bounces and only rises to a height of 0.80 m.

(i) Write the energy change during the bounce.

ΔE = ... [1]

(ii) Suggest one reason why energy is lost during the bounce.

....

.... [1]

(c) On another occasion, the boy **throws** the ball down from a height of 1.1 m, giving it an initial kinetic energy of 9.0 J.

Calculate the speed at which the ball hits the ground.

speed = ... [3]

[Total: 7]

10 Fig. 1.1 shows a simple pendulum being used by a student to investigate the energy changes at various points in the pendulum's swing.

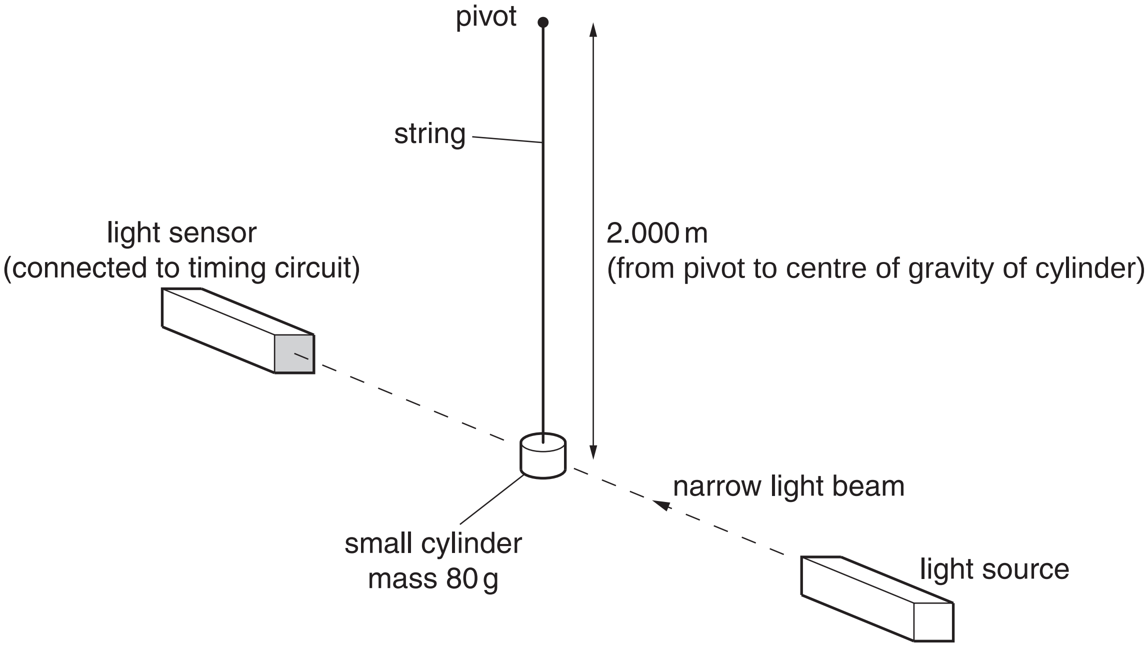


Fig. 1.1

(a) When the string is displaced by a small angle from the vertical, the vertical position of the cylinder changes so that its centre of gravity is now 1.932 m below the pivot. Determine the gravitational potential energy gained by the cylinder.

gravitational potential energy gained = ... [3]

(b) The cylinder is released from the displaced position in **(a)**. Calculate the expected speed of the cylinder when the string is vertical.

expected speed = ... [2]

(c) As the string passes through the vertical, the narrow beam of light is interrupted by the cylinder for 22 ms. The cylinder has a diameter of 2.5 cm.

(i) Calculate the actual speed of the cylinder.

actual speed = ...

(ii) Suggest how the difference between the actual and expected speeds could occur.

....

....

....

....
[3]

[Total: 8]

11 Fig. 3.1 shows a water turbine that is generating electricity in a small tidal energy scheme.

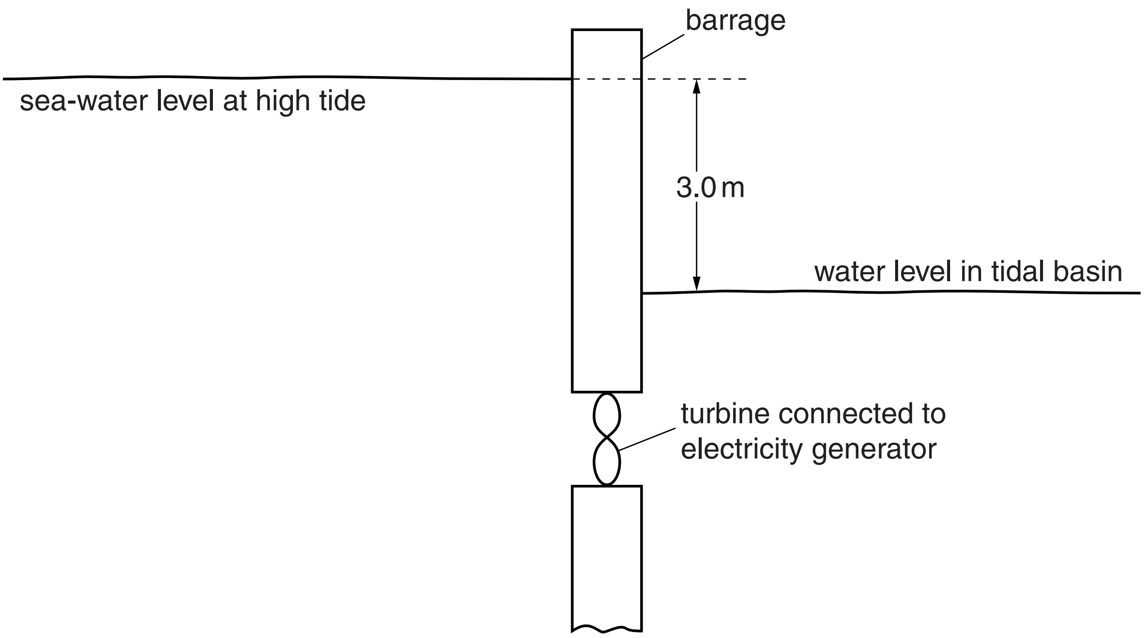


Fig. 3.1

At high tide, 1.0 m^3 of sea-water of density 1030 kg/m^3 flows through the turbine every second.

(a) Calculate the loss of gravitational potential energy when 1.0 m^3 of sea-water falls through a vertical distance of 3.0 m.

loss of gravitational potential energy = ... [3]

(b) Assume that your answer to **(a)** is the energy lost per second by the sea-water passing through the turbine at high tide. The generator delivers a current of 26 A at 400 V.

Calculate the efficiency of the scheme.

efficiency = ...% [3]

(c) At low tide, the sea-water level is lower than the water level in the tidal basin.

(i) State the direction of the flow of water through the turbine at low tide.

....

(ii) Suggest an essential feature of the turbine and generator for electricity to be generated at low tide.

....

....

....
[2]

[Total: 8]

12 **(a)** State what is meant by the *centre of gravity* of a body.

....

....

.... [1]

(b) Fig. 4.1 shows an athlete successfully performing a high jump.

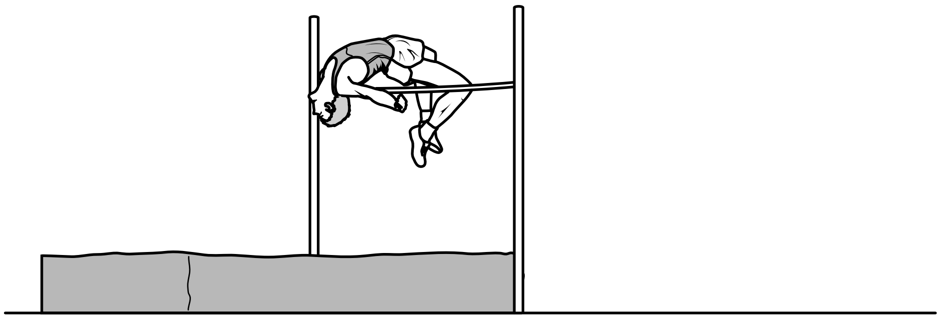


Fig. 4.1

The height of the bar above the ground is 2.0 m. The maximum change in gravitational potential energy (g.p.e.) of the athlete during the jump is calculated using the expression $\Delta E_p = mg\,\Delta h$

Explain why the value of *h* used in the calculation is much less than 2.0 m.

....

....

.... [1]

(c) Fig. 4.2 shows, in order, five stages of an athlete successfully performing a pole-vault.

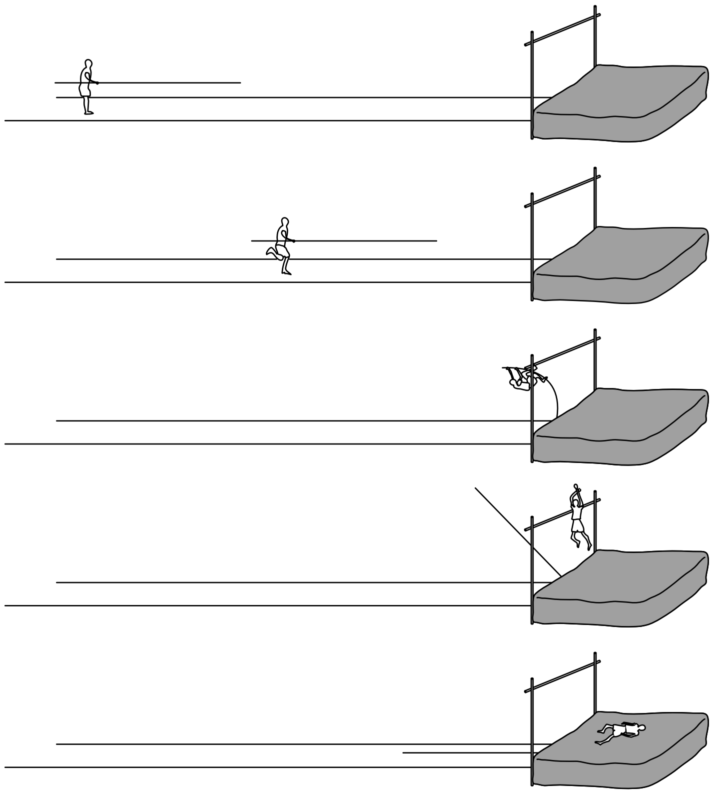


Fig. 4.2

Describe the energy changes which take place during the performance of the pole-vault, from the original stationary position of the pole-vaulter before the run-up, to the final stationary position after the vault.

....

....

....

....

....

....

....

....

....

....

.... [6]

[Total: 8]

13 Fig. 1.1 shows a car on a roller-coaster ride.

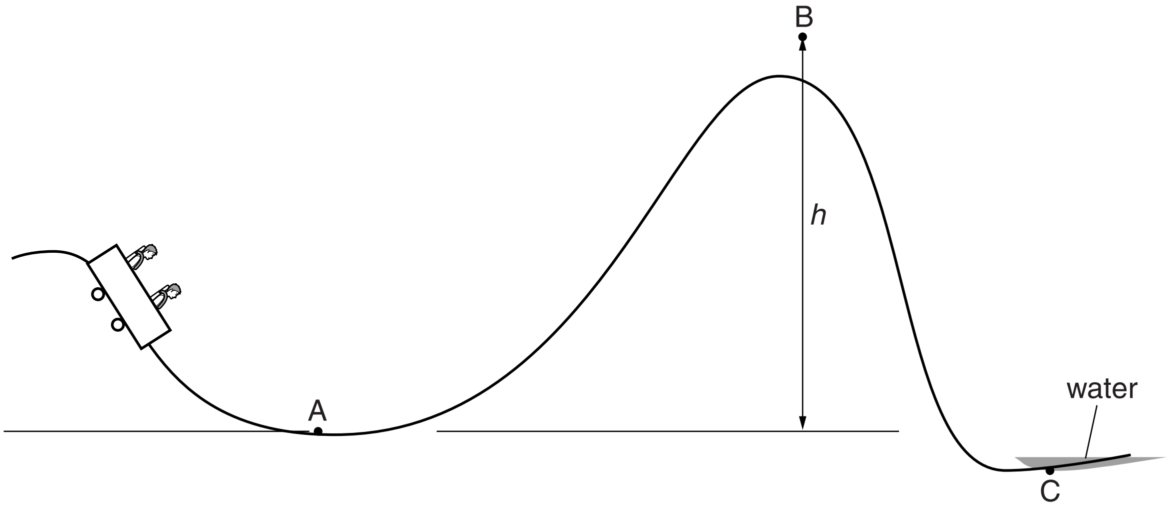


Fig. 1.1

mass of car = 600 kg
kinetic energy of car at point A = 160 kJ

(a) Calculate the speed of the car at A.

speed = ... [3]

(b) As the car travels from A to B, it loses 40 kJ of energy due to friction.

The car just manages to roll over the crest of the hill at B.

Calculate the height *h*.

height h = ... [2]

(c) At C, the car is slowed down by a shallow tank of water and the kinetic energy of the car is reduced to zero.

Make **three** suggestions for what happens to this kinetic energy.

1. ....

2. ....

3. ....

[3]

[Total: 8]

14 Fig. 3.1 shows an aeroplane of mass 3.4×10^5 kg accelerating uniformly from rest along a runway.

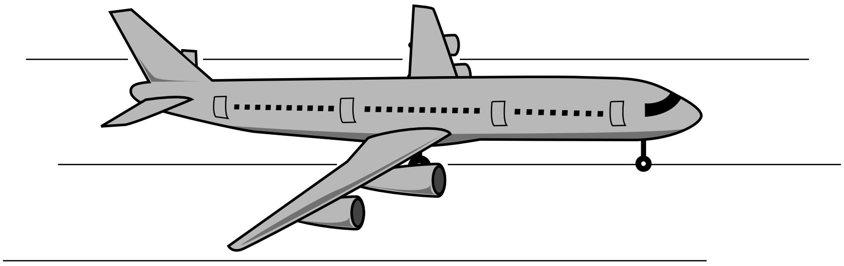


Fig. 3.1

After 26 s it reaches a speed of 65 m/s.

(a) Calculate

(i) the acceleration of the aeroplane,

acceleration = ... [2]

(ii) the resultant force on the aeroplane.

force = ... [2]

(b) Just after taking off, the aeroplane continues to accelerate as it gains height.

(i) State **two** forms of energy that increase during this time.

1. ....

2. .... [2]

(ii) State **one** form of energy that decreases during this time.

.... [1]

(iii) State why the total energy of the aeroplane decreases during this time.

....

.... [1]

(c) When the aeroplane reaches its maximum height, it starts to follow a curved path at a constant speed.

State the direction of the resultant force on the aeroplane.

.... [1]

[Total: 9]

Chapter 7. Energy resources

1.7.3 Energy resources

Core

1 Describe how useful energy may be obtained, or electrical power generated, from:

(a) chemical energy stored in fossil fuels

(b) chemical energy stored in biofuels

(c) water, including the energy stored in waves, in tides, and in water behind hydroelectric dams

(d) geothermal resources

(e) nuclear fuel

(f) light from the Sun to generate electrical power (solar cells)

(g) infrared and other electromagnetic waves from the Sun to heat water (solar panels) and be the source of wind energy

including references to a boiler, turbine and generator where they are used

2 Describe advantages and disadvantages of each method in terms of renewability, availability, reliability, scale and environmental impact

3 Understand, qualitatively, the concept of efficiency of energy transfer

Supplement

4 Know that radiation from the Sun is the main source of energy for all our energy resources except geothermal, nuclear and tidal

5 Know that energy is released by nuclear fusion in the Sun

6 Know that research is being carried out to investigate how energy released by nuclear fusion can be used to produce electrical energy on a large scale

7 Define efficiency as:

(a)

$$(\%)\ \text{efficiency} = \frac{(\text{useful energy output})}{(\text{total energy input})}\ (\times 100\%)$$

(b)

$$(\%)\ \text{efficiency} = \frac{(\text{useful power output})}{(\text{total power input})}\ (\times 100\%)$$

recall and use these equations

1 **(a)** Name the process by which energy is released in the core of the Sun.

.... [1]

(b) Describe how energy from the Sun becomes stored energy in water behind a dam.

....

....

....

.... [3]

(c) Data for two small power stations is given in Table 2.1.

	input to power station	**output of power station**
gas-fired	100 MW	25 MW
hydroelectric	90 MW	30 MW

Table 2.1

(i) State what is meant by the *efficiency* of a power station.

....

....

....

.... [1]

(ii) Use the data in Table 2.1 to explain that the hydroelectric station is more efficient than the gas-fired power station.

....

....

.... [1]

[Total: 6]

2 **(a)** Energy from the Sun evaporates water from the sea. Some of this water eventually drives a hydroelectric power station. Give an account of the processes and energy changes involved.

....

....

....

....

....

....

....

....

....

....[4]

(b) In a hydroelectric power station, 200 000 kg of water per second fall through a vertical distance of 120 m. The water passes through turbines to generate electricity, and leaves the turbines with a speed of 14 m/s.

(i) Calculate the gravitational potential energy lost by the water in 1 second. Use $g = 10\,\text{m/s}^2$.

potential energy lost = ...[2]

(ii) Calculate the kinetic energy of the water leaving the turbines in 1 second.

kinetic energy = ...[2]

[Total: 8]

3 **(a)** In terms of fuel source origins, how do bio and fossil fuels differ?

....

....

....

....[2]

(b) What are some advantages and disadvanges of bio versus fossil fuels?

....

....

....

....

....

....

....[4]

[Total: 6]

4 **(a)** (i) Name two methods in which energy can be derived from nuclear processe.

....

....[2]

(ii) How do the processes you mentioned above differ?

....

....

....

....[2]

(b) What are some advantages and disadvanges of the two methods mentioned above?

....

....

....

....

....

....

....[4]

[Total: 8]

5 **(a)** (i) Briefly explain the differences between renewable and nonrenewable resources.

....

....

....

....[2]

(b) (i) List some examples of nenewable resources.

....

....

....[2]

(ii) List some examples of nonnenewable resources.

....

....

....[2]

(c) What is meant by resource availability. Provide some examples to explain your answer.

....

....

....[3]

[Total: 8]

6 **(a)** Modern day attempts to reduce humanity's dependence on fossil fuels includes the use of renewable energy sources, such as wave energy.

(i) Describe some different types of energy involved in this process.

....

....

....

....[2]

(i) In the space below, construct a Sankey diagram illustrating the energy transfer processes.

[4]

(a) Discuss some of the issues of consideration in deriving electricty from ocean waves.

....

....

....

....[3]

[Total: 9]

Chapter 8. Work,energy and power

1.7 Energy, work and power continued

1.7.2 Work

Core

1 Understand that mechanical or electrical work done is equal to the energy transferred

2 Recall and use the equation for mechanical working

$W = Fd = \Delta E$

Supplement

1.7 Energy, work and power continued

1.7.4 Power

Core

1 Define power as work done per unit time and also as energy transferred per unit time; recall and use the equations

(a) $P = \frac{W}{t}$

(b) $P = \frac{\Delta E}{t}$

Supplement

1 A group of students attempts to find out how much power each student can generate. The students work in pairs in order to find the time taken for each student to run up a flight of stairs.
The stairs used are shown in Fig. 1.

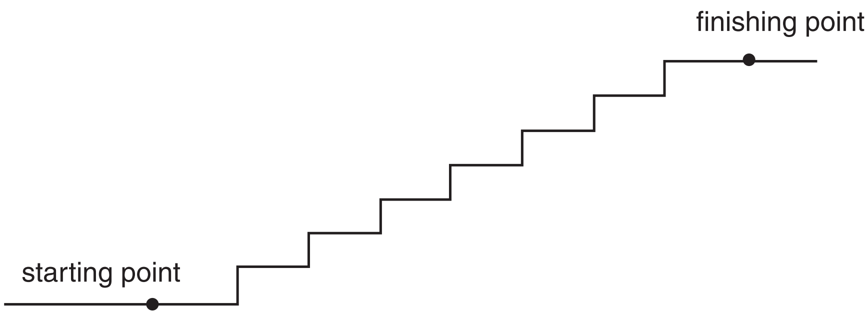


Fig. 1

(a) Make a list of all the readings that would be needed. Where possible, indicate how the accuracy of the readings could be improved.

....

....

....

....

....

.... [4]

(b) Using words, not symbols, write down all equations that would be needed to work out the power of a student.

....

....

.... [2]

(c) **(i)** When the student has reached the finishing point and is standing at the top of the stairs, what form of energy has increased to its maximum?

....

(ii) Suggest why the total power of the student is greater than the power calculated by this method.

....

....
[3]

2 Fig. 1.1 shows a smooth metal block about to slide down BD, along DE and up EF.
BD and DE are friction-free surfaces, but EF is rough. The block stops at F.

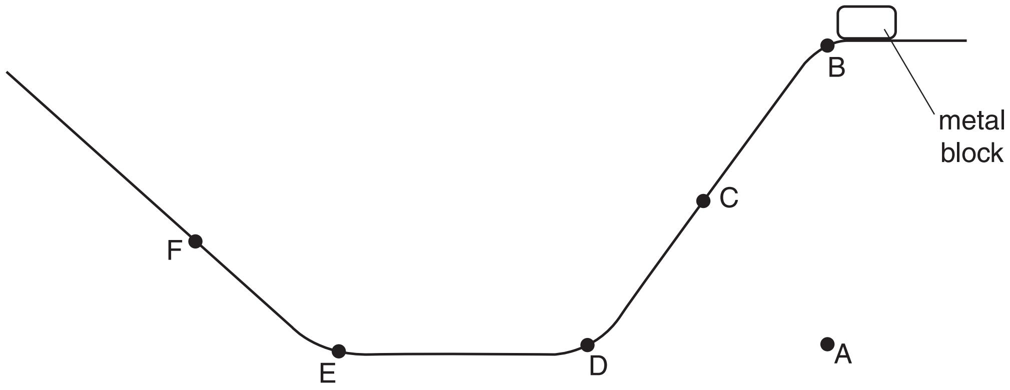


Fig. 1.1

(a) On Fig. 1.2, sketch the speed-time graph for the journey from B to F.
Label D, E and F on your graph. [3]

Fig. 1.2

(b) The mass of the block is 0.2 kg. The vertical height of B above A is 0.6 m.
The acceleration due to gravity is 9.81 m/s^2.

(i) Calculate the work done in lifting the block from A to B.

W = ...

(ii) At C, the block is moving at a speed of 2.5 m/s. Calculate its kinetic energy at C.

E_k = ...

[5]

(c) As it passes D, the speed of the block remains almost constant but the velocity changes. Using the terms *vector* and *scalar*, explain this statement.

....

....

....[2]

(d) F is the point where the kinetic energy of the block is zero. In terms of energy changes, explain why F is lower than B.

....

....

....

....[3]

3 Fig. 3.1 shows the arm of a crane when it is lifting a heavy box.

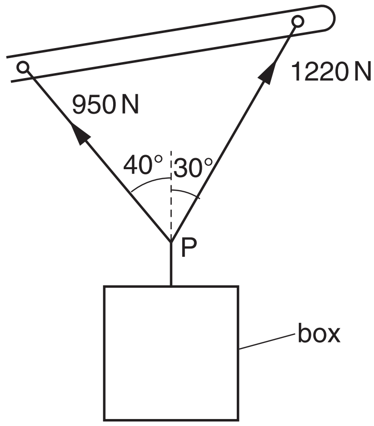


Fig. 3.1

(a) By the use of a scale diagram (**not** calculation) of the forces acting at P, find the weight of the box. [5]

(b) Another box of weight 1500 N is raised vertically by 3.0 m.

(i) Calculate the work done on the box.

work done = ...

(ii) The crane takes 2.5 s to raise this box 3.0 m. Calculate the power output of the crane.

power = ...
[4]

4 Fig. 2.1 shows a rock that is falling from the top of a cliff into the river below.

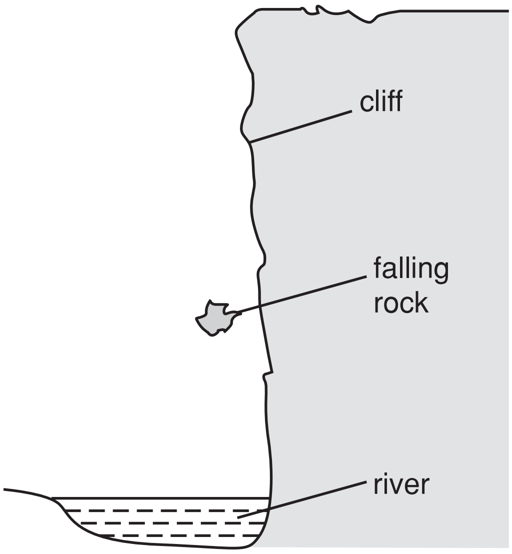


Fig. 2.1

(a) The mass of the rock is 75 kg. The acceleration of free fall is 10 m/s^2.
Calculate the weight of the rock.

weight = ...[1]

(b) The rock falls from rest through a distance of 15 m before it hits the water.
Calculate its kinetic energy just before hitting the water. Show your working.

kinetic energy = ...[3]

(c) The rock hits the water. Suggest what happens to the kinetic energy of the rock during the impact.

....

....

....[3]

5 An electric pump is used to raise water from a well, as shown in Fig. 3.1.

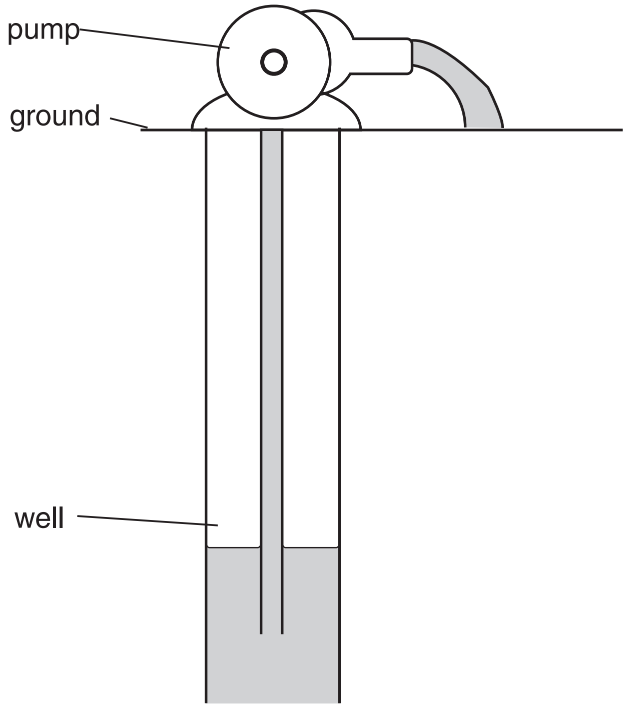


Fig. 3.1

(a) The pump does work in raising the water. State an equation that could be used to calculate the work done in raising the water.

....[2]

(b) The water is raised through a vertical distance of 8.0 m. The weight of water raised in 5.0 s is 100 N.

(i) Calculate the work done in raising the water in this time.

work done = ...[1]

(ii) Calculate the power the pump uses to raise the water.

power = ...[1]

(iii) The energy transferred by the pump to the water is greater than your answer to **(i)**. Suggest what the additional energy is used for.

....[1]

6 A student wishes to work out how much power she uses to lift her body when climbing a flight of stairs.

Her body mass is 60 kg and the vertical height of the stairs is 3.0 m. She takes 12 s to walk up the stairs.

(a) Calculate

(i) the work done in raising her body mass as she climbs the stairs,

work = ... [2]

(ii) the output power she develops when raising her body mass.

power = ... [2]

(b) At the top of the stairs she has gravitational potential energy.

Describe the energy transformations taking place as she walks back down the stairs and stops at the bottom.

....

....

....

.... [2]

[Total: 6]

7 A farmer uses an electric pump to raise water from a river in order to fill the irrigation channels that keep the soil in his fields moist.

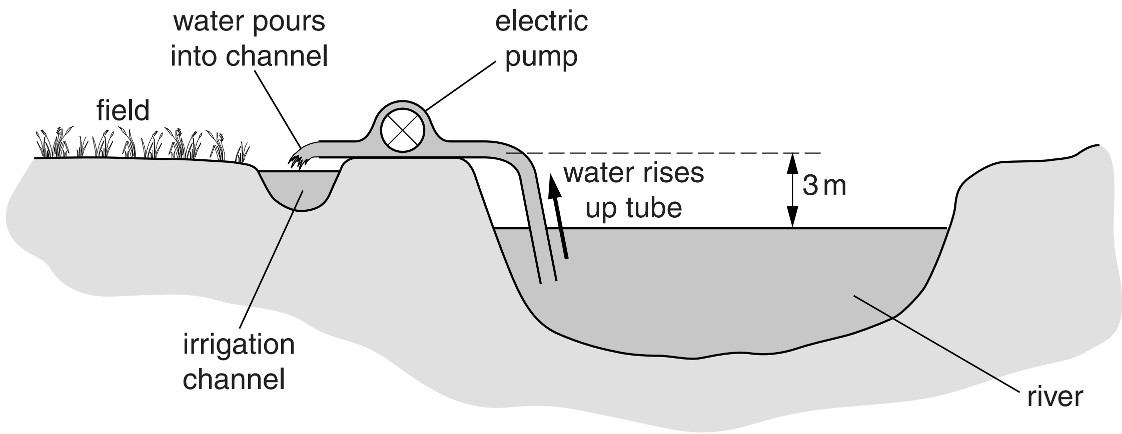


Fig. 5.1

Every minute, the pump raises 12 kg of water through a vertical height of 3 m.

(a) Calculate the increase in the gravitational potential energy of 12 kg of water when it is raised 3 m.

increase in gravitational potential energy = ... [3]

(b) Calculate the useful power output of the pump as it raises the water.

power = ... [3]

[Total: 6]

8 A car of mass 900 kg is travelling at a steady speed of 30 m/s against a resistive force of 2000 N, as illustrated in Fig. 2.1.

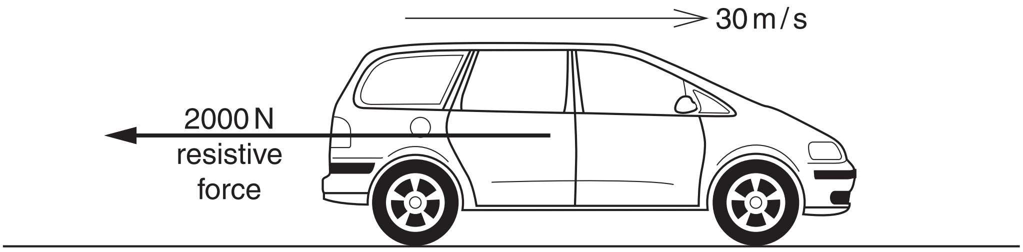


Fig. 2.1

(a) Calculate the kinetic energy of the car.

kinetic energy = ... [2]

(b) Calculate the energy used in 1.0 s against the resistive force.

energy = ... [2]

(c) What is the minimum power that the car engine has to deliver to the wheels?

minimum power = ... [1]

(d) What form of energy is in the fuel, used by the engine to drive the car?

.... [1]

(e) State why the energy in the fuel is converted at a greater rate than you have calculated in **(c)**.

....

.... [1]

[Total: 7]

(f) Illustrate the above scenario, to scale, using a Sankey diagram highlighting energy storage.

[3]

Total: [10]

9 An ornamental garden includes a small pond, which contains a pumped system that causes water to go up a pipe and then to run down a heap of rocks.

Fig. 3.1 shows a section through this water feature.

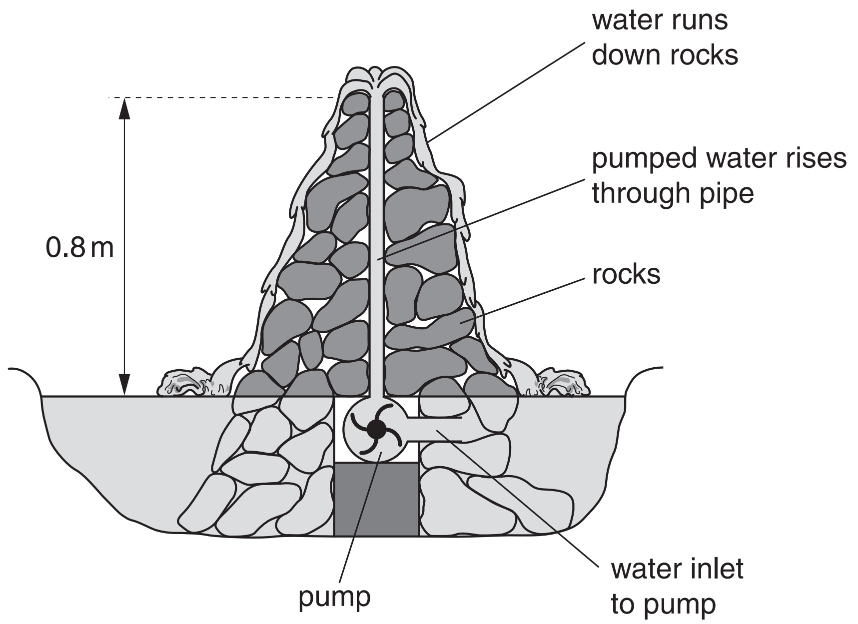


Fig. 3.1

The density of water is 1000 kg / m^3. A volume of 1 litre is equal to 0.001 m^3.

(a) Calculate the mass of 1 litre of water.

mass = ... [2]

(b) Calculate the work done raising 1 litre of water through a height of 0.8 m.

work = ... [2]

(c) The pump lifts 90 litres of water per minute.

Calculate the minimum power of the pump.

power = ... [2]

(d) The pump is switched off.

Immediately after the pump is switched off, what is the value of the water pressure at the bottom of the 0.8 m pipe, due to the water in the pipe?

pressure = ... [2]

[Total: 8]

10 Fig. 5.1 shows a model cable-car system. It is driven by an electric motor coupled to a gear system.

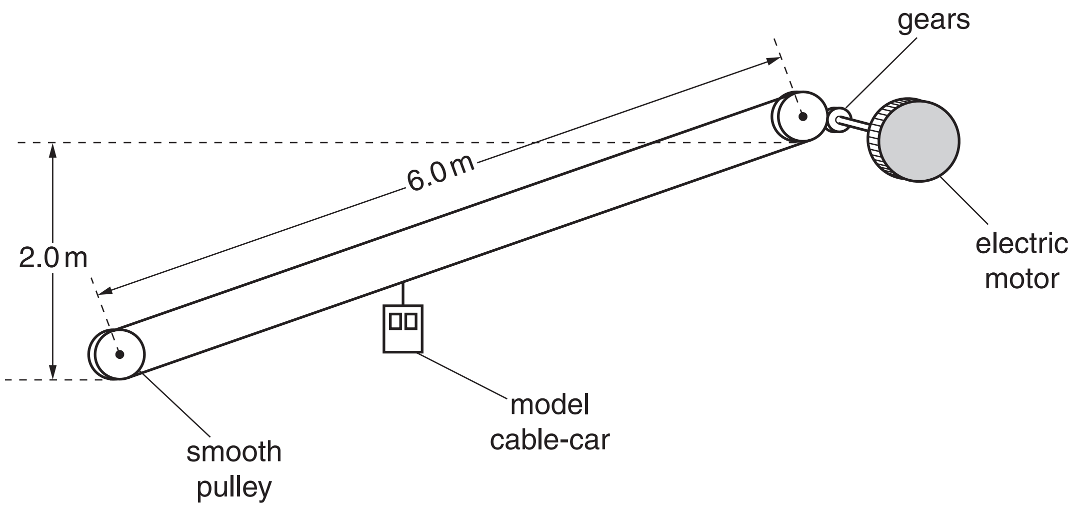


Fig. 5.1

The model cable-car has a mass of 5.0 kg and is lifted from the bottom pulley to the top pulley in 40 s. It stops automatically at the top.

(a) Calculate

(i) the average speed of the cable-car,

< v > = ... [2]

(ii) the gravitational potential energy gained by the cable-car,

gravitational potential energy gained = ... [2]

(iii) the useful output power of the driving mechanism.

power = ... [2]

(b) How would the electrical power input to the motor compare with your answer to **(a)(iii)**?

.... [1]

[Total: 7]

11 Some builders decide to measure their personal power ratings using apparatus they already have on site. Fig. 2.1 shows the arrangement they use.

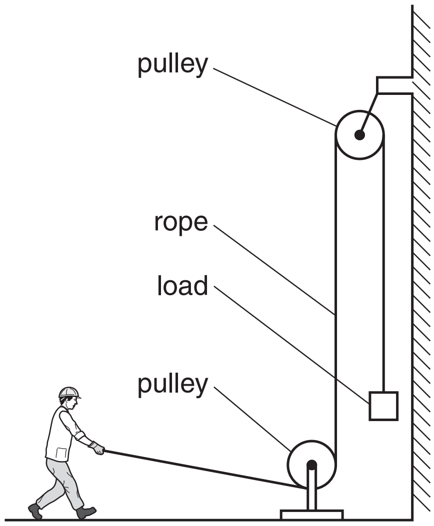


Fig. 2.1

(a) In the table below, list the three quantities they must measure in order to calculate one man's power, and the instrument they would use for each measurement.

quantity to be measured	instrument used for measurement
1.	
2.	
3.	

[3]

(b) One workman is measured as having a power of 528 W. His weight is 800 N.

He can develop the same power climbing a ladder, whose rungs are 30 cm apart.

How many rungs can he climb in 5 s?

number of rungs = ...[3]

(c) The human body is only about 15% efficient when climbing ladders.

Calculate the actual energy used from the body of the workman in **(b)** when he climbs 20 rungs.

energy used = ...[2]

[Total: 8]

12 Fig. 2.1 shows a conveyor belt transporting a package to a raised platform. The belt is driven by a motor.

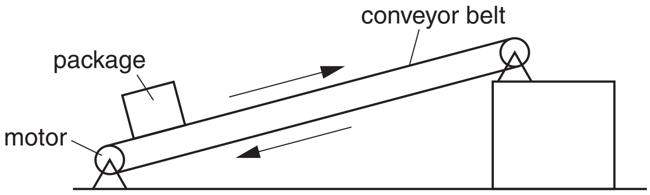


Fig. 2.1

(a) State **three** types of energy, other than gravitational potential energy, into which the electrical energy supplied to the motor is converted.

1. ....

2. ....

3. ....[2]

(b) The mass of the package is 36 kg. Calculate the increase in gravitational potential energy E_p of the package when it is raised through a vertical height of 2.4 m.

increase in p.e. = ...[2]

(c) The package is raised through the vertical height of 2.4 m in 4.4 s. Calculate the power needed to raise the package.

power = ... [2]

(d) Assume that the power available to raise packages is constant. A package of mass greater than 36 kg is raised through the same height. Suggest and explain the effect of this increase in mass on the operation of the belt.

....

....

....

....

....[3]

[Total: 9]

13 The racing car shown in Fig. 2.1 uses a Kinetic Energy Recovery System (KERS). This system stores within the car some of the kinetic energy lost when the car slows down for a corner. The driver can later release the stored energy when maximum power is required.

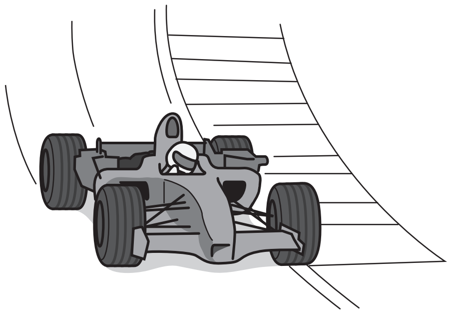


Fig. 2.1

(a) The car approaches a corner and decelerates from 82 m/s to 61 m/s in 0.90 s.
Calculate the car's acceleration and deceleration.

acceleration = ... [1]

deceleration = ... [1]

(b) **(i)** The energy lost during the braking in **(a)** is 8.4×10^5 J. 40% of this lost energy is directed to the KERS system. Determine the amount of energy stored.

energy stored = ...

(ii) The driver later uses all of this stored energy to give 60 kW of useful extra power for 3.0 s.
Calculate the energy released.

energy released = ...

(iii) Calculate the efficiency of the KERS system.

efficiency = ...
[4]

(c) Suggest a possible device to store energy when a moving vehicle slows down. For this device, state the change that occurs as more energy is stored.

device ....

change ....

....

.... [2]

[Total: 8]

14 Two workmen are employed on a building project, as shown in Fig. 5.1.

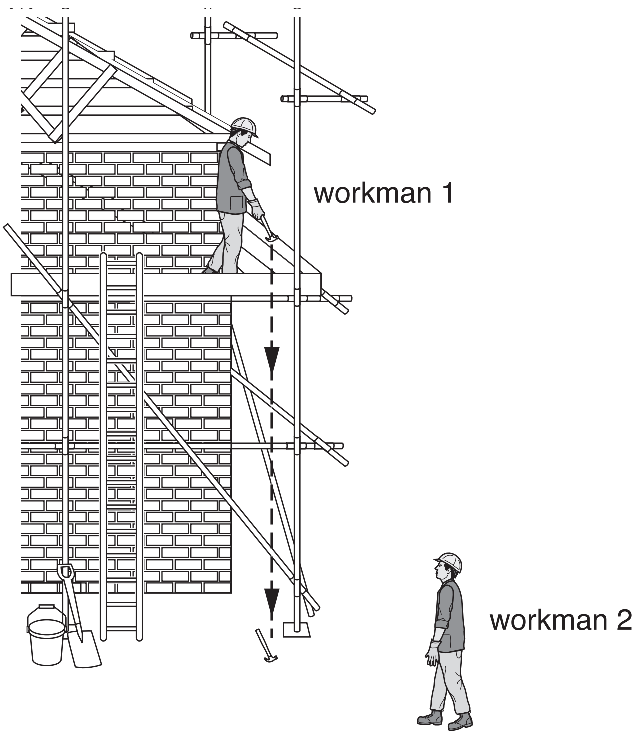


Fig. 5.1

(a) Workman 1 drops a hammer, which falls to the ground. The hammer has a mass of 2.0 kg, and is dropped from a height of 4.8 m above the ground.

(i) Calculate the change in gravitational potential energy of the hammer when it is dropped.

ΔE_p = ...[2]

(ii) Describe the energy changes from the time the hammer leaves the hand of workman 1 until it is at rest on the ground.

....

....

....

....[2]

(b) Workman 2 picks up the hammer and takes it back up the ladder to workman 1.

He climbs the first 3.0 m in 5.0 s. His total weight, including the hammer, is 520 N.

(i) Calculate the useful power which his legs are producing.

power = ...[2]

(ii) In fact his body is only 12% efficient when climbing the ladder.

Calculate the rate at which energy stored in his body is being used.

rate = ...[1]

(b) What might be the fate of workman 1?

....

....

....

.... [3

Total: [10]

15 **(a)** State an example of the conversion of chemical energy to another form of energy.

example ....

energy conversion ....[1]

(b) The electrical output of a solar panel powers a pump. The pump operates a water fountain. The output of the solar panel is 17 V and the current supplied to the pump is 0.27 A.

(i) Calculate the electrical power generated by the solar panel.

power = ... [2]

(ii) The pump converts electrical energy to kinetic energy of water with an efficiency of 35%.

Calculate the kinetic energy of the water delivered by the pump in 1 second.

kinetic energy = ... [2]

(iii) The pump propels 0.00014 m^3 of water per second. This water rises vertically as a jet. The density of water is 1000 kg/m^3.

Calculate

1. the mass of water propelled by the pump in 1 second,

mass = ... [2]

2. the maximum height of the jet of water.

maximum height = ... [2]

[Total: 9]

Part II
Thermal physics

Chapter 9. Thermal Physics

2.1 Kinetic particle model of matter

2.1.1 States of matter

Core

1 Know the distinguishing properties of solids, liquids and gases

2 Know the terms for the changes in state between solids, liquids and gases (gas to solid and solid to gas transfers are **not** required)

Supplement

2.1.2 Particle model

Core

1 Describe the particle structure of solids, liquids and gases in terms of the arrangement, separation and motion of the particles, and represent these states using simple particle diagrams

2 Describe the relationship between the motion of particles and temperature, including the idea that there is a lowest possible temperature (–273 °C), known as absolute zero, where the particles have least kinetic energy

3 Describe the pressure and the changes in pressure of a gas in terms of the motion of its particles and their collisions with a surface

4 Know that the random motion of microscopic particles in a suspension is evidence for the kinetic particle model of matter

5 Describe and explain this motion (sometimes known as Brownian motion) in terms of random collisions between the microscopic particles in a suspension and the particles of the gas or liquid

Supplement

6 Know that the forces and distances between particles (atoms, molecules, ions and electrons) and the motion of the particles affects the properties of solids, liquids and gases

7 Describe the pressure and the changes in pressure of a gas in terms of the forces exerted by particles colliding with surfaces, creating a force per unit area

8 Know that microscopic particles may be moved by collisions with light fast-moving molecules and correctly use the terms atoms or molecules as distinct from microscopic particles

Part II
Thermal physics

2.1.3 Gases and the absolute scale of temperature

Core

1 Describe qualitatively, in terms of particles, the effect on the pressure of a fixed mass of gas of:

(a) a change of temperature at constant volume

(b) a change of volume at constant temperature

2 Convert temperatures between kelvin and degrees Celsius; recall and use the equation

T (in K) = θ (in °C) + 273

Supplement

3 Recall and use the equation

pV = constant

for a fixed mass of gas at constant temperature, including a graphical representation of this relationship

2.2.3 ...evaporation

Core

4 Describe evaporation in terms of the escape of more energetic particles from the surface of a liquid

5 Know that evaporation causes cooling of a liquid

Supplement

7 Describe how temperature, surface area and air movement over a surface affect evaporation

8 Explain the cooling of an object in contact with an evaporating liquid

9.1 The kinetic model of matter

1 (a) Explain, in terms of particles, how thermal expansion takes place in a solid and in a gas.

solid ....

....

....

....

....

gas ....

....

....

....

.... [4]

(b) Complete Table 5.1 to show the relative expansion of equal volumes of liquids, gases and solids.

Choose words from

much less, **slightly less**, **slightly more** and **much more**. [2]

state of matter	**expansion compared to solids, for the same temperature rise**
liquids	
gases	

Table 5.1

(c) Alcohol is often used in thermometers.

State one property of alcohol that makes it suitable for use in thermometers.

....

.... [1]

[Total: 7]

2 The whole of a sealed, empty, dusty room is kept at a constant temperature of 15 °C. Light shines into the room through a small outside window.

An observer points a TV camera with a magnifying lens into the room through a second small window, set in an inside wall at right angles to the outside wall.

Dust particles in the room show up on the TV monitor screen as tiny specks of light.

(a) In the space below draw a diagram to show the motion of one of the specks of light over a short period of time.

[1]

(b) After a period of one hour the specks are still observed, showing that the dust particles have not fallen to the floor.

Explain why the dust particles have not fallen to the floor. You may draw a labelled diagram to help your explanation.

....

....

....

.... [2]

(c) On another day, the temperature of the room is only 5 °C. All other conditions are the same and the specks of light are again observed.

Suggest any differences that you would expect in the movement of the specks when the temperature is 5 °C, compared to before.

....

....

.... [1]

[Total: 4]

3 **(a)** Fig. 3.1 represents the path taken in air by a smoke particle, as seen in a Brownian motion experiment. The smoke particles can be seen through a microscope, but particles composing the air cannot.

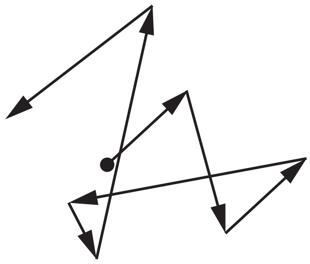


Fig. 3.1

(i) State what causes the smoke particles to move like this.

....

.... [1]

(ii) What conclusions about air particles can be drawn from this observation of the smoke particles?

....

....

....

....

.... [2]

(b) A can, containing only air, has its lid tightly screwed on and is left in strong sunlight.

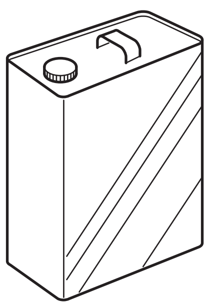


Fig. 3.2

(i) State what happens to the pressure of the air in the can when it gets hot.

.... [1]

(ii) In terms of particles, explain your answer to **(b)(i)** .

....

....

....

.... [3]

[Total: 7]

9.2 Evaporation

1 Fig.1 is an attempt to show the water particles and the water vapour particles over the water surface.

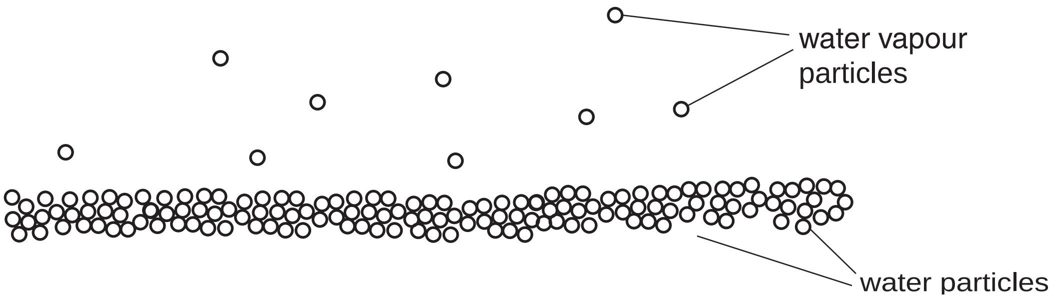


Fig.1

(a) Explain, in terms of the energies of the particles, why only a few water particles have escaped from the water surface.

....

....

.... [2]

(b) State two ways of increasing the number of water particles escaping from the surface.

1 ....

2 .... [2]

(c) Energy is required to evaporate water.

Explain, in terms of particles, why this energy is needed.

....

....

.... [2]

2 **(a)** Fig. 5.1 shows the paths of a few particles composing air and a single dust particle. The actual air particles are too small to show on the diagram.

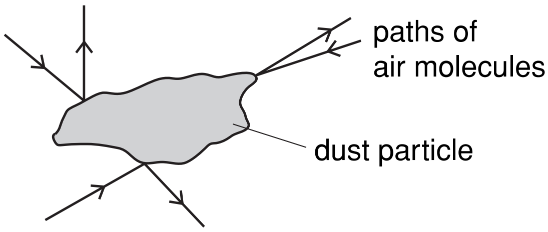


Fig. 5.1

Explain why the dust particle undergoes small random movements.

....

....

....

.... [4]

(b) Fig. 5.2 shows the paths of a few particles leaving the surface of a liquid. The liquid is below its boiling point.

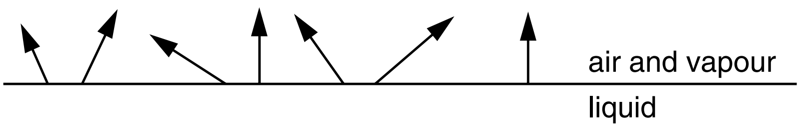


Fig. 5.2

(i) State which liquid particles are most likely to leave the surface.

....

.... [1]

(ii) Explain your answer to **(i)**.

....

....

.... [2]

3 **(a)** Some water is poured onto a plastic table-top, forming a puddle. The same volume of water is poured into a plastic dish, which is placed alongside the puddle. This is illustrated in Fig. 7.1.

Fig. 7.1

Both lots of water begin to evaporate.

(i) In terms of the behaviour of particles, describe what happens during the process of evaporation.

....

....

....

.... [2]

(ii) Explain why the puddle dries out more rapidly than the water in the dish.

....

....

....

.... [2]

(iii) State two changes that would make both lots of water evaporate more rapidly.

1. ....

2. .... [2]

(b) In a place where refrigeration is not possible, a person attempts to keep a bottle of milk cool by using the procedure illustrated in Fig. 7.2.

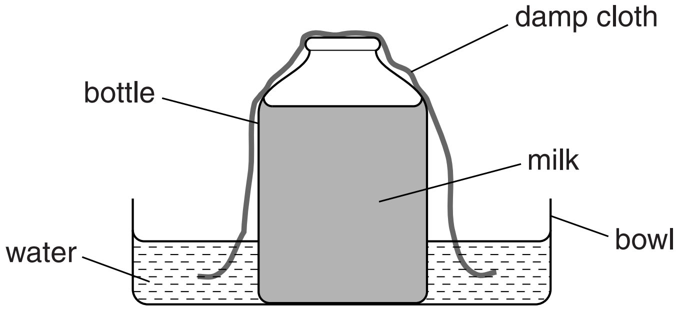


Fig. 7.2

Explain in terms of particles why this procedure would be successful.

....

....

.... [3]

[Total: 9]

4 **(a)** Two students hang out identical T-shirts to dry at the same time in the same neighbourhood. The only difference between the drying conditions is that one T-shirt is sheltered from any wind and the other is in a strong breeze, as shown in Fig. 6.1.

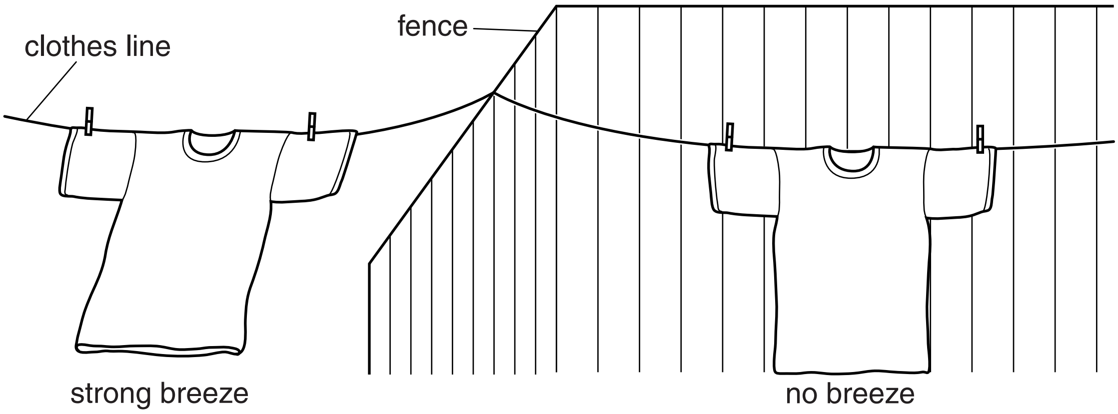


Fig. 6.1

State and explain, in terms of water particles, the difference between the drying times of the T-shirts.

....

....

....

....

.... [2]

(b) Fig. 6.2 shows another occasion when a student hangs out two identical T-shirts to dry next to each other on a line. One T-shirt is folded double as shown in Fig. 6.2.

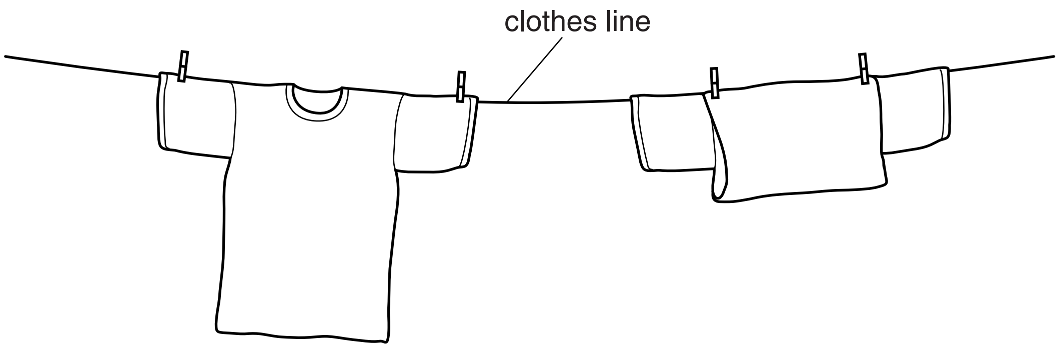


Fig. 6.2

State and explain, in terms of water particles, the difference between the drying times of the T-shirts.

....

....

....

....

.... [2]

(c) A runner in a hot country feels cooler if she pours water over her hair to keep it wet, even when the water is at the same temperature as the air around her.

Explain, in terms of a change of state of water, why she feels cooler.

....

....

....

.... [2]

[Total: 6]

5 **(a)** Explain why a liquid cools when evaporation takes place from its surface.

....

....

.... [2]

(b) Fig. 7.1 shows five vessels each made of the same metal and containing water.

Vessels A, B, C and D are identical in size and shape. Vessel E is shallower and wider. The temperature of the air surrounding each vessel is 20 °C.

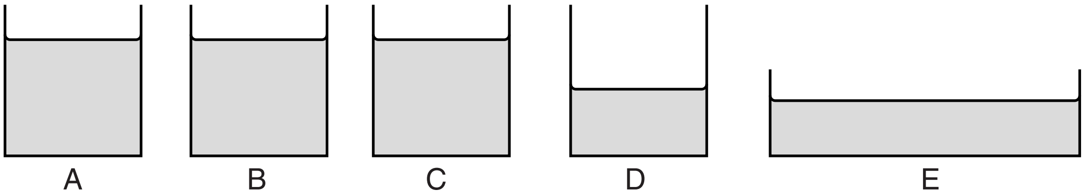


Fig. 7.1

The table shows details about each vessel and their contents.

vessel	outer surface	volume of water / cm^3	initial temperature of water / °C
A	dull	200	80
B	shiny	200	80
C	dull	200	95
D	dull	100	80
E	dull	200	80

The following questions are about the time taken for the temperature of the water in the vessels to fall by 10 °C from the initial temperature.

(i) Explain why the water in B takes longer to cool than the water in A.

....

.... [1]

(ii) Explain why the water in C cools more quickly than the water in A.

....

.... [1]

(iii) Explain why the water in D cools more quickly than the water in A.

....

.... [1]

(iv) Suggest **two** reasons why the water in E cools more quickly than the water in A.

1. ....

....

2. ....

.... [2]

[Total: 7]

9.3 [Boyle's law]

1 **(a)** Fig.1 shows a cylinder containing air at a pressure of 1.0×10^5 Pa. The length of the air column in the cylinder is 80 mm.

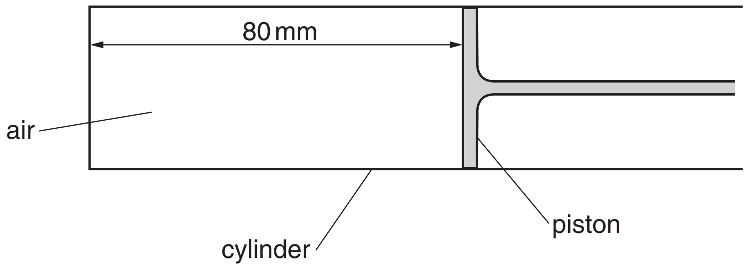


Fig.1

The piston is pushed in until the pressure in the cylinder rises to 3.8×10^5 Pa.

Calculate the new length of the air column in the cylinder, assuming that the temperature of the air has not changed.

new length = ... [3]

(b) Fig.2 shows the same cylinder containing air.

Fig.2

The volume of the air in the cylinder changes as the temperature of the air changes.

(i) The apparatus is to be used as a thermometer. Describe how two fixed points, 0 °C and 100 °C, and a temperature scale could be marked on the apparatus.

....

....

....

....

(ii) Describe how this apparatus could be used to indicate the temperature of a large beaker of water.

....

....

....

....

[5]

2 Fig. 4.1 shows a sealed glass syringe that contains air and many very tiny suspended dust particles.

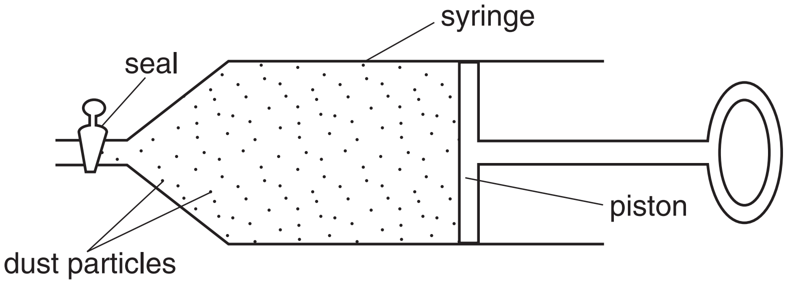


Fig. 4.1

(a) Explain why the dust particles are suspended in the air and do not settle to the bottom.

....

....

....

....[3]

(b) The air in the syringe is at a pressure of 2.0×10^5 Pa. The piston is slowly moved into the syringe, keeping the temperature constant, until the volume of the air is reduced from $80\,cm^3$ to $25\,cm^3$. Calculate the final pressure of the air.

pressure = ...[3]

3 **(a)** Fig. 5.1 shows a sealed box.

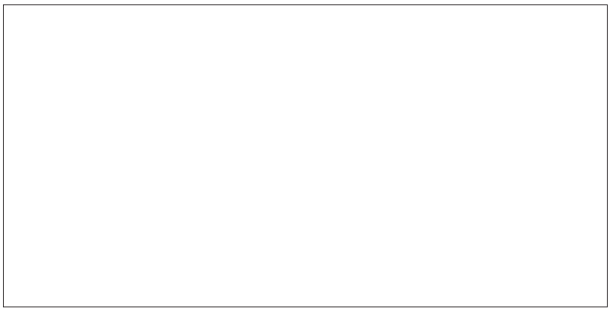


Fig. 5.1

(i) The box contains a large number of air particles. On Fig.5.1, draw a possible path of **one** of the air molecules, as it moves inside the box.

(ii) Explain

1 how air particles in the box create a pressure on the inside walls,

....

....

....

2 why this pressure rises as the temperature of the air in the box increases.

....

....

....
[5]

(b) Air in a cylinder is compressed slowly, so that the temperature does not rise. The pressure changes from 2.0×10^5 Pa to 5.0×10^5 Pa. The original volume was $0.35\ m^3$. Calculate the new volume.

volume = …………………...[3]

4 Fig. 5.1 shows a way of indicating the positions and direction of movement of some molecules* in a gas at one instant.

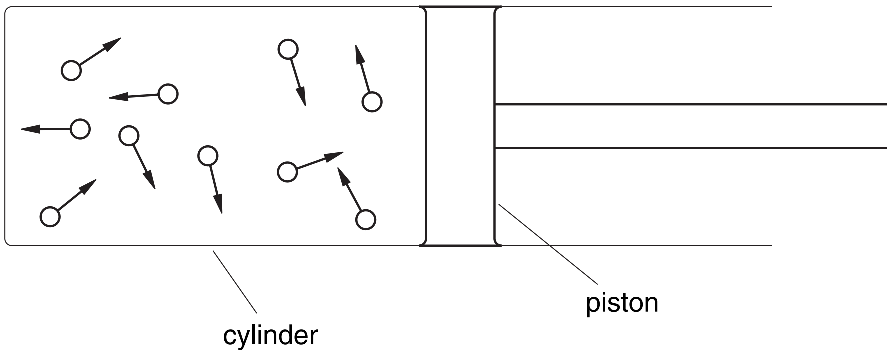


Fig. 5.1

(a) **(i)** Describe the movement of the molecules.

.... [1]

(ii) Explain how the molecules exert a pressure on the container walls.

....

.... [1]

(b) When the gas in the cylinder is heated, it pushes the piston further out of the cylinder.

State what happens to

(i) the average spacing of the molecules,

.... [1]

(ii) the average speed of the molecules.

.... [1]

(c) The gas shown in Fig. 5.1 is changed into a liquid and then into a solid by cooling.

Compare the gaseous and solid states in terms of

(i) the movement of the molecules,

....

.... [1]

(ii) the average separation of the molecules.

....

.... [1]

*or particles composing the air

5 **(a)** Fig. 5.1 shows a tank used for evaporating salt solution to produce crystals.

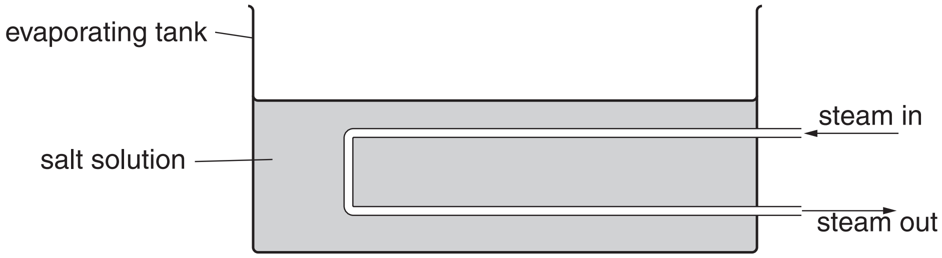


Fig. 5.1

Suggest two ways of increasing the rate of evaporation of the water from the solution. Changes may be made to the apparatus, but the rate of steam supply must stay constant. You may assume the temperature of the salt solution remains constant.

1. ....

....

2. ....

....[2]

(b) A manufacturer of liquid-in-glass thermometers changes the design in order to meet new requirements.

Describe the changes that could be made to

(i) give the thermometer a greater range,

....[1]

(ii) make the thermometer more sensitive.

....[1]

(c) A toilet flush is operated by the compression of air. The air inside the flush has a pressure of 1.0×10^5 Pa and a volume of 150 cm^3. When the flush is operated the volume is reduced to 50 cm^3. The temperature of the air remains constant during this process.
Calculate the new pressure of the air inside the flush.

pressure = ...[2]

6 Fig. 4.1 is a design for remotely operating an electrical switch using air pressure.

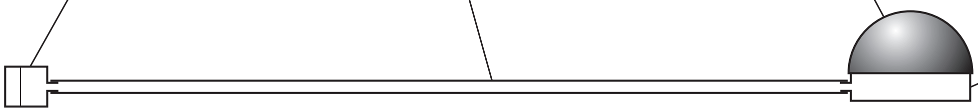


Fig. 4.1

The metal box and the pipe contain air at normal atmospheric pressure and the switch is off. When the pressure in the metal box and pipe is raised to 1.5 times atmospheric pressure by pressing down on the flexible rubber box cover, the switch comes on.

(a) Explain in terms of pressure and volume how the switch is made to come on.

....

....

....

.... [2]

(b) Normal atmospheric pressure is 1.0×10^5 Pa. At this pressure, the volume of the box and pipe is 60 cm^3.

Calculate the **reduction** in volume that must occur for the switch to be on.

reduction in volume = ... [3]

(c) Explain, in terms of air particles, why the switch may operate, without the rubber cover being squashed, when there is a large rise in temperature.

....

....

....

.... [2]

[Total: 7]

7 **(a)** One of the laws about the behaviour of gases states that

"For a fixed amount of gas at constant temperature, the pressure is inversely proportional to the volume".

In the space below, write an **equation** that represents this law.

[1]

(b) Table 4.1 gives a series of pressures and their corresponding volumes, obtained in an experiment with a fixed amount of gas. The gas obeys the law referred to in **(a)**.

pressure / kPa	100	200	400	500	1000
volume / cm^3	50.0	25.0	12.5	10.0	5.0

Table 4.1

How do these figures indicate that the temperature was constant throughout the experiment?

....

....

....

.... [2]

(c) Air is trapped by a piston in a cylinder. The pressure of the air is 1.2×10^5 Pa. The distance from the closed end of the cylinder to the piston is 75 mm.

The piston is pushed in until the pressure of the air has risen to 3.0×10^5 Pa.

Calculate how far the piston has moved.

distance moved = ... [4]

[Total: 7]

8 A vertical cylinder has a smooth well-fitting piston in it. Weights can be added to or removed from a tray on the top of the piston.

(a) Weights are added to the tray, as shown in Fig. 6.1.

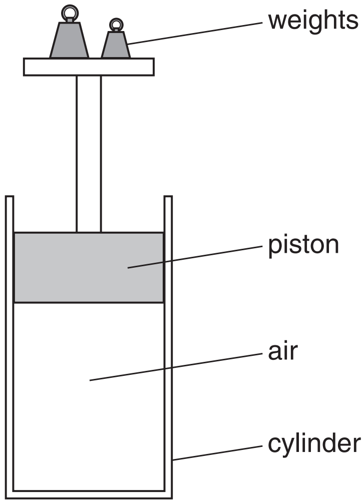


Fig. 6.1

(i) State what happens to the pressure of the air in the cylinder as a result of adding these weights.

.... [1]

(ii) The initial pressure of the trapped air is 1.05×10^5 Pa. When the weights are added, the volume of the air decreases from 860 cm^3 to 645 cm^3.

The temperature of the air does not change.

Calculate the final pressure of the trapped air.

pressure = ... [3]

(iii) The area of the piston is 5.0×10^{-3} m^2.

Calculate the weight that is added to the piston.

weight added = ... [4]

(b) The weights are kept as shown in Fig. 6.1. The temperature of the air in the cylinder is increased.

(i) State what happens to the volume of the air in the cylinder as a result of this temperature rise.

.... [1]

(ii) State how, if at all, the pressure of the air changes as the temperature changes.

.... [1]

(iii) State what must be done to prevent the volume change in **(b)(i)**.

.... [1]

(iv) The volume change in **(b)(i)** is prevented. State what happens to the pressure of the air in the cylinder.

.... [1]

[Total: 12]

9 Fig. 5.1 shows a gas contained in a cylinder enclosed by a piston.

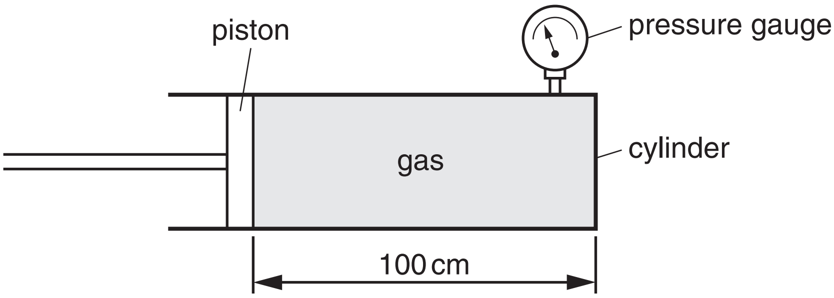


Fig. 5.1

At first, the length of cylinder containing the gas is 100 cm. The pressure of the gas, shown by the pressure gauge, is 300 kPa. The area of cross-section of the cylinder is 0.12 m^2.

(a) **(i)** Describe the motion of the particles composing the gas.

....

....

....[1]

(ii) Explain how these particles exert a force on the walls of the cylinder.

....

....[1]

(iii) Calculate the force exerted by the gas on the piston.

force = ...[2]

(b) The piston is moved so that the new length of cylinder occupied by the gas is 50 cm. The temperature of the gas is unchanged.

(i) Calculate the new pressure of the gas.

pressure = ...[2]

(ii) Explain, in terms of the behaviour of the molecules, why the pressure has changed.

....

....

....[1]

[Total: 7]

10 A sealed balloon containing some helium gas is released and rises into the upper atmosphere. As the balloon rises the temperature of the helium falls and the balloon expands.

Explain, in terms of atoms,

(a) the effect of the fall in temperature on the helium pressure,

....

....

....

....

.... [3]

(b) the effect of the expansion of the balloon on the helium pressure.

....

....

....

....

.... [3]

[Total: 6]

11 **(a)** Explain

(i) how the particles composing the gas exert a force on a solid surface,

....

....

.... [1]

(ii) the increase in pressure of a gas when its volume is decreased at constant temperature.

....

....

....

.... [3]

(b) A cylinder of volume $5.0 \times 10^3 \text{cm}^3$ contains air at a pressure of 8.0×10^5 Pa.

A leak develops so that air gradually escapes from the cylinder until the air in the cylinder is at atmospheric pressure. The pressure of the atmosphere is 1.0×10^5 Pa.

Calculate the volume of the escaped air, now at atmospheric pressure. Assume that the temperature stays constant.

volume = ...cm ^{3} [4]

[Total: 8]

12 **(a)** Fig. 4.1 shows some gas contained in a cylinder by a heavy piston. The piston can move up and down in the cylinder with negligible friction.

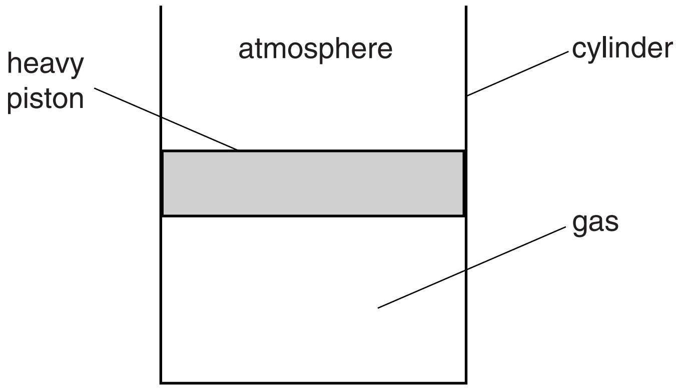


Fig. 4.1

There is a small increase in the pressure of the atmosphere above the piston.

(i) On Fig. 4.1, draw a possible new position for the lower face of the piston. [1]

(ii) Explain, in terms of the molecules of the gas and the molecules of the atmosphere, your answer to **(a)(i)**.

....

....

....

....

....

.... [3]

(b) The pressure of the atmosphere above the piston returns to its original value, and the piston returns to its original position, as shown in Fig. 4.2.

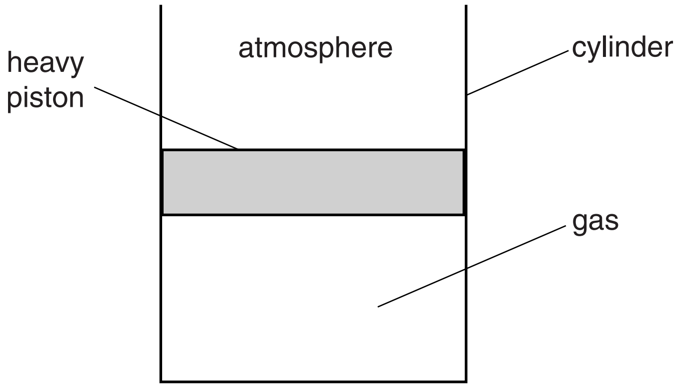


Fig. 4.2

The gas, piston and cylinder are now heated to a much higher temperature.

(i) On Fig. 4.2, draw a possible new position for the lower face of the piston. [1]

(ii) Explain, in terms of the particles composing the gas and the particles composing the atmosphere, your answer to **(b)(i)**.

....

....

....

....

.... [2]

[Total: 7]

Chapter 10. Thermal properties of matter

2.2.1 Thermal expansion of solids, liquids and gases

Core

1 Describe, qualitatively, the thermal expansion of solids, liquids and gases at constant pressure

2 Describe some of the everyday applications and consequences of thermal expansion

Supplement

3 Explain, in terms of the motion and arrangement of particles, the relative order of magnitudes of the expansion of solids, liquids and gases as their temperatures rise

2.2.2 Specific heat capacity

Core

1 Know that a rise in the temperature of an object increases its internal energy

Supplement

2 Describe an increase in temperature of an object in terms of an increase in the average kinetic energies of all of the particles in the object

3 Define specific heat capacity as the energy required per unit mass per unit temperature increase; recall and use the equation

$$c = \frac{\Delta E}{m\Delta\theta}$$

4 Describe experiments to measure the specific heat capacity of a solid and a liquid

2.2.3 Melting, boiling

Core

1 Describe melting and boiling in terms of energy input without a change in temperature

2 Know the melting and boiling temperatures for water at standard atmospheric pressure

3 Describe condensation and solidification in terms of particles

Supplement

6 Describe the differences between boiling and evaporation

10.1 Thermal instruments

1 A thermocouple is used to measure the temperature of the inner wall of a pottery kiln.

(a) In the space below, draw a labelled diagram of a thermocouple that could be used for this purpose. [2]

(b) Describe

(i) how you would read the temperature of the wall from the thermocouple,

....

....

(ii) how the thermocouple works.

....

....

....
[2]

(c) State two conditions in which a thermocouple is very suitable for temperature measurement.

....

....[2]

2 Fig. 5.1 shows a thermocouple set up to measure the temperature at a point on a solar panel.

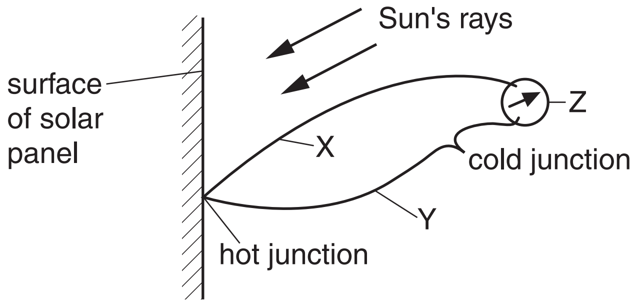


Fig. 5.1

(a) X is a copper wire.

(i) Suggest a material for Y.

....

(ii) Name the component Z.

....
[2]

(b) Explain how a thermocouple is used to measure temperature.

....

....

....[3]

(c) Experiment shows that the temperature of the surface depends upon the type of surface used.

Describe the nature of the surface that will cause the temperature to rise most.

....

....[1]

3 **(a)** Equal volumes of nitrogen, water and copper at 20 °C are heated to 50 °C.

(i) Which one of the three will have a much greater expansion than the other two?

....

(ii) Explain your answer in terms of the way the molecules are arranged in the three substances.

....

....

....
[3]

(b) Fig. 5.1 shows a thermometer with a range of –10 °C to 50 °C.

Fig. 5.1

Explain what is meant by

(i) the *sensitivity* of a thermometer,

....

....

(ii) the *linearity* of a thermometer.

....

....
[2]

4 **(a)** Fig. 4.1 shows a simple type of thermocouple that has been calibrated to measure temperature.

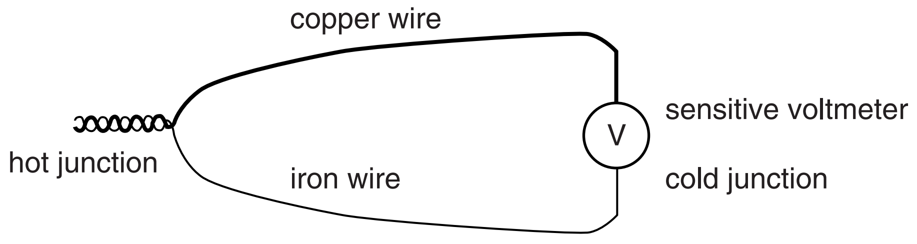


Fig. 4.1

(i) Describe how the thermocouple could be used to measure the temperature of a beaker of hot water.

....

....

....

(ii) State two situations where a thermocouple would be a good choice of thermometer to measure temperature.

1. ....

....

2. ....

....

[4]

(b) A mercury-in-glass thermometer is placed in an insulated beaker of water at 60 °C. The water is heated at a constant rate. The temperature of the water is measured and recorded on the graph shown in Fig. 4.2.

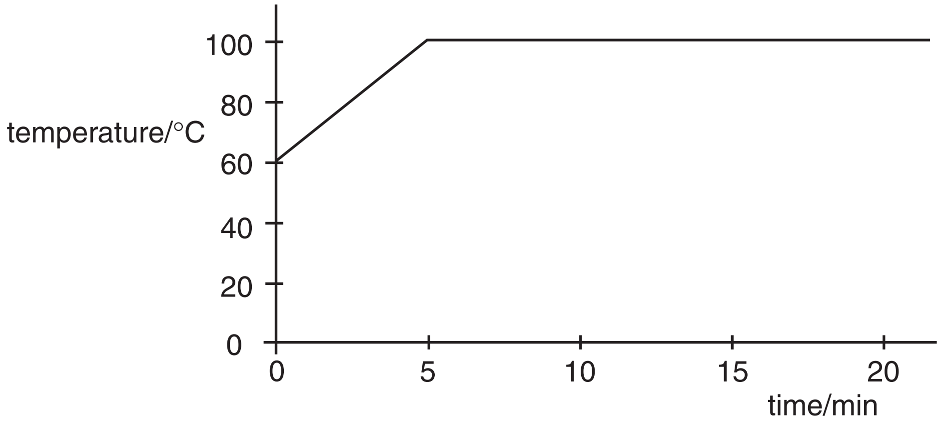


Fig. 4.2

State the effect of the heat supplied

(i) during the period 0 to 5 minutes,

....

....

(ii) during the period 10 to 15 minutes.

....

....

[2]

5 Fig. 5.1 shows some apparatus designed to compare the ability of two surfaces to absorb infra-red radiation.

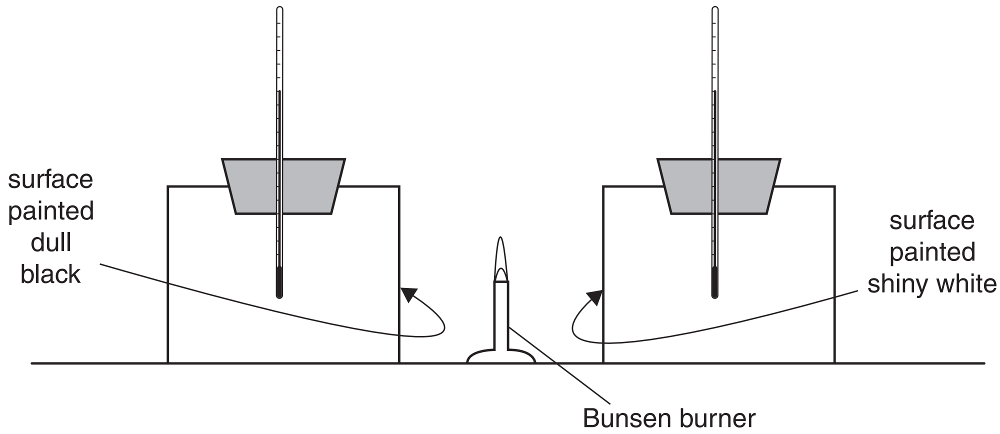


Fig. 5.1

The containers, which are identical, are painted on the outside. One is dull black, the other is shiny white. Both are filled with water, initially at the same temperature.

(a) (i) Describe how you would use the apparatus to compare the abilities of the two surfaces to absorb infra-red radiation.

....

....

....

.... [2]

(ii) State the result that you would expect.

.... [1]

(b) The thermometers used have high sensitivity and linear scales.

(i) State what is meant by *high sensitivity*.

....

.... [1]

(ii) Explain why a high sensitivity is important for this experiment.

....

.... [1]

(iii) State what is meant by a *linear scale*.

....

.... [1]

[Total: 6]

6 **(a)** A certain volume of water at room temperature and the same volume of ice in a freezer are each heated through the same temperature rise.

Which of them will have the greater expansion, and why?

Which? ....

Why? .... [1]

(b) For strength, concrete pillars are usually reinforced with metal rods, which are embedded in the concrete before it sets.

The list below shows how much a length of 1 m of each material expands when the temperature rises by 1 °C.

aluminium	0.03 mm
concrete	0.01 mm
steel	0.01 mm

Use this information to decide which metal should be used to reinforce concrete, why it is suitable, and why the other metal is not suitable.

Which metal should be used? ....

Why is it suitable? ....

Why is the other metal unsuitable? ....

.... [3]

[Total: 4]

7 Three wires and a meter are used to construct a thermocouple for measuring the surface temperature of a pipe carrying hot liquid, as shown in Fig. 7.1.

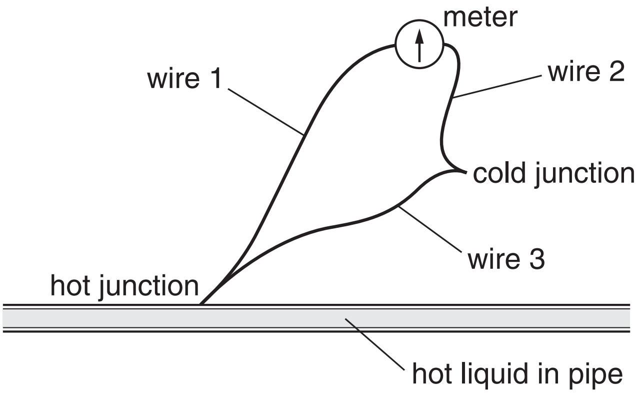


Fig. 7.1

(a) Copper wire and constantan wire are used in the construction of the thermocouple.

State which metal might be used for

wire 1 ....

wire 2 ....

wire 3 ....
[1]

(b) State what type of meter is used.

.... [1]

(c) State one particular advantage of thermocouples for measuring temperature.

.... [1]

[Total: 3]

8 A technician has been asked to design a liquid-in-glass thermometer, using alcohol as the liquid.

(a) **(i)** State what is meant by the *sensitivity* of the thermometer.

....

.... [1]

(ii) State one design feature the technician could use in order to ensure a very sensitive thermometer.

....

.... [1]

(b) **(i)** State what is meant by the *range* of the thermometer.

....

.... [1]

(ii) State one design feature that would ensure that the thermometer measured the desired range of temperatures.

....

.... [1]

(c) **(i)** State what is meant by *linearity*, as it applies to the thermometer.

....

.... [1]

(ii) State one design feature that would ensure linearity in the technician's thermometer.

....

.... [1]

[Total: 6]

9 **(a)** Equal volumes of a gas held at constant pressure, a liquid and a solid undergo the same temperature rise.

(i) State which of the three, solid, liquid or gas,

1. expands the most, ...

2. expands the least. ....

(ii) Explain why the pressure of the gas must be kept constant for this comparison.

....

....[2]

(b) Fig. 5.1 shows an alcohol thermometer.

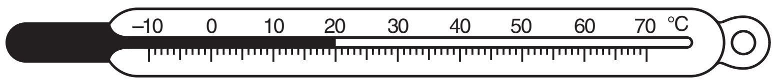


Fig. 5.1

(i) State two properties of alcohol which make it suitable for use in a thermometer.

1. ....

....

2. ....

....[2]

(ii) State **two** changes to the design of this thermometer which would make it more sensitive.

1. ....

....

2. ....

....[2]

(c) Explain why it is an advantage for the glass surrounding the alcohol in the bulb of the thermometer to be very thin.

....

....[1]

[Total: 7]

10 Fig. 6.1 shows a glass flask full of water at 10 °C and sealed with a bung. A long glass tube passes through the bung into the water. The water level in the tube is at X.

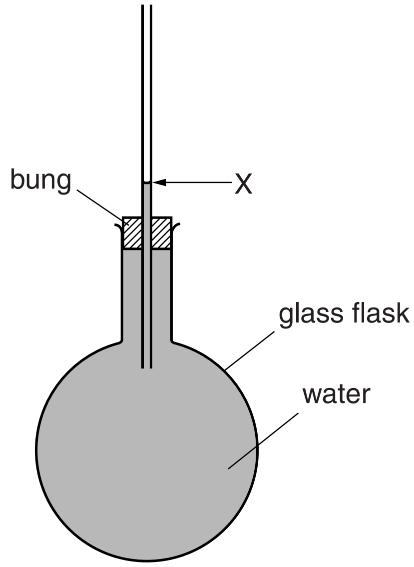


Fig. 6.1

When the flask is placed in hot water, the water level initially falls a little below X, and then rises some way above X.

(a) Suggest why

(i) the water level initially falls,

....

.... [2]

(ii) the water level then rises,

....

.... [2]

(iii) the rise is greater than the fall.

....

.... [1]

(b) Suggest a change to the apparatus that would make the fall and rise of the water level greater.

....

.... [1]

[Total: 6]

11 A thermometer uses the value of a physical property to indicate the temperature.

(a) A particular thermometer is sensitive, linear and has a wide range.

Draw a straight line from each characteristic of this thermometer to the appropriate feature.

characteristic of thermometer	feature of thermometer
	reacts quickly to change of temperature
sensitive	
	large difference between highest and lowest measurable temperatures
linear	same change of physical property for same change of temperature
	fixed points at 0°C and 100°C
wide range	
	large change of physical property for small change of temperature

[3]

(b) (i) In the space below, draw a diagram to show the structure of a thermocouple thermometer.

[2]

(ii) Explain why a thermocouple thermometer is particularly well suited to measure

1. high temperatures,

....

....

2. very rapidly changing temperatures.

....

....
[2]

[Total: 7]

10.2 Specific heat capacity

1 Fig. 4.1 shows apparatus that a student uses to make an estimate of the specific heat capacity of iron.

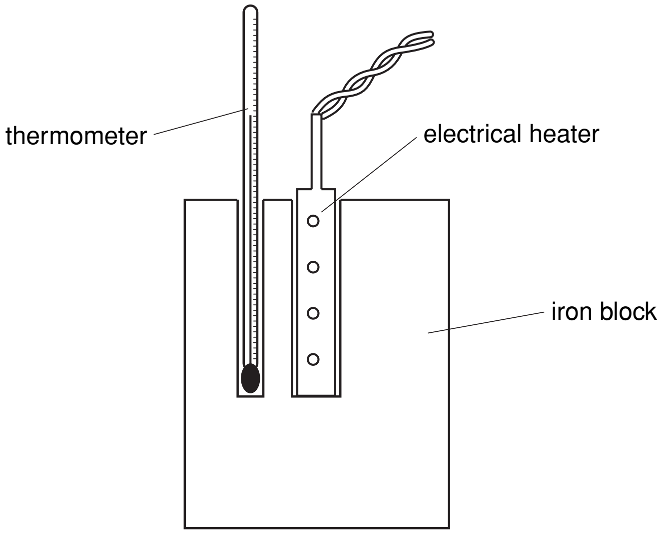


Fig. 4.1

(a) The power of the heater is known. State the four readings the student must take to find the specific heat capacity of iron.

1. ....

2. ....

3. ....

4. .... [3]

(b) Write down an equation, in words or in symbols, that could be used to work out the specific heat capacity of iron from the readings in **(a)**.

[2]

(c) **(i)** Explain why the value obtained with this apparatus is higher than the actual value.

....

.... [1]

(ii) State one addition to the apparatus that would help to improve the accuracy of the value obtained.

....

.... [1]

2 Some water is heated electrically in a glass beaker in an experiment to find the specific heat capacity of water. The temperature of the water is taken at regular intervals.

The temperature-time graph for this heating is shown in Fig. 4.1.

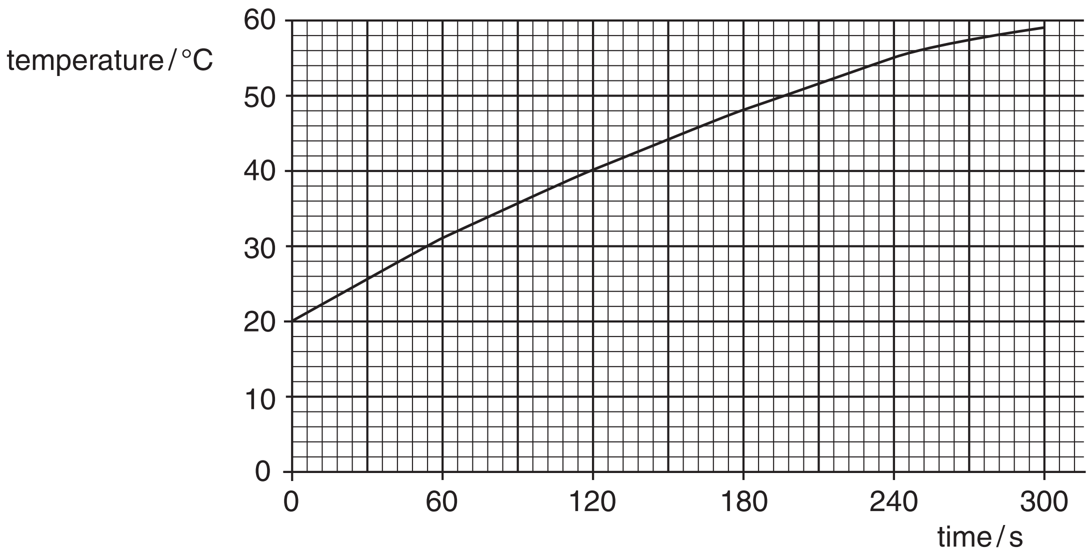


Fig. 4.1

(a) **(i)** Use the graph to find

1. the temperature rise in the first 120 s,

....

2. the temperature rise in the second 120 s interval.

....

(ii) Explain why these values are different.

....

....
[2]

(b) The experiment is repeated in an insulated beaker. This time, the temperature of the water increases from 20 °C to 60 °C in 210 s. The beaker contains 75 g of water. The power of the heater is 60 W. Calculate the specific heat capacity of water.

specific heat capacity = ... [4]

(c) In order to measure the temperature during the heating, a thermocouple is used.
Draw a labelled diagram of a thermocouple connected to measure temperature.

[2]

3 **(a)** State what is meant by *specific heat capacity*.

....

.... [2]

(b) Water has a very high specific heat capacity.

Suggest why this might be a disadvantage when using water for cooking.

....

.... [1]

(c) Fig. 9.1 illustrates an experiment to measure the specific heat capacity of some metal.

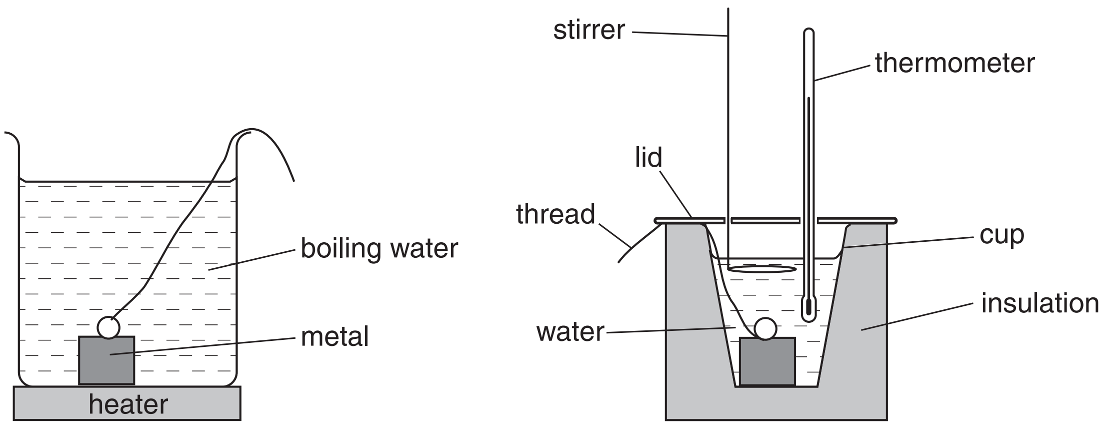


Fig. 9.1

The piece of metal is heated in boiling water until it has reached the temperature of the water. It is then transferred rapidly to some water in a well-insulated cup. A very sensitive thermometer is used to measure the initial and final temperatures of the water in the cup.

specific heat capacity of water = 4200 J / (kg K)

The readings from the experiment are as follows.

mass of metal = 0.050 kg
mass of water in cup = 0.200 kg
initial temperature of water in cup = 21.1 °C
final temperature of water in cup = 22.9 °C

(i) Calculate the temperature rise of the water in the cup and the temperature fall of the piece of metal.

temperature rise of water = ...

temperature fall of metal = ...
[1]

(ii) Calculate the thermal energy gained by the water in the cup. State the equation that you use.

thermal energy gained = ... [3]

(iii) Assume that only the water gained thermal energy from the piece of metal.

Making use of your answers to **(c)(i)** and **(c)(ii)**, calculate the value of the specific heat capacity of the metal. Give your answer to 3 significant figures.

specific heat capacity = ... [2]

(iv) Suggest one reason why the experiment might not have given a correct value for the specific heat capacity of the metal.

....

.... [1]

[Total: 10]

4 A certain substance is in the solid state at a temperature of –36 °C. It is heated at a constant rate for 32 minutes. The record of its temperature is given in Fig. 5.1.

time / min	0	1	2	6	10	14	18	22	24	26	28	30	32
temperature / °C	–36	–16	–9	–9	–9	–9	32	75	101	121	121	121	121

Fig. 5.1

(a) State what is meant by the term *latent heat*.

....

.... [2]

(b) State a time at which the energy is being supplied as latent heat of fusion.

.... [1]

(c) Explain the energy changes undergone by the molecules of a substance during the period when latent heat of vaporisation is being supplied.

....

....

.... [2]

(d) **(i)** The rate of heating is 2.0 kW.

Calculate how much energy is supplied to the substance during the period 18 – 22 minutes.

energy supplied = ... [2]

(ii) The specific heat capacity of the substance is 1760 J / (kg °C).

Use the information in the table for the period 18 – 22 minutes to calculate the mass of the substance being heated.

mass heated = ... [3]

[Total: 10]

5 A student in a laboratory uses the apparatus shown in Fig. 4.1 to determine the specific heat capacity of aluminium.

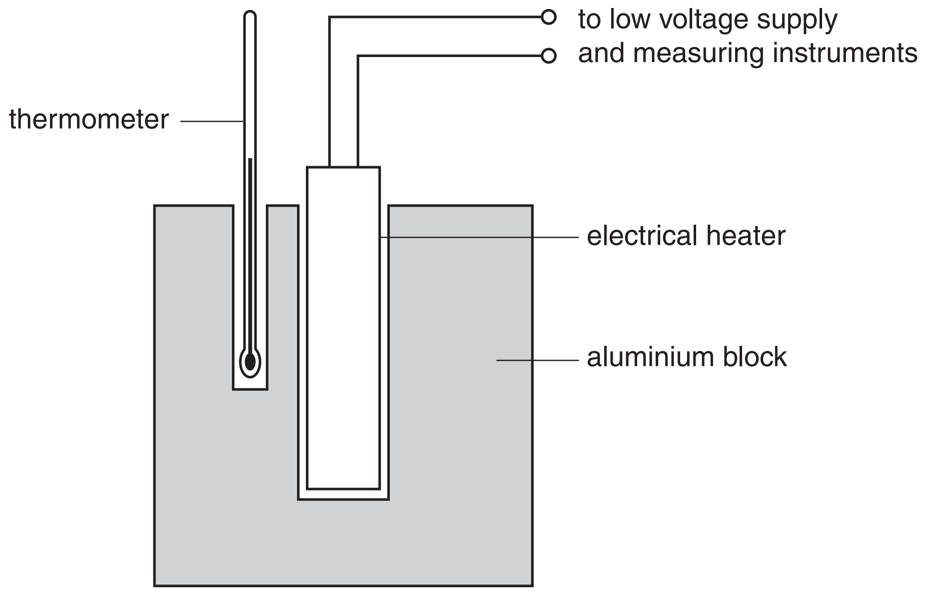


Fig. 4.1

The readings obtained in the experiment are given below.

mass of aluminium block = 0.930 kg

initial temperature of block = 13.1 °C

final temperature of block = 41.3 °C

electrical energy supplied = 23 800 J

(a) Define *specific heat capacity*.

....

.... [2]

(b) Use the readings above to calculate the specific heat capacity of aluminium.

State the equation you use.

specific heat capacity = ... [3]

(c) Because the student knows it is good scientific practice to repeat readings, after a short time he carries out the experiment again, supplying the same quantity of electrical energy.

This time the temperature readings are:

initial temperature of block = 41.0 °C

final temperature of block = 62.1 °C

(i) Use these figures to calculate a second value for the specific heat capacity of aluminium.

specific heat capacity = ... [1]

(ii) The student did not make any mistakes when taking the readings.

Suggest why the second value for the specific heat capacity of the aluminium is greater than the first.

....

.... [2]

(d) Suggest two ways of improving the experiment in order to give as accurate a result as possible.

1. ....

....

2. ....

.... [2]

[Total: 10]

6 **(a)** Define *specific heat capacity*.

....

.... [2]

(b) Solar energy is striking the steel deck of a ship.

(i) Describe how the colour of the deck affects the absorption of the solar energy.

....

.... [1]

(ii) The solar energy strikes the deck at the rate of 1400 W on every square metre.

The steel plate of the deck is 0.010 m thick.

Steel has a density of 7800 kg/m^3 and a specific heat capacity of 450 J/(kg °C).

13% of the solar energy striking the deck is absorbed and the rest is reflected.

Using these figures, calculate

1. how many joules of solar energy are absorbed by 1.0 m^2 of the deck in 1.0 s,

number of joules = ... [1]

2. the mass of 1.0 m^2 of deck,

mass = ... [2]

3. the rate of rise in temperature of the deck, stating the equation you use.

rate of rise = ... °C/s [3]

[Total: 9]

7 Solar panels are positioned on the roof of the house shown in Fig. 6.1. They use thermal energy from the Sun to provide hot water in an environmentally friendly way.

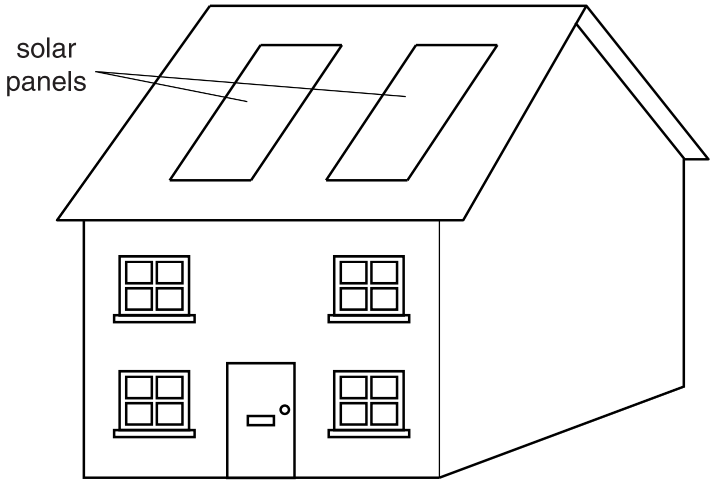


Fig. 6.1

Cold water flows to the panels at 15 °C. During the day, the panels supply 3.8 kg of hot water at 65 °C every hour.

(a) Calculate the average energy that the solar panels deliver to the water in one hour. Specific heat capacity of water = 4200 J / (kg °C).

energy = ... [3]

(b) The solar power incident on the roof during this heating period is 170 W / m^2. The solar panels have a total area of 8.0 m^2.

Calculate the solar energy incident on the panels in one hour.

solar energy = ... [2]

(c) Calculate the efficiency of the solar panels, stating the equation you use.

efficiency = ... [2]

(d) Explain why solar energy is called *renewable* energy.

....

.... [1]

(e) State one disadvantage of using solar energy.

....

.... [1]

[Total: 9]

10.3 Specific latent heat

1 **(a)** In an experiment to find the specific latent heat of water, the following readings were taken.

m_1	mass of water at 100 °C, before boiling starts	120 g
m_2	mass of water at 100 °C, after boiling finishes	80 g
V	voltage across the heater	12 V
I	current through the heater	2.0 A
t	time that the heater was supplying energy	3750 s

(i) Using the symbols above, write down the equation that must be used to find the value of the specific latent heat L of water.

(ii) Use the equation to calculate the specific latent heat of water from the readings above.

specific latent heat = ...
[4]

(b) Explain, in terms of the energy of molecules, why the specific latent heat of water has a high value.

....

....

....[2]

2 Fig. 4.1 shows water being heated by an electrical heater. The water in the can is not boiling, but some is evaporating.

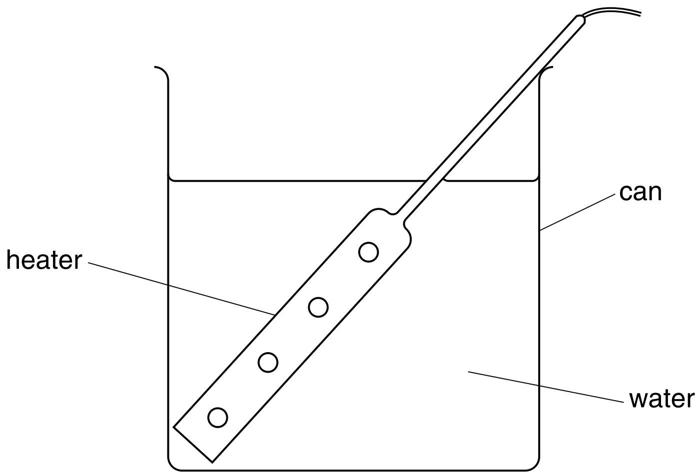


Fig. 4.1

(a) Describe, in terms of the movement and energies of the water molecules, how evaporation takes place.

....

....

....

.... [2]

(b) State two differences between evaporation and boiling.

1 ....

....

2 ....

.... [2]

(c) After the water has reached its boiling point, the mass of water in the can is reduced by 3.2 g in 120 s. The heater supplies energy to the water at a rate of 60 W. Use this information to calculate the specific latent heat of vaporisation of water.

specific latent heat = ... [3]

3 4 **(a)** Two identical open boxes originally contain the same volume of water. One is kept at 15 °C and the other at 85 °C for the same length of time.

Fig. 4.1 shows the final water levels.

Fig. 4.1

With reference to the energies of the particles composing the water, explain why the levels are different.

....

....

....

....[3]

(b) In an experiment to find the specific latent heat of vaporisation of water, it took 34 500 J of energy to evaporate 15 g of water that was originally at 100 °C.

A second experiment showed that 600 J of energy was lost to the atmosphere from the apparatus during the time it took to evaporate 15 g of water.

Calculate the specific latent heat of vaporisation of water that would be obtained from this experiment.

specific latent heat = …………………[3]

4 Fig. 4.1 shows apparatus that could be used to measure the [specific latent heat] of ice.

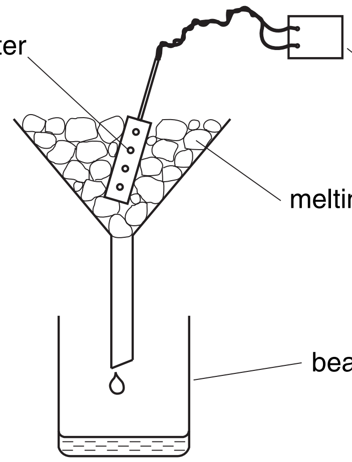


Fig. 4.1

(a) Describe how you would use the apparatus. You may assume that ice at 0 °C and a stopwatch are available. State all the readings that would be needed at each stage.

....

....

....

....

.... [4]

(b) In an experiment, 120 g of ice at 0 °C is to be melted. The specific latent heat of ice is 340 J/g. Assume that all the energy from the heater will be used to melt the ice.

Calculate the expected time for which the 60 W heater is switched on.

expected time = ... [2]

(c) When the experiment is carried out, the ice melts in slightly less time than the expected time.

(i) State one reason why this happens.

....

.... [1]

(ii) Suggest one modification to the experiment that would reduce the difference between the experimental time and the expected time.

....

.... [1]

5 **(a)** State two differences between evaporation of water and boiling of water.

1. ....

2. ....[2]

(b) The specific latent heat of vaporisation of water is 2260 kJ/kg.
Explain why this energy is needed to boil water and why the temperature of the water does not change during the boiling.

....

....

....

....[3]

(c) A laboratory determination of the specific latent heat of vaporisation of water uses a 120 W heater to keep water boiling at its boiling point. Water is turned into steam at the rate of 0.050 g/s.
Calculate the value of the specific latent heat of vaporisation obtained from this experiment. Show your working.

specific latent heat of vaporisation = ...[3]

6 Fig. 4.1 shows a student's attempt to estimate the specific latent heat of fusion of ice by adding ice at 0 °C to water at 20 °C. The water is stirred continuously as ice is slowly added until the temperature of the water is 0 °C and all the added ice has melted.

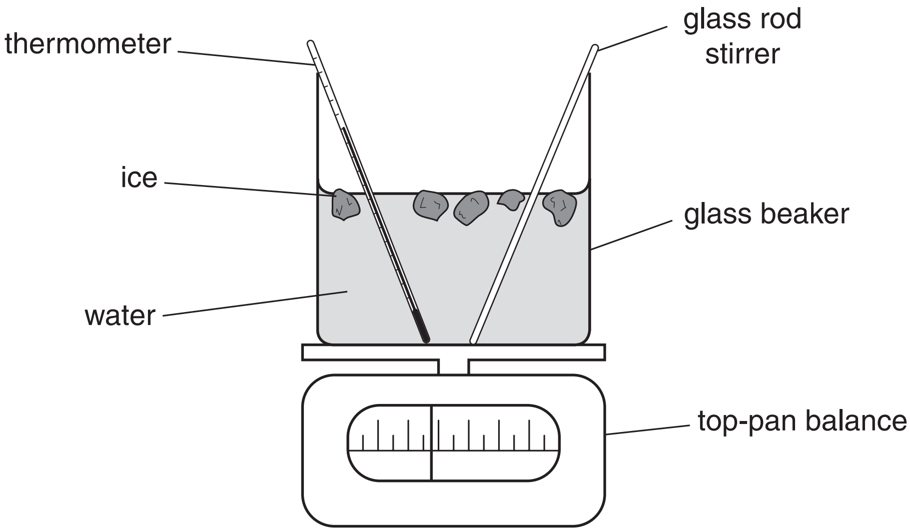


Fig. 4.1

(a) Three mass readings are taken. A description of the first reading is given.

Write down descriptions of the other two.

reading 1 the mass of the beaker + stirrer + thermometer

reading 2 ....

reading 3 .... [2]

(b) Write down word equations which the student could use to find

the heat lost by the water as it cools from 20 °C to 0 °C,

.... [1]

the heat gained by the melting ice.

.... [1]

(c) The student calculates that the water loses 12 800 J and that the mass of ice melted is 30 g.

Calculate a value for the specific latent heat of fusion of ice.

specific latent heat of fusion = ... [2]

(d) Suggest two reasons why this value is only an approximate value.

Reason 1 ....

....

Reason 2 ....

.... [2]

[Total: 8]

7 Fig. 4.1 shows a sealed steel cylinder filled with high pressure steam.

Fig. 4.1

Fig. 4.2 shows the same cylinder much later when all the steam has condensed.

Fig. 4.2

(a) **(i)** Describe the movement of the particles composing the high pressure steam.

....

....

.... [2]

(ii) Explain how the molecules in the steam exert a high pressure on the inside walls of the cylinder.

....

....

.... [2]

(b) Describe, in terms of particles, the process by which heat is transferred through the cylinder wall.

....

....

.... [2]

(c) When all the steam has condensed, 75 g of water is in the cylinder.

Under these high pressure conditions, the specific latent heat of vaporisation of steam is 3200 J/g.

Calculate the heat lost by the steam as it condenses.

heat = ... [2]

[Total: 8]

8 Fig. 5.1 shows apparatus that could be used to determine the specific latent heat of fusion of ice.

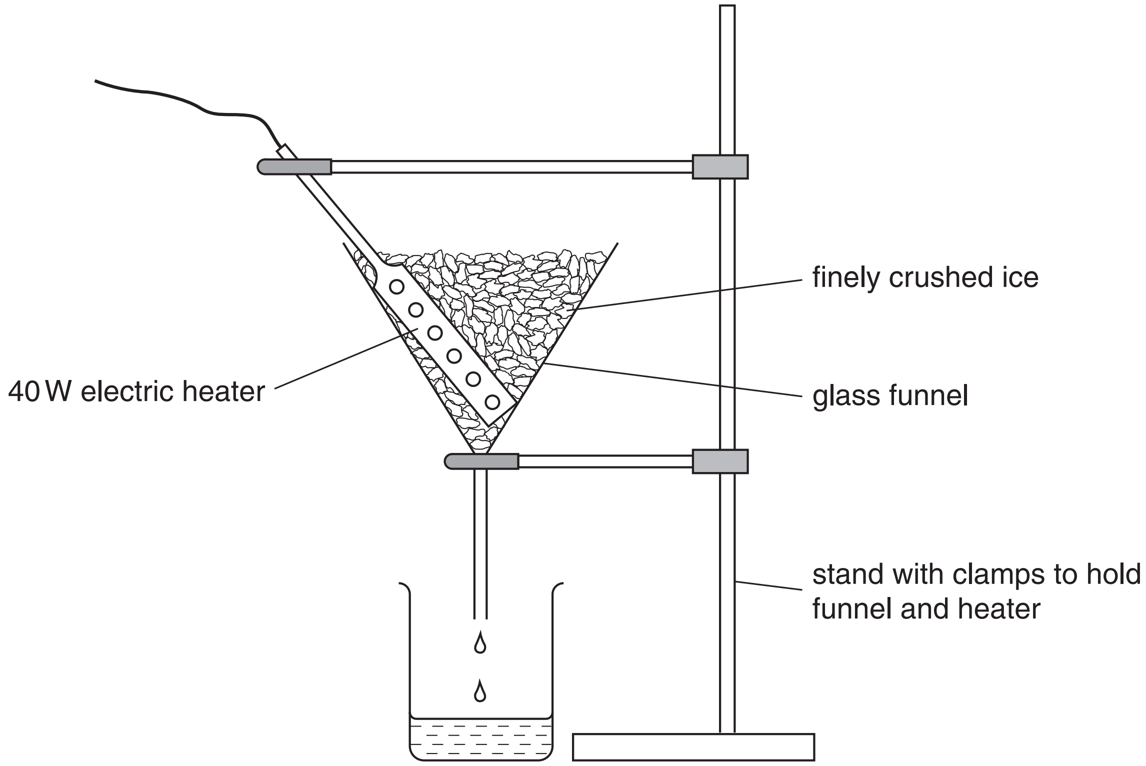


Fig. 5.1

(a) In order to obtain as accurate a result as possible, state why it is necessary to

(i) wait until water is dripping into the beaker at a constant rate before taking readings,

....

.... [1]

(ii) use finely crushed ice rather than large pieces.

....

.... [1]

(b) The power of the heater and the time for which water is collected are known. Write down all the other readings that are needed to obtain a value for the specific latent heat of fusion of ice.

....

.... [2]

(c) Using a 40 W heater, 16.3 g of ice is melted in 2.0 minutes. The heater is then switched off. In a further 2.0 minutes, 2.1 g of ice is melted.

Calculate the value of the specific latent heat of fusion of ice from these results.

specific latent heat of fusion of ice = ... [4]

[Total: 8]

9 A mass of 0.36 kg of a certain substance is in the solid state in a well-insulated container. The substance is heated at the rate of 1.2×10^4 J/minute.

2.0 minutes after starting the heating, the substance is all at the same temperature, and it starts to melt.

11.0 minutes after starting the heating, the substance finishes melting and the temperature starts to rise again.

(a) Calculate the specific latent heat of the substance.

specific latent heat = ...[3]

(b) **(i)** After 11 minutes of heating, when the temperature starts rising again, in which state is the substance?

....[1]

(ii) Describe what happens to the molecules as thermal energy is supplied to them in this state.

....

....

....

....[2]

[Total: 6]

10 Use the information in the table when answering this question.

specific heat capacity of ice	2.0 J / (g °C)
specific heat capacity of water	4.2 J / (g °C)
specific [latent heat] of fusion of ice	330 J/g
specific [latent heat] of vaporisation of water	2260 J / g

(a) Explain what is meant by the statement: 'the specific latent heat of fusion of ice is 330 J / g'.

....

....

....[1]

(b) A block of ice is taken from a freezer at –25 °C, placed in a metal container, and heated by a source of constant power.

The graph in Fig. 4.1 shows how the temperature of the contents of the container changes with time. At point E on the graph the container is empty.

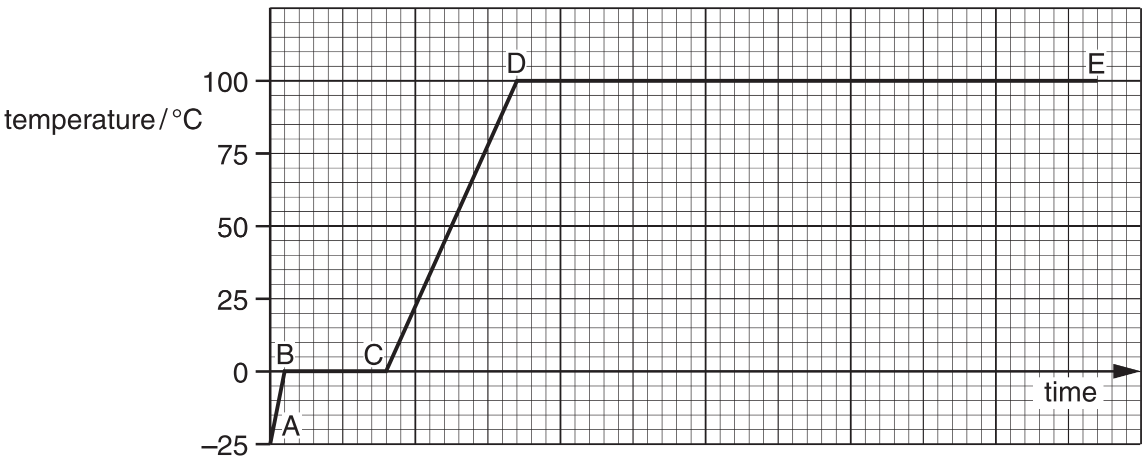


Fig. 4.1

(i) State what is taking place in the regions of the graph from B to C, and from D to E.

B to C ....

....

D to E ....

....[2]

(ii) Use the information in the table to explain why the line DE is longer than the line BC.

....

....

....[1]

(iii) Use the information in the table to explain why the graph is steeper from A to B than from C to D.

....

....

....[2]

[Total: 6]

11 **(a)** **(i)** In the space below, draw a labelled diagram of the apparatus you would use to measure the specific heat capacity of a liquid. If you choose an electrical method, you must include the circuit.

[3]

(ii) List the quantities you would need to measure, or previously know, in order to calculate the specific heat capacity of the liquid.

....

....

....

....

....[3]

(b) Some sea water has a specific heat capacity of 3900 J/(kg °C) and a boiling point of 100.6 °C.

(i) Calculate the energy required to raise the temperature of 0.800 kg of this sea water from 12.0 °C up to its boiling point. State the equation that you use.

(ii) The energy to raise the temperature in **(b)(i)** is supplied at the rate of 620 W.

Calculate the time taken to raise the sea water to its boiling point.

time = ...[2]

[Total: 12]

12 **(a)** Suggest

(i) an example of a change of state resulting from the removal of thermal energy from a quantity of material,

.... [1]

(ii) the effect of this change of state on the temperature of the material.

.... [1]

(b) Define the *thermal capacity* of a body.

....

....

.... [2]

(c) A polystyrene cup holds 250 g of water at 20 °C. In order to cool the water to make a cold drink, small pieces of ice at 0 °C are added until the water reaches 0 °C and no unmelted ice is present.

[specific heat capacity of water = 4.2 J/(g °C), specific latent heat of fusion of ice = 330 J/g]

Assume no thermal energy is lost or gained by the cup.

(i) Calculate the thermal energy lost by the water in cooling to 0 °C.

thermal energy lost = ... [2]

(ii) State the thermal energy gained by the ice in melting.

thermal energy gained = ... [1]

(iii) Calculate the mass of ice added.

mass of ice = ... [2]

[Total: 9]

13 **(a)** Define *specific latent heat of fusion*.

....

....

.... [1]

(b) **(i)** A tray of area $0.25\,m^2$, filled with ice to a depth of 12 mm, is removed from a refrigerator.

Calculate the mass of ice on the tray. The density of ice is $920\,kg/m^3$.

mass = ... [2]

(ii) Thermal energy from the Sun is falling on the ice at a rate of $250\,W/m^2$. The ice absorbs 60 % of this energy.

Calculate the energy absorbed in 1.0 s by the $0.25\,m^2$ area of ice on the tray.

energy = ... [2]

(iii) The ice is at its melting temperature.

Calculate the time taken for all the ice to melt. The specific latent heat of fusion of ice is $3.3 \times 10^5\,J/kg$.

time = ... [3]

[Total: 8]

Chapter 11. Thermal energy transfers

2.3.1 Conduction

Core

1 Describe experiments to demonstrate the properties of good thermal conductors and bad thermal conductors (thermal insulators)

Supplement

2 Describe thermal conduction in all solids in terms of atomic or molecular lattice vibrations and also in terms of the movement of free (delocalised) electrons in metallic conductors

3 Describe, in terms of particles, why thermal conduction is bad in gases and most liquids

4 Know that there are many solids that conduct thermal energy better than thermal insulators but do so less well than good thermal conductors

2.3.2 Convection

Core

1 Know that convection is an important method of thermal energy transfer in liquids and gases

2 Explain convection in liquids and gases in terms of density changes and describe experiments to illustrate convection

Supplement

2.3.3 Radiation

Core

1 Know that thermal radiation is infrared radiation and that all objects emit this radiation

2 Know that thermal energy transfer by thermal radiation does not require a medium

3 Describe the effect of surface colour (black or white) and texture (dull or shiny) on the emission, absorption and reflection of infrared radiation

Supplement

4 Know that for an object to be at a constant temperature it needs to transfer energy away from the object at the same rate that it receives energy

5 Know what happens to an object if the rate at which it receives energy is less or more than the rate at which it transfers energy away from the object

6 Know how the temperature of the Earth is affected by factors controlling the balance between incoming radiation and radiation emitted from the Earth's surface

continued

Chapter 11. Thermal energy transfers

2.3.3 Radiation continued

Core

Supplement

7 Describe experiments to distinguish between good and bad emitters of infrared radiation

8 Describe experiments to distinguish between good and bad absorbers of infrared radiation

9 Describe how the rate of emission of radiation depends on the surface temperature and surface area of an object

2.3.4 Consequences of thermal energy transfer

Core

1 Explain some of the basic everyday applications and consequences of conduction, convection and radiation, including:

(a) heating objects such as kitchen pans

(b) heating a room by convection

Supplement

2 Explain some of the complex applications and consequences of conduction, convection and radiation where more than one type of thermal energy transfer is significant, including:

(a) a fire burning wood or coal

(b) a radiator in a car

1 **(a)** Fig. 5.1 shows two identical metal plates. The front surface of one is dull black and the front surface of the other is shiny silver.
The plates are fitted with heaters that keep the surfaces of the plates at the same temperature.

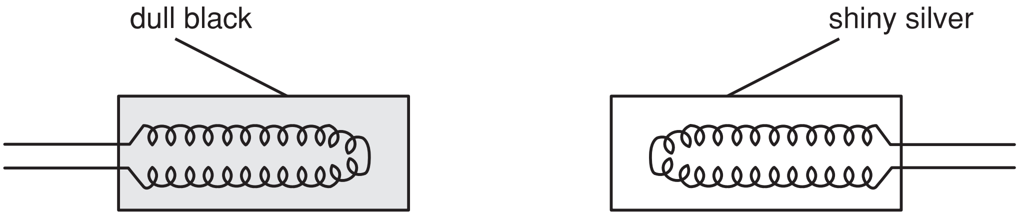


Fig. 5.1

(i) State the additional apparatus needed to test which surface is the best emitter of heat radiation.

....

(ii) State one precaution that is needed to ensure a fair comparison.

....

....

(iii) State the result that you expect.

....

(iv) Write down another name for heat radiation.

....
[4]

(b) In the space below, draw a labelled diagram of an everyday situation in which a convection current occurs.

Mark the path of the current with a line and show its direction with arrows. [3]

2 **(a)** Fig. 5.1 shows a copper rod AB being heated at one end.

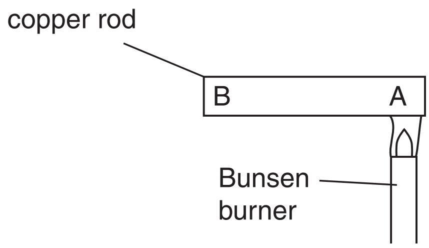


Fig. 5.1

(i) Name the process by which heat moves from A to B.

....

(ii) By reference to the behaviour of the particles of copper along AB, state how this process happens.

....

....
[3]

(b) Give an account of an experiment that is designed to show which of four surfaces will absorb most heat radiation.
The four surfaces are all the same metal, but one is a polished black surface, one is a polished silver surface, one is a dull black surface and the fourth one is painted white.
Give your answer under the headings below.

labelled diagram of the apparatus

readings to be taken

one precaution to try to achieve a fair comparison between the various surfaces

....

....[3]

3 **(a)** Four identical metal plates, at the same temperature, are laid side by side on the ground. The rays from the Sun fall on the plates.

One plate has a matt black surface.

One plate has a shiny black surface.

One plate has a matt silver surface.

One plate has a shiny silver surface.

State which plate has the fastest-rising temperature when the sunlight first falls on the plates.

.... [1]

(b) The apparatus shown in Fig. 4.1 is known as Leslie's Differential Air Thermometer.

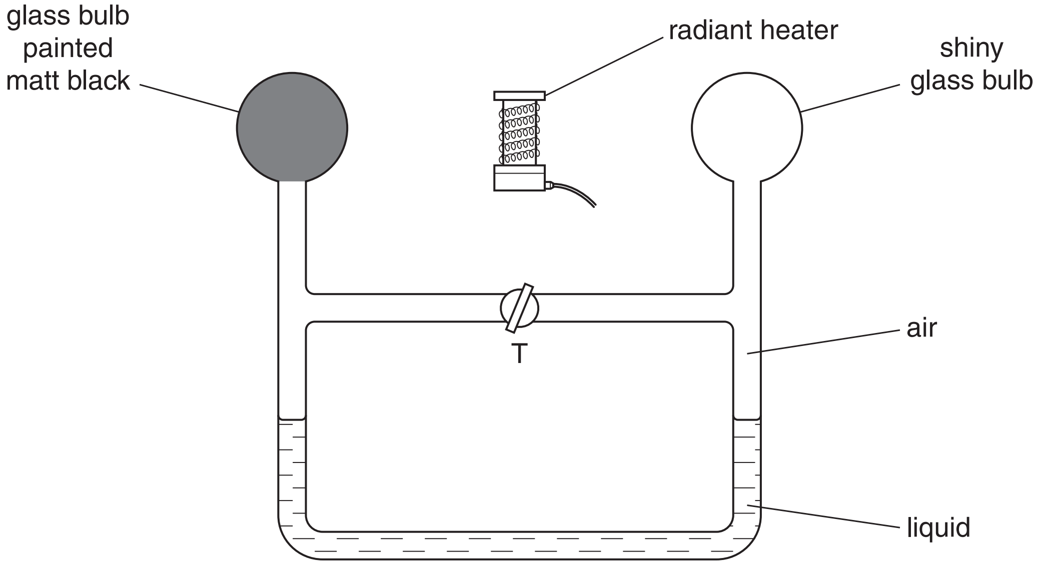


Fig. 4.1

The heater is switched off. Tap T is opened so that the air on the two sides of T has the same pressure. Tap T is then closed.

(i) The heater is switched on. On Fig. 4.1, mark clearly where the two liquid levels might be a short time later. [1]

(ii) Explain your answer to **(b)(i)**.

....

....

.... [2]

[Total: 4]

4 A solar panel is mounted on the roof of a house. Fig. 4.1 shows a section through part of the solar panel.

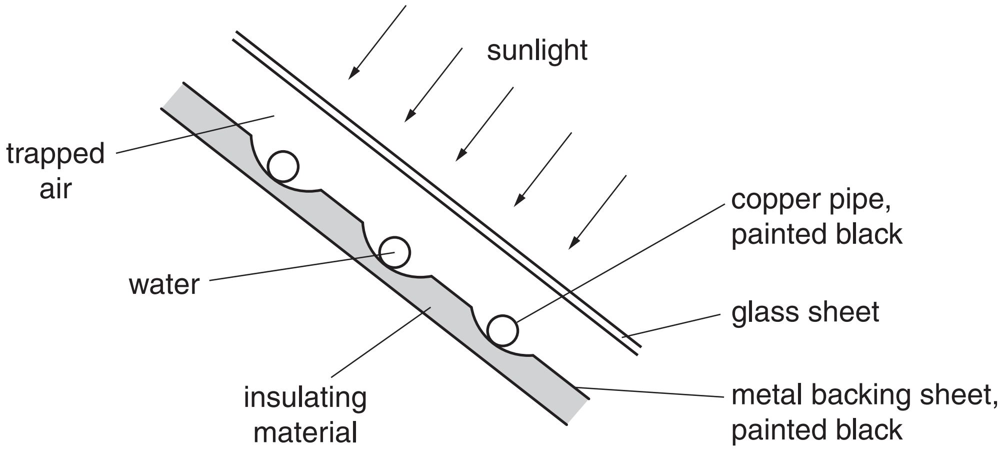


Fig. 4.1

A pump makes water circulate through the copper pipes. The water is heated by passing through the solar panel.

(a) Suggest why

(i) the pipes are made of copper,

....

.... [1]

(ii) the pipes and the metal backing sheet are painted black,

....

.... [1]

(iii) an insulating material is attached to the metal backing sheet,

....

.... [1]

(iv) the presence of the glass sheet increases the energy collected by the water.

....

.... [1]

(b) During one day, 250 kg of water is pumped through the solar panel. The temperature of this water rises from 16 °C to 38 °C.

The water absorbs 25% of the energy falling on the solar panel, and the specific heat capacity of water is 4200 J / (kg °C).

Calculate the energy falling on the solar panel during that day.

energy = ... [4]

[Total: 8]

5 **(a)** **(i)** Name the process by which [thermal] energy is transferred through a metal rod.

.... [1]

(ii) Describe how this process occurs.

....

....

....

.... [2]

(b) An iron rod and a copper rod of equal length are each held by hand at one end, with the other end in the flame from a Bunsen burner, as shown in Fig. 4.1.

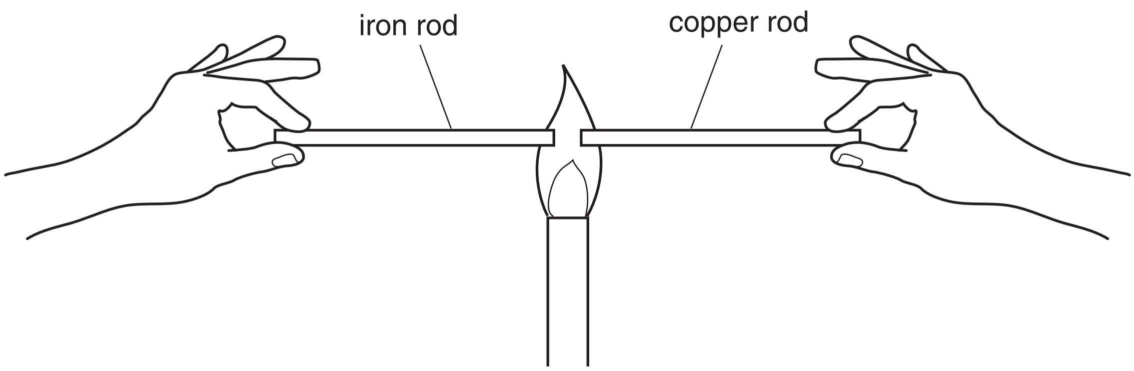


Fig. 4.1

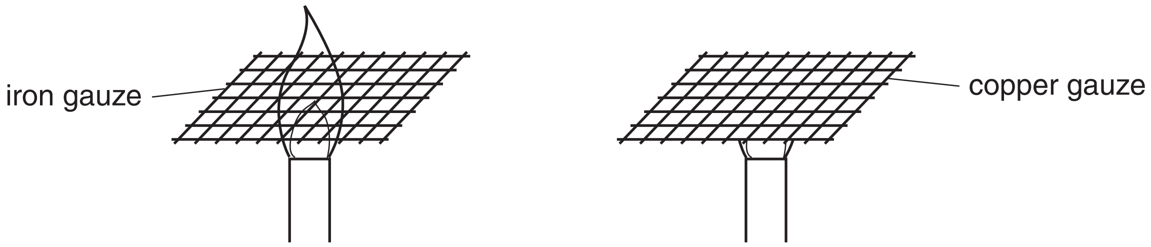
The copper rod becomes too hot to hold much sooner than the iron rod.

What does this information tell you about iron and copper?

.... [1]

(c) Gas has to be above a certain temperature before it burns.

Fig. 4.2 shows two similar wire gauzes, one made of iron wire and one made of copper wire. Each is held over a Bunsen burner. When the gas supply is turned on and ignited below the gauze, the effect is as shown in Fig. 4.2.



observation:
flame appears both above and below the gauze

observation:
flame only appears below the gauze

Fig. 4.2

How can these observations be explained?

....

....

....

....

.... [4]

[Total: 8]

6 Fig. 5.1 shows an X-ray tube.

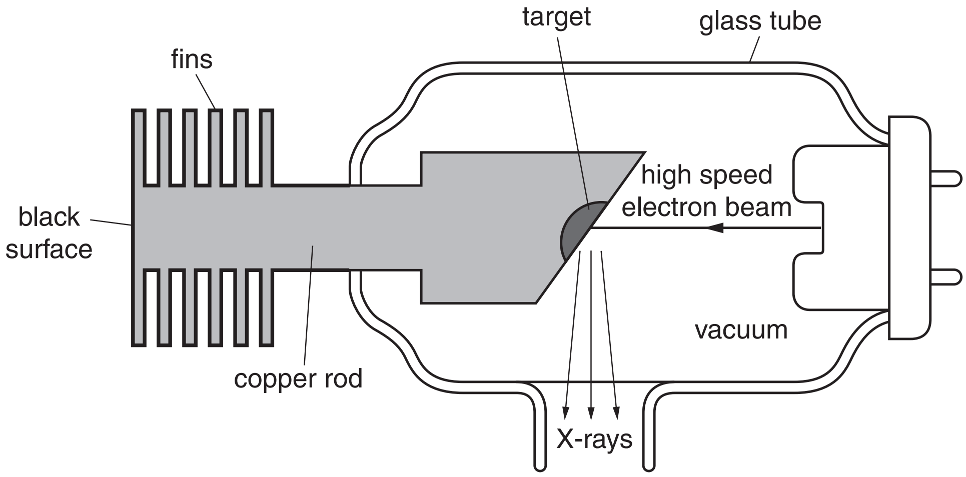


Fig. 5.1

In the production of X-rays, the target gets very hot. Thermal energy must be removed from the target. The tube has several design features to enable this to happen.

For each of the following types of energy transfer, describe how the design of the tube increases the rate of energy transfer. State where the thermal energy transfer mostly happens, the particular design feature that increases the rate of this transfer, and a brief explanation.

(a) conduction

where ....

design feature ....

explanation ....

.... [3]

(b) convection

where ....

design feature ....

explanation ....

.... [3]

(c) radiation

where ....

design feature ....

explanation ....

.... [3]

[Total: 9]

7 Fig. 5.1 shows a thin plastic cup containing hot coffee, which an IGCSE Physics student gets from a machine.

Fig. 5.2 shows how another student, who finds an empty second cup, has placed his identical cup of coffee inside this second cup.

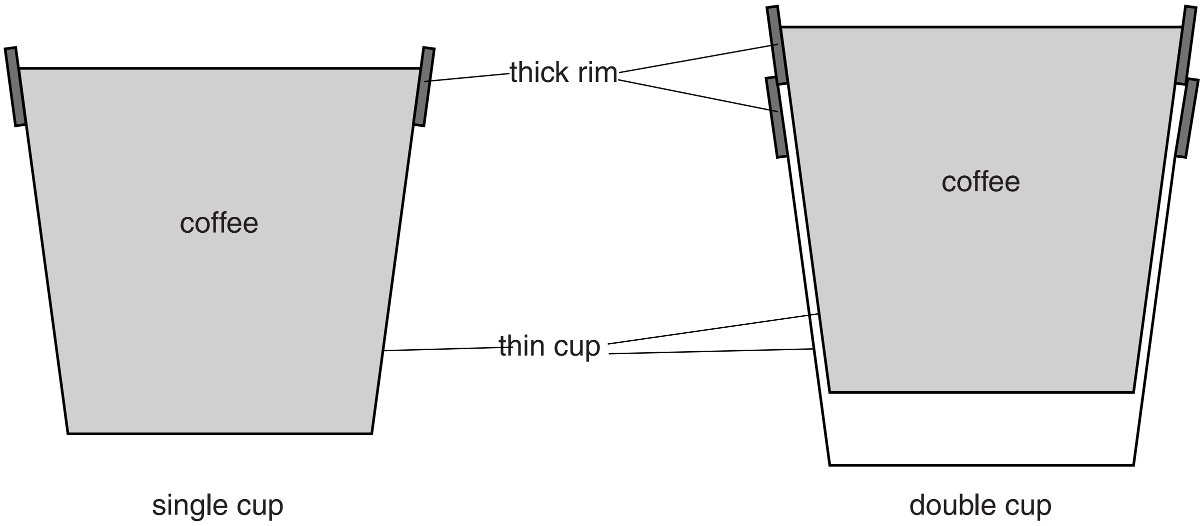


Fig. 5.1 **Fig. 5.2**

(a) Suggest and explain a difference that the students will feel when holding the cups.

....

....

....

.... [2]

(b) The students discuss this experience with their teacher, who makes hot drinks the subject of an experiment.

The same volume of hot water at the same temperature is placed in the single cup and in the double cup.

The temperature of the water in each cup is recorded for 10 minutes.

Fig. 5.3 shows the cooling curve for the water in the single cup.

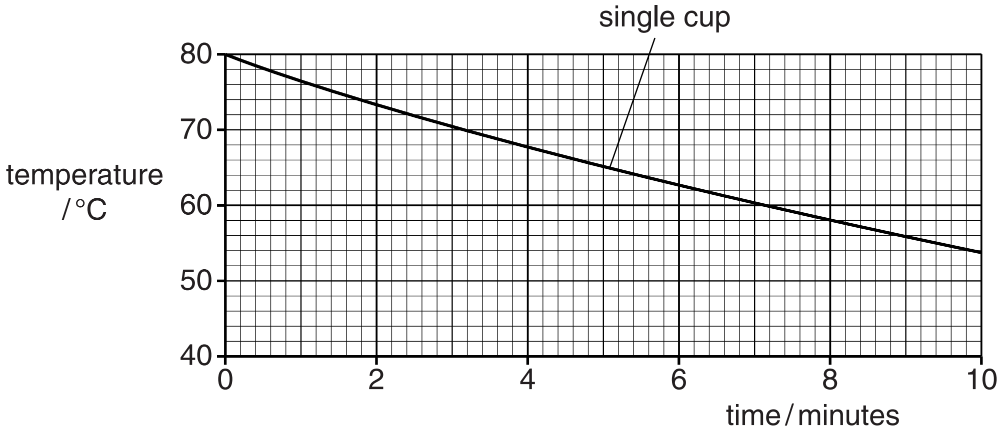


Fig. 5.3

On Fig. 5.3, sketch and label a possible cooling curve for the water in the double cup. [2]

(c) Explain why a cup of coffee cools more slowly when a lid is placed over the cup.

....

....

....

....

.... [2]

[Total: 6]

8 The water in a copper hot-water tank is heated during the night. During the day, the water cools as thermal energy (heat) passes from the water to the air surrounding the tank.

(a) **(i)** Describe the process by which the thermal energy is transferred from the hot water to the air.

....

....

....

....

.... [3]

(ii) State why the rate at which thermal energy passes into the air decreases as the water temperature falls.

....

.... [1]

(b) The manufacturer of the hot-water tank says that when the outside surface is polished regularly and kept bright and shiny, the hot water will cool more slowly.

Describe, with the aid of a diagram, an experiment that shows whether a container with a bright and shiny surface is better at keeping its contents warm than one with a dull and dark surface.

....

....

....

....

....

.... [4]

[Total: 8]

Part III
Physics of waves

Chapter 12. Sound

3.4 Sound

Core

1 Describe the production of sound by vibrating sources

2 Describe the longitudinal nature of sound waves

3 State the approximate range of frequencies audible to humans as 20 Hz to 20 000 Hz

4 Know that a medium is needed to transmit sound waves

5 Know that the speed of sound in air is approximately 330–350 m / s

6 Describe a method involving a measurement of distance and time for determining the speed of sound in air

7 Describe how changes in amplitude and frequency affect the loudness and pitch of sound waves

8 Describe an echo as the reflection of sound waves

9 Define ultrasound as sound with a frequency higher than 20 kHz

Supplement

10 Describe compression and rarefaction

11 Know that, in general, sound travels faster in solids than in liquids and faster in liquids than in gases

12 Describe the uses of ultrasound in non-destructive testing of materials, medical scanning of soft tissue and sonar including calculation of depth or distance from time and wave speed

1 **(a)** Fig. 5.1 shows the air pressure variation along a sound wave.

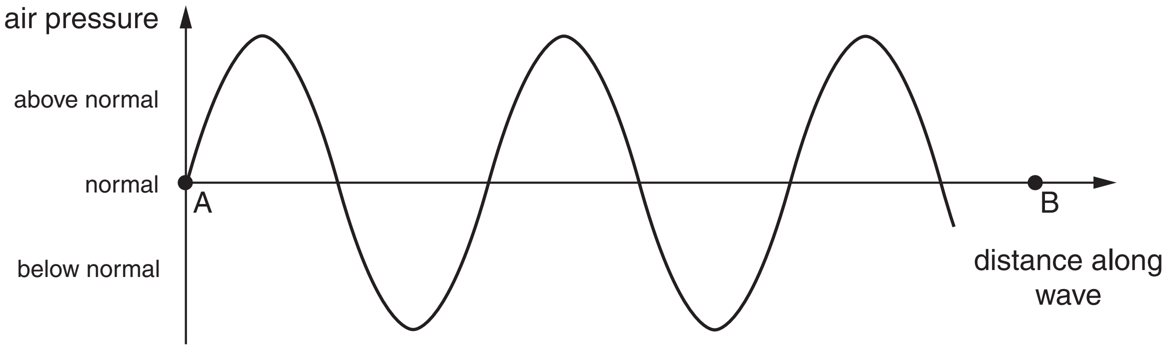


Fig. 5.1

(i) On AB in Fig. 5.1, mark one point of compression with a dot and the letter C and the next point of rarefaction with a dot and the letter R.

(ii) In terms of the wavelength, what is the distance along the wave between a compression and the next rarefaction?

.... [3]

(b) A sound wave travels through air at a speed of 340 m/s. Calculate the frequency of a sound wave of wavelength 1.3 m.

frequency = ... [2]

2 In a thunderstorm, both light and sound waves are generated at the same time.

(a) How fast does the light travel towards an observer?

speed = ... [1]

(b) Explain why the sound waves always reach the observer after the light waves.

....[1]

(c) The speed of sound waves in air may be determined by experiment using a source that generates light waves and sound waves at the same time.

(i) Draw a labelled diagram of the arrangement of suitable apparatus for the experiment.

(ii) State the readings you would take.

....

....

....

(iii) Explain how you would calculate the speed of sound in air from your readings.

....

....
[4]

3 **(a)** Fig. 9.1 shows the screen of a c.r.o. (cathode-ray oscilloscope).

The c.r.o. is being used to display the output from a microphone.

The vertical scale on the screen is in volts.

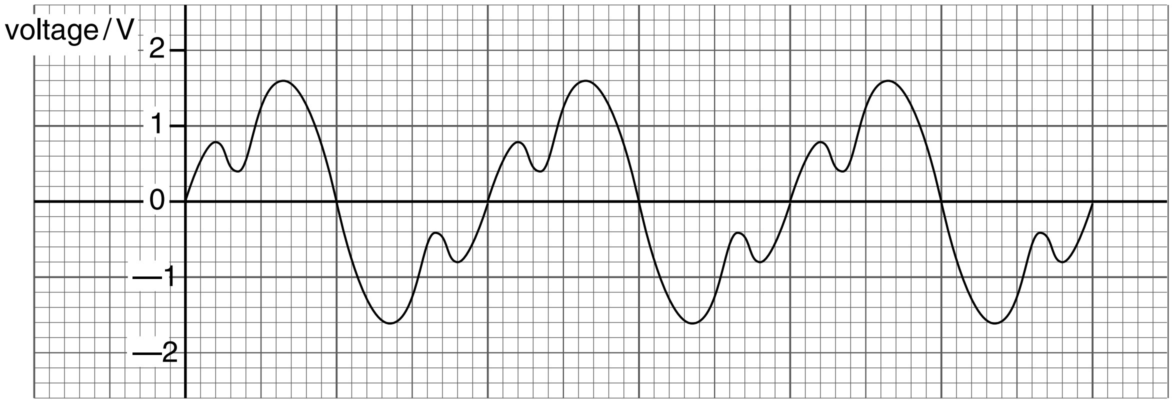


Fig. 9.1

(i) Describe the output from the microphone.

....

....

(ii) Use the graph to determine the peak voltage of the output.

....

(iii) Describe how you could check that the voltage calibration on the screen is correct.

....

....

[4]

(b) Fig. 9.2 shows the screen of the c.r.o. when it is being used to measure a small time interval between two voltage pulses.

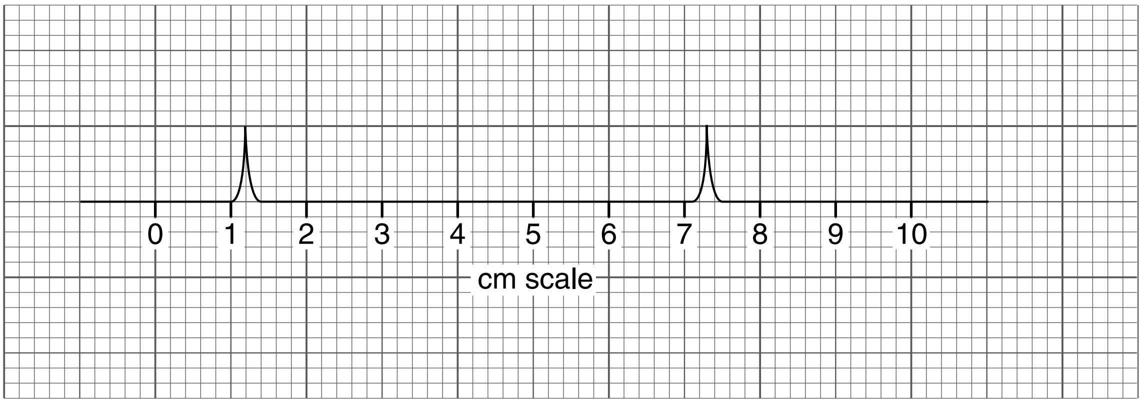


Fig. 9.2

(i) What is the distance on the screen between the two voltage pulses?

....

(ii) The time-base control of the c.r.o. is set at 5.0 ms / cm.

Calculate the time interval between the voltage pulses.

time = ...

(iii) Suggest **one** example where a c.r.o. can be used to measure a small time interval.

....

[4]

4 Two students are asked to determine the speed of sound in air on the school playing fields.

(a) List the apparatus they need.

....

....

.... [1]

(b) List the readings that the students need to take.

....

....

.... [1]

(c) State how the speed of sound is calculated from the readings.

.... [1]

(d) State one precaution that could be taken to improve the accuracy of the value obtained.

....

.... [1]

(e) The table gives some speeds.

speed/ m/s	speed of sound in air	speed of sound in water
10		
100		
1000		
10 000		

Place a tick in the table to show the speed which is closest to

(i) the speed of sound in air,

(ii) the speed of sound in water.

[2]

[Total: 6]

5 During a thunderstorm, thunder and lightning are produced at the same time.

(a) A person is some distance away from the storm.

Explain why the person sees the lightning before hearing the thunder.

....

....

.... [1]

(b) A scientist in a laboratory made the following measurements during a thunderstorm.

time from start of storm / minutes	0.0	2.0	4.0	6.0	8.0	10.0
time between seeing lightning and hearing thunder / s	3.6	2.4	1.6	2.4	3.5	4.4

Fig. 7.1

(i) How many minutes after the storm started did it reach its closest point to the laboratory?

.... [1]

(ii) How can you tell that the storm was never immediately over the laboratory?

.... [1]

(iii) When the storm started, it was immediately above a village 1200 m from the laboratory.

Using this information and information from Fig. 7.1, calculate the speed of sound.

speed of sound = ... [2]

(iv) State the assumption you made when you calculated your answer to **(b)(iii)**.

.... [1]

(c) Some waves are longitudinal; some waves are transverse.

Some waves are electromagnetic; some waves are mechanical.

Put ticks (✓) in the table below to indicate which of these descriptions apply to the light waves of the lightning and the sound waves of the thunder.

	light waves	sound waves
longitudinal		
transverse		
electromagnetic		
mechanical		

[3]

[Total: 9]

6 A disused railway line has a length of 300 m. A man puts his ear against one end of the rail and another man hits the other end with a metal hammer, as shown in Fig. 7.1.

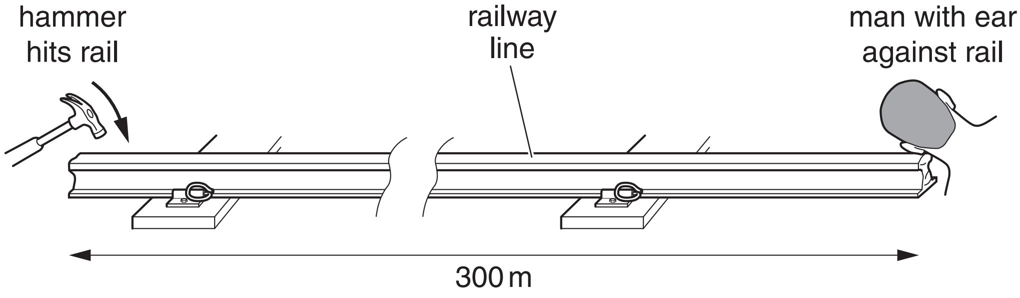


Fig. 7.1

(a) **(i)** State an approximate value for the speed of sound in air.

.... [1]

(ii) Sound travels at 5000 m/s in steel.

Calculate the time it takes for the sound to travel along the rail.

time taken = ... [2]

(b) The man with his ear to the railway line actually hears two sounds from the hammer, separated by a short interval.

Explain why he hears two sounds.

....

....

....

.... [2]

[Total: 5]

7 **(a)** Fig. 6.1 shows the position of layers of air, at one moment, as a sound wave of constant frequency passes through the air. Compressions are labelled C. Rarefactions are labelled R.

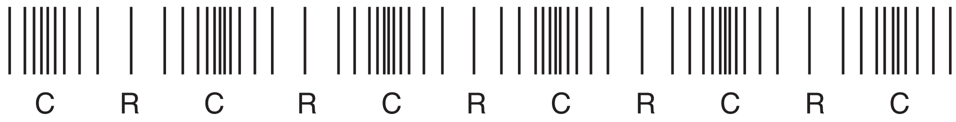


Fig. 6.1

(i) State how Fig. 6.1 would change if

1. the sound had a higher frequency,

....[1]

2. the sound were louder.

....

....

....[2]

(ii) On Fig. 6.1, draw a line marked with arrows at each end to show the wavelength of the sound. [1]

(b) In an experiment to measure the speed of sound in steel, a steel pipe of length 200 m is struck at one end with a hammer. A microphone at the other end of the pipe is connected to an accurate timer. The timer records a delay of 0.544 s between the arrival of the sound transmitted by the steel pipe and the sound transmitted by the air in the pipe.

The speed of sound in air is 343 m/s. Calculate the speed of sound in steel.

speed of sound in steel = ...[3]

[Total: 7]

8 Fig. 8.1 shows a loudspeaker cone oscillating to produce sound waves.

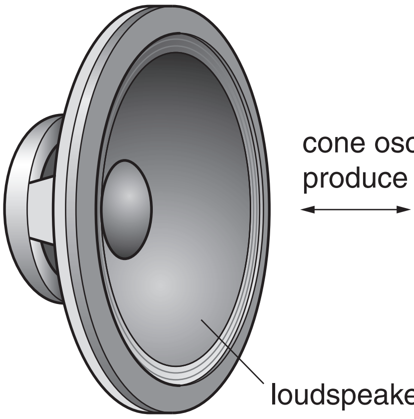


Fig. 8.1

(a) As the sound wave passes a point, it produces regions of higher and lower pressure. State the names of these regions.

higher pressure ....

lower pressure .... [2]

(b) Describe how the movement of the loudspeaker cone produces these regions of different pressure.

higher pressure ....

....

lower pressure ....

.... [2]

(c) State the effect on the loudness and pitch of the sound from the loudspeaker when

(i) the amplitude increases but the frequency of the sound stays the same,

loudness ....

pitch ....

(ii) the amplitude stays the same but the frequency increases.

loudness ....

pitch ....

[2]

[Total: 6]

Chapter 13. Light

3.2 Light

3.2.1 Reflection of light

Core

1. Define and use the terms normal, angle of incidence and angle of reflection
2. Describe the formation of an optical image by a plane mirror, and give its characteristics, i.e. same size, same distance from mirror, virtual
3. State that for reflection, the angle of incidence is equal to the angle of reflection; recall and use this relationship

Supplement

4. Use simple constructions, measurements and calculations for reflection by plane mirrors

3.2.2 Refraction of light

Core

1. Define and use the terms normal, angle of incidence and angle of refraction
2. Describe an experiment to show refraction of light by transparent blocks of different shapes
3. Describe the passage of light through a transparent material (limited to the boundaries between two media only)
4. State the meaning of critical angle
5. Describe internal reflection and total internal reflection using both experimental and everyday examples

Supplement

6. Define refractive index, n, as the ratio of the speeds of a wave in two different regions
7. Recall and use the equation
   $$n = \frac{\sin i}{\sin r}$$
8. Recall and use the equation
   $$n = \frac{1}{\sin c}$$
9. Describe the use of optical fibres, particularly in telecommunications

3.2.3 Thin lenses

Core

1. Describe the action of thin converging and thin diverging lenses on a parallel beam of light
2. Define and use the terms focal length, principal axis and principal focus (focal point)
3. Draw and use ray diagrams for the formation of a real image by a converging lens
4. Describe the characteristics of an image using the terms enlarged/same size/diminished, upright/inverted and real/virtual
5. Know that a virtual image is formed when diverging rays are extrapolated backwards and does not form a visible projection on a screen

Supplement

6. Draw and use ray diagrams for the formation of a virtual image by a converging lens
7. Describe the use of a single lens as a magnifying glass
8. Describe the use of converging and diverging lenses to correct long-sightedness and short-sightedness

3.2.4 Dispersion of light

Core

1. Describe the dispersion of light as illustrated by the refraction of white light by a glass prism
2. Know the traditional seven colours of the visible spectrum in order of frequency and in order of wavelength

Supplement

3. Recall that visible light of a single frequency is described as monochromatic

13.1 Reflecting light

1 Fig.1 shows an arrangement where a plane mirror is used in a shop to watch a display counter. The arrangement is drawn to a scale of 1 cm : 1 m.

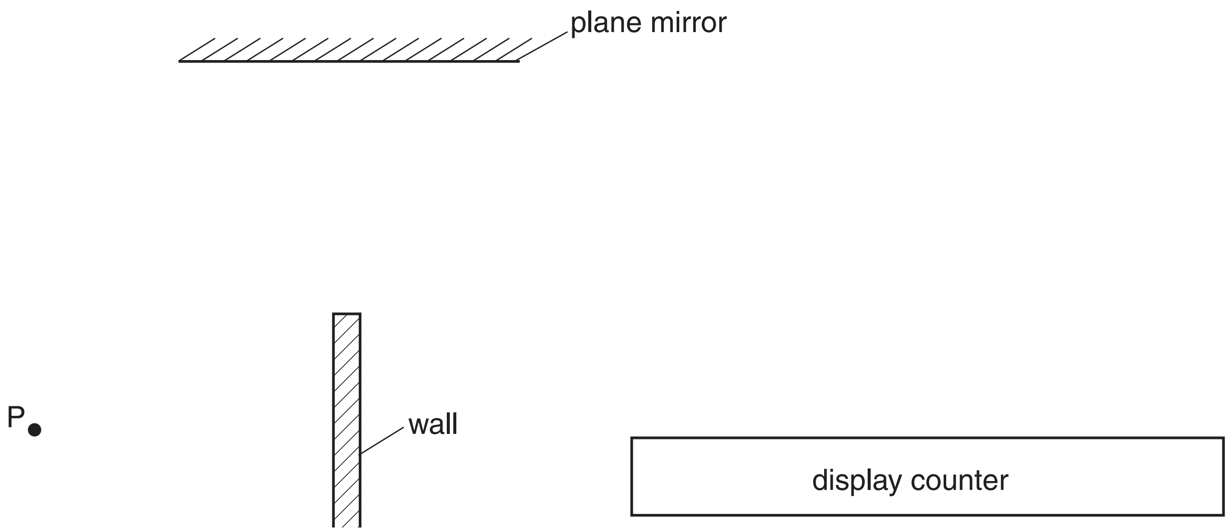


Fig.1

(a) (i) State the law of reflection.

....

(ii) On Fig. 5.1, draw rays to show how much of the display cannot be seen from P. Indicate this by shading in the part that cannot be seen.

[3]

(b) By construction on Fig. 5.1 and by using the scale, calculate how far the mirror must be moved so that all of the display counter can be seen from P.

distance moved = ... [2]

(c) State the characteristics of an image seen in a plane mirror.

....

....

.... [2]

13.2 Refraction of light

1 Fig. 6.1 shows wavefronts of light crossing the edge of a glass block from air into glass.

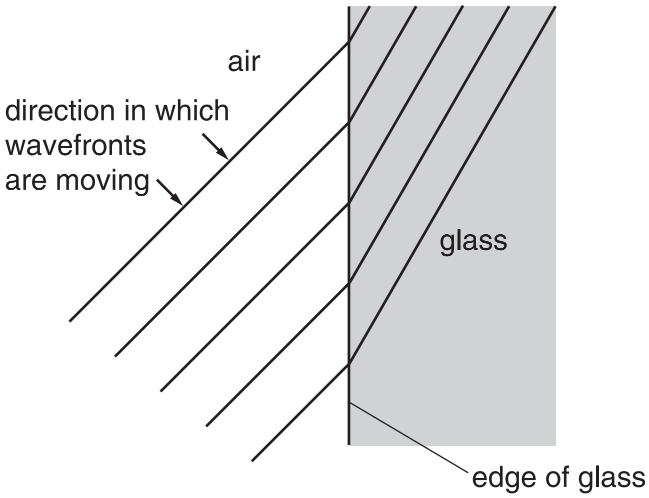


Fig. 6.1

(a) On Fig. 6.1

(i) draw in an incident ray, a normal and a refracted ray that meet at the same point on the edge of the glass block,

(ii) label the angle of incidence and the angle of refraction,

(iii) measure the two angles and record their values.

angle of incidence = ...

angle of refraction = ...

[4]

(b) Calculate the refractive index of the glass.

refractive index = ...[3]

2 Fig. 6.1 shows a ray PQ of blue light incident on the side of a rectangular glass block.

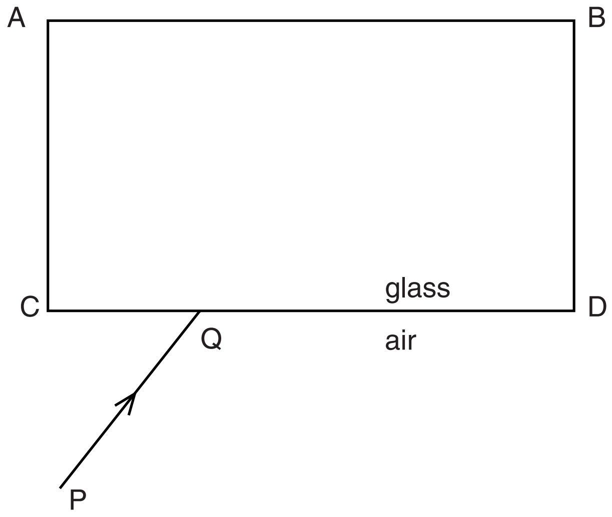


Fig. 6.1

(a) **(i)** By drawing on Fig. 6.1, continue the ray PQ through and beyond the block.

(ii) Mark the angle of incidence at CD with the letter *i* and the angle of refraction at CD with the letter *r*.

[3]

(b) The speed of light in air is 3.0×10^8 m/s and the speed of light in glass is 2.0×10^8 m/s.

(i) Write down a formula that gives the refractive index of glass in terms of the speeds of light in air and glass.

refractive index =

(ii) Use this formula to calculate the refractive index of glass.

refractive index = …………………
[2]

(c) The frequency of the blue light in ray PQ is 6.0×10^{14} Hz.
Calculate the wavelength of this light in air.

wavelength = ………………..……[2]

3 Fig. 6.1 shows a ray of light OPQ passing through a semi-circular glass block.

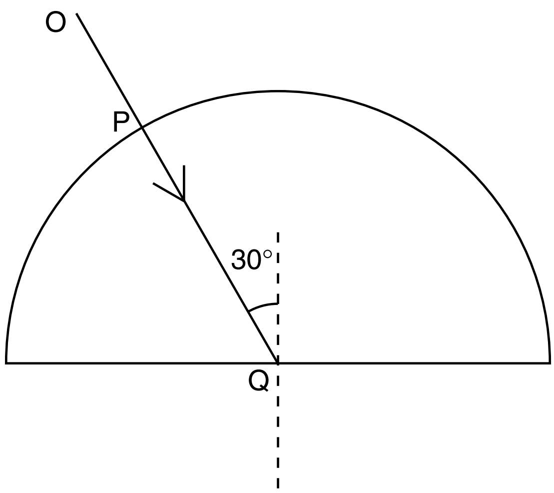


Fig. 6.1

(a) Explain why there is no change in the direction of the ray at P.

....

.... [1]

(b) State the changes, if any, that occur to the speed, wavelength and frequency of the light as it enters the glass block.

....

....

....

(c) At Q some of the light in ray OPQ is reflected and some is refracted.

On Fig. 6.1, draw in the approximate positions of the reflected ray and the refracted ray. Label these rays. [2]

(d) The refractive index for light passing from glass to air is 0.67.

Calculate the angle of refraction of the ray that is refracted at Q into air.

angle = ………………. [3]

4 Fig. 6.1 shows a ray of light, from the top of an object PQ, passing through two glass prisms.

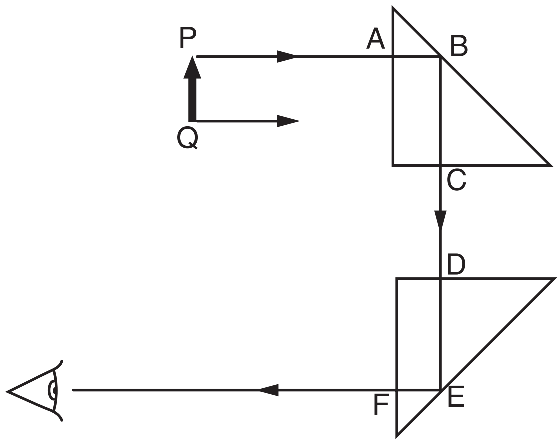


Fig. 6.1

(a) Complete the path through the two prisms of the ray shown leaving Q. [1]

(b) A person looking into the lower prism, at the position indicated by the eye symbol, sees an image of PQ.
State the properties of this image.

....[2]

(c) Explain why there is no change in direction of the ray from P at points A, C, D and F.

....

....[1]

(d) The speed of light as it travels from P to A is 3×10^8 m/s and the refractive index of the prism glass is 1.5.
Calculate the speed of light in the prism.

speed = ...[2]

(e) Explain why the ray AB reflects through 90° at B and does not pass out of the prism at B.

....

....

....[2]

5 Fig. 6.1 shows a rectangular glass block ABCD.

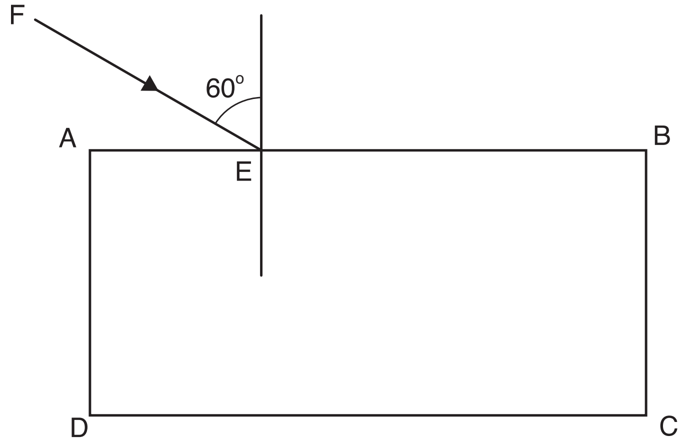


Fig. 6.1

(a) The ray FE is partly reflected and partly refracted at E.

(i) On Fig. 6.1, draw in the approximate path of the refracted ray, within and beyond the block. Label the ray *refracted ray*. [1]

(ii) On Fig. 6.1, draw in the path of the reflected ray. Label the ray *reflected ray*. [1]

(b) A second ray, almost parallel to AE, strikes the block at E and is partly refracted at an angle of refraction of 43°.

(i) State an approximate value for the angle of incidence at E.

(ii) State an approximate value for the critical angle for the light in the glass block.

(iii) Calculate an approximate value for the refractive index of the glass of the block.

refractive index = ... [2]

(c) The speed of the light along ray FE is 3.0×10^8 m/s. Calculate the speed of the refracted light in the glass block.

speed = ... [2]

[Total: 8]

6 Fig. 7.1 and Fig. 7.2 show wavefronts of light approaching a plane mirror and a rectangular glass block, respectively.

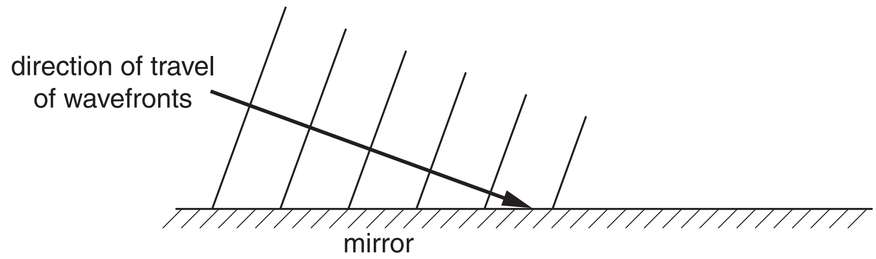


Fig. 7.1

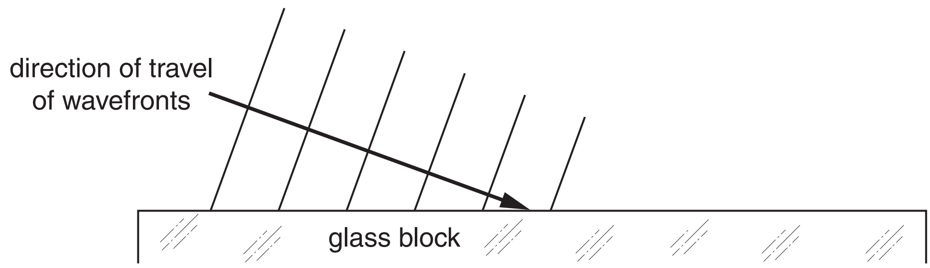


Fig. 7.2

(a) On Fig. 7.1 and on Fig. 7.2 draw wavefronts to show what happens after the waves strike the surface. [4]

(b) In Fig. 7.2, the waves approaching the block have a speed of 3.0×10^8 m/s and an angle of incidence of 70°. The refractive index of the glass of the block is 1.5.

(i) Calculate the speed of light waves in the block.

speed = ... [2]

(ii) Calculate the angle of refraction in the block.

angle = ... [2]

[Total: 8]

7 Fig. 6.1 shows a cross-section through a swimming pool.

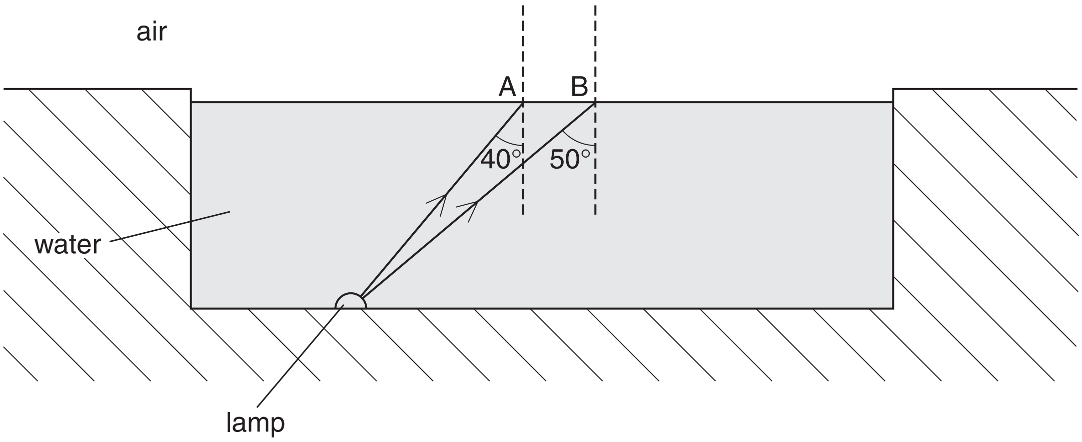


Fig. 6.1

(a) A ray of monochromatic light from a lamp at the bottom of the pool strikes the surface at A, as shown.

(i) State what is meant by *monochromatic* light.

.... [1]

(ii) The water in the swimming pool has a refractive index of 1.33.

Using information from Fig. 6.1, calculate the angle of refraction at A.

angle of refraction = ... [3]

(iii) On Fig. 6.1, draw the refracted ray. [1]

(b) The critical angle for the water-air surface is 48.8°.

Another ray of monochromatic light from the lamp strikes the surface at B, as shown in Fig. 6.1.

(i) State and explain what happens to the ray after reaching B.

....

.... [2]

(ii) On Fig. 6.1, draw this ray. [1]

[Total: 8]

8 A ray of monochromatic light passes through the glass prism shown in Fig. 6.1.

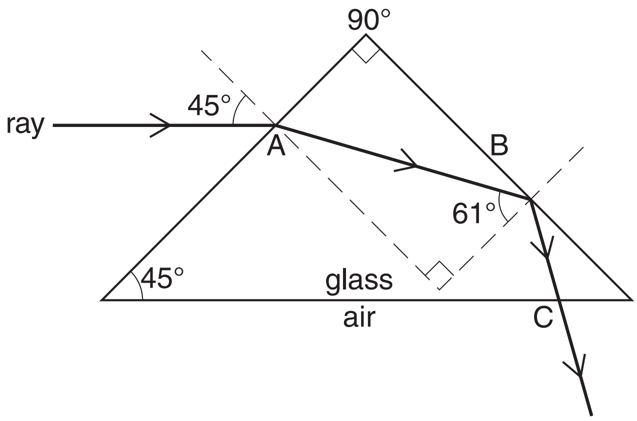


Fig. 6.1

(a) State what is meant by the term *monochromatic*.

....

.... [1]

(b) State the name given to what happens to the ray at A.

.... [1]

(c) Use the values on the diagram to calculate the angle of refraction at A (The angles in a triangle add up to 180°).

angle of refraction = ... [1]

(d) Calculate the refractive index of the glass.

refractive index = ... [3]

(e) Explain why the ray does not emerge into the air at B, but does emerge at C.

....

....

....

.... [2]

(f) An identical prism is stuck to the first prism using a transparent adhesive with the same refractive index as the glass. This is shown in Fig. 6.2.

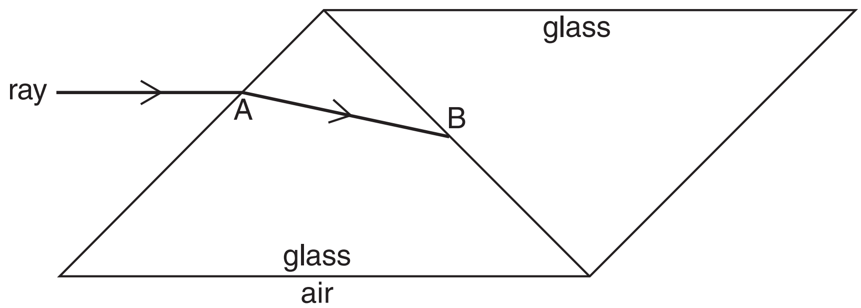


Fig. 6.2

On Fig. 6.2, draw the path of the ray after it has reached B and until it has passed into the air again. [3]

[Total: 11]

9 In Fig. 9.1, a ray of light TRS is shown entering, passing through and leaving a semicircular glass block.

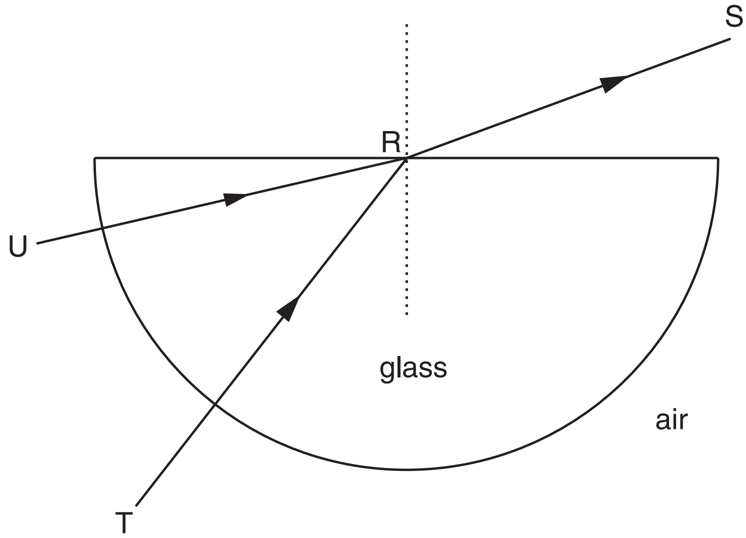


Fig. 9.1

(a) As the light enters the block, its frequency remains constant.

State what happens to

(i) the speed of the light as it enters the block,

....

(ii) the wavelength of the light as it enters the block.

.... [2]

(b) The refractive index of the glass is 1.48.

The speed of light in air is 3.00×10^8 m/s.

Calculate the speed of the light in the glass. State the equation you use.

speed = ... [2]

(c) Another ray of light enters the block along UR.

On Fig. 9.1, draw a line to show what happens to this ray after it has reached R. [2]

[Total: 6]

10 **(a)** Fig. 7.1 shows a ray of monochromatic red light, in air, incident on a glass block at an angle of incidence of 50°.

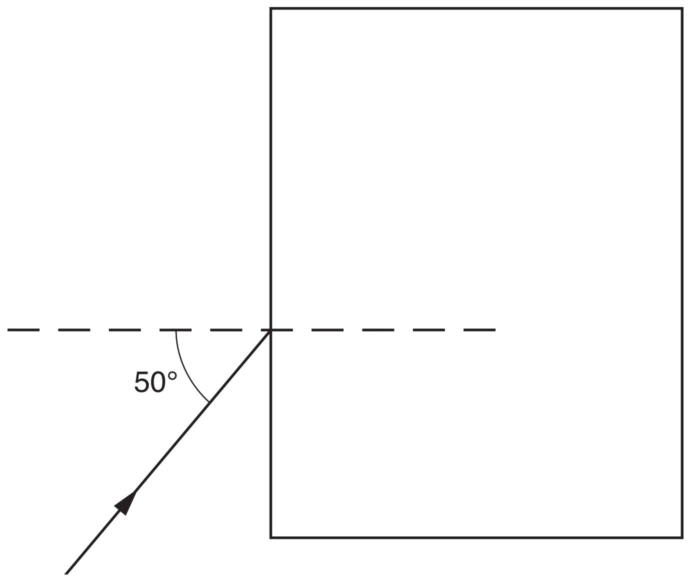


Fig. 7.1

(i) State what is meant by *monochromatic* light.

....[1]

(ii) For this red ray the refractive index of the glass is 1.52. Calculate the angle of refraction for the ray.

angle of refraction = ...[2]

(iii) Without measuring angles, use a ruler to draw the approximate path of the ray in the glass block and emerging from the block. [2]

(b) The red ray in Fig. 7.1 is replaced by a ray of monochromatic violet light. For this violet ray the refractive index of the glass is 1.54. The speed of light in air is 3.00×10^8 m/s.

(i) Calculate the speed of the violet light in the glass block.

speed = ...[2]

(ii) Use a ruler to draw the approximate path of this violet ray in the glass block and emerging from the block. Make sure this path is separated from the path drawn for the red light in **(a)(iii)**. Mark both parts of this path with the letter V. [2]

[Total: 9]

11 Fig. 6.1 shows an enlarged view of a spherical raindrop, centre O.

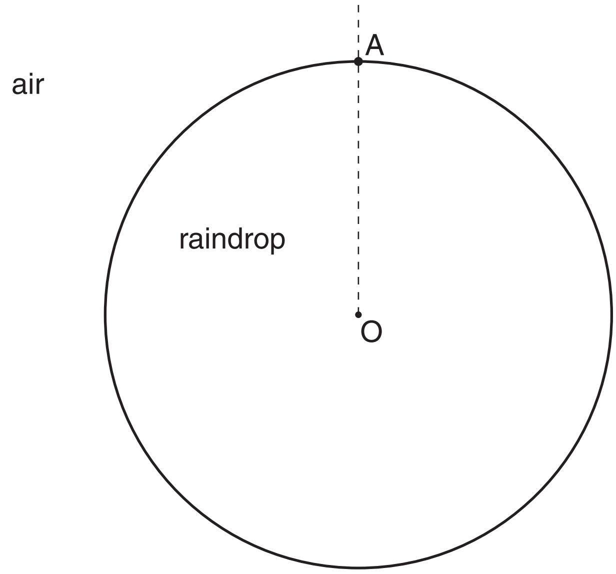


Fig. 6.1

(a) On Fig. 6.1, draw a ray in the air striking the raindrop at A with an angle of incidence of 59° and coming from the left. [1]

(b) The water in the raindrop has a refractive index of 1.33.

(i) Show by calculation that the angle of refraction at A is about 40°.

[2]

(ii) On Fig. 6.1, draw the path of the refracted ray to the point where it strikes the inner surface of the raindrop. Label this point B. [1]

(c) The ray is partially reflected at B.
Draw the normal and the reflected ray at B. [1]

(d) Extend the reflected ray to strike the surface of the raindrop again. At this point it is partially refracted out of the raindrop. Draw the approximate path of this ray as it emerges into the air. [1]

[Total: 6]

12 Fig. 9.1 represents a ray of monochromatic light passing through a rectangular glass block.

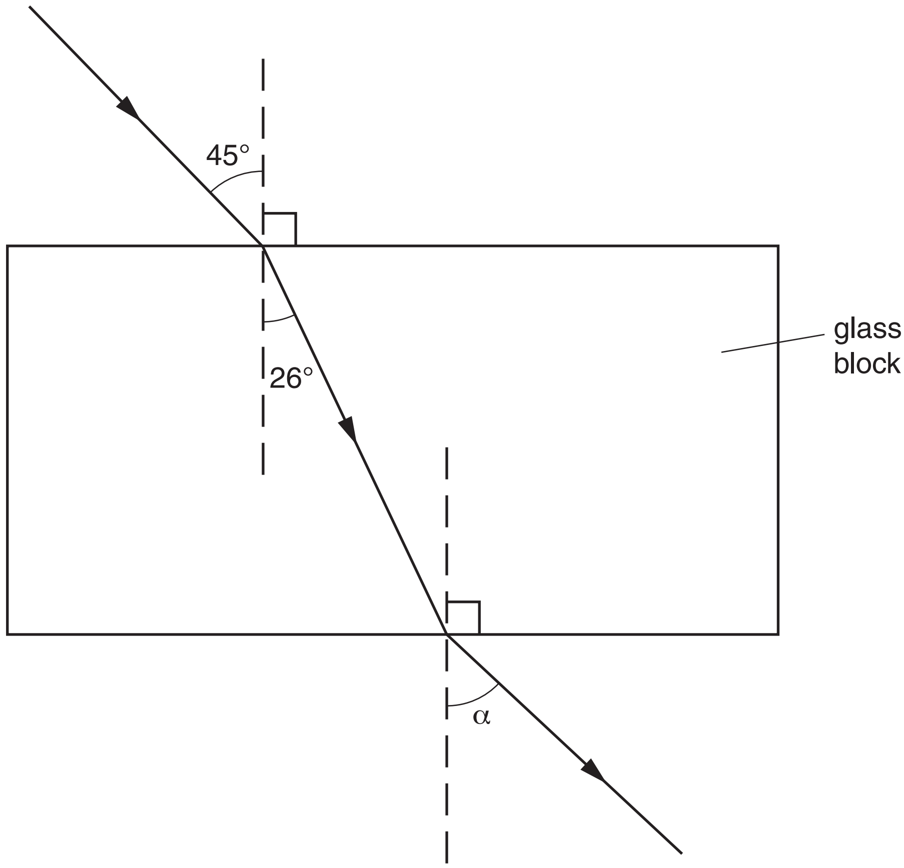


Fig. 9.1 (not to scale)

(a) What is meant by the term *monochromatic*?

....

....[1]

(b) Use the information on Fig. 9.1 to determine the refractive index of the glass.

refractive index = ...[2]

(c) The angle α on Fig. 9.1 is not drawn with the correct value.

State the correct value of angle α.

α = ...[1]

(d) After the ray has left the glass block, it passes into a block of ice, whose refractive index is 1.31.

How does the speed of light in ice compare with

(i) the speed of light in air, ...

(ii) the speed of light in glass. .... [2]

[Total: 6]

13 **(a)** A ray of light in air travels across a flat boundary into glass. The angle of incidence is 51°. The angle of refraction is 29°.

(i) In the space below, draw a labelled diagram to illustrate this information. [3]

(ii) Calculate the refractive index of the glass.

refractive index = ... [2]

(b) A ray of light in glass travels towards a flat boundary with air. The angle of incidence is 51°. This ray does not emerge into the air.

State and explain what happens to this ray.

....

....

....

.... [2]

[Total: 7]

14 A laser produces a ray of blue light of wavelength 4.0×10^{-7} m (0.000 000 40 m).

(a) (i) State the speed of light in a vacuum.

speed = ... [1]

(ii) Calculate the frequency of the light produced by the laser.

frequency = ... [2]

(b) The ray of blue light passes from air into a glass block. Fig. 6.1 shows the ray making an angle of 35° with the side of the block.

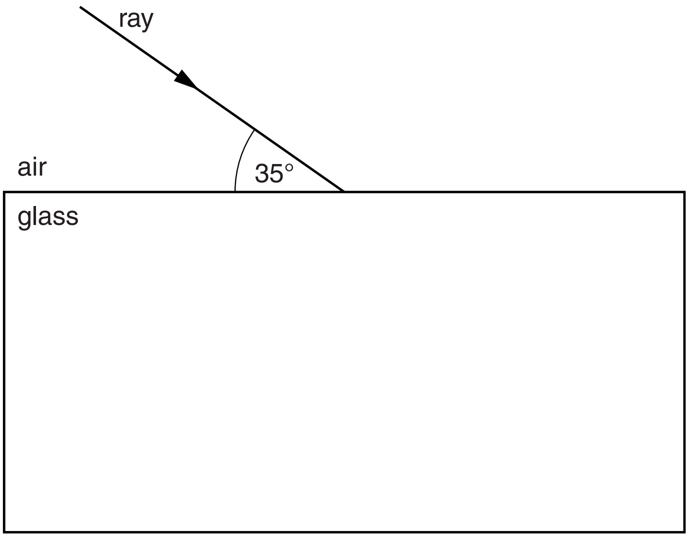


Fig. 6.1

(i) State the angle of incidence of the ray of blue light on the glass.

angle of incidence = ... [1]

(ii) Glass has a refractive index of 1.5.

Calculate the angle of refraction of the light in the glass.

angle of refraction = ... [2]

[Total: 6]

13.3 Total internal reflection

1 **(a)** Fig. 6.1 shows the results of an experiment to find the critical angle for light in a semi-circular glass block.

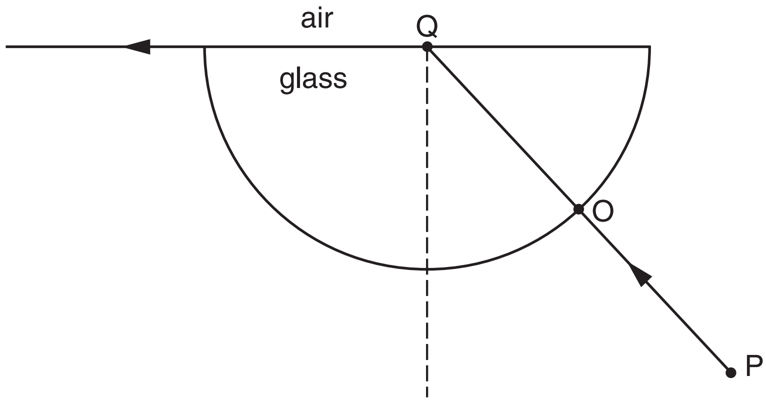


Fig. 6.1

The ray of light PO hits the glass at O at an angle of incidence of 0°.
Q is the centre of the straight side of the block.

(i) Measure the critical angle of the glass from Fig. 6.1.

critical angle = ...

(ii) Explain what is meant by the *critical angle* of the light in the glass.

....

....

....
[3]

(b) Fig. 6.2 shows another ray passing through the same block.

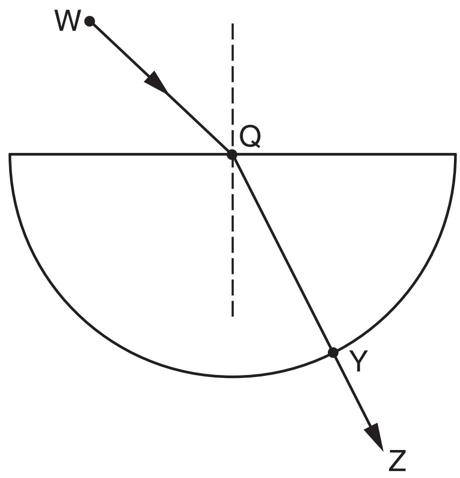


Fig. 6.2

The speed of the light between W and Q is 3.0×10^8 m/s. The speed of the light between Q and Y is 2.0×10^8 m/s.

(i) State the speed of the light between Y and Z.

speed = ...

(ii) Write down an expression, in terms of the speeds of the light, that may be used to find the refractive index of the glass. Determine the value of the refractive index.

refractive index = ...

(iii) Explain why there is no change of direction of ray QY as it passes out of the glass.

....

(iv) What happens to the wavelength of the light as it passes out of the glass?

....

[5]

2 Fig. 6.1 shows two rays of monochromatic light, one entering the prism along the normal DE and the second one along PQ.

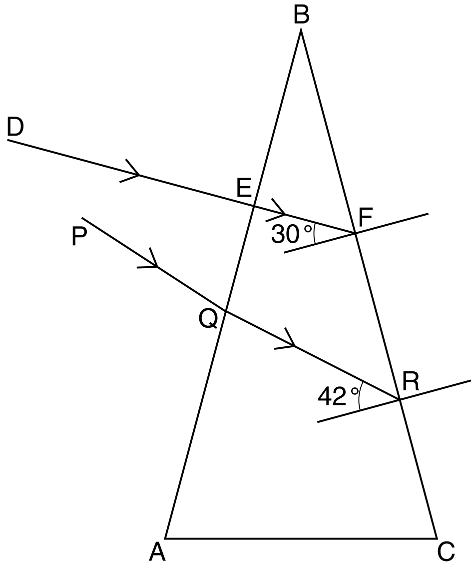


Fig. 6.1

(a) State what is meant by *monochromatic* light.

.... [1]

(b) The refractive index of the glass of the prism is 1.49. The ray EF is refracted at F. Use information from Fig. 6.1 to calculate the angle of refraction at F.

angle of refraction = ... [3]

(c) On Fig. 6.1, draw in the refracted ray, starting from F. [1]

(d) State how the refraction, starting at F, would be different if the monochromatic ray were replaced by a ray of white light.

.... [1]

(e) The critical angle for the glass of the prism is just over 42°. State the approximate angle of refraction for the ray striking BC at R.

.... [1]

(f) Another monochromatic ray, not shown in Fig. 6.1, passes through the prism and strikes BC at an angle of incidence of 50°. State what happens to this ray at the point where it strikes BC.

.... [1]

[Total: 8]

3 In an optics lesson, a Physics student traces the paths of three rays of light near the boundary between medium A and air. The student uses a protractor to measure the various angles.

Fig. 8.1 illustrates the three measurements.

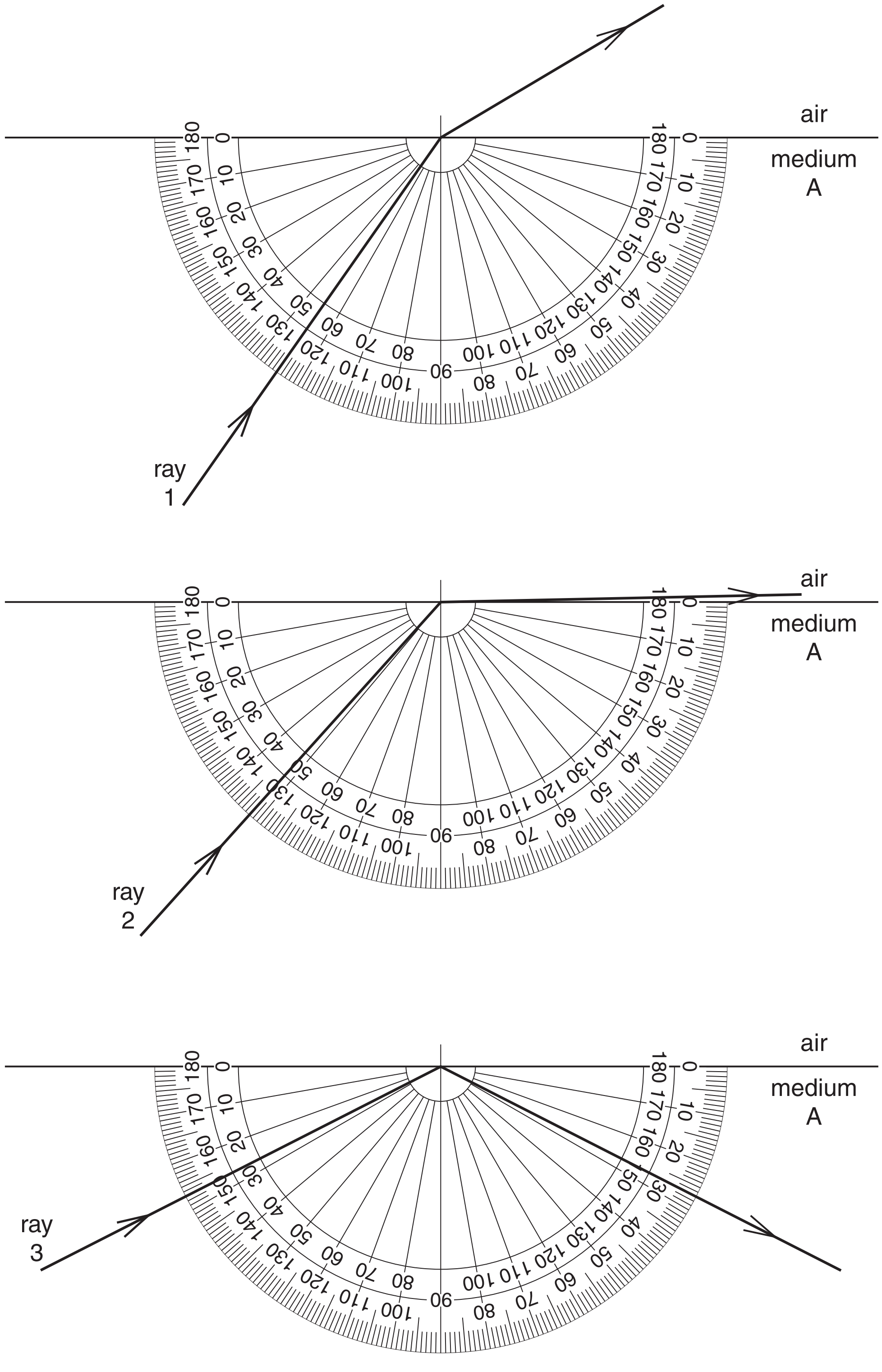


Fig. 8.1

(a) State which is the optically denser medium, A or air, and how you can tell this.

....

.... [1]

(b) State in which medium the light travels the faster, and how you know this.

....

.... [1]

(c) State the critical angle of medium A.

....[1]

(d) State the full name for what is happening to ray 3.

....[1]

(e) The refractive index of medium A is 1.49.

Calculate the value of the angle of refraction of ray 1, showing all your working.

angle of refraction = ... [2]

(f) The speed of light in air is 3.0×10^8 m/s.

Calculate the speed of light in medium A, showing all your working.

speed of light = ... [2]

[Total: 8]

4 Fig. 6.1 shows part of the path of a ray of light PQ travelling in an optical fibre.

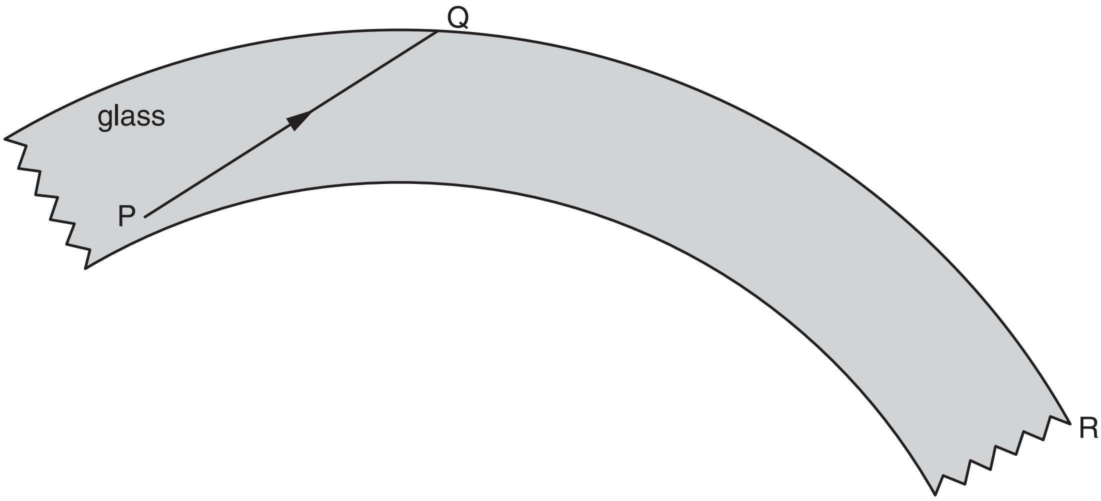


Fig. 6.1

PQ undergoes total internal reflection at Q.

(a) Explain what is meant by *total internal reflection*, and state the conditions under which it occurs.

....

....

....

....

.... [3]

(b) Carefully complete the path of the ray of light, until it reaches the end R of the optical fibre. [2]

[Total: 5]

5 **(a)** Fig. 8.1 shows a section of an optical fibre. It consists of a fibre of denser transparent material, coated with a layer of a less dense transparent material.

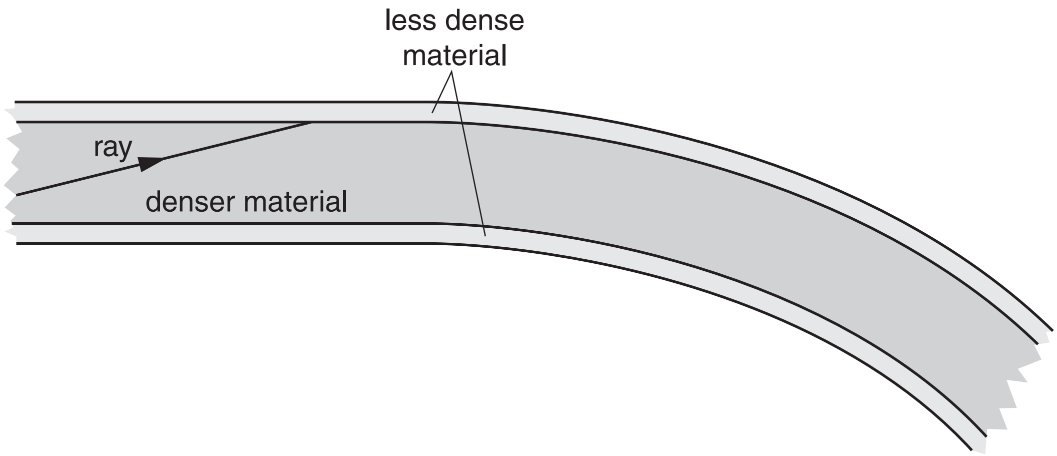


Fig. 8.1

One ray within the fibre has been started for you on Fig. 8.1.

(i) State and explain what happens to the ray already drawn, after it reaches the boundary between the materials.

....

....

....[2]

(ii) On Fig. 8.1, carefully continue the ray until it reaches the end of the section of optical fibre. [1]

(b) Fibre-optic cables are sometimes used to carry out internal examinations on the human stomach.

(i) Suggest one reason why the cable is made of thousands of very thin optical fibres.

....

....

....[1]

(ii) Describe briefly how the inside of the stomach is illuminated.

....

....

....[1]

(iii) Describe briefly how the light from the stomach is transferred to the detecting equipment outside the body.

....

....

....[1]

[Total: 6]

6 Figs. 4.1 and 4.2 show a semi-circular glass block as rays of blue light are directed into the block at different angles. The rays are directed towards the centre C of the semi-circle so that no refraction occurs as the rays enter the block.

(a) At the angle shown in Fig. 4.1, no refracted ray emerges from the block at C.

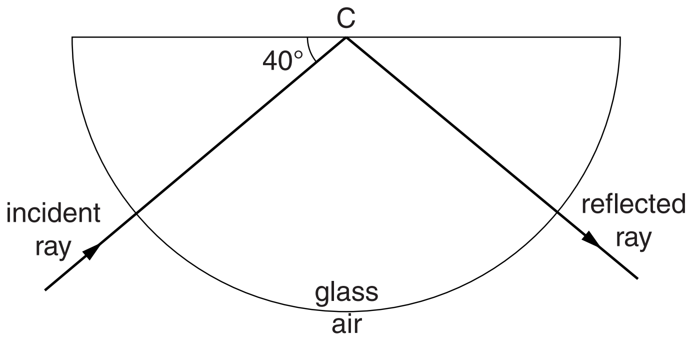


Fig. 4.1

(i) Determine the angle of reflection at C.

angle of reflection = ...

(ii) State the type of reflection occurring at C.

.... [2]

(b)

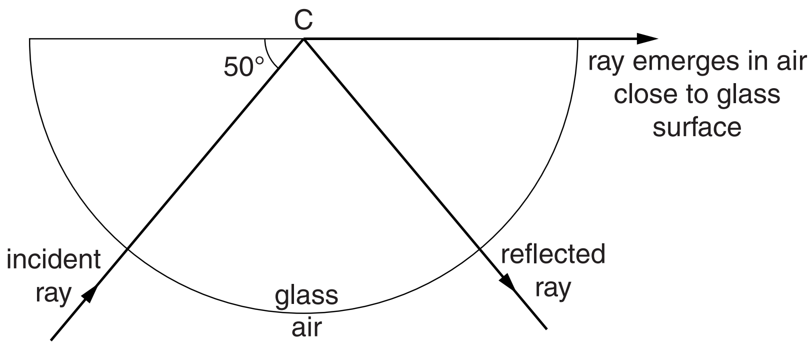


Fig. 4.2

Calculate the refractive index of the glass.

refractive index = ... [3]

(c) The experiment in **(b)** is now repeated with red light.

On Fig. 4.3, draw and label the paths of the reflected and refracted rays of red light. The dashed lines show the paths taken by the blue light in **(b)**.

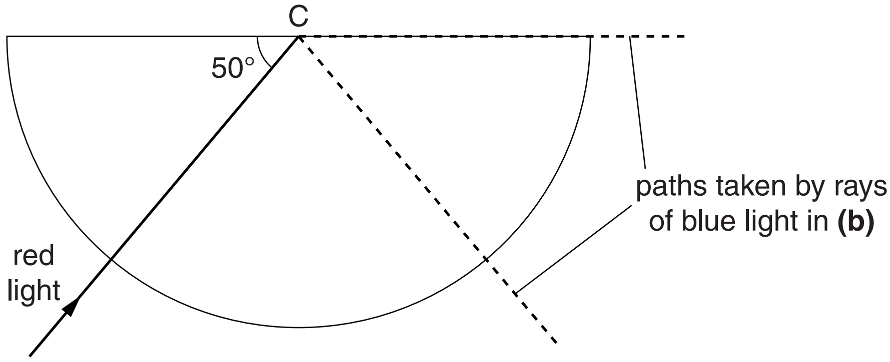


Fig. 4.3 [2]

(d) Fig. 4.4 shows a 45° – 45° – 90° prism used in an optical instrument. Part of the path of a ray of light passing through the instrument is also shown. Light leaves the instrument along path B.

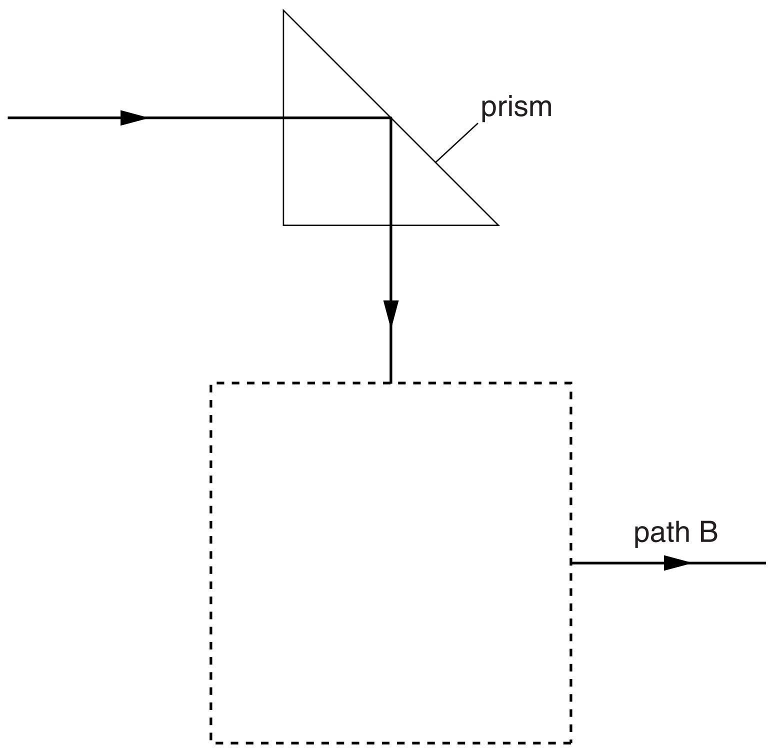


Fig. 4.4

In the dashed box, draw another 45° – 45° – 90° prism and complete the path of the light through this box. [2]

[Total: 9]

13.4 Lenses

1 Fig. 7.1 is drawn to full scale. The focal length of the lens is 5.0 cm.

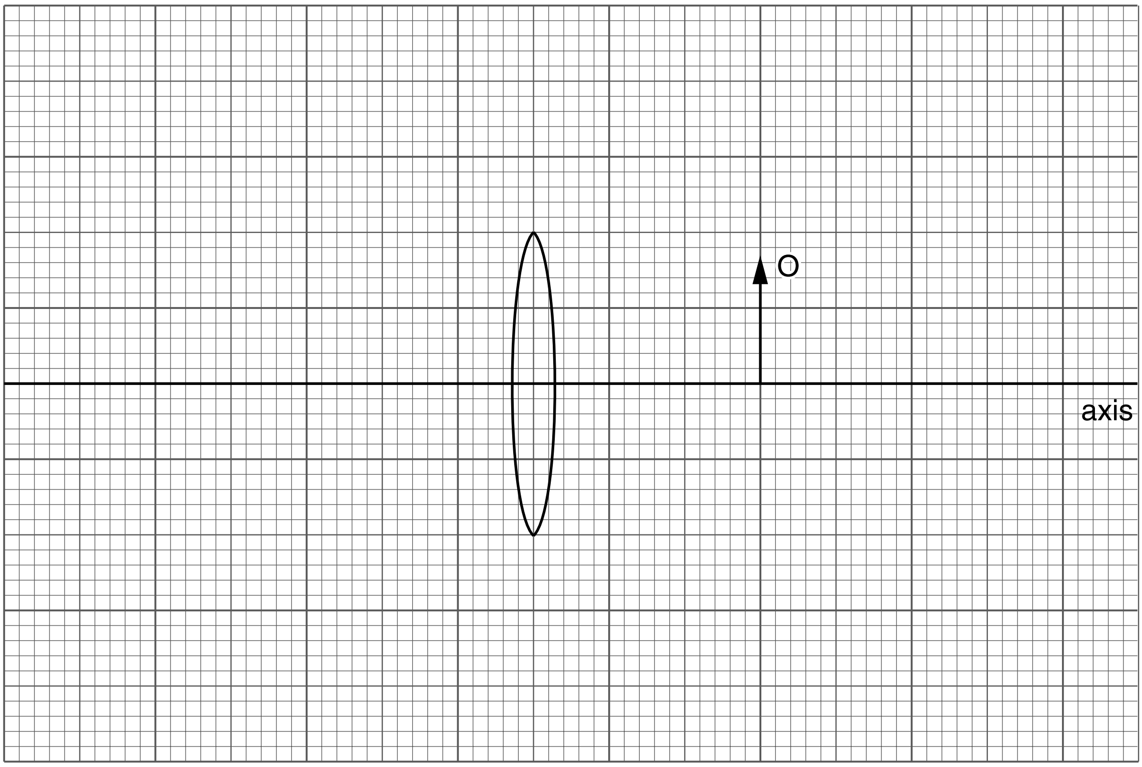


Fig. 7.1

(a) On Fig. 7.1, mark each principal focus of the lens with a dot and the letter F. [2]

(b) On Fig. 7.1, draw **two** rays from the tip of the object O that appear to pass through the tip of the image. [2]

(c) On Fig. 7.1, draw the image and label it with the letter I. [1]

(d) Explain why the base of the image lies on the axis.

....

.... [1]

(e) State a practical use of a convex lens when used as shown in Fig. 7.1.

.... [1]

2 **(a)** Fig. 7.1 shows two rays of light from a point O on an object. These rays are incident on a plane mirror.

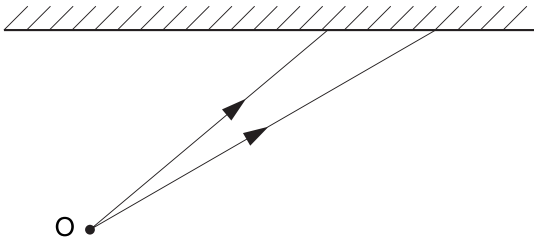


Fig. 7.1

(i) On Fig. 7.1, continue the paths of the two rays after they reach the mirror. Hence locate the image of the object O. Label the image I. [2]

(ii) Describe the nature of the image I.

....

.... [2]

(b) Fig. 7.2 is drawn to scale. It shows an object PQ and a convex lens.

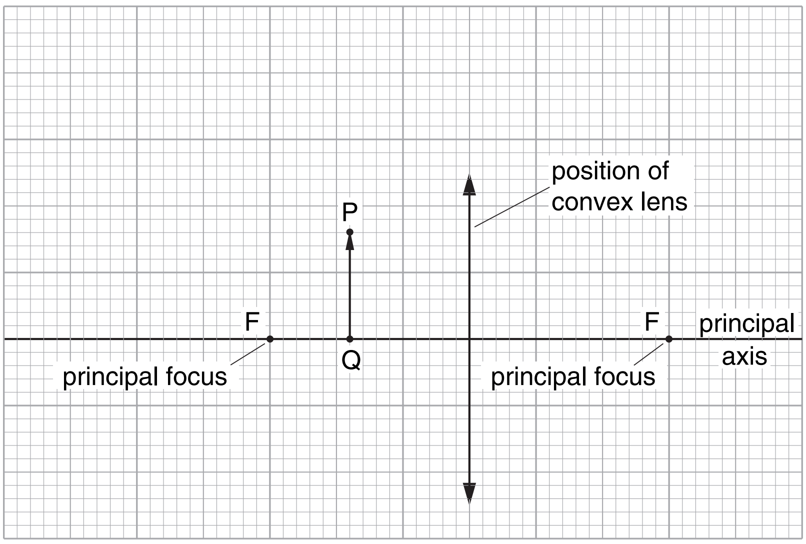


Fig. 7.2

(i) On Fig. 7.2, draw two rays from the top of the object P that pass through the lens. Use these rays to locate the top of the image. Label this point T. [3]

(ii) On Fig. 7.2, draw an eye symbol to show the position from which the image T should be viewed. [1]

3 Virtual images may be formed by both plane mirrors and by convex lenses.

Fig. 6.1 shows a plane mirror and a convex lens.

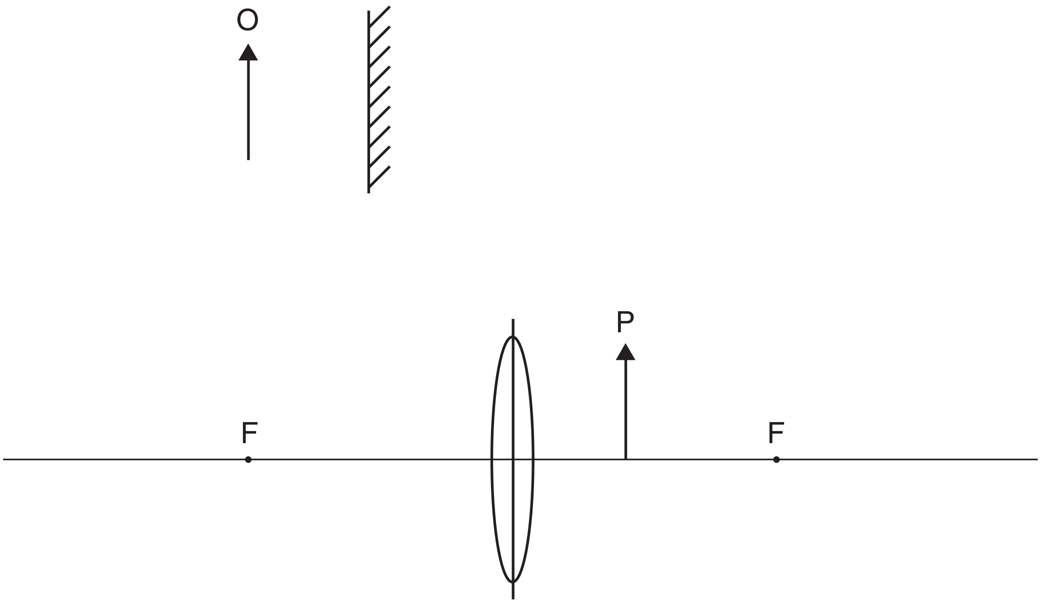


Fig. 6.1

(a) On Fig. 6.1, draw rays to locate the approximate positions of the images of the tops of the two arrow objects O and P.
Label the images. [5]

(b) Both images are virtual.

(i) What is meant by a *virtual image*?

.... [1]

(ii) State **one** other similarity between the two images.

.... [1]

(iii) State **one** difference between the two images.

.... [1]

[Total: 8]

4 Fig. 6.1 shows an object, the tip of which is labelled O, placed near a lens L.

The two principal foci of the lens are F_1 and F_2.

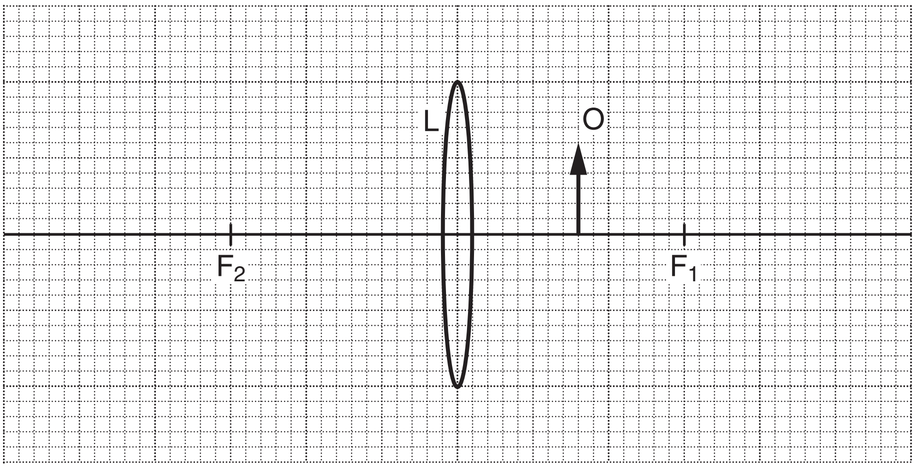


Fig. 6.1

(a) On Fig. 6.1, draw the paths of two rays from the tip of the object so that they pass through the lens and continue beyond.

Complete the diagram to locate the image of the tip of the object. Draw in the whole image and label it I. [3]

(b) Describe image I.

....

....

....

.... [3]

[Total: 6]

5 Fig. 6.1 shows an object, the tip of which is labelled O, placed near a lens L.

The two principal foci of the lens are F_1 and F_2.

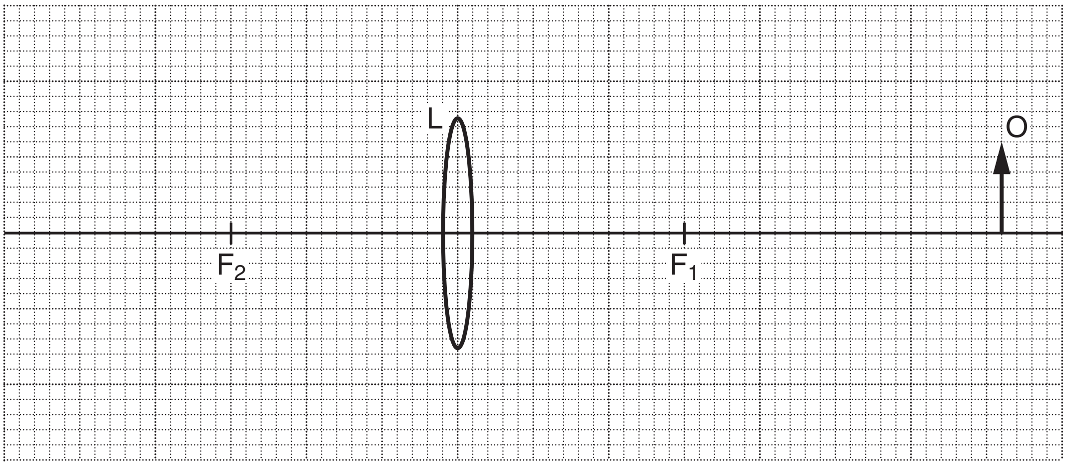


Fig. 6.1

(a) On Fig. 6.1, draw the paths of two rays from the tip of the object so that they pass through the lens and continue beyond.

Complete the diagram to locate the image of the tip of the object. Draw in the whole image and label it I. [2]

(b) State two changes to the image when the object is moved

(i) a small distance closer to the lens,

1. ....

2. .... [2]

(ii) to a position between F_1 and the lens.

1. ....

2. .... [2]

[Total: 6]

6 Fig. 8.1 shows a thin converging lens. The two principal foci are shown.

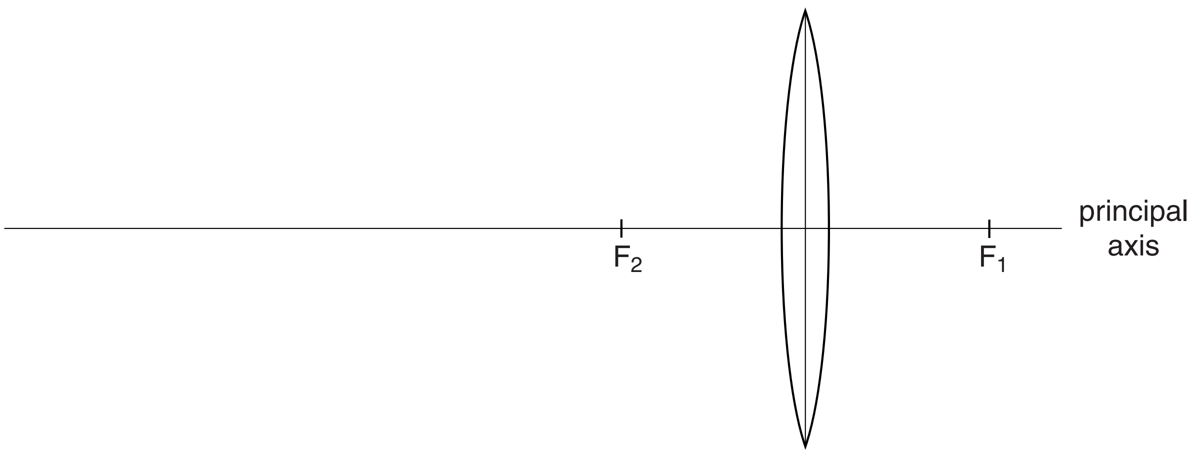


Fig. 8.1

A vertical object, 2 cm tall, is to be positioned to the left of the lens, with one end on the principal axis.

On Fig. 8.1,

(a) draw the object in a position which will produce a virtual image, labelling the object with the letter O, [1]

(b) draw two rays showing how the virtual image is formed, [2]

(c) draw in the image, labelling it with the letter I. [1]

[Total: 4]

7 Fig. 9.1 shows three rays of light, parallel to the axis of a thin converging lens.

The rays strike the first surface of the lens. F_1 and F_2 are the two principal foci of the lens.

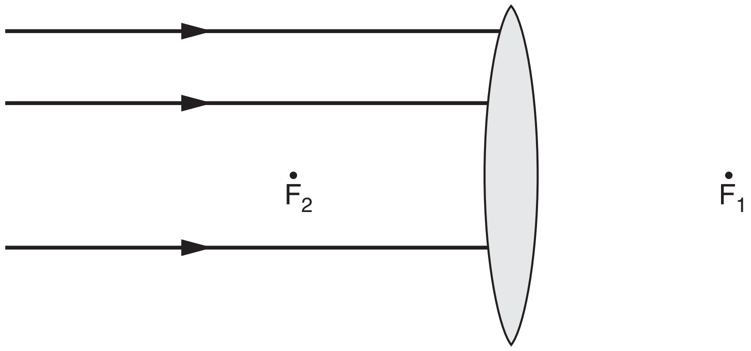


Fig. 9.1

(a) Describe and explain what happens to the top ray as it enters the lens.

....

....

....

....

....

.... [3]

(b) On Fig. 9.1, use a ruler to,

(i) complete the three rays through the lens, until they reach about 5 cm to the right of the lens, [2]

(ii) draw a fourth ray, parallel to the others on the left of the lens, which passes through F_2, until it reaches about 5 cm to the right of the lens. [1]

(c) A lens such as that shown in Fig. 9.1 can be used as a magnifying glass.

(i) On Fig. 9.1, show with an X where the object could be positioned for the lens to be used as a magnifying glass. [1]

(ii) State 3 characteristics of the image formed by a magnifying glass.

1. ....

2. ....

3. .... [2]

[Total: 9]

8 **(a)** What is meant by the *focal length* of a converging lens?

....

....[1]

(b) An object is placed in front of a converging lens. A real image is formed, as shown in Fig. 7.1. The converging lens is not shown.

Fig. 7.1

(i) Explain what is meant by a *real image*.

....[1]

(ii) Rays of light from point A on the object form point B on the image.

On Fig. 6.1, draw

1. a ray to find the position of the converging lens, showing the lens as a vertical straight line in this position,

2. a ray to find the position of a principal focus of the lens, marking this position **F**,

3. a third possible ray from A to B. [3]

(iii) The distance between the object and the lens is increased. State any changes which take place in

1. the distance of the image from the lens,

....

2. the size of the image.

....[2]

[Total: 7]

9 A small object is placed 3.0 cm from the centre of a convex lens of focal length 6.0 cm. An enlarged image is observed from the other side of the lens.

(a) On Fig. 7.1, draw a ray diagram to show the formation of this image.

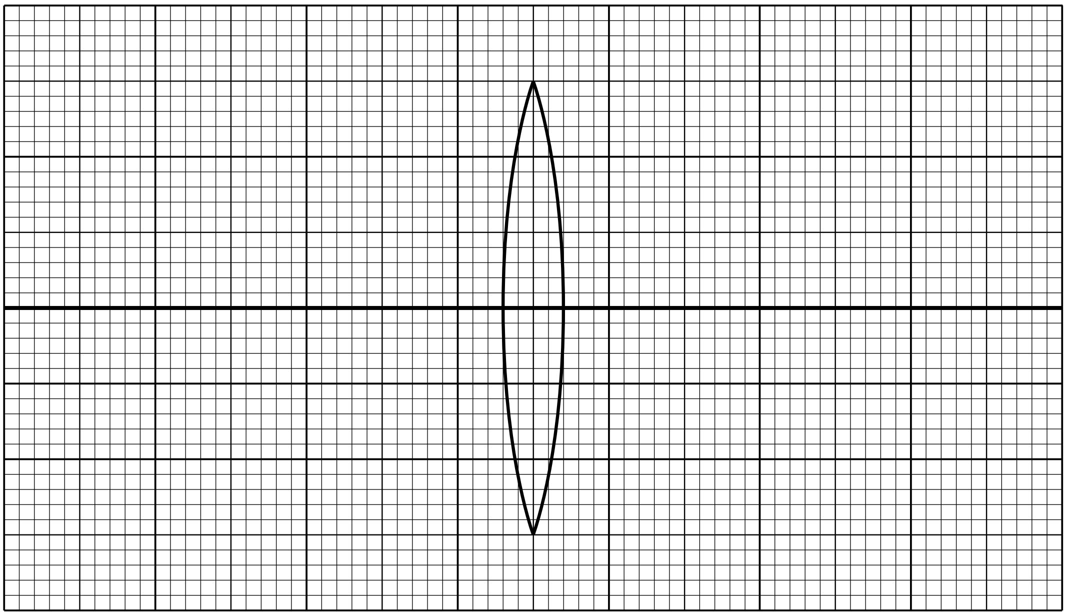


Fig. 7.1

[3]

(b) **(i)** State why this type of image is called *virtual*.

....

.... [1]

(ii) State the common name given to a convex lens used in this manner.

.... [1]

[Total: 5]

10 A converging lens has a focal length of 7.0 cm. An object of height 2.0 cm is placed 3.0 cm from the centre of the lens. Fig. 7.1 is a full-scale grid that shows the arrangement of the object, the lens and the two principal foci (focal points).

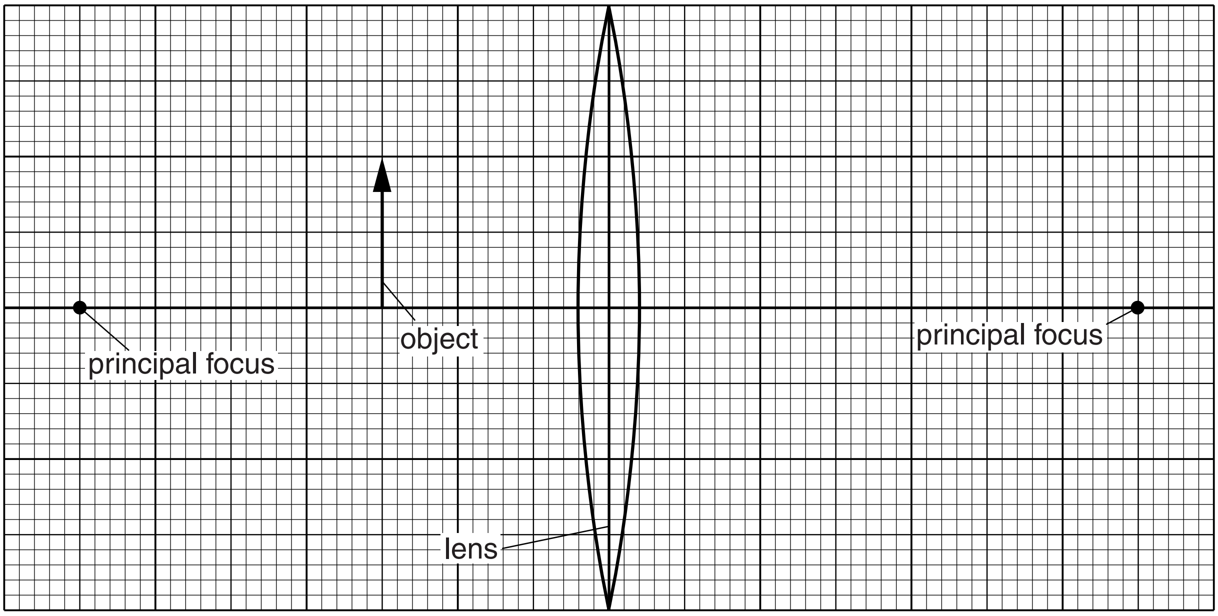


Fig. 7.1

(a) **(i)** By drawing on Fig. 7.1, show how the lens forms an image of the object. [3]

(ii) State **two** features of the image.

1. ....

2. ....
[2]

(b) **(i)** Determine the height of the image.

height = ... [1]

(ii) State the name of one device where a lens is used in the way shown in Fig. 7.1.

.... [1]

[Total: 7]

Chapter 14. Properties of waves

3.1 General properties of waves

Core

1 Know that waves transfer energy without transferring matter

2 Describe what is meant by wave motion as illustrated by vibrations in ropes and springs, and by experiments using water waves

3 Describe the features of a wave in terms of wavefront, wavelength, frequency, crest (peak), trough, amplitude and wave speed

4 Recall and use the equation for wave speed
$v = f\lambda$

5 Know that for a transverse wave, the direction of vibration is at right angles to the direction of propagation and understand that electromagnetic radiation, water waves and seismic S-waves (secondary) can be modelled as transverse

6 Know that for a longitudinal wave, the direction of vibration is parallel to the direction of propagation and understand that sound waves and seismic P-waves (primary) can be modelled as longitudinal

7 Describe how waves can undergo:
(a) reflection at a plane surface
(b) refraction due to a change of speed
(c) diffraction through a narrow gap

8 Describe the use of a ripple tank to show:
(a) reflection at a plane surface
(b) refraction due to a change in speed caused by a change in depth
(c) diffraction due to a gap
(d) diffraction due to an edge

Supplement

9 Describe how wavelength and gap size affects diffraction through a gap

10 Describe how wavelength affects diffraction at an edge

14.1 Wave speed

1 Fig. 7.1 shows the cone of a loudspeaker that is producing sound waves in air.
At any given moment, a series of compressions and rarefactions exist along the line XY.

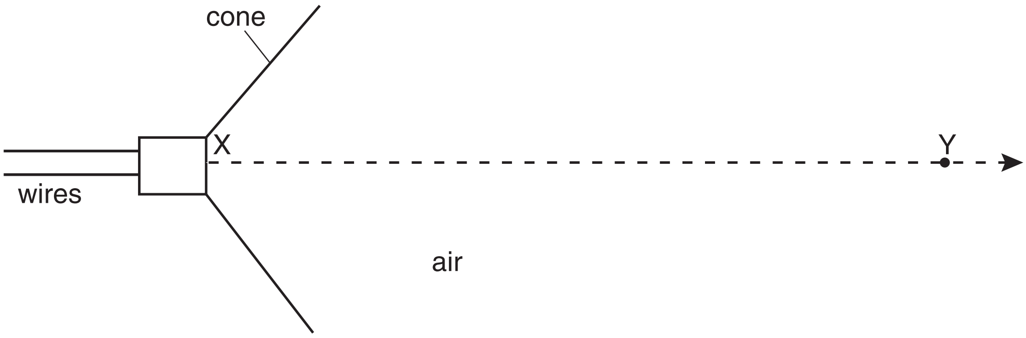


Fig. 7.1

(a) On Fig. 7.1, use the letter C to mark **three** compressions and the letter R to mark **three** rarefactions along XY. [1]

(b) Explain what is meant by

(i) a *compression*,

....

....

(ii) a *rarefaction*.

....

....
[2]

(c) A sound wave is a longitudinal wave. With reference to the sound wave travelling along XY in Fig. 7.1, explain what is meant by a *longitudinal* wave.

....

....[2]

(d) There is a large vertical wall 50 m in front of the loudspeaker. The wall reflects the sound waves.
The speed of sound in air is 340 m/s.
Calculate the time taken for the sound waves to travel from X to the wall and to return to X.

time = …………………[2]

2 Fig. 6.1 shows an optical fibre. XY is a ray of light passing along the fibre.

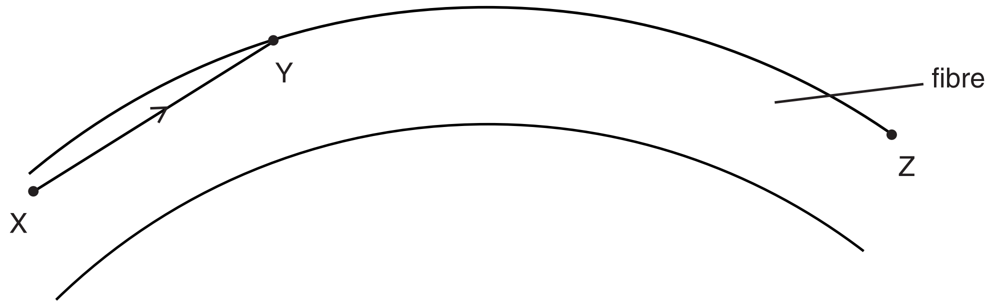


Fig. 6.1

(a) On Fig. 6.1, continue the ray XY until it passes Z. [1]

(b) Explain why the ray does **not** leave the fibre at Y.

....

....

....[2]

(c) The light in the optical fibre has a wavelength of 3.2×10^{-7} m and is travelling at a speed of 1.9×10^{8} m/s.

(i) Calculate the frequency of the light.

frequency = …………………...

(ii) The speed of light in air is 3.0×10^{8} m/s.
Calculate the refractive index of the material from which the fibre is made.

refractive index = …………………...
[4]

3 Fig. 6.1 shows the path of a sound wave from a source X.

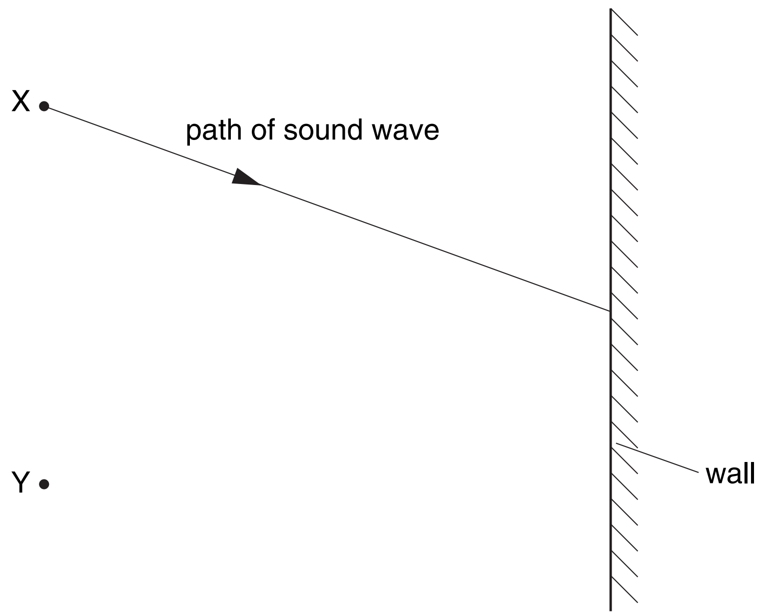


Fig. 6.1

(a) State why a person standing at point Y hears an echo.

.... [1]

(b) The frequency of the sound wave leaving X is 400 Hz. State the frequency of the sound wave reaching Y.

frequency = ……………….. [1]

(c) The speed of the sound wave leaving X is 330 m/s. Calculate the wavelength of these sound waves.

wavelength = ………………………. [2]

(d) Sound waves are longitudinal waves.

State what is meant by the term *longitudinal*.

....

.... [1]

4 Fig. 7.1 shows how the air pressure at one instant varies with distance along the path of a continuous sound wave.

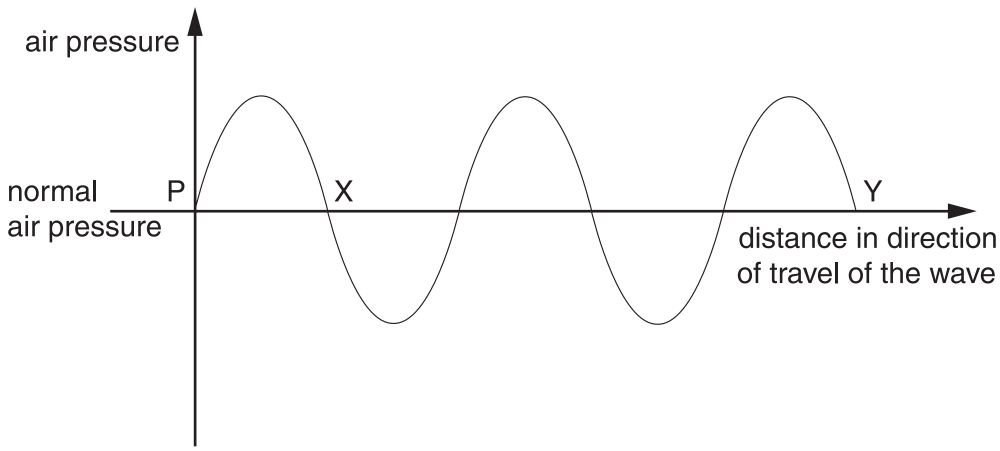


Fig. 7.1

(a) What type of waves are sound waves?

....[1]

(b) On Fig. 7.1, mark on the axis PY

(i) one point C where there is a compression in the wave, [1]

(ii) one point R where there is a rarefaction in the wave. [1]

(c) Describe the motion of a group of air particles situated on the path of the wave shown in Fig. 7.1.

....

....

....[2]

(d) The sound wave shown has speed of 340 m/s and a frequency of 200 Hz.
Calculate the distance represented by PX on Fig. 7.1.

distance = ...[2]

5 **(a)** The speed of light in air is known to be 3.0×10^8 m/s.

Outline how you would use a refraction experiment to deduce the speed of light in glass. You may draw a diagram if it helps to clarify your answer.

....

....

....

....

....

....[4]

(b) A tsunami is a giant water wave. It may be caused by an earthquake below the ocean.

Waves from a certain tsunami have a wavelength of 1.9×10^5 m and a speed of 240 m/s.

(i) Calculate the frequency of the tsunami waves.

frequency = ...[2]

(ii) The shock wave from the earthquake travels at 2.5×10^3 m/s.

The centre of the earthquake is 6.0×10^5 m from the coast of a country.

Calculate how much warning of the arrival of the tsunami at the coast is given by the earth tremor felt at the coast.

warning time = ...[4]

[Total: 10]

6 **(a)** State an approximate value for

(i) the speed of sound in air, ...

(ii) the speed of light in air. .... [2]

(b) Use your value from **(a)(i)** to calculate the frequency of a sound wave that has a wavelength of 1.2 m.

frequency = ... [2]

(c) A meteorologist observes an approaching thunderstorm and records a time difference of 4.8 s between seeing a lightning flash and hearing the thunder that follows.

(i) Calculate the distance of the thunderstorm from the meteorologist.

distance = ...

(ii) State an assumption you made when calculating this distance.

....

....

....
[2]

[Total: 6]

14.2 Explaining wave phenomena

1 Fig. 6.1 shows the diffraction of waves by a narrow gap.

P is a wavefront that has passed through the gap.

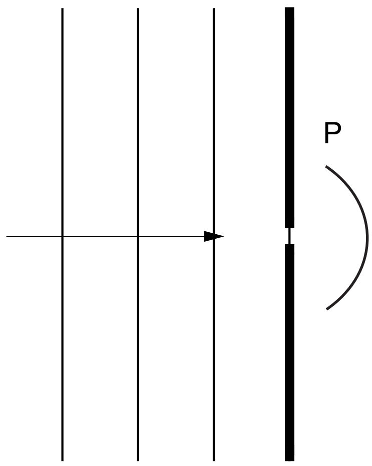


Fig. 6.1

(a) On Fig. 6.1, draw three more wavefronts to the right of the gap. [3]

(b) The waves travel towards the gap at a speed of 3×10^8 m/s and have a frequency of 5×10^{14} Hz. Calculate the wavelength of these waves.

wavelength = ... [3]

2 Fig. 8.1 shows plane waves passing through a gap in a barrier that is approximately equal to the wavelength of the waves.

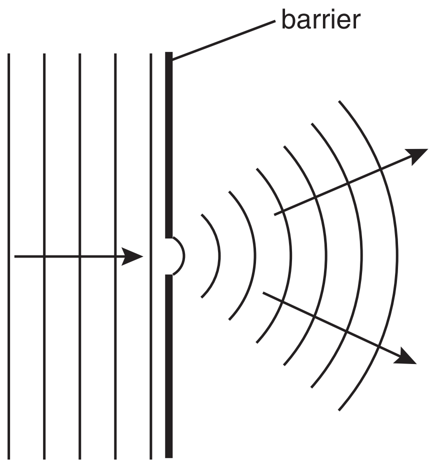


Fig. 8.1

(a) What is the name given to the wave property shown in Fig. 8.1?

....[1]

(b) In the space below, carefully draw the pattern that would be obtained if the gap were increased to six times the wavelength of the waves. [4]

(c) The effect in Fig. 8.1 is often shown using water waves on the surface of a tank of water. These are transverse waves. Explain what is meant by a *transverse* wave.

....

....

....[2]

3 Fig. 7.1 is a drawing of a student's attempt to show the diffraction pattern of water waves that have passed through a narrow gap in a barrier.

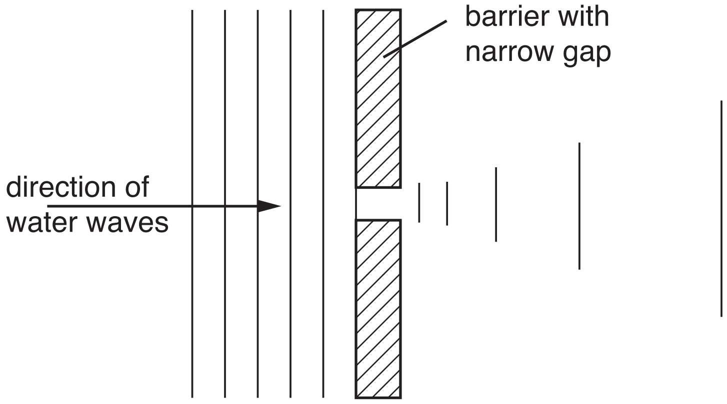


Fig. 7.1

(a) State two things that are wrong with the wave pattern shown to the right of the barrier.

1. ....

2. ....[2]

(b) In the space below, sketch the wave pattern when the gap in the barrier is made five times wider.

[2]

(c) The waves approaching the barrier have a wavelength of 1.2 cm and a frequency of 8.0 Hz.
Calculate the speed of the water waves.

speed = ...[2]

4 Fig. 7.1 shows a scale drawing of plane waves approaching a gap in a barrier.

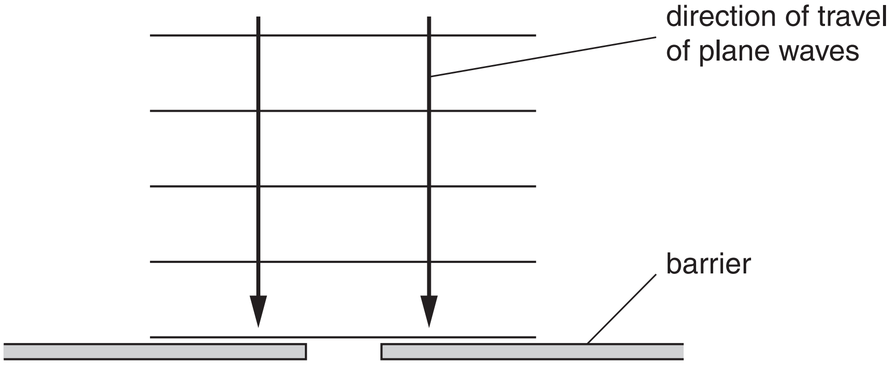


Fig. 7.1

(a) On Fig. 7.1, draw in the pattern of the waves after they have passed the gap. [3]

(b) The waves approaching the barrier have a wavelength of 2.5 cm and a speed of 20 cm/s. Calculate the frequency of the waves.

frequency = ... [2]

(c) State the frequency of the diffracted waves.

.... [1]

[Total: 6]

5 Some plane waves travel on the surface of water in a tank. They pass from a region of deep water into a region of shallow water. Fig. 6.1 shows what the waves look like from above.

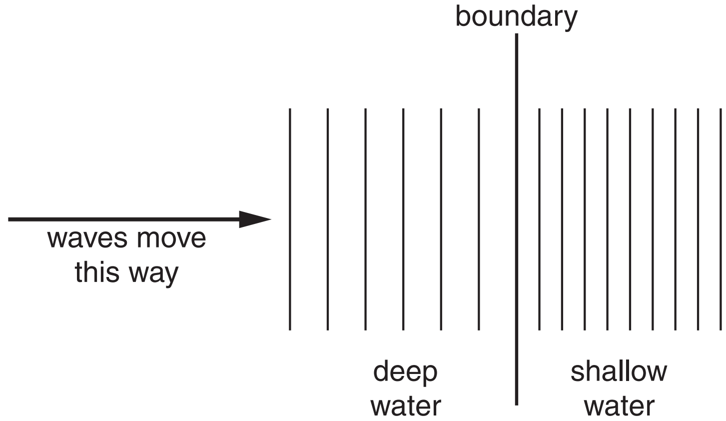


Fig. 6.1

(a) State what happens at the boundary, if anything, to

(i) the frequency of the waves,

.... [1]

(ii) the speed of the waves,

.... [1]

(iii) the wavelength of the waves.

.... [1]

(b) The waves have a speed of 0.12 m/s in the deep water. Wave crests are 0.08 m apart in the deep water.

Calculate the frequency of the source producing the waves. State the equation that you use.

frequency = ... [3]

(c) Fig. 6.2 shows identical waves moving towards the boundary at an angle.

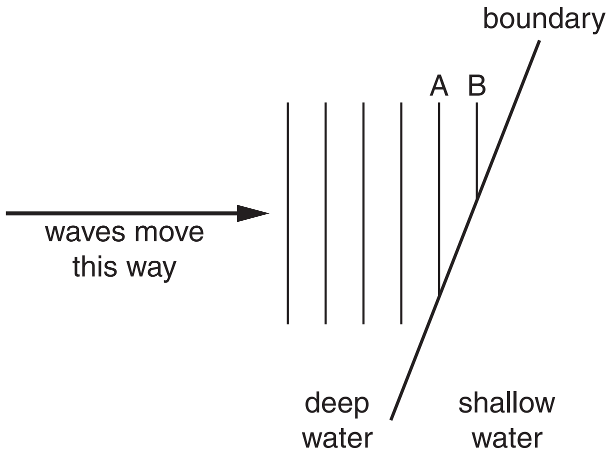


Fig. 6.2

On Fig. 6.2, draw carefully the remainder of waves A and B, plus the two previous waves which reached the shallow water. You will need to use your ruler to do this. [3]

[Total: 9]

6 **(a)** A small object S is dipped repeatedly into water near a flat reflecting surface.

Fig. 10.1 gives an instantaneous view from above of the position of part of the waves produced.

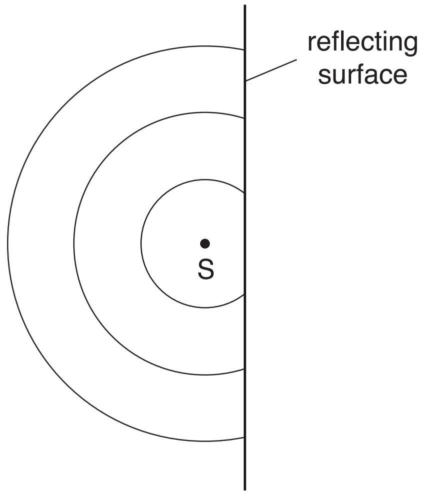


Fig. 10.1

On Fig. 10.1,

(i) put a clear dot at the point from which the reflected waves appear to come (label the dot R),

(ii) draw the reflected portion of each of the three waves shown. [3]

(b) Fig. 10.2 shows a small object P in front of a plane mirror M.

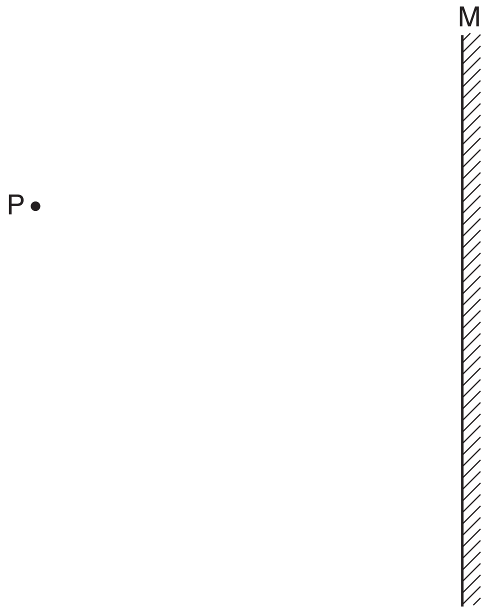


Fig. 10.2

On Fig. 10.2, carefully draw two rays that show how the mirror forms the image of object P. Label the image I. [3]

[Total: 6]

7 **(a)** **(i)** A long rope, fixed at one end, is being used by a student to demonstrate transverse waves.
State what the student does to the rope to produce the transverse wave.

....

....[1]

(ii) Fig. 6.1 shows a section of the rope when the transverse wave is present.

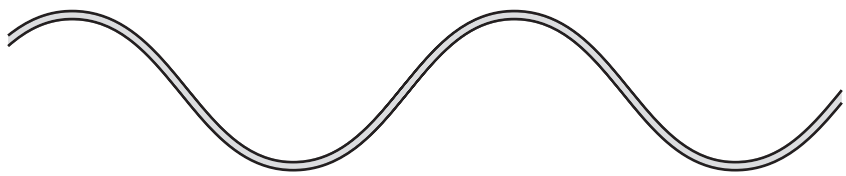


Fig. 6.1

On Fig. 6.1, show

1. a distance, labelled λ, corresponding to the wavelength of the wave,

2. a distance, labelled A, corresponding to the amplitude of the wave. [2]

(iii) Suggest what the student could do to reduce the wavelength of the wave.

....

....[1]

(b) The diagram in Fig. 6.2 represents waves on the surface of water in a ripple tank. The waves are travelling from deep water across a boundary into shallow water.

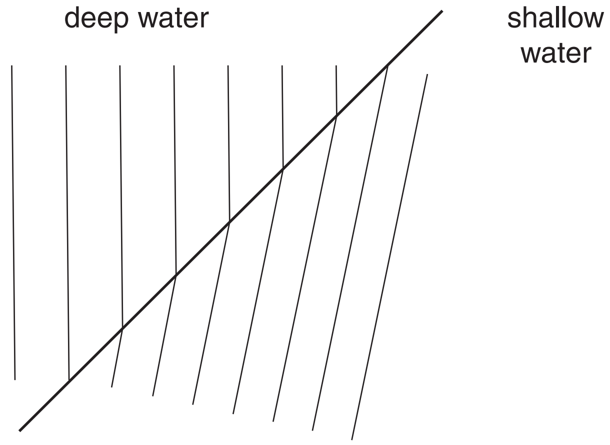


Fig. 6.2

Explain how the diagram shows that water waves travel more slowly in shallow water than in deep water.

....

....

....

.... [3]

[Total: 7]

8 **(a)** A wave passes along the surface of the water in a ripple tank. Describe the motion of a molecule on the surface as the wave passes.

....

.... [1]

(b) Fig. 7.1 shows a view from above of water waves approaching a narrow gap in a barrier. The water on both sides of the barrier has the same depth.

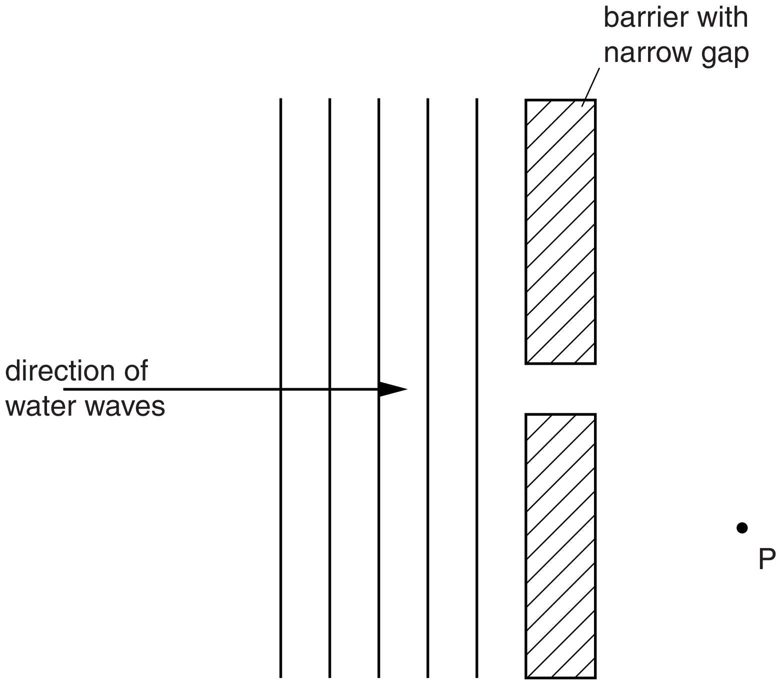


Fig. 7.1

(i) On Fig. 7.1, sketch the pattern of waves in the region to the right of the barrier. [2]

(ii) State the process by which waves arrive at point P to the right of the barrier.

....[1]

(c) The waves approaching the barrier in Fig. 7.1 have a wavelength of 1.4 cm and travel at a speed of 12 cm/s.

Calculate the frequency of the waves.

frequency = ... [2]

[Total: 6]

9 Fig. 5.1 shows a view from above of waves on the surface of water in a water tank.

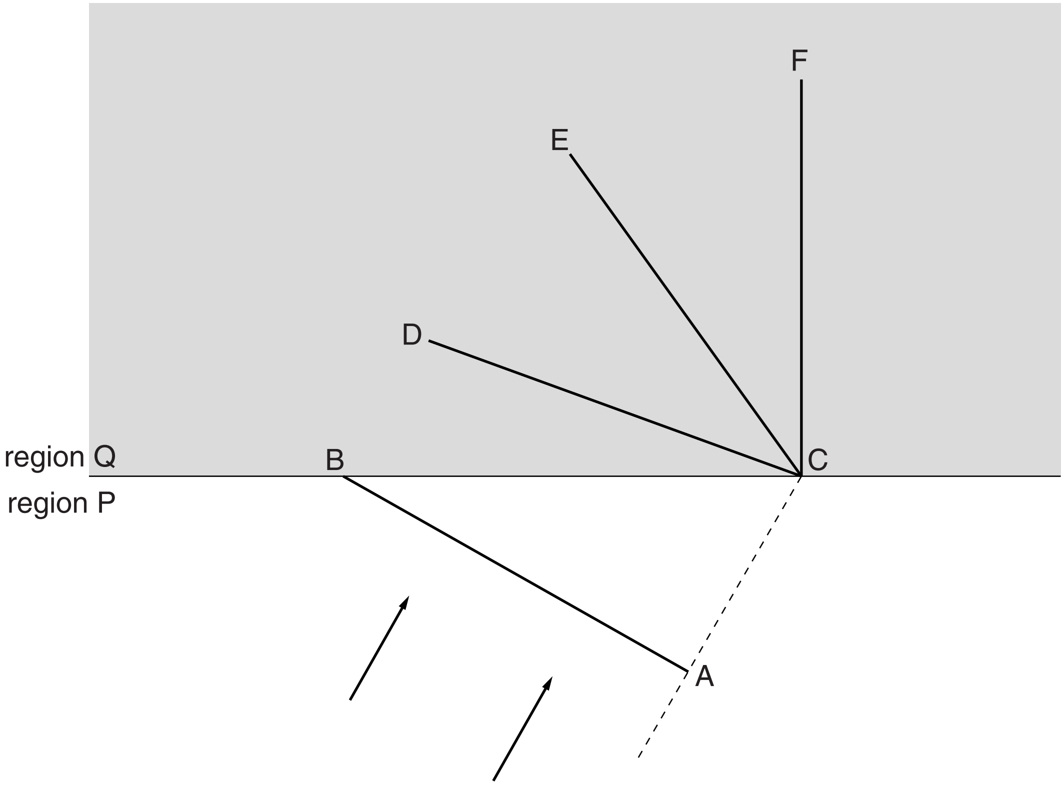


Fig. 5.1

The wavefront AB is travelling in region P towards region Q, where the water is shallower and the waves travel more slowly.

(a) Some time later, the wavefront has moved into region Q.

CD, CE and CF are suggested positions of the new wavefront.

(i) State which is the correct position of the new wavefront.

....

(ii) Explain your answer to **(i)**.

....

....

....

....
[4]

(b) Fig. 5.2 shows the waves after a change is made to the way the tank is set up, and the experiment is repeated.

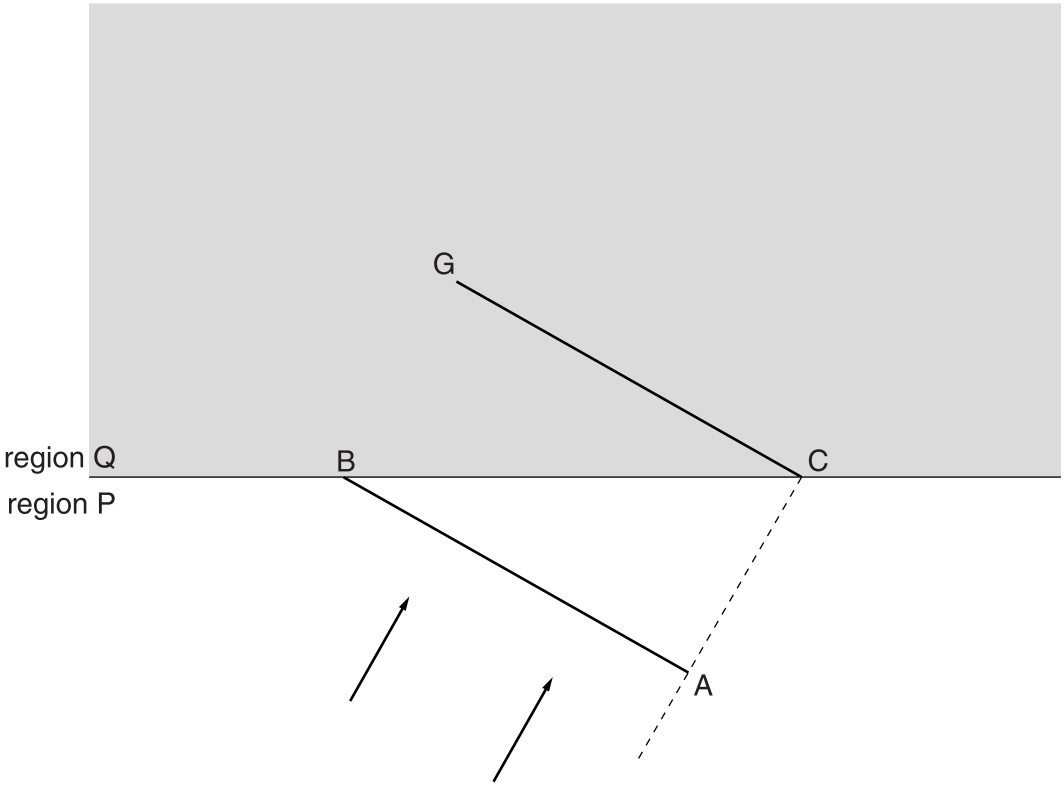


Fig. 5.2

The wave from position AB in region P now moves to position CG in region Q.

State the change that has been made and explain your reasoning.

change ....

explanation ....

....

.... [2]

[Total: 6]

Chapter 15. Spectra

3.3 Electromagnetic spectrum

Core

1 Know the main regions of the electromagnetic spectrum in order of frequency and in order of wavelength

2 Know that all electromagnetic waves travel at the same high speed in a vacuum

3 Describe typical uses of the different regions of the electromagnetic spectrum including:

(a) radio waves; radio and television transmissions, astronomy, radio frequency identification (RFID)

(b) microwaves; satellite television, mobile phones (cell phones), microwave ovens

(c) infrared; electric grills, short range communications such as remote controllers for televisions, intruder alarms, thermal imaging, optical fibres

(d) visible light; vision, photography, illumination

(e) ultraviolet; security marking, detecting fake bank notes, sterilising water

(f) X-rays; medical scanning, security scanners

(g) gamma rays; sterilising food and medical equipment, detection of cancer and its treatment

4 Describe the harmful effects on people of excessive exposure to electromagnetic radiation, including:

(a) microwaves; internal heating of body cells

(b) infrared; skin burns

(c) ultraviolet; damage to surface cells and eyes, leading to skin cancer and eye conditions

(d) X-rays and gamma rays; mutation or damage to cells in the body

continued

Supplement

6 Know that the speed of electromagnetic waves in a vacuum is 3.0×10^8 m / s and is approximately the same in air

3.3 Electromagnetic spectrum continued

Core

5 Know that communication with artificial satellites is mainly by microwaves:
   (a) some satellite phones use low orbit artificial satellites
   (b) some satellite phones and direct broadcast satellite television use geostationary satellites

Supplement

7 Know that many important systems of communications rely on electromagnetic radiation including:
   (a) mobile phones (cell phones) and wireless internet use microwaves because microwaves can penetrate some walls and only require a short aerial for transmission and reception
   (b) Bluetooth uses radio waves because radio waves pass through walls but the signal is weakened on doing so
   (c) optical fibres (visible light or infrared) are used for cable television and high-speed broadband because glass is transparent to visible light and some infrared; visible light and short wavelength infrared can carry high rates of data

8 Know the difference between a digital and analogue signal

9 Know that a sound can be transmitted as a digital or analogue signal

10 Explain the benefits of digital signaling including increased rate of transmission of data and increased range due to accurate signal regeneration

15.1 Dispersion of light

1 Observations of a distant thunderstorm are made.

(a) During a lightning flash, the average wavelength of the light emitted is 5×10^{-7} m. This light travels at 3×10^{8} m/s.

Calculate the average frequency of this light.

frequency = ... [2]

(b) The interval between the lightning flash being seen and the thunder being heard is 3.6 s. The speed of sound in air is 340 m/s.

(i) Calculate the distance between the thunderstorm and the observer.

distance = ...

(ii) Explain why the speed of light is not taken into account in this calculation.

....

....
[3]

(c) A single ray of white light from the lightning is incident on a prism as shown in Fig. 6.1.

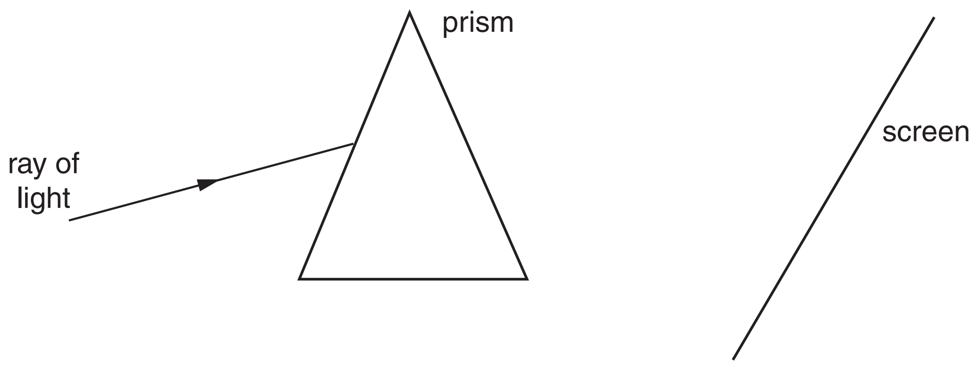


Fig. 6.1

Complete the path of the ray to show how a spectrum is formed on the screen. Label the colours. [2]

2 Fig. 6.1 shows white light incident at P on a glass prism. Only the refracted red ray PQ is shown in the prism.

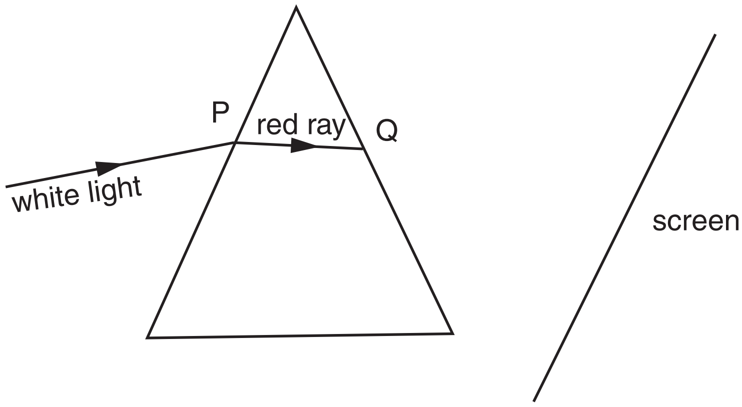


Fig. 6.1

(a) On Fig. 6.1, draw rays to complete the path of the red ray and the whole path of the violet ray up to the point where they hit the screen. Label the violet ray. [3]

(b) The angle of incidence of the white light is increased to 40°. The refractive index of the glass for the red light is 1.52.
Calculate the angle of refraction at P for the red light.

angle of refraction = ...[3]

(c) State the approximate speed of

(i) the white light incident at P, speed = ...[1]

(ii) the red light after it leaves the prism at Q. speed = ...[1]

15.2 The electromagnetic spectrum

1 Fig. 7.1 shows the parts of the electromagnetic spectrum.

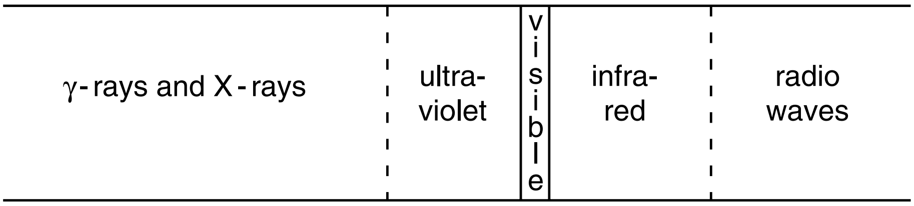


Fig. 7.1

(a) Name one type of radiation that has

(i) a higher frequency than ultra-violet,

.... [1]

(ii) a longer wavelength than visible light.

.... [1]

(b) Some γ-rays emitted from a radioactive source have a speed in air of 3.0×10^8 m/s and a wavelength of 1.0×10^{-12} m.

Calculate the frequency of the γ-rays.

frequency = ... [2]

(c) State the approximate speed of infra-red waves in air.

.... [1]

2 **(a)** In the space below, draw a diagram to represent a sound wave.

On your diagram, mark and label

(i) **two** consecutive compressions and **two** consecutive rarefactions,

(ii) the wavelength of the wave.

[3]

(b) Fig. 7.1 shows part of the electromagnetic spectrum.

Fig. 7.1

(i) On Fig. 7.1, label the positions of γ-rays, visible light waves and radio waves. [1]

(ii) State which of the three types of wave in **(i)** has the lowest frequency.

.... [1]

(iii) State the approximate value of the speed in air of radio waves.

.... [1]

[Total: 6]

3 **(a)** The following list contains the names of types of energy transfer by means of waves.

γ-rays, infra-red, radio/TV/microwaves, sound, visible light, X-rays

(i) Which one of these is **not** a type of electromagnetic wave?

.... [1]

(ii) State the nature of the wave you have named in **(a)(i)**.

.... [1]

(iii) The remaining names in the list are all regions of the electromagnetic spectrum, but one region is missing.

Name the missing region.

.... [1]

(b) A television station emits waves with a frequency of 2.5×10^8 Hz. Electromagnetic waves travel at a speed of 3.0×10^8 m/s.

Calculate the wavelength of the waves emitted by this television station. State the equation you use.

wavelength = ... [3]

[Total: 6]