Contents

For Examiner's Use

2 Make estimates of the following quantities.

(a) the speed of sound in air

speed = ... [1]

(b) the density of air at room temperature and pressure

density = ... [1]

(c) the mass of a protractor

mass = ... [1]

(d) the volume, in cm^3, of the head of an adult person

volume = ... cm^3 [1]

3 **(a)** Derive the SI base unit of force.

SI base unit of force = ... [1]

(b) A spherical ball of radius r experiences a resistive force F due to the air as it moves through the air at speed v. The resistive force F is given by the expression

$$F = crv,$$

where c is a constant.

Derive the SI base unit of the constant c.

SI base unit of c = ... [1]

(c) The ball is dropped from rest through a height of 4.5 m.

(i) Assuming air resistance to be negligible, calculate the final speed of the ball.

speed = ... $m\,s^{-1}$ [2]

(ii) The ball has mass 15 g and radius 1.2 cm.

The numerical value of the constant *c* in the equation in **(b)** is equal to 3.2×10^{-4} when measured using the SI system of units.

Show quantitatively whether the assumption made in **(i)** is justified.

[3]

4 The uncalibrated scale and the pointer of a meter are shown in Fig. 1.1.

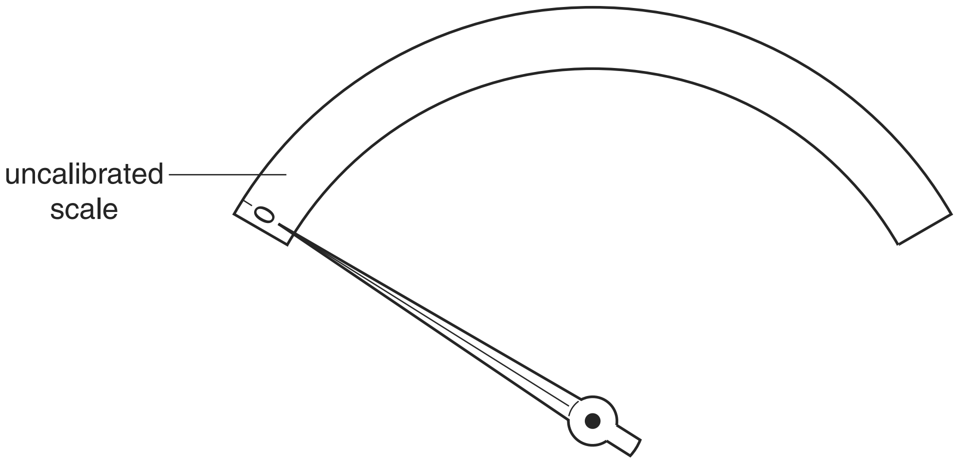


Fig. 1.1

The pointer is shown in the zero position.
The meter is to be used to indicate the volume of fuel in the tank of a car.
A known volume V of fuel is poured into the tank and the deflection θ of the pointer is noted.
Fig. 1.2 shows the variation with θ of V.

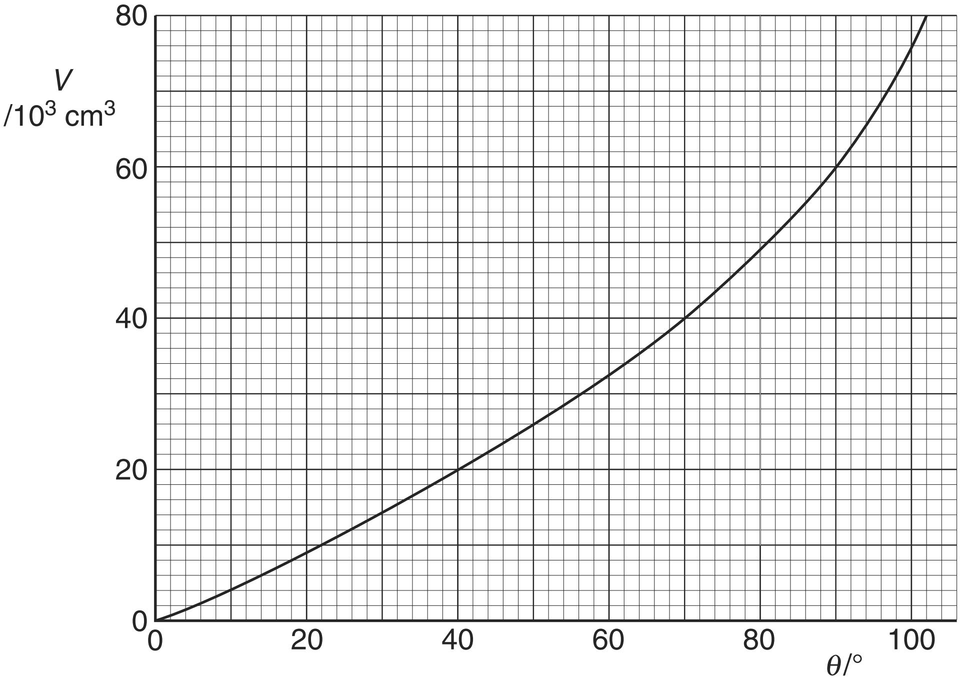


Fig. 1.2

For Examiner's Use

(a) On Fig. 1.1,

(i) calibrate the scale at 20×10^3 cm^3 intervals, [2]

(ii) mark a possible position for a volume of 1.0×10^5 cm^3. [1]

(b) Suggest one advantage of this scale, as compared with a uniform scale, for measuring fuel volumes in the tank of the car.

....

....[1]

For Examiner's Use

5 Make reasonable estimates of the following quantities.

(a) the frequency of an audible sound wave

frequency = ... Hz [1]

(b) the wavelength, in nm, of ultraviolet radiation

wavelength = ... nm [1]

(c) the mass of a plastic 30 cm ruler

mass = ... g [1]

(d) the density of air at atmospheric pressure

density = ... kg m^{-3} [1]

For Examiner's Use

6 **(a)** State the most appropriate instrument, or instruments, for the measurement of the following.

(i) the diameter of a wire of diameter about 1 mm

.... [1]

(ii) the resistance of a filament lamp

.... [1]

(iii) the peak value of an alternating voltage

.... [1]

(b) The mass of a cube of aluminium is found to be 580 g with an uncertainty in the measurement of 10 g. Each side of the cube has a length of (6.0 ± 0.1) cm.

Calculate the density of aluminium with its uncertainty. Express your answer to an appropriate number of significant figures.

density = ... ± .... $g\,cm^{-3}$ [5]

7 A student determines the acceleration of free fall using the apparatus illustrated in Fig. 2.1.

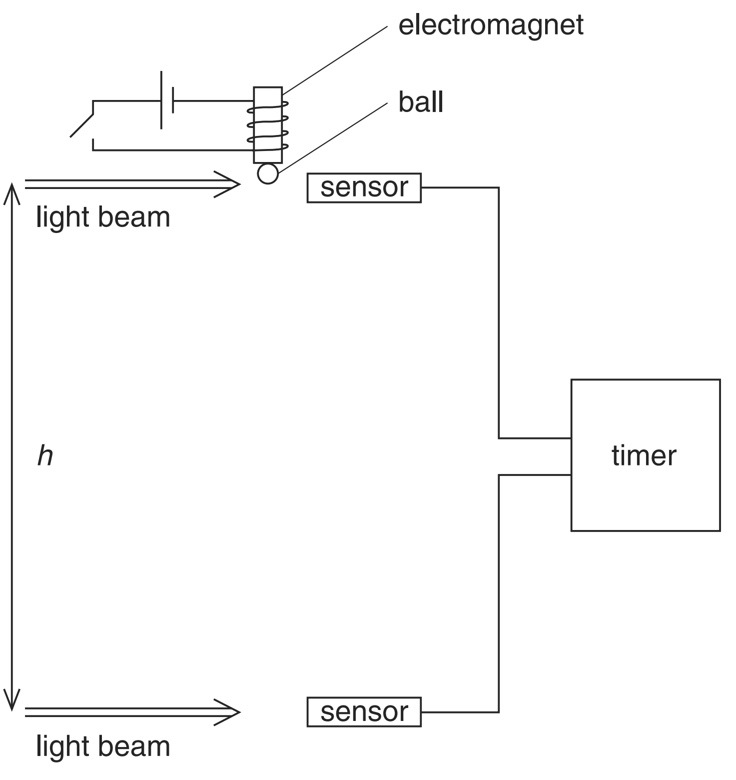


Fig. 2.1

A steel ball is held on an electromagnet. When the electromagnet is switched off, the ball immediately interrupts a beam of light and a timer is started. As the ball falls, it interrupts a second beam of light and the timer is stopped. The vertical distance h between the light beams and the time t recorded on the timer are noted. The procedure is repeated for different values of h. The student calculates values of t^2 and then plots the graph of Fig. 2.2.

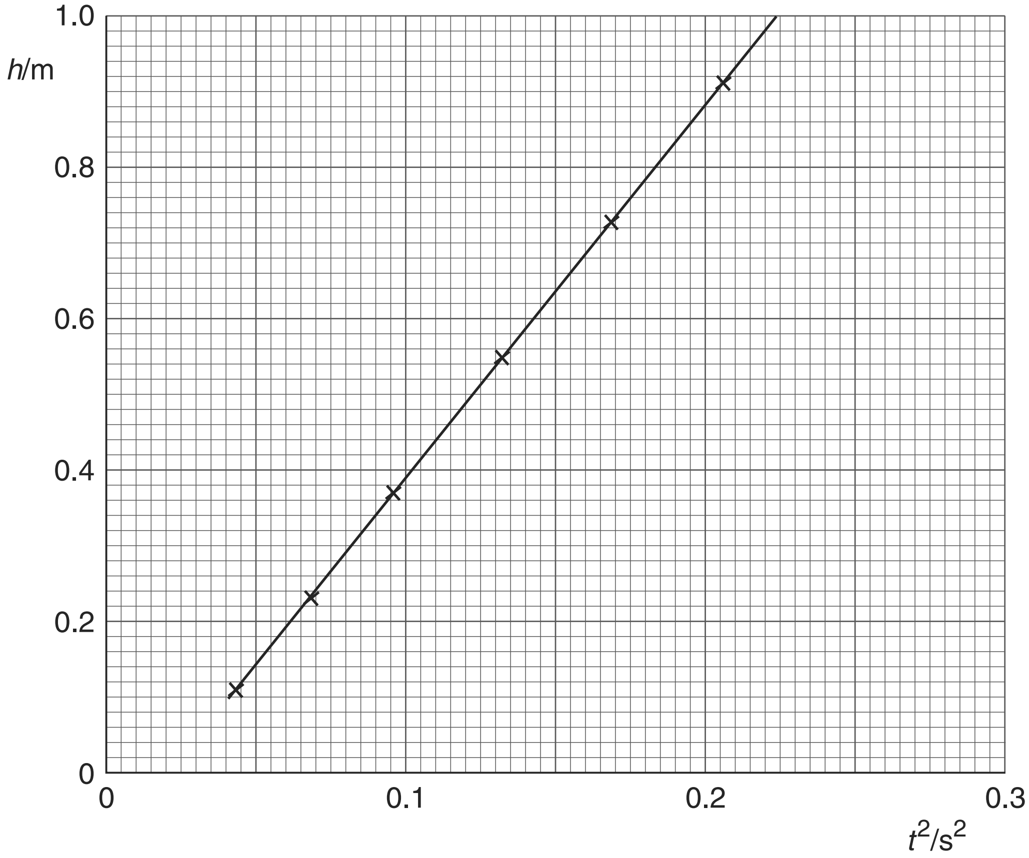


Fig. 2.2

(a) Use Fig. 2.2 to calculate a value for g, the acceleration of free fall of the ball. Explain your working.

g = ... m s^{-2} [4]

(b) Identify one possible source of random error in the determination of g and suggest how this error may be reduced.

....

....

....[2]

8 **(a)** **(i)** Define *density*.

....

....

(ii) State the base units in which density is measured.

.... [2]

(b) The speed v of sound in a gas is given by the expression

$$v = \sqrt{\left(\frac{\gamma p}{\rho}\right)},$$

where p is the pressure of the gas of density ρ. γ is a constant.

Given that p has the base units of $\mathrm{kg\,m^{-1}\,s^{-2}}$, show that the constant γ has no unit. [3]

9 A student uses a metre rule to measure the length of an elastic band before and after stretching it.

The lengths are recorded as

length of band before stretching, $L_0 = 50.0 \pm 0.1$ cm

length of band after stretching, $L_S = 51.6 \pm 0.1$ cm.

Determine

(a) the change in length $(L_S - L_0)$, quoting your answer with its uncertainty,

$(L_S - L_0)$ = ... cm [1]

(b) the fractional change in length, $\frac{(L_S - L_0)}{L_0}$,

fractional change = ………………………………. [1]

(c) the uncertainty in your answer in **(b)**.

uncertainty = ………………………………… [3]

For Examiner's Use

10 A student takes readings to measure the mean diameter of a wire using a micrometer screw gauge.

(a) Make suggestions, one in each case, that the student may adopt in order to

(i) reduce a systematic error in the readings,

....

....

(ii) allow for a wire of varying diameter along its length,

....

....

(iii) allow for a non-circular cross-section of the wire.

....

....
[3]

(b) The mean diameter of the wire is found to be 0.50 ± 0.02 mm. Calculate the percentage uncertainty in

(i) the diameter,

uncertainty = ... %

(ii) the area of cross-section of the wire.

uncertainty = ... %
[2]

For Examiner's Use

11 **(a)** **(i)** Define *pressure*.

....

.... [1]

(ii) State the units of pressure in base units.

.... [1]

(b) The pressure p at a depth h in an incompressible fluid of density ρ is given by

$$p = \rho g h,$$

where g is the acceleration of free fall.
Use base units to check the homogeneity of this equation.

....

....

....

.... [3]

12 **(a)** Distinguish between systematic errors and random errors.

systematic errors ....

....

random errors ....

.... [2]

(b) A cylinder of length *L* has a circular cross-section of radius *R*, as shown in Fig. 1.1.

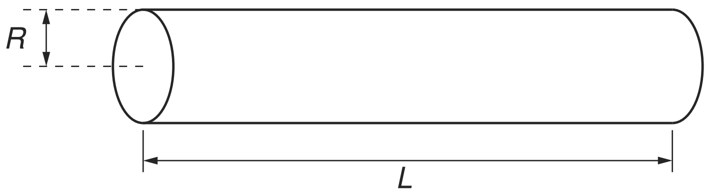


Fig. 1.1

The volume *V* of the cylinder is given by the expression

$$V = \pi R^2 L.$$

The volume and length of the cylinder are measured as

$V = 15.0 \pm 0.5\,\text{cm}^3$
$L = 20.0 \pm 0.1\,\text{cm}.$

Calculate the radius of the cylinder, with its uncertainty.

radius = ... ± .... cm [5]

For Examiner's Use

13 **(a)** The current in a wire is I. Charge Q passes one point in the wire in time t. State

(i) the relation between I, Q and t,

.... [1]

(ii) which of the quantities I, Q and t are base quantities.

....

.... [2]

(b) The current in the wire is due to electrons, each with charge q, that move with speed v along the wire. There are n of these electrons per unit volume.
For a wire having a cross-sectional area S, the current I is given by the equation

$$I = nSqv^k,$$

where k is a constant.

(i) State the units of I, n, S, q and v in terms of the base units.

I ....

n ....

S ....

q ....

v ....
[3]

(ii) By considering the homogeneity of the equation, determine the value of k.

k = ... [2]

For Examiner's Use

14 The volume of fuel in the tank of a car is monitored using a meter as illustrated in Fig. 1.1.

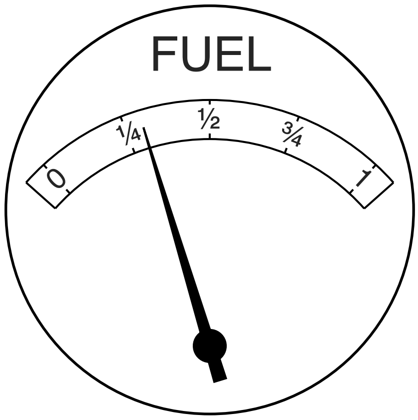


Fig. 1.1

The meter has an analogue scale. The meter reading for different volumes of fuel in the tank is shown in Fig. 1.2.

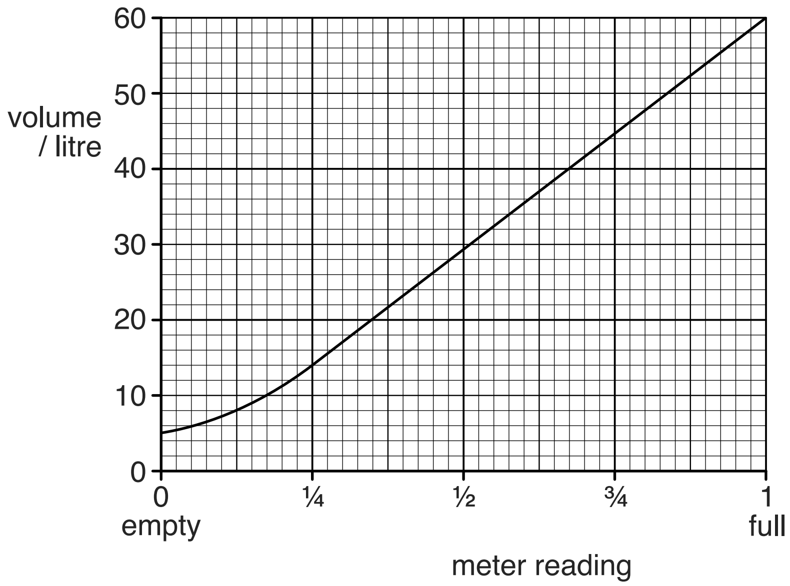


Fig. 1.2

The meter is calibrated in terms of the fraction of the tank that remains filled with fuel.

For Examiner's Use

(a) The car uses 1.0 litre of fuel when travelling 14 km. The car starts a journey with a full tank of fuel.

(i) Calculate the volume of fuel remaining in the tank after a journey of 210 km.

volume = ... litres [2]

(ii) Use your answer to **(i)** and Fig. 1.2 to determine the change in the meter reading during the 210 km journey.

from *full* to .... [1]

(b) There is a systematic error in the meter.

(i) State the feature of Fig. 1.2 that indicates that there is a systematic error.

....

.... [1]

(ii) Suggest why, for this meter, it is an advantage to have this systematic error.

....

.... [1]

For Examiner's Use

15 A simple pendulum may be used to determine a value for the acceleration of free fall g. Measurements are made of the length L of the pendulum and the period T of oscillation.

The values obtained, with their uncertainties, are as shown.

$T = (1.93 \pm 0.03)\,\text{s}$
$L = (92 \pm 1)\,\text{cm}$

(a) Calculate the percentage uncertainty in the measurement of

(i) the period T,

uncertainty = ... % [1]

(ii) the length L.

uncertainty = ... % [1]

For Examiner's Use

(b) The relationship between T, L and g is given by

$$g = \frac{4\pi^2 L}{T^2}.$$

Using your answers in **(a)**, calculate the percentage uncertainty in the value of g.

uncertainty = ... % [1]

(c) The values of L and T are used to calculate a value of g as 9.751 m s^{-2}.

(i) By reference to the measurements of L and T, suggest why it would not be correct to quote the value of g as 9.751 m s^{-2}.

....

.... [1]

(ii) Use your answer in **(b)** to determine the absolute uncertainty in g.

Hence state the value of g, with its uncertainty, to an appropriate number of significant figures.

g = ... ± .... m s^{-2} [2]

16 A student has been asked to determine the linear acceleration of a toy car as it moves down a slope. He sets up the apparatus as shown in Fig. 3.1.

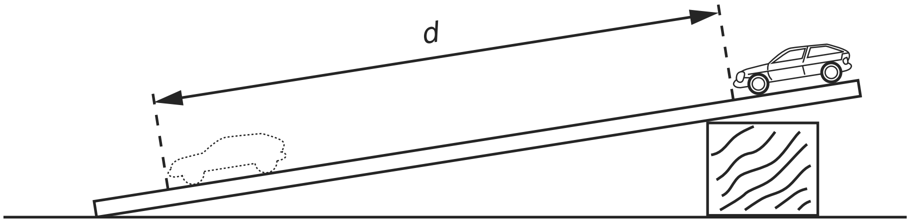


Fig. 3.1

The time *t* to move from rest through a distance *d* is found for different values of *d*. A graph of *d* (*y*-axis) is plotted against t^2 (*x*-axis) as shown in Fig. 3.2.

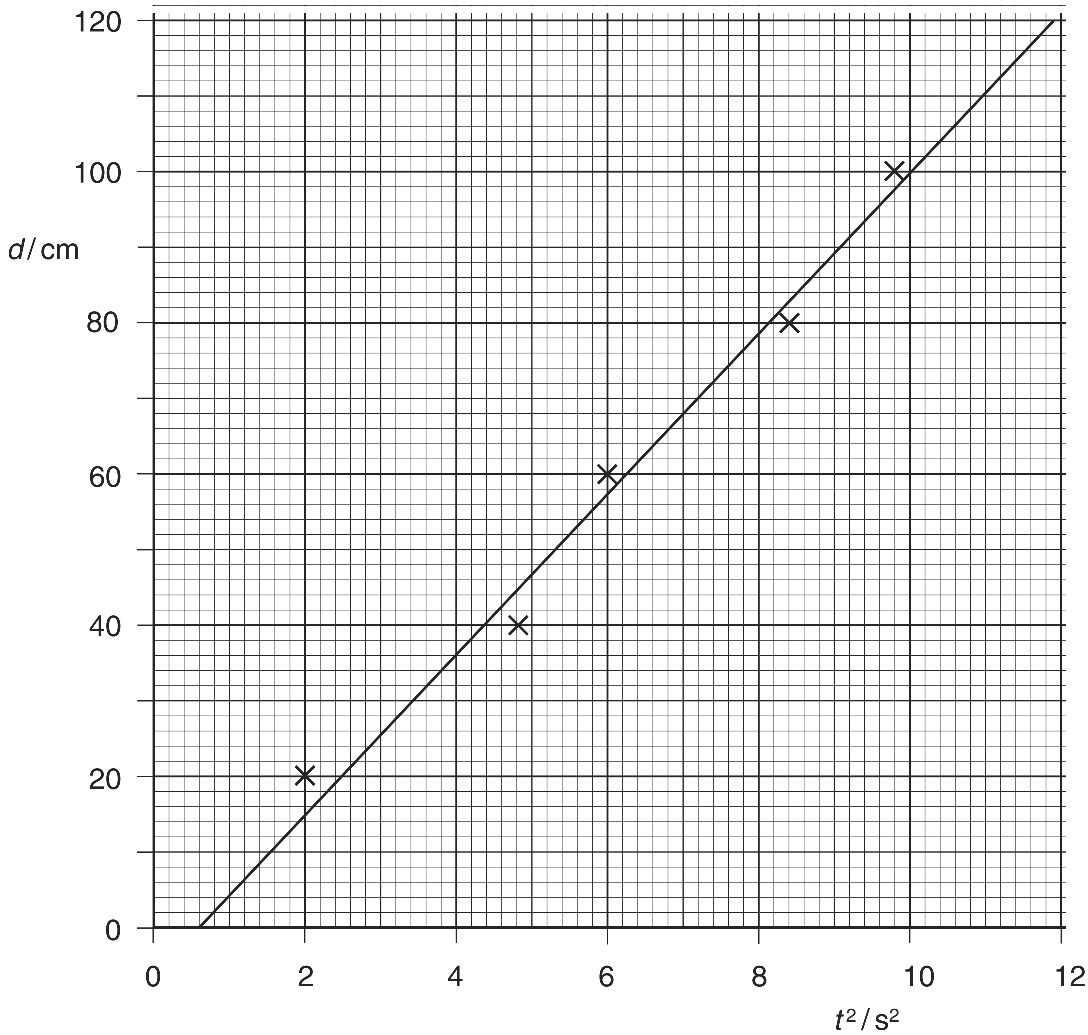


Fig. 3.2

For Examiner's Use

(a) Theory suggests that the graph is a straight line through the origin.
Name the feature on Fig. 3.2 that indicates the presence of

(i) random error,

....

(ii) systematic error.

....
[2]

(b) **(i)** Determine the gradient of the line of the graph in Fig. 3.2.

gradient = ... [2]

(ii) Use your answer to **(i)** to calculate the acceleration of the toy down the slope.
Explain your working.

acceleration = ... $m\,s^{-2}$ [3]

For Examiner's Use

1 A unit is often expressed with a prefix. For example, the gram may be written with the prefix 'kilo' as the kilogram. The prefix represents a power-of-ten. In this case, the power-of-ten is 10^3.

Complete Fig. 1.1 to show each prefix with its symbol and power-of-ten.

prefix	symbol	power-of-ten
kilo	k	10^3
nano	n	....
centi	....	10^{-2}
....	M	10^6
....	T	10^{12}

Fig. 1.1

[4]

For Examiner's Use

1 A metal wire has a cross-section of diameter approximately 0.8 mm.

(a) State what instrument should be used to measure the diameter of the wire.

.... [1]

(b) State how the instrument in **(a)** is

(i) checked so as to avoid a systematic error in the measurements,

....

.... [1]

(ii) used so as to reduce random errors.

....

....

.... [2]

For Examiner's Use

1 A digital voltmeter with a three-digit display is used to measure the potential difference across a resistor. The manufacturers of the meter state that its accuracy is ±1% and ±1 digit.
The reading on the voltmeter is 2.05 V.

(a) For this reading, calculate, to the nearest digit,

(i) a change of 1% in the voltmeter reading,

change = ... V [1]

(ii) the maximum possible value of the potential difference across the resistor.

maximum value = ... V [1]

(b) The reading on the voltmeter has high precision. State and explain why the reading may not be accurate.

....

....

....[2]

For Examiner's Use

1 **(a)** Two of the SI base quantities are mass and time. State three other SI base quantities.

1. ....

2. ....

3. ....
[3]

(b) A sphere of radius r is moving at speed v through air of density ρ. The resistive force F acting on the sphere is given by the expression

$$F = Br^2\rho v^k$$

where B and k are constants without units.

(i) State the SI base units of F, ρ and v.

F ....

ρ ....

v ....
[3]

(ii) Use base units to determine the value of k.

k = ... [2]

For Examiner's Use

1 (a) (i) Distinguish between vector quantities and scalar quantities.

....

....

.... [2]

(ii) State whether each of the following is a vector quantity or a scalar quantity.

1. temperature

.... [1]

2. acceleration of free fall

.... [1]

3. electrical resistance

.... [1]

For Examiner's Use

1 Make estimates of the following quantities.

(a) the thickness of a sheet of paper

thickness = ... mm [1]

(b) the time for sound to travel 100 m in air

time = ... s [1]

(c) the weight of 1000 cm^3 of water

weight = ... N [1]

2 Briefly describe the structures of crystalline solids, polymers and amorphous materials.

crystalline solids ....

....

....

polymers ....

....

....

amorphous materials ....

....

....
[5]

For Examiner's Use

3 A loudspeaker produces a sound wave of constant frequency.

Outline how a cathode-ray oscilloscope (c.r.o.) may be used to determine this frequency.

....

....

....

....

.... [4]

1 **(a)** For each of the following, tick [✓] one box to indicate whether the experimental technique would reduce random error, systematic error or neither. The first row has been completed as an example.

	random error	systematic error	neither
keeping your eye in line with the scale and the liquid level for a single reading of a thermometer		✓	
averaging many readings of the time taken for a ball to roll down a slope			
using a linear scale on an ammeter			
correcting for a non-zero reading when a micrometer screw gauge is closed			

[2]

(b) The measurement of a particular time interval is repeated many times. The readings are found to vary. The results are shown in Fig. 1.1.

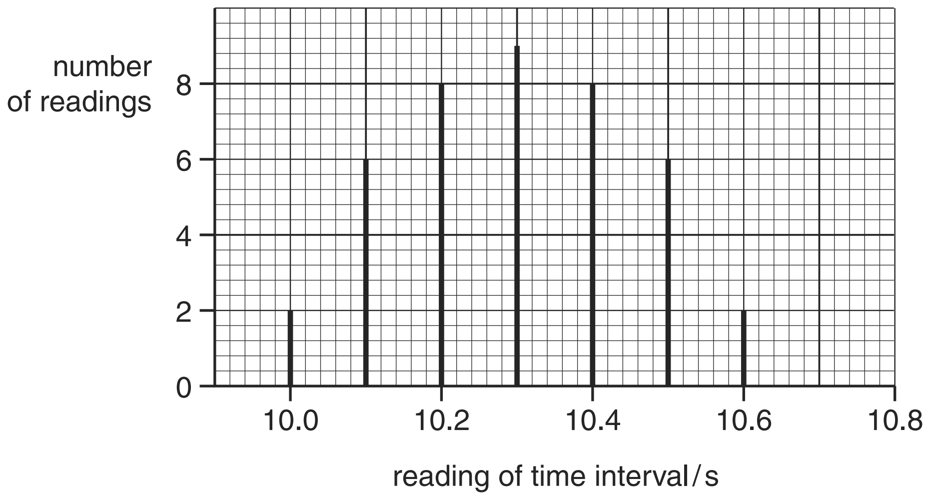


Fig. 1.1

The true value of the time interval is 10.1 s.

For Examiner's Use

(i) State how the readings on Fig. 1.1 show the presence of

1. a systematic error,

....

.... [1]

2. a random error.

....

.... [1]

(ii) State the expected changes to Fig. 1.1 for experimental measurements that are

1. more accurate,

....

.... [1]

2. more precise.

....

.... [1]

For Examiner's Use

1 Measurements made for a sample of metal wire are shown in Fig. 1.1.

quantity	measurement	uncertainty
length	1750 mm	± 3 mm
diameter	0.38 mm	± 0.01 mm
resistance	7.5 Ω	± 0.2 Ω

Fig. 1.1

(a) State the appropriate instruments used to make each of these measurements.

(i) length

.... [1]

(ii) diameter

.... [1]

(iii) resistance

.... [1]

(b) (i) Show that the resistivity of the metal is calculated to be $4.86 \times 10^{-7}\,\Omega\,m$.

[2]

(ii) Calculate the uncertainty in the resistivity.

uncertainty = ± .... Ω m [4]

(c) Use the answers in **(b)** to express the resistivity with its uncertainty to the appropriate number of significant figures.

For Examiner's Use

resistivity = ... ± .... Ω m [1]

2 **(a)** A sphere of radius R is moving through a fluid with constant speed v. There is a frictional force F acting on the sphere, which is given by the expression

For Examiner's Use

$$F = 6\pi DRv$$

where D depends on the fluid.

(i) Show that the SI base units of the quantity D are $kg\,m^{-1}\,s^{-1}$.

[3]

(ii) A raindrop of radius 1.5 mm falls vertically in air at a velocity of $3.7\,m\,s^{-1}$. The value of D for air is $6.6 \times 10^{-4}\,kg\,m^{-1}\,s^{-1}$. The density of water is $1000\,kg\,m^{-3}$.

Calculate

1. the magnitude of the frictional force F,

F = ... N [1]

2. the acceleration of the raindrop.

acceleration = ... $m\,s^{-2}$ [3]

(b) The variation with time *t* of the speed *v* of the raindrop in **(a)** is shown in Fig. 2.1.

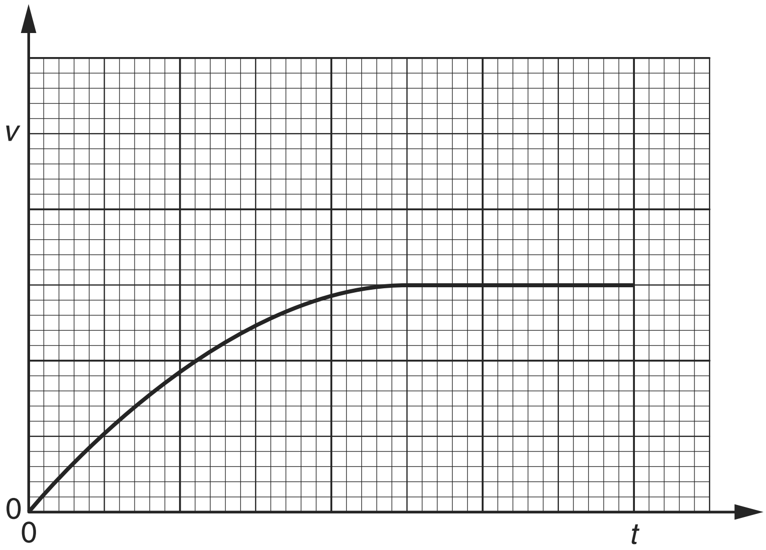


Fig. 2.1

(i) State the variation with time of the **acceleration** of the raindrop.

....

....

....

....

.... [3]

(ii) A second raindrop has a radius that is smaller than that given in **(a)**. On Fig. 2.1, sketch the variation of speed with time for this second raindrop. [2]

For Examiner's Use

1 **(a)** Define *density*.

....

.... [1]

(b) Explain how the difference in the densities of solids, liquids and gases may be related to the spacing of their molecules.

....

....

....

.... [2]

(c) A paving slab has a mass of 68 kg and dimensions 50 mm × 600 mm × 900 mm.

(i) Calculate the density, in kg m^{-3}, of the material from which the paving slab is made.

density = ... kg m^{-3} [2]

(ii) Calculate the maximum pressure a slab could exert on the ground when resting on one of its surfaces.

pressure = ... Pa [3]

For Examiner's Use

1 **(a)** **(i)** State the SI base units of volume.

base units of volume .... [1]

(ii) Show that the SI base units of pressure are $\text{kg}\,\text{m}^{-1}\,\text{s}^{-2}$.

[1]

(b) The volume V of liquid that flows through a pipe in time t is given by the equation

$$\frac{V}{t} = \frac{\pi P r^4}{8Cl}$$

where P is the pressure difference between the ends of the pipe of radius r and length l. The constant C depends on the frictional effects of the liquid.

Determine the base units of C.

base units of C .... [3]

For Examiner's Use

1 The volume V of liquid flowing in time t through a pipe of radius r is given by the equation

$$\frac{V}{t} = \frac{\pi P r^4}{8Cl}$$

where P is the pressure difference between the ends of the pipe of length l, and C depends on the frictional effects of the liquid.

An experiment is performed to determine C. The measurements made are shown in Fig. 1.1.

$\frac{V}{t}$ / $10^{-6}\,m^3\,s^{-1}$	P / $10^3\,N\,m^{-2}$	r / mm	l / m
1.20 ± 0.01	2.50 ± 0.05	0.75 ± 0.01	0.250 ± 0.001

Fig. 1.1

(a) Calculate the value of C.

C = ... $N\,s\,m^{-2}$ [2]

(b) Calculate the uncertainty in C.

uncertainty = ... $N\,s\,m^{-2}$ [3]

(c) State the value of C and its uncertainty to the appropriate number of significant figures.

C = ... ± .... $N\,s\,m^{-2}$ [1]

For Examiner's Use

1 **(a)** The spacing between two atoms in a crystal is 3.8×10^{-10} m. State this distance in pm.

spacing = ... pm [1]

(b) Calculate the time of one day in Ms.

time = ... Ms [1]

(c) The distance from the Earth to the Sun is 0.15 Tm. Calculate the time in minutes for light to travel from the Sun to the Earth.

time = ... min [2]

(d) Underline all the vector quantities in the list below.

distance   energy   momentum   weight   work   [1]

Answer **all** the questions in the spaces provided.

For Examiner's Use

1 Energy is stored in a metal wire that is extended elastically.

(a) Explain what is meant by *extended elastically*.

....

.... [2]

(b) Show that the SI units of energy per unit volume are $kg\,m^{-1}\,s^{-2}$.

[2]

(c) For a wire extended elastically, the elastic energy per unit volume X is given by

$$X = C\varepsilon^2 E$$

where C is a constant,
ε is the strain of the wire,
and E is the Young modulus of the wire.

Show that C has no units.

[3]

For Examiner's Use

Answer **all** the questions in the spaces provided.

1 **(a)** State the SI base units of force.

.... [1]

(b) Two wires each of length l are placed parallel to each other a distance x apart, as shown in Fig. 1.1.

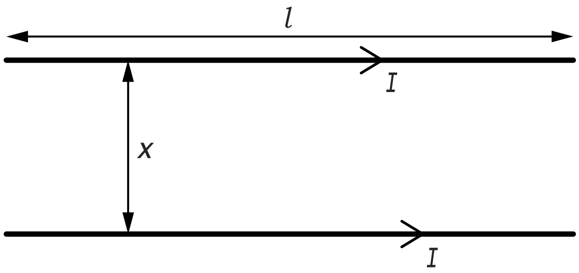


Fig. 1.1

Each wire carries a current I. The currents give rise to a force F on each wire given by

$$F = \frac{KI^2 l}{x}$$

where K is a constant.

(i) Determine the SI base units of K.

units of K .... [2]

(ii) On Fig. 1.2, sketch the variation with x of F. The quantities I and l remain constant.

Fig. 1.2 [2]

(iii) The current I in both of the wires is varied.

On Fig. 1.3, sketch the variation with I of F. The quantities x and l remain constant.

For Examiner's Use

Fig. 1.3

[1]

For Examiner's Use

Answer **all** the questions in the spaces provided.

1 **(a)** Determine the SI base units of power.

SI base units of power .... [3]

(b) Fig. 1.1 shows a turbine that is used to generate electrical power from the wind.

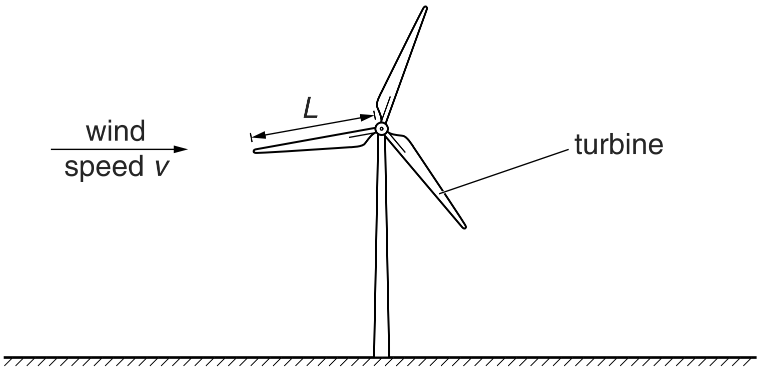


Fig. 1.1

The power *P* available from the wind is given by

$$P = CL^2\rho v^3$$

where *L* is the length of each blade of the turbine,
ρ is the density of air,
v is the wind speed,
C is a constant.

(i) Show that *C* has no units.

[3]

For Examiner's Use

(ii) The length L of each blade of the turbine is 25.0 m and the density ρ of air is 1.30 in SI units. The constant C is 0.931.
The efficiency of the turbine is 55% and the electric power output P is 3.50×10^5 W.

Calculate the wind speed.

wind speed = ... $m\,s^{-1}$ [3]

(iii) Suggest two reasons why the electrical power output of the turbine is less than the power available from the wind.

1. ....

....

2. ....

....
[2]

Answer **all** the questions in the spaces provided.

For Examiner's Use

1 **(a)** State two SI base units other than the kilogram, metre and second.

1. ....

2. .... [2]

(b) A metal wire has original length l_0. It is then suspended and hangs vertically as shown in Fig. 1.1.

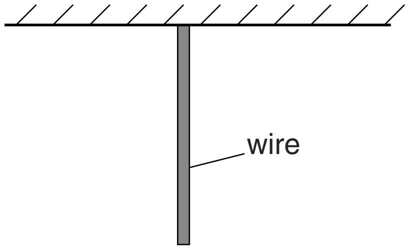


Fig. 1.1

The weight of the wire causes it to stretch. The elastic potential energy stored in the wire is E.

(i) Show that the SI base units of E are $\text{kg}\,\text{m}^2\,\text{s}^{-2}$.

[2]

For Examiner's Use

(ii) The elastic potential energy E is given by

$$E = C\rho^2 g^2 A l_0^3$$

where ρ is the density of the metal,
g is the acceleration of free fall,
A is the cross-sectional area of the wire
and C is a constant.

Determine the SI base units of C.

SI base units of C .... [3]

For Examiner's Use

2 The time T for a satellite to orbit the Earth is given by

$$T = \sqrt{\left(\frac{KR^3}{M}\right)}$$

where R is the distance of the satellite from the centre of the Earth,
M is the mass of the Earth,
and K is a constant.

(a) Determine the SI base units of K.

SI base units of K .... [2]

(b) Data for a particular satellite are given in Fig. 2.1.

quantity	measurement	uncertainty
T	8.64×10^4 s	± 0.5%
R	4.23×10^7 m	± 1%
M	6.0×10^{24} kg	± 2%

Fig. 2.1

Calculate K and its actual uncertainty in SI units.

K = ... ± .... SI units [4]

Answer **all** the questions in the spaces provided.

For Examiner's Use

1 A cylindrical disc is shown in Fig. 1.1.

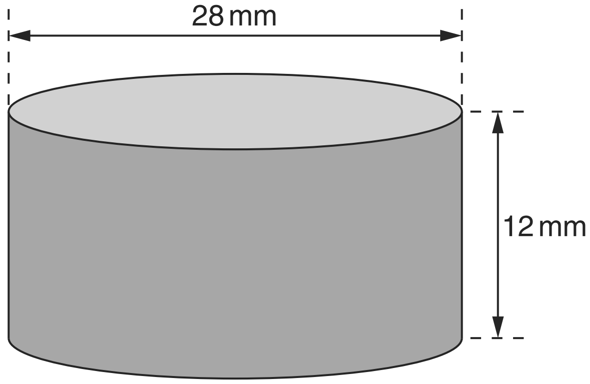


Fig. 1.1

The disc has diameter 28 mm and thickness 12 mm.
The material of the disc has density $6.8 \times 10^3\,\text{kg}\,\text{m}^{-3}$.

Calculate, to two significant figures, the weight of the disc.

weight = ... N [4]

2 A source of radio waves sends a pulse towards a reflector. The pulse returns from the reflector and is detected at the same point as the source. The emitted and reflected pulses are recorded on a cathode-ray oscilloscope (c.r.o.) as shown in Fig. 2.1.

For Examiner's Use

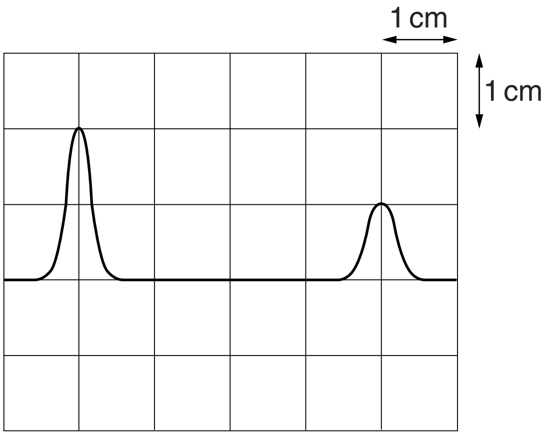


Fig. 2.1

The time-base setting is $0.20\,\mu s\,cm^{-1}$.

(a) Using Fig. 2.1, determine the distance between the source and the reflector.

distance = ... m [4]

(b) Determine the time-base setting required to produce the same separation of pulses on the c.r.o. when sound waves are used instead of radio waves.
The speed of sound is $300\,m\,s^{-1}$.

....

....

....[3]

Answer **all** the questions in the spaces provided.

1 **(a)** Underline **all** the base quantities in the following list.

ampere charge current mass second temperature weight [2]

(b) The potential energy E_P stored in a stretched wire is given by

$$E_P = ½C\sigma^2V$$

where C is a constant,
σ is the strain,
V is the volume of the wire.

Determine the SI base units of C.

base units ....[3]

Answer **all** the questions in the spaces provided.

1 **(a)** Show that the SI base units of power are kg m^2 s^{-3}.

[3]

(b) The rate of flow of thermal energy $\frac{Q}{t}$ in a material is given by

$$\frac{Q}{t} = \frac{CAT}{x}$$

where *A* is the cross-sectional area of the material,
T is the temperature difference across the thickness of the material,
x is the thickness of the material,
C is a constant.

Determine the SI base units of *C*.

base units .... [4]

2 A coin is made in the shape of a thin cylinder, as shown in Fig. 2.1.

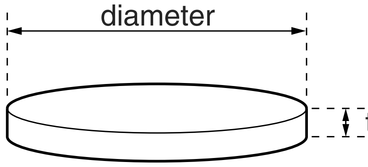


Fig. 2.1

Fig. 2.2 shows the measurements made in order to determine the density ρ of the material used to make the coin.

quantity	measurement	uncertainty
mass	9.6 g	± 0.5 g
thickness	2.00 mm	± 0.01 mm
diameter	22.1 mm	± 0.1 mm

Fig. 2.2

(a) Calculate the density ρ in $kg\,m^{-3}$.

ρ = ... $kg\,m^{-3}$ [3]

(b) **(i)** Calculate the percentage uncertainty in ρ.

percentage uncertainty = ... [3]

(ii) State the value of ρ with its actual uncertainty.

ρ = ... ± .... $kg\,m^{-3}$ [1]

Answer **all** the questions in the spaces provided.

1 **(a)** Mass, length and time are SI base quantities.
State two other base quantities.

1. ....

2. ....
[2]

(b) A mass *m* is placed on the end of a spring that is hanging vertically, as shown in Fig. 1.1.

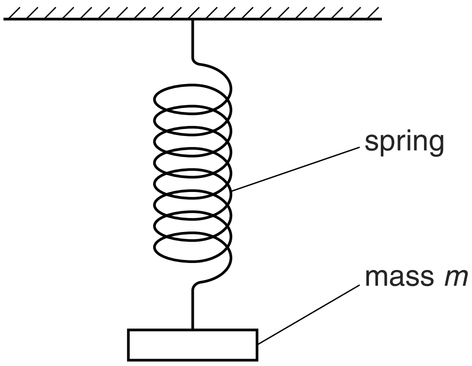


Fig. 1.1

The mass is made to oscillate vertically. The time period of the oscillations of the mass is *T*.

The period *T* is given by

$$T = C\sqrt{\frac{m}{k}}$$

where *C* is a constant and *k* is the spring constant.

Show that *C* has no units.

[3]

2 **(a)** Define *pressure*.

.... [1]

(b) A cylinder is placed on a horizontal surface, as shown in Fig. 2.1.

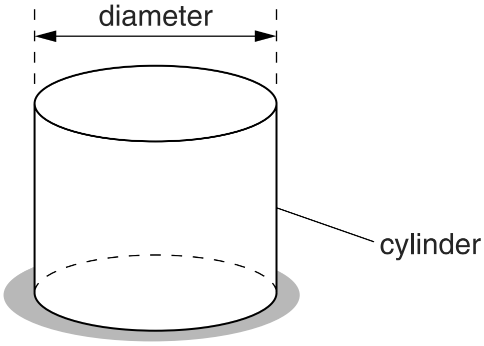


Fig. 2.1

The following measurements were made on the cylinder:

mass = 5.09 ± 0.01 kg
diameter = 9.4 ± 0.1 cm.

(i) Calculate the pressure produced by the cylinder on the surface.

pressure = ... Pa [3]

(ii) Calculate the actual uncertainty in the pressure.

actual uncertainty = ... Pa [3]

(iii) State the pressure, with its actual uncertainty.

pressure = ... ± .... Pa [1]

Answer **all** the questions in the spaces provided.

1 **(a)** The Young modulus of the metal of a wire is 1.8×10^{11} Pa. The wire is extended and the strain produced is 8.2×10^{-4}.
Calculate the stress in GPa.

stress = ... GPa [2]

(b) An electromagnetic wave has frequency 12 THz.

(i) Calculate the wavelength in μm.

wavelength = ... μm [2]

(ii) State the name of the region of the electromagnetic spectrum for this frequency.

.... [1]

(c) An object B is on a horizontal surface. Two forces act on B in this horizontal plane. A vector diagram for these forces is shown to scale in Fig. 1.1.

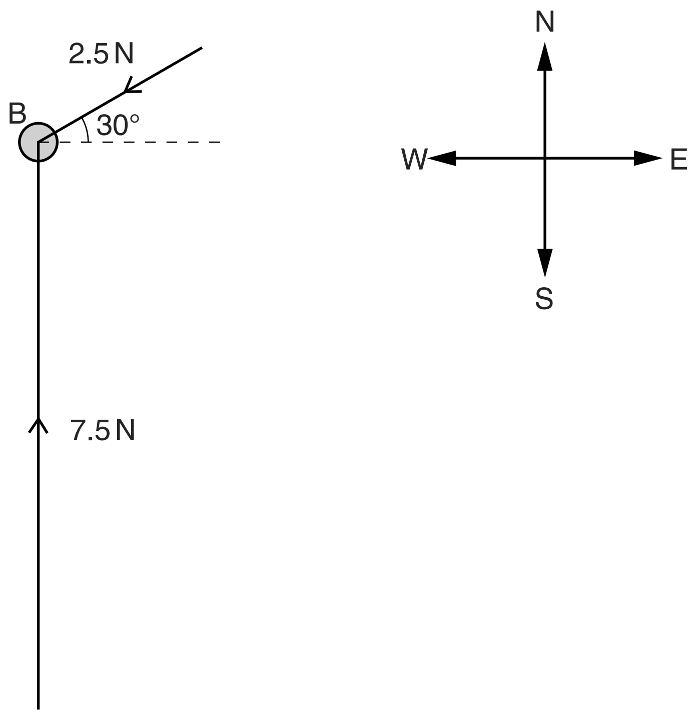


Fig. 1.1

A force of 7.5 N towards north and a force of 2.5 N from 30° north of east act on B. The mass of B is 750 g.

(i) On Fig. 1.1, draw an arrow to show the approximate direction of the resultant of these two forces. [1]

(ii) **1.** Show that the magnitude of the resultant force on B is 6.6 N.

[1]

2. Calculate the magnitude of the acceleration of B produced by this resultant force.

magnitude = ... $m\,s^{-2}$ [2]

(iii) Determine the angle between the direction of the acceleration and the direction of the 7.5 N force.

angle = ... ° [1]

Answer **all** the questions in the spaces provided.

1 **(a)** The kilogram, metre and second are SI base units.

State two other base units.

1. ....

2. ....
[2]

(b) Determine the SI base units of

(i) stress,

SI base units ....[2]

(ii) the Young modulus.

SI base units ....[1]

2 A microphone detects a musical note of frequency f. The microphone is connected to a cathode-ray oscilloscope (c.r.o.). The signal from the microphone is observed on the c.r.o. as illustrated in Fig. 2.1.

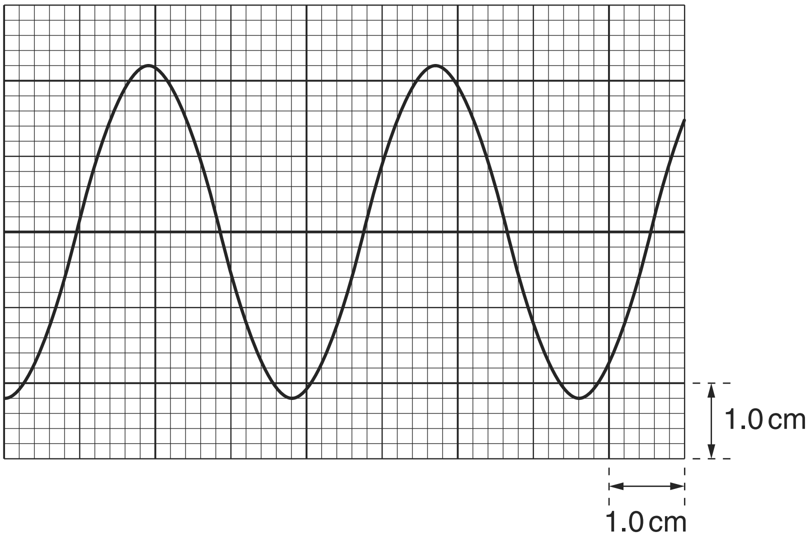


Fig. 2.1

The time-base setting of the c.r.o. is $0.50\,\text{ms}\,\text{cm}^{-1}$. The Y-plate setting is $2.5\,\text{mV}\,\text{cm}^{-1}$.

(a) Use Fig. 2.1 to determine

(i) the amplitude of the signal,

amplitude = ... mV [2]

(ii) the frequency f,

f = ... Hz [3]

(iii) the actual uncertainty in f caused by reading the scale on the c.r.o.

actual uncertainty = ... Hz [2]

(b) State f with its actual uncertainty.

f = ... ± .... Hz [1]

1 **(a)** The distance between the Sun and the Earth is 1.5×10^{11} m. State this distance in Gm.

distance = ... Gm [1]

(b) The distance from the centre of the Earth to a satellite above the equator is 42.3 Mm. The radius of the Earth is 6380 km.
A microwave signal is sent from a point on the Earth directly below the satellite.

Calculate the time taken for the microwave signal to travel to the satellite and back.

time = ... s [2]

(c) The speed v of a sound wave through a gas of density ρ and pressure P is given by

$$v = \sqrt{\frac{CP}{\rho}}$$

where C is a constant.

Show that C has no unit.

[3]

(d) Underline all the scalar quantities in the list below.

acceleration energy momentum power weight [1]

(e) A boat travels across a river in which the water is moving at a speed of $1.8\,\mathrm{m\,s^{-1}}$.
The velocity vectors for the boat and the river water are shown to scale in Fig. 1.1.

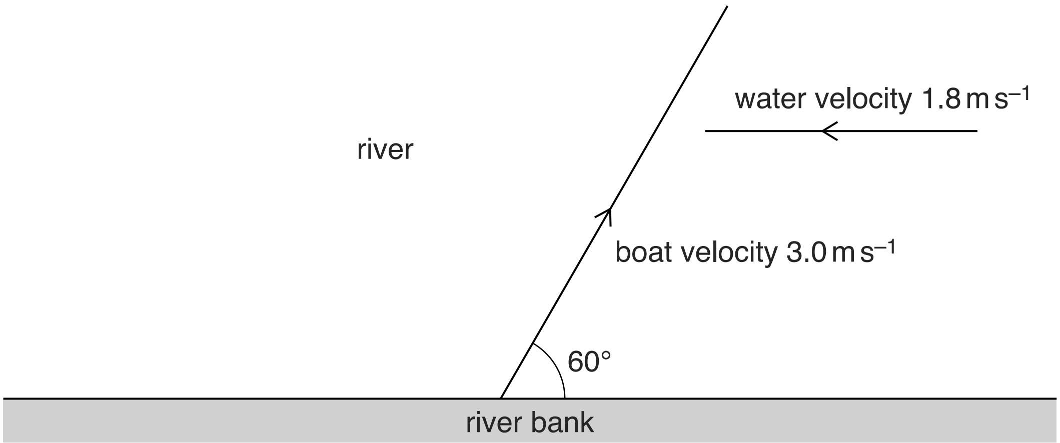


Fig. 1.1 (shown to scale)

In still water the speed of the boat is $3.0\,\mathrm{m\,s^{-1}}$. The boat is directed at an angle of 60° to the river bank.

(i) On Fig. 1.1, draw a vector triangle or a scale diagram to show the resultant velocity of the boat. [2]

(ii) Determine the magnitude of the resultant velocity of the boat.

resultant velocity = ... $\mathrm{m\,s^{-1}}$ [2]

Answer **all** the questions in the spaces provided.

1 **(a)** Use the definition of work done to show that the SI base units of energy are $kg\,m^2\,s^{-2}$.

[2]

(b) Define potential difference.

....

.... [1]

(c) Determine the SI base units of resistance. Show your working.

units .... [3]

1 **(a)** Use the definition of power to show that the SI base units of power are $kg\,m^2\,s^{-3}$.

[2]

(b) Use an expression for electrical power to determine the SI base units of potential difference.

units ....[2]

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

scalar: ....

....

vector: ....

.... [2]

(b) Two forces of magnitude 6.0 N and 8.0 N act at a point P. Both forces act away from point P and the angle between them is 40°.
Fig. 1.1 shows two lines at an angle of 40° to one another.

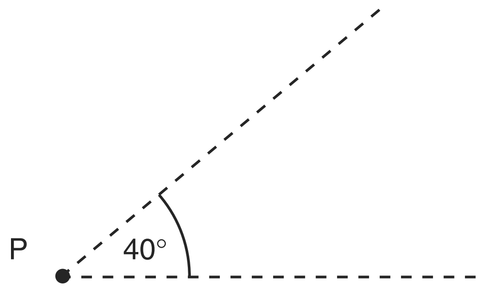


Fig. 1.1

On Fig. 1.1, draw a vector diagram to determine the magnitude of the resultant of the two forces.

magnitude of resultant = ... N [4]

For Examiner's Use

1 **(a)** **(i)** Distinguish between vector quantities and scalar quantities.

....

....

.... [2]

(ii) State whether each of the following is a vector quantity or a scalar quantity.

1. temperature

.... [1]

2. acceleration of free fall

.... [1]

3. electrical resistance

.... [1]

(b) A block of wood of weight 25 N is held stationary on a slope by means of a string, as shown in Fig. 1.1.

For Examiner's Use

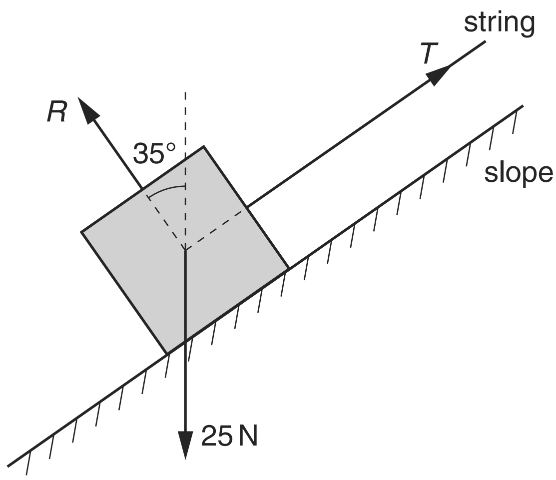


Fig. 1.1

The tension in the string is *T* and the slope pushes on the block with a force *R* that is normal to the slope.

Either by scale drawing on Fig. 1.1 or by calculation, determine the tension *T* in the string.

T = ... N [3]

For Examiner's Use

1 **(a)** Distinguish between scalars and vectors.

....

.... [1]

(b) Underline **all** the vector quantities in the list below.

acceleration kinetic energy momentum power weight [2]

(c) A force of 7.5 N acts at 40° to the horizontal, as shown in Fig. 1.1.

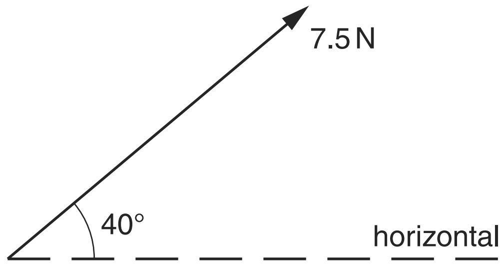


Fig. 1.1

Calculate the component of the force that acts

(i) horizontally,

horizontal component = ... N [1]

(ii) vertically.

vertical component = ... N [1]

(d) Two strings support a load of weight 7.5 N, as shown in Fig. 1.2.

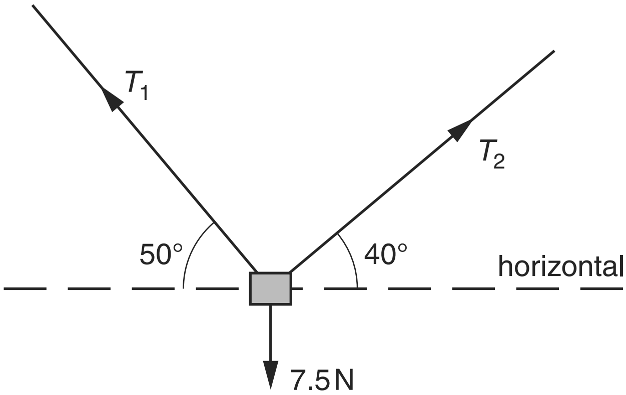


Fig. 1.2

One string has a tension T_1 and is at an angle 50° to the horizontal. The other string has a tension T_2 and is at an angle 40° to the horizontal. The object is in equilibrium. Determine the values of T_1 and T_2 by using a vector triangle or by resolving forces.

T_1 = ... N

T_2 = ... N
[4]

For Examiner's Use

1 **(a)** Explain the differences between the quantities *distance* and *displacement.*

....

....

.... [2]

(b) State Newton's first law.

....

....

.... [1]

(c) Two tugs pull a tanker at constant velocity in the direction XY, as represented in Fig. 1.1.

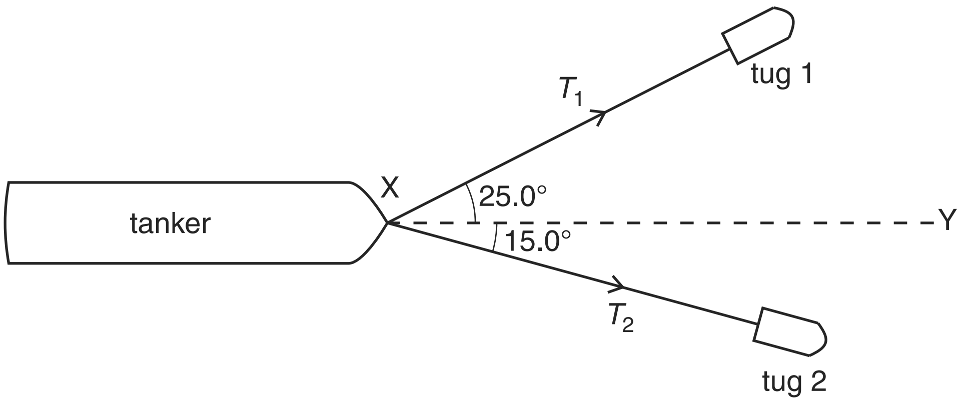


Fig. 1.1

Tug 1 pulls the tanker with a force T_1 at 25.0° to XY. Tug 2 pulls the tanker with a force of T_2 at 15.0° to XY. The resultant force R due to the two tugs is 25.0×10^3 N in the direction XY.

(i) By reference to the forces acting on the tanker, explain how the tanker may be described as being in equilibrium.

....

....

....

.... [2]

(ii) **1.** Complete Fig. 1.2 to draw a vector triangle for the forces R, T_1 and T_2. [2]

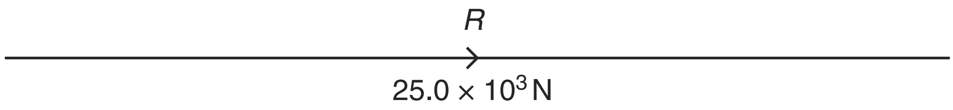


Fig. 1.2

2. Use your vector triangle in Fig. 1.2 to determine the magnitude of T_1 and of T_2.

T_1 = ... N

T_2 = ... N
[2]

For Examiner's Use

1 **(a)** The spacing between two atoms in a crystal is 3.8×10^{-10} m. State this distance in pm.

spacing = ... pm [1]

(b) Calculate the time of one day in Ms.

time = ... Ms [1]

(c) The distance from the Earth to the Sun is 0.15 Tm. Calculate the time in minutes for light to travel from the Sun to the Earth.

time = ... min [2]

(d) Underline all the vector quantities in the list below.

distance energy momentum weight work [1]

For Examiner's Use

(e) The velocity vector diagram for an aircraft heading due north is shown to scale in Fig. 1.1. There is a wind blowing from the north-west.

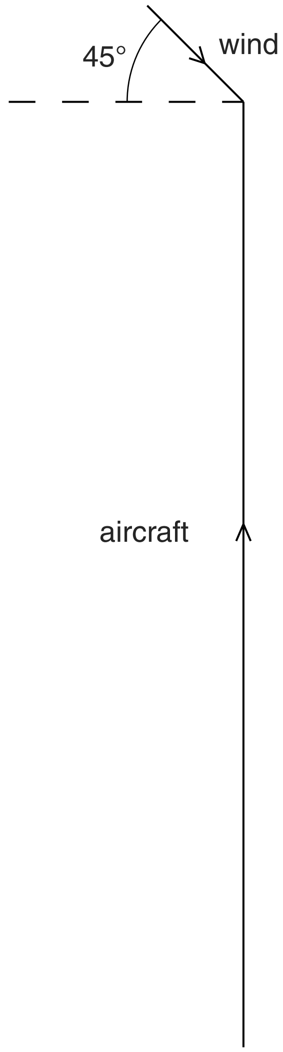


Fig. 1.1

The speed of the wind is $36\,\mathrm{m\,s^{-1}}$ and the speed of the aircraft is $250\,\mathrm{m\,s^{-1}}$.

(i) Draw an arrow on Fig. 1.1 to show the direction of the resultant velocity of the aircraft. [1]

(ii) Determine the magnitude of the resultant velocity of the aircraft.

resultant velocity = ... $\mathrm{m\,s^{-1}}$ [2]

For Examiner's Use

2 **(a)** Distinguish between *mass and weight*.

mass: ....

....

weight: ....

....
[2]

(b) An object O of mass 4.9 kg is suspended by a rope A that is fixed at point P. The object is pulled to one side and held in equilibrium by a second rope B, as shown in Fig. 2.1.

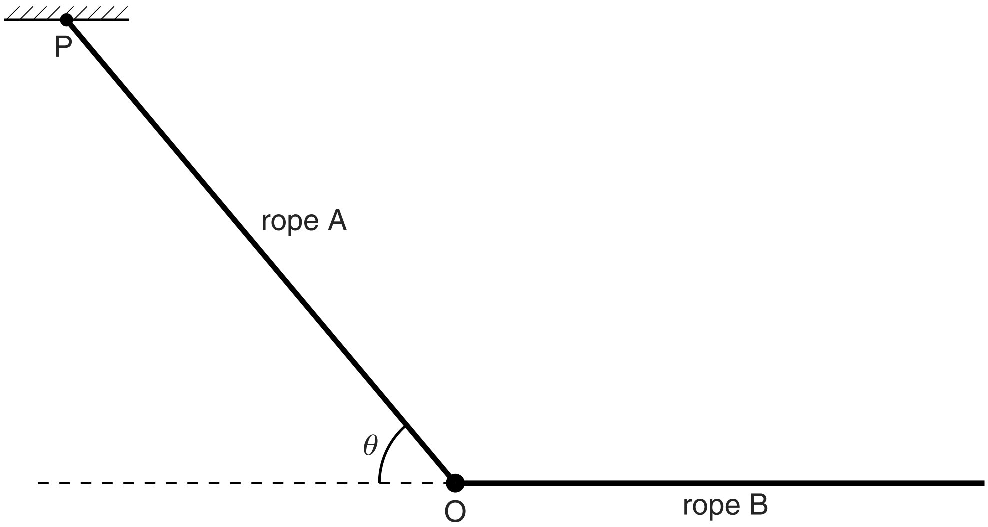


Fig. 2.1

Rope A is at an angle θ to the horizontal and rope B is horizontal. The tension in rope A is 69 N and the tension in rope B is T.

(i) On Fig. 2.1, draw arrows to represent the directions of all the forces acting on object O. [2]

(ii) Calculate

1. the angle θ,

θ = ...° [3]

2. the tension T.

T = ... N [2]

3 **(a)** Force is a vector quantity. State three other vector quantities.

1. ....

2. ....

3. ....
[2]

(b) Three coplanar forces X, Y and Z act on an object, as shown in Fig. 3.1.

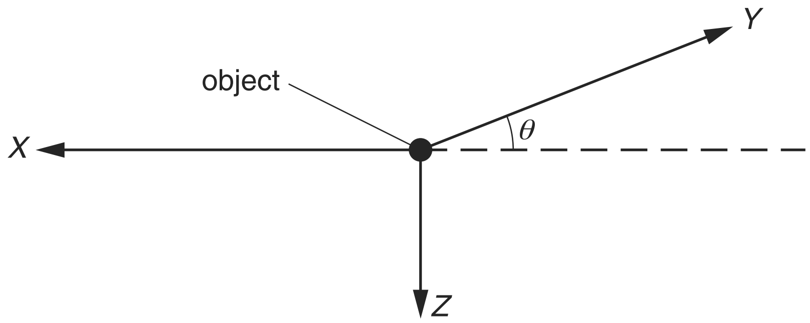


Fig. 3.1

The force Z is vertical and X is horizontal. The force Y is at an angle θ to the horizontal. The force Z is kept constant at 70 N.

In an experiment, the magnitude of force X is varied. The magnitude and direction of force Y are adjusted so that the object remains in equilibrium.

Fig. 3.2 shows the variation of the magnitude of force Y with the magnitude of force X.

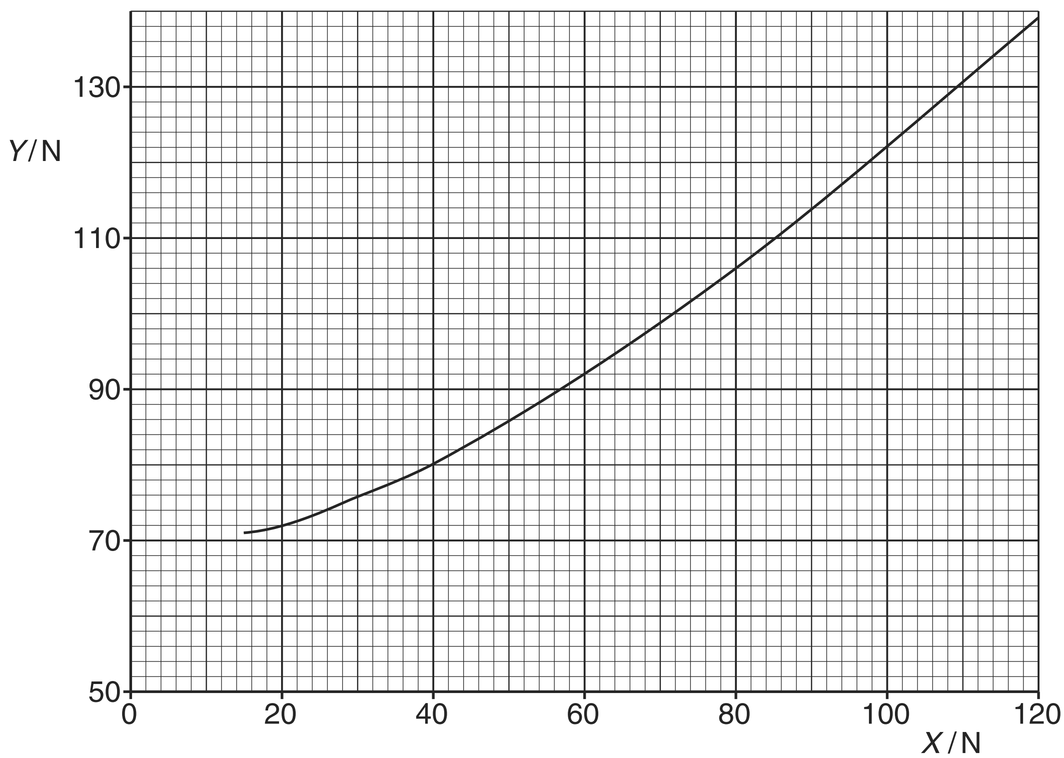


Fig. 3.2

(i) Use Fig. 3.2 to estimate the magnitude of Y for $X = 0$.

Y = ... N [1]

(ii) State and explain the value of θ for $X = 0$.

....

....

....[2]

(iii) The magnitude of X is increased to 160 N. Use resolution of forces to calculate the value of

1. angle θ,

θ = ... ° [2]

2. the magnitude of force Y.

Y = ... N [2]

(c) The angle θ decreases as X increases. Explain why the object cannot be in equilibrium for $\theta = 0$.

....

....

....[1]

2 An experiment is conducted on the surface of the planet Mars.
A sphere of mass 0.78 kg is projected almost vertically upwards from the surface of the planet. The variation with time *t* of the vertical velocity *v* in the upward direction is shown in Fig. 2.1.

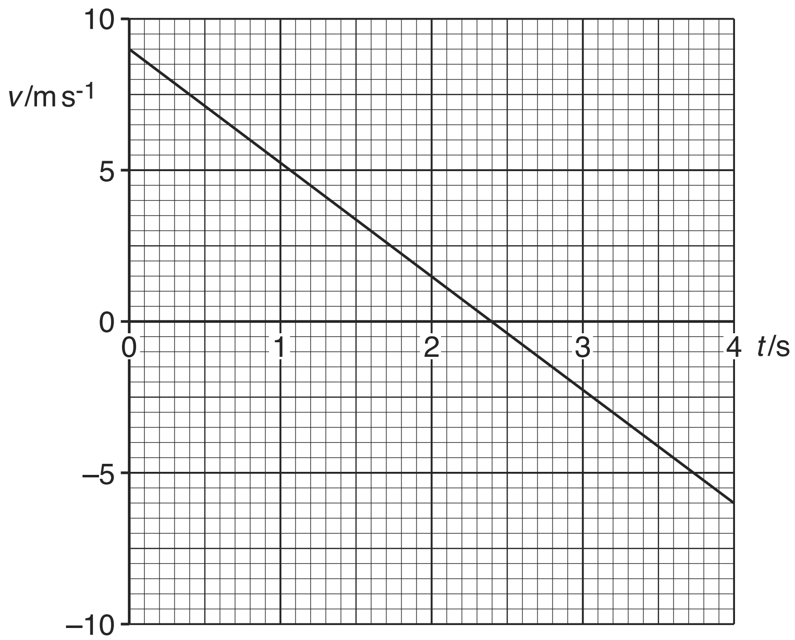


Fig. 2.1

The sphere lands on a small hill at time *t* = 4.0 s.

(a) State the time *t* at which the sphere reaches its maximum height above the planet's surface.

t = ... s [1]

(b) Determine the vertical height above the point of projection at which the sphere finally comes to rest on the hill.

height = ... m [3]

For Examiner's Use

(c) Calculate, for the first 3.5 s of the motion of the sphere,

(i) the change in momentum of the sphere,

change in momentum = ...N s [2]

(ii) the force acting on the sphere.

force = ...N [2]

(d) Using your answer in **(c)(ii)**,

(i) state the weight of the sphere,

weight = ...N [1]

(ii) determine the acceleration of free fall on the surface of Mars.

acceleration = ...m s^{-2} [2]

6 A girl stands at the top of a cliff and throws a ball vertically upwards with a speed of $12\,\text{m}\,\text{s}^{-1}$, as illustrated in Fig. 3.1.

For Examiner's Use

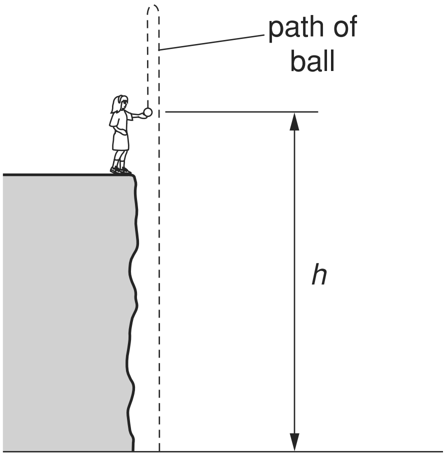


Fig. 3.1

At the time that the girl throws the ball, her hand is a height h above the horizontal ground at the base of the cliff.
The variation with time t of the speed v of the ball is shown in Fig. 3.2.

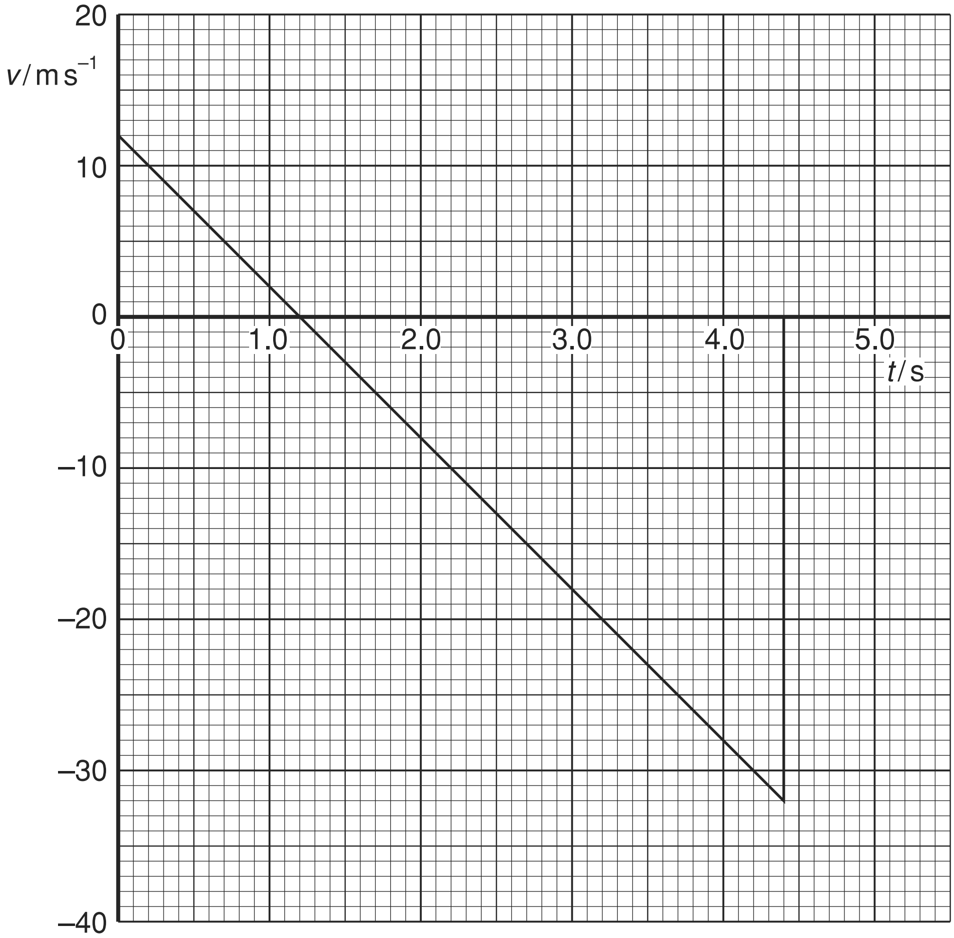


Fig. 3.2

Speeds in the upward direction are shown as being positive. Speeds in the downward direction are negative.

(a) State the feature of Fig. 3.2 that shows that the acceleration is constant.

.... [1]

(b) Use Fig. 3.2 to determine the time at which the ball

(i) reaches maximum height,

time = ... s

(ii) hits the ground at the base of the cliff.

time = ... s
[2]

(c) Determine the maximum height above the base of the cliff to which the ball rises.

height = ... m [3]

(d) The ball has mass 250 g. Calculate the magnitude of the change in momentum of the ball between the time that it leaves the girl's hand to time t = 4.0 s.

change = ... N s [3]

7 A trolley of mass 930 g is held on a horizontal surface by means of two springs, as shown in Fig. 4.1.

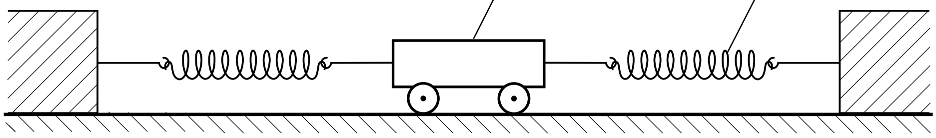


Fig. 4.1

The variation with time *t* of the speed *v* of the trolley for the first 0.60 s of its motion is shown in Fig. 4.2.

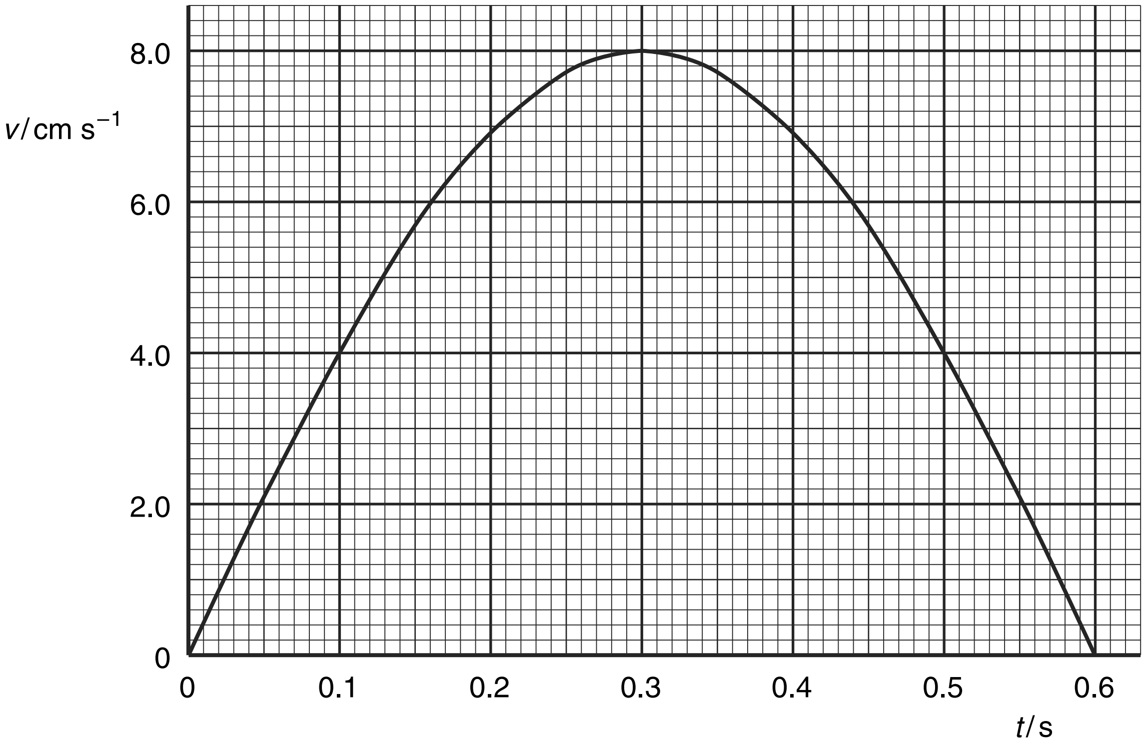


Fig. 4.2

(a) Use Fig. 4.2 to determine

(i) the initial acceleration of the trolley,

acceleration = ……………………….. m s^{-2} [2]

For Examiner's Use

(ii) the distance moved during the first 0.60 s of its motion.

distance = ……………..………………… m [3]

(b) **(i)** Use your answer to **(a)(i)** to determine the resultant force acting on the trolley at time $t = 0$.

force = …………………………….. N [2]

(ii) Describe qualitatively the variation with time of the resultant force acting on the trolley during the first 0.60 s of its motion.

....

....

....

.... [3]

9 A student investigates the speed of a trolley as it rolls down a slope, as illustrated in Fig. 2.1.

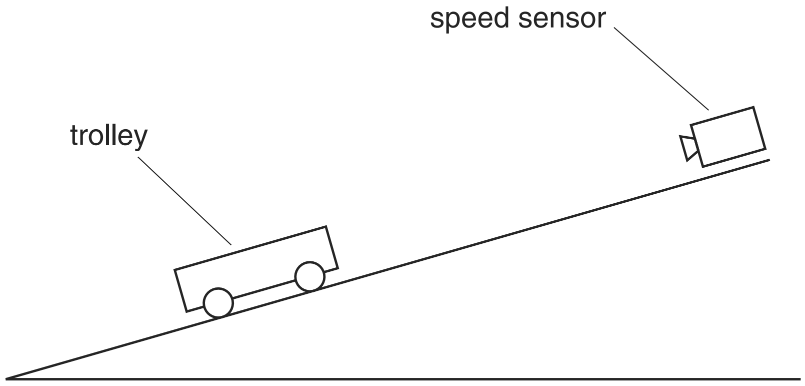


Fig. 2.1

The speed v of the trolley is measured using a speed sensor for different values of the time t that the trolley has moved from rest down the slope.

Fig. 2.2 shows the variation with t of v.

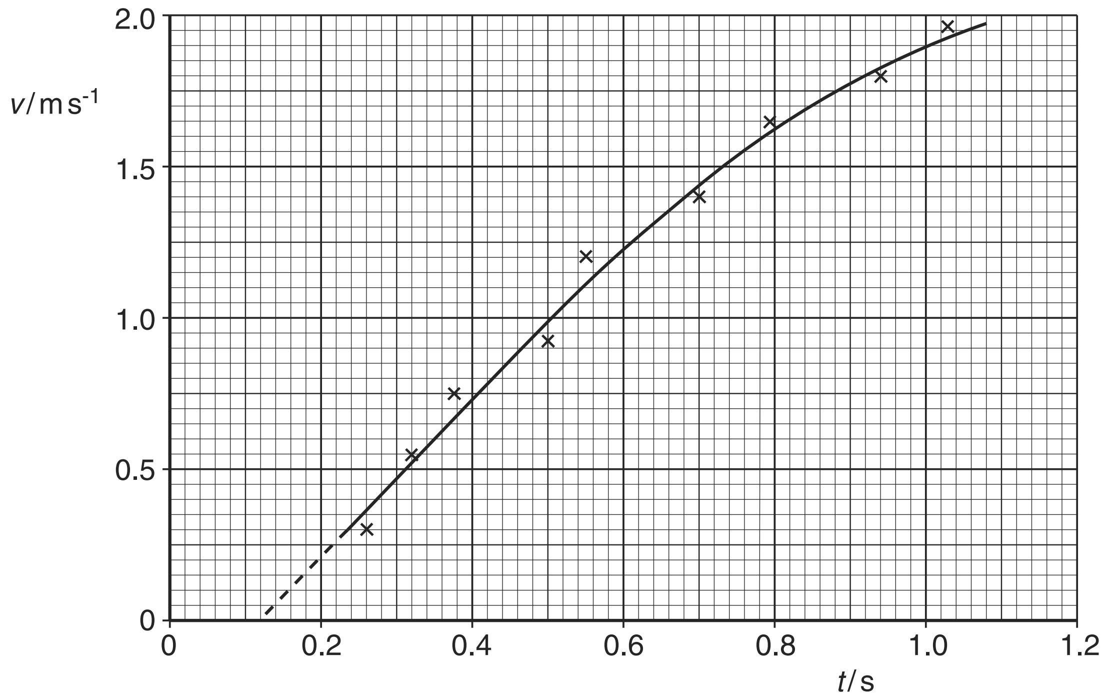


Fig. 2.2

For Examiner's Use

(a) Use Fig. 2.2 to determine the acceleration of the trolley at the point on the graph where $t = 0.80$ s.

acceleration = ... m s^{-2} [4]

(b) **(i)** State whether the acceleration is increasing or decreasing for values of t greater than 0.6 s. Justify your answer by reference to Fig. 2.2.

....

....

.... [2]

(ii) Suggest an explanation for this change in acceleration.

....

.... [1]

(c) Name the feature of Fig. 2.2 that indicates the presence of

(i) random error,

....

.... [1]

(ii) systematic error.

....

.... [1]

11 A girl G is riding a bicycle at a constant velocity of $3.5\,\text{m}\,\text{s}^{-1}$. At time $t = 0$, she passes a boy B sitting on a bicycle that is stationary, as illustrated in Fig. 2.1.

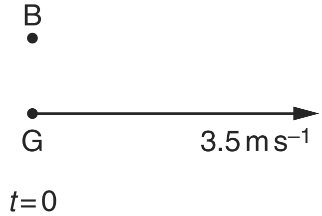


Fig. 2.1

At time $t = 0$, the boy sets off to catch up with the girl. He accelerates uniformly from time $t = 0$ until he reaches a speed of $5.6\,\text{m}\,\text{s}^{-1}$ in a time of 5.0 s. He then continues at a constant speed of $5.6\,\text{m}\,\text{s}^{-1}$. At time $t = T$, the boy catches up with the girl.
T is measured in seconds.

(a) State, in terms of T, the distance moved by the girl before the boy catches up with her.

distance = ... m [1]

(b) For the boy, determine

(i) the distance moved during his acceleration,

distance = ... m [2]

(ii) the distance moved during the time that he is moving at constant speed.
Give your answer in terms of T.

distance = ... m [1]

(c) Use your answers in **(a)** and **(b)** to determine the time T taken for the boy to catch up with the girl.

T = ... s [2]

(d) The boy and the bicycle have a combined mass of 67 kg.

(i) Calculate the force required to cause the acceleration of the boy.

force = ... N [3]

(ii) At a speed of 4.5 m s^{-1}, the total resistive force acting on the boy and bicycle is 23 N.
Determine the output power of the boy's legs at this speed.

power = ... W [2]

12 A car is travelling along a straight road at speed *v*. A hazard suddenly appears in front of the car. In the time interval between the hazard appearing and the brakes on the car coming into operation, the car moves forward a distance of 29.3 m. With the brakes applied, the front wheels of the car leave skid marks on the road that are 12.8 m long, as illustrated in Fig. 2.1.

For Examiner's Use

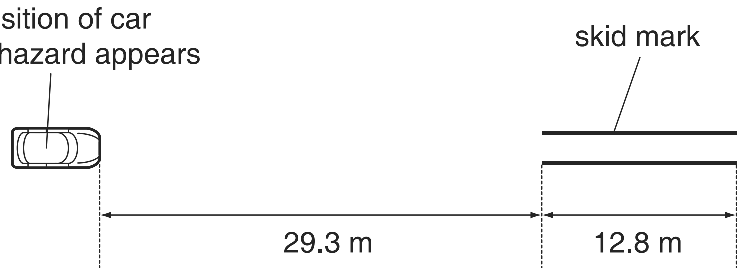


Fig. 2.1

It is estimated that, during the skid, the magnitude of the deceleration of the car is 0.85 *g*, where *g* is the acceleration of free fall.

(a) Determine

(i) the speed *v* of the car before the brakes are applied,

v = ... m s^{-1} [2]

(ii) the time interval between the hazard appearing and the brakes being applied.

time = ... s [2]

For Examiner's Use

(b) The legal speed limit on the road is 60 km per hour.
Use both of your answers in **(a)** to comment on the standard of the driving of the car.

....

....

....

.... [3]

13 A sky-diver jumps from a high-altitude balloon.

(a) Explain briefly why the acceleration of the sky-diver

(i) decreases with time,

....

....

.... [2]

(ii) is $9.8\,\text{m}\,\text{s}^{-2}$ at the start of the jump.

....

.... [1]

(b) The variation with time *t* of the vertical speed *v* of the sky-diver is shown in Fig. 2.1.

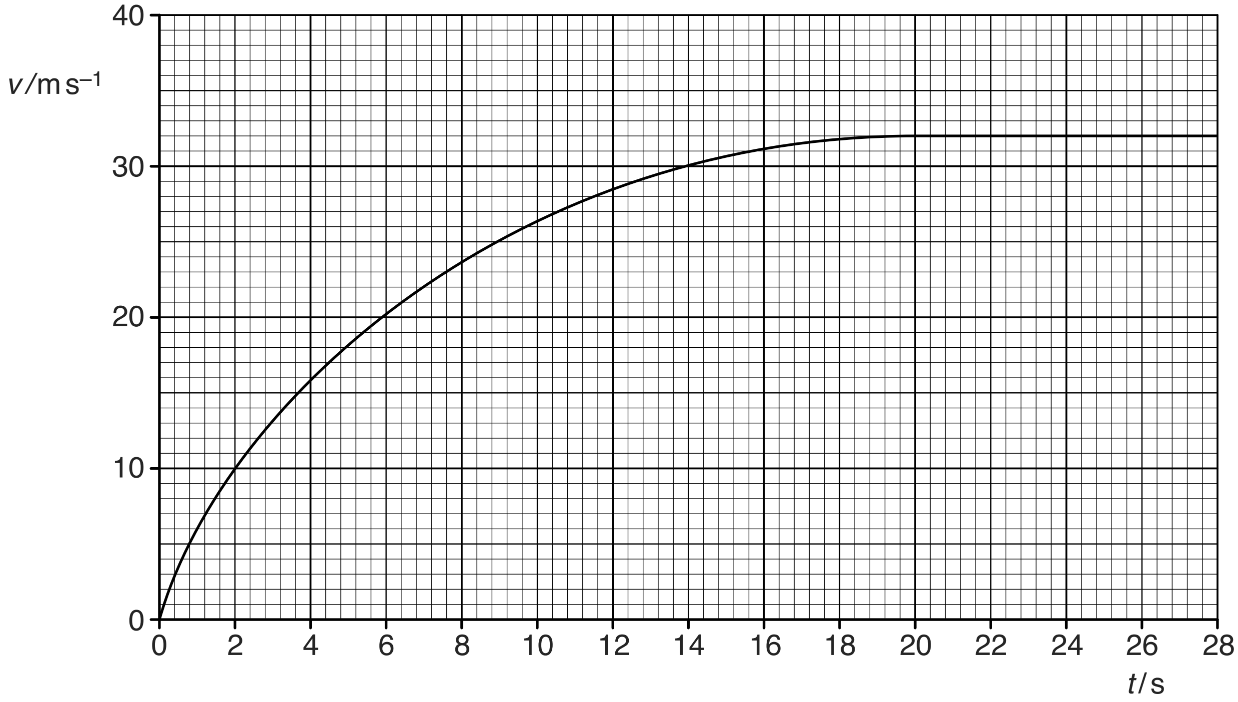


Fig. 2.1

For Examiner's Use

Use Fig. 2.1 to determine the magnitude of the acceleration of the sky-diver at time $t = 6.0$ s.

acceleration = ... m s^{-2} [3]

(c) The sky-diver and his equipment have a total mass of 90 kg.

(i) Calculate, for the sky-diver and his equipment,

1. the total weight,

weight = ... N [1]

2. the accelerating force at time $t = 6.0$ s.

force = ... N [1]

(ii) Use your answers in **(i)** to determine the total resistive force acting on the sky-diver at time $t = 6.0$ s.

force = ... N [1]

16 A steel ball of mass 73 g is held 1.6 m above a horizontal steel plate, as illustrated in Fig. 4.1.

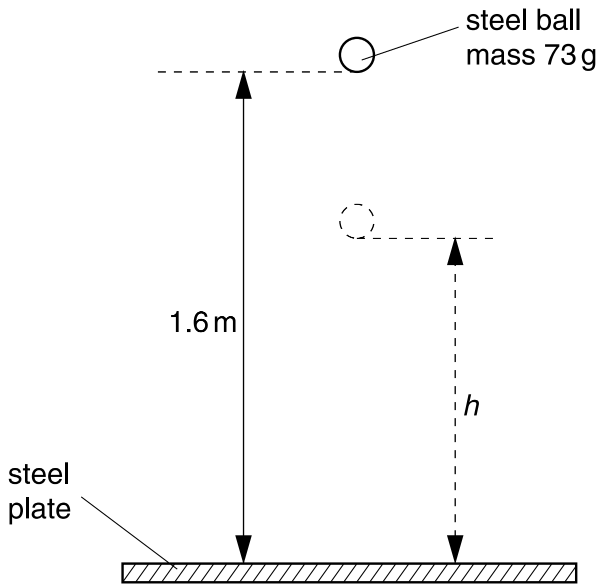


Fig. 4.1

The ball is dropped from rest and it bounces on the plate, reaching a height *h*.

(a) Calculate the speed of the ball as it reaches the plate.

speed = ... m s^{-1} [2]

(b) As the ball loses contact with the plate after bouncing, the kinetic energy of the ball is 90% of that just before bouncing. Calculate

(i) the height *h* to which the ball bounces,

h = ... m

(ii) the speed of the ball as it leaves the plate after bouncing.

speed = ... m s^{-1} [4]

(c) Using your answers to **(a)** and **(b)**, determine the change in momentum of the ball during the bounce.

change = ... N s [3]

(d) With reference to the law of conservation of momentum, comment on your answer to **(c)**.

....

....

....[3]

2 **(a)** Complete Fig. 2.1 to show whether each of the quantities listed is a vector or a scalar.

For Examiner's Use

	vector / scalar
distance moved	....
speed	....
acceleration	....

Fig. 2.1

[3]

(b) A ball falls vertically in air from rest. The variation with time *t* of the distance *d* moved by the ball is shown in Fig. 2.2.

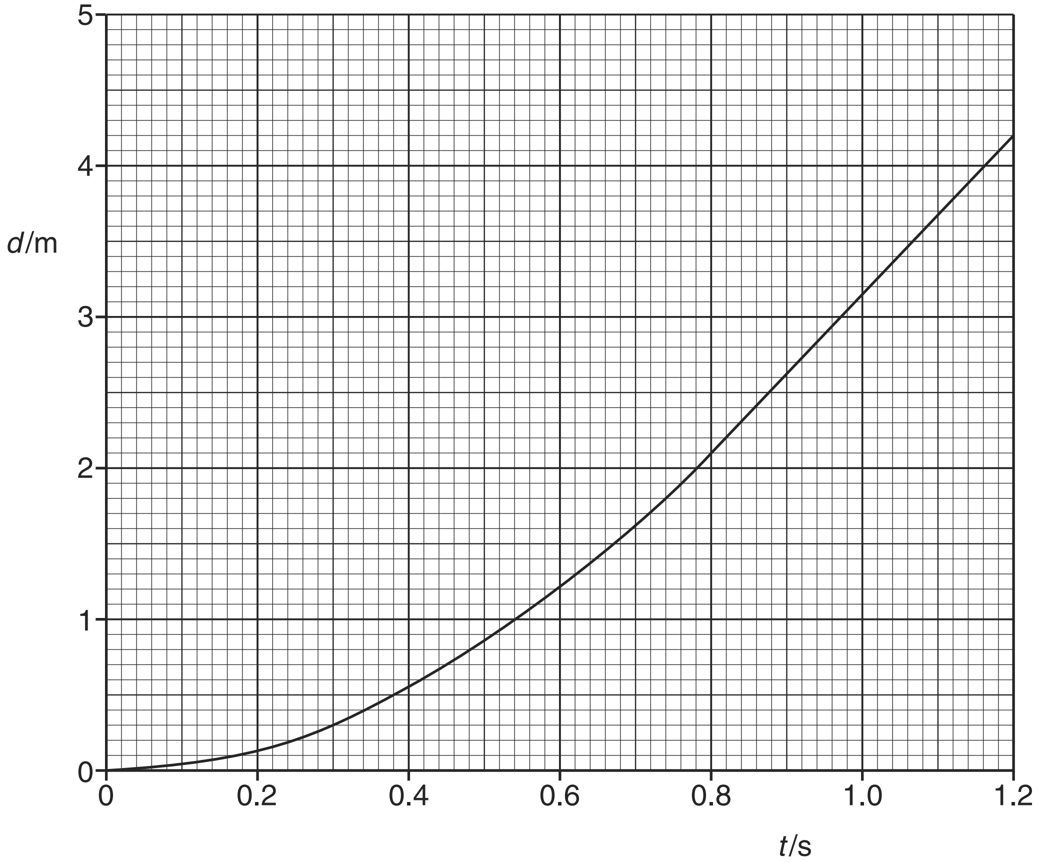


Fig. 2.2

For Examiner's Use

(i) By reference to Fig. 2.2, explain how it can be deduced that

1. the ball is initially at rest,

....

....

.... [2]

2. air resistance is not negligible.

....

.... [1]

(ii) Use Fig. 2.2 to determine the speed of the ball at a time of 0.40 s after it has been released.

speed = ... $m\ s^{-1}$ [2]

(iii) On Fig. 2.2, sketch a graph to show the variation with time *t* of the distance *d* moved by the ball for negligible air resistance. You are not expected to carry out any further calculations. [3]

2 **(a)** The distance *s* moved by an object in time *t* may be given by the expression

$$s = \frac{1}{2}at^2$$

where *a* is the acceleration of the object.

State two conditions for this expression to apply to the motion of the object.

1. ....

....

2. ....

....
[2]

(b) A student takes a photograph of a steel ball of radius 5.0 cm as it falls from rest. The image of the ball is blurred, as illustrated in Fig. 2.1.
The image is blurred because the ball is moving while the photograph is being taken.

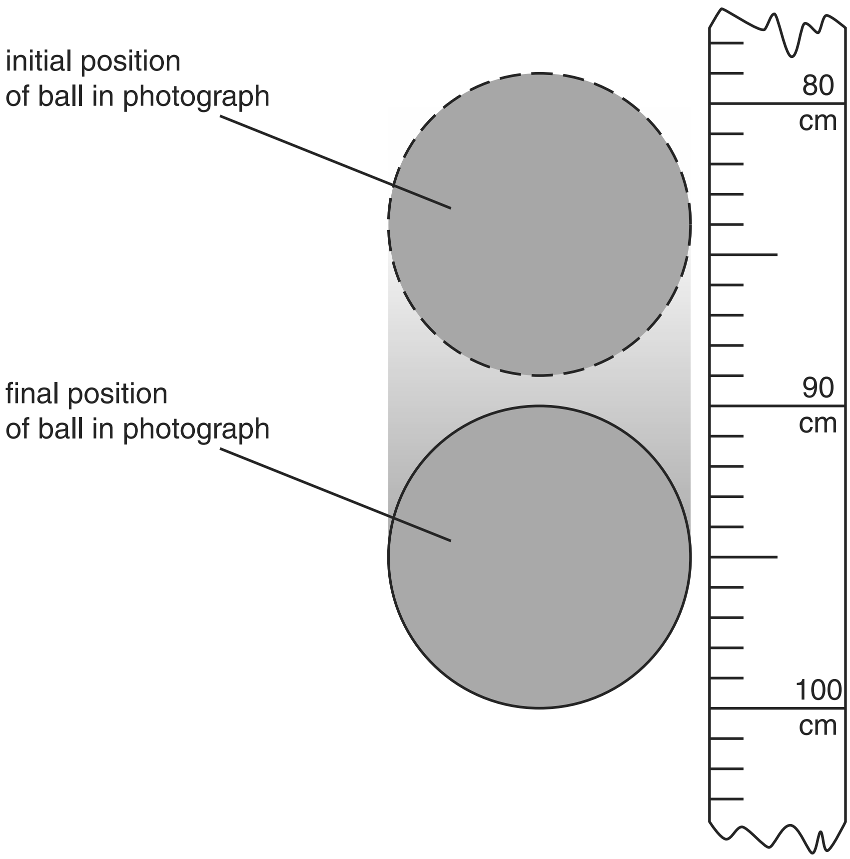


Fig. 2.1

The scale shows the distance fallen from rest by the ball. At time $t = 0$, the top of the ball is level with the zero mark on the scale. Air resistance is negligible.

Calculate, to an appropriate number of significant figures,

(i) the time the ball falls before the photograph is taken,

time = ... s [3]

(ii) the time interval during which the photograph is taken.

time interval = ... s [3]

(c) The student in **(b)** takes a second photograph starting at the same position on the scale. The ball has the same radius but is less dense, so that air resistance is not negligible.

State and explain the changes that will occur in the photograph.

....

....

....

....[2]

4 A student takes measurements to determine a value for the acceleration of free fall. Some of the apparatus used is illustrated in Fig. 4.1.

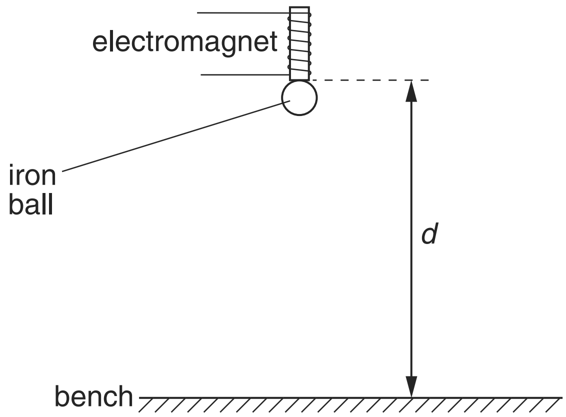


Fig. 4.1

The student measures the vertical distance *d* between the base of the electromagnet and the bench. The time *t* for an iron ball to fall from the electromagnet to the bench is also measured.
Corresponding values of t^2 and *d* are shown in Fig. 4.2.

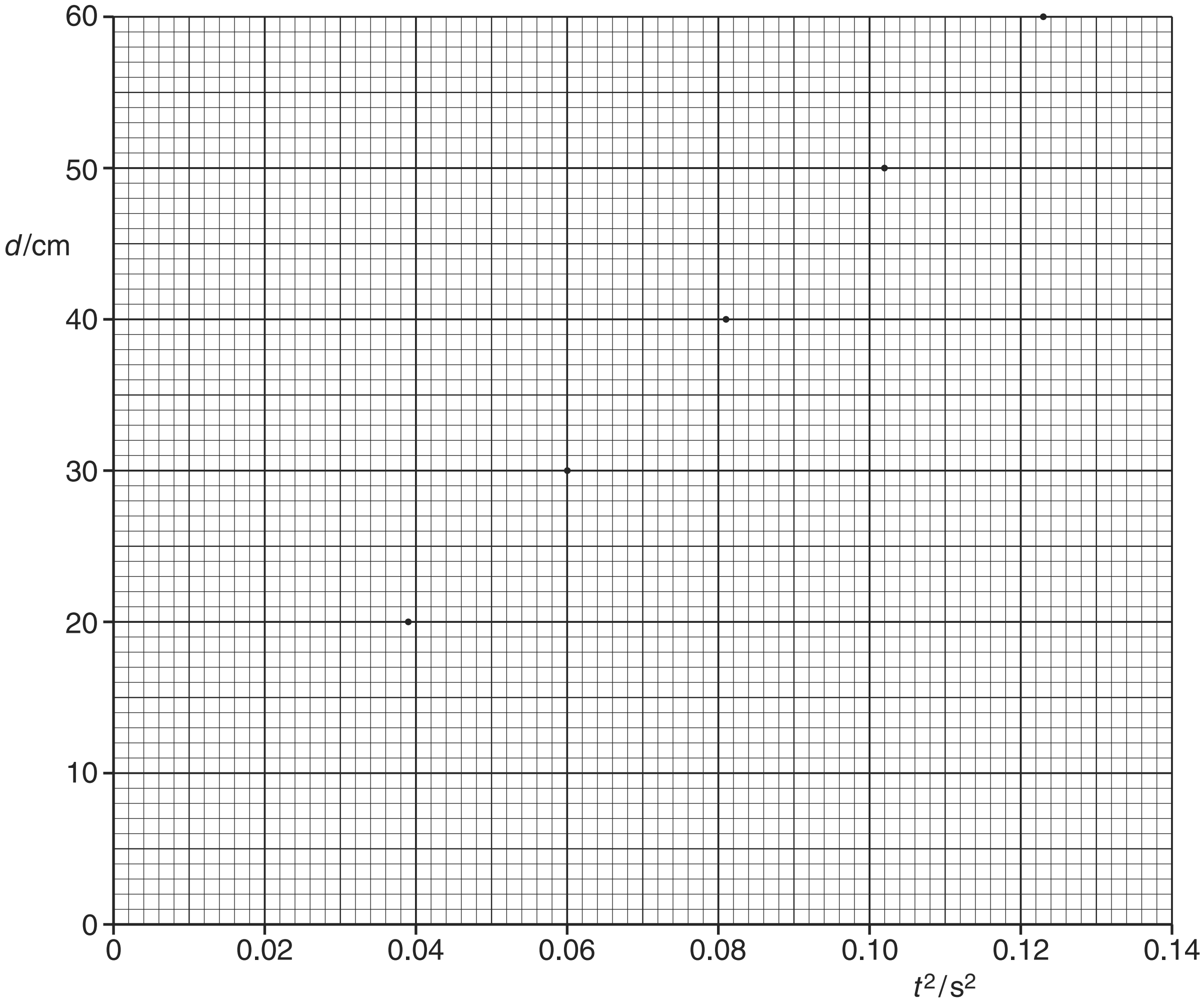


Fig. 4.2

(a) On Fig. 4.2, draw the line of best fit for the points. [1]

(b) State and explain why there is a non-zero intercept on the graph of Fig. 4.2.

....

....

.... [2]

(c) Determine the student's value for

(i) the diameter of the ball,

diameter = ... cm [1]

(ii) the acceleration of free fall.

acceleration = ... $m\,s^{-2}$ [3]

3 A helicopter has a cable hanging from it towards the sea below, as shown in Fig. 3.1.

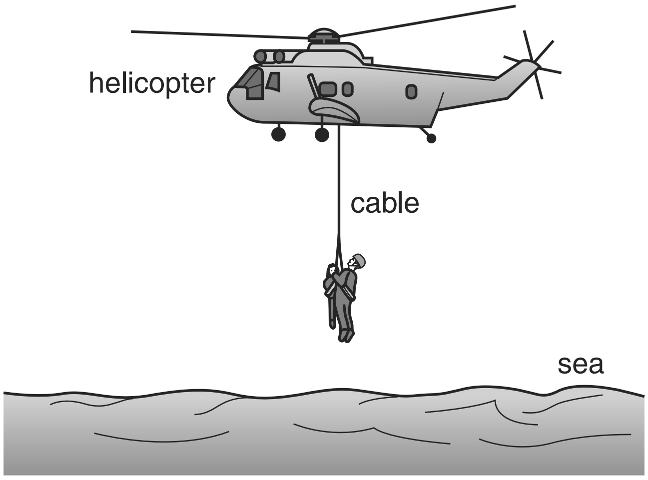


Fig. 3.1

A man of mass 80 kg rescues a child of mass 50.5 kg. The two are attached to the cable and are lifted from the sea to the helicopter. The lifting process consists of an initial uniform acceleration followed by a period of constant velocity and then completed by a final uniform deceleration.

(a) Calculate the combined weight of the man and child.

weight = ... N [1]

(b) Calculate the tension in the cable during

(i) the initial acceleration of 0.570 m s^{-2},

tension = ... N [2]

(ii) the period of constant velocity of 2.00 m s^{-1}.

tension = ... N [1]

For Examiner's Use

(c) During the final deceleration the tension in the cable is 1240 N. Calculate this deceleration.

deceleration = ... $m s^{-2}$ [2]

(d) (i) Calculate the time over which the man and child are

1. moving with uniform acceleration,

time = ... s [1]

2. moving with uniform deceleration.

time = ... s [1]

(ii) The time over which the man and child are moving with constant velocity is 20 s. On Fig. 3.2, sketch a graph to show the variation with time of the velocity of the man and child for the complete lifting process.

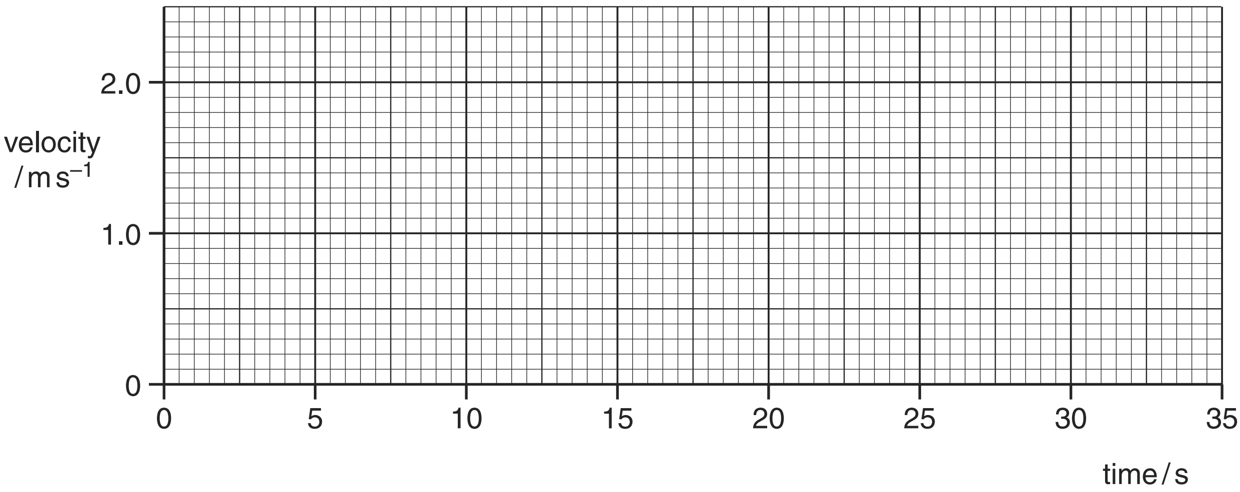


Fig. 3.2

[2]

1 The variation with time t of the displacement s for a car is shown in Fig. 1.1.

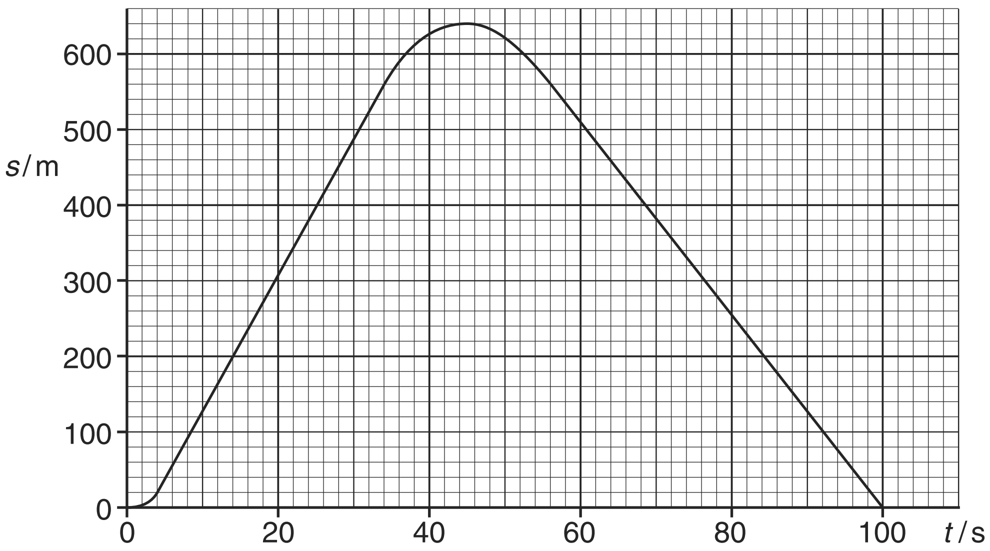


Fig. 1.1

(a) Determine the magnitude of the average velocity between the times 5.0 s and 35.0 s.

average velocity = ... m s^{-1} [2]

(b) On Fig. 1.2, sketch the variation with time t of the velocity v for the car.

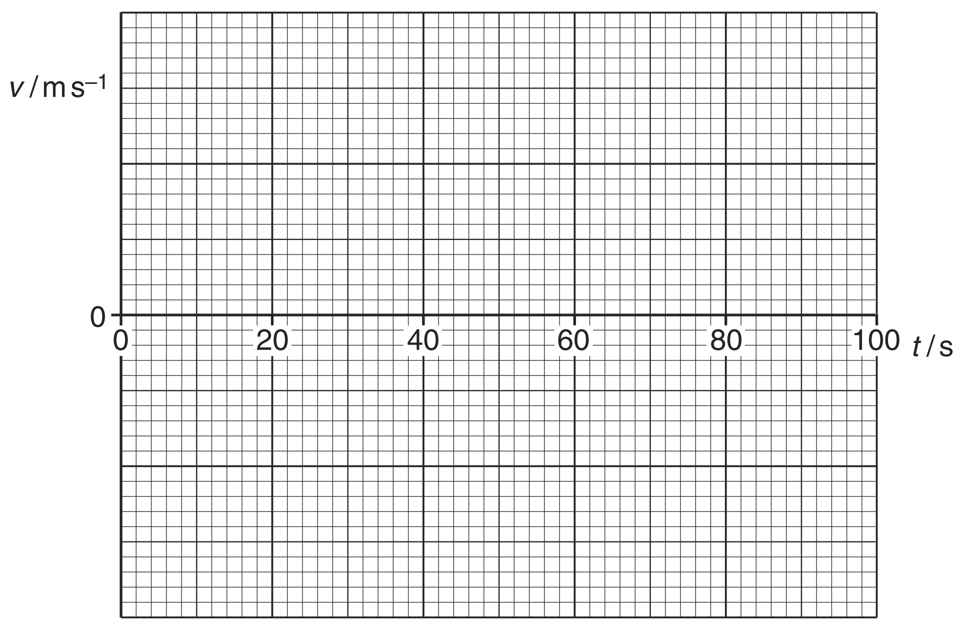


Fig. 1.2

[4]

2 The variation with time t of velocity v of a car is shown in Fig. 2.1.

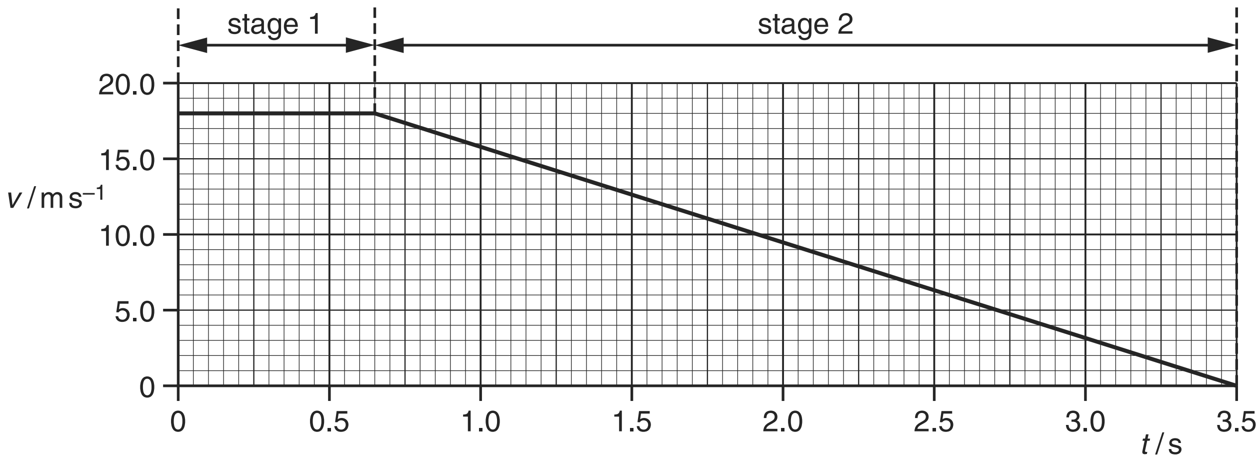


Fig. 2.1

At time $t = 0$, the driver sees an obstacle in the road. A short time later, the driver applies the brakes. The car travels in two stages, as shown in Fig. 2.1.

(a) Use Fig. 2.1 to describe the velocity of the car in

1. stage 1,

....

....[1]

2. stage 2.

....

....[1]

(b) (i) Calculate the distance travelled by the car from $t = 0$ to $t = 3.5$ s.

total distance = ... m [2]

(ii) The car has a total mass of 1250 kg. Determine the total resistive force acting on the car in stage 2.

For Examiner's Use

force = ... N [3]

(c) For safety reasons drivers are asked to travel at lower speeds. For each stage, describe and explain the effect on the distance travelled for the same car and driver travelling at half the initial speed shown in Fig. 2.1.

(i) stage 1:

....

....

....[1]

(ii) stage 2:

....

....

....

....[2]

For Examiner's Use

2 A ball is thrown vertically down towards the ground with an initial velocity of $4.23\,m\,s^{-1}$. The ball falls for a time of 1.51 s before hitting the ground. Air resistance is negligible.

(a) **(i)** Show that the downwards velocity of the ball when it hits the ground is $19.0\,m\,s^{-1}$.

[2]

(ii) Calculate, to three significant figures, the distance the ball falls to the ground.

distance = ... m [2]

(b) The ball makes contact with the ground for 12.5 ms and rebounds with an upwards velocity of $18.6\,m\,s^{-1}$. The mass of the ball is 46.5 g.

(i) Calculate the average force acting on the ball on impact with the ground.

magnitude of force = ... N

direction of force ....

[4]

(ii) Use conservation of energy to determine the maximum height the ball reaches after it hits the ground.

height = ... m [2]

(c) State and explain whether the collision the ball makes with the ground is elastic or inelastic.

....

....

....[1]

2 **(a)** A ball is thrown vertically down towards the ground and rebounds as illustrated in Fig. 2.1.

For Examiner's Use

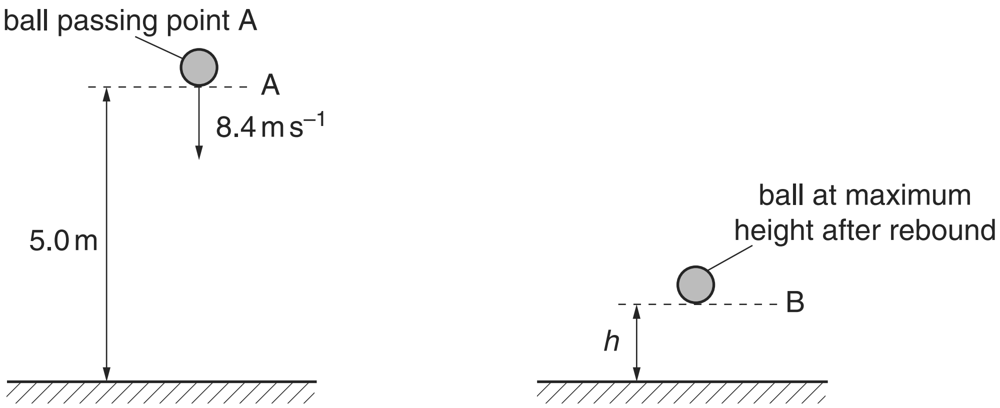


Fig. 2.1

As the ball passes A, it has a speed of $8.4\,\mathrm{m\,s^{-1}}$. The height of A is 5.0 m above the ground. The ball hits the ground and rebounds to B. Assume that air resistance is negligible.

(i) Calculate the speed of the ball as it hits the ground.

speed = ... $\mathrm{m\,s^{-1}}$ [2]

(ii) Show that the time taken for the ball to reach the ground is 0.47 s.

[1]

For Examiner's Use

(b) The ball rebounds vertically with a speed of 4.2 m s^{-1} as it leaves the ground. The time the ball is in contact with the ground is 20 ms. The ball rebounds to a maximum height *h*.

The ball passes A at time $t = 0$. On Fig. 2.2, plot a graph to show the variation with time *t* of the velocity *v* of the ball. Continue the graph until the ball has rebounded from the ground and reaches B.

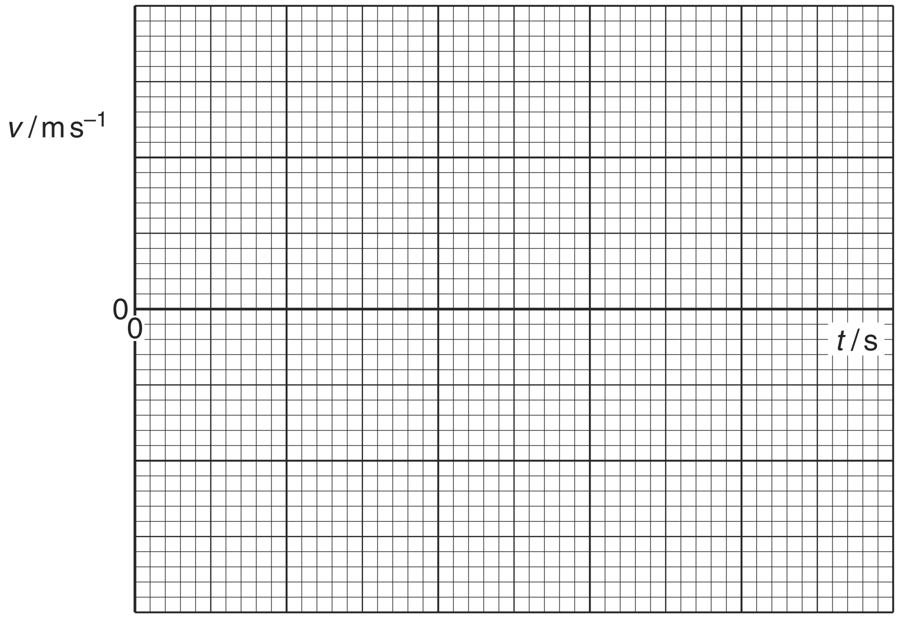


Fig. 2.2 [3]

(c) The ball has a mass of 0.050 kg. It moves from A and reaches B after rebounding.

(i) For this motion, calculate the change in

1. kinetic energy,

change in kinetic energy = ... J [2]

2. gravitational potential energy.

change in potential energy = ... J [3]

For Examiner's Use

(ii) State and explain the total change in energy of the ball for this motion.

....

....

....

....[2]

For Examiner's Use

2 **(a)** A student walks from A to B along the path shown in Fig. 2.1.

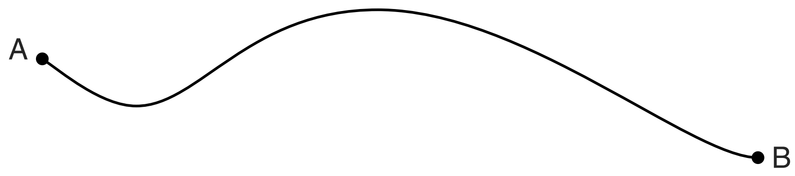


Fig. 2.1

The student takes time *t* to walk from A to B.

(i) State the quantity, apart from *t*, that must be measured in order to determine the average value of

1. speed,

....

....[1]

2. velocity.

....

....[1]

(ii) Define *acceleration*.

....[1]

(b) A girl falls vertically onto a trampoline, as shown in Fig. 2.2.

For Examiner's Use

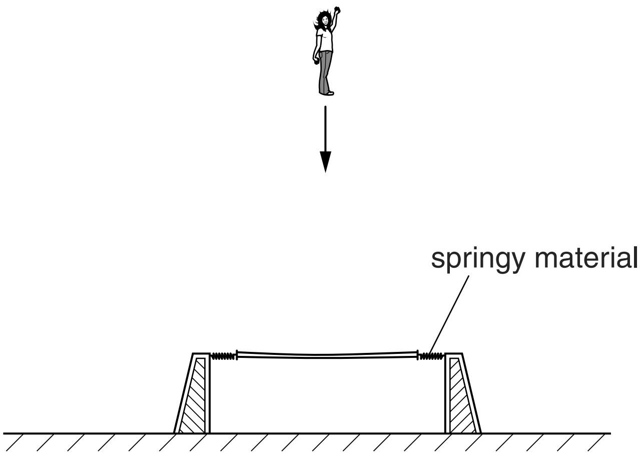


Fig. 2.2

The trampoline consists of a central section supported by springy material. At time t = 0 the girl starts to fall. The girl hits the trampoline and rebounds vertically. The variation with time t of velocity v of the girl is illustrated in Fig. 2.3.

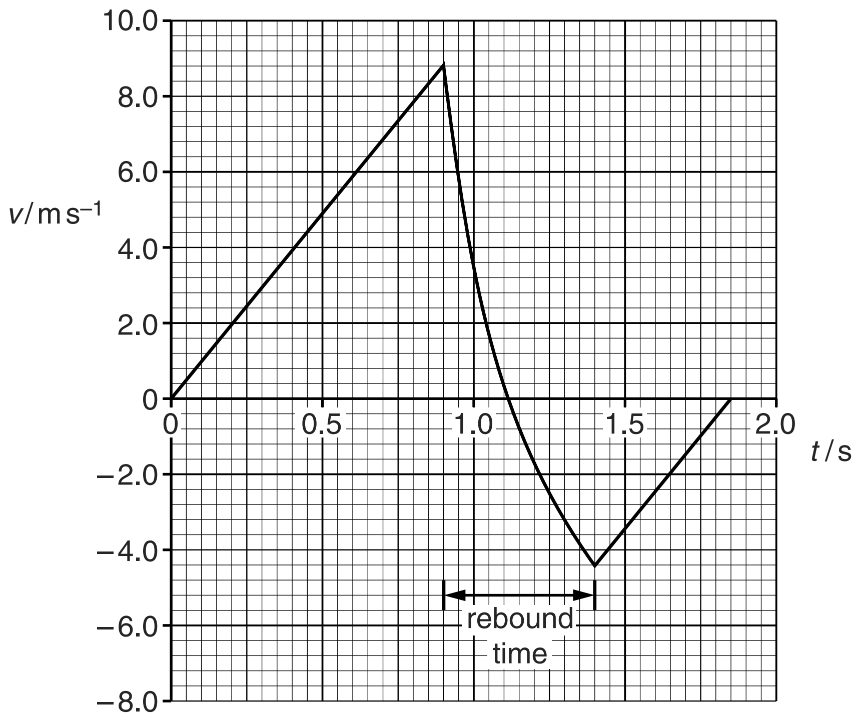


Fig. 2.3

For the motion of the girl, calculate

(i) the distance fallen between time t = 0 and when she hits the trampoline,

distance = ... m [2]

For Examiner's Use

(ii) the average acceleration during the rebound.

acceleration = ... $m s^{-2}$ [2]

(c) **(i)** Use Fig. 2.3 to compare, without calculation, the accelerations of the girl before and after the rebound. Explain your answer.

....

....

.... [2]

(ii) Use Fig. 2.3 to compare, without calculation, the potential energy of the girl at $t = 0$ and $t = 1.85$ s. Explain your answer.

....

....

.... [2]

For Examiner's Use

3 **(a)** Define

(i) *velocity*,

....

.... [1]

(ii) *acceleration*.

....

.... [1]

(b) A car of mass 1500 kg travels along a straight horizontal road.
The variation with time t of the displacement x of the car is shown in Fig. 3.1.

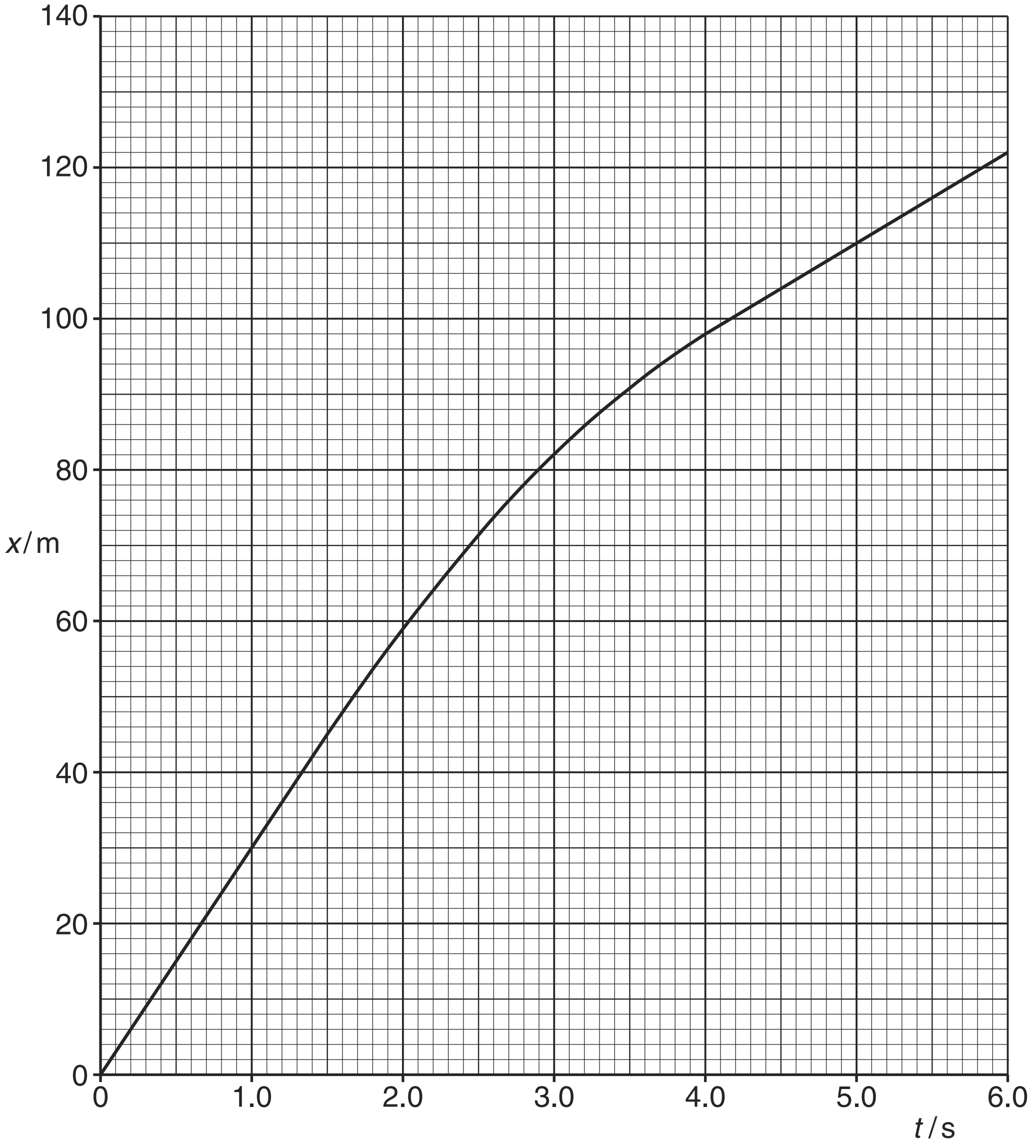


Fig. 3.1

For Examiner's Use

(i) Use Fig. 3.1 to describe qualitatively the velocity of the car during the first six seconds of the motion shown.
Give reasons for your answers.

....

....

....

....

.... [3]

(ii) Calculate the average velocity during the time interval $t = 0$ to $t = 1.5\,\text{s}$.

average velocity = ... m s^{-1} [1]

(iii) Show that the average acceleration between $t = 1.5\,\text{s}$ and $t = 4.0\,\text{s}$ is $-7.2\,\text{m s}^{-2}$.

[2]

(iv) Calculate the average force acting on the car between $t = 1.5\,\text{s}$ and $t = 4.0\,\text{s}$.

force = ... N [2]

3 (a) State Newton's first law of motion.

....

.... [1]

(b) A box slides down a slope, as shown in Fig. 3.1.

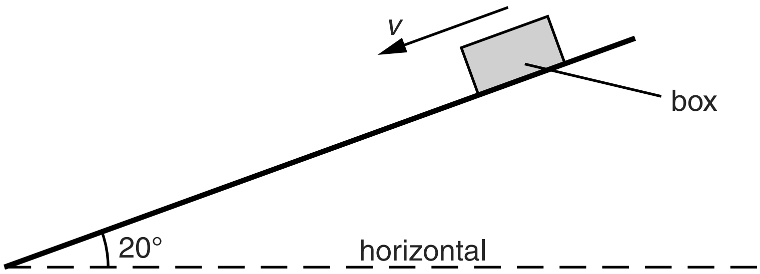


Fig. 3.1

The angle of the slope to the horizontal is 20°. The box has a mass of 65 kg. The total resistive force *R* acting on the box is constant as it slides down the slope.

(i) State the names and directions of the other two forces acting on the box.

1. ....

2. ....
[2]

(ii) The variation with time *t* of the velocity *v* of the box as it moves down the slope is shown in Fig. 3.2.

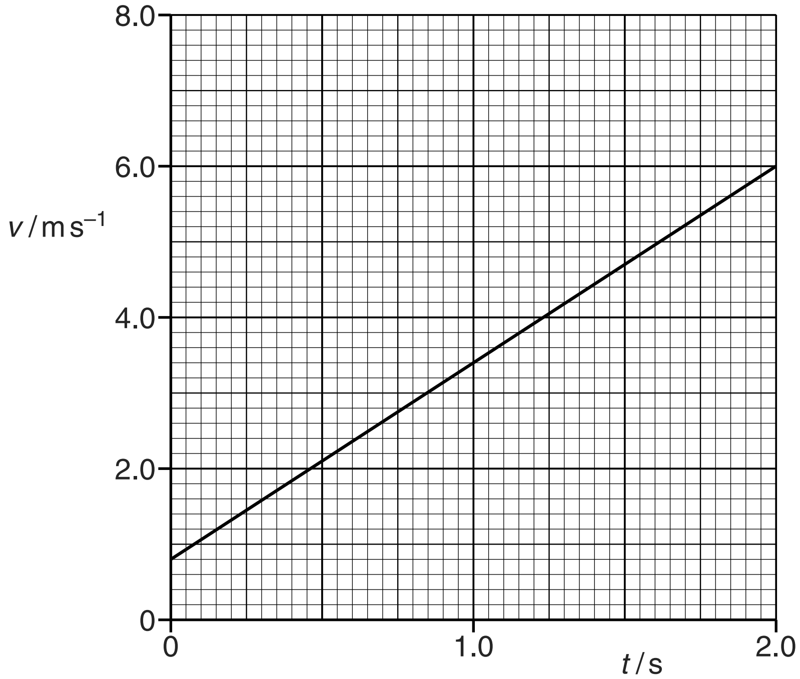


Fig. 3.2

1. Use data from Fig. 3.2 to show that the acceleration of the box is 2.6 m s^{-2}.

[2]

2. Calculate the resultant force on the box.

resultant force = ... N [1]

3. Determine the resistive force *R* on the box.

R = ... N [3]

Answer **all** the questions in the spaces provided.

1 **(a)** **(i)** Define *velocity*.

....

.... [1]

(ii) Distinguish between *speed* and *velocity*.

....

.... [2]

(b) A car of mass 1500 kg moves along a straight, horizontal road. The variation with time t of the velocity v for the car is shown in Fig. 1.1.

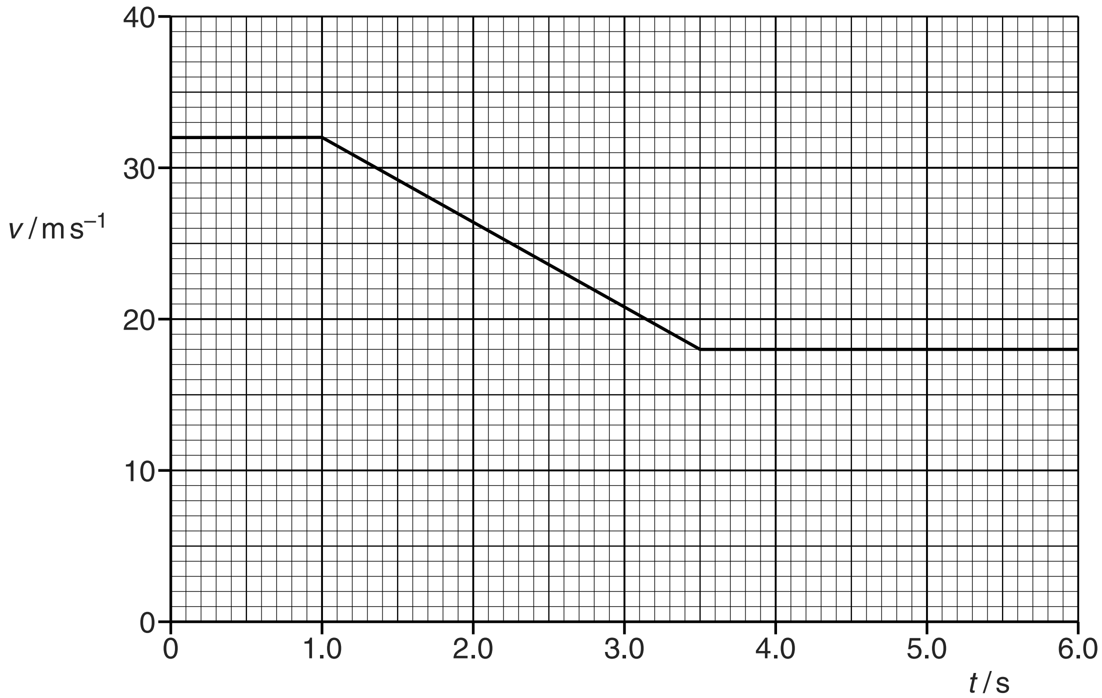


Fig. 1.1

The brakes of the car are applied from t = 1.0 s to t = 3.5 s.
For the time when the brakes are applied,

(i) calculate the distance moved by the car,

distance = ... m [3]

(ii) calculate the magnitude of the resultant force on the car.

resultant force = ... N [3]

(c) The direction of motion of the car in **(b)** at time t = 2.0 s is shown in Fig. 1.2.

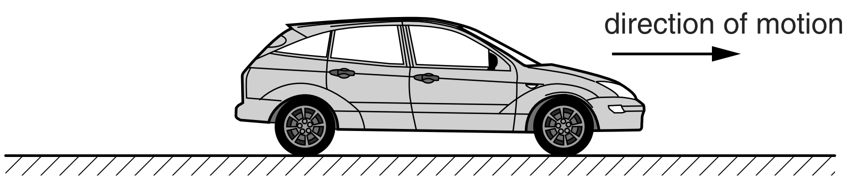


Fig. 1.2

On Fig. 1.2, show with arrows the directions of the acceleration (label this arrow A) and the resultant force (label this arrow F). [1]

2 The variation with time t of the velocity v of a ball is shown in Fig. 2.1.

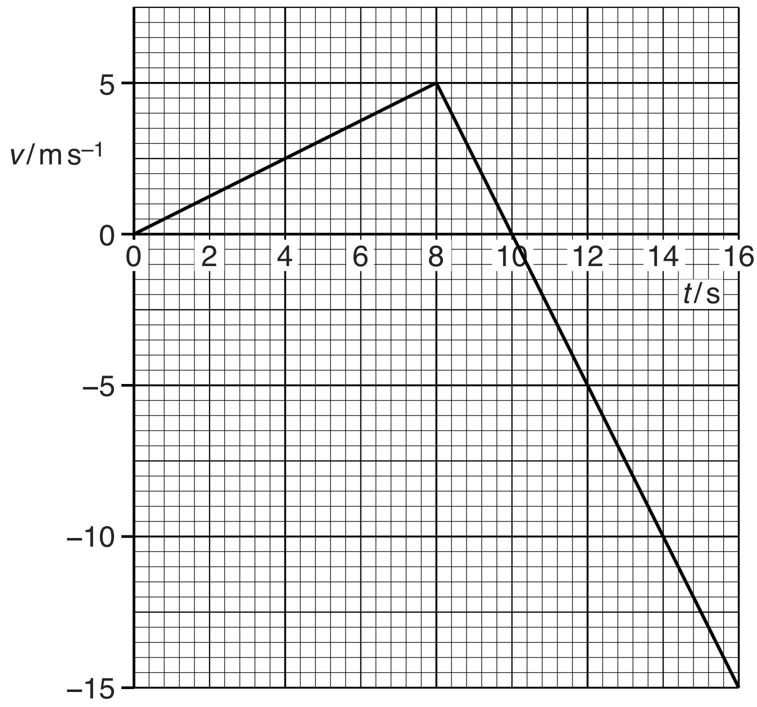


Fig. 2.1

The ball moves in a straight line from a point P at $t = 0$. The mass of the ball is 400 g.

(a) Use Fig. 2.1 to describe, without calculation, the velocity of the ball from $t = 0$ to $t = 16$ s.

....

....

....

....

....[2]

(b) Use Fig. 2.1 to calculate, for the ball,

(i) the displacement from P at $t = 10\,s$,

displacement = ... m [2]

(ii) the acceleration at $t = 10\,s$,

acceleration = ... $m\,s^{-2}$ [2]

(iii) the maximum kinetic energy.

kinetic energy = ... J [2]

(c) Use your answers in **(b)(i)** and **(b)(ii)** to determine the time from $t = 0$ for the ball to return to P.

time = ... s [2]

2 A stone is thrown vertically upwards. The variation with time t of the displacement s of the stone is shown in Fig. 2.1.

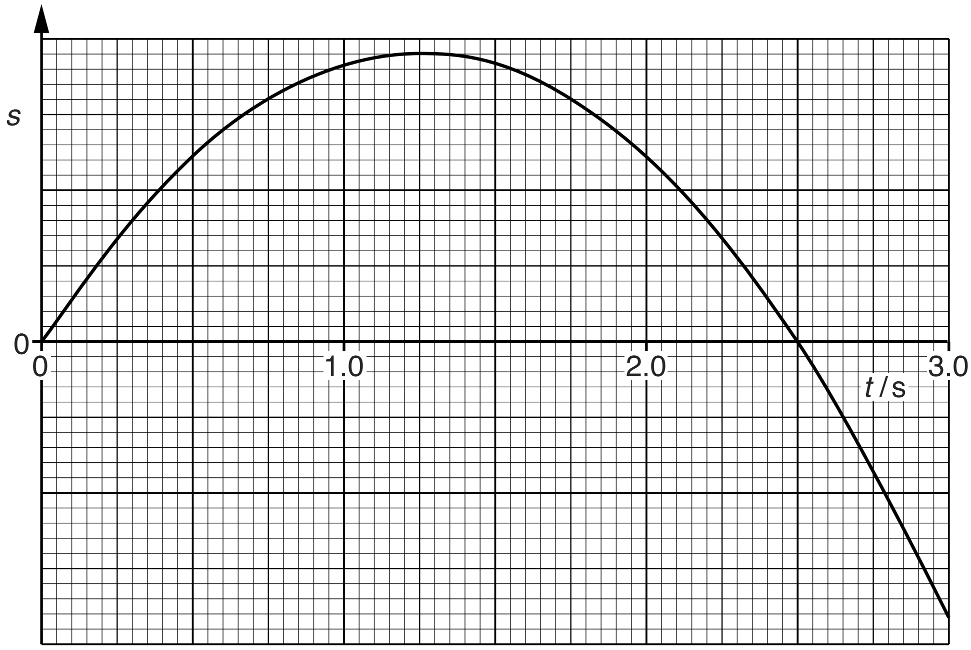


Fig. 2.1

(a) Use Fig. 2.1 to describe, without calculation, the speed of the stone from $t = 0$ to $t = 3.0$ s.

....

....

.... [2]

(b) Assume air resistance is negligible and therefore the stone has constant acceleration.

Calculate, for the stone,

(i) the speed at 3.0 s,

speed = ... $m s^{-1}$ [3]

(ii) the distance travelled from $t = 0$ to $t = 3.0\,s$,

distance = ... m [3]

(iii) the displacement from $t = 0$ to $t = 3.0\,s$.

displacement = ... m

direction ....
[2]

(c) On Fig. 2.2, draw the variation with time t of the velocity v of the stone from $t = 0$ to $t = 3.0\,s$.

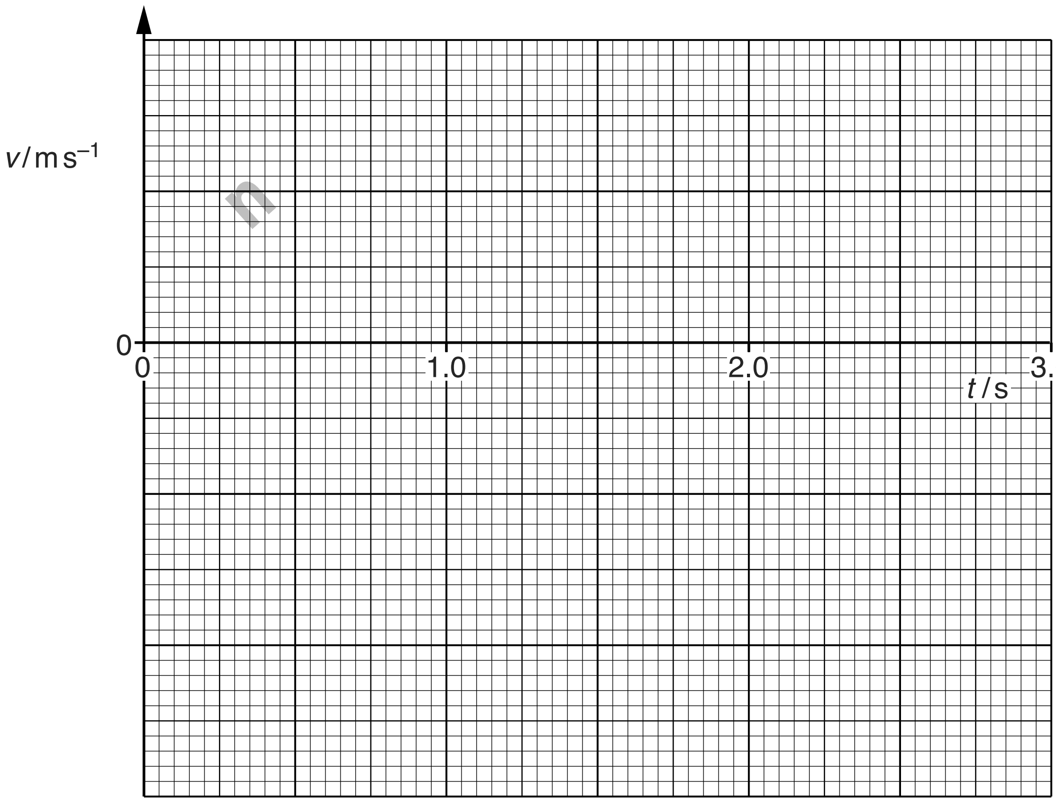


Fig. 2.2

[3]

2 **(a)** Define *speed* and *velocity* and use these definitions to explain why one of these quantities is a scalar and the other is a vector.

speed: ....

velocity: ....

....

.... [2]

(b) A ball is released from rest and falls vertically. The ball hits the ground and rebounds vertically, as shown in Fig. 2.1.

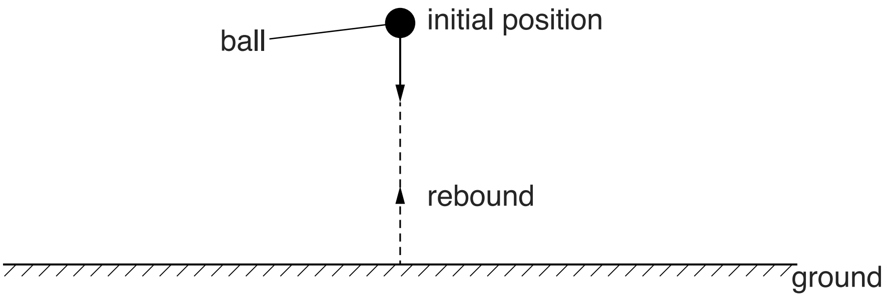


Fig. 2.1

The variation with time *t* of the velocity *v* of the ball is shown in Fig. 2.2.

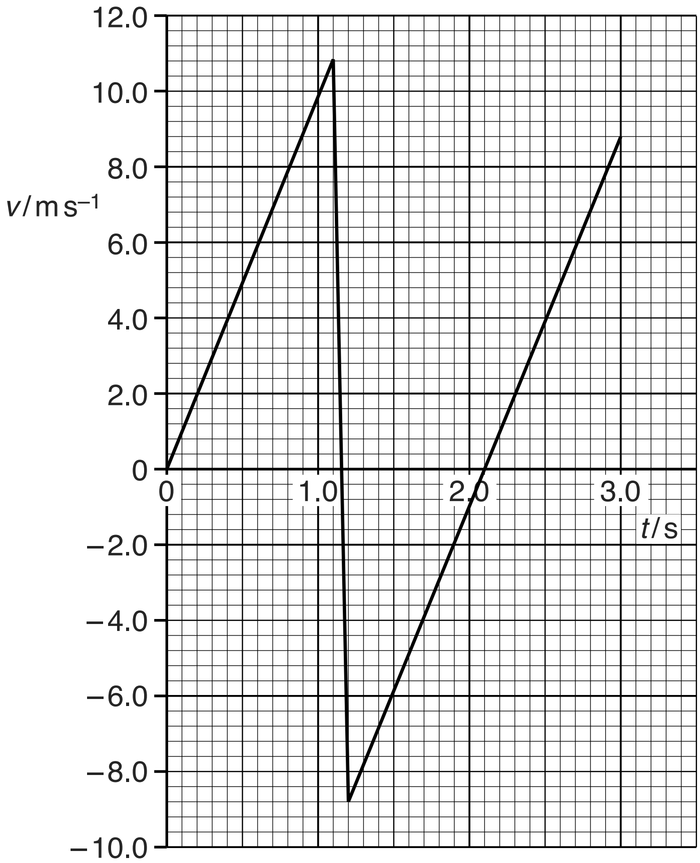


Fig. 2.2

Air resistance is negligible.

(i) Without calculation, use Fig. 2.2 to describe the variation with time *t* of the velocity of the ball from $t = 0$ to $t = 2.1$ s.

....

....

....

....

....

....[3]

(ii) Calculate the acceleration of the ball after it rebounds from the ground. Show your working.

acceleration = ... $m s^{-2}$ [3]

(iii) Calculate, for the ball, from $t = 0$ to $t = 2.1\,s$,

1. the distance moved,

distance = ... m [3]

2. the displacement from the initial position.

displacement = ... m [2]

(iv) On Fig. 2.3, sketch the variation with t of the speed of the ball.

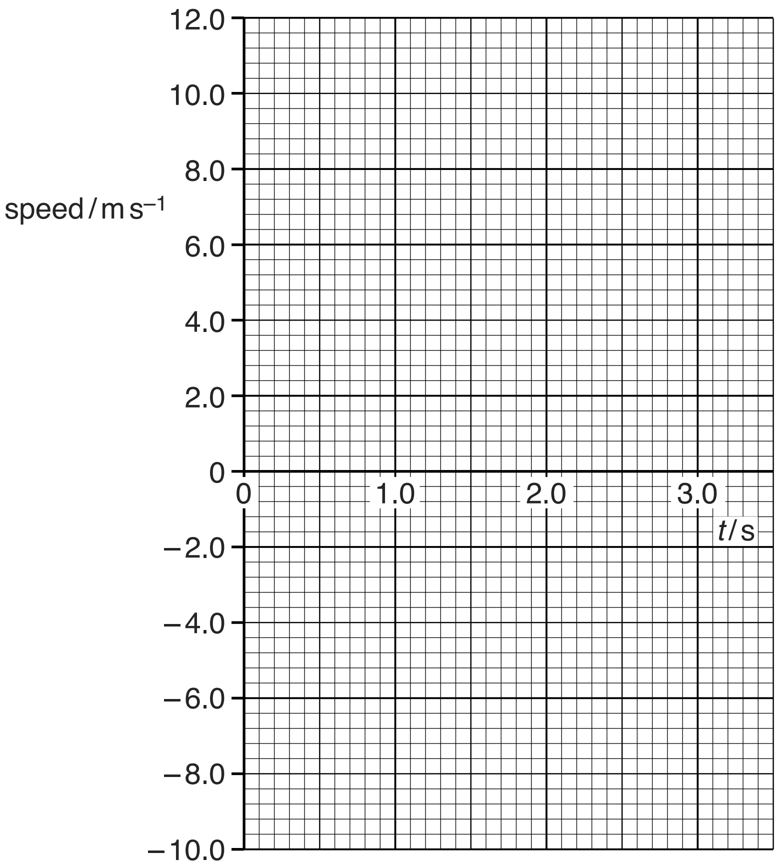


Fig. 2.3

[2]

For Examiner's Use

3 **(a)** A stone of mass 56 g is thrown horizontally from the top of a cliff with a speed of $18\,m\,s^{-1}$, as illustrated in Fig. 4.1.

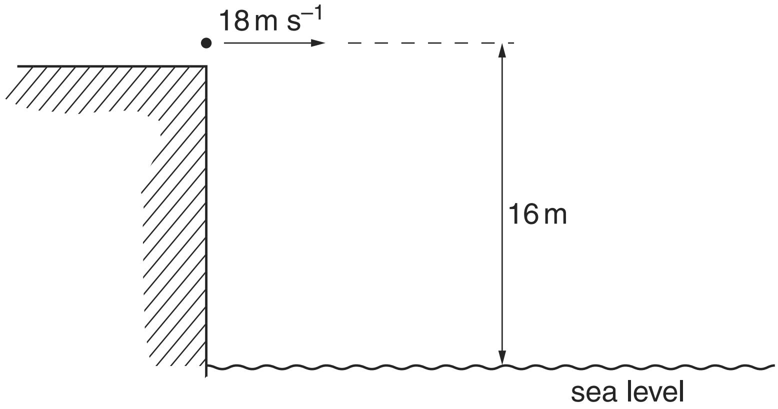


Fig. 4.1

The initial height of the stone above the level of the sea is 16 m. Air resistance may be neglected.

(i) Calculate the change in gravitational potential energy of the stone as a result of falling through 16 m.

change = ... J [2]

(ii) Calculate the total kinetic energy of the stone as it reaches the sea.

kinetic energy = ... J [3]

(b) Use your answer in **(a)(ii)** to show that the speed of the stone as it hits the water is approximately 25 m s^{-1}.

[1]

(c) State the horizontal velocity of the stone as it hits the water.

horizontal velocity = ...m s^{-1} [1]

(d) **(i)** On the grid of Fig. 4.2, draw a vector diagram to represent the horizontal velocity and the resultant velocity of the stone as it hits the water. [1]

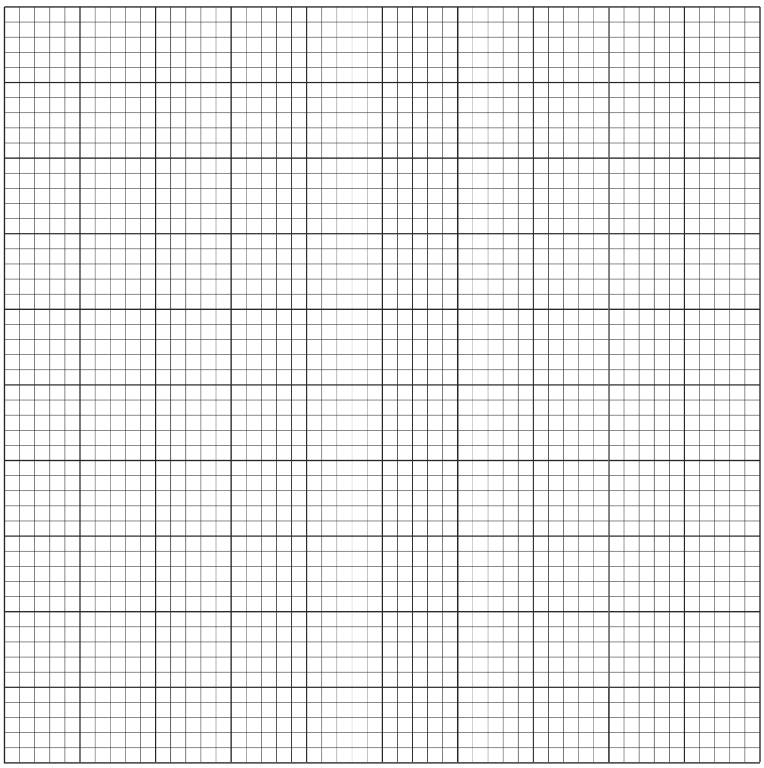


Fig. 4.2

(ii) Use your vector diagram to determine the angle with the horizontal at which the stone hits the water.

angle = ... ° [2]

15 A small ball is thrown horizontally with a speed of $4.0\,m\,s^{-1}$. It falls through a vertical height of 1.96 m before bouncing off a horizontal plate, as illustrated in Fig. 3.1.

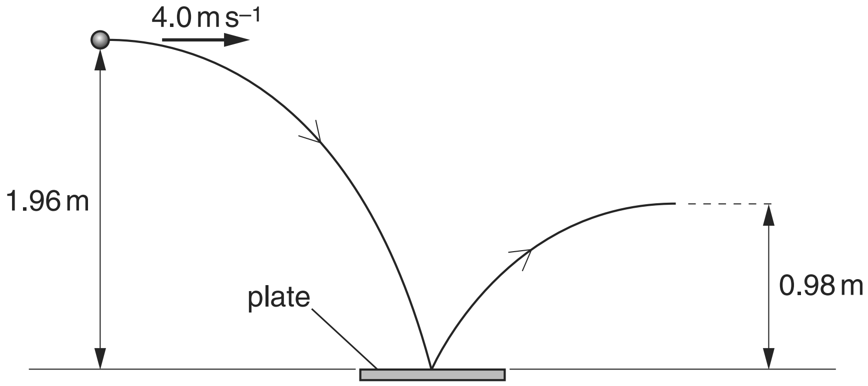


Fig. 3.1

Air resistance is negligible.

(a) For the ball, as it hits the horizontal plate,

(i) state the magnitude of the horizontal component of its velocity,

horizontal velocity = ... $m\,s^{-1}$ [1]

(ii) show that the vertical component of the velocity is $6.2\,m\,s^{-1}$.

[1]

(b) The components of the velocity in **(a)** are both vectors.

Complete Fig. 3.2 to draw a vector diagram, to scale, to determine the velocity of the ball as it hits the horizontal plate.

Fig. 3.2

velocity = ...m s^{-1}

at .... ° to the vertical

[3]

(c) After bouncing on the plate, the ball rises to a vertical height of 0.98 m.

(i) Calculate the vertical component of the velocity of the ball as it leaves the plate.

vertical velocity = ... m s^{-1} [2]

For Examiner's Use

(ii) The ball of mass 34 g is in contact with the plate for a time of 0.12 s.

Use your answer in **(c)(i)** and the data in **(a)(ii)** to calculate, for the ball as it bounces on the plate,

1. the change in momentum,

change = ... $kg\,m\,s^{-1}$ [3]

2. the magnitude of the average force exerted by the plate on the ball due to this momentum change.

force = ... N [2]

2 A ball is thrown horizontally from the top of a building, as shown in Fig. 2.1.

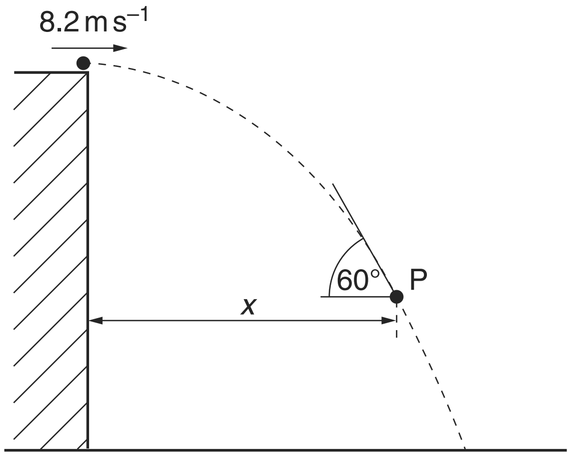


Fig. 2.1

The ball is thrown with a horizontal speed of $8.2\,\text{m s}^{-1}$. The side of the building is vertical. At point P on the path of the ball, the ball is distance x from the building and is moving at an angle of 60° to the horizontal. Air resistance is negligible.

(a) For the ball at point P,

(i) show that the vertical component of its velocity is $14.2\,\text{m s}^{-1}$,

[2]

(ii) determine the vertical distance through which the ball has fallen,

distance = ... m [2]

(iii) determine the horizontal distance x.

For Examiner's Use

x = ... m [2]

(b) The path of the ball in **(a)**, with an initial horizontal speed of $8.2\,m\,s^{-1}$, is shown again in Fig. 2.2.

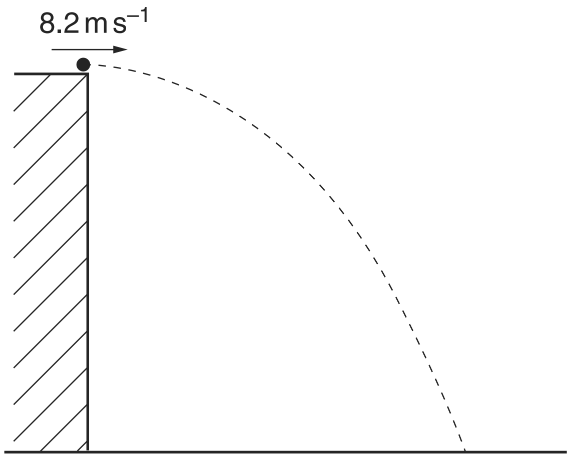


Fig. 2.2

On Fig. 2.2, sketch the new path of the ball for the ball having an initial horizontal speed

(i) greater than $8.2\,m\,s^{-1}$ and with negligible air resistance (label this path G), [2]

(ii) equal to $8.2\,m\,s^{-1}$ but with air resistance (label this path A). [2]

2 A ball is thrown from a point P, which is at ground level, as illustrated in Fig. 2.1.

For Examiner's Use

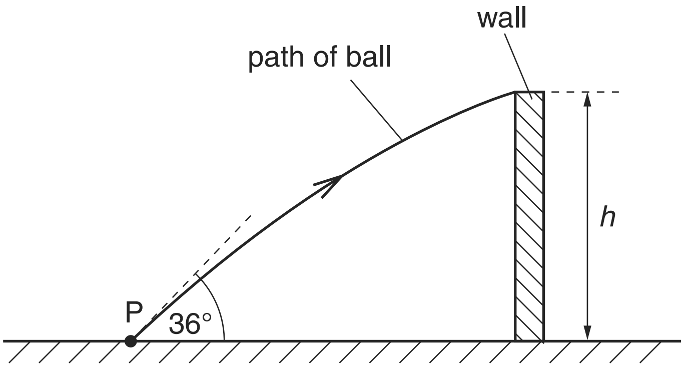


Fig. 2.1

The initial velocity of the ball is 12.4 m s^{-1} at an angle of 36° to the horizontal.
The ball just passes over a wall of height h. The ball reaches the wall 0.17 s after it has been thrown.

(a) Assuming air resistance to be negligible, calculate

(i) the horizontal distance of point P from the wall,

distance = ... m [2]

(ii) the height h of the wall.

h = ... m [3]

(b) A second ball is thrown from point P with the same velocity as the ball in **(a)**. For this ball, air resistance is not negligible.
This ball hits the wall and rebounds.

On Fig. 2.1, sketch the path of this ball between point P and the point where it first hits the ground. [2]

For Examiner's Use

1 **(a)** Distinguish between *scalar* quantities and *vector* quantities.

....

....

.... [2]

(b) In the following list, underline **all** the scalar quantities.

acceleration force kinetic energy mass power weight [1]

(c) A stone is thrown with a horizontal velocity of $20\,\mathrm{m\,s^{-1}}$ from the top of a cliff 15 m high. The path of the stone is shown in Fig. 1.1.

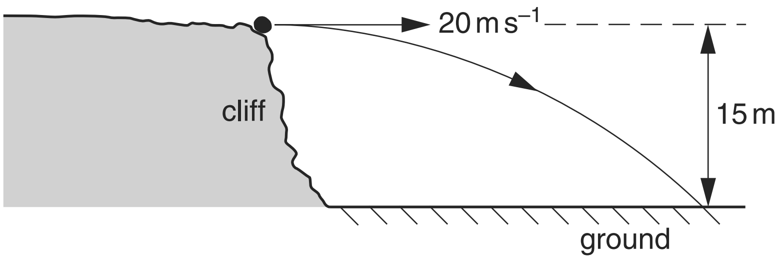


Fig. 1.1

Air resistance is negligible.

For this stone,

(i) calculate the time to fall 15 m,

time = ... s [2]

(ii) calculate the magnitude of the resultant velocity after falling 15 m,

resultant velocity = ... $\mathrm{m\,s^{-1}}$ [3]

(iii) describe the difference between the displacement of the stone and the distance that it travels.

....

....

.... [2]

For Examiner's Use

3 A ball is thrown against a vertical wall. The path of the ball is shown in Fig. 3.1.

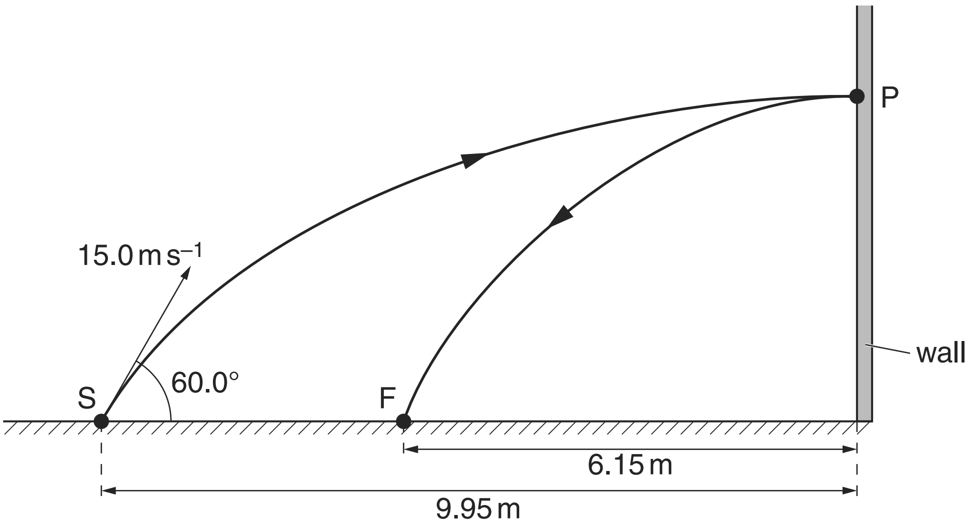


Fig. 3.1 (not to scale)

The ball is thrown from S with an initial velocity of 15.0 m s^{-1} at 60.0° to the horizontal. Assume that air resistance is negligible.

(a) For the ball at S, calculate

(i) its horizontal component of velocity,

horizontal component of velocity = ... m s^{-1} [1]

(ii) its vertical component of velocity.

vertical component of velocity = ... m s^{-1} [1]

(b) The horizontal distance from S to the wall is 9.95 m. The ball hits the wall at P with a velocity that is at right angles to the wall. The ball rebounds to a point F that is 6.15 m from the wall.

Using your answers in **(a)**,

(i) calculate the vertical height gained by the ball when it travels from S to P,

height = ... m [1]

(ii) show that the time taken for the ball to travel from S to P is 1.33 s,

For Examiner's Use

[1]

(iii) show that the velocity of the ball immediately after rebounding from the wall is about $4.6\,\text{m}\,\text{s}^{-1}$.

[1]

(c) The mass of the ball is 60×10^{-3} kg.

(i) Calculate the change in momentum of the ball as it rebounds from the wall.

change in momentum = ... N s [2]

(ii) State and explain whether the collision is elastic or inelastic.

....

....

.... [1]

2 **(a)** Explain what is meant by a *scalar* quantity and by a *vector* quantity.

scalar: ....

....

vector: ....

....
[2]

(b) A ball leaves point P at the top of a cliff with a horizontal velocity of 15 m s^{-1}, as shown in Fig. 2.1.

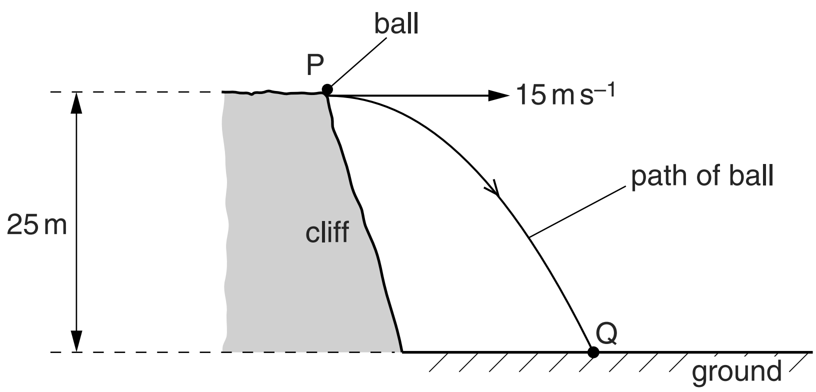


Fig. 2.1

The height of the cliff is 25 m. The ball hits the ground at point Q.
Air resistance is negligible.

(i) Calculate the vertical velocity of the ball just before it makes impact with the ground at Q.

vertical velocity = ... m s^{-1} [2]

(ii) Show that the time taken for the ball to fall to the ground is 2.3 s.

[1]

(iii) Calculate the magnitude of the displacement of the ball at point Q from point P.

displacement = ... m [4]

(iv) Explain why the distance travelled by the ball is different from the magnitude of the displacement of the ball.

....

....

....[2]

4 **(a)** Explain what is meant by *gravitational potential* energy and *kinetic* energy.

gravitational potential energy: ....

....

kinetic energy: ....

.... [2]

(b) A ball of mass 400 g is thrown with an initial velocity of 30.0 m s^{-1} at an angle of 45.0° to the horizontal, as shown in Fig. 4.1.

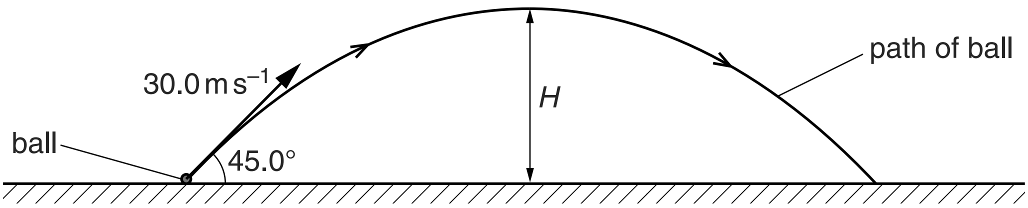


Fig. 4.1

Air resistance is negligible. The ball reaches a maximum height H after a time of 2.16 s.

(i) Calculate

1. the initial kinetic energy of the ball,

kinetic energy = ... J [3]

2. the maximum height H of the ball,

H = ... m [2]

3. the gravitational potential energy of the ball at height *H*.

potential energy = ... J [2]

(ii) **1.** Determine the kinetic energy of the ball at its maximum height.

kinetic energy = ... J [1]

2. Explain why the kinetic energy of the ball at maximum height is not zero.

....

.... [1]

2 A ball is thrown from A to B as shown in Fig. 2.1.

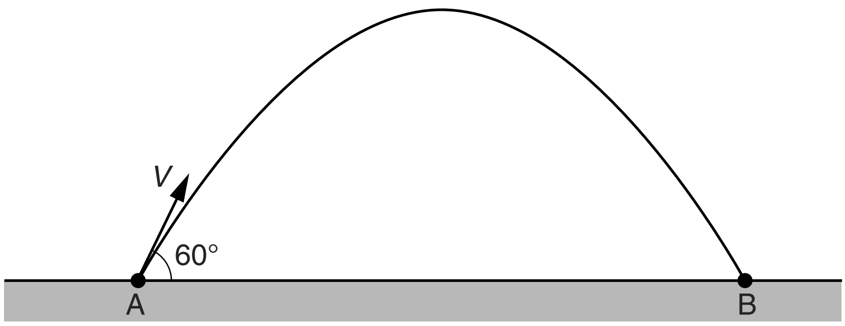


Fig. 2.1

The ball is thrown with an initial velocity V at 60° to the horizontal.
The variation with time t of the vertical component V_v of the velocity of the ball from t = 0 to t = 0.60 s is shown in Fig. 2.2.

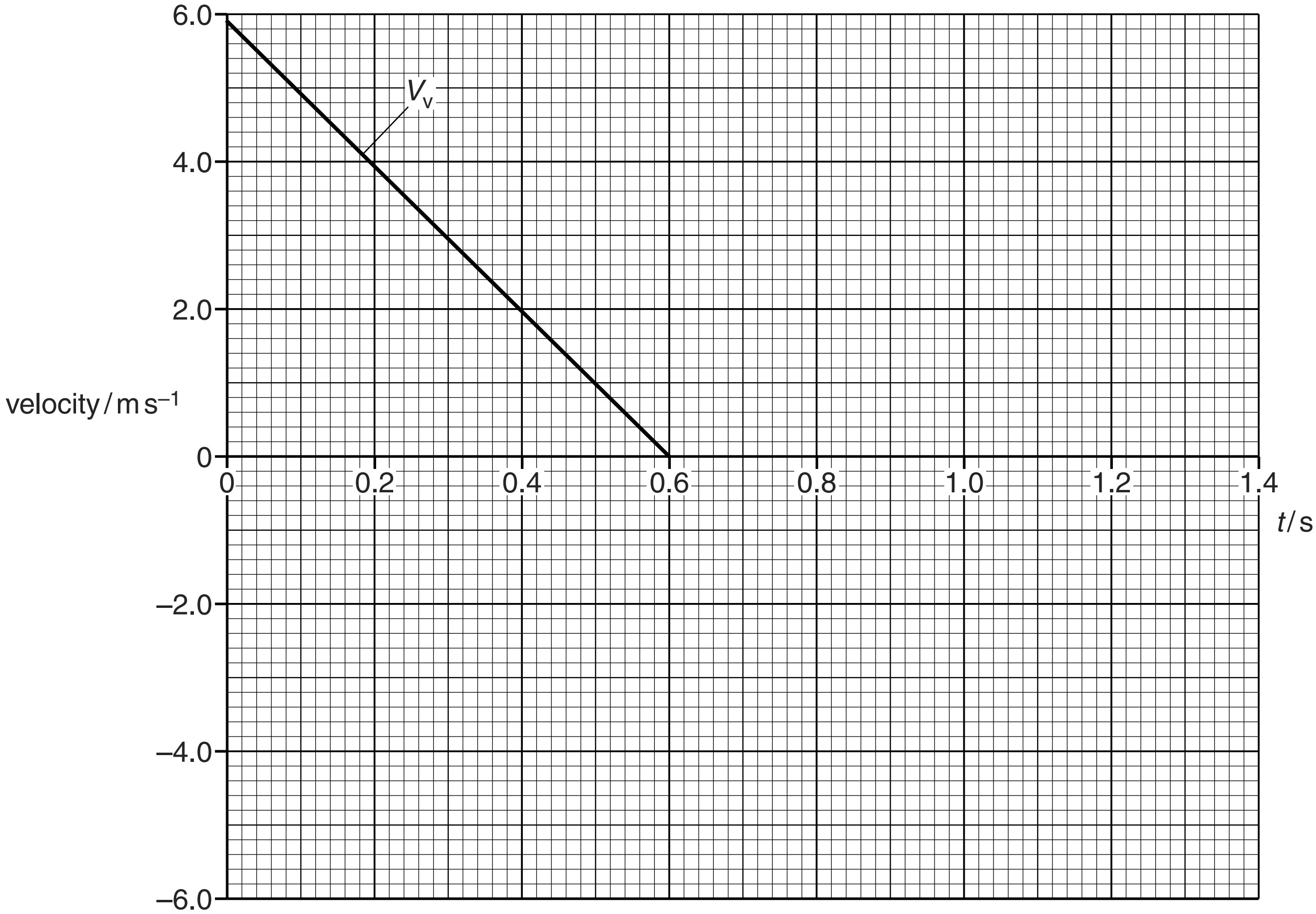


Fig. 2.2

Assume air resistance is negligible.

(a) **(i)** Complete Fig. 2.2 for the time until the ball reaches B. [2]

(ii) Calculate the maximum height reached by the ball.

height = ... m [2]

(iii) Calculate the horizontal component V_h of the velocity of the ball at time $t = 0$.

V_h = ... $m s^{-1}$ [2]

(iv) On Fig. 2.2, sketch the variation with t of V_h. **Label** this sketch V_h. [1]

(b) The ball has mass 0.65 kg.
Calculate, for the ball,

(i) the maximum kinetic energy,

maximum kinetic energy = ... J [3]

(ii) the maximum potential energy above the ground.

maximum potential energy = ... J [2]

1 (a) Explain what is meant by the *centre of gravity* of an object. 1

....

....

....[2]

(b) A non-uniform plank of wood XY is 2.50 m long and weighs 950 N. Force-meters (spring balances) A and B are attached to the plank at a distance of 0.40 m from each end, as illustrated in Fig. 3.1.

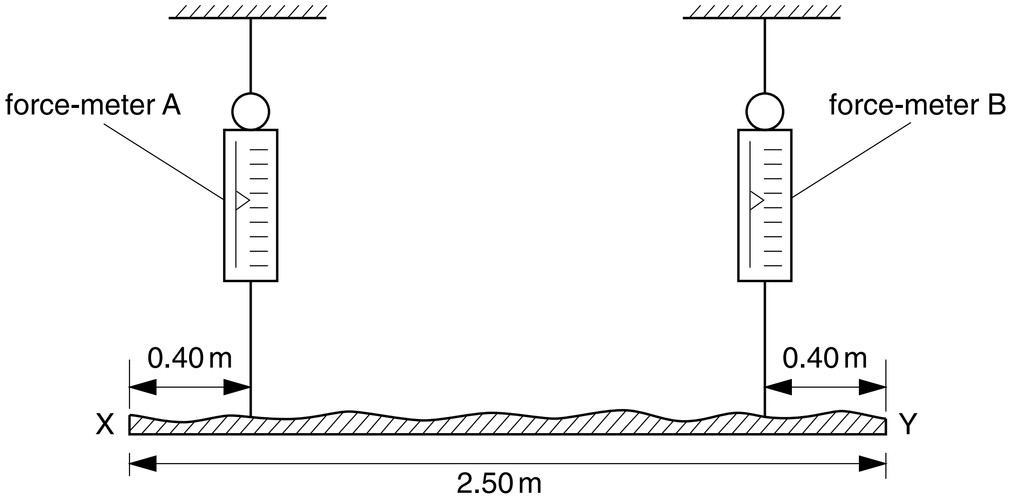


Fig. 3.1

When the plank is horizontal, force-meter A records 570 N.

(i) Calculate the reading on force-meter B.

reading = ... N

(ii) On Fig. 3.1, mark a likely position for the centre of gravity of the plank.

(iii) Determine the distance of the centre of gravity from the end X of the plank.

distance = ... m

[6]

2 Two forces, each of magnitude F, form a couple acting on the edge of a disc of radius r, as shown in Fig. 5.1.

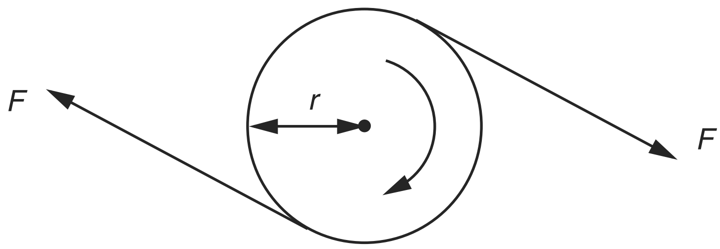


Fig. 5.1

(a) The disc is made to complete n revolutions about an axis through its centre, normal to the plane of the disc. Write down an expression for

(i) the distance moved by a point on the circumference of the disc,

distance = ...

(ii) the work done by one of the two forces.

work done = ...
[2]

(b) Using your answer to **(a)**, show that the work W done by a couple producing a torque T when it turns through n revolutions is given by

$$W = 2\pi nT.$$ [2]

(c) A car engine produces a torque of 470 N m at 2400 revolutions per minute. Calculate the output power of the engine.

power = ... W [2]

3 A rod AB is hinged to a wall at A. The rod is held horizontally by means of a cord BD, attached to the rod at end B and to the wall at D, as shown in Fig. 2.1.

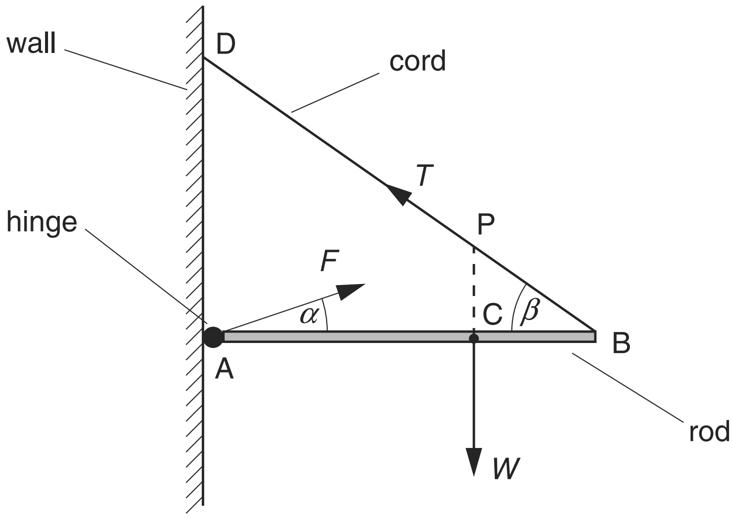


Fig. 2.1

The rod has weight W and the centre of gravity of the rod is at C. The rod is held in equilibrium by a force T in the cord and a force F produced at the hinge.

(a) Explain what is meant by

(i) the *centre of gravity* of a body,

....

....

.... [2]

(ii) the *equilibrium* of a body.

....

....

....

.... [2]

(b) The line of action of the weight *W* of the rod passes through the cord at point P.

Explain why, for the rod to be in equilibrium, the force *F* produced at the hinge must also pass through point P.

....

....

....

.... [2]

(c) The forces *F* and *T* make angles α and β respectively with the rod and AC = $\frac{2}{3}$AB, as shown in Fig. 2.1.

Write down equations, in terms of *F*, *W*, *T*, α and β, to represent

(i) the resolution of forces horizontally,

.... [1]

(ii) the resolution of forces vertically,

.... [1]

(iii) the taking of moments about A.

.... [1]

4 **(a)** Define the *torque* of a couple.

....

....

.... [2]

(b) A torque wrench is a type of spanner for tightening a nut and bolt to a particular torque, as illustrated in Fig. 3.1.

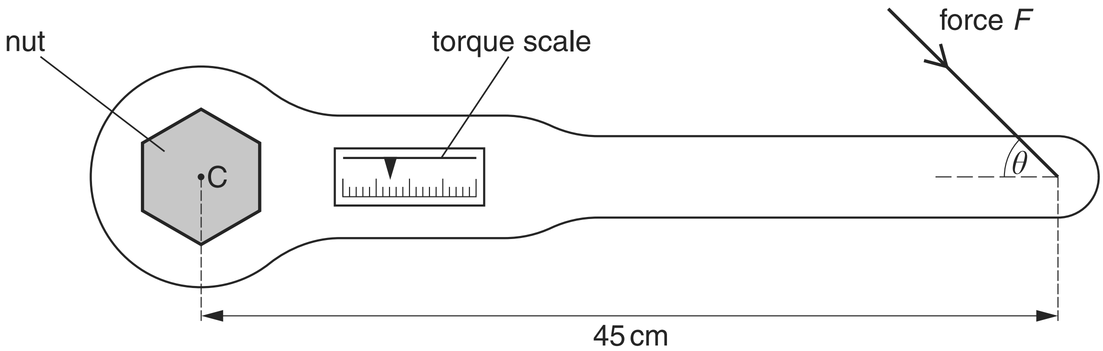


Fig. 3.1

The wrench is put on the nut and a force is applied to the handle. A scale indicates the torque applied.

The wheel nuts on a particular car must be tightened to a torque of 130 N m. This is achieved by applying a force F to the wrench at a distance of 45 cm from its centre of rotation C. This force F may be applied at any angle θ to the axis of the handle, as shown in Fig. 3.1.

For the minimum value of F to achieve this torque,

(i) state the magnitude of the angle θ that should be used,

θ = ... ° [1]

(ii) calculate the magnitude of F.

F = ... N [2]

For Examiner's Use

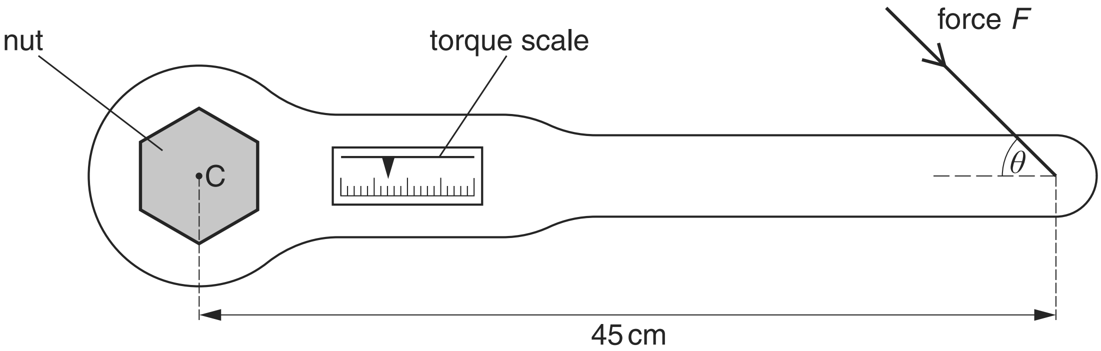
5 **(a)** Define the *torque* of a couple.

....

....

.... [2]

(b) A torque wrench is a type of spanner for tightening a nut and bolt to a particular torque, as illustrated in Fig. 3.1.



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For the minimum value of F to achieve this torque,

(i) state the magnitude of the angle θ that should be used,

θ = ... ° [1]

(ii) calculate the magnitude of F.

F = ... N [2]

6 **(a)** State the two conditions necessary for the equilibrium of a body which is acted upon by a number of forces.

1. ....

....

2. ....

....[2]

(b) Three identical springs S_1, S_2 and S_3 are attached to a point A such that the angle between any two of the springs is 120°, as shown in Fig. 3.1.

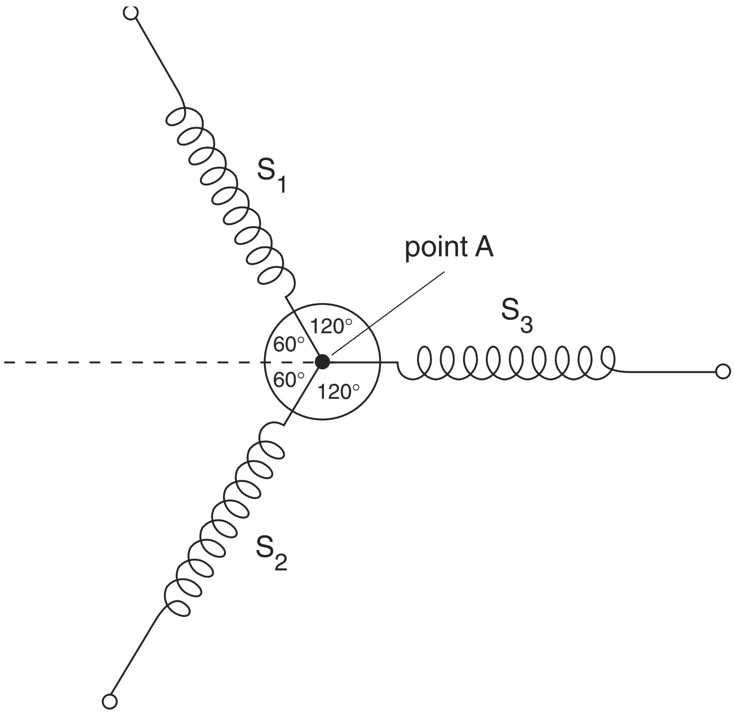


Fig. 3.1

The springs have extended elastically and the extensions of S_1 and S_2 are *x*. Determine, in terms of *x*, the extension of S_3 such that the system of springs is in equilibrium. Explain your working.

extension of S_3 = ... [3]

(c) The lid of a box is hinged along one edge E, as shown in Fig. 3.2.

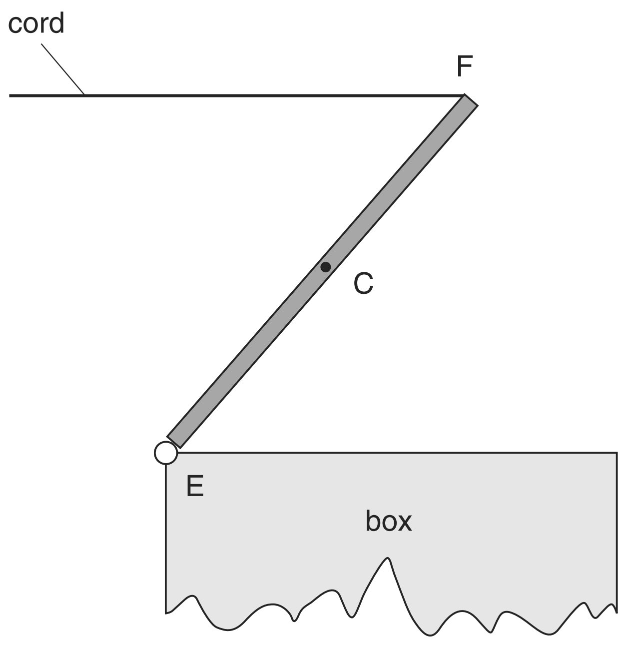


Fig. 3.2

The lid is held open by means of a horizontal cord attached to the edge F of the lid. The centre of gravity of the lid is at point C.

On Fig. 3.2 draw

(i) an arrow, labelled W, to represent the weight of the lid,

(ii) an arrow, labelled T, to represent the tension in the cord acting on the lid,

(iii) an arrow, labelled R, to represent the force of the hinge on the lid.

[3]

7 (a) Explain what is meant by the *centre of gravity* of a body.

....

....

.... [2]

(b) An irregularly-shaped piece of cardboard is hung freely from one point near its edge, as shown in Fig. 2.1.

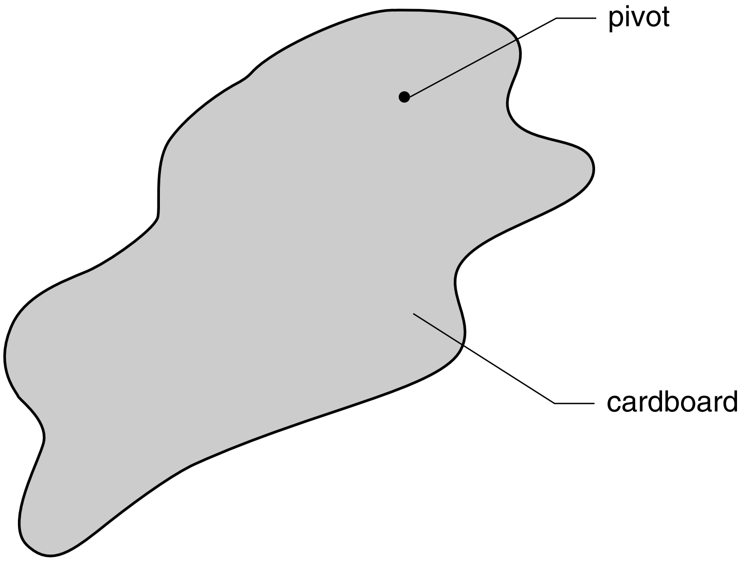


Fig. 2.1

Explain why the cardboard will come to rest with its centre of gravity vertically below the pivot. You may draw on Fig. 2.1 if you wish.

....

....

.... [2]

8 **(a)** Distinguish between the moment of a force and the torque of a couple.

moment of a force ....

....

....

torque of a couple ....

....

....
[4]

(b) One type of weighing machine, known as a steelyard, is illustrated in Fig. 3.1.

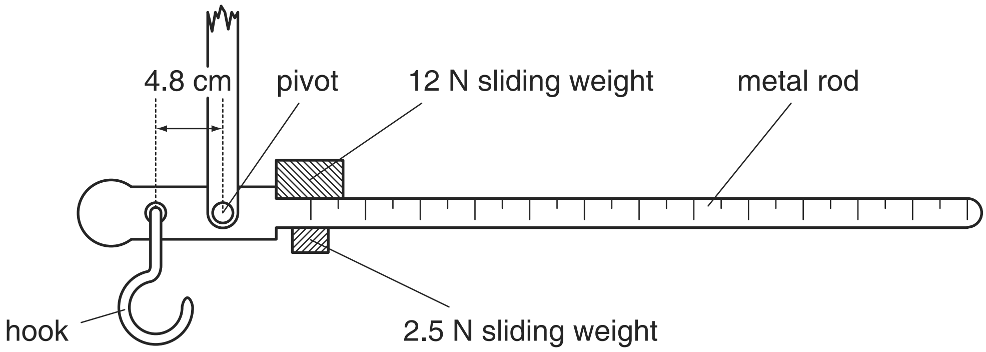


Fig. 3.1

The two sliding weights can be moved independently along the rod.

With no load on the hook and the sliding weights at the zero mark on the metal rod, the metal rod is horizontal. The hook is 4.8 cm from the pivot.

A sack of flour is suspended from the hook. In order to return the metal rod to the horizontal position, the 12 N sliding weight is moved 84 cm along the rod and the 2.5 N weight is moved 72 cm.

(i) Calculate the weight of the sack of flour.

weight = ………………………….N [2]

(ii) Suggest why this steelyard would be imprecise when weighing objects with a weight of about 25 N.

....

....[1]

2 **(a)** State the two conditions that must be satisfied for a body to be in equilibrium.

1. ....

....

2. ....

.... [2]

(b) Three co-planar forces act on a body that is in equilibrium.

(i) Describe how to draw a vector triangle to represent these forces.

....

....

....

....

....

....

....[3]

(ii) State how the triangle confirms that the forces are in equilibrium.

....

....[1]

For Examiner's Use

(c) A weight of 7.0 N hangs vertically by two strings AB and AC, as shown in Fig. 2.1.

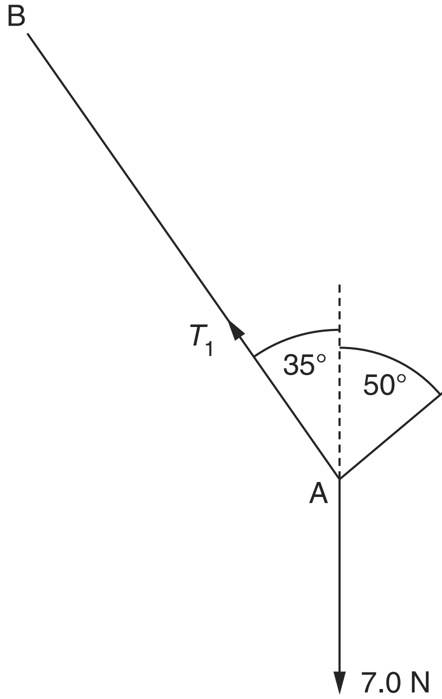


Fig. 2.1

For the weight to be in equilibrium, the tension in string AB is T_1 and in string AC it is T_2.

On Fig. 2.1, draw a vector triangle to determine the magnitudes of T_1 and T_2.

T_1 = ... N

T_2 = ... N
[3]

(d) By reference to Fig. 2.1, suggest why the weight could not be supported with the strings AB and AC both horizontal.

....

....[2]

3 **(a)** State the relation between force and momentum.

.... [1]

(b) A rigid bar of mass 450 g is held horizontally by two supports A and B, as shown in Fig. 3.1.

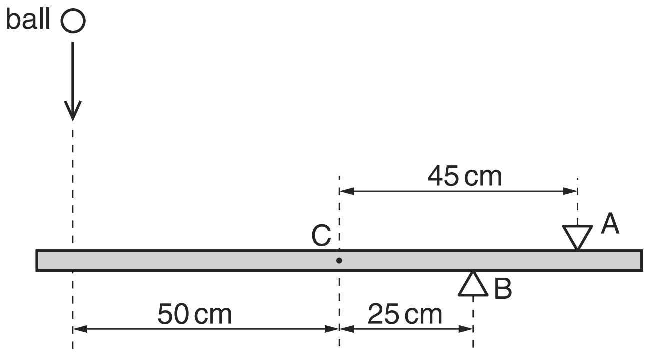


Fig. 3.1

The support A is 45 cm from the centre of gravity C of the bar and support B is 25 cm from C.

A ball of mass 140 g falls vertically onto the bar such that it hits the bar at a distance of 50 cm from C, as shown in Fig. 3.1.
The variation with time t of the velocity v of the ball before, during and after hitting the bar is shown in Fig. 3.2.

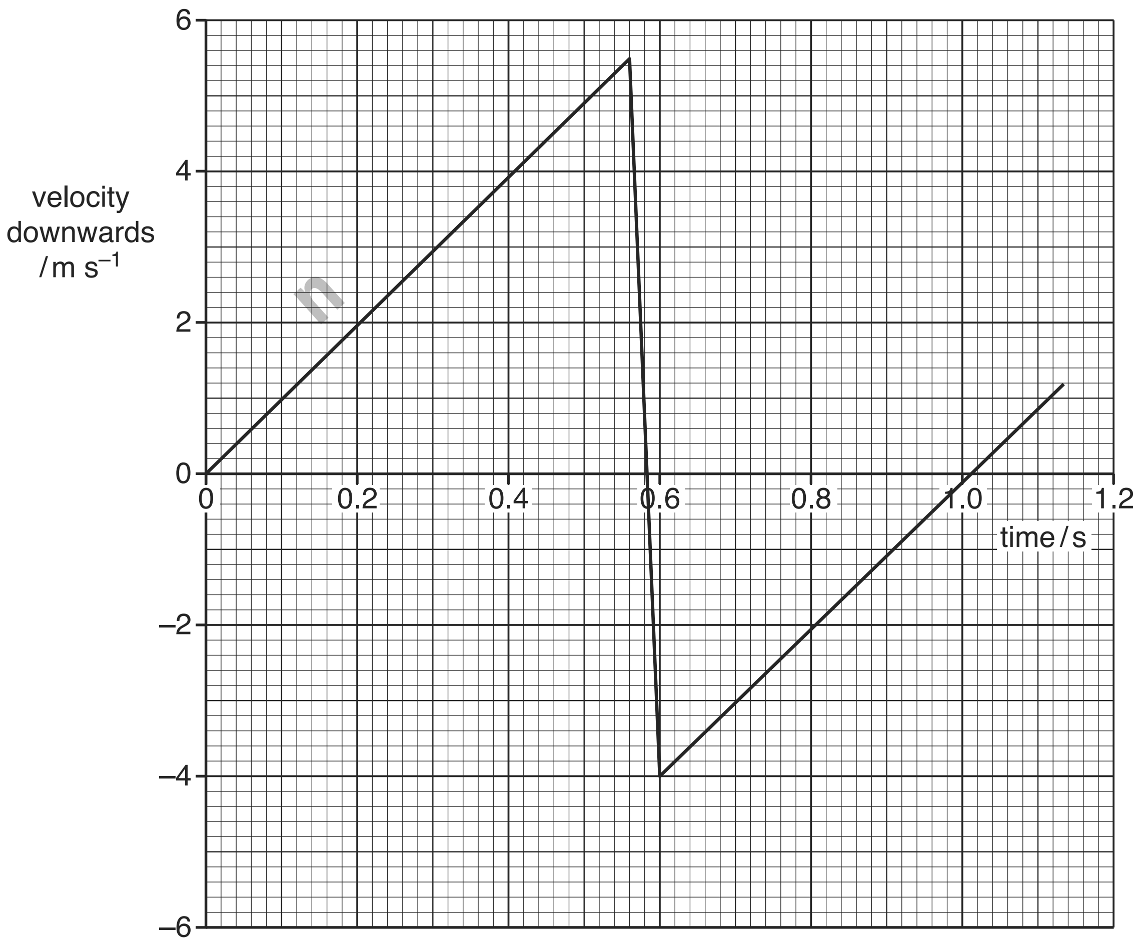


Fig. 3.2

For Examiner's Use

For the time that the ball is in contact with the bar, use Fig. 3.2

(i) to determine the change in momentum of the ball,

change = ... kg m s^{-1} [2]

(ii) to show that the force exerted by the ball on the bar is 33 N.

[1]

(c) For the time that the ball is in contact with the bar, use data from Fig. 3.1 and **(b)(ii)** to calculate the force exerted on the bar by

(i) the support A,

force = ... N [3]

(ii) the support B.

force = ... N [2]

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

....

....

.... [2]

(b) A uniform rectangular sheet of card of weight *W* is suspended from a wooden rod. The card is held to one side, as shown in Fig. 3.1.

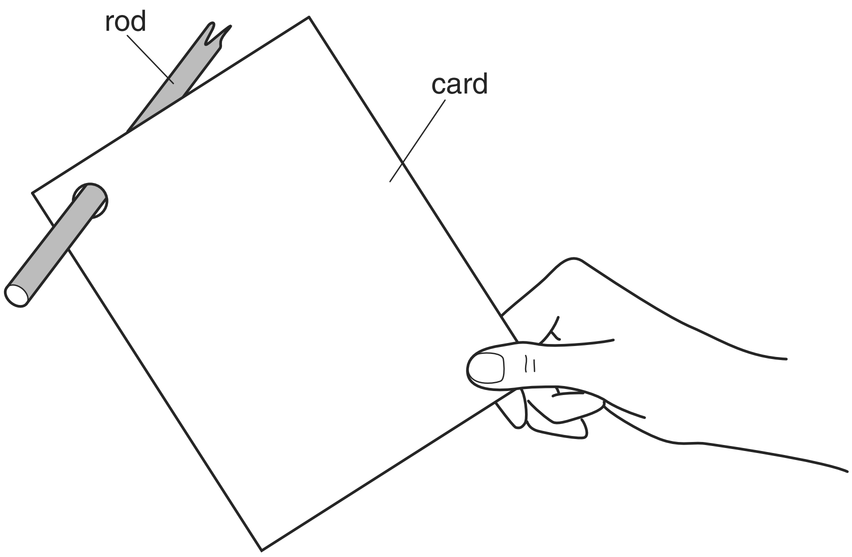


Fig. 3.1

On Fig. 3.1,

(i) mark, and label with the letter C, the position of the centre of gravity of the card, [1]

(ii) mark with an arrow labelled *W* the weight of the card. [1]

(c) The card in **(b)** is released. The card swings on the rod and eventually comes to rest.

For Examiner's Use

(i) List the two forces, other than its weight and air resistance, that act on the card during the time that it is swinging. State where the forces act.

1. ....

....

2. ....

....
[3]

(ii) By reference to the completed diagram of Fig. 3.1, state the position in which the card comes to rest.
Explain why the card comes to rest in this position.

....

....

....[2]

3 (a) Explain what is meant by *centre of gravity*.

....

.... [2]

(b) Define *moment* of a force.

....

.... [1]

(c) A student is being weighed. The student, of weight W, stands 0.30 m from end A of a uniform plank AB, as shown in Fig. 3.1.

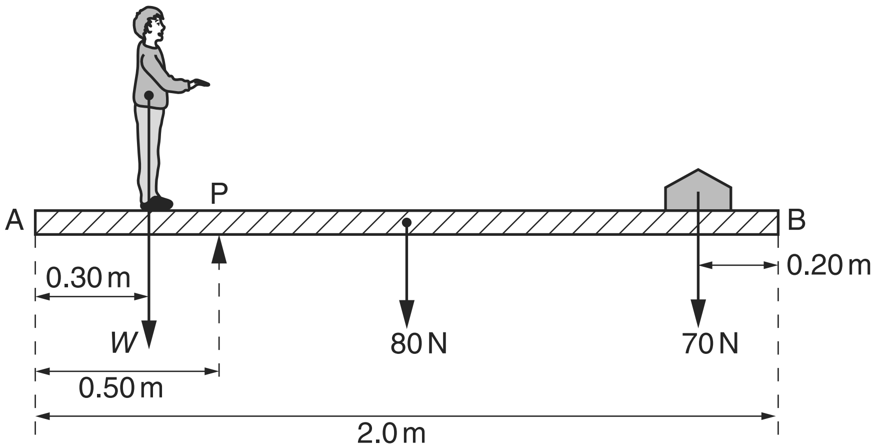


Fig. 3.1 (not to scale)

The plank has weight 80 N and length 2.0 m. A pivot P supports the plank and is 0.50 m from end A.
A weight of 70 N is moved to balance the weight of the student. The plank is in equilibrium when the weight is 0.20 m from end B.

(i) State the two conditions necessary for the plank to be in equilibrium.

1. ....

....

2. ....

....

[2]

(ii) Determine the weight W of the student.

For Examiner's Use

W = ... N [3]

(iii) If only the 70 N weight is moved, there is a maximum weight of student that can be determined using the arrangement shown in Fig. 3.1. State and explain **one** change that can be made to increase this maximum weight.

....

....

.... [2]

For Examiner's Use

2 A climber is supported by a rope on a vertical wall, as shown in Fig. 2.1.

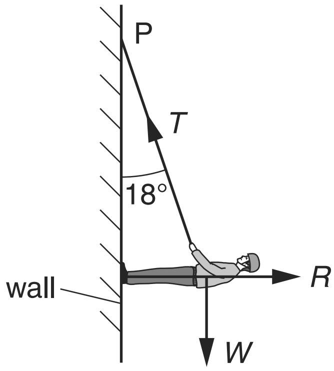


Fig. 2.1

The weight W of the climber is 520 N. The rope, of negligible weight, is attached to the climber and to a fixed point P where it makes an angle of 18° to the vertical. The reaction force R acts at right-angles to the wall.
The climber is in equilibrium.

(a) State the conditions necessary for the climber to be in equilibrium.

....

....

.... [2]

(b) Complete Fig. 2.2 by drawing a labelled vector triangle to represent the forces acting on the climber.

Fig. 2.2

[2]

For Examiner's Use

(c) Resolve forces or use your vector triangle to calculate

(i) the tension *T* in the rope,

T = ... N [2]

(ii) the reaction force *R*.

R = ... N [1]

(d) The climber moves up the wall and the angle the rope makes with the vertical increases. Explain why the magnitude of the tension in the rope increases.

....

....

.... [1]

For Examiner's Use

2 **(a)** Define the *torque* of a couple.

....

.... [2]

(b) A uniform rod of length 1.5 m and weight 2.4 N is shown in Fig. 2.1.

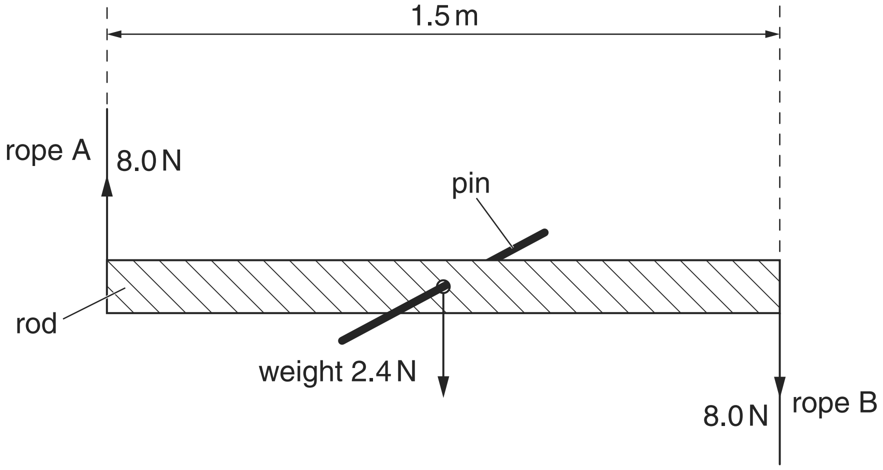


Fig. 2.1

The rod is supported on a pin passing through a hole in its centre. Ropes A and B provide equal and opposite forces of 8.0 N.

(i) Calculate the torque on the rod produced by ropes A and B.

torque = ... N m [1]

(ii) Discuss, briefly, whether the rod is in equilibrium.

....

....

....

.... [2]

(c) The rod in **(b)** is removed from the pin and supported by ropes A and B, as shown in Fig. 2.2.

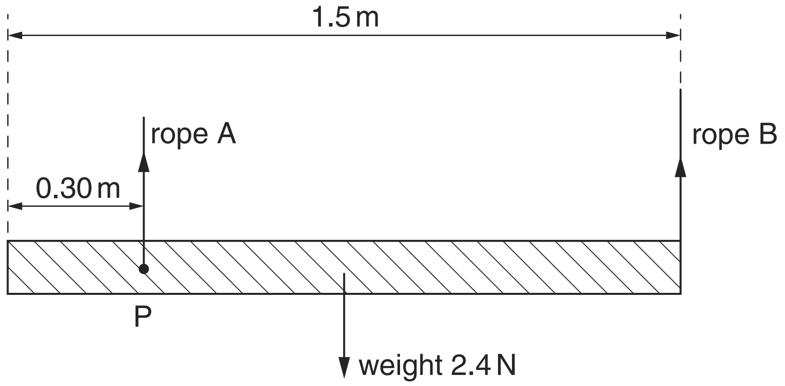


Fig. 2.2

Rope A is now at point P 0.30 m from one end of the rod and rope B is at the other end.

(i) Calculate the tension in rope B.

tension in B = ... N [2]

(ii) Calculate the tension in rope A.

tension in A = ... N [1]

For Examiner's Use

2 **(a)** Define

(i) *force*,

....

....[1]

(ii) *work done*.

....

....[1]

(b) A force F acts on a mass m along a straight line for a distance s. The acceleration of the mass is a and the speed changes from an initial speed u to a final speed v.

(i) State the work W done by F.

[1]

(ii) Use your answer in **(i)** and an equation of motion to show that kinetic energy of a mass can be given by the expression

$$\text{kinetic energy} = \tfrac{1}{2} \times \text{mass} \times (\text{speed})^2.$$

[3]

(c) A resultant force of 3800 N causes a car of mass of 1500 kg to accelerate from an initial speed of $15\,\text{m}\,\text{s}^{-1}$ to a final speed of $30\,\text{m}\,\text{s}^{-1}$.

(i) Calculate the distance moved by the car during this acceleration.

distance = ... m [2]

(ii) The same force is used to change the speed of the car from $30\,\text{m}\,\text{s}^{-1}$ to $45\,\text{m}\,\text{s}^{-1}$. Explain why the distance moved is not the same as that calculated in **(i)**.

....

....

....[1]

For Examiner's Use

3 **(a)** Define the terms

(i) *power*,

.... [1]

(ii) the *Young modulus*.

....

....

.... [1]

(b) A crane is used to lift heavy objects, as shown in Fig. 3.1.

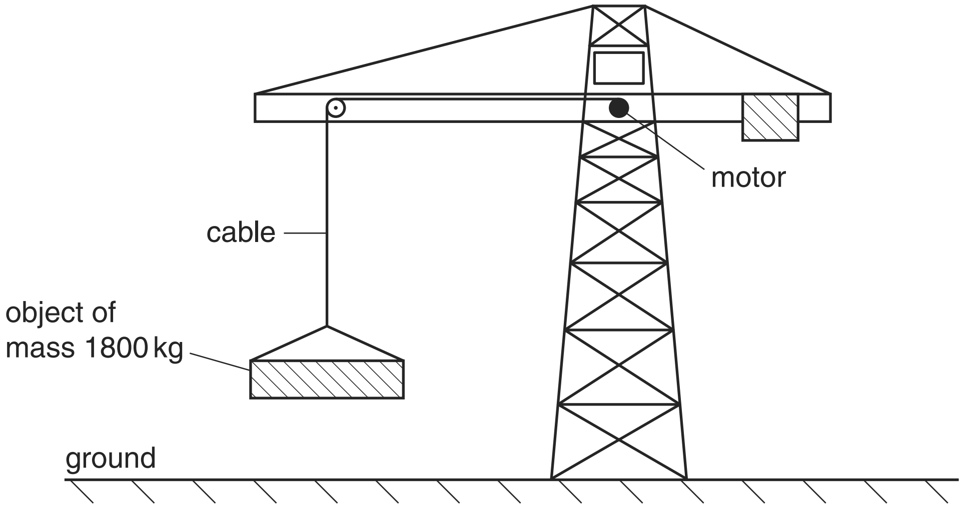


Fig. 3.1

The motor in the crane lifts a total mass of 1800 kg from rest on the ground. The cable supporting the mass is made of steel of Young modulus 2.4×10^{11} Pa. The cross-sectional area of the cable is $1.3 \times 10^{-4}\,m^2$. As the mass leaves the ground, the strain in the cable is 0.0010. Assume the weight of the cable to be negligible.

(i) **1.** Use the Young Modulus of the steel to show that the tension in the cable is 3.1×10^4 N.

[2]

2. Calculate the acceleration of the mass as it is lifted from the ground.

acceleration = ... $m\,s^{-2}$ [3]

(ii) The motor now lifts the mass through a height of 15 m at a constant speed.

Calculate

1. the tension in the lifting cable,

tension = ... N [1]

2. the gain in potential energy of the mass.

gain in potential energy = ... J [2]

(iii) The motor of the crane is 30% efficient. Calculate the input power to the motor required to lift the mass at a constant speed of 0.55 m s^{-1}.

input power = ... W [3]

2 A ball is thrown vertically down towards the ground with an initial velocity of $4.23\,\mathrm{m\,s^{-1}}$. The ball falls for a time of 1.51 s before hitting the ground. Air resistance is negligible.

(a) **(i)** Show that the downwards velocity of the ball when it hits the ground is $19.0\,\mathrm{m\,s^{-1}}$.

[2]

(ii) Calculate, to three significant figures, the distance the ball falls to the ground.

distance = ... m [2]

(b) The ball makes contact with the ground for 12.5 ms and rebounds with an upwards velocity of $18.6\,\mathrm{m\,s^{-1}}$. The mass of the ball is 46.5 g.

(i) Calculate the average force acting on the ball on impact with the ground.

magnitude of force = ... N

direction of force ....

[4]

(ii) Use conservation of energy to determine the maximum height the ball reaches after it hits the ground.

height = ... m [2]

(c) State and explain whether the collision the ball makes with the ground is elastic or inelastic.

....

....

....[1]

3 (a) State Newton's first law.

....

.... [1]

(b) A log of mass 450 kg is pulled up a slope by a wire attached to a motor, as shown in Fig. 3.1.

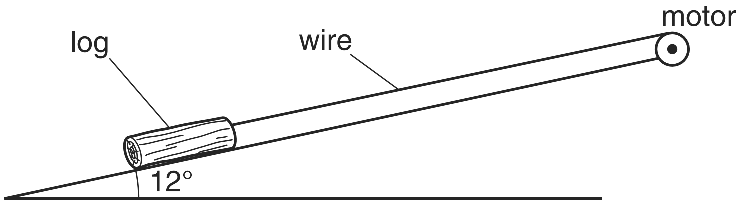


Fig. 3.1

The angle that the slope makes with the horizontal is 12°. The frictional force acting on the log is 650 N. The log travels with constant velocity.

(i) With reference to the motion of the log, discuss whether the log is in equilibrium.

....

....

....

.... [2]

(ii) Calculate the tension in the wire.

tension = ... N [3]

(iii) State and explain whether the gain in the potential energy per unit time of the log is equal to the output power of the motor.

....

....

....

.... [2]

2 A motor drags a log of mass 452 kg up a slope by means of a cable, as shown in Fig. 2.1.

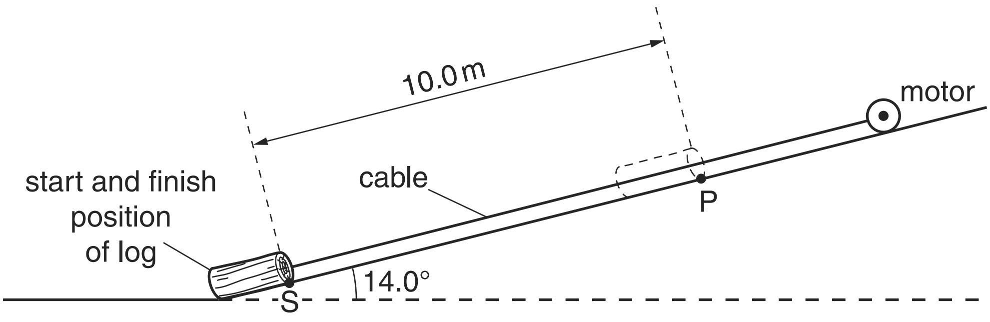


Fig. 2.1

The slope is inclined at 14.0° to the horizontal.

(a) Show that the component of the weight of the log acting down the slope is 1070 N.

[1]

(b) The log starts from rest. A constant frictional force of 525 N acts on the log. The log accelerates up the slope at 0.130 m s^{-2}.

(i) Calculate the tension in the cable.

tension = ... N [3]

(ii) The log is initially at rest at point S. It is pulled through a distance of 10.0 m to point P.

Calculate, for the log,

1. the time taken to move from S to P,

time = ... s [2]

2. the magnitude of the velocity at P.

velocity = ... $m\,s^{-1}$ [1]

(c) The cable breaks when the log reaches point P. On Fig. 2.2, sketch the variation with time *t* of the velocity *v* of the log. The graph should show *v* from the start at S until the log returns to S. [4]

Fig. 2.2

2 **(a)** State Newton's second law.

....

.... [1]

(b) A ball of mass 65 g hits a wall with a velocity of 5.2 m s^{-1} perpendicular to the wall. The ball rebounds perpendicularly from the wall with a speed of 3.7 m s^{-1}. The contact time of the ball with the wall is 7.5 ms.

Calculate, for the ball hitting the wall,

(i) the change in momentum,

change in momentum = ... N s [2]

(ii) the magnitude of the average force.

force = ... N [1]

(c) **(i)** For the collision in **(b)** between the ball and the wall, state how the following apply:

1. Newton's third law,

....

....

....

.... [2]

2. the law of conservation of momentum.

....

.... [1]

(ii) State, with a reason, whether the collision is elastic or inelastic.

....

.... [1]

For Examiner's Use

1 **(a)** The drag force D on an object of cross-sectional area A, moving with a speed v through a fluid of density ρ, is given by

$$D = \frac{1}{2} C\rho A v^2$$

where C is a constant.

Show that C has no unit.

[2]

(b) A raindrop falls vertically from rest. Assume that air resistance is negligible.

(i) On Fig. 1.1, sketch a graph to show the variation with time t of the velocity v of the raindrop for the first 1.0 s of the motion.

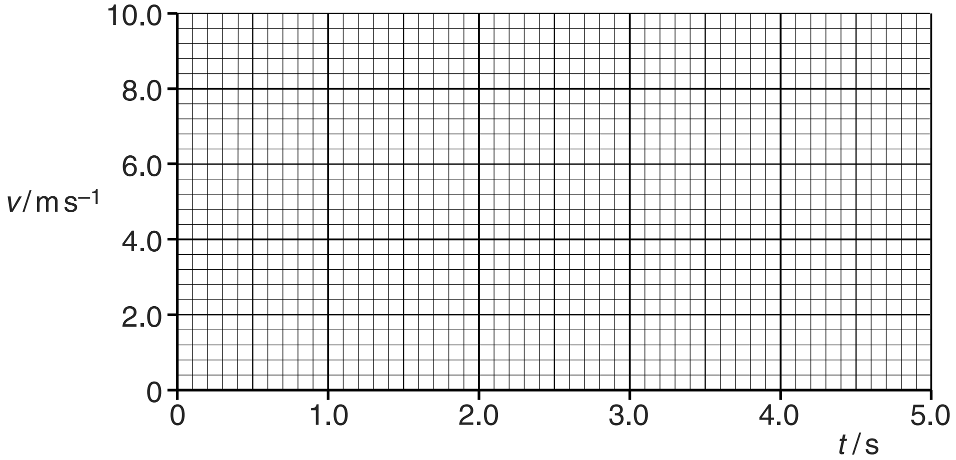


Fig. 1.1

[1]

(ii) Calculate the velocity of the raindrop after falling 1000 m.

velocity = ... m s^{-1} [2]

(c) In practice, air resistance on raindrops is not negligible because there is a drag force. This drag force is given by the expression in **(a)**.

For Examiner's Use

(i) State an equation relating the forces acting on the raindrop when it is falling at terminal velocity.

[1]

(ii) The raindrop has mass 1.4×10^{-5} kg and cross-sectional area $7.1 \times 10^{-6}\,m^2$. The density of the air is $1.2\,kg\,m^{-3}$ and the initial velocity of the raindrop is zero. The value of C is 0.60.

1. Show that the terminal velocity of the raindrop is about $7\,m\,s^{-1}$.

[2]

2. The raindrop reaches terminal velocity after falling approximately 10 m. On Fig. 1.1, sketch the variation with time t of velocity v for the raindrop. The sketch should include the first 5 s of the motion.

[2]

3 (a) Define *centre of gravity*.

....

.... [2]

(b) A uniform rod AB is attached to a vertical wall at A. The rod is held horizontally by a string attached at B and to point C, as shown in Fig. 3.1.

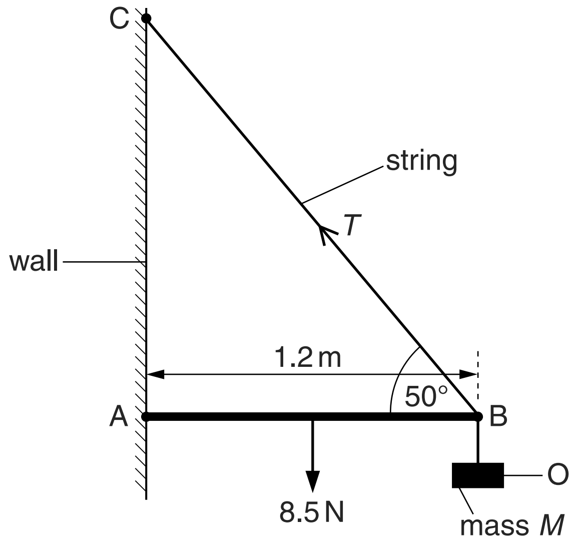


Fig. 3.1

The angle between the rod and the string at B is 50°. The rod has length 1.2 m and weight 8.5 N. An object O of mass M is hung from the rod at B. The tension T in the string is 30 N.

(i) Use the resolution of forces to calculate the vertical component of T.

vertical component of T = ... N [1]

(ii) State the *principle of moments*.

....

.... [1]

(iii) Use the principle of moments and take moments about A to show that the weight of the object O is 19 N.

For Examiner's Use

[3]

(iv) Hence determine the mass *M* of the object O.

M = ... kg [1]

(c) Use the concept of equilibrium to explain why a force must act on the rod at A.

....

....

....[2]

4 **(a)** Define the *torque* of a couple.

....

.... [2]

(b) A wheel is supported by a pin P at its centre of gravity, as shown in Fig. 4.1.

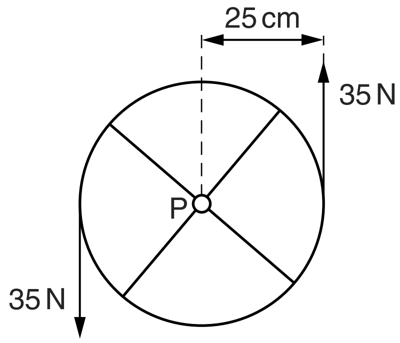


Fig. 4.1

The plane of the wheel is vertical. The wheel has radius 25 cm.
Two parallel forces each of 35 N act on the edge of the wheel in the vertical directions shown in Fig. 4.1. Friction between the pin and the wheel is negligible.

(i) List two other forces that act on the wheel. State the direction of these forces and where they act.

1. ....

2. ....
[2]

(ii) Calculate the torque of the couple acting on the wheel.

torque = ... N m [2]

(iii) The resultant force on the wheel is zero. Explain, by reference to the four forces acting on the wheel, how it is possible that the resultant force is zero.

....

.... [1]

(iv) State and explain whether the wheel is in equilibrium.

.... [1]

3 **(a)** Explain what is meant by *work done*.

....

....[1]

(b) A boy on a board B slides down a slope, as shown in Fig. 3.1.

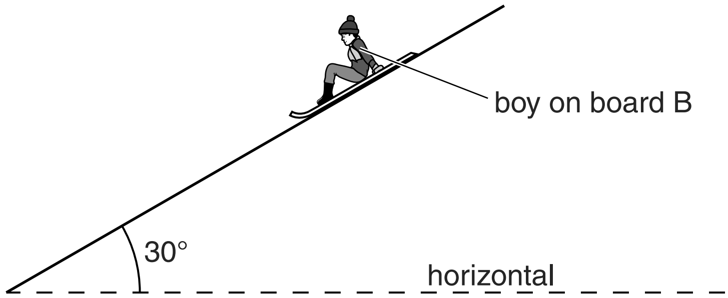


Fig. 3.1

The angle of the slope to the horizontal is 30°. The total resistive force F acting on B is constant.

(i) State a word equation that links the work done by the force F on B to the changes in potential and kinetic energy.

....

....[1]

(ii) The boy on the board B moves with velocity v down the slope. The variation with time t of v is shown in Fig. 3.2.

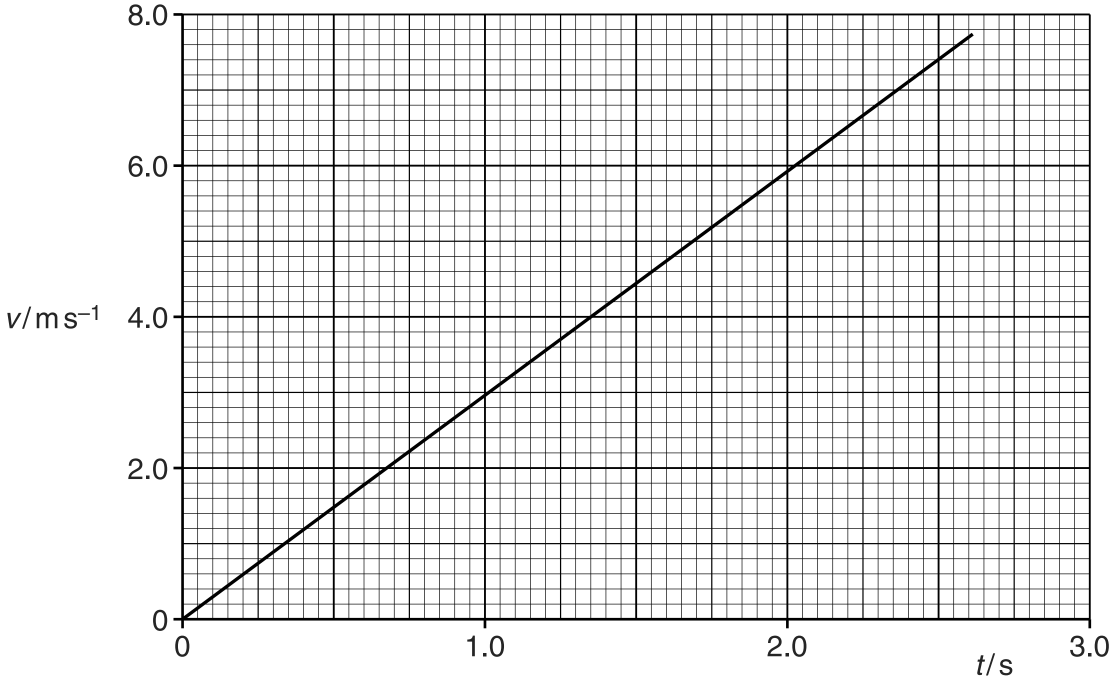


Fig. 3.2

The total mass of B is 75 kg.
For B, from $t = 0$ to $t = 2.5$ s,

1. show that the distance moved down the slope is 9.3 m,

[2]

2. calculate the gain in kinetic energy,

gain in kinetic energy = ... J [3]

3. calculate the loss in potential energy,

loss in potential energy = ... J [3]

4. calculate the resistive force *F*.

F = ... N [3]

3 **(a)** State Newton's first law of motion.

....

.... [1]

(b) A box slides down a slope, as shown in Fig. 3.1.

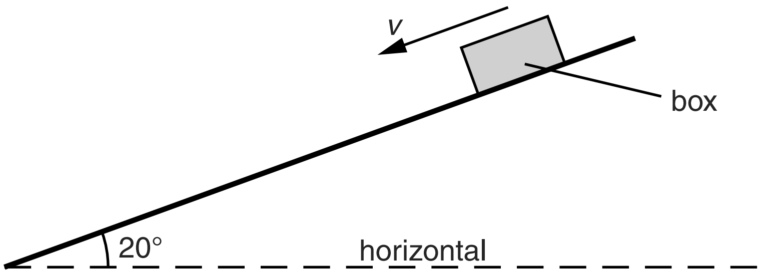


Fig. 3.1

The angle of the slope to the horizontal is 20°. The box has a mass of 65 kg. The total resistive force *R* acting on the box is constant as it slides down the slope.

(i) State the names and directions of the other two forces acting on the box.

1. ....

2. ....
[2]

(ii) The variation with time *t* of the velocity *v* of the box as it moves down the slope is shown in Fig. 3.2.

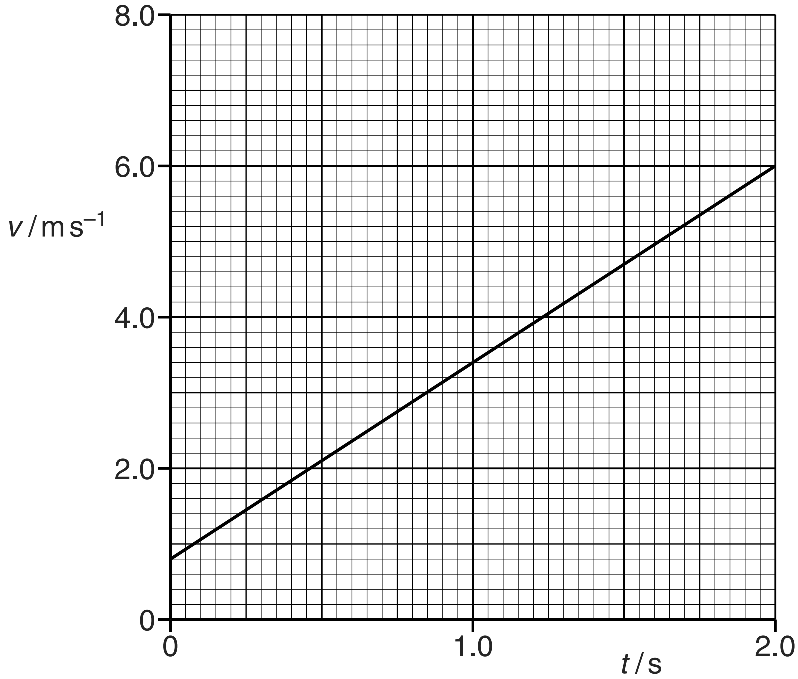


Fig. 3.2

1. Use data from Fig. 3.2 to show that the acceleration of the box is 2.6 m s^{-2}.

[2]

2. Calculate the resultant force on the box.

resultant force = ... N [1]

3. Determine the resistive force *R* on the box.

R = ... N [3]

3 A uniform plank AB of length 5.0 m and weight 200 N is placed across a stream, as shown in Fig. 3.1.

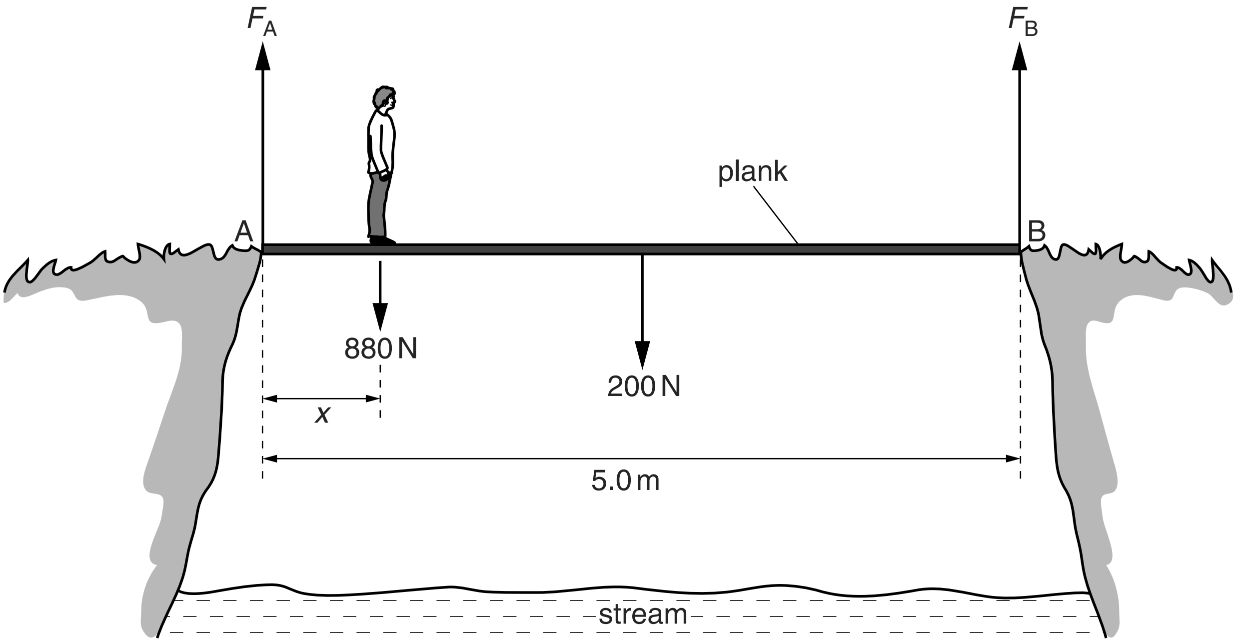


Fig. 3.1

A man of weight 880 N stands a distance x from end A. The ground exerts a vertical force F_A on the plank at end A and a vertical force F_B on the plank at end B.
As the man moves along the plank, the plank is always in equilibrium.

(a) **(i)** Explain why the sum of the forces F_A and F_B is constant no matter where the man stands on the plank.

....

....

.... [2]

(ii) The man stands a distance x = 0.50 m from end A. Use the principle of moments to calculate the magnitude of F_B.

F_B = ... N [4]

(b) The variation with distance x of force F_A is shown in Fig. 3.2.

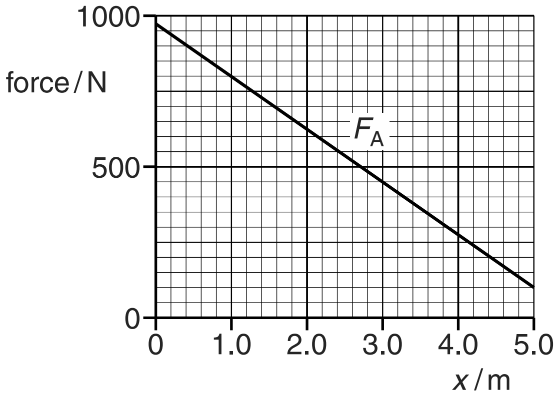


Fig. 3.2

On the axes of Fig. 3.2, sketch a graph to show the variation with x of force F_B. [3]

4 A trolley moves down a slope, as shown in Fig. 4.1.

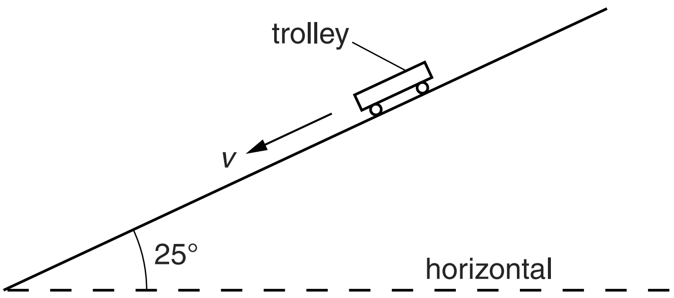


Fig. 4.1

The slope makes an angle of 25° with the horizontal. A constant resistive force F_R acts up the slope on the trolley.
At time $t = 0$, the trolley has velocity $v = 0.50\,\text{m}\,\text{s}^{-1}$ down the slope.
At time $t = 4.0\,\text{s}$, $v = 12\,\text{m}\,\text{s}^{-1}$ down the slope.

(a) **(i)** Show that the acceleration of the trolley down the slope is approximately $3\,\text{m}\,\text{s}^{-2}$.

[2]

(ii) Calculate the distance x moved by the trolley down the slope from time $t = 0$ to $t = 4.0\,\text{s}$.

x = ... m [2]

(iii) On Fig. 4.2, sketch the variation with time t of distance x moved by the trolley.

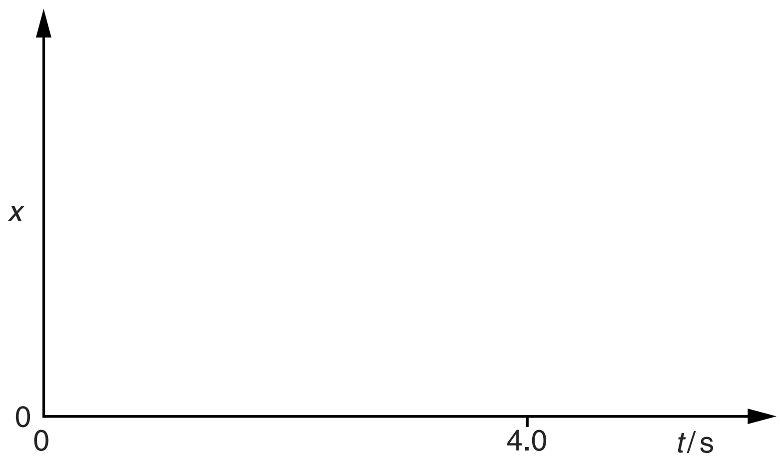


Fig. 4.2

[2]

(b) The mass of the trolley is 2.0 kg.

(i) Show that the component of the weight of the trolley down the slope is 8.3 N.

[1]

(ii) Calculate the resistive force F_R.

F_R = ... N [2]

Answer **all** the questions in the spaces provided.

1 **(a)** The Young modulus of the metal of a wire is 1.8×10^{11} Pa. The wire is extended and the strain produced is 8.2×10^{-4}.
Calculate the stress in GPa.

stress = ... GPa [2]

(b) An electromagnetic wave has frequency 12 THz.

(i) Calculate the wavelength in μm.

wavelength = ... μm [2]

(ii) State the name of the region of the electromagnetic spectrum for this frequency.

.... [1]

(c) An object B is on a horizontal surface. Two forces act on B in this horizontal plane. A vector diagram for these forces is shown to scale in Fig. 1.1.

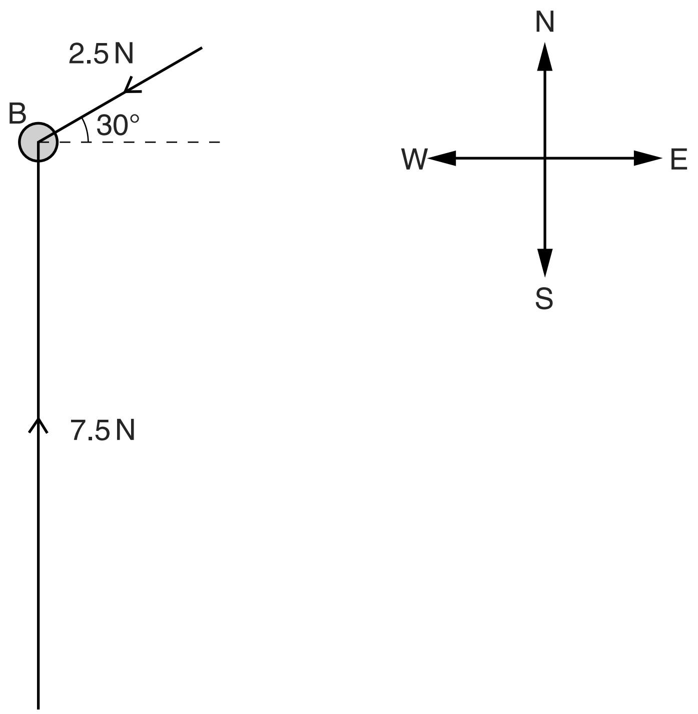


Fig. 1.1

A force of 7.5 N towards north and a force of 2.5 N from 30° north of east act on B. The mass of B is 750 g.

(i) On Fig. 1.1, draw an arrow to show the approximate direction of the resultant of these two forces. [1]

(ii) **1.** Show that the magnitude of the resultant force on B is 6.6 N.

[1]

2. Calculate the magnitude of the acceleration of B produced by this resultant force.

magnitude = ... $m s^{-2}$ [2]

(iii) Determine the angle between the direction of the acceleration and the direction of the 7.5 N force.

angle = ... ° [1]

3 A rod PQ is attached at P to a vertical wall, as shown in Fig. 3.1.

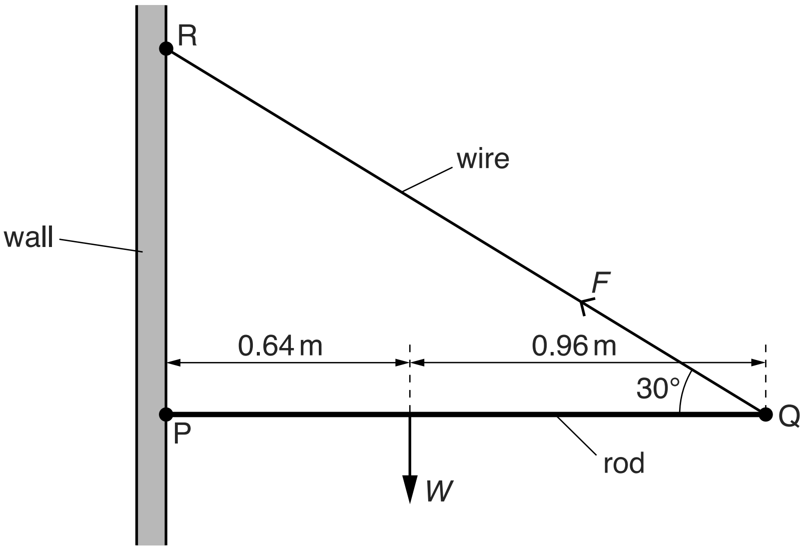


Fig. 3.1

The length of the rod is 1.60 m. The weight *W* of the rod acts 0.64 m from P. The rod is kept horizontal and in equilibrium by a wire attached to Q and to the wall at R. The wire provides a force *F* on the rod of 44 N at 30° to the horizontal.

(a) Determine

(i) the vertical component of *F*,

vertical component = ... N [1]

(ii) the horizontal component of *F*.

horizontal component = ... N [1]

(b) By taking moments about P, determine the weight *W* of the rod.

W = ... N [2]

(c) Explain why the wall must exert a force on the rod at P.

....

....

.... [1]

(d) On Fig. 3.1, draw an arrow to represent the force acting on the rod at P. Label your arrow with the letter S. [1]

1 A bullet of mass 2.0 g is fired horizontally into a block of wood of mass 600 g. The block is suspended from strings so that it is free to move in a vertical plane.
The bullet buries itself in the block. The block and bullet rise together through a vertical distance of 8.6 cm, as shown in Fig. 3.1.

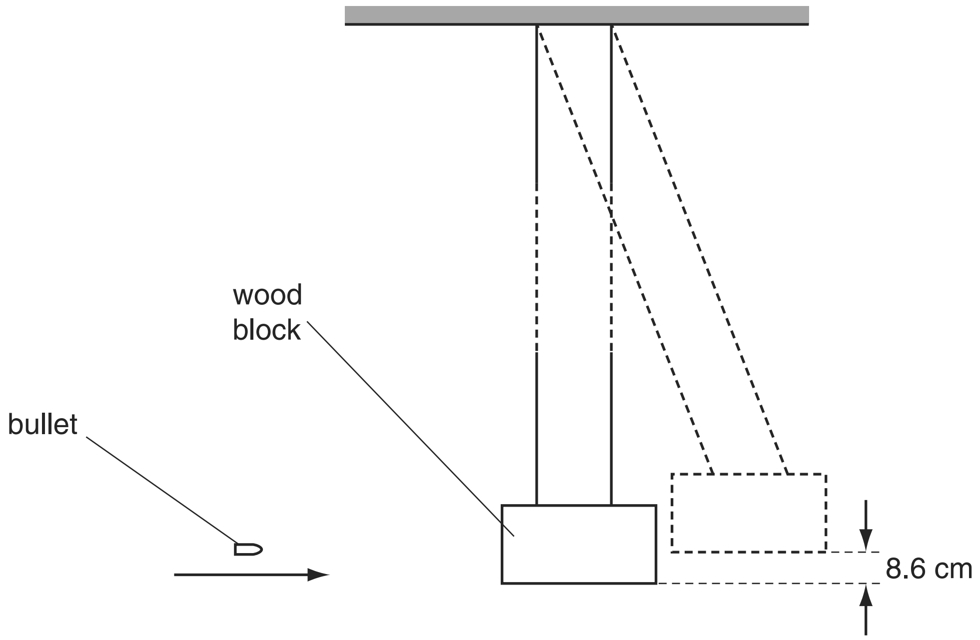


Fig. 3.1

(a) **(i)** Calculate the change in gravitational potential energy of the block and bullet.

change = ... J [2]

(ii) Show that the initial speed of the block and the bullet, after they began to move off together, was 1.3 m s^{-1}.

[1]

(b) Using the information in **(a)(ii)** and the principle of conservation of momentum, determine the speed of the bullet before the impact with the block.

speed = ... m s^{-1} [2]

(c) **(i)** Calculate the kinetic energy of the bullet just before impact.

kinetic energy = ... J [2]

(ii) State and explain what can be deduced from your answers to **(c)(i)** and **(a)(i)** about the type of collision between the bullet and the block.

....

....

....[2]

2 An experiment is conducted on the surface of the planet Mars.
A sphere of mass 0.78 kg is projected almost vertically upwards from the surface of the planet. The variation with time t of the vertical velocity v in the upward direction is shown in Fig. 2.1.

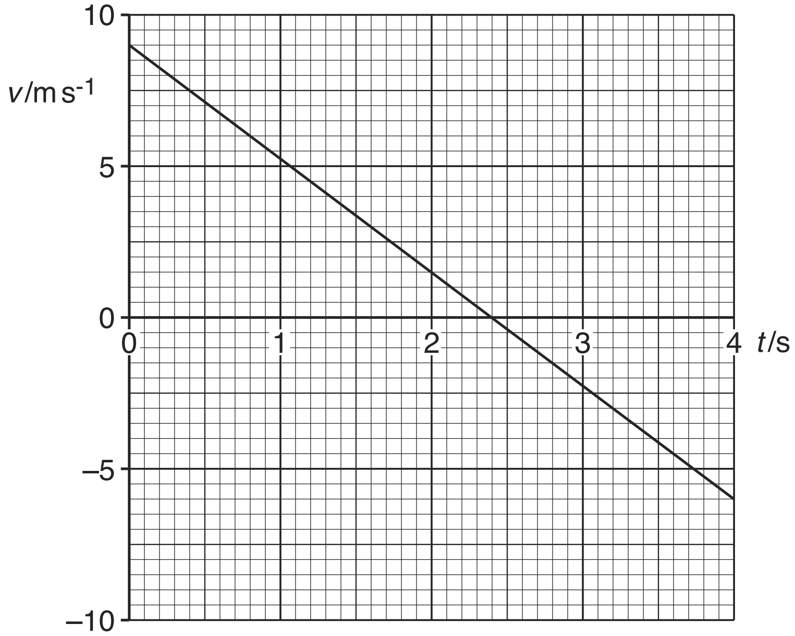


Fig. 2.1

The sphere lands on a small hill at time t = 4.0 s.

(a) State the time t at which the sphere reaches its maximum height above the planet's surface.

t = ... s [1]

(b) Determine the vertical height above the point of projection at which the sphere finally comes to rest on the hill.

height = ... m [3]

For Examiner's Use

(c) Calculate, for the first 3.5 s of the motion of the sphere,

(i) the change in momentum of the sphere,

change in momentum = ... N s [2]

(ii) the force acting on the sphere.

force = ... N [2]

(d) Using your answer in **(c)(ii)**,

(i) state the weight of the sphere,

weight = ... N [1]

(ii) determine the acceleration of free fall on the surface of Mars.

acceleration = ... m s^{-2} [2]

4 A ball B of mass 1.2 kg travelling at constant velocity collides head-on with a stationary ball S of mass 3.6 kg, as shown in Fig. 2.1.

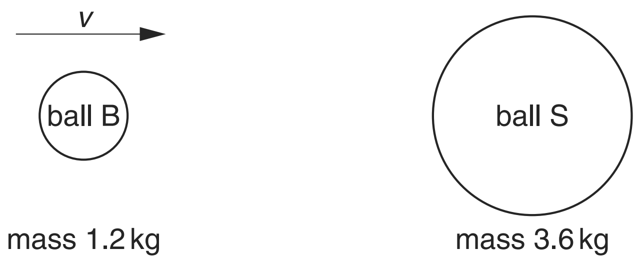


Fig. 2.1

Frictional forces are negligible.

The variation with time *t* of the velocity *v* of ball B before, during and after colliding with ball S is shown in Fig. 2.2.

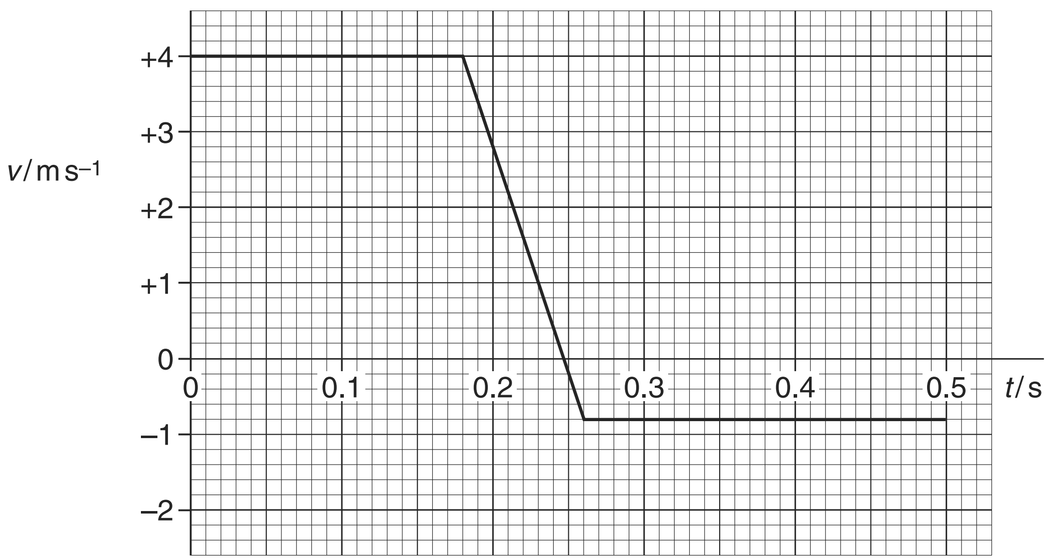


Fig. 2.2

(a) State the significance of positive and negative values for *v* in Fig. 2.2.

....

.... [1]

For Examiner's Use

(b) Use Fig. 2.2 to determine, for ball B during the collision with ball S,

(i) the change in momentum of ball B,

change in momentum = ... N s [3]

(ii) the magnitude of the force acting on ball B.

force = ... N [3]

(c) Calculate the speed of ball S after the collision.

speed = ... m s^{-1} [2]

For Examiner's Use

(d) Using your answer in **(c)** and information from Fig. 2.2, deduce quantitatively whether the collision is elastic or inelastic.

....

.... [2]

5 A ball falls from rest onto a flat horizontal surface. Fig. 3.1 shows the variation with time t of the velocity v of the ball as it approaches and rebounds from the surface.

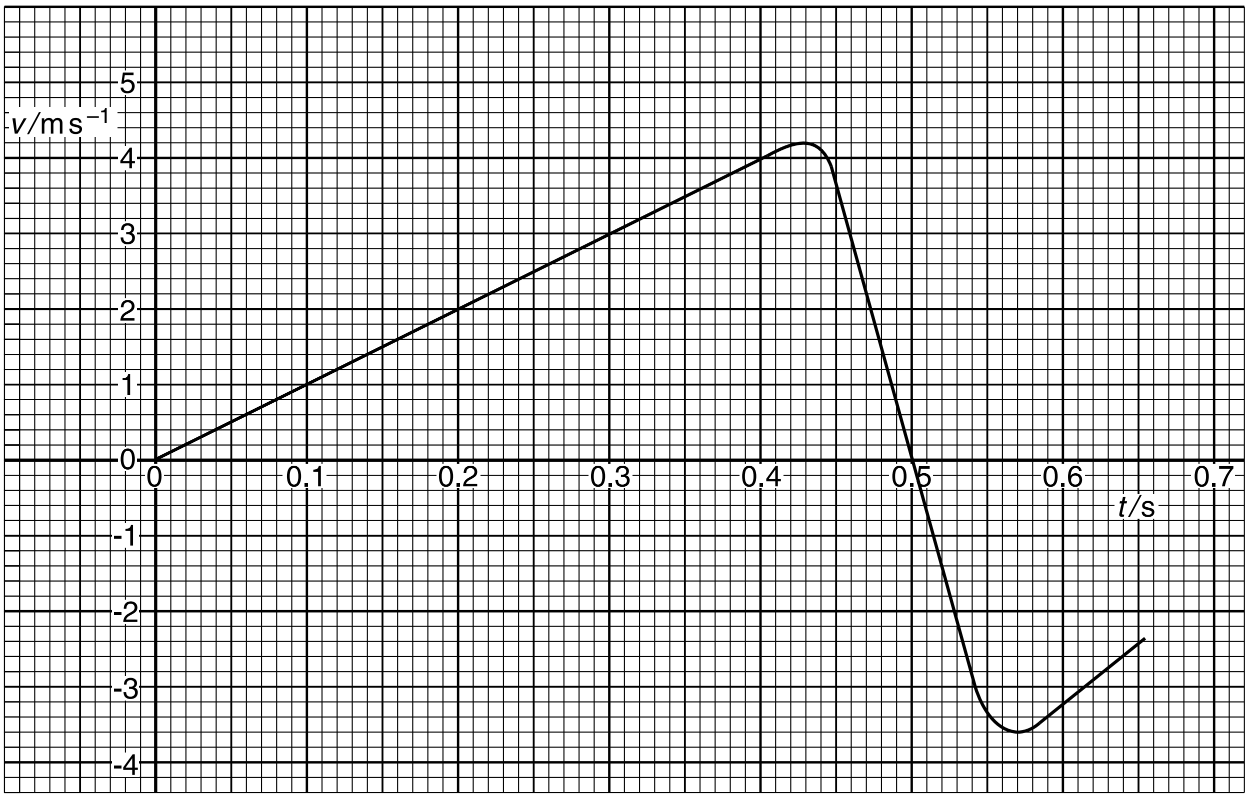


Fig. 3.1

Use data from Fig. 3.1 to determine

(a) the distance travelled by the ball during the first 0.40 s,

distance = ... m [2]

(b) the change in momentum of the ball, of mass 45 g, during contact of the ball with the surface,

change = ... N s [4]

(c) the average force acting on the ball during contact with the surface.

force = ... N [2]

6 A girl stands at the top of a cliff and throws a ball vertically upwards with a speed of $12\,m\,s^{-1}$, as illustrated in Fig. 3.1.

For Examiner's Use

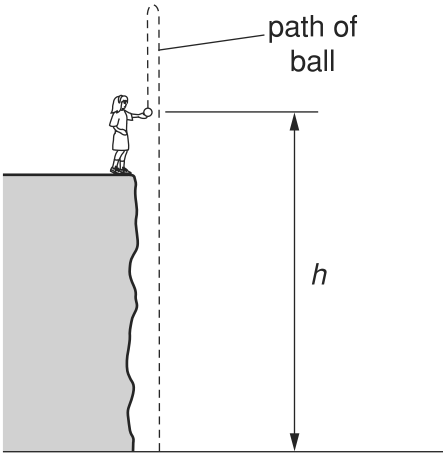


Fig. 3.1

At the time that the girl throws the ball, her hand is a height *h* above the horizontal ground at the base of the cliff.
The variation with time *t* of the speed *v* of the ball is shown in Fig. 3.2.

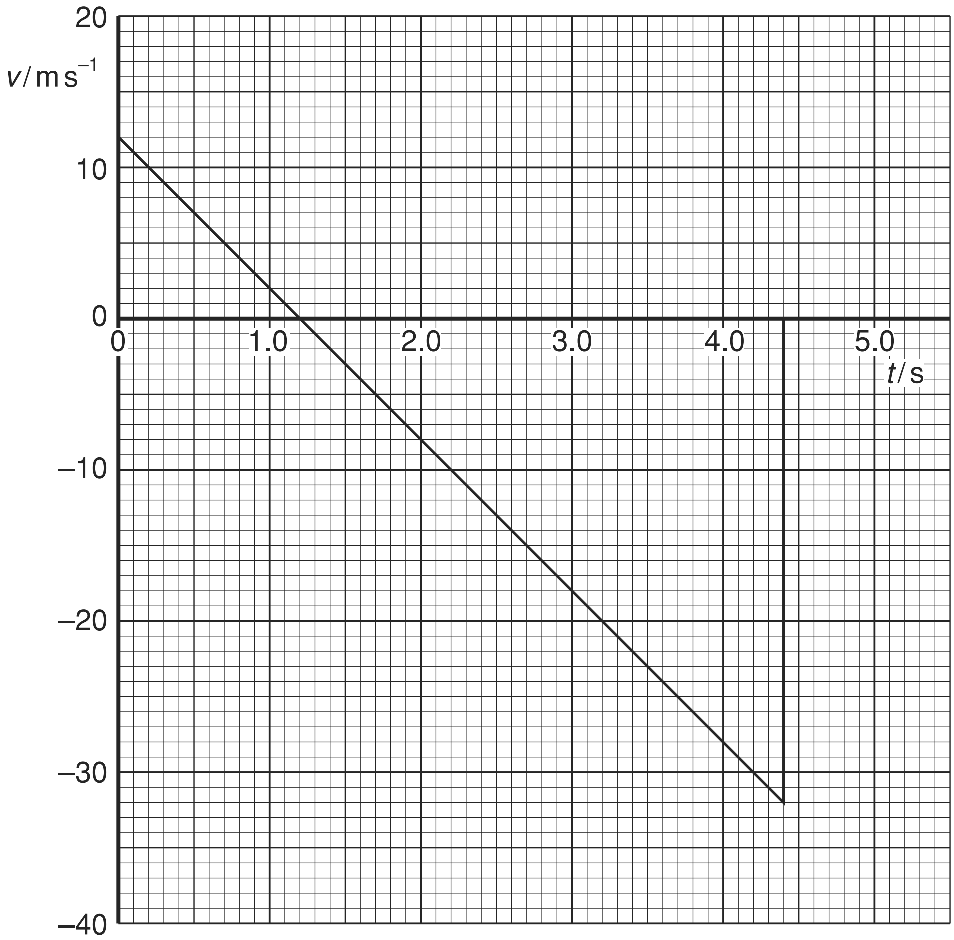


Fig. 3.2

Speeds in the upward direction are shown as being positive. Speeds in the downward direction are negative.

(a) State the feature of Fig. 3.2 that shows that the acceleration is constant.

.... [1]

(b) Use Fig. 3.2 to determine the time at which the ball

(i) reaches maximum height,

time = ... s

(ii) hits the ground at the base of the cliff.

time = ... s
[2]

(c) Determine the maximum height above the base of the cliff to which the ball rises.

height = ... m [3]

(d) The ball has mass 250 g. Calculate the magnitude of the change in momentum of the ball between the time that it leaves the girl's hand to time $t = 4.0$ s.

change = ... N s [3]

For Examiner's Use

(e) **(i)** State the principle of conservation of momentum.

....

....

.... [2]

(ii) Comment on your answer to **(d)** by reference to this principle.

....

....

....

.... [3]

For Examiner's Use

7 A trolley of mass 930 g is held on a horizontal surface by means of two springs, as shown in Fig. 4.1.

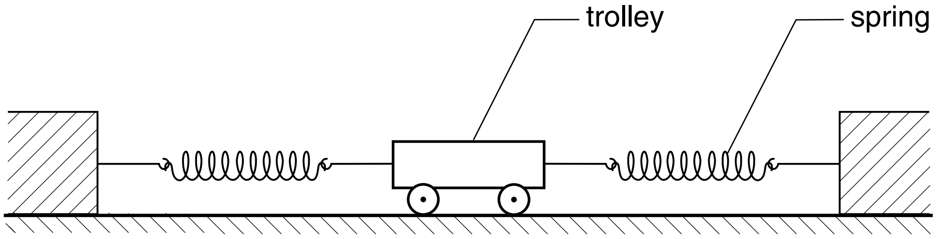


Fig. 4.1

The variation with time t of the speed v of the trolley for the first 0.60 s of its motion is shown in Fig. 4.2.

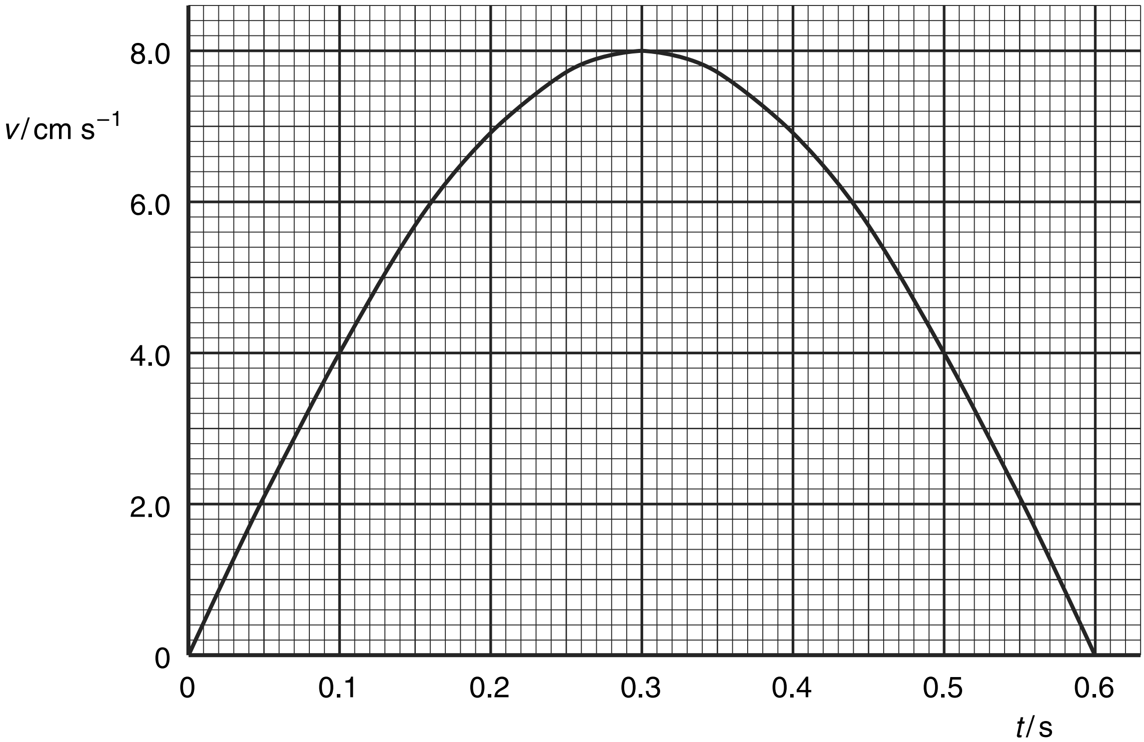


Fig. 4.2

(a) Use Fig. 4.2 to determine

(i) the initial acceleration of the trolley,

acceleration = ... m s^{-2} [2]

(ii) the distance moved during the first 0.60 s of its motion.

distance = ... m [3]

(b) **(i)** Use your answer to **(a)(i)** to determine the resultant force acting on the trolley at time $t = 0$.

force = ... N [2]

(ii) Describe qualitatively the variation with time of the resultant force acting on the trolley during the first 0.60 s of its motion.

....

....

....

.... [3]

8 A stone on a string is made to travel along a horizontal circular path, as shown in Fig. 3.1.

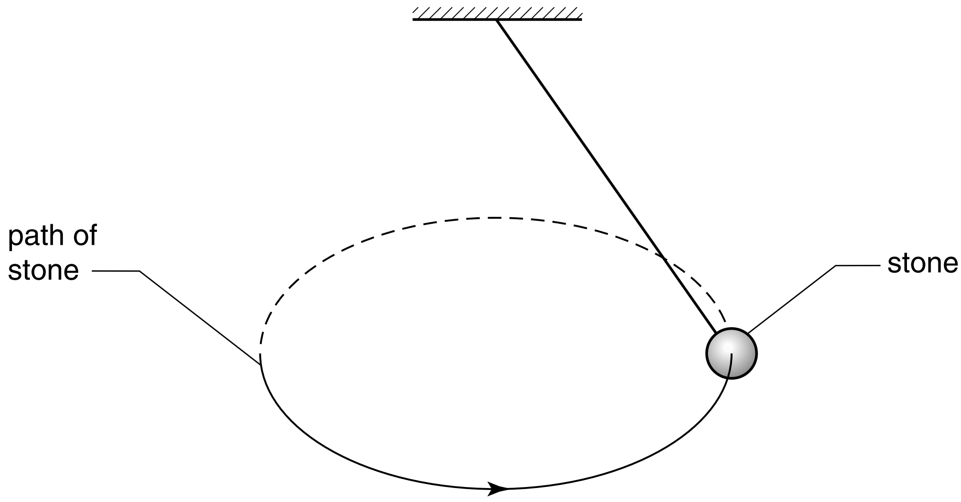


Fig. 3.1

The stone has a constant speed.

(a) Define *acceleration*.

....

.... [1]

(b) Use your definition to explain whether the stone is accelerating.

....

....

.... [2]

For Examiner's Use

(c) The stone has a weight of 5.0 N. When the string makes an angle of 35° to the vertical, the tension in the string is 6.1 N, as illustrated in Fig. 3.2.

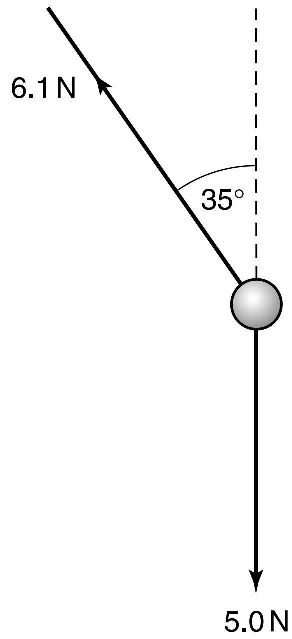


Fig. 3.2

Determine the resultant force acting on the stone in the position shown.

magnitude of force = ……………..…………………… N

direction of force….………………..………………….. [4]

9 A student investigates the speed of a trolley as it rolls down a slope, as illustrated in Fig. 2.1.

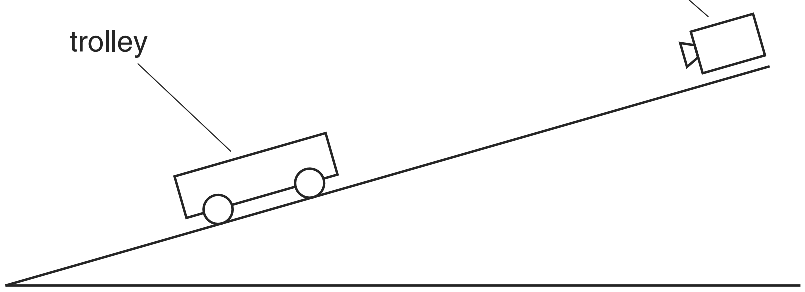


Fig. 2.1

The speed v of the trolley is measured using a speed sensor for different values of the time t that the trolley has moved from rest down the slope.

Fig. 2.2 shows the variation with t of v.

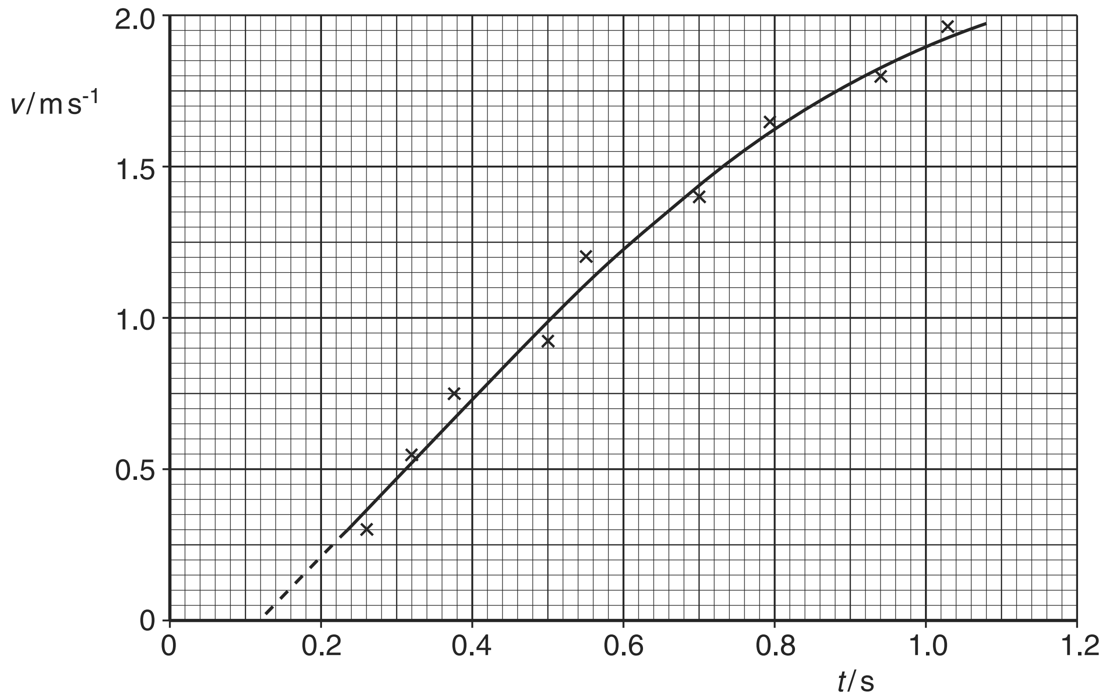


Fig. 2.2

For Examiner's Use

(a) Use Fig. 2.2 to determine the acceleration of the trolley at the point on the graph where $t = 0.80$ s.

acceleration = ... $m\,s^{-2}$ [4]

(b) **(i)** State whether the acceleration is increasing or decreasing for values of t greater than 0.6 s. Justify your answer by reference to Fig. 2.2.

....

....

.... [2]

(ii) Suggest an explanation for this change in acceleration.

....

.... [1]

(c) Name the feature of Fig. 2.2 that indicates the presence of

(i) random error,

....

.... [1]

(ii) systematic error.

....

.... [1]

For Examiner's Use

10 Francium-208 is radioactive and emits α-particles with a kinetic energy of 1.07×10^{-12} J to form nuclei of astatine, as illustrated in Fig. 3.1.

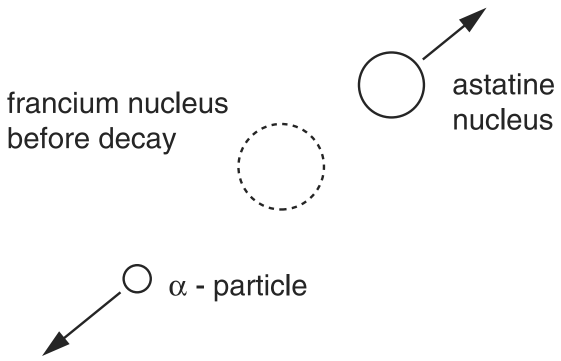


Fig. 3.1

(a) State the nature of an α-particle.

....

.... [1]

(b) Show that the initial speed of an α-particle after the decay of a francium nucleus is approximately $1.8 \times 10^{7}\,\mathrm{m\,s^{-1}}$.

[2]

(c) (i) State the principle of conservation of linear momentum.

....

....

.... [2]

(ii) The Francium-208 nucleus is stationary before the decay. Estimate the speed of the astatine nucleus immediately after the decay.

For Examiner's Use

speed = ... m s^{-1} [3]

(d) Close examination of the decay of the francium nucleus indicates that the astatine nucleus and the α-particle are not ejected exactly in opposite directions.

Suggest an explanation for this observation.

....

....

.... [2]

11 A girl G is riding a bicycle at a constant velocity of $3.5\,m\,s^{-1}$. At time $t = 0$, she passes a boy B sitting on a bicycle that is stationary, as illustrated in Fig. 2.1.

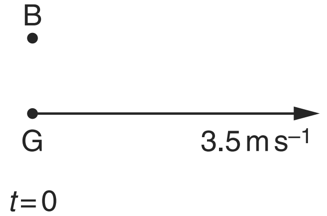


Fig. 2.1

At time $t = 0$, the boy sets off to catch up with the girl. He accelerates uniformly from time $t = 0$ until he reaches a speed of $5.6\,m\,s^{-1}$ in a time of 5.0 s. He then continues at a constant speed of $5.6\,m\,s^{-1}$. At time $t = T$, the boy catches up with the girl.
T is measured in seconds.

(a) State, in terms of T, the distance moved by the girl before the boy catches up with her.

distance = ... m [1]

(b) For the boy, determine

(i) the distance moved during his acceleration,

distance = ... m [2]

(ii) the distance moved during the time that he is moving at constant speed.
Give your answer in terms of T.

distance = ... m [1]

(c) Use your answers in **(a)** and **(b)** to determine the time *T* taken for the boy to catch up with the girl.

T = ... s [2]

(d) The boy and the bicycle have a combined mass of 67 kg.

(i) Calculate the force required to cause the acceleration of the boy.

force = ... N [3]

(ii) At a speed of 4.5 m s^{-1}, the total resistive force acting on the boy and bicycle is 23 N.
Determine the output power of the boy's legs at this speed.

power = ... W [2]

12 A car is travelling along a straight road at speed *v*. A hazard suddenly appears in front of the car. In the time interval between the hazard appearing and the brakes on the car coming into operation, the car moves forward a distance of 29.3 m. With the brakes applied, the front wheels of the car leave skid marks on the road that are 12.8 m long, as illustrated in Fig. 2.1.

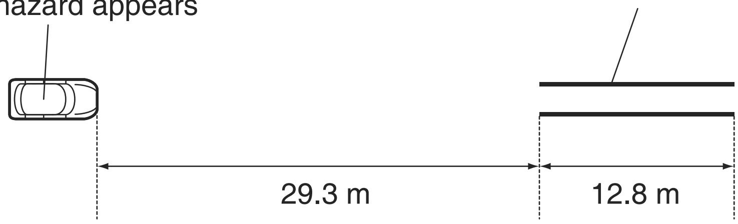


Fig. 2.1

It is estimated that, during the skid, the magnitude of the deceleration of the car is 0.85 *g*, where *g* is the acceleration of free fall.

(a) Determine

(i) the speed *v* of the car before the brakes are applied,

v = ... m s^{-1} [2]

(ii) the time interval between the hazard appearing and the brakes being applied.

time = ... s [2]

For Examiner's Use

(b) The legal speed limit on the road is 60 km per hour.
Use both of your answers in **(a)** to comment on the standard of the driving of the car.

....

....

....

.... [3]

For Examiner's Use

13 A sky-diver jumps from a high-altitude balloon.

(a) Explain briefly why the acceleration of the sky-diver

(i) decreases with time,

....

....

.... [2]

(ii) is $9.8\,m\,s^{-2}$ at the start of the jump.

....

.... [1]

(b) The variation with time t of the vertical speed v of the sky-diver is shown in Fig. 2.1.

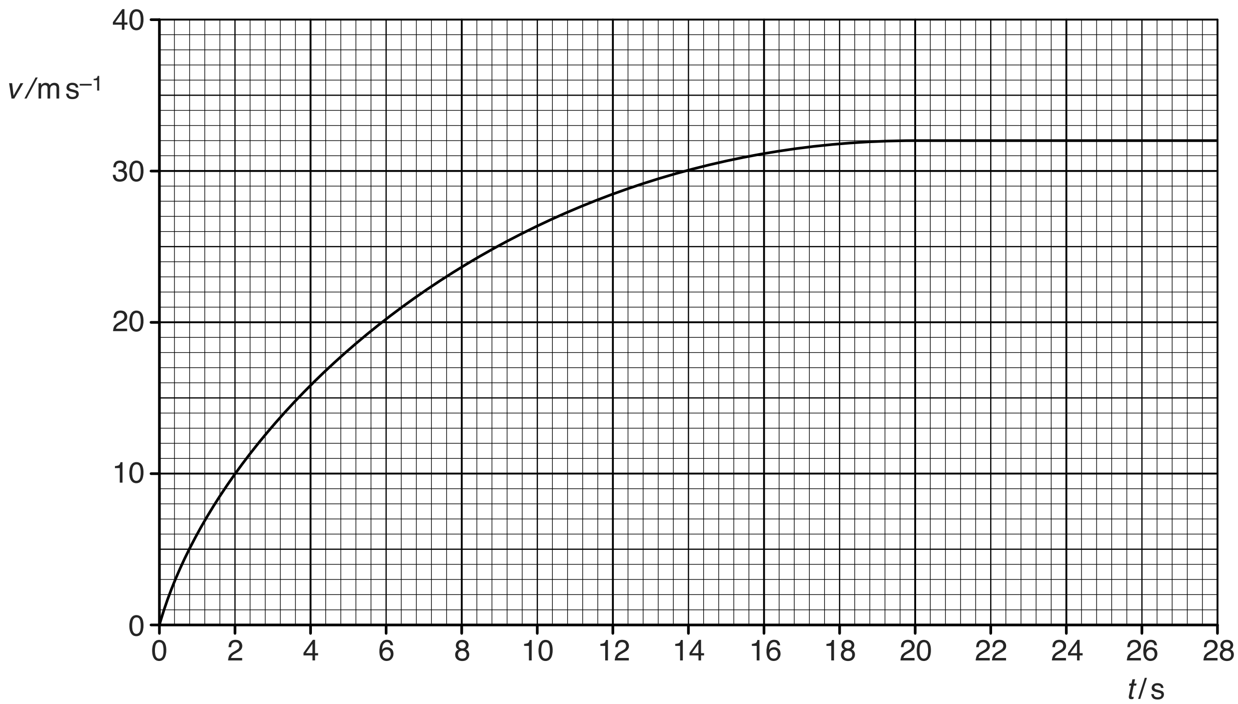


Fig. 2.1

For Examiner's Use

Use Fig. 2.1 to determine the magnitude of the acceleration of the sky-diver at time $t = 6.0$ s.

acceleration = ... m s^{-2} [3]

(c) The sky-diver and his equipment have a total mass of 90 kg.

(i) Calculate, for the sky-diver and his equipment,

1. the total weight,

weight = ... N [1]

2. the accelerating force at time $t = 6.0$ s.

force = ... N [1]

(ii) Use your answers in **(i)** to determine the total resistive force acting on the sky-diver at time $t = 6.0$ s.

force = ... N [1]

14 A stationary nucleus of mass 220u undergoes radioactive decay to produce a nucleus D of mass 216u and an α-particle of mass 4u, as illustrated in Fig. 3.1.

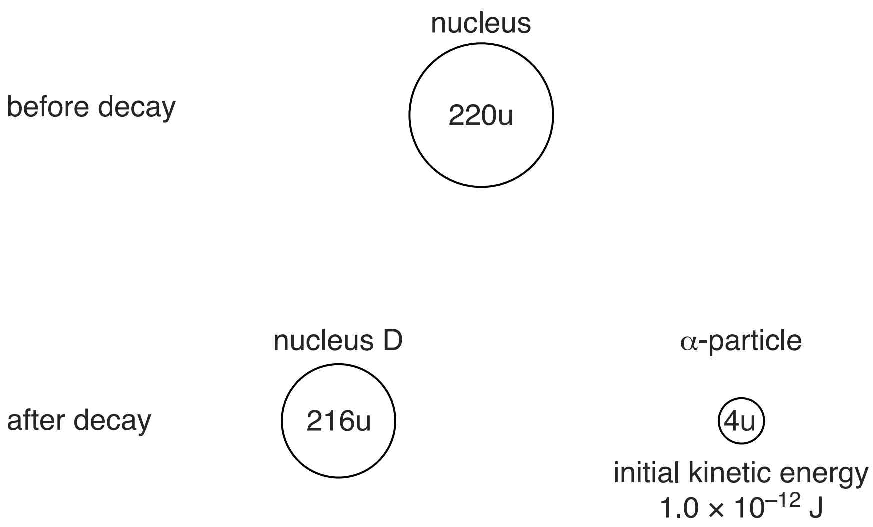


Fig. 3.1

The initial kinetic energy of the α-particle is 1.0×10^{-12} J.

(a) **(i)** State the law of conservation of linear momentum.

....

....

.... [2]

(ii) Explain why the initial velocities of the nucleus D and the α-particle must be in opposite directions.

....

....

.... [2]

(b) **(i)** Show that the initial speed of the α-particle is $1.7 \times 10^{7}\,\text{m s}^{-1}$.

[2]

(ii) Calculate the initial speed of nucleus D.

For Examiner's Use

speed = ... m s^{-1} [2]

(c) The range in air of the emitted α-particle is 4.5 cm.
Calculate the average deceleration of the α-particle as it is stopped by the air.

deceleration = ... m s^{-2} [2]

16 A steel ball of mass 73 g is held 1.6 m above a horizontal steel plate, as illustrated in Fig. 4.1.

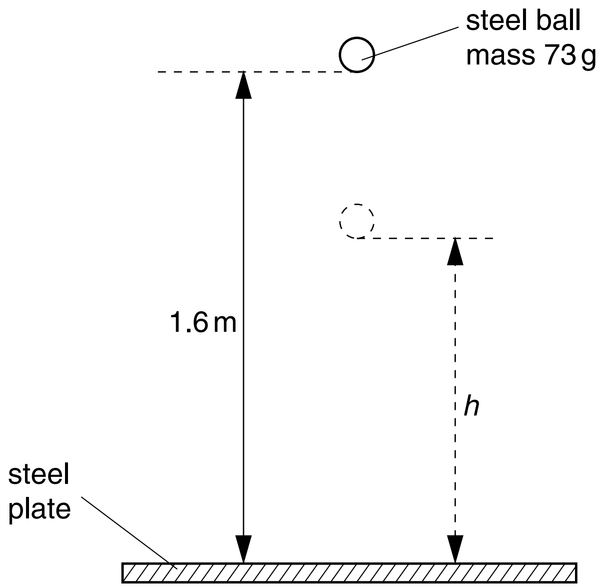


Fig. 4.1

The ball is dropped from rest and it bounces on the plate, reaching a height *h*.

(a) Calculate the speed of the ball as it reaches the plate.

speed = ... m s^{-1} [2]

(b) As the ball loses contact with the plate after bouncing, the kinetic energy of the ball is 90% of that just before bouncing. Calculate

(i) the height *h* to which the ball bounces,

h = ... m

For Examiner's Use

(ii) the speed of the ball as it leaves the plate after bouncing.

speed = ... m s^{-1}
[4]

(c) Using your answers to **(a)** and **(b)**, determine the change in momentum of the ball during the bounce.

change = ... N s [3]

(d) With reference to the law of conservation of momentum, comment on your answer to **(c)**.

....

....

....[3]

17 A ball has mass m. It is dropped onto a horizontal plate as shown in Fig. 4.1.

Fig. 4.1

Just as the ball makes contact with the plate, it has velocity v, momentum p and kinetic energy E_k.

(a) (i) Write down an expression for momentum p in terms of m and v.

....

(ii) Hence show that the kinetic energy is given by the expression

$$E_k = \frac{p^2}{2m}.$$

[3]

(b) Just before impact with the plate, the ball of mass 35 g has speed 4.5 m s^{-1}. It bounces from the plate so that its speed immediately after losing contact with the plate is 3.5 m s^{-1}. The ball is in contact with the plate for 0.14 s.

Calculate, for the time that the ball is in contact with the plate,

(i) the average force, in addition to the weight of the ball, that the plate exerts on the ball,

magnitude of force = ... N

direction of force = ...
[4]

(ii) the loss in kinetic energy of the ball.

loss = ... J [2]

(c) State and explain whether linear momentum is conserved during the bounce.

....

....

....

.... [3]

2 **(a)** Complete Fig. 2.1 to show whether each of the quantities listed is a vector or a scalar.

	vector / scalar
distance moved	....
speed	....
acceleration	....

Fig. 2.1

[3]

(b) A ball falls vertically in air from rest. The variation with time *t* of the distance *d* moved by the ball is shown in Fig. 2.2.

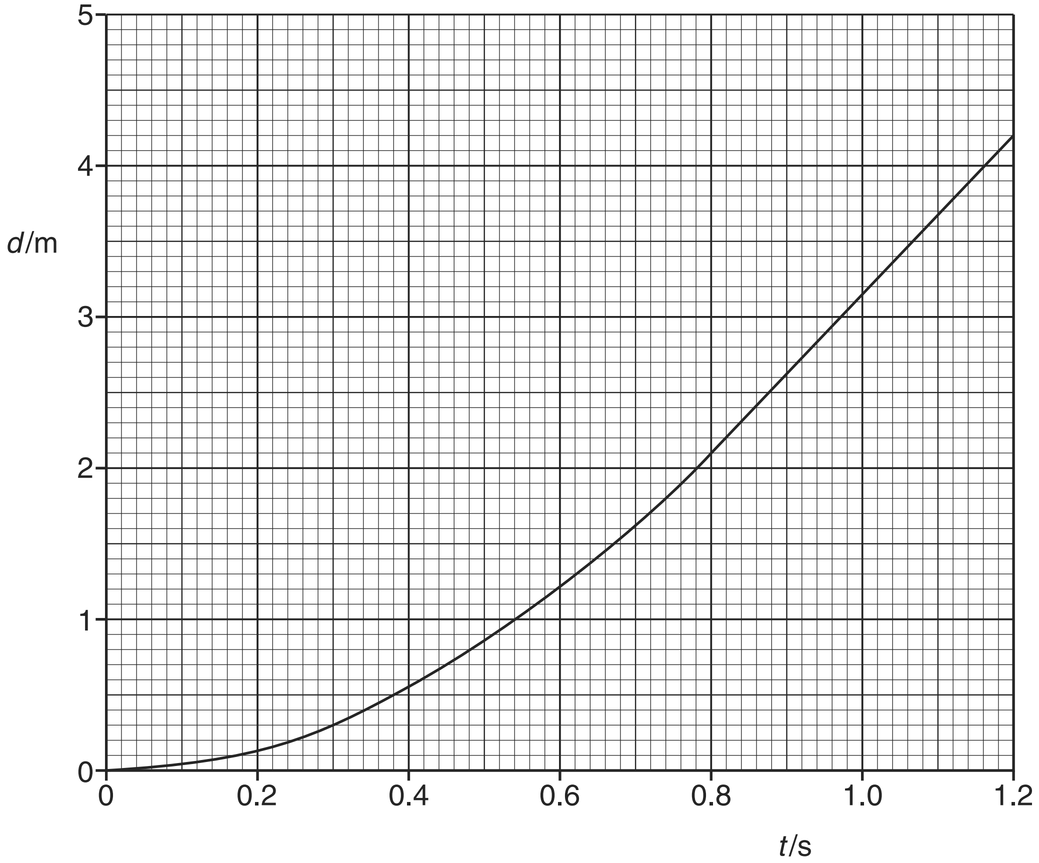


Fig. 2.2

(i) By reference to Fig. 2.2, explain how it can be deduced that

1. the ball is initially at rest,

....

....

....[2]

2. air resistance is not negligible.

....

....[1]

(ii) Use Fig. 2.2 to determine the speed of the ball at a time of 0.40 s after it has been released.

speed = ... $m\ s^{-1}$ [2]

(iii) On Fig. 2.2, sketch a graph to show the variation with time *t* of the distance *d* moved by the ball for negligible air resistance. You are not expected to carry out any further calculations. [3]

For Examiner's Use

2 **(a)** The distance s moved by an object in time t may be given by the expression

$$s = \frac{1}{2}at^2$$

where a is the acceleration of the object.

State two conditions for this expression to apply to the motion of the object.

1. ....

....

2. ....

....
[2]

(b) A student takes a photograph of a steel ball of radius 5.0 cm as it falls from rest. The image of the ball is blurred, as illustrated in Fig. 2.1.
The image is blurred because the ball is moving while the photograph is being taken.

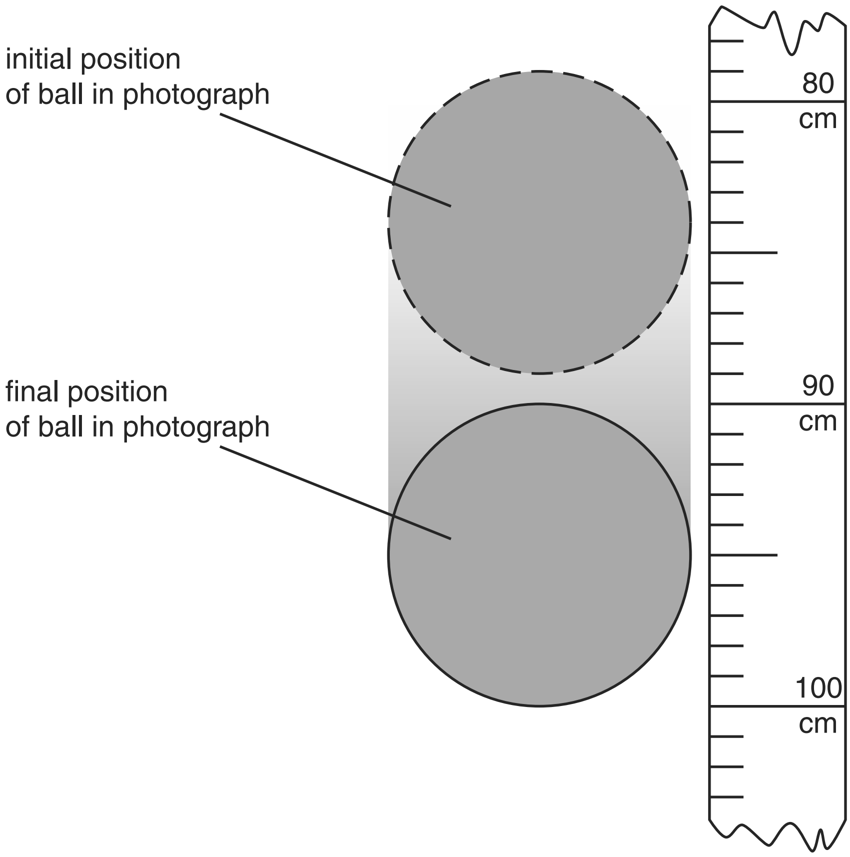


Fig. 2.1

The scale shows the distance fallen from rest by the ball. At time $t = 0$, the top of the ball is level with the zero mark on the scale. Air resistance is negligible.

For Examiner's Use

Calculate, to an appropriate number of significant figures,

(i) the time the ball falls before the photograph is taken,

time = ... s [3]

(ii) the time interval during which the photograph is taken.

time interval = ... s [3]

(c) The student in **(b)** takes a second photograph starting at the same position on the scale. The ball has the same radius but is less dense, so that air resistance is not negligible.

State and explain the changes that will occur in the photograph.

....

....

....

....[2]

4 A student takes measurements to determine a value for the acceleration of free fall. Some of the apparatus used is illustrated in Fig. 4.1.

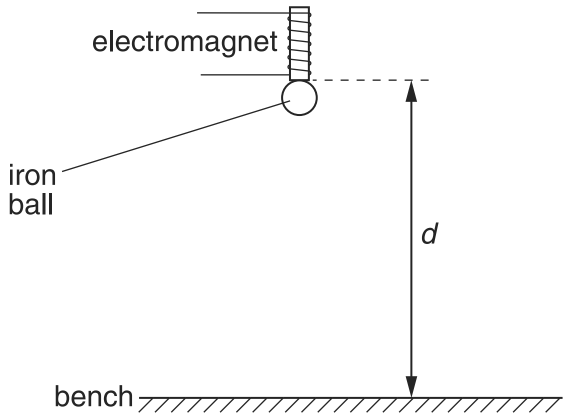


Fig. 4.1

The student measures the vertical distance d between the base of the electromagnet and the bench. The time t for an iron ball to fall from the electromagnet to the bench is also measured.
Corresponding values of t^2 and d are shown in Fig. 4.2.

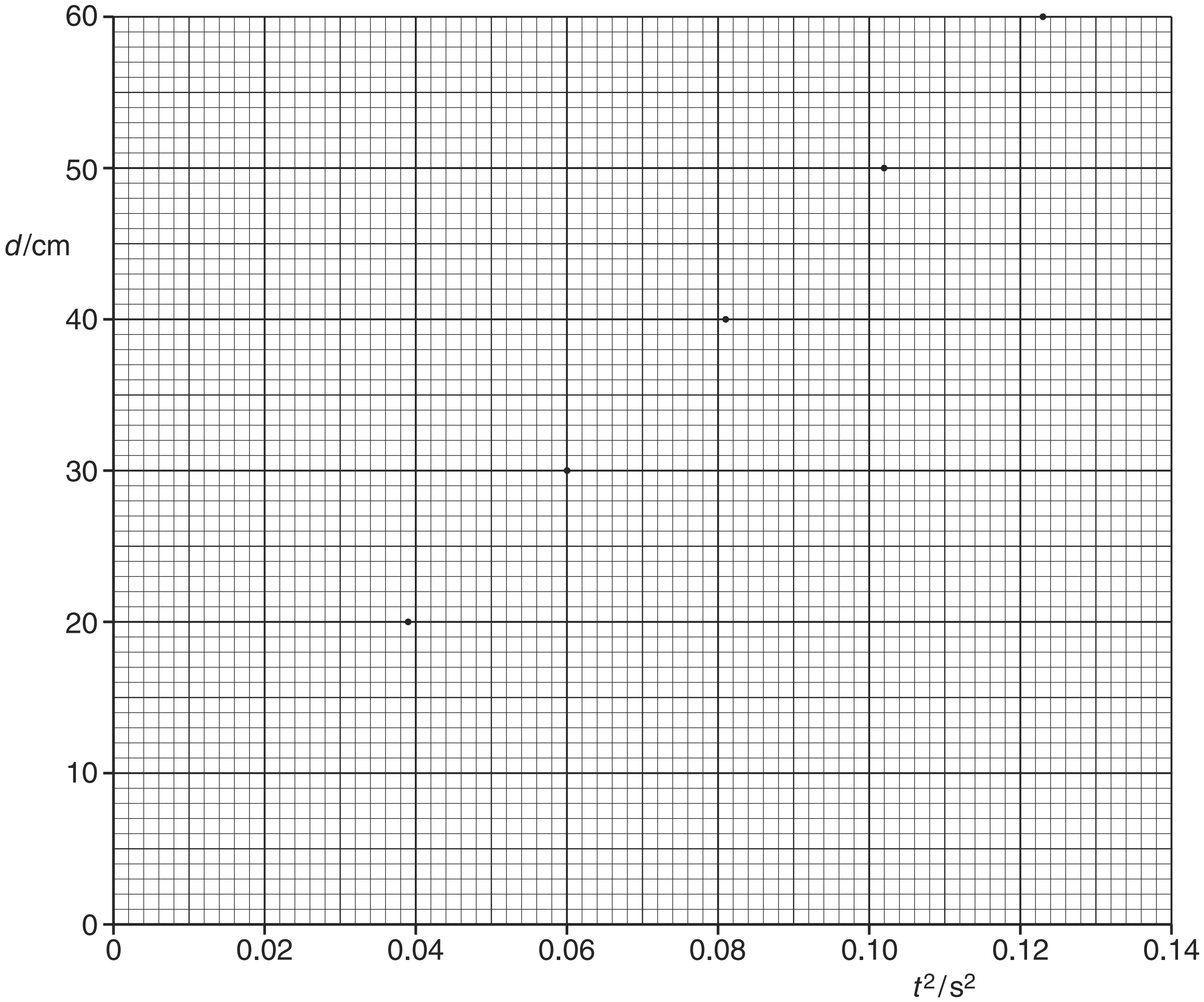


Fig. 4.2

(a) On Fig. 4.2, draw the line of best fit for the points. [1]

(b) State and explain why there is a non-zero intercept on the graph of Fig. 4.2.

....

....

.... [2]

(c) Determine the student's value for

(i) the diameter of the ball,

diameter = ... cm [1]

(ii) the acceleration of free fall.

acceleration = ... m s^{-2} [3]

3 A helicopter has a cable hanging from it towards the sea below, as shown in Fig. 3.1.

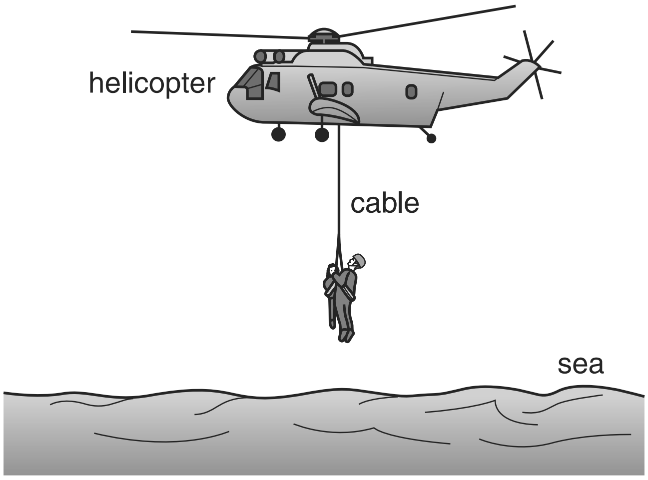


Fig. 3.1

A man of mass 80 kg rescues a child of mass 50.5 kg. The two are attached to the cable and are lifted from the sea to the helicopter. The lifting process consists of an initial uniform acceleration followed by a period of constant velocity and then completed by a final uniform deceleration.

(a) Calculate the combined weight of the man and child.

weight = ... N [1]

(b) Calculate the tension in the cable during

(i) the initial acceleration of $0.570\,\mathrm{m\,s^{-2}}$,

tension = ... N [2]

(ii) the period of constant velocity of $2.00\,\mathrm{m\,s^{-1}}$.

tension = ... N [1]

For Examiner's Use

(c) During the final deceleration the tension in the cable is 1240 N. Calculate this deceleration.

deceleration = ... $m\,s^{-2}$ [2]

(d) (i) Calculate the time over which the man and child are

1. moving with uniform acceleration,

time = ... s [1]

2. moving with uniform deceleration.

time = ... s [1]

(ii) The time over which the man and child are moving with constant velocity is 20 s. On Fig. 3.2, sketch a graph to show the variation with time of the velocity of the man and child for the complete lifting process.

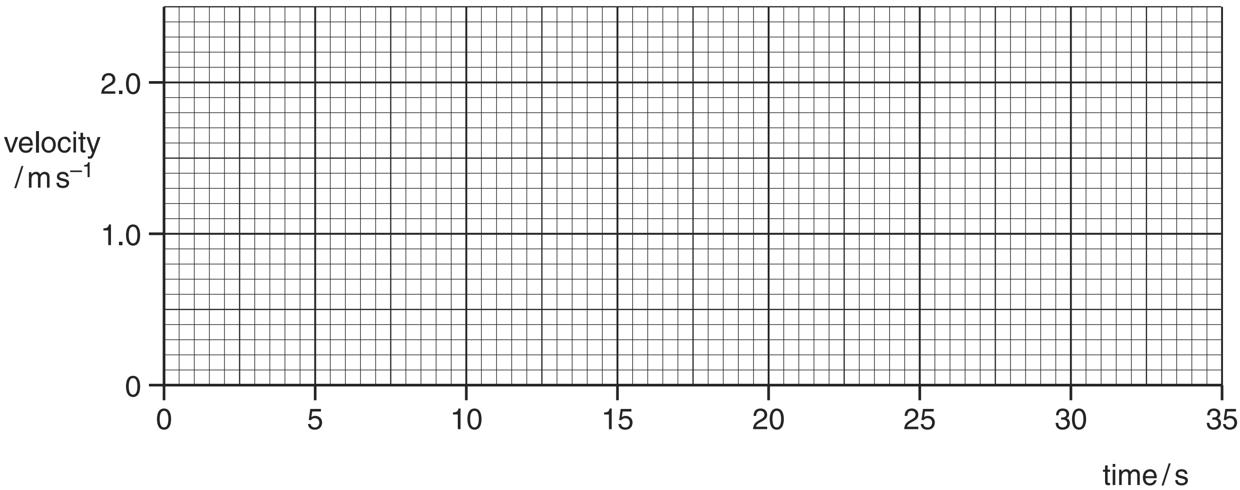


Fig. 3.2

[2]

For Examiner's Use

1 The variation with time t of the displacement s for a car is shown in Fig. 1.1.

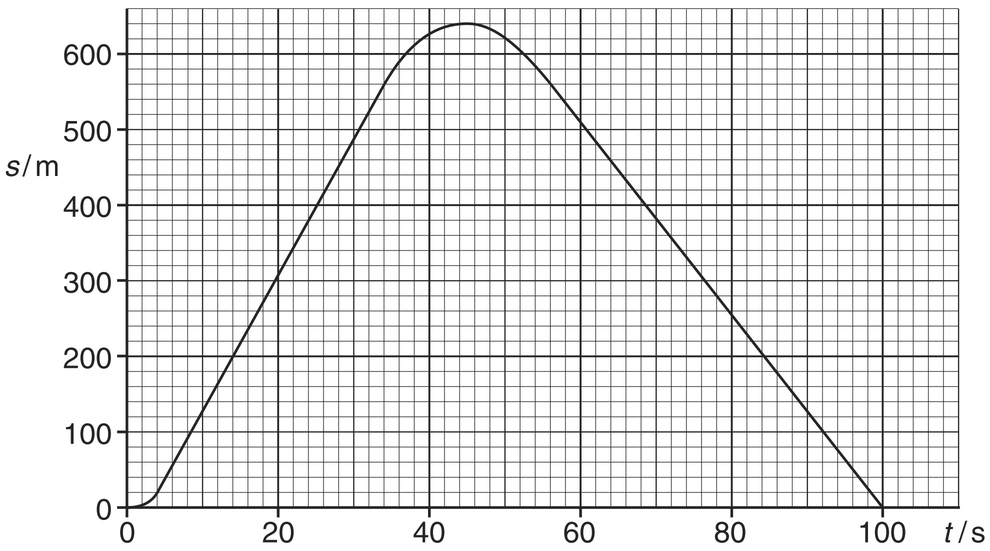


Fig. 1.1

(a) Determine the magnitude of the average velocity between the times 5.0 s and 35.0 s.

average velocity = ... $m\,s^{-1}$ [2]

(b) On Fig. 1.2, sketch the variation with time t of the velocity v for the car.

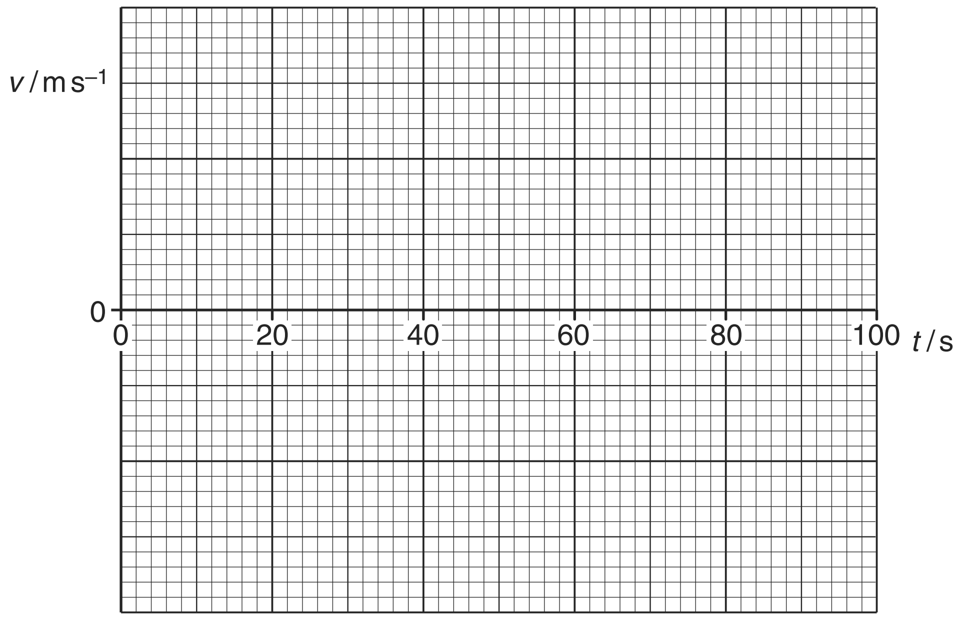


Fig. 1.2

[4]

2 The variation with time t of velocity v of a car is shown in Fig. 2.1.

For Examiner's Use

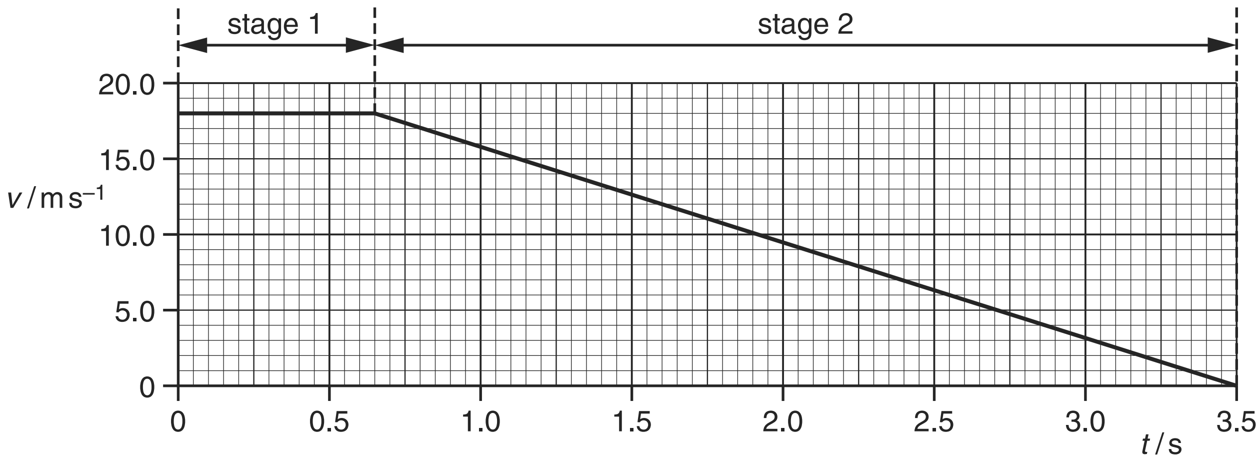


Fig. 2.1

At time $t = 0$, the driver sees an obstacle in the road. A short time later, the driver applies the brakes. The car travels in two stages, as shown in Fig. 2.1.

(a) Use Fig. 2.1 to describe the velocity of the car in

1. stage 1,

....

.... [1]

2. stage 2.

....

.... [1]

(b) **(i)** Calculate the distance travelled by the car from $t = 0$ to $t = 3.5$ s.

total distance = ... m [2]

(ii) The car has a total mass of 1250 kg. Determine the total resistive force acting on the car in stage 2.

For Examiner's Use

force = ... N [3]

(c) For safety reasons drivers are asked to travel at lower speeds. For each stage, describe and explain the effect on the distance travelled for the same car and driver travelling at half the initial speed shown in Fig. 2.1.

(i) stage 1:

....

....

.... [1]

(ii) stage 2:

....

....

....

.... [2]

For Examiner's Use

2 A ball is thrown vertically down towards the ground with an initial velocity of $4.23\,\text{m}\,\text{s}^{-1}$. The ball falls for a time of 1.51 s before hitting the ground. Air resistance is negligible.

(a) **(i)** Show that the downwards velocity of the ball when it hits the ground is $19.0\,\text{m}\,\text{s}^{-1}$.

[2]

(ii) Calculate, to three significant figures, the distance the ball falls to the ground.

distance = ... m [2]

(b) The ball makes contact with the ground for 12.5 ms and rebounds with an upwards velocity of $18.6\,\text{m}\,\text{s}^{-1}$. The mass of the ball is 46.5 g.

(i) Calculate the average force acting on the ball on impact with the ground.

magnitude of force = ... N

direction of force ....

[4]

(ii) Use conservation of energy to determine the maximum height the ball reaches after it hits the ground.

height = ... m [2]

(c) State and explain whether the collision the ball makes with the ground is elastic or inelastic.

....

....

....[1]

For Examiner's Use

2 **(a)** A ball is thrown vertically down towards the ground and rebounds as illustrated in Fig. 2.1.

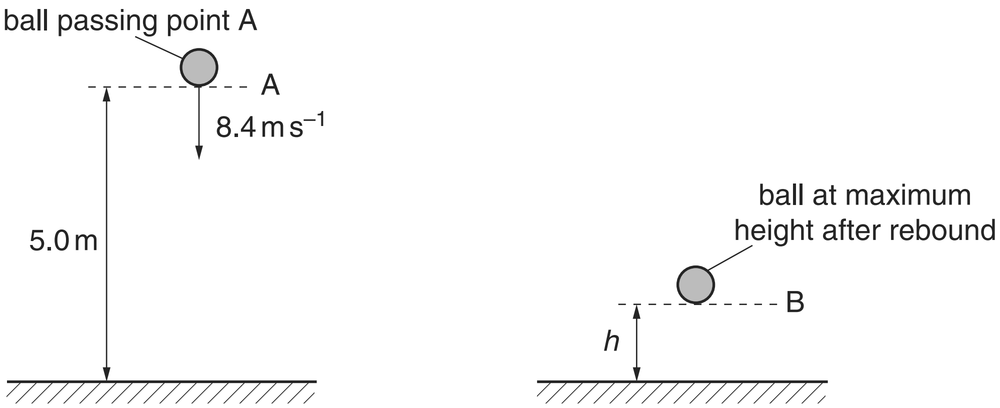


Fig. 2.1

As the ball passes A, it has a speed of $8.4\,\text{m s}^{-1}$. The height of A is 5.0 m above the ground. The ball hits the ground and rebounds to B. Assume that air resistance is negligible.

(i) Calculate the speed of the ball as it hits the ground.

speed = ... m s^{-1} [2]

(ii) Show that the time taken for the ball to reach the ground is 0.47 s.

[1]

(b) The ball rebounds vertically with a speed of $4.2\,m\,s^{-1}$ as it leaves the ground. The time the ball is in contact with the ground is 20 ms. The ball rebounds to a maximum height *h*.

The ball passes A at time $t = 0$. On Fig. 2.2, plot a graph to show the variation with time *t* of the velocity *v* of the ball. Continue the graph until the ball has rebounded from the ground and reaches B.

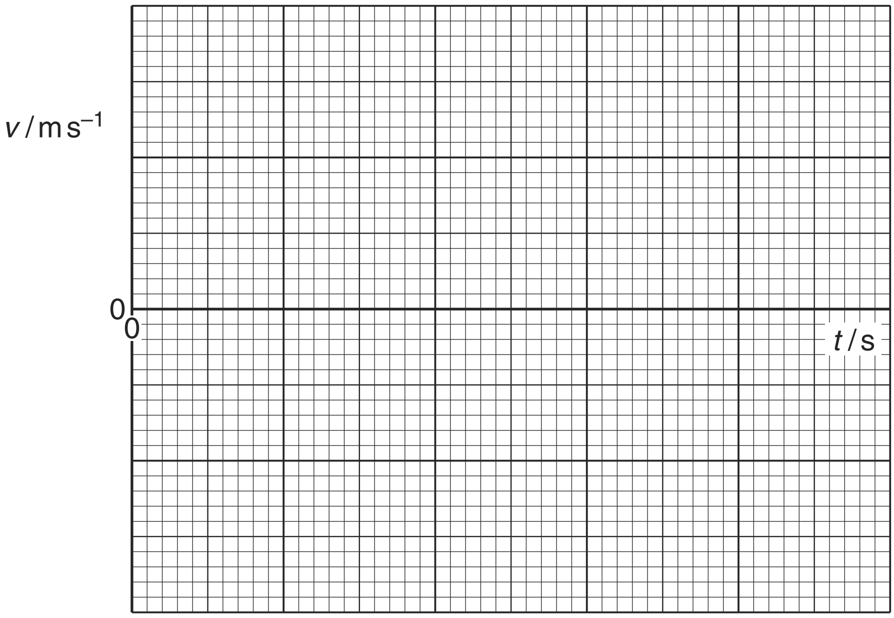


Fig. 2.2 [3]

(c) The ball has a mass of 0.050 kg. It moves from A and reaches B after rebounding.

(i) For this motion, calculate the change in

1. kinetic energy,

change in kinetic energy = ... J [2]

2. gravitational potential energy.

change in potential energy = ... J [3]

For Examiner's Use

(ii) State and explain the total change in energy of the ball for this motion.

....

....

....

.... [2]

For Examiner's Use

2 Two planks of wood AB and BC are inclined at an angle of 15° to the horizontal. The two wooden planks are joined at point B, as shown in Fig. 2.1.

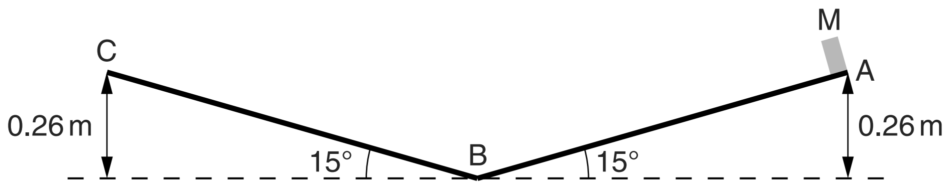


Fig. 2.1

A small block of metal M is released from rest at point A. It slides down the slope to B and up the opposite side to C. Points A and C are 0.26 m above B. Assume frictional forces are negligible.

(a) **(i)** Describe and explain the acceleration of M as it travels from A to B and from B to C.

....

....

....

.... [3]

(ii) Calculate the time taken for M to travel from A to B.

time = ... s [3]

(iii) Calculate the speed of M at B.

speed = ... $m\,s^{-1}$ [2]

(b) The plank BC is adjusted so that the angle it makes with the horizontal is 30°. M is released from rest at point A and slides down the slope to B. It then slides a distance along the plank from B towards C.

Use the law of conservation of energy to calculate this distance. Explain your working.

distance = ... m [2]

For Examiner's Use

Answer **all** the questions in the spaces provided.

1 **(a)** **(i)** Define *acceleration*.

....

.... [1]

(ii) State Newton's first law of motion.

....

.... [1]

(b) The variation with time t of vertical speed v of a parachutist falling from an aircraft is shown in Fig. 1.1.

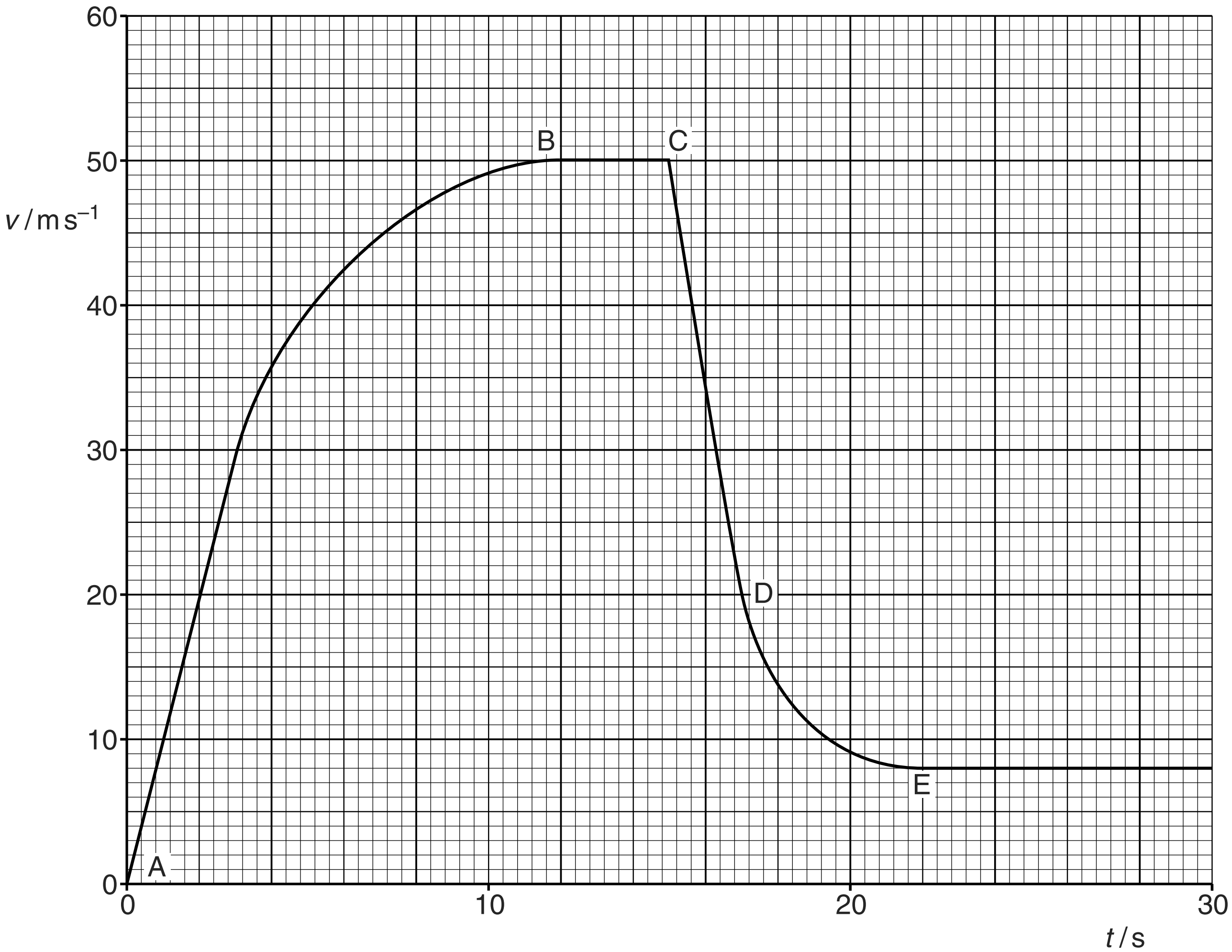


Fig. 1.1

For Examiner's Use

(i) Calculate the distance travelled by the parachutist in the first 3.0 s of the motion.

distance = ... m [2]

(ii) Explain the variation of the resultant force acting on the parachutist from t = 0 (point A) to t = 15 s (point C).

....

....

....

....

.... [3]

(iii) Describe the changes to the frictional force on the parachutist

1. at t = 15 s (point C),

....

....

.... [1]

2. between t = 15 s (point C) and t = 22 s (point E).

....

....

.... [1]

(iv) The mass of the parachutist is 95 kg.

Calculate, for the parachutist between t = 15 s (point C) and t = 17 s (point D),

1. the average acceleration,

acceleration = ... $m\,s^{-2}$ [2]

2. the average frictional force.

frictional force = ... N [3]

3 **(a)** **(i)** Define *force*.

....

.... [1]

(ii) State Newton's third law of motion.

....

....

....

.... [3]

(b) Two spheres approach one another along a line joining their centres, as illustrated in Fig. 3.1.

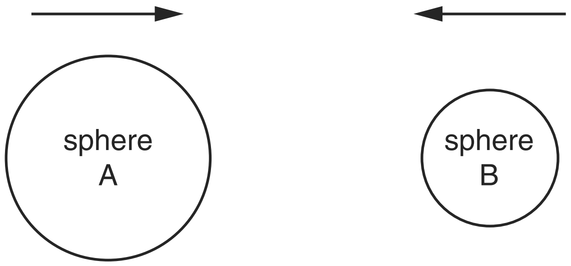


Fig. 3.1

When they collide, the average force acting on sphere A is F_A and the average force acting on sphere B is F_B.

The forces act for time t_A on sphere A and time t_B on sphere B.

(i) State the relationship between

1. F_A and F_B,

.... [1]

2. t_A and t_B.

.... [1]

(ii) Use your answers in **(i)** to show that the change in momentum of sphere A is equal in magnitude and opposite in direction to the change in momentum of sphere B.

....

.... [1]

For Examiner's Use

(c) For the spheres in **(b)**, the variation with time of the momentum of sphere A before, during and after the collision with sphere B is shown in Fig. 3.2.

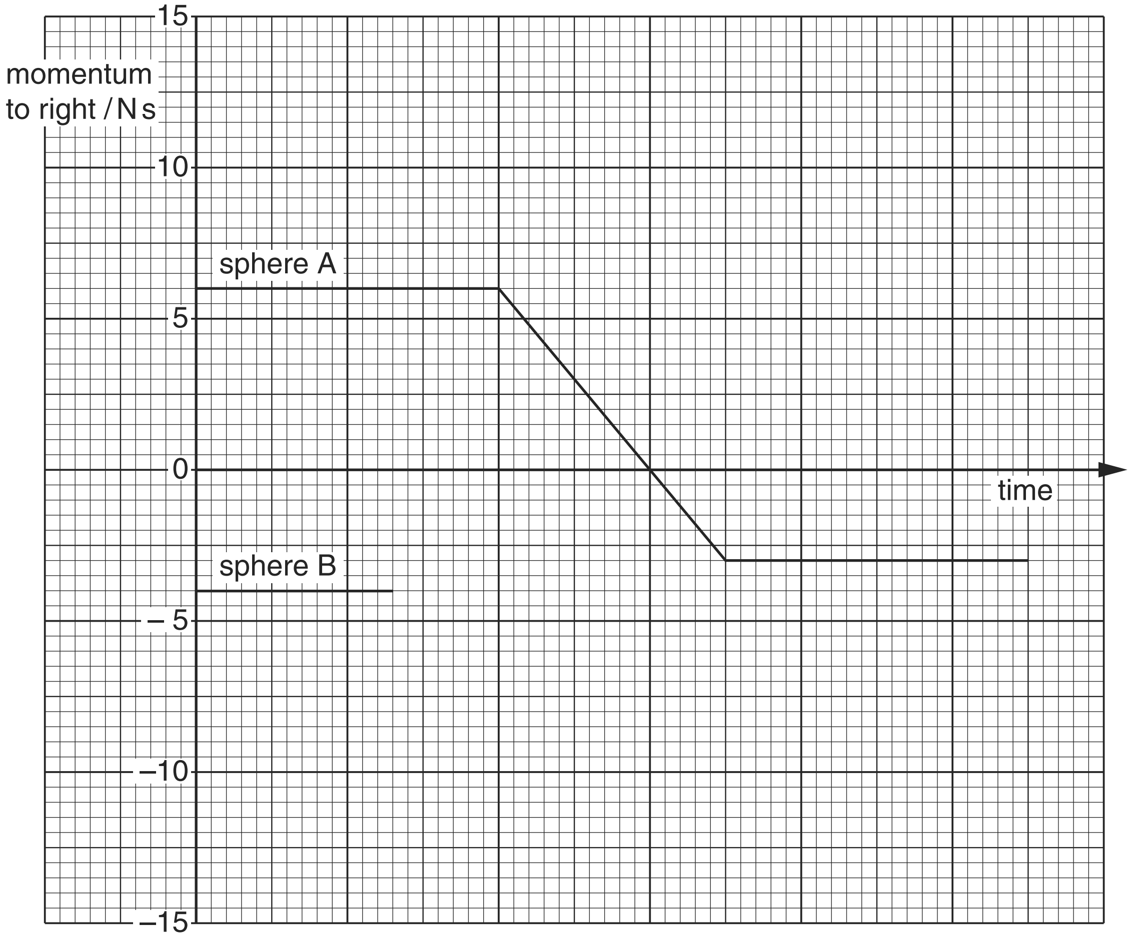


Fig. 3.2

The momentum of sphere B before the collision is also shown on Fig. 3.2.

Complete Fig. 3.2 to show the variation with time of the momentum of sphere B during and after the collision with sphere A. [3]

3 **(a)** **(i)** State the principle of conservation of momentum.

....

....

.... [2]

(ii) State the difference between an elastic and an inelastic collision.

.... [1]

(b) An object A of mass 4.2 kg and horizontal velocity 3.6 m s^{-1} moves towards object B as shown in Fig. 3.1.

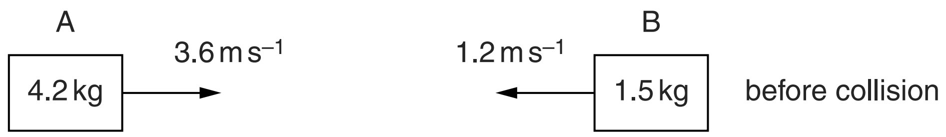


Fig. 3.1

Object B of mass 1.5 kg is moving with a horizontal velocity of 1.2 m s^{-1} towards object A.

The objects collide and then both move to the right, as shown in Fig. 3.2.

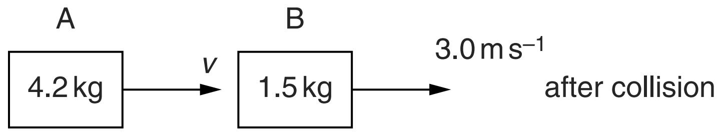


Fig. 3.2

Object A has velocity *v* and object B has velocity 3.0 m s^{-1}.

(i) Calculate the velocity *v* of object A after the collision.

velocity = ... m s^{-1} [3]

(ii) Determine whether the collision is elastic or inelastic.

[3]

For Examiner's Use

2 **(a)** Define *force*.

.... [1]

(b) A resultant force F acts on an object of mass 2.4 kg. The variation with time t of F is shown in Fig. 2.1.

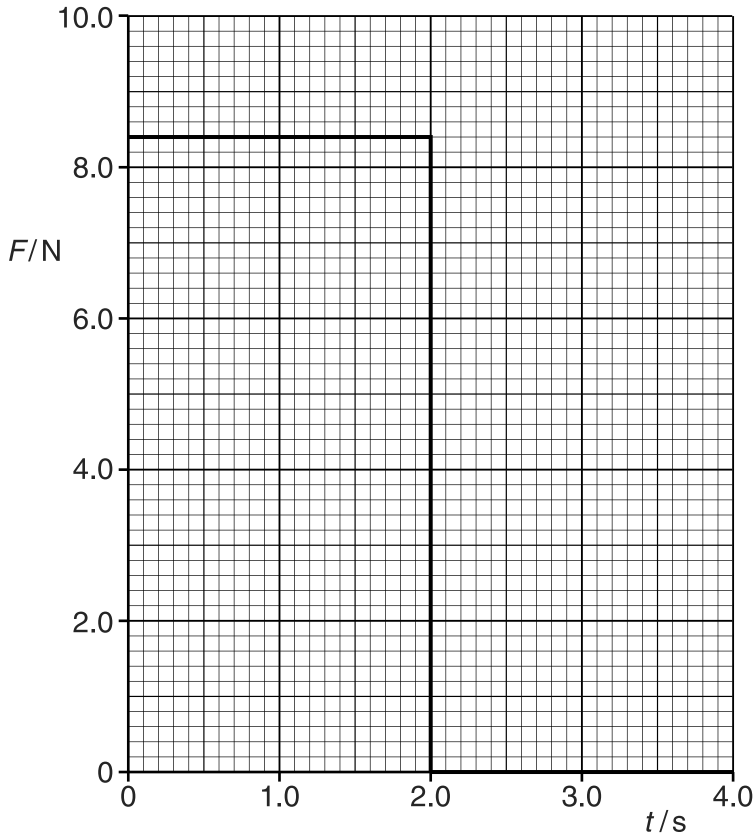


Fig. 2.1

The object starts from rest.

For Examiner's Use

(i) On Fig. 2.2, show quantitatively the variation with *t* of the acceleration *a* of the object. Include appropriate values on the *y*-axis.

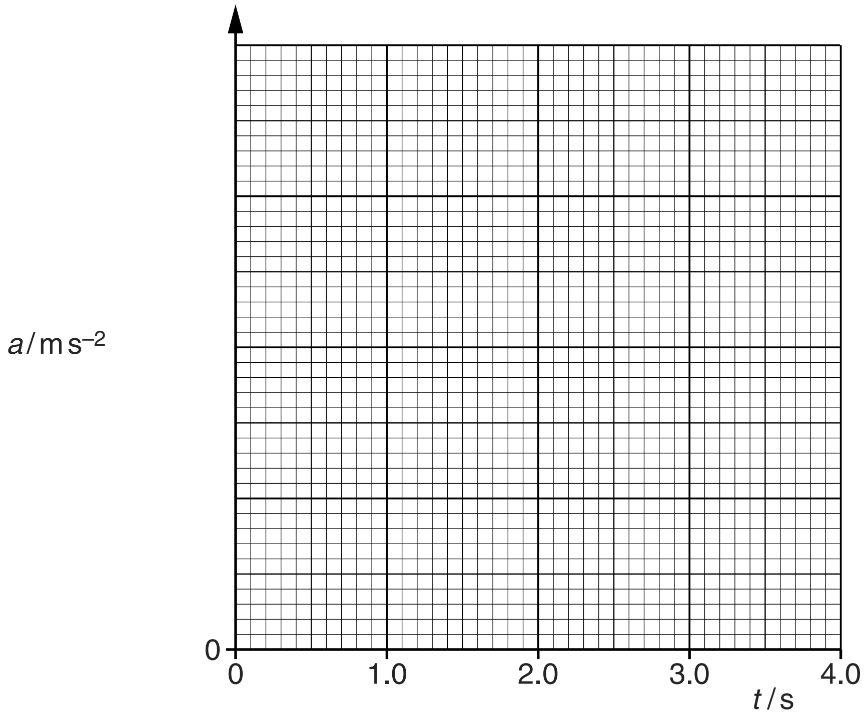


Fig. 2.2

[4]

(ii) On Fig. 2.3, show quantitatively the variation with *t* of the momentum *p* of the object. Include appropriate values on the *y*-axis.

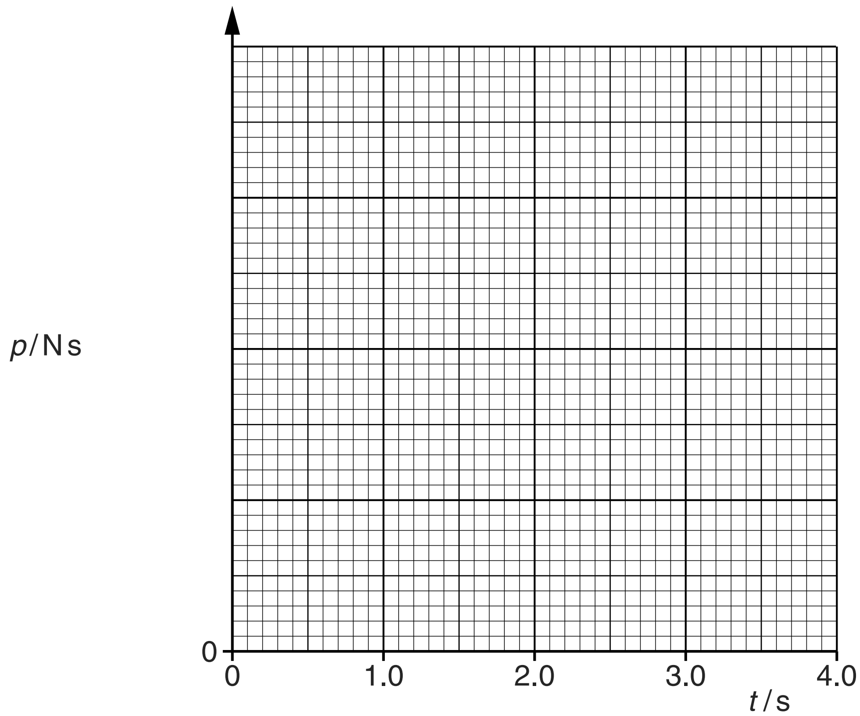


Fig. 2.3

[5]

Answer **all** the questions in the spaces provided.

1 **(a)** **(i)** Define *velocity*.

....

.... [1]

(ii) Distinguish between *speed* and *velocity*.

....

.... [2]

(b) A car of mass 1500 kg moves along a straight, horizontal road. The variation with time t of the velocity v for the car is shown in Fig. 1.1.

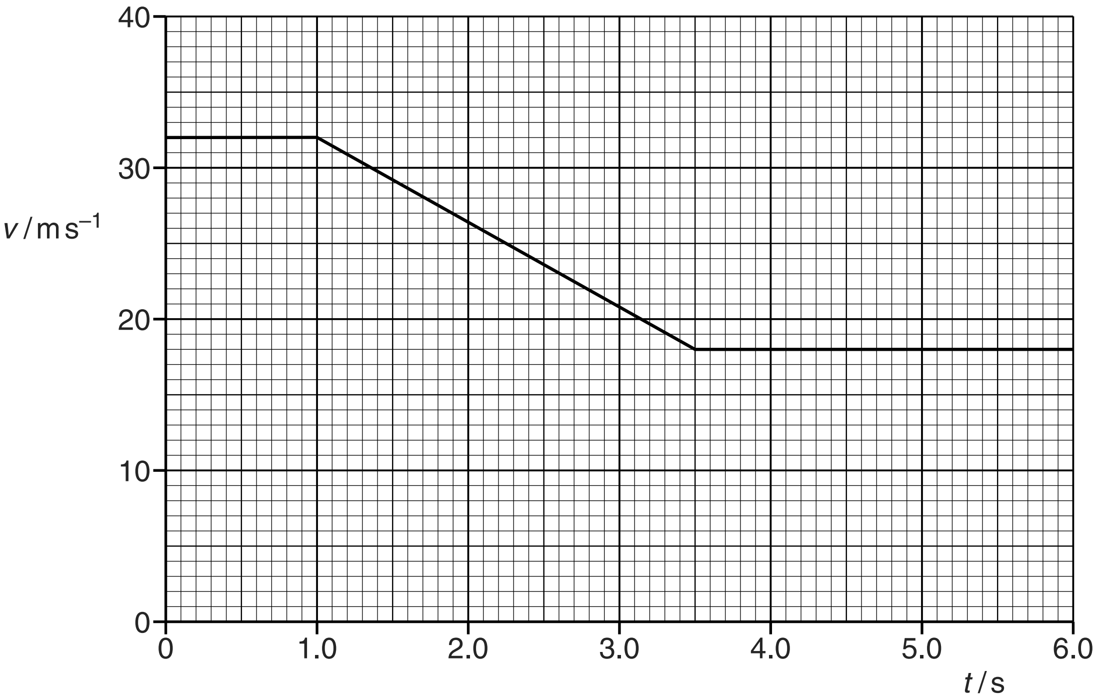


Fig. 1.1

The brakes of the car are applied from t = 1.0 s to t = 3.5 s.
For the time when the brakes are applied,

(i) calculate the distance moved by the car,

distance = ... m [3]

(ii) calculate the magnitude of the resultant force on the car.

resultant force = ... N [3]

(c) The direction of motion of the car in **(b)** at time $t = 2.0\,\text{s}$ is shown in Fig. 1.2.

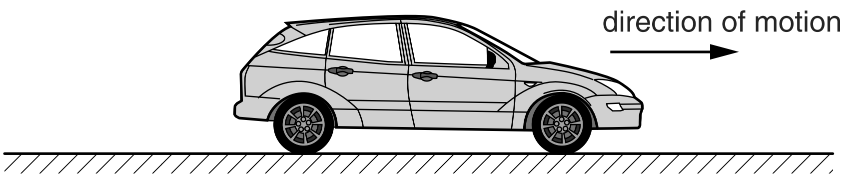


Fig. 1.2

On Fig. 1.2, show with arrows the directions of the acceleration (label this arrow A) and the resultant force (label this arrow F). [1]

4 **(a)** State the principle of conservation of momentum.

....

....

....[2]

(b) A ball X and a ball Y are travelling along the same straight line in the same direction, as shown in Fig. 4.1.

Fig. 4.1

Ball X has mass 400 g and horizontal velocity $0.65\,m\,s^{-1}$.
Ball Y has mass 600 g and horizontal velocity $0.45\,m\,s^{-1}$.

Ball X catches up and collides with ball Y. After the collision, X has horizontal velocity $0.41\,m\,s^{-1}$ and Y has horizontal velocity *v*, as shown in Fig. 4.2.

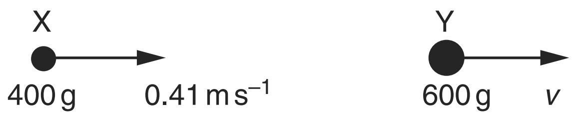


Fig. 4.2

Calculate

(i) the total initial momentum of the two balls,

momentum = ... N s [3]

(ii) the velocity *v*,

v = ... $m\,s^{-1}$ [2]

(iii) the total initial kinetic energy of the two balls.

kinetic energy = ... J [3]

(c) Explain how you would check whether the collision is elastic.

....

....[1]

(d) Use Newton's third law to explain why, during the collision, the change in momentum of X is equal and opposite to the change in momentum of Y.

....

....

....

....[2]

3 Two balls X and Y are supported by long strings, as shown in Fig. 3.1.

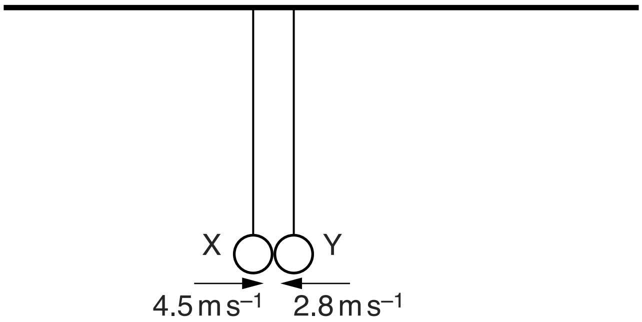


Fig. 3.1

The balls are each pulled back and pushed towards each other. When the balls collide at the position shown in Fig. 3.1, the strings are vertical. The balls rebound in opposite directions.

Fig. 3.2 shows data for X and Y during this collision.

ball	mass	velocity just before collision / $m\,s^{-1}$	velocity just after collision / $m\,s^{-1}$
X	50 g	+4.5	–1.8
Y	*M*	–2.8	+1.4

Fig. 3.2

The positive direction is horizontal and to the right.

(a) Use the conservation of linear momentum to determine the mass *M* of Y.

M = ... g [3]

(b) State and explain whether the collision is elastic.

....

....

....[1]

(c) Use Newton's second and third laws to explain why the magnitude of the change in momentum of each ball is the same.

....

....

....

....

....[3]

1

1 Some gas is contained in a cylinder by means of a moveable piston, as illustrated in Fig. 5.1.

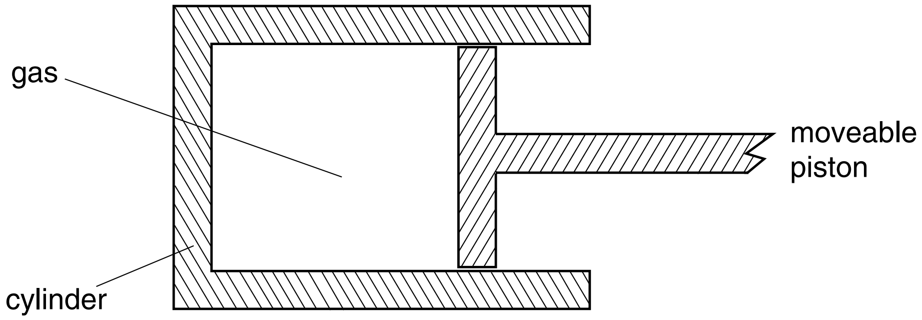


Fig. 5.1

State how, for this mass of gas, the following changes may be achieved.

(a) increase its gravitational potential energy

....[1]

(b) decrease its internal energy

....

....[1]

(c) increase its elastic potential energy

....

....[1]

2 **(a)** Explain what is meant by the *internal energy* of a substance.

....

....

.... [2]

(b) State and explain, in molecular terms, whether the internal energy of the following increases, decreases or does not change.

(i) a lump of iron as it is cooled

....

....

....

.... [3]

(ii) some water as it evaporates at constant temperature

....

....

....

.... [3]

3 A shopping trolley and its contents have a total mass of 42 kg. The trolley is being pushed along a horizontal surface at a speed of 1.2 m s^{-1}. When the trolley is released, it travels a distance of 1.9 m before coming to rest.

(a) Assuming that the total force opposing the motion of the trolley is constant,

(i) calculate the deceleration of the trolley,

deceleration = ... m s^{-2} [2]

(ii) show that the total force opposing the motion of the trolley is 16 N.

[1]

(b) Using the answer in **(a)(ii)**, calculate the power required to overcome the total force opposing the motion of the trolley at a speed of 1.2 m s^{-1}.

power = ... W [2]

(c) The trolley now moves down a straight slope that is inclined at an angle of 2.8° to the horizontal, as shown in Fig. 3.1.

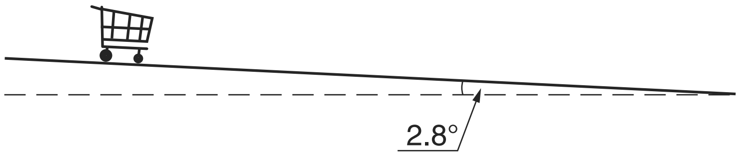


Fig. 3.1

The constant force that opposes the motion of the trolley is 16 N.

Calculate, for the trolley moving down the slope,

(i) the component down the slope of the trolley's weight,

component of weight = ... N [2]

(ii) the time for the trolley to travel from rest a distance of 3.5 m along the length of the slope.

time = ... s [4]

(d) Use your answer to **(c)(ii)** to explain why, for safety reasons, the slope is not made any steeper.

....

....[1]

For Examiner's Use

4 **(a)** Explain the concept of *work*.

....

....

.... [2]

(b) A table tennis ball falls vertically through air. Fig. 8.1 shows the variation of the kinetic energy E_K of the ball with distance h fallen. The ball reaches the ground after falling through a distance h_0.

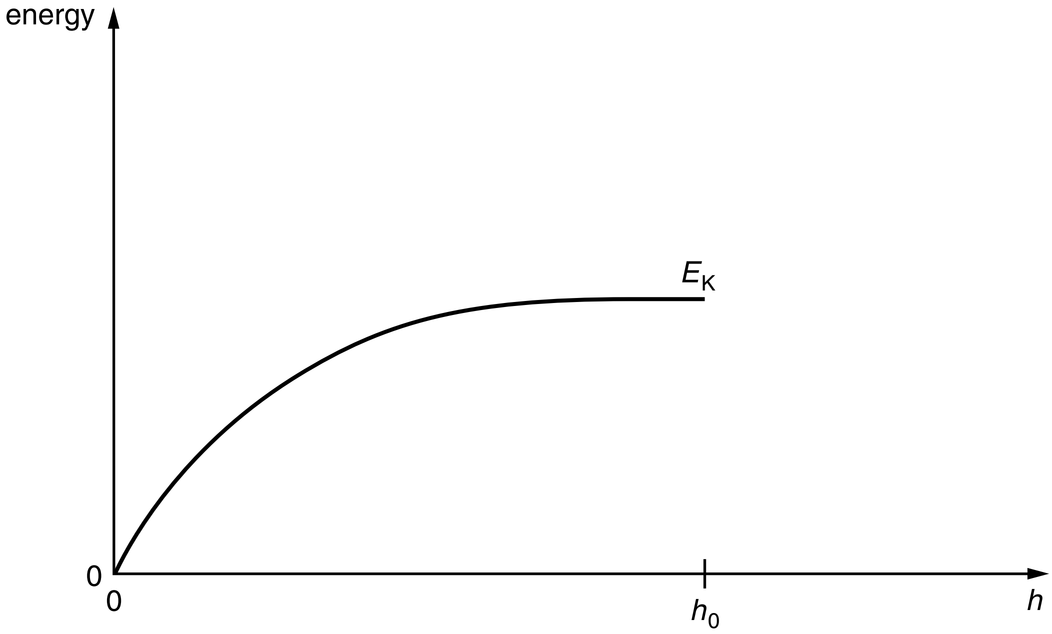


Fig. 8.1

(i) Describe the motion of the ball.

....

....

....

....

.... [3]

(ii) On Fig. 8.1, draw a line to show the variation with h of the gravitational potential energy E_P of the ball. At $h = h_0$, the potential energy is zero. [3]

For Examiner's Use

5 **(a)** Define what is meant by

(i) *work done*,

....

....

.... [2]

(ii) *power*.

....

.... [1]

(b) A force F is acting on a body that is moving with velocity v in the direction of the force.

Derive an expression relating the power P dissipated by the force to F and v.

[2]

(c) A car of mass 1900 kg accelerates from rest to a speed of 27 m s^{-1} in 8.1 s.

(i) Calculate the average rate at which kinetic energy is supplied to the car during the acceleration.

rate = ... W [2]

(ii) The car engine provides power at a constant rate. Suggest and explain why the acceleration of the car is **not** constant.

....

....

.... [2]

For Examiner's Use

6 **(a)** **(i)** Define potential energy.

....

.... [1]

(ii) Distinguish between *gravitational* potential energy and *elastic* potential energy.

gravitational potential energy ....

....

elastic potential energy ....

.... [2]

(b) A small sphere of mass 51 g is suspended by a light inextensible string from a fixed point P.
The centre of the sphere is 61 cm vertically below point P, as shown in Fig. 3.1.

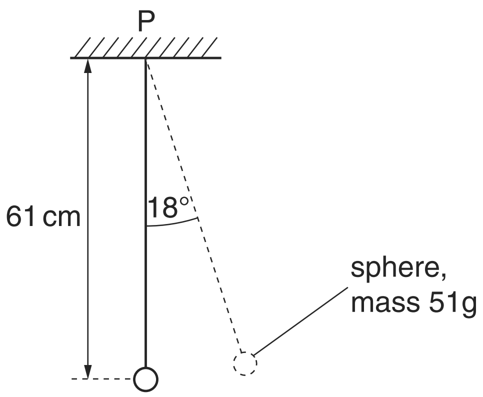


Fig. 3.1

The sphere is moved to one side, keeping the string taut, so that the string makes an angle of 18° with the vertical. Calculate

(i) the gain in gravitational potential energy of the sphere,

gain = ... J [2]

(ii) the moment of the weight of the sphere about point P.

moment = ... N m [2]

For Examiner's Use

3 A cyclist is moving up a slope that has a constant gradient. The cyclist takes 8.0 s to climb the slope.
The variation with time t of the speed v of the cyclist is shown in Fig. 3.1.

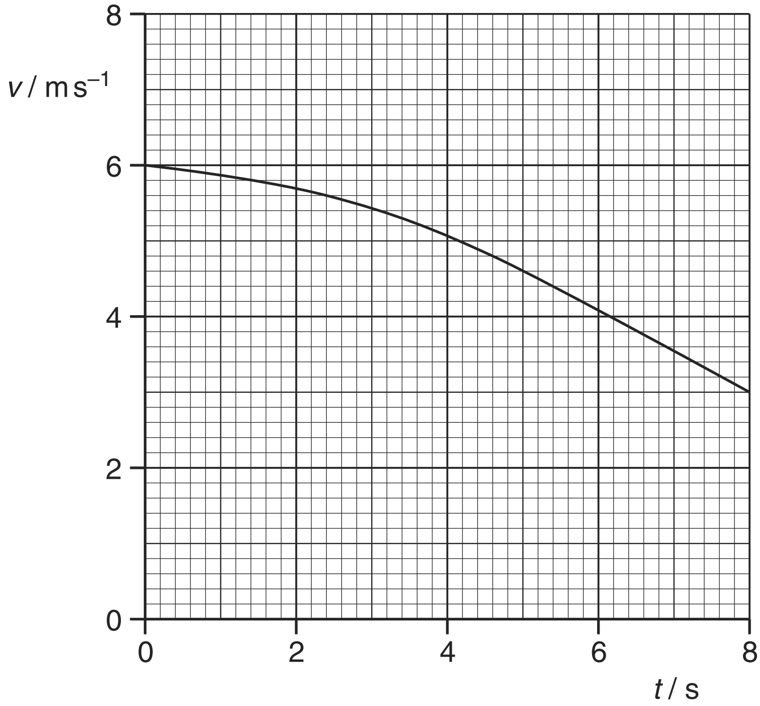


Fig. 3.1

(a) Use Fig. 3.1 to determine the total distance moved up the slope.

distance = ... m [3]

(b) The bicycle and cyclist have a combined mass of 92 kg.
The vertical height through which the cyclist moves is 1.3 m.

(i) For the movement of the bicycle and cyclist between $t = 0$ and $t = 8.0$ s,

1. use Fig. 3.1 to calculate the change in kinetic energy,

change = ... J [2]

2. calculate the change in gravitational potential energy.

change = ... J [2]

(ii) The cyclist pedals continuously so that the useful power delivered to the bicycle is 75 W.
Calculate the useful work done by the cyclist climbing up the slope.

work done = ... J [2]

(c) Some energy is used in overcoming frictional forces.

(i) Use your answers in **(b)** to show that the total energy converted in overcoming frictional forces is approximately 670 J.

[1]

(ii) Determine the average magnitude of the frictional forces.

average force = ...N [1]

(d) Suggest why the magnitude of the total resistive force would not be constant.

....

....

....[2]

3 **(a)** **(i)** Explain what is meant by *work done*.

....

.... [1]

(ii) Define *power*.

....

.... [1]

(b) Fig. 3.1 shows part of a fairground ride with a carriage on rails.

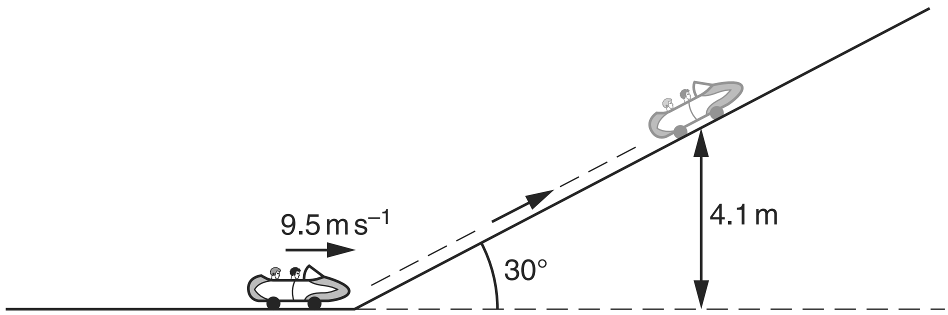


Fig. 3.1

The carriage and passengers have a total mass of 600 kg. The carriage is travelling at a speed of 9.5 m s^{-1} towards a slope inclined at 30° to the horizontal. The carriage comes to rest after travelling up the slope to a vertical height of 4.1 m.

(i) Calculate the kinetic energy, in kJ, of the carriage and passengers as they travel towards the slope.

kinetic energy = ... kJ [3]

(ii) Show that the gain in potential energy of the carriage and passengers is 24 kJ.

[2]

For Examiner's Use

(iii) Calculate the work done against the resistive force as the carriage moves up the slope.

work done = ... kJ [1]

(iv) Use your answer in **(iii)** to calculate the resistive force acting against the carriage as it moves up the slope.

resistive force = ... N [2]

2 **(a)** Explain what is meant by *work done*.

....

.... [1]

(b) A car is travelling along a road that has a uniform downhill gradient, as shown in Fig. 2.1.

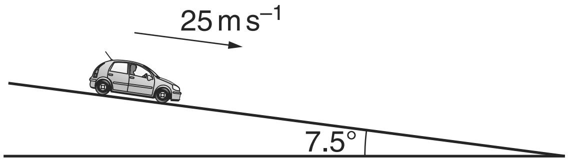


Fig. 2.1

The car has a total mass of 850 kg. The angle of the road to the horizontal is 7.5°.

Calculate the component of the weight of the car down the slope.

component of weight = ... N [2]

(c) The car in **(b)** is travelling at a constant speed of 25 m s^{-1}. The driver then applies the brakes to stop the car. The constant force resisting the motion of the car is 4600 N.

(i) Show that the deceleration of the car with the brakes applied is 4.1 m s^{-2}.

[2]

(ii) Calculate the distance the car travels from when the brakes are applied until the car comes to rest.

distance = ... m [2]

For Examiner's Use

(iii) Calculate

1. the loss of kinetic energy of the car,

loss of kinetic energy = ... J [2]

2. the work done by the resisting force of 4600 N.

work done = ... J [1]

(iv) The quantities in **(iii) part 1** and in **(iii) part 2** are not equal. Explain why these two quantities are not equal.

....

.... [1]

4 **(a)** Distinguish between *gravitational potential energy* and *electric potential energy*.

....

....

.... [2]

(b) A body of mass *m* moves vertically through a distance *h* near the Earth's surface. Use the defining equation for work done to derive an expression for the gravitational potential energy change of the body.

[2]

(c) Water flows down a stream from a reservoir and then causes a water wheel to rotate, as shown in Fig. 4.1.

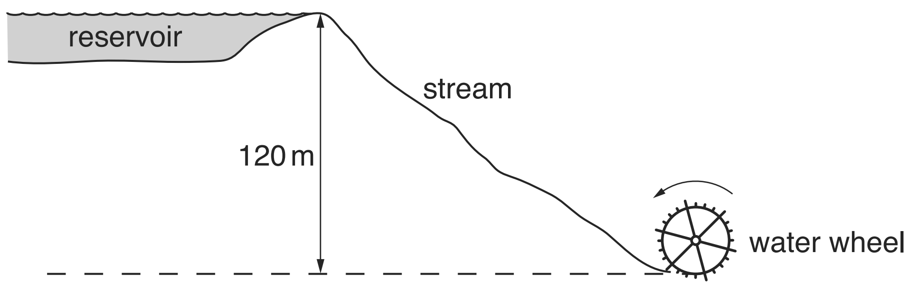


Fig. 4.1

As the water falls through a vertical height of 120 m, gravitational potential energy is converted to different forms of energy, including kinetic energy of the water. At the water wheel, the kinetic energy of the water is only 10% of its gravitational potential energy at the reservoir.

(i) Show that the speed of the water as it reaches the wheel is $15\,m\,s^{-1}$.

[2]

(ii) The rotating water wheel is used to produce 110 kW of electrical power. Calculate the mass of water flowing per second through the wheel, assuming that the production of electric energy from the kinetic energy of the water is 25% efficient.

For Examiner's Use

mass of water per second = ... $kg\,s^{-1}$ [3]

For Examiner's Use

2 **(a)** Define

(i) *force*,

....

....[1]

(ii) *work done*.

....

....[1]

(b) A force F acts on a mass m along a straight line for a distance s. The acceleration of the mass is a and the speed changes from an initial speed u to a final speed v.

(i) State the work W done by F.

[1]

(ii) Use your answer in **(i)** and an equation of motion to show that kinetic energy of a mass can be given by the expression

kinetic energy = ½ × mass × (speed)^2.

[3]

(c) A resultant force of 3800 N causes a car of mass of 1500 kg to accelerate from an initial speed of 15 m s^{-1} to a final speed of 30 m s^{-1}.

(i) Calculate the distance moved by the car during this acceleration.

distance = ... m [2]

(ii) The same force is used to change the speed of the car from 30 m s^{-1} to 45 m s^{-1}. Explain why the distance moved is not the same as that calculated in **(i)**.

....

....

....[1]

3 **(a)** Define the terms

(i) *power*,

.... [1]

(ii) the *Young modulus*.

....

....

.... [1]

(b) A crane is used to lift heavy objects, as shown in Fig. 3.1.

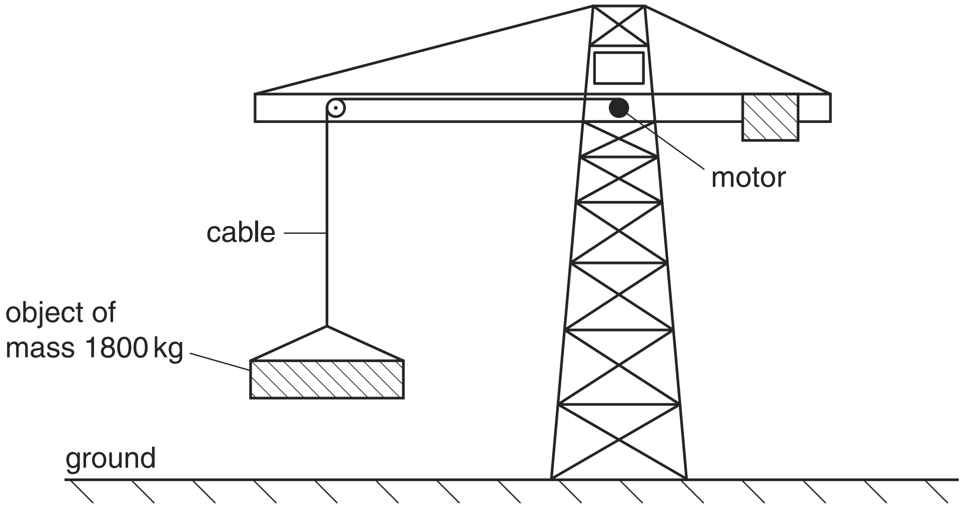


Fig. 3.1

The motor in the crane lifts a total mass of 1800 kg from rest on the ground. The cable supporting the mass is made of steel of Young modulus 2.4×10^{11} Pa. The cross-sectional area of the cable is 1.3×10^{-4} m^2. As the mass leaves the ground, the strain in the cable is 0.0010. Assume the weight of the cable to be negligible.

(i) **1.** Use the Young Modulus of the steel to show that the tension in the cable is 3.1×10^4 N.

[2]

2. Calculate the acceleration of the mass as it is lifted from the ground.

acceleration = ... m s^{-2} [3]

For Examiner's Use

(ii) The motor now lifts the mass through a height of 15 m at a constant speed.

Calculate

1. the tension in the lifting cable,

tension = ... N [1]

2. the gain in potential energy of the mass.

gain in potential energy = ... J [2]

(iii) The motor of the crane is 30% efficient. Calculate the input power to the motor required to lift the mass at a constant speed of $0.55\,\mathrm{m\,s^{-1}}$.

input power = ... W [3]

For Examiner's Use

2 **(a)** A ball is thrown vertically down towards the ground and rebounds as illustrated in Fig. 2.1.

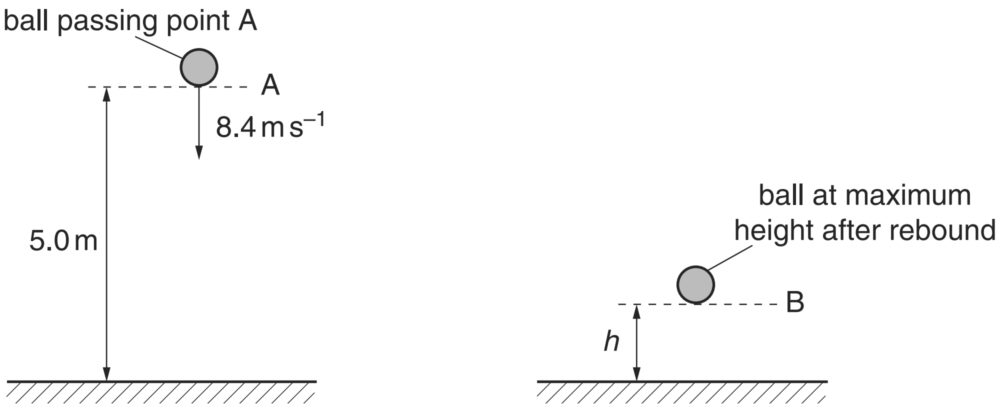


Fig. 2.1

As the ball passes A, it has a speed of 8.4 m s^{-1}. The height of A is 5.0 m above the ground. The ball hits the ground and rebounds to B. Assume that air resistance is negligible.

(i) Calculate the speed of the ball as it hits the ground.

speed = ... m s^{-1} [2]

(ii) Show that the time taken for the ball to reach the ground is 0.47 s.

[1]

For Examiner's Use

(b) The ball rebounds vertically with a speed of 4.2 m s^{-1} as it leaves the ground. The time the ball is in contact with the ground is 20 ms. The ball rebounds to a maximum height *h*.

The ball passes A at time *t* = 0. On Fig. 2.2, plot a graph to show the variation with time *t* of the velocity *v* of the ball. Continue the graph until the ball has rebounded from the ground and reaches B.

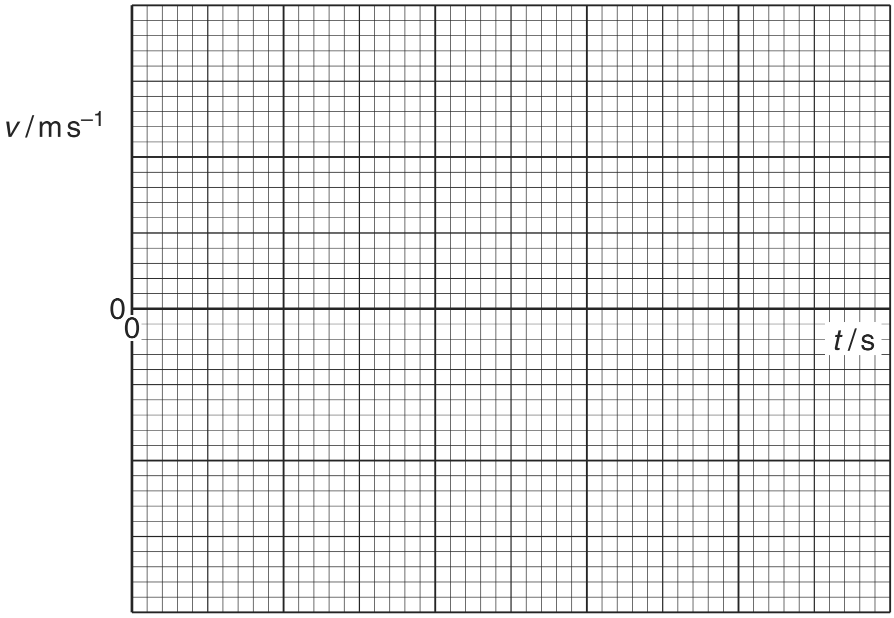


Fig. 2.2 [3]

(c) The ball has a mass of 0.050 kg. It moves from A and reaches B after rebounding.

(i) For this motion, calculate the change in

1. kinetic energy,

change in kinetic energy = ... J [2]

2. gravitational potential energy.

change in potential energy = ... J [3]

(ii) State and explain the total change in energy of the ball for this motion.

....

....

....

.... [2]

3 **(a)** Define *power*.

....

.... [1]

(b) A cyclist travels along a horizontal road. The variation with time t of speed v is shown in Fig. 3.1.

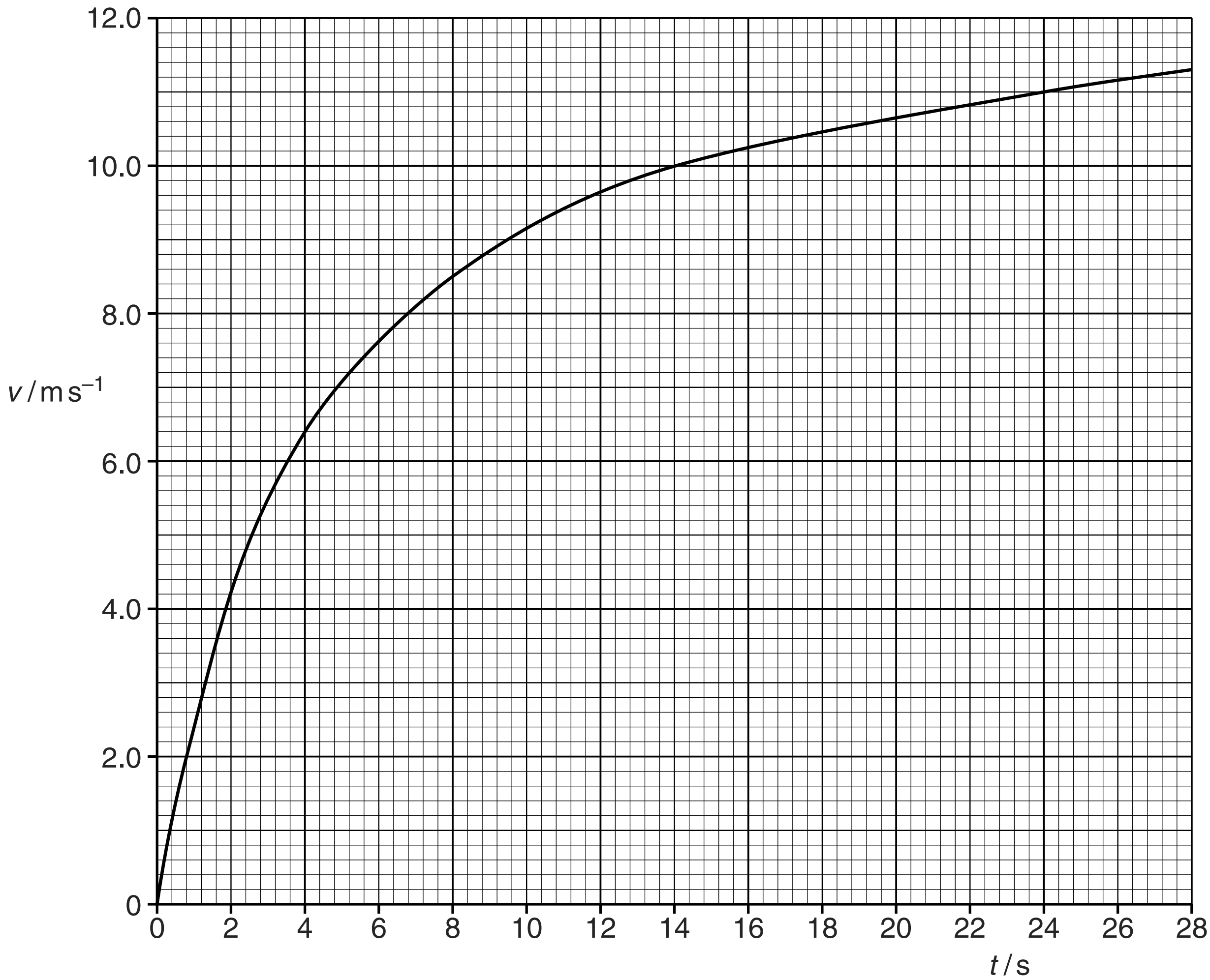


Fig. 3.1

The cyclist maintains a constant power and after some time reaches a constant speed of 12 m s^{-1}.

(i) Describe and explain the motion of the cyclist.

....

....

....

....

.... [3]

(ii) When the cyclist is moving at a constant speed of $12\,m\,s^{-1}$ the resistive force is 48 N. Show that the power of the cyclist is about 600 W. Explain your working.

[2]

(iii) Use Fig. 3.1 to show that the acceleration of the cyclist when his speed is $8.0\,m\,s^{-1}$ is about $0.5\,m\,s^{-2}$.

[2]

(iv) The total mass of the cyclist and bicycle is 80 kg. Calculate the resistive force *R* acting on the cyclist when his speed is $8.0\,m\,s^{-1}$. Use the value for the acceleration given in **(iii)**.

R = ... N [3]

(v) Use the information given in **(ii)** and your answer to **(iv)** to show that, in this situation, the resistive force *R* is proportional to the speed *v* of the cyclist.

[1]

For Examiner's Use

3 **(a)** An object falls vertically from rest through air. State and explain the energy conversions that occur as the object falls.

....

....

....

.... [3]

(b) A ball of mass 150 g is thrown vertically upwards with an initial speed of 25 m s^{-1}.

(i) Calculate the initial kinetic energy of the ball.

kinetic energy = ... J [3]

(ii) The ball reaches a height of 21 m above the point of release.

For the ball rising to this height, calculate

1. the loss of energy of the ball to air resistance,

energy loss = ... J [3]

2. the average force due to the air resistance.

force = ... N [2]

For Examiner's Use

3 **(a)** State what is meant by *work done*.

....

.... [1]

(b) A trolley of mass 400 g is moving at a constant velocity of 2.5 m s^{-1} to the right as shown in Fig. 3.1.

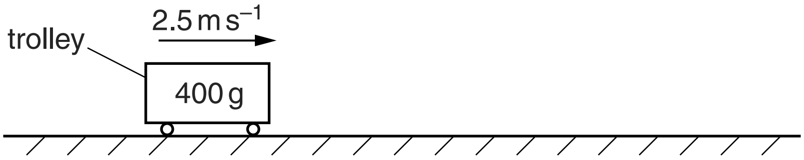


Fig. 3.1

Show that the kinetic energy of the trolley is 1.3 J.

[2]

(c) The trolley in **(b)** moves to point P as shown in Fig. 3.2.

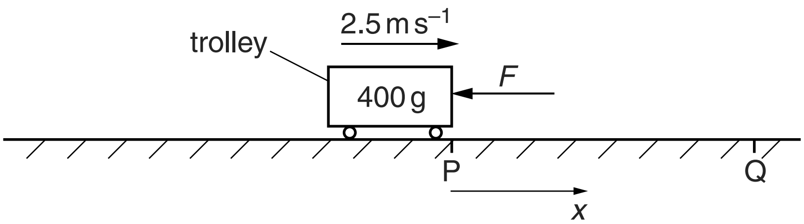


Fig. 3.2

At point P the speed of the trolley is 2.5 m s^{-1}.
A variable force F acts to the left on the trolley as it moves between points P and Q.
The variation of F with displacement x from P is shown in Fig. 3.3.

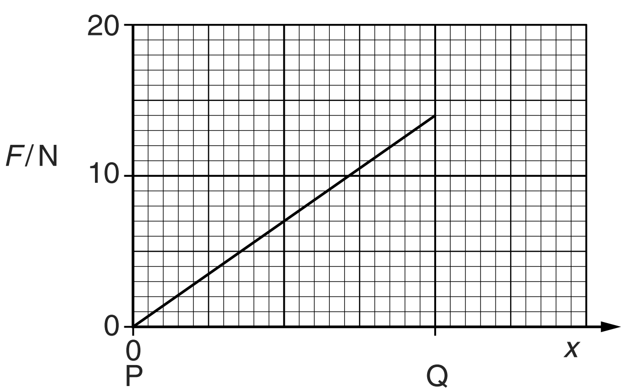


Fig. 3.3

For Examiner's Use

The trolley comes to rest at point Q.

(i) Calculate the distance PQ.

distance PQ = ... m [3]

(ii) On Fig. 3.4, sketch the variation with x of velocity v for the trolley moving between P and Q.

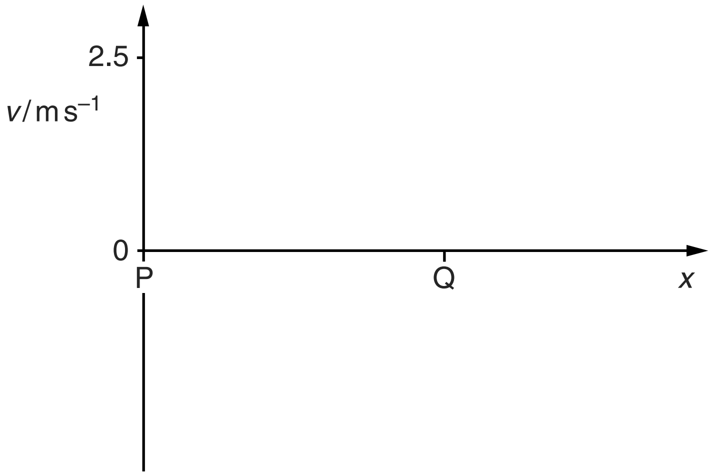


Fig. 3.4

[2]

For Examiner's Use

4 **(a)** Distinguish between gravitational potential energy and elastic potential energy.

....

....

.... [2]

(b) A ball of mass 65 g is thrown vertically upwards from ground level with a speed of $16\,\text{m}\,\text{s}^{-1}$. Air resistance is negligible.

(i) Calculate, for the ball,

1. the initial kinetic energy,

kinetic energy = ... J [2]

2. the maximum height reached.

maximum height = ... m [2]

(ii) The ball takes time t to reach maximum height. For time $\frac{t}{2}$ after the ball has been thrown, calculate the ratio

$$\frac{\text{potential energy of ball}}{\text{kinetic energy of ball}}.$$

ratio = ... [3]

(iii) State and explain the effect of air resistance on the time taken for the ball to reach maximum height.

....

....

.... [1]

2 **(a)** **(i)** Define *power*.

.... [1]

(ii) Use your definition in **(i)** to show that power may also be expressed as the product of force and velocity.

[2]

(b) A lorry moves up a road that is inclined at 9.0° to the horizontal, as shown in Fig. 2.1.

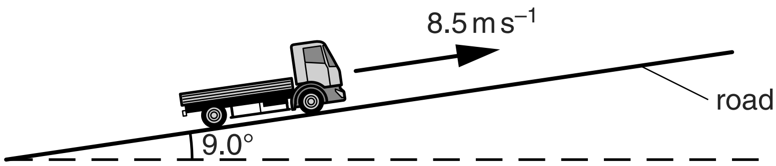


Fig. 2.1

The lorry has mass 2500 kg and is travelling at a constant speed of 8.5 m s^{-1}. The force due to air resistance is negligible.

(i) Calculate the useful power from the engine to move the lorry up the road.

power = ... kW [3]

(ii) State two reasons why the rate of change of potential energy of the lorry is equal to the power calculated in **(i)**.

1. ....

....

2. ....

....

[2]

3 **(a)** Explain what is meant by *work done*.

....

....[1]

(b) A boy on a board B slides down a slope, as shown in Fig. 3.1.

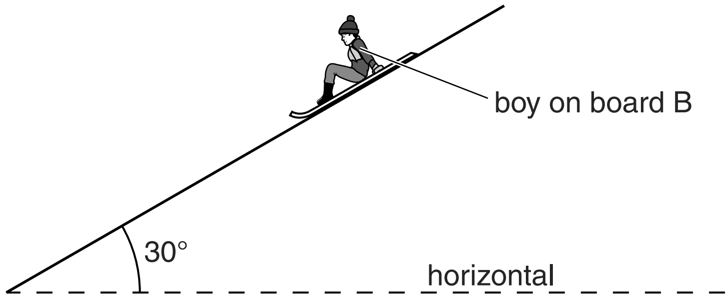


Fig. 3.1

The angle of the slope to the horizontal is 30°. The total resistive force F acting on B is constant.

(i) State a word equation that links the work done by the force F on B to the changes in potential and kinetic energy.

....

....[1]

(ii) The boy on the board B moves with velocity v down the slope. The variation with time t of v is shown in Fig. 3.2.

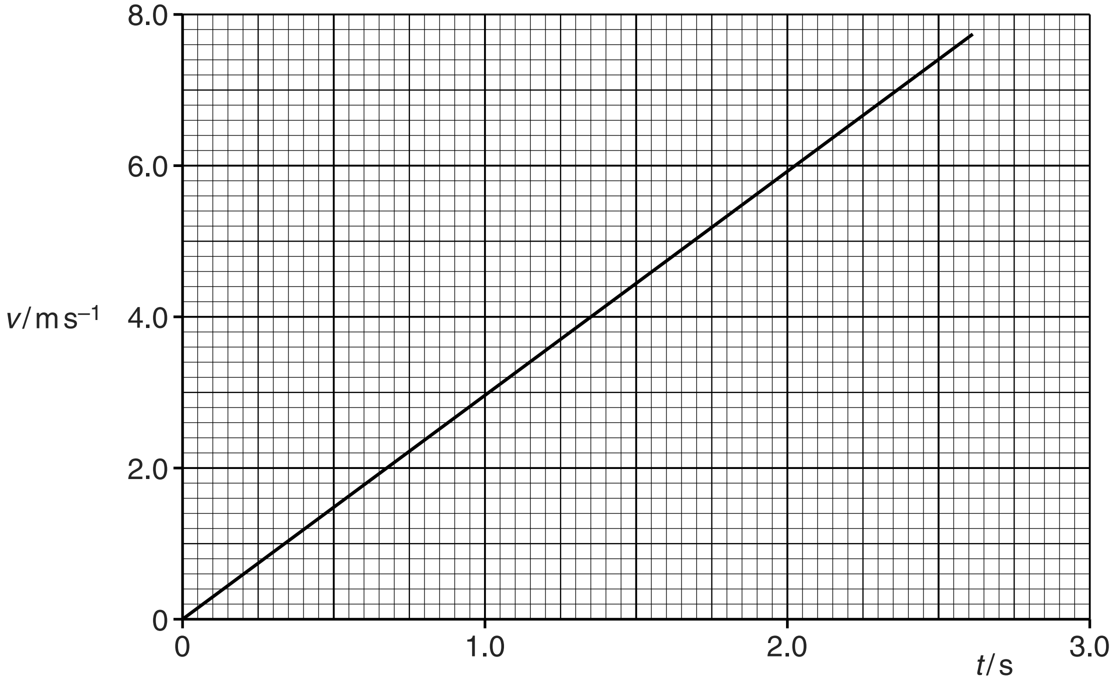


Fig. 3.2

The total mass of B is 75 kg.
For B, from $t = 0$ to $t = 2.5$ s,

1. show that the distance moved down the slope is 9.3 m,

[2]

2. calculate the gain in kinetic energy,

gain in kinetic energy = ... J [3]

3. calculate the loss in potential energy,

loss in potential energy = ... J [3]

4. calculate the resistive force *F*.

F = ... N [3]

5 A motor is used to move bricks vertically upwards, as shown in Fig. 5.1.

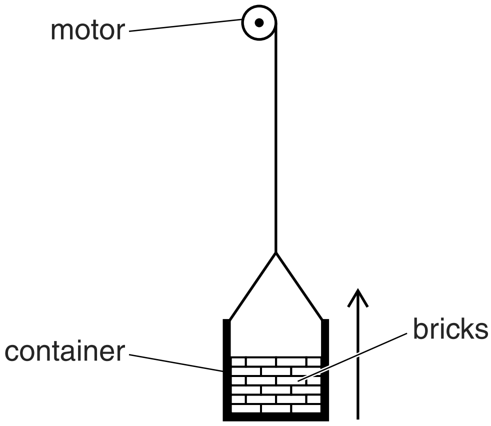


Fig. 5.1

The bricks start from rest and accelerate for 2.0 s. The bricks then travel at a constant speed of 0.64 m s^{-1} for 25 s. Finally the bricks are brought to rest in a further 3.0 s.

The total mass of the bricks is 25 kg.

(a) Determine the change in kinetic energy of the bricks

(i) in the first 2.0 s,

change in kinetic energy = ... J [2]

(ii) in the next 25 s,

change in kinetic energy = ... J [1]

(iii) in the final 3.0 s.

change in kinetic energy = ... J [1]

(b) The bricks are in a container. The weight of the container and bricks is 350 N.

Calculate, for the lifting of the bricks and container when travelling at constant speed,

(i) the gain in potential energy,

energy gain = ... J [3]

(ii) the power required.

power = ... W [2]

3 **(a)** Define *power*.

....

....[1]

(b) Fig. 3.1 shows a car travelling at a speed of 22 m s^{-1} on a horizontal road.

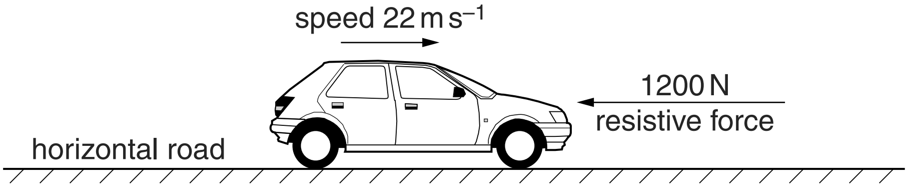


Fig. 3.1

The car has a mass of 1500 kg. A resistive force of 1200 N acts on the car.

Calculate

(i) the force *F* required from the car to produce an acceleration of 0.82 m s^{-2},

F = ... N [3]

(ii) the power required to produce this acceleration.

power = ... W [2]

(c) The resistive force on the car is proportional to v^2, where *v* is the speed of the car.
Suggest why the car has a maximum speed.

....

....[1]

1 A glass fibre of length 0.24 m and area of cross-section $7.9 \times 10^{-7}\,m^2$ is tested until it breaks. The variation with load *F* of the extension *x* of the fibre is shown in Fig. 4.1.

For Examiner's Use

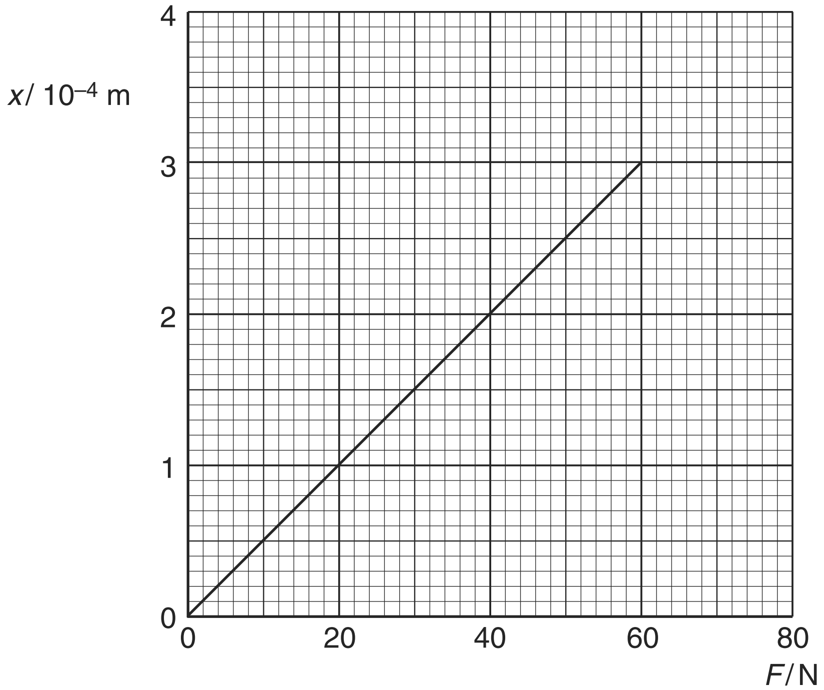


Fig. 4.1

(a) State whether glass is ductile, brittle or polymeric.

....[1]

(b) Use Fig. 4.1 to determine, for this sample of glass,

(i) the ultimate tensile stress,

ultimate tensile stress = ... Pa [2]

For Examiner's Use

(ii) the Young modulus,

Young modulus = ... Pa [3]

(iii) the maximum strain energy stored in the fibre before it breaks.

maximum strain energy = ... J [2]

(c) A hard ball and a soft ball, with equal masses and volumes, are thrown at a glass window. The balls hit the window at the same speed. Suggest why the hard ball is more likely than the soft ball to break the glass window.

....

....

....

....[3]

2 Fig. 5.1 shows the variation with force F of the extension x of a spring as the force is increased to F_3 and then decreased to zero.

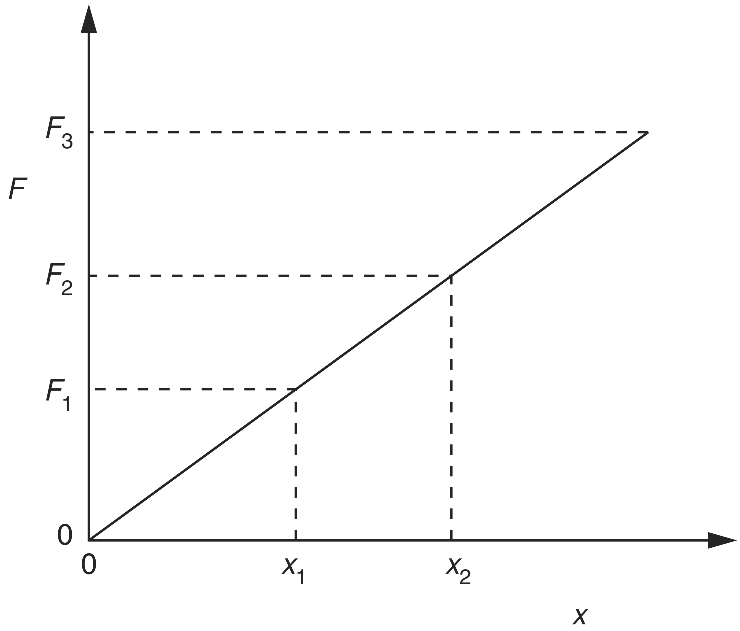


Fig. 5.1

(a) State, with a reason, whether the spring is undergoing an elastic change.

....

.... [1]

(b) The extension of the spring is increased from x_1 to x_2.

Show that the work W done in extending the spring is given by

$$W = \tfrac{1}{2}k(x_2{}^2 - x_1{}^2),$$

where k is the spring constant.

[3]

(c) A trolley of mass 850 g is held between two fixed points by means of identical springs, as shown in Fig. 5.2.

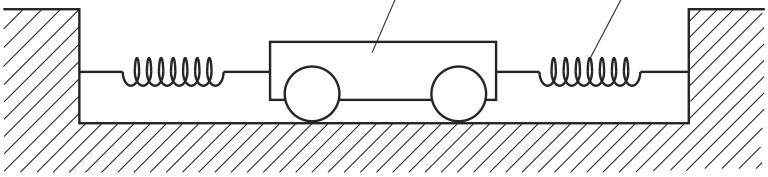


Fig. 5.2

When the trolley is in equilibrium, the springs are each extended by 4.5 cm. Each spring has a spring constant $16\,\text{N cm}^{-1}$.

The trolley is moved a distance of 1.5 cm along the direction of the springs. This causes the extension of one spring to be increased and the extension of the other spring to be decreased. The trolley is then released. The trolley accelerates and reaches its maximum speed at the equilibrium position.

Assuming that the springs obey Hooke's law, use the expression in **(b)** to determine the maximum speed of the trolley.

speed = ... m s^{-1} [4]

3 A spring is placed on a flat surface and different weights are placed on it, as shown in Fig. 2.1.

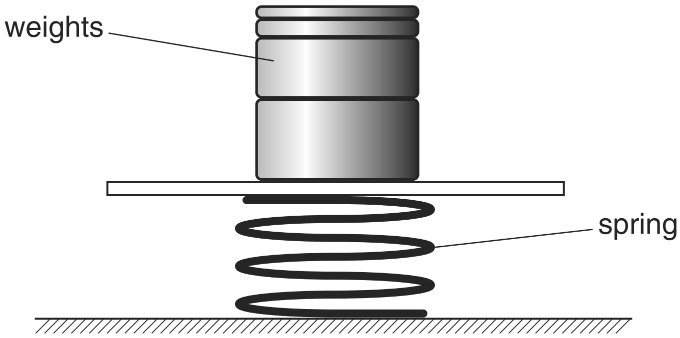


Fig. 2.1

The variation with weight of the compression of the spring is shown in Fig. 2.2.

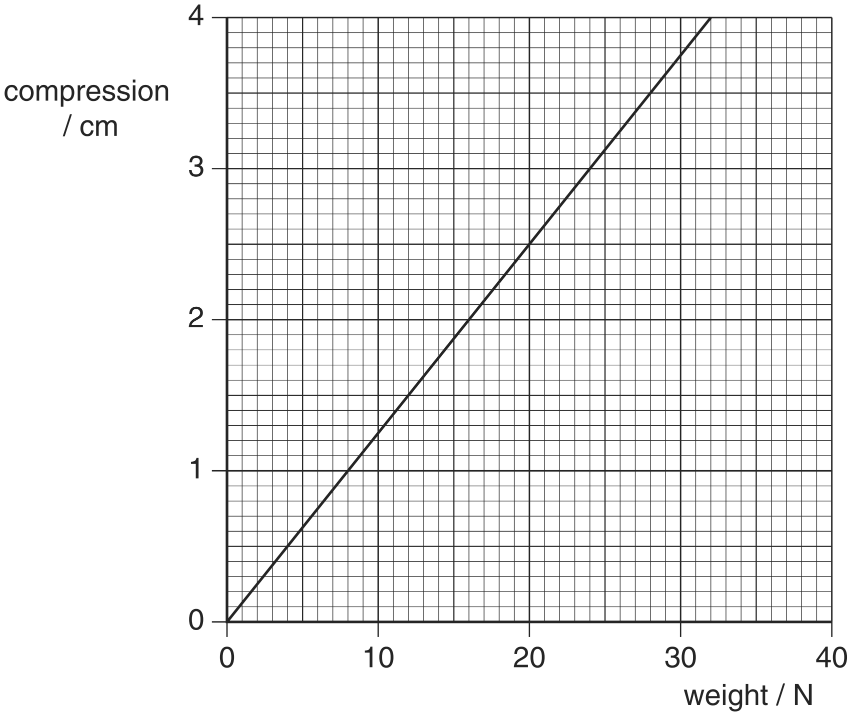


Fig. 2.2

The elastic limit of the spring has not been exceeded.

(a) **(i)** Determine the spring constant k of the spring.

k = ... $N\,m^{-1}$ [2]

For Examiner's Use

(ii) Deduce that the strain energy stored in the spring is 0.49 J for a compression of 3.5 cm.

[2]

(b) Two trolleys, of masses 800 g and 2400 g, are free to move on a horizontal table. The spring in **(a)** is placed between the trolleys and the trolleys are tied together using thread so that the compression of the spring is 3.5 cm, as shown in Fig. 2.3.

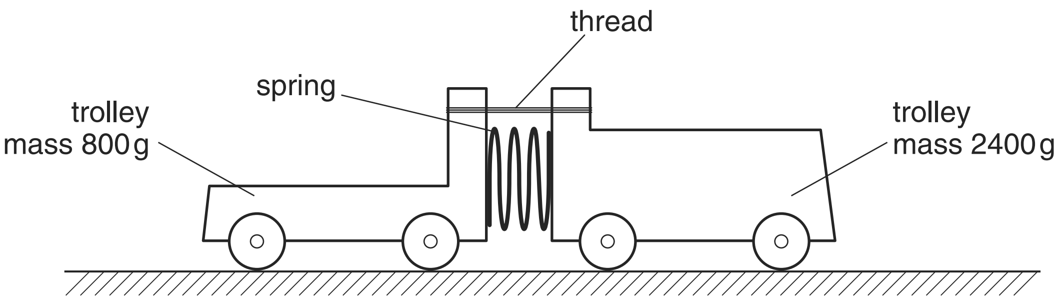


Fig. 2.3

Initially, the trolleys are not moving.
The thread is then cut and the trolleys move apart.

(i) Deduce that the ratio

$$\frac{\text{speed of trolley of mass 800 g}}{\text{speed of trolley of mass 2400 g}}$$

is equal to 3.0.

[2]

For Examiner's Use

(ii) Use the answers in **(a)(ii)** and **(b)(i)** to calculate the speed of the trolley of mass 800 g.

speed = ... m s^{-1} [3]

For Examiner's Use

4 A spring having spring constant k hangs vertically from a fixed point. A load of weight L, when hung from the spring, causes an extension e. The elastic limit of the spring is not exceeded.

(a) State

(i) what is meant by an *elastic deformation*,

....

....

.... [2]

(ii) the relation between k, L and e.

.... [1]

Question 4 continues on page 10

(b) Some identical springs, each with spring constant k, are arranged as shown in Fig. 4.1.

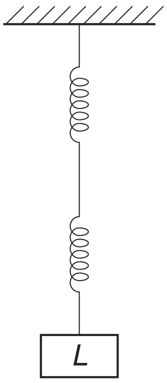
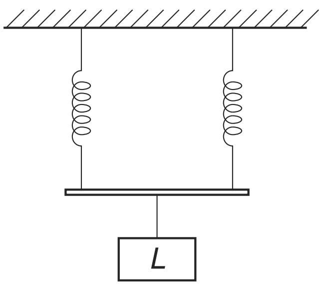
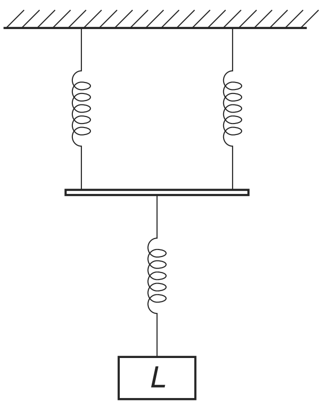
arrangement	total extension	spring constant of arrangement
	....	....
	....	....
	....	....

Fig. 4.1

The load on each of the arrangements is L.

For each arrangement in Fig. 4.1, complete the table by determining

(i) the total extension in terms of e,

(ii) the spring constant in terms of k.

[5]

5 **(a)** In the following list of solids, underline those materials which are crystalline.

rubber copper nylon glass aluminium [2]

(b) The three graphs A, B and C of Fig. 5.1 represent the variation with extension *x* of the tension *F* in specimens of three different materials. One of the materials is polymeric, one is brittle and the other is ductile. They are not shown in that order in Fig. 5.1.

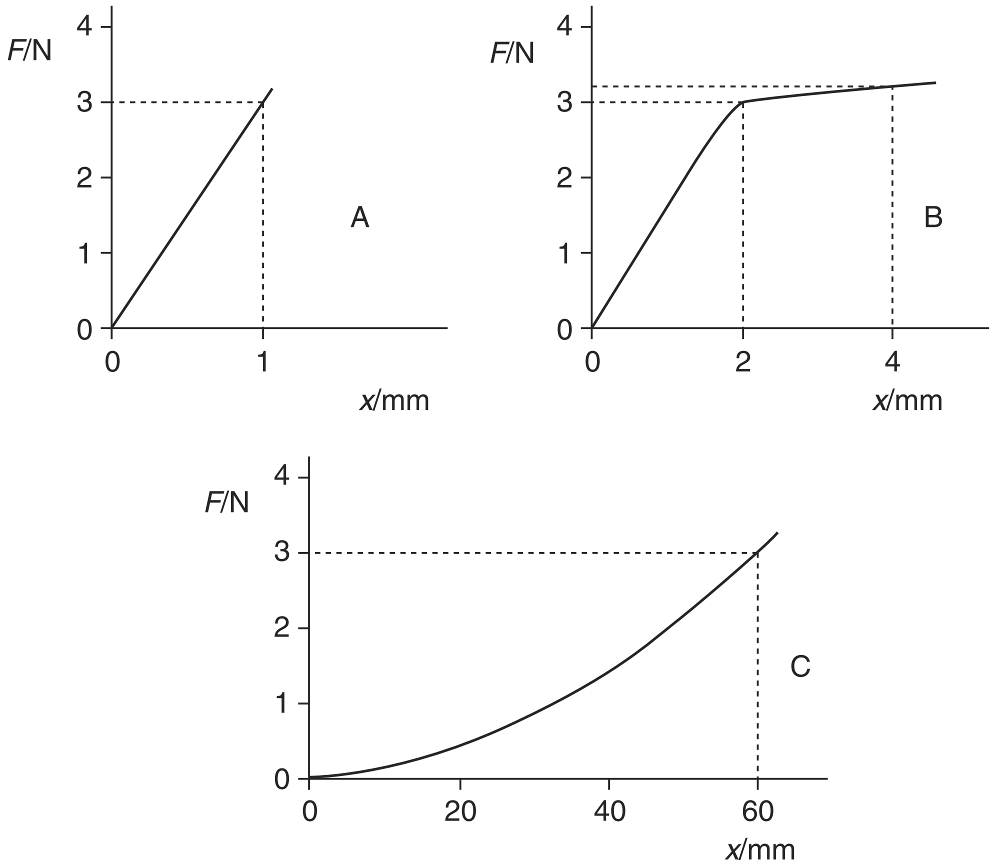


Fig. 5.1

(i) State the type of material which would produce the line shown in each graph.

Graph A is for a .... material.

Graph B is for a .... material.

Graph C is for a .... material. [2]

(ii) Use graph B to estimate the work done in stretching the specimen from 0 to 4 mm.

work done = ... J [3]

[Turn over

For Examiner's Use

6 An aluminium wire of length 1.8 m and area of cross-section $1.7 \times 10^{-6}\,m^2$ has one end fixed to a rigid support. A small weight hangs from the free end, as illustrated in Fig. 9.1.

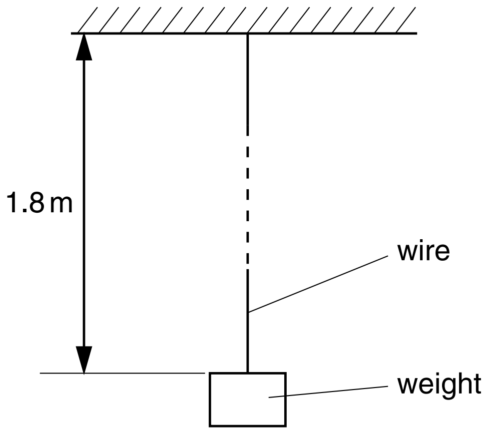


Fig. 9.1

The resistance of the wire is $0.030\,\Omega$ and the Young modulus of aluminium is 7.1×10^{10} Pa.

The load on the wire is increased by 25 N.

(a) Calculate

(i) the increase in stress,

increase = ... Pa

(ii) the change in length of the wire.

change = ... m
[4]

For Examiner's Use

(b) Assuming that the area of cross-section of the wire does not change when the load is increased, determine the change in resistance of the wire.

change = ……………………………… Ω [3]

7 **(a)** A metal wire has an unstretched length *L* and area of cross-section *A*. When the wire supports a load *F*, the wire extends by an amount ΔL. The wire obeys Hooke's law.

Write down expressions, in terms of *L*, *A*, *F* and ΔL, for

(i) the applied stress,

....

(ii) the tensile strain in the wire,

....

(iii) the Young modulus of the material of the wire.

....

[3]

(b) A steel wire of uniform cross-sectional area $7.9 \times 10^{-7}\ m^2$ is heated to a temperature of 650 K. It is then clamped between two rigid supports, as shown in Fig. 5.1.

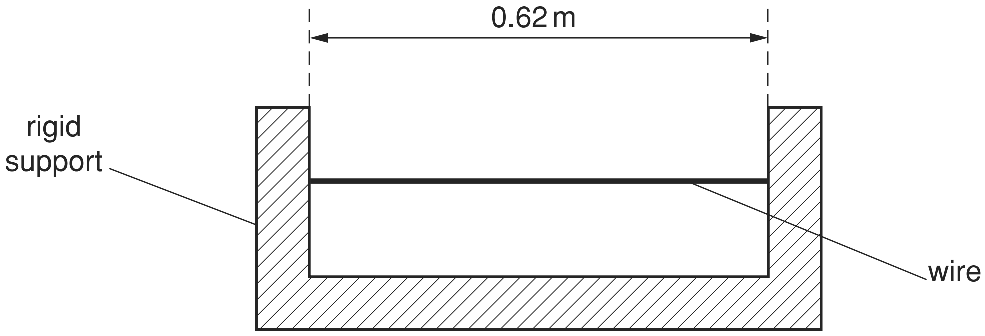


Fig. 5.1

The wire is straight but not under tension and the length between the supports is 0.62 m. The wire is then allowed to cool to 300 K.

When the wire is allowed to contract freely, a 1.00 m length of the wire decreases in length by 0.012 mm for every 1 K decrease in temperature.

(i) Show that the change in length of the wire, if it were allowed to contract as it cools from 650 K to 300 K, would be 2.6 mm.

[2]

(ii) The Young modulus of steel is 2.0×10^{11} Pa. Calculate the tension in the wire at 300 K, assuming that the wire obeys Hooke's law.

For Examiner's Use

tension = ... N [2]

(iii) The ultimate tensile stress of steel is 250 MPa. Use this information and your answer in **(ii)** to suggest whether the wire will, in practice, break as it cools.

....

.... [3]

7 A straight wire of unstretched length L has an electrical resistance R. When it is stretched by a force F, the wire extends by an amount ΔL and the resistance increases by ΔR. The area of cross-section A of the wire may be assumed to remain constant.

(a) (i) State the relation between R, L, A and the resistivity ρ of the material of the wire.

....

.... [1]

(ii) Show that the fractional change in resistance $\frac{\Delta R}{R}$ is equal to the strain in the wire.

[2]

(b) A steel wire has area of cross-section $1.20 \times 10^{-7}\,\text{m}^2$ and a resistance of $4.17\,\Omega$.

The Young modulus of steel is $2.10 \times 10^{11}\,\text{Pa}$.

The tension in the wire is increased from zero to 72.0 N. The wire obeys Hooke's law at these values of tension.

Determine the strain in the wire and hence its change in resistance. Express your answer to an appropriate number of significant figures.

change = ... Ω [5]

8 A sample of material in the form of a cylindrical rod has length *L* and uniform area of cross-section *A*. The rod undergoes an increasing tensile stress until it breaks.
Fig. 4.1 shows the variation with stress of the strain in the rod.

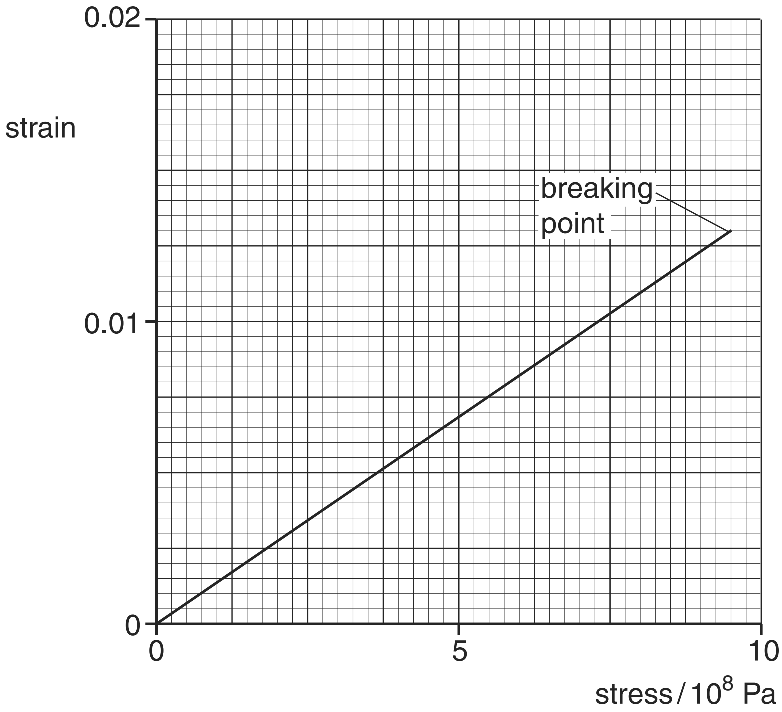


Fig. 4.1

(a) State whether the material of the rod is ductile, brittle or polymeric.

.... [1]

(b) Determine the Young modulus of the material of the rod.

Young modulus = ... Pa [2]

(c) A second cylindrical rod of the same material has a spherical bubble in it, as illustrated in Fig. 4.2.

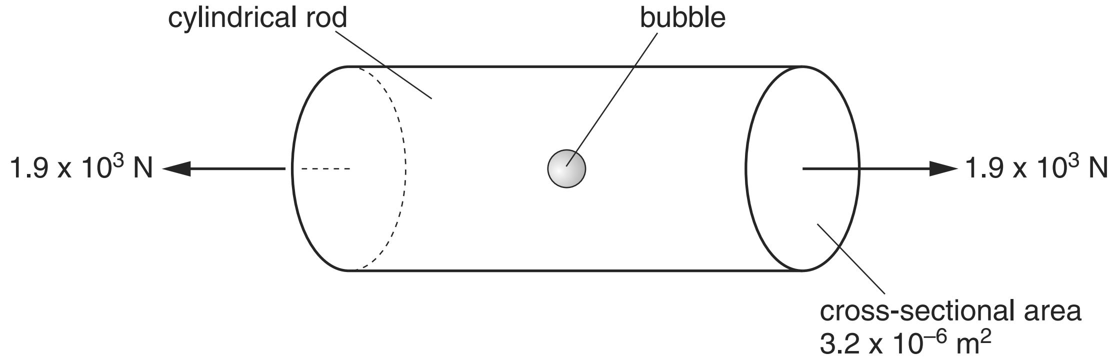


Fig. 4.2

The rod has an area of cross-section of $3.2 \times 10^{-6}\,m^2$ and is stretched by forces of magnitude $1.9 \times 10^3\,N$.
By reference to Fig. 4.1, calculate the maximum area of cross-section of the bubble such that the rod does not break.

area = ... m^2 [3]

(d) A straight rod of the same material is bent as shown in Fig. 4.3.

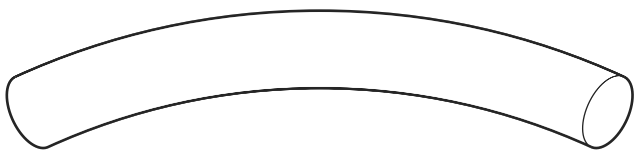


Fig. 4.3

Suggest why a thin rod can bend more than a thick rod without breaking.

....

....

.... [2]

For Examiner's Use

9 A uniform wire has length L and area of cross-section A.
The wire is fixed at one end so that it hangs vertically with a load attached to its free end, as shown in Fig. 4.1.

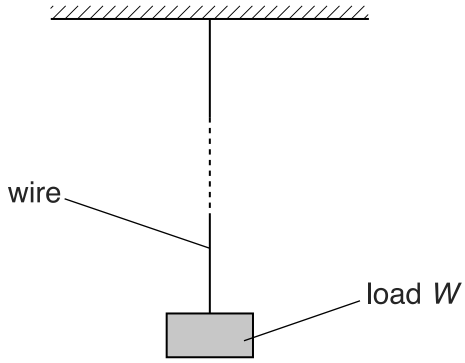


Fig. 4.1

When the load of magnitude W is attached to the wire, it extends by an amount e. The elastic limit of the wire is not exceeded.

The material of the wire has resistivity ρ.

(a) **(i)** Explain what is meant by extends *elastically*.

....

....

.... [2]

(ii) Write down expressions, in terms of L, A, W, ρ and e for

1. the resistance R of the unstretched wire,

R = ... [1]

2. the Young modulus E of the wire.

E = ... [1]

(b) A steel wire has resistance 0.44 Ω. Steel has resistivity $9.2 \times 10^{-8}\,\Omega\,m$.

A load of 34 N hung from the end of the wire causes an extension of 7.7×10^{-4} m.

Using your answers in **(a)(ii)**, calculate the Young modulus *E* of steel.

E = ... Pa [3]

For Examiner's Use

For Examiner's Use

10 **(a)** Explain what is meant by *strain energy* (*elastic potential energy*).

....

....

.... [2]

(b) A spring that obeys Hooke's law has a spring constant k.

Show that the energy E stored in the spring when it has been extended elastically by an amount x is given by

$$E = \frac{1}{2}kx^2.$$

[3]

For Examiner's Use

(c) A light spring of unextended length 14.2 cm is suspended vertically from a fixed point, as illustrated in Fig. 4.1.

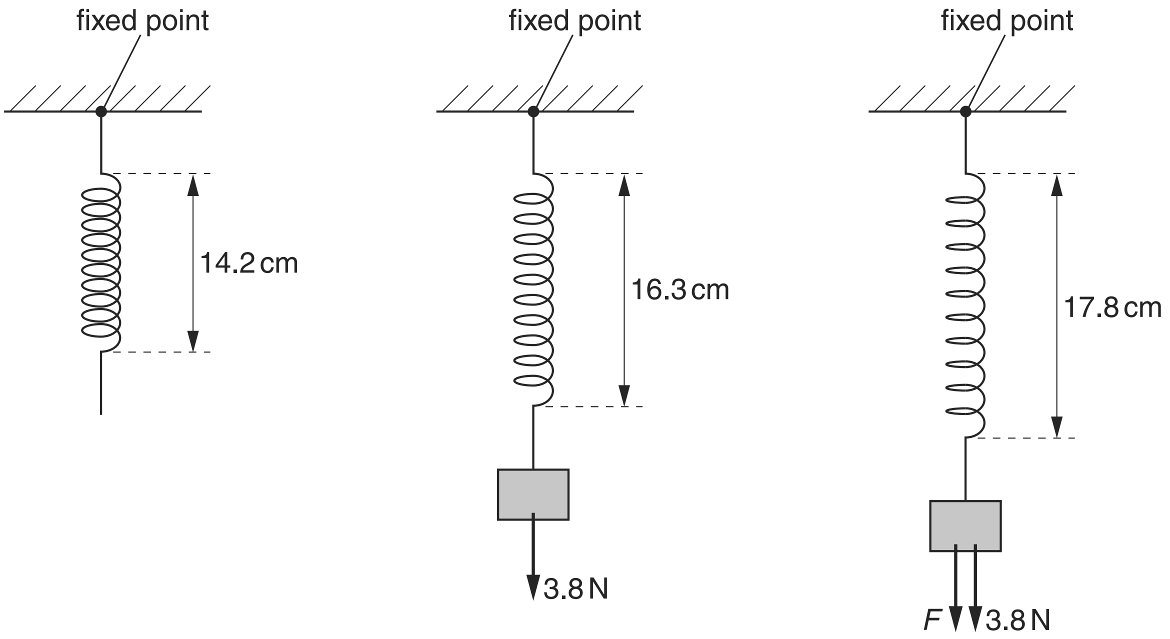


Fig. 4.1 **Fig. 4.2** **Fig. 4.3**

A mass of weight 3.8 N is hung from the end of the spring, as shown in Fig. 4.2. The length of the spring is now 16.3 cm.

An additional force *F* then extends the spring so that its length becomes 17.8 cm, as shown in Fig. 4.3.

The spring obeys Hooke's law and the elastic limit of the spring is not exceeded.

(i) Show that the spring constant of the spring is 1.8 $N\,cm^{-1}$.

[1]

For Examiner's Use

(ii) For the extension of the spring from a length of 16.3 cm to a length of 17.8 cm,

1. calculate the change in the gravitational potential energy of the mass on the spring,

change in energy = ... J [2]

2. show that the change in elastic potential energy of the spring is 0.077 J,

[1]

3. determine the work done by the force *F*.

work done = ... J [1]

For Examiner's Use

11 **(a)** **(i)** Define the terms

1. tensile stress,

....

.... [1]

2. tensile strain,

....

.... [1]

3. the Young modulus.

....

.... [1]

(ii) Suggest why the Young modulus is not used to describe the deformation of a liquid or a gas.

....

.... [1]

(b) The change ΔV in the volume V of some water when the pressure on the water increases by Δp is given by the expression

$$\Delta p = 2.2 \times 10^9 \frac{\Delta V}{V},$$

where Δp is measured in pascal.
In many applications, water is assumed to be incompressible.
By reference to the expression, justify this assumption.

....

....

.... [2]

(c) Normal atmospheric pressure is 1.01×10^5 Pa.

Divers in water of density $1.08 \times 10^3\,\mathrm{kg\,m^{-3}}$ frequently use an approximation that every 10 m increase in depth of water is equivalent to one atmosphere increase in pressure. Determine the percentage error in this approximation.

error = ... % [3]

25

For Examiner's Use

3 **(a)** The variation with extension x of the tension F in a spring is shown in Fig. 3.1.

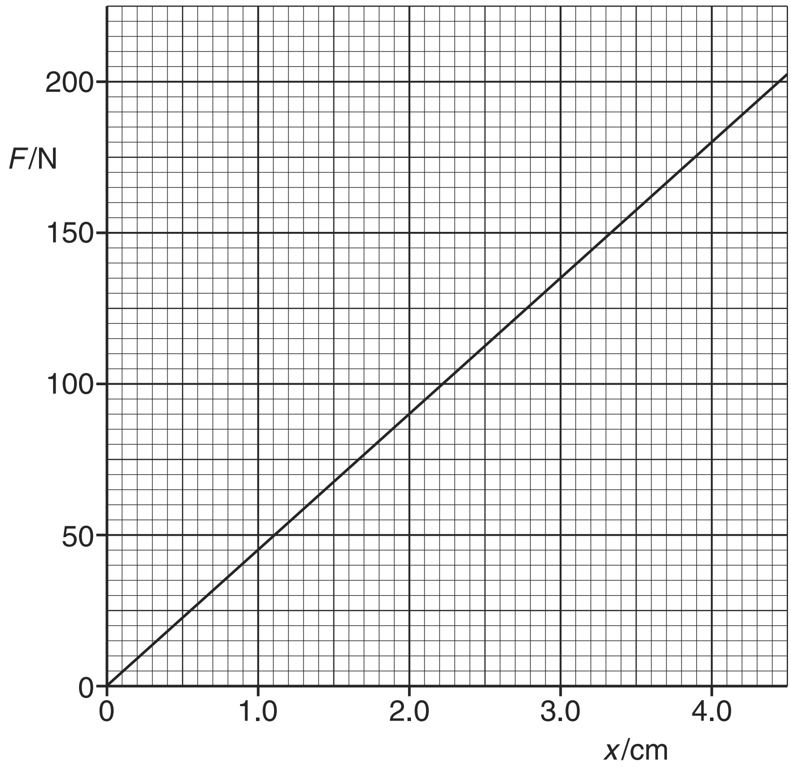


Fig. 3.1

Use Fig. 3.1 to calculate the energy stored in the spring for an extension of 4.0 cm. Explain your working.

energy = ... J [3]

For Examiner's Use

(b) The spring in **(a)** is used to join together two frictionless trolleys A and B of mass M_1 and M_2 respectively, as shown in Fig. 3.2.

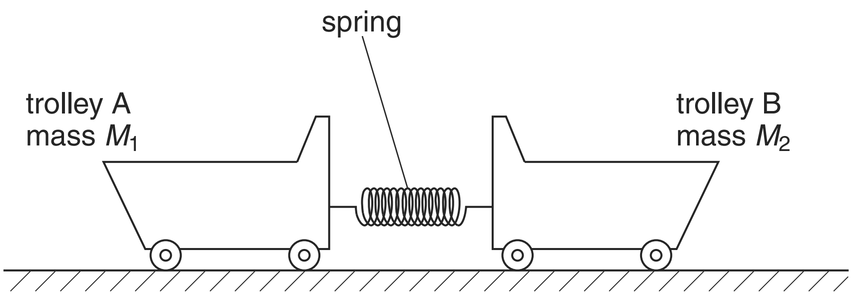


Fig. 3.2

The trolleys rest on a horizontal surface and are held apart so that the spring is extended.

The trolleys are then released.

(i) Explain why, as the extension of the spring is reduced, the momentum of trolley A is equal in magnitude but opposite in direction to the momentum of trolley B.

....

....

....

....[2]

(ii) At the instant when the extension of the spring is zero, trolley A has speed V_1 and trolley B has speed V_2.
Write down

1. an equation, based on momentum, to relate V_1 and V_2,

....

....[1]

2. an equation to relate the initial energy E stored in the spring to the final energies of the trolleys.

....

....[1]

For Examiner's Use

(iii) **1.** Show that the kinetic energy E_K of an object of mass m is related to its momentum p by the expression

$$E_K = \frac{p^2}{2m}.$$

[1]

2. Trolley A has a larger mass than trolley B.
Use your answer in **(ii) part 1** to deduce which trolley, A or B, has the larger kinetic energy at the instant when the extension of the spring is zero.

....

....[1]

For Examiner's Use

5 **(a)** Tensile forces are applied to opposite ends of a copper rod so that the rod is stretched. The variation with stress of the strain of the rod is shown in Fig. 5.1.

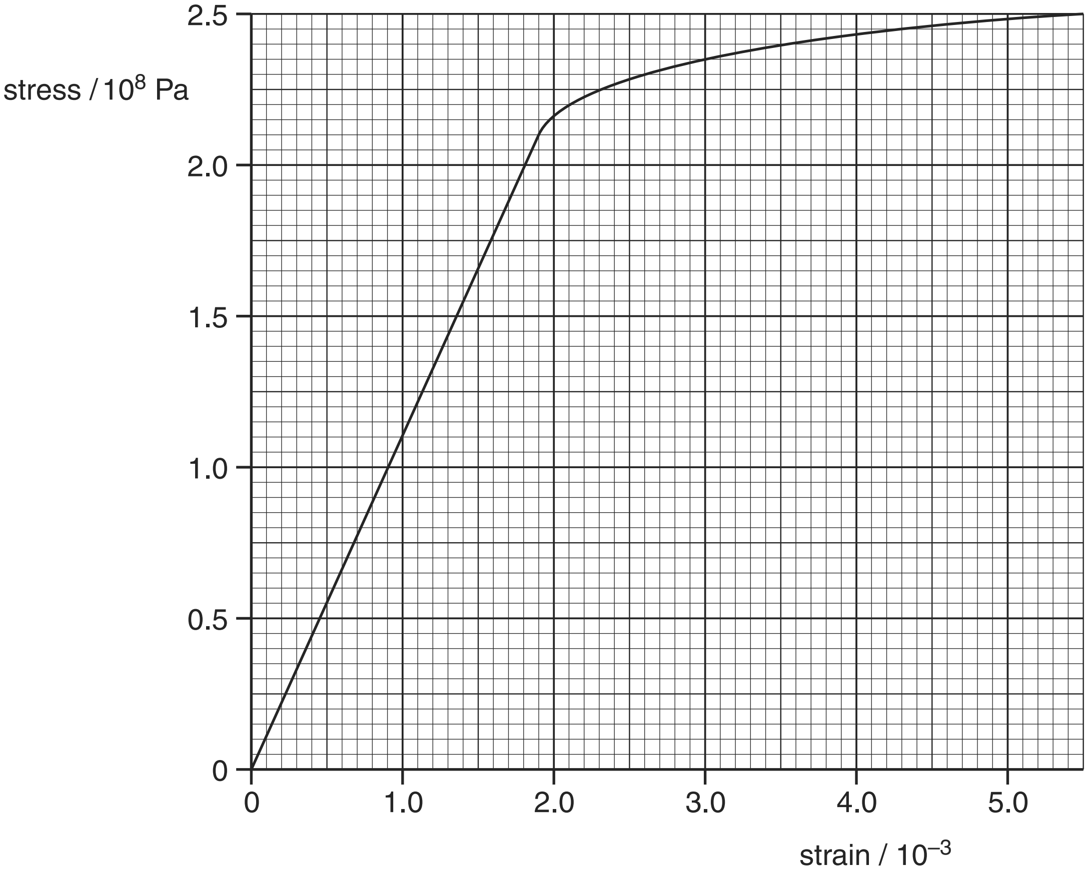


Fig. 5.1

(i) Use Fig. 5.1 to determine the Young modulus of copper.

Young modulus = ... Pa [3]

(ii) On Fig. 5.1, sketch a line to show the variation with stress of the strain of the rod as the stress is reduced from 2.5×10^6 Pa to zero. No further calculations are expected. [1]

For Examiner's Use

(b) The walls of the tyres on a car are made of a rubber compound.
The variation with stress of the strain of a specimen of this rubber compound is shown in Fig. 5.2.

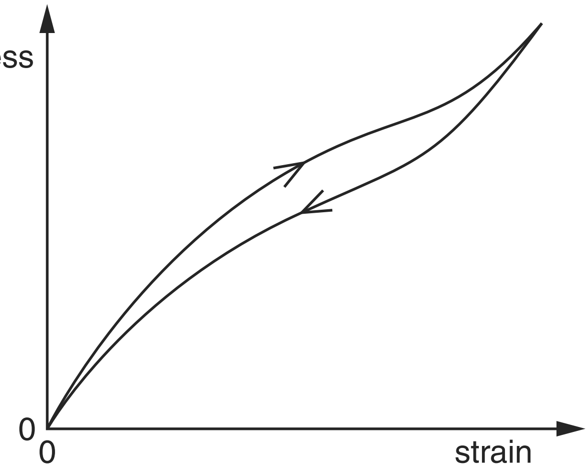


Fig. 5.2

As the car moves, the walls of the tyres bend and straighten continuously.

Use Fig. 5.2 to explain why the walls of the tyres become warm.

....

....

....

....[3]

30

For Examiner's Use

4 **(a)** A uniform wire has length L and constant area of cross-section A. The material of the wire has Young modulus E and resistivity ρ. A tension F in the wire causes its length to increase by ΔL.

For this wire, state expressions, in terms of L, A, F, ΔL and ρ for

(i) the stress σ,

.... [1]

(ii) the strain ε,

.... [1]

(iii) the Young modulus E,

.... [1]

(iv) the resistance R.

.... [1]

(b) One end of a metal wire of length 2.6 m and constant area of cross-section $3.8 \times 10^{-7}\,m^2$ is attached to a fixed point, as shown in Fig. 4.1.

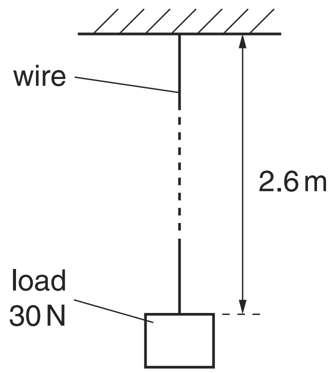


Fig. 4.1

The Young modulus of the material of the wire is 7.0×10^{10} Pa and its resistivity is $2.6 \times 10^{-8}\,\Omega$ m.
A load of 30 N is attached to the lower end of the wire. Assume that the area of cross-section of the wire does not change.
For this load of 30 N,

(i) show that the extension of the wire is 2.9 mm,

[1]

(ii) calculate the change in resistance of the wire.

change = ... Ω [2]

(c) The resistance of the wire changes with the applied load.
Comment on the suggestion that this change of resistance could be used to measure the magnitude of the load on the wire.

....

....

.... [2]

For Examiner's Use

4 **(a)** A metal wire has spring constant k. Forces are applied to the ends of the wire to extend it within the limit of Hooke's law.
Show that, for an extension x, the strain energy E stored in the wire is given by

$$E = \tfrac{1}{2}kx^2.$$

[4]

(b) The wire in **(a)** is now extended beyond its elastic limit. The forces causing the extension are then removed.
The variation with extension x of the tension F in the wire is shown in Fig. 4.1.

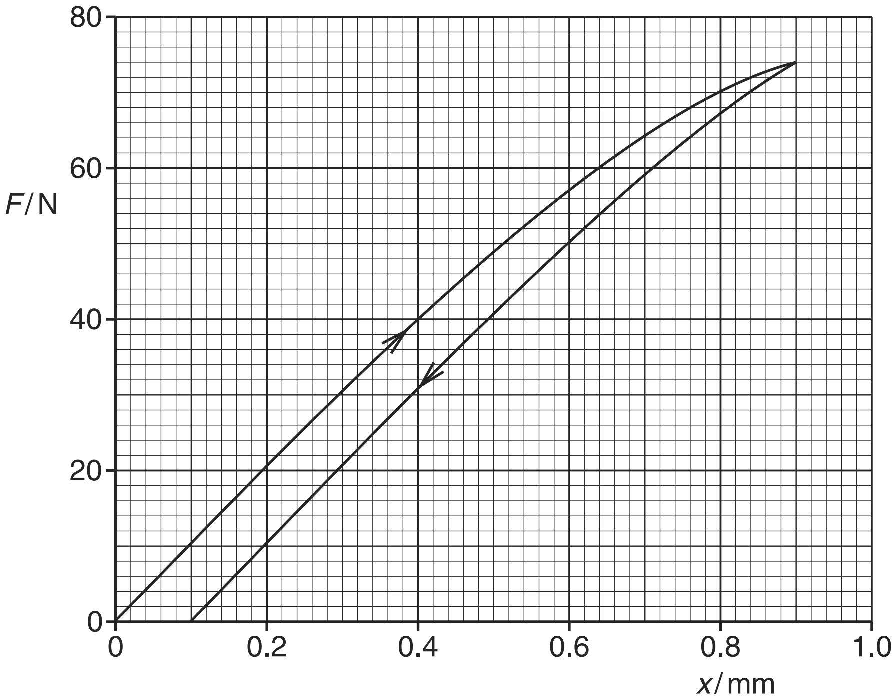


Fig. 4.1

Energy E_S is expended to cause a permanent extension of the wire.

(i) On Fig. 4.1, shade the area that represents the energy E_S. [1]

(ii) Use Fig. 4.1 to calculate the energy E_S.

E_S = ... mJ [3]

(iii) Suggest the change in the structure of the wire that is caused by the energy E_S.

....

.... [1]

5 A spring hangs vertically from a fixed point and a mass of 94 g is suspended from the spring, stretching the spring as shown in Fig. 5.1.

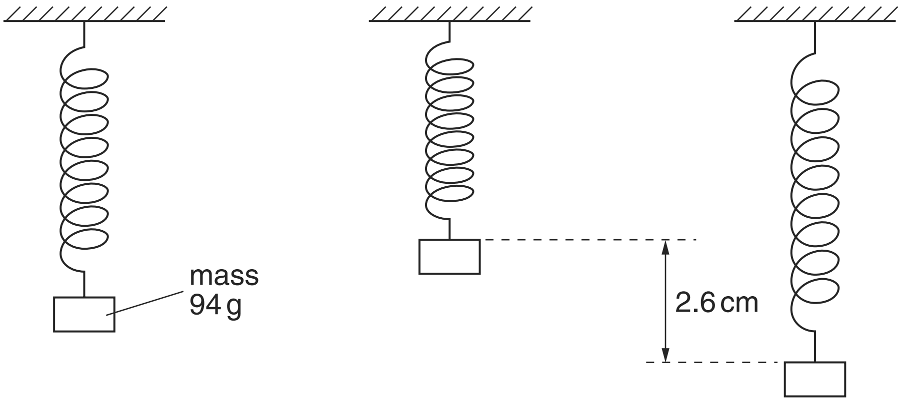


Fig. 5.1 **Fig. 5.2** **Fig. 5.3**

The mass is raised vertically so that the length of the spring is its unextended length. This is illustrated in Fig. 5.2.

The mass is then released. The mass moves through a vertical distance of 2.6 cm before temporarily coming to rest. This position is illustrated in Fig. 5.3.

(a) State which diagram, Fig. 5.1, Fig. 5.2 or Fig. 5.3, illustrates the position of the mass such that

(i) the mass has maximum gravitational potential energy,

.... [1]

(ii) the spring has maximum strain energy.

.... [1]

(b) Briefly describe the variation of the kinetic energy of the mass as the mass falls from its highest position (Fig. 5.2) to its lowest position (Fig. 5.3).

....

.... [1]

(c) The strain energy E stored in the spring is given by the expression

$$E = \frac{1}{2}kx^2$$

where k is the spring constant and x is the extension of the spring.

For the mass moving between the positions shown in Fig. 5.2 and Fig. 5.3,

(i) calculate the change in the gravitational potential energy of the mass,

change = ... J [2]

(ii) determine the extension of the spring at which the strain energy is half its maximum value.

extension = ... cm [3]

For Examiner's Use

4 A student measures the Young modulus of a metal in the form of a wire.

(a) Describe, with the aid of a diagram, the apparatus that could be used.

....

....

....

.... [2]

(b) Describe the method used to obtain the required measurements.

....

....

....

....

....

....

....

....

....

.... [4]

(c) Describe how the measurements taken can be used to determine the Young modulus.

For Examiner's Use

....

....

....

....

....

....

....

....

....

.... [4]

For Examiner's Use

4 (a) State Hooke's Law.

....

.... [1]

(b) A spring is compressed by applying a force. The variation with compression x of the force F is shown in Fig. 4.1.

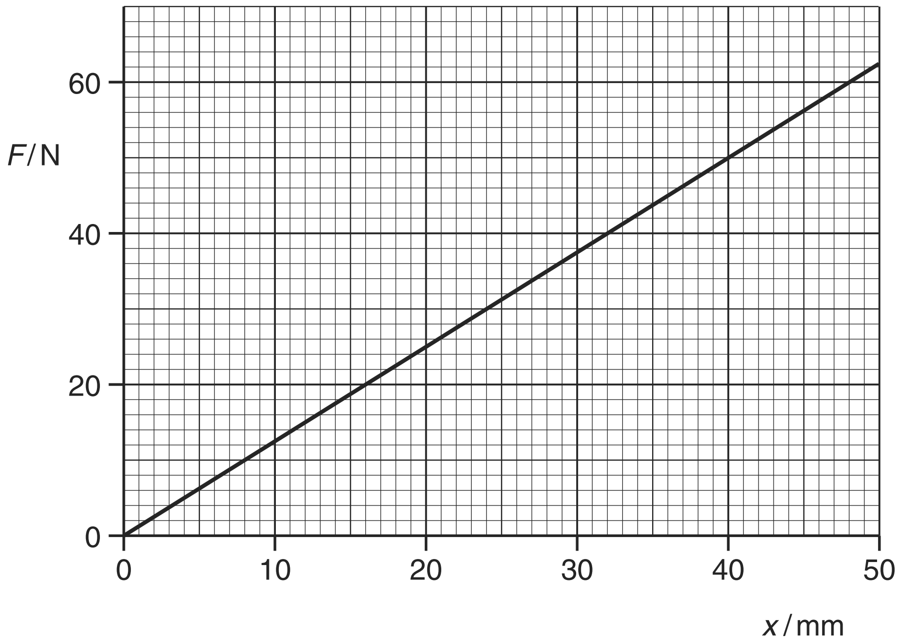


Fig. 4.1

(i) Calculate the spring constant.

spring constant = ... $N\,m^{-1}$ [1]

(ii) Show that the work done in compressing the spring by 36 mm is 0.81 J.

[2]

For Examiner's Use

(c) A child's toy uses the spring in **(b)** to shoot a small ball vertically upwards. The ball has a mass of 25 g. The toy is shown in Fig. 4.2.

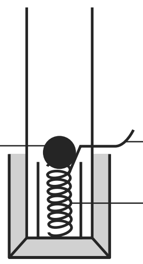


Fig. 4.2

(i) The spring in the toy is compressed by 36 mm. The spring is released. Assume all the strain energy in the spring is converted to kinetic energy of the ball. Using the result in **(b)(ii)**, calculate the speed with which the ball leaves the spring.

speed = ... $m\,s^{-1}$ [2]

(ii) Determine the compression of the spring required for the ball to leave the spring with twice the speed determined in **(i)**.

compression = ... mm [2]

(iii) Determine the ratio

$$\frac{\text{maximum possible height for compression in (i)}}{\text{maximum possible height for compression in (ii)}}.$$

ratio = ... [2]

For Examiner's Use

4 **(a)** Define, for a wire,

(i) *stress*,

....

.... [1]

(ii) *strain*.

....

.... [1]

(b) A wire of length 1.70 m hangs vertically from a fixed point, as shown in Fig. 4.1.

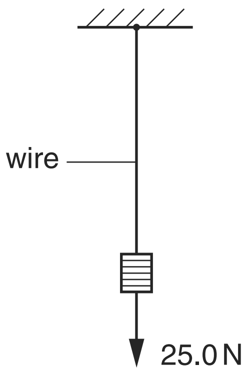


Fig. 4.1

The wire has cross-sectional area $5.74 \times 10^{-8}\,m^2$ and is made of a material that has a Young modulus of 1.60×10^{11} Pa. A load of 25.0 N is hung from the wire.

(i) Calculate the extension of the wire.

extension = ... m [3]

(ii) The same load is hung from a second wire of the same material. This wire is twice the length but the **same volume** as the first wire. State and explain how the extension of the second wire compares with that of the first wire.

....

....

.... [3]

For Examiner's Use

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

....

.... [1]

(b) The variation with extension x of the force F for a spring A is shown in Fig. 6.1.

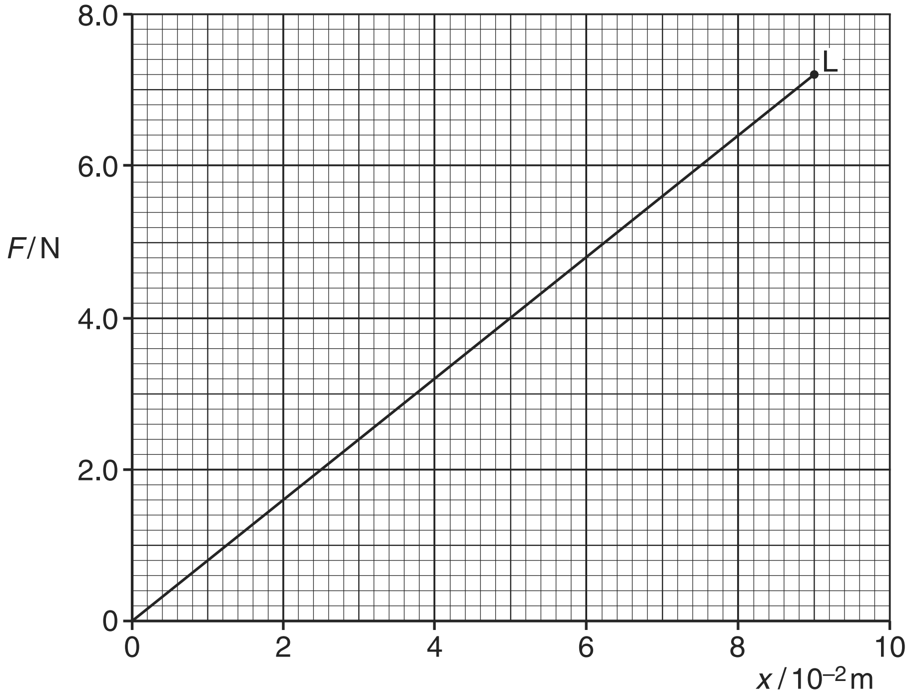


Fig. 6.1

The point L on the graph is the elastic limit of the spring.

(i) Describe the meaning of *elastic limit*.

....

....

.... [1]

(ii) Calculate the spring constant k_A for spring A.

k_A = ... $N m^{-1}$ [1]

For Examiner's Use

(iii) Calculate the work done in extending the spring with a force of 6.4 N.

work done = ... J [2]

(c) A second spring B of spring constant $2k_A$ is now joined to spring A, as shown in Fig. 6.2.

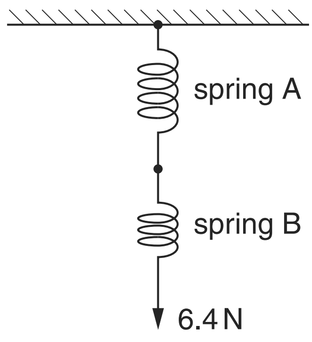


Fig. 6.2

A force of 6.4 N extends the combination of springs.

For the combination of springs, calculate

(i) the total extension,

extension = ... m [1]

(ii) the spring constant.

spring constant = ... N m^{-1} [1]

For Examiner's Use

3 **(a)** Define

(i) *stress*,

....

.... [1]

(ii) *strain*.

....

.... [1]

(b) Explain the term *elastic limit*.

....

.... [1]

(c) Explain the term *ultimate tensile stress*.

....

....

.... [2]

(d) **(i)** A **ductile** material in the form of a wire is stretched up to its breaking point. On Fig. 3.1, sketch the variation with extension x of the stretching force F.

Fig. 3.1

[2]

(ii) On Fig. 3.2, sketch the variation with x of F for a **brittle** material up to its breaking point.

For Examiner's Use

Fig. 3.2

[1]

(e) (i) Explain the features of the graphs in **(d)** that show the characteristics of ductile and brittle materials.

....

....

....

....

.... [2]

(ii) The force F is removed from the materials in **(d)** just before the breaking point is reached. Describe the subsequent change in the extension for

1. the ductile material,

....

.... [1]

2. the brittle material.

....

.... [1]

For Examiner's Use

3 **(a)** Define the terms

(i) *power*,

.... [1]

(ii) the *Young modulus*.

....

....

.... [1]

(b) A crane is used to lift heavy objects, as shown in Fig. 3.1.

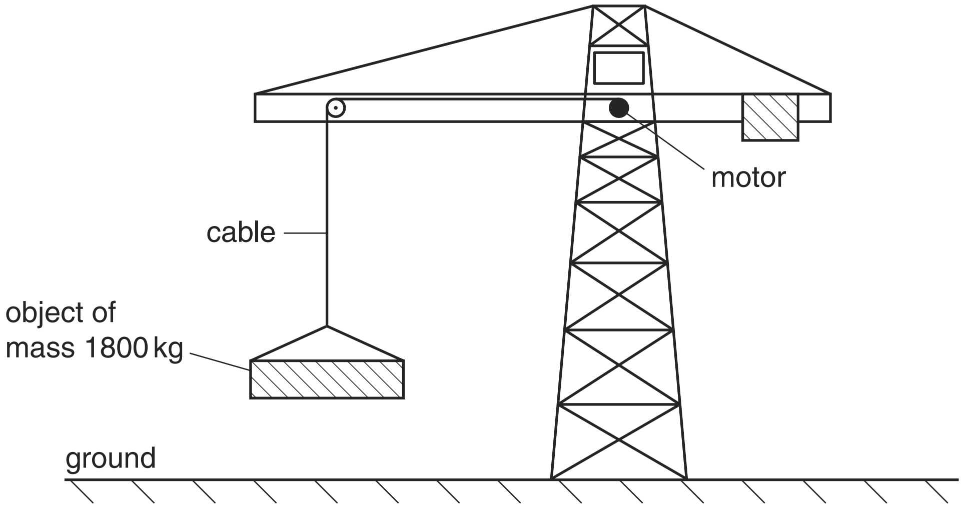


Fig. 3.1

The motor in the crane lifts a total mass of 1800 kg from rest on the ground. The cable supporting the mass is made of steel of Young modulus 2.4×10^{11} Pa. The cross-sectional area of the cable is $1.3 \times 10^{-4}\,\text{m}^2$. As the mass leaves the ground, the strain in the cable is 0.0010. Assume the weight of the cable to be negligible.

(i) **1.** Use the Young Modulus of the steel to show that the tension in the cable is 3.1×10^4 N.

[2]

2. Calculate the acceleration of the mass as it is lifted from the ground.

acceleration = ... m s^{-2} [3]

For Examiner's Use

(ii) The motor now lifts the mass through a height of 15 m at a constant speed.

Calculate

1. the tension in the lifting cable,

tension = ... N [1]

2. the gain in potential energy of the mass.

gain in potential energy = ... J [2]

(iii) The motor of the crane is 30% efficient. Calculate the input power to the motor required to lift the mass at a constant speed of 0.55 m s^{-1}.

input power = ... W [3]

3 One end of a spring is fixed to a support. A mass is attached to the other end of the spring. The arrangement is shown in Fig. 3.1.

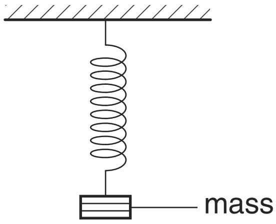


Fig. 3.1

(a) The mass is in equilibrium. Explain, by reference to the forces acting on the mass, what is meant by equilibrium.

....

....

.... [2]

(b) The mass is pulled down and then released at time $t = 0$. The mass oscillates up and down. The variation with t of the displacement of the mass d is shown in Fig. 3.2.

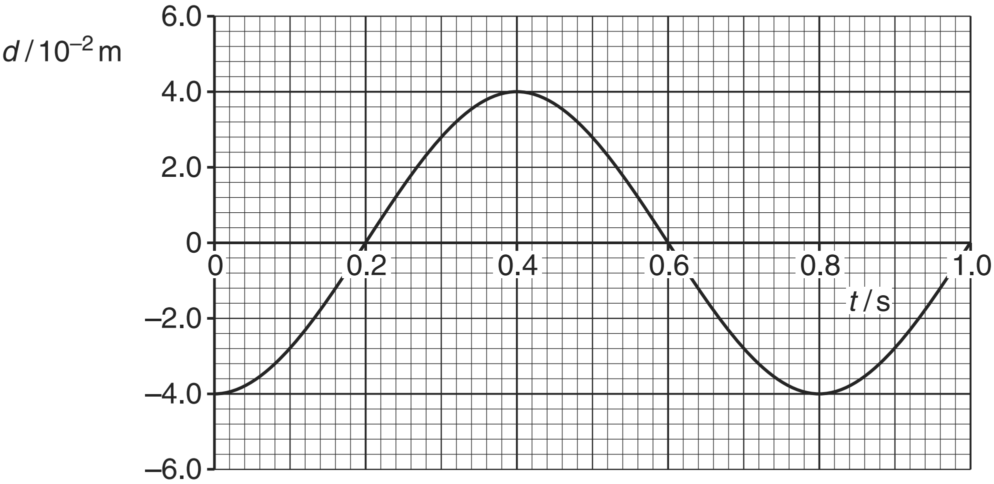


Fig. 3.2

Use Fig. 3.2 to state a time, one in each case, when

(i) the mass is at maximum speed,

time = ... s [1]

(ii) the elastic potential energy stored in the spring is a maximum,

time = ... s [1]

(iii) the mass is in equilibrium.

time = ... s [1]

For Examiner's Use

(c) The arrangement shown in Fig. 3.3 is used to determine the length l of a spring when different masses M are attached to the spring.

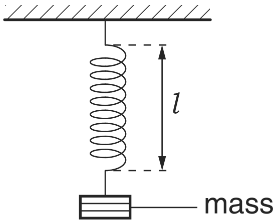


Fig. 3.3

The variation with mass M of l is shown in Fig. 3.4.

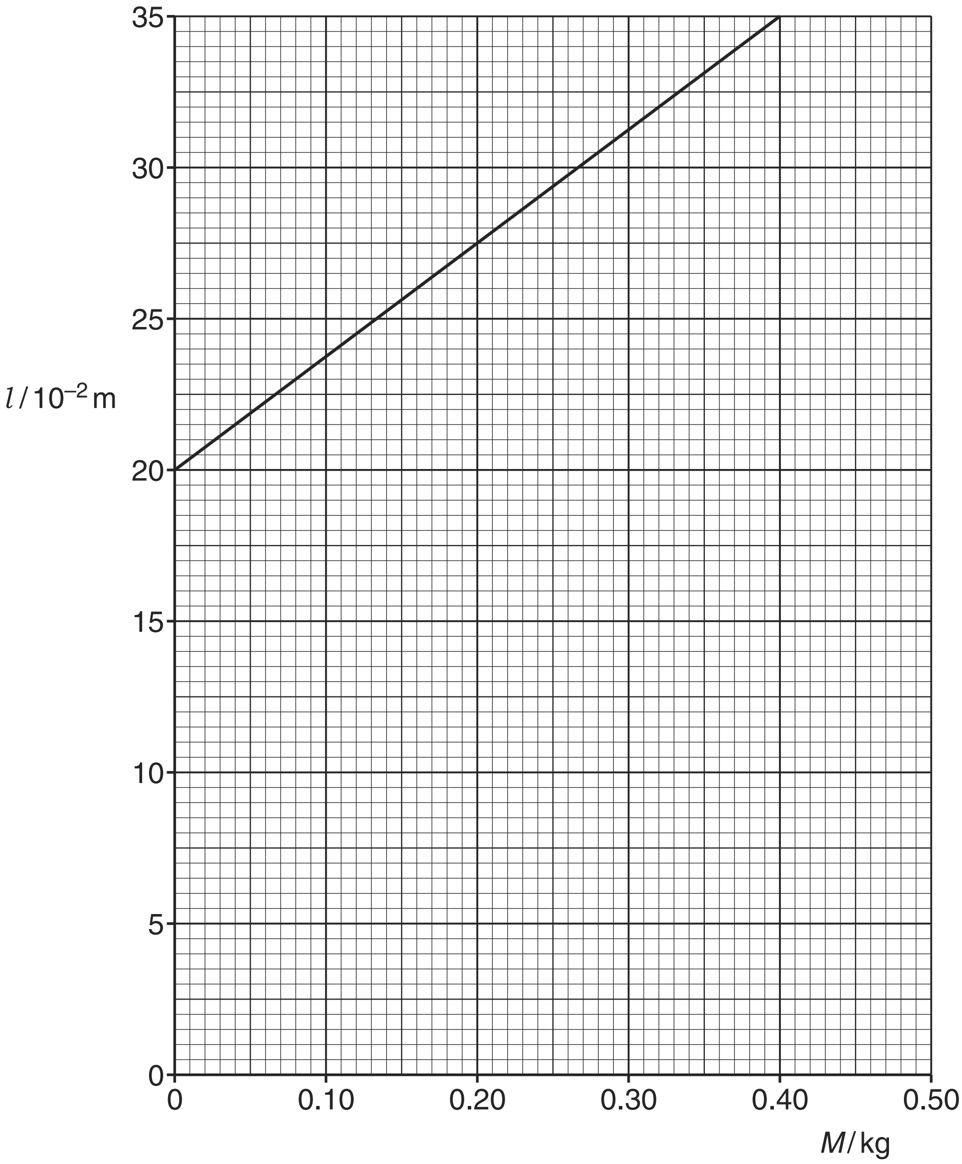


Fig. 3.4

For Examiner's Use

(i) State and explain whether the spring obeys Hooke's law.

....

....

.... [2]

(ii) Show that the force constant of the spring is 26 N m^{-1}.

[2]

(iii) A mass of 0.40 kg is attached to the spring. Calculate the energy stored in the spring.

energy = ... J [3]

5 **(a)** Define the *Young modulus*.

....

.... [1]

(b) A load F is suspended from a fixed point by a steel wire. The variation with extension x of F for the wire is shown in Fig. 5.1.

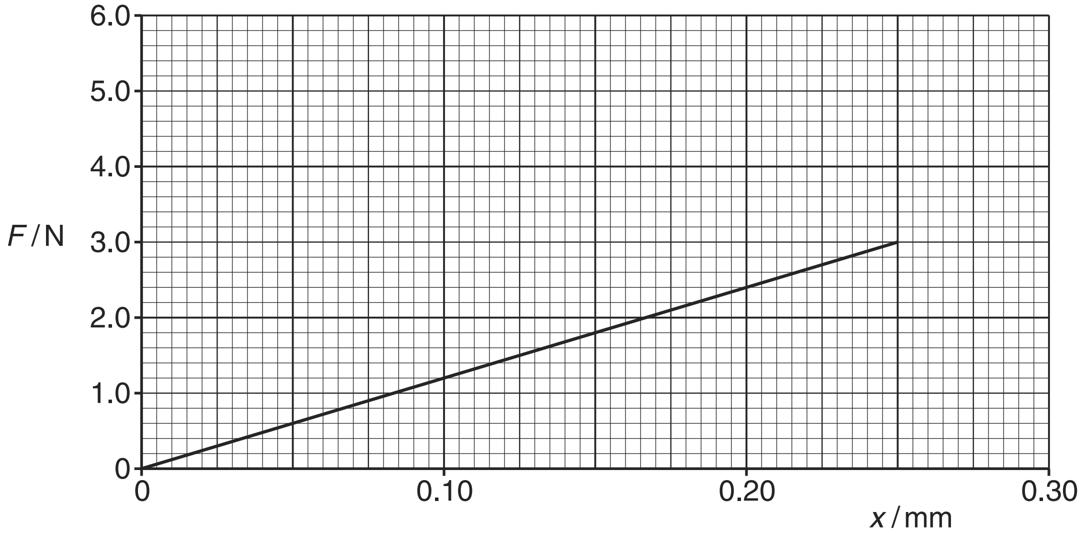


Fig. 5.1

(i) State two quantities, other than the gradient of the graph in Fig. 5.1, that are required in order to determine the Young modulus of steel.

1. ....

2. ....
[1]

(ii) Describe how the quantities you listed in **(i)** may be measured.

....

....

.... [2]

For Examiner's Use

(iii) A load of 3.0 N is applied to the wire. Use Fig. 5.1 to calculate the energy stored in the wire.

energy = ... J [2]

(c) A copper wire has the same original dimensions as the steel wire. The Young modulus for steel is $2.2 \times 10^{11}\,\mathrm{N\,m^{-2}}$ and for copper is $1.1 \times 10^{11}\,\mathrm{N\,m^{-2}}$.

On Fig. 5.1, sketch the variation with x of F for the copper wire for extensions up to 0.25 mm. The copper wire is not extended beyond its limit of proportionality. [2]

For Examiner's Use

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

....

.... [1]

(b) A spring is attached to a support and hangs vertically, as shown in Fig. 6.1. An object M of mass 0.41 kg is attached to the lower end of the spring. The spring extends until M is at rest at R.

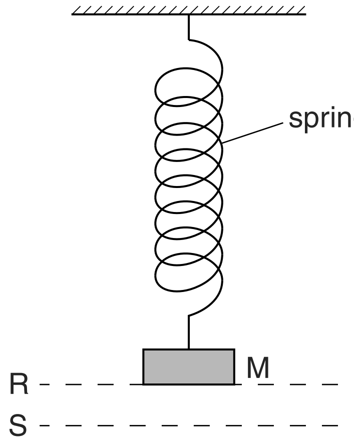


Fig. 6.1

The spring constant of the spring is 25 N m^{-1}. Show that the extension of the spring is about 0.16 m.

[2]

(c) The object M in Fig. 6.1 is pulled down a further 0.060 m to S and is then released. For M, just as it is released,

(i) state the forces acting on M,

.... [1]

(ii) calculate the acceleration of M.

acceleration = ... m s^{-2} [3]

(d) Describe and explain the energy changes from the time the object M in Fig. 6.1 is released to the time it first returns to R.

For Examiner's Use

....

....

....

.... [2]

Please turn over for Question 7.

5 **(a)** Explain what is meant by *plastic deformation*.

....

.... [1]

(b) A copper wire of uniform cross-sectional area $1.54 \times 10^{-6}\,m^2$ and length 1.75 m has a breaking stress of 2.20×10^8 Pa. The Young modulus of copper is 1.20×10^{11} Pa.

(i) Calculate the breaking force of the wire.

breaking force = ... N [2]

(ii) A stress of 9.0×10^7 Pa is applied to the wire. Calculate the extension.

extension = ... m [2]

(c) Explain why it is not appropriate to use the Young modulus to determine the extension when the breaking force is applied.

....

.... [1]

For Examiner's Use

4 **(a)** Define

(i) stress,

.... [1]

(ii) strain.

.... [1]

(b) The Young modulus of the metal of a wire is 0.17 TPa. The cross-sectional area of the wire is $0.18\,mm^2$.

The wire is extended by a force F. This causes the length of the wire to be increased by 0.095 %.

Calculate

(i) the stress,

stress = ... Pa [4]

(ii) the force F.

F = ... N [2]

4 A spring hangs vertically from a point P, as shown in Fig. 4.1.

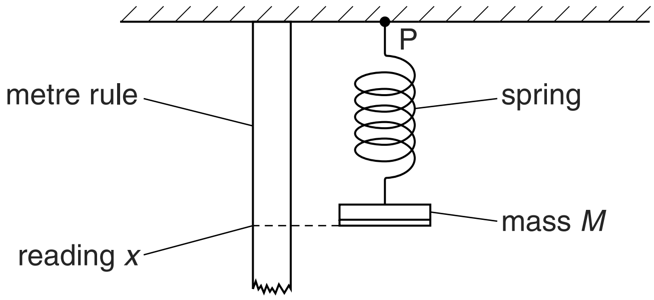


Fig. 4.1

A mass *M* is attached to the lower end of the spring. The reading *x* from the metre rule is taken, as shown in Fig. 4.1. Fig. 4.2 shows the relationship between *x* and *M*.

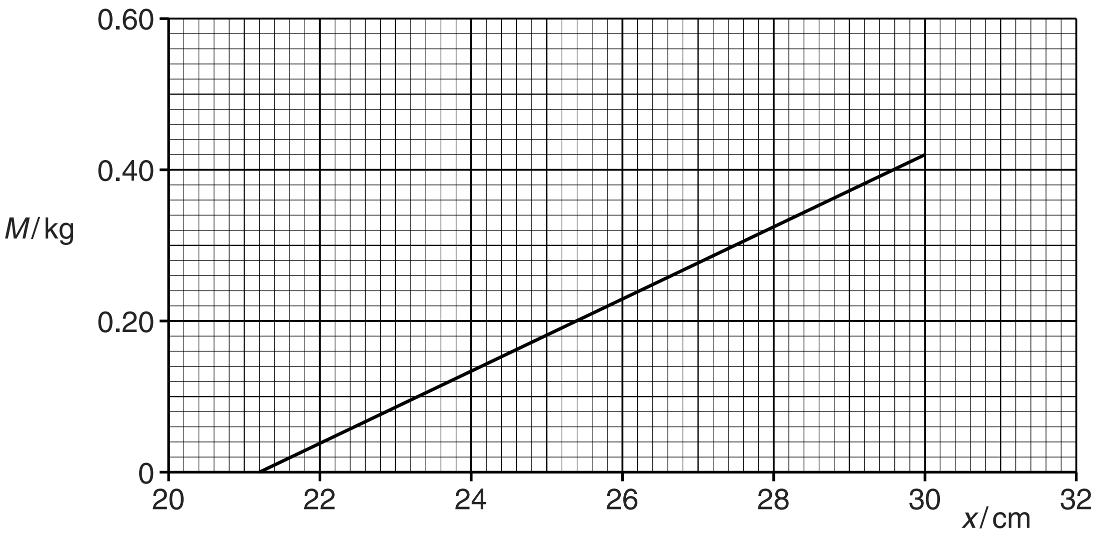


Fig. 4.2

(a) Explain how the apparatus in Fig. 4.1 may be used to determine the load on the spring at the elastic limit.

....

....

....

....[2]

(b) State and explain whether Fig. 4.2 suggests that the spring obeys Hooke's law.

....

....

....[2]

(c) Use Fig. 4.2 to determine the spring constant, in $N\,m^{-1}$, of the spring.

spring constant = ... $N\,m^{-1}$ [3]

5 (a) Define the *Young modulus*.

....

.... [1]

(b) Two wires P and Q of the same material and same original length l_0 are fixed so that they hang vertically, as shown in Fig. 5.1.

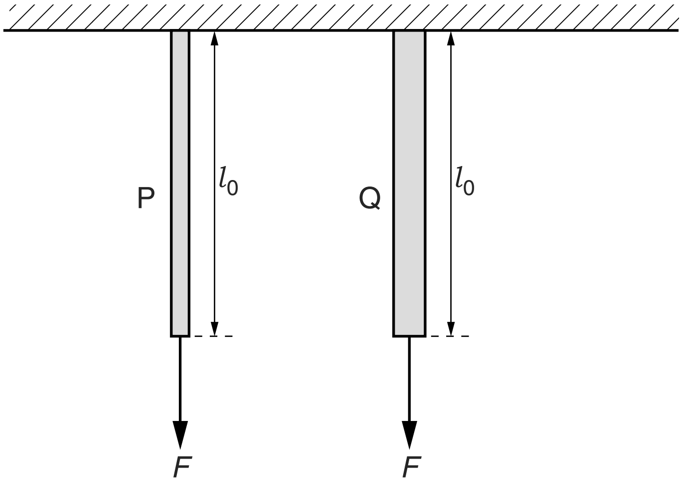


Fig. 5.1 (not to scale)

The diameter of P is *d* and the diameter of Q is 2*d*. The same force *F* is applied to the lower end of each wire.

Show your working and determine the ratio

(i) $\dfrac{\text{stress in P}}{\text{stress in Q}}$,

ratio = ... [2]

(ii) $\dfrac{\text{strain in P}}{\text{strain in Q}}$.

ratio = ... [2]

4 A metal ball of mass 40 g falls vertically onto a spring, as shown in Fig. 4.1.

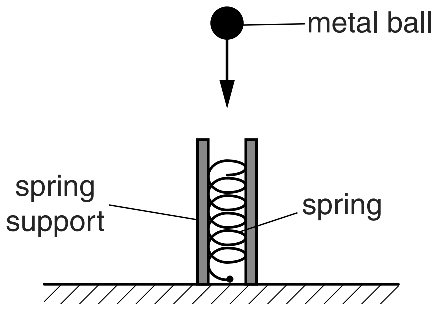


Fig. 4.1 (not to scale)

The spring is supported and stands vertically. The ball has a speed of $2.8\,m\,s^{-1}$ as it makes contact with the spring. The ball is brought to rest as the spring is compressed.

(a) Show that the kinetic energy of the ball as it makes contact with the spring is 0.16 J.

[2]

(b) The variation of the force F acting on the spring with the compression x of the spring is shown in Fig. 4.2.

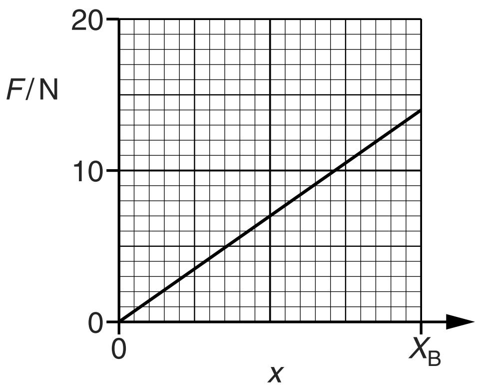


Fig. 4.2

The ball produces a maximum compression X_B when it comes to rest. The spring has a spring constant of $800\,N\,m^{-1}$.
Use Fig. 4.2 to

(i) calculate the compression X_B,

X_B = ... m [2]

(ii) show that not all the kinetic energy in **(a)** is converted into elastic potential energy in the spring.

[2]

4 **(a)** Compare the molecular motion of a liquid with

(i) a solid,

....

....[2]

(ii) a gas.

....

....[1]

(b) **(i)** A ductile material in the form of a wire is stretched up to its breaking point. On Fig. 4.1, sketch the variation with extension *x* of the stretching force *F*.

ductile material

Fig. 4.1 [1]

(ii) On Fig. 4.2, sketch the variation with extension *x* of the stretching force *F* for a brittle material up to its breaking point.

brittle material

Fig. 4.2 [1]

(c) Describe a similarity and a difference between ductile and brittle materials.

similarity: ....

....

difference: ....

....
[2]

4 Fig. 4.1 shows the values obtained in an experiment to determine the Young modulus *E* of a metal in the form of a wire.

quantity	value	instrument
diameter *d*	0.48 mm	
length *l*	1.768 m	
load *F*	5.0 N to 30.0 N in 5.0 N steps	
extension *e*	0.25 mm to 1.50 mm	

Fig. 4.1

(a) (i) Complete Fig. 4.1 with the name of an instrument that could be used to measure each of the quantities. [3]

(ii) Explain why a series of values of *F*, each with corresponding extension *e*, are measured.

....

....[1]

(b) Explain how a series of readings of the quantities given in Fig. 4.1 is used to determine the Young modulus of the metal. A numerical answer for *E* is not required.

....

....

....

....[2]

4 A spring is kept horizontal by attaching it to points A and B, as shown in Fig. 4.1.

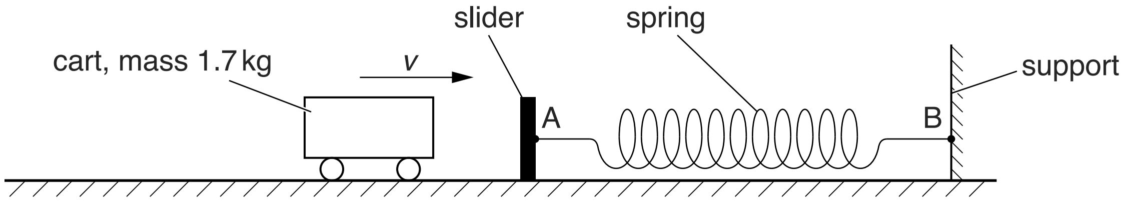


Fig. 4.1

Point A is on a movable slider and point B is on a fixed support. A cart of mass 1.7 kg has horizontal velocity *v* towards the slider. The cart collides with the slider. The spring is compressed as the cart comes to rest. The variation of compression *x* of the spring with force *F* exerted on the spring is shown in Fig. 4.2.

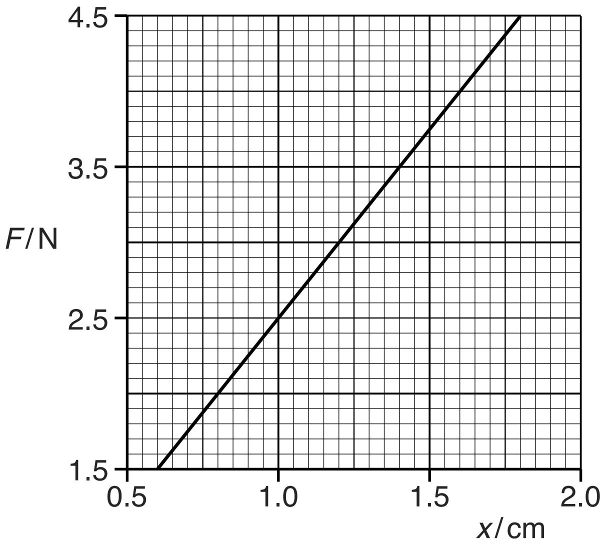


Fig. 4.2

Fig. 4.2 shows the compression of the spring for F = 1.5 N to F = 4.5 N. The cart comes to rest when F is 4.5 N.

(a) Use Fig. 4.2 to

(i) show that the compression of the spring obeys Hooke's law,

....

....

....[2]

(ii) determine the spring constant of the spring,

spring constant = ... $N\,m^{-1}$ [2]

(iii) determine the elastic potential energy E_P stored in the spring due to the cart being brought to rest.

E_P = ... J [3]

(b) Calculate the speed v of the cart as it makes contact with the slider. Assume that all the kinetic energy of the cart is converted to the elastic potential energy of the spring.

speed = ... $m\,s^{-1}$ [2]

1 The Brownian motion of smoke particles in air may be observed using the apparatus shown in Fig. 2.1.

For Examiner's Use

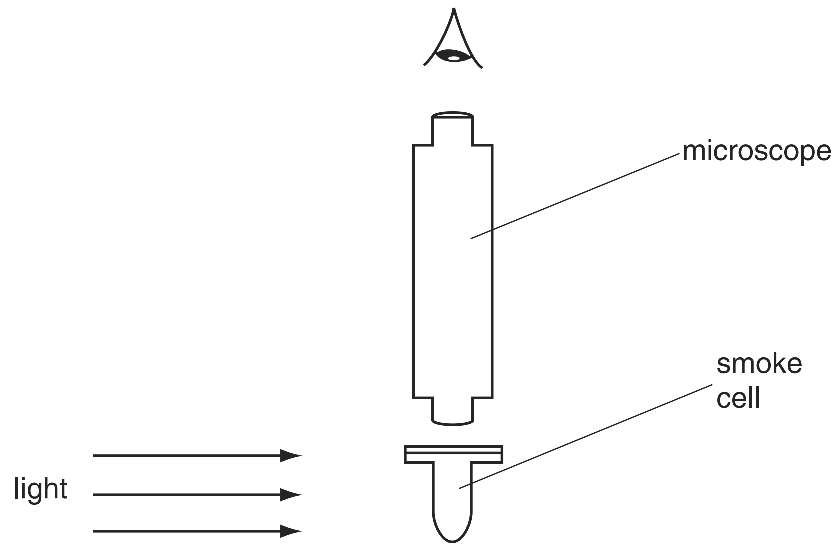


Fig. 2.1

(a) Describe what is seen when viewing a smoke particle through the microscope.

....

....

....[2]

(b) Suggest and explain what difference, if any, would be observed in the movement of smoke particles when larger smoke particles than those observed in **(a)** are viewed through the microscope.

....

....

....[2]

2 (a) Define *density*.

....

....

.... [1]

(b) A U-tube contains some mercury. Water is poured into one arm of the U-tube and oil is poured into the other arm, as shown in Fig. 4.1.

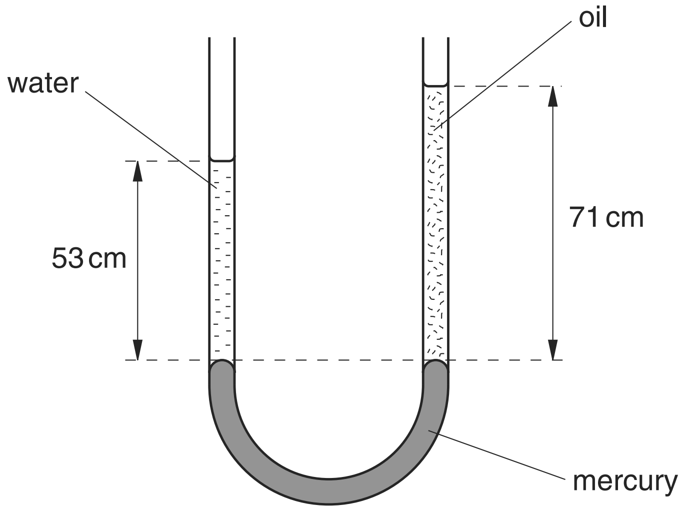


Fig. 4.1

The amounts of oil and water are adjusted until the surface of the mercury in the two arms is at the same horizontal level.

(i) State how it is known that the pressure at the base of the column of water is the same as the pressure at the base of the column of oil.

....

.... [1]

(ii) The column of water, density $1.0 \times 10^3\,\text{kg m}^{-3}$, is 53 cm high. The column of oil is 71 cm high.

Calculate the density of the oil. Explain your working.

density = ... kg m^{-3} [3]

(c) The density of liquid water is 1.0 g cm^{-3}. The density of water vapour at atmospheric pressure is approximately $\frac{1}{1600}$ g cm^{-3}.

Determine the ratio

(i) $\dfrac{\text{volume of water vapour}}{\text{volume of equal mass of liquid water}}$,

ratio = ...[1]

(ii) $\dfrac{\text{mean separation of molecules in water vapour}}{\text{mean separation of molecules in liquid water}}$.

ratio = ...[2]

(d) State the evidence for

(i) the molecules in solids and liquids having approximately the same separation,

....

....[1]

(ii) strong rigid forces between molecules in solids.

strong: ....

rigid: ....[2]

3 A sphere has volume V and is made of metal of density ρ.

(a) Write down an expression for the mass m of the sphere in terms of V and ρ.

....[1]

(b) The sphere is immersed in a liquid. Explain the apparent loss in the weight of the sphere.

....

....

....

....[3]

(c) The sphere in **(b)** has mass 2.0×10^{-3} kg. When the sphere is released, it eventually falls in the liquid with a constant speed of $6.0\,\text{cm}\,\text{s}^{-1}$.

(i) For this sphere travelling at constant speed, calculate

1. its kinetic energy,

kinetic energy = ... J

2. its rate of loss of gravitational potential energy.

rate = ... $\text{J}\,\text{s}^{-1}$ [5]

(ii) Suggest why it is possible for the sphere to have constant kinetic energy whilst losing potential energy at a steady rate.

....

....

....[2]

4 **(a)** Distinguish between the structure of a metal and of a polymer.

metal: ....

....

....

polymer: ....

....

.... [4]

(b) Latex is a natural form of rubber. It is a polymeric material.

(i) Describe the properties of a sample of latex.

....

....

.... [2]

(ii) The process of heating latex with a small amount of sulphur creates cross-links between molecules. Natural latex has very few cross-links between its molecules.

Suggest how this process changes the properties of latex.

....

....

.... [2]

5 Some smoke particles are viewed through a microscope, as illustrated in Fig. 5.1.

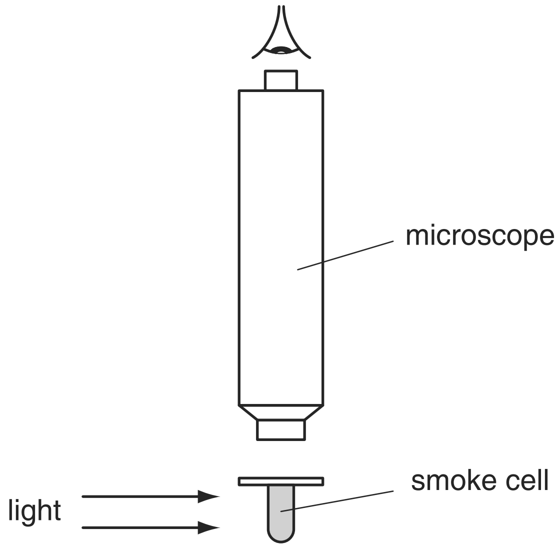


Fig. 5.1

Brownian motion is observed.

(a) Explain what is meant by *Brownian motion.*

....

....

.... [2]

(b) Suggest and explain why Brownian motion provides evidence for the movement of molecules as assumed in the kinetic theory of gases.

....

....

....

.... [2]

(c) Smoke from a poorly maintained engine contains large particles of soot.
Suggest why the Brownian motion of such large particles is undetectable.

....

....

.... [2]

For Examiner's Use

6 **(a)** **(i)** State one **similarity** between the processes of evaporation and boiling.

....

.... [1]

(ii) State two **differences** between the processes of evaporation and boiling.

1. ....

....

2. ....

....
[4]

(b) Titanium metal has a density of $4.5\,g\,cm^{-3}$.

A cube of titanium of mass 48 g contains 6.0×10^{23} atoms.

(i) Calculate the volume of the cube.

volume = ... cm^3 [1]

(ii) Estimate

1. the volume occupied by each atom in the cube,

volume = ... cm^3 [1]

2. the separation of the atoms in the cube.

separation = ... cm [1]

For Examiner's Use

4 **(a)** State the evidence for the assumption that

(i) there are significant forces of attraction between molecules in the solid state,

....

....[1]

(ii) the forces of attraction between molecules in a gas are negligible.

....

....[1]

(b) Explain, on the basis of the kinetic model of gases, the pressure exerted by a gas.

....

....

....

....

....[4]

(c) Liquid nitrogen has a density of 810 kg m^{-3}. The density of nitrogen gas at room temperature and pressure is approximately 1.2 kg m^{-3}.
Suggest how these densities relate to the spacing of nitrogen molecules in the liquid and in the gaseous states.

....

....

....[2]

For Examiner's Use

7 **(a)** Explain the difference in densities in solids, liquids and gases using ideas of the spacing between molecules.

....

....

....

....

....

....

....[3]

(b) A hydrogen nucleus (proton) may be assumed to be a sphere of radius 1×10^{-15} m. Calculate the density of a hydrogen nucleus.

density = ... $kg\,m^{-3}$ [3]

(c) The density of hydrogen gas in a pressurised cylinder is $4\,kg\,m^{-3}$. Suggest a reason why this density is much less than your answer in **(b)**.

....

....

....[1]

For Examiner's Use

6 **(a)** State two assumptions of the simple kinetic model of a gas.

1. ....

....

2. ....

....
[2]

(b) Use the kinetic model of gases and Newton's laws of motion to explain how a gas exerts a pressure on the sides of its container.

....

....

....

....

.... [3]

For Examiner's Use

1 **(a)** Define *density*.

....

.... [1]

(b) Explain how the difference in the densities of solids, liquids and gases may be related to the spacing of their molecules.

....

....

....

.... [2]

(c) A paving slab has a mass of 68 kg and dimensions 50 mm × 600 mm × 900 mm.

(i) Calculate the density, in kg m^{-3}, of the material from which the paving slab is made.

density = ... kg m^{-3} [2]

(ii) Calculate the maximum pressure a slab could exert on the ground when resting on one of its surfaces.

pressure = ... Pa [3]

For Examiner's Use

3 **(a)** Show that the pressure P due to a liquid of density ρ is proportional to the depth h below the surface of the liquid.

[4]

(b) The pressure of the air at the top of a mountain is less than that at the foot of the mountain. Explain why the difference in air pressure is not proportional to the difference in height as suggested by the relationship in **(a)**.

....

....

....

....[2]

For Examiner's Use

3 **(a)** Define *pressure*.

....

.... [1]

(b) Explain, in terms of the air molecules, why the pressure at the top of a mountain is less than at sea level.

....

....

....

....

.... [3]

(c) Fig. 3.1 shows a liquid in a cylindrical container.

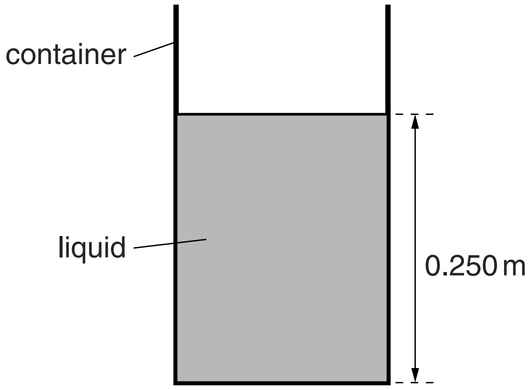


Fig. 3.1

The cross-sectional area of the container is 0.450 m^2. The height of the column of liquid is 0.250 m and the density of the liquid is 13 600 $kg\,m^{-3}$.

(i) Calculate the weight of the column of liquid.

weight = ... N [3]

(ii) Calculate the pressure on the base of the container caused by the weight of the liquid.

pressure = ... Pa [1]

(iii) Explain why the pressure exerted on the base of the container is different from the value calculated in **(ii)**.

....

.... [1]

For Examiner's Use

4 **(a)** Describe apparatus that demonstrates Brownian motion. Include a diagram.

....

....

....

....

....[2]

(b) Describe the observations made using the apparatus in **(a)**.

....

....

....[2]

(c) State and explain two conclusions about the properties of molecules of a gas that follow from the observations in **(b)**.

1. ....

....

2. ....

....

[2]

For Examiner's Use

4 **(a)** Define *pressure*.

....

.... [1]

(b) Use the kinetic model to explain the pressure exerted by a gas.

....

....

....

....

....

.... [4]

(c) Explain whether the collisions between the molecules of an ideal gas are elastic or inelastic.

....

....

.... [2]

6 Distinguish between *melting* and *evaporation*.

melting: ....

....

....

evaporation: ....

....

....
[4]

4 **(a)** A gas molecule has a mass of 6.64×10^{-27} kg and a speed of $1250\,\mathrm{m\,s^{-1}}$. The molecule collides normally with a flat surface and rebounds with the same speed, as shown in Fig. 4.1.

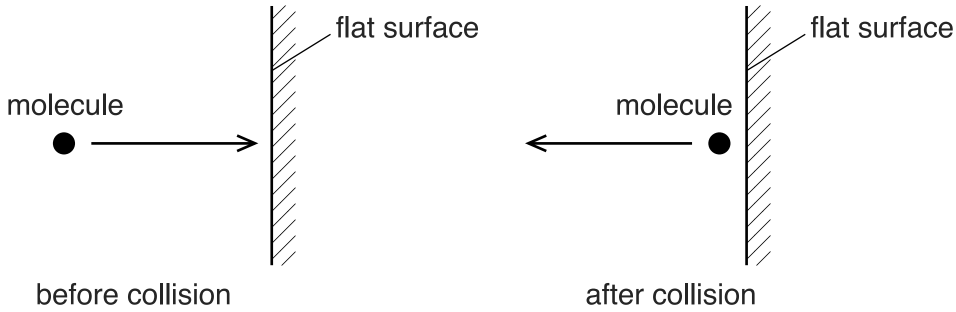


Fig. 4.1

Calculate the change in momentum of the molecule.

change in momentum = ... N s [2]

(b) **(i)** Use the kinetic model to explain the pressure exerted by gases.

....

....

....

....

....

.... [3]

(ii) Explain the effect of an increase in density, at constant temperature, on the pressure of a gas.

....

.... [1]

1 Two horizontal metal plates are situated 1.2 cm apart, as illustrated in Fig. 6.1.

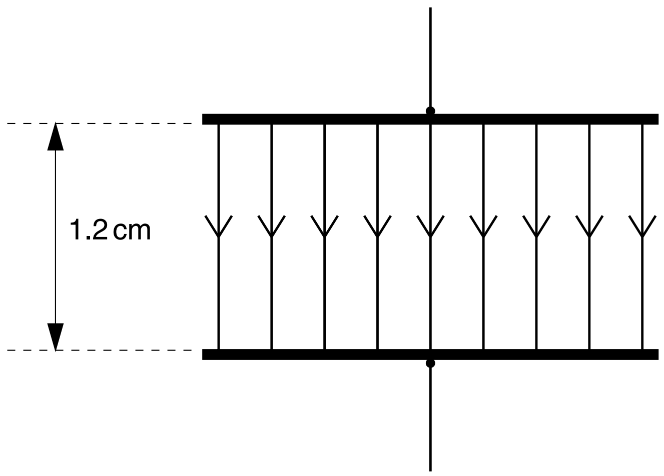


Fig. 6.1

The electric field between the plates is found to be $3.0 \times 10^4\,\mathrm{N\,C^{-1}}$ in the downward direction.

(a) **(i)** On Fig. 6.1, mark with a + the plate which is at the more positive potential.

(ii) Calculate the potential difference between the plates.

potential difference = ... V [3]

(b) Determine the acceleration of an electron between the plates, assuming there is a vacuum between them.

acceleration = ... $\mathrm{m\,s^{-2}}$ [3]

2 Two parallel metal plates P and Q are situated 8.0 cm apart in air, as shown in Fig. 6.1.

For Examiner's Use

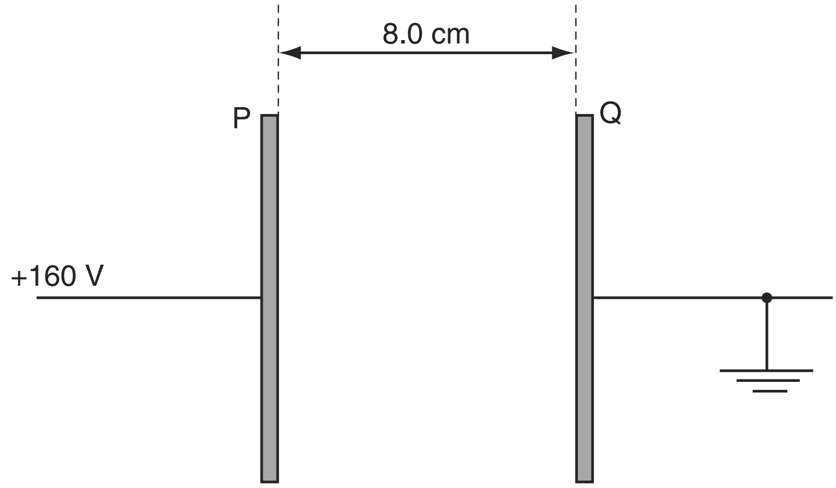


Fig. 6.1

Plate Q is earthed and plate P is maintained at a potential of +160 V.

(a) **(i)** On Fig. 6.1, draw lines to represent the electric field in the region between the plates. [2]

(ii) Show that the magnitude of the electric field between the plates is $2.0 \times 10^3\,\mathrm{V\,m^{-1}}$.

[1]

(b) A dust particle is suspended in the air between the plates. The particle has charges of $+1.2 \times 10^{-15}$ C and -1.2×10^{-15} C near its ends. The charges may be considered to be point charges separated by a distance of 2.5 mm, as shown in Fig. 6.2.

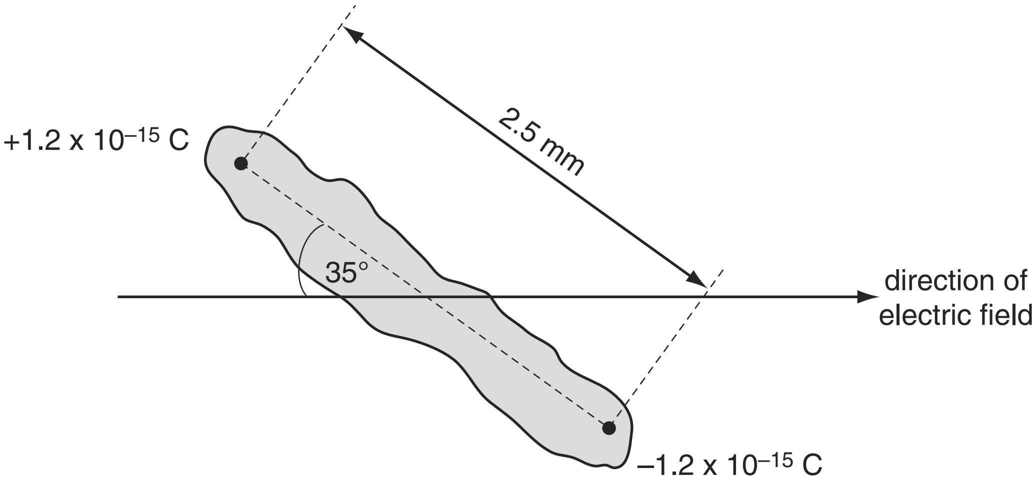


Fig. 6.2

The particle makes an angle of 35° with the direction of the electric field.

(i) On Fig. 6.2, draw arrows to show the direction of the force on each charge due to the electric field. [1]

(ii) Calculate the magnitude of the force on each charge due to the electric field.

force = ... N [2]

(iii) Determine the magnitude of the couple acting on the particle.

couple = ... N m [2]

(iv) Suggest the subsequent motion of the particle in the electric field.

....

....

....[2]

3 **(a)** Define *electric field strength*.

....

....[1]

(b) Two flat parallel metal plates, each of length 12.0 cm, are separated by a distance of 1.5 cm, as shown in Fig. 2.1.

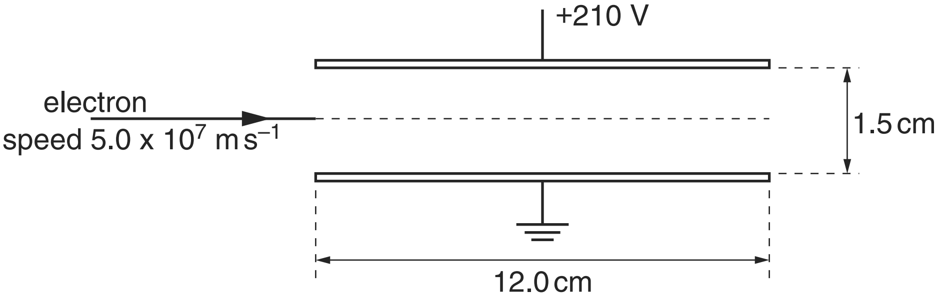


Fig. 2.1

The space between the plates is a vacuum.
The potential difference between the plates is 210 V. The electric field may be assumed to be uniform in the region between the plates and zero outside this region.
Calculate the magnitude of the electric field strength between the plates.

field strength = ...N C^{-1} [1]

(b) The electron accelerates horizontally across the space between the plates. Determine

(i) the horizontal acceleration of the electron,

acceleration = ... $m\,s^{-2}$ [2]

(ii) the time to travel the horizontal distance of 2.50 cm between the plates.

time = ... s [2]

(c) Explain why gravitational effects on the electron need not be taken into consideration in your calculation in **(b)**.

....

....

.... [2]

For Examiner's Use

4 Two vertical parallel metal plates are situated 2.50 cm apart in a vacuum. The potential difference between the plates is 350 V, as shown in Fig. 6.1.

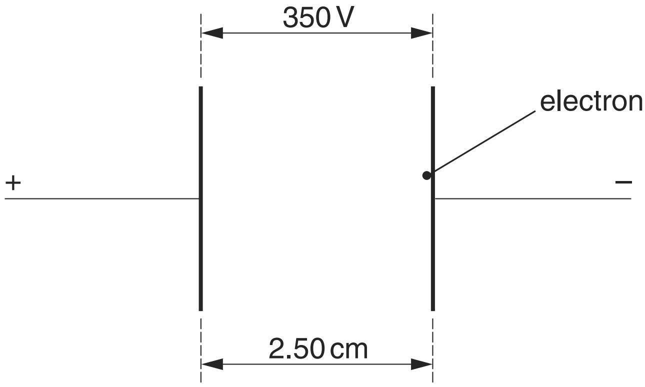


Fig. 6.1

An electron is initially at rest close to the negative plate and in the uniform electric field between the plates.

(a) (i) Calculate the magnitude of the electric field between the plates.

electric field strength = ... $N\,C^{-1}$ [2]

(ii) Show that the force on the electron due to the electric field is 2.24×10^{-15} N.

[2]

For Examiner's Use

(b) The electron accelerates horizontally across the space between the plates. Determine

(i) the horizontal acceleration of the electron,

acceleration = ... $m\,s^{-2}$ [2]

(ii) the time to travel the horizontal distance of 2.50 cm between the plates.

time = ... s [2]

(c) Explain why gravitational effects on the electron need not be taken into consideration in your calculation in **(b)**.

....

....

.... [2]

For Examiner's Use

5 An electron travelling horizontally in a vacuum enters the region between two horizontal metal plates, as shown in Fig. 6.1.

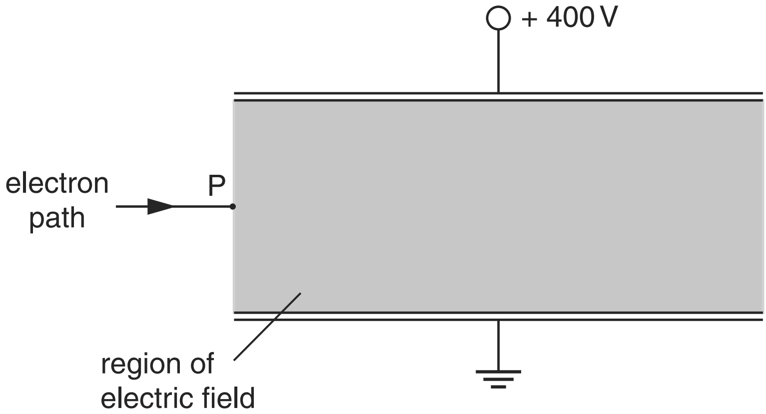


Fig. 6.1

The lower plate is earthed and the upper plate is at a potential of + 400 V. The separation of the plates is 0.80 cm.

The electric field between the plates may be assumed to be uniform and outside the plates to be zero.

(a) On Fig. 6.1,

(i) draw an arrow at P to show the direction of the force on the electron due to the electric field between the plates,

(ii) sketch the path of the electron as it passes between the plates and beyond them. [3]

(b) Determine the electric field strength *E* between the plates.

E = ... V m^{-1} [2]

(c) Calculate, for the electron between the plates, the magnitude of

(i) the force on the electron,

force = …………………………….. N

(ii) its acceleration.

acceleration = ……………………………… m s^{-2}
[4]

(d) State and explain the effect, if any, of this electric field on the horizontal component of the motion of the electron.

....

....

....[2]

For Examiner's Use

6 Two horizontal metal plates X and Y are at a distance 0.75 cm apart. A positively charged particle of mass 9.6×10^{-15} kg is situated in a vacuum between the plates, as illustrated in Fig. 6.1.

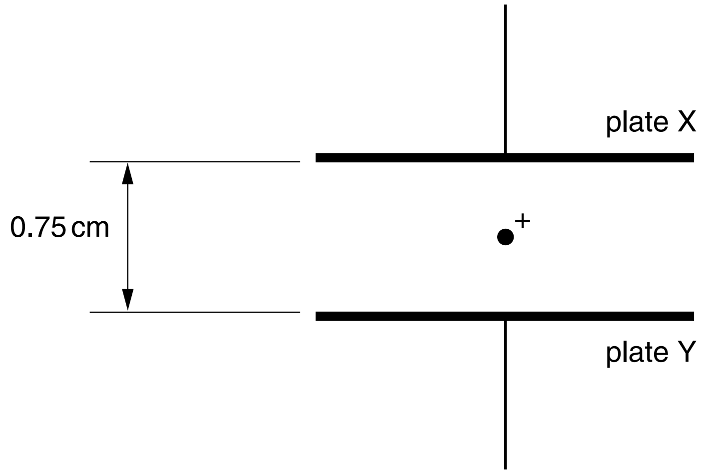


Fig. 6.1

The potential difference between the plates is adjusted until the particle remains stationary.

(a) State, with a reason, which plate, X or Y, is positively charged.

....

....

.... [2]

(b) The potential difference required for the particle to be stationary between the plates is found to be 630 V. Calculate

(i) the electric field strength between the plates,

field strength = ... N C^{-1} [2]

For Examiner's Use

(ii) the charge on the particle.

charge = …………………………….. C [3]

7 Two parallel plates P and Q are separated by a distance of 7.6 mm in a vacuum. There is a potential difference of 250 V between the plates, as illustrated in Fig. 4.1.

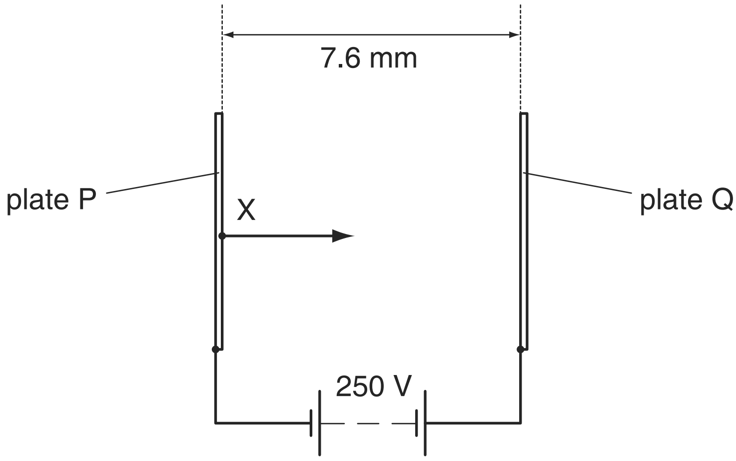


Fig. 4.1

Electrons are produced at X on plate P. These electrons accelerate from rest and travel to plate Q.
The electric field between the plates may be assumed to be uniform.

(a) **(i)** Determine the force on an electron due to the electric field.

force = …………………….. N [3]

(ii) Show that the change in kinetic energy of an electron as it moves from plate P to plate Q is 4.0×10^{-17} J.

[2]

For Examiner's Use

(iii) Determine the speed of an electron as it reaches plate Q.

speed = ... $m\,s^{-1}$ [2]

(b) The positions of the plates are adjusted so that the electric field between them is not uniform. The potential difference remains unchanged.
State and explain the effect, if any, of this adjustment on the speed of an electron as it reaches plate Q.

....

....

....

.... [3]

For Examiner's Use

5 **(a)** State what is meant by an *electric field*.

....

.... [1]

(b) The electric field between an earthed metal plate and two charged metal spheres is illustrated in Fig. 5.1.

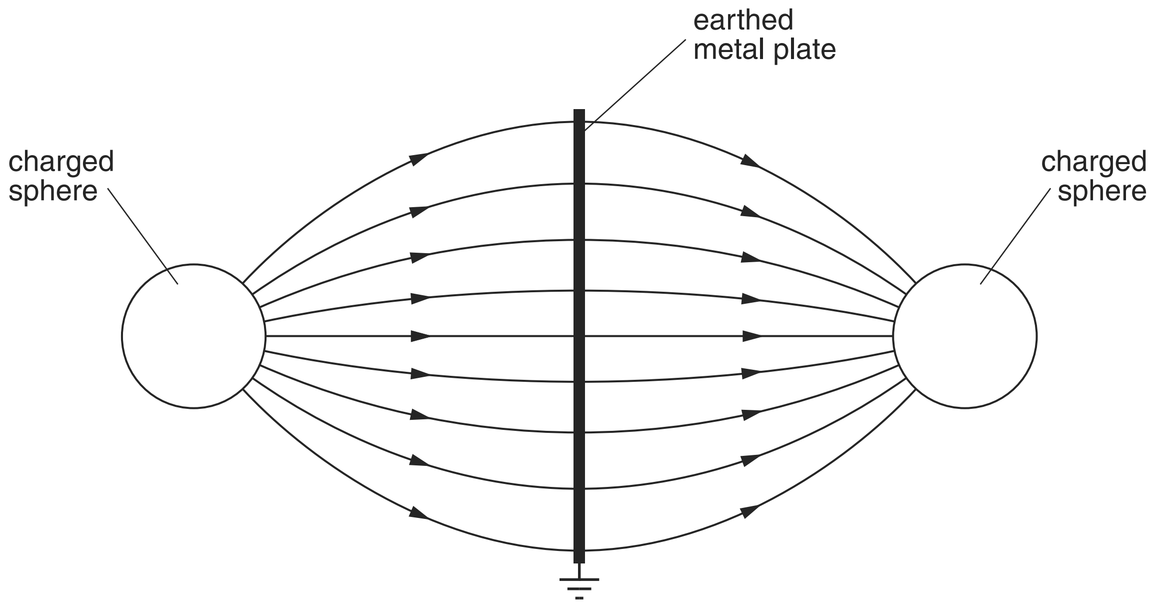


Fig. 5.1

(i) On Fig. 5.1, label each sphere with (+) or (–) to show its charge. [1]

(ii) On Fig. 5.1, mark a region where the magnitude of the electric field is

1. constant (label this region C), [1]

2. decreasing (label this region D). [1]

For Examiner's Use

(c) A molecule has its centre P of positive charge situated a distance of 2.8×10^{-10} m from its centre N of negative charge, as illustrated in Fig. 5.2.

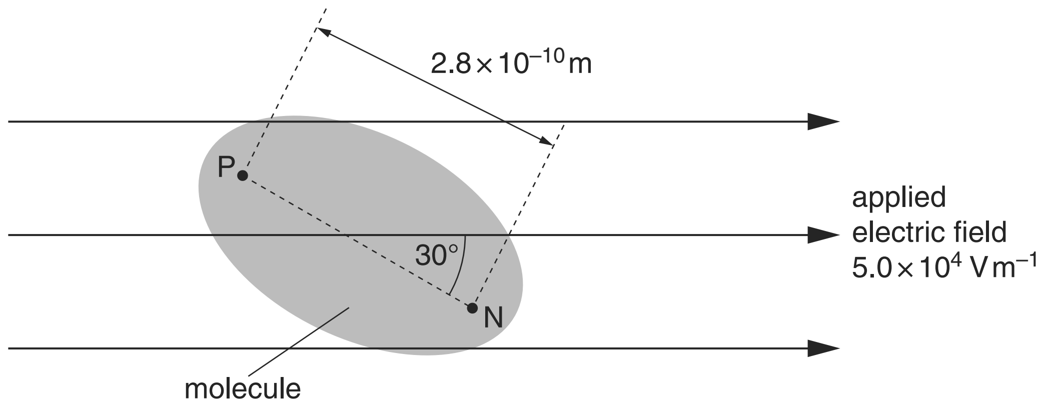


Fig. 5.2

The molecule is situated in a uniform electric field of field strength 5.0×10^4 V m^{-1}. The axis NP of the molecule is at an angle of 30° to this uniform applied electric field.
The magnitude of the charge at P and at N is 1.6×10^{-19} C.

(i) On Fig. 5.2, draw an arrow at P and an arrow at N to show the directions of the forces due to the applied electric field at each of these points. [1]

(ii) Calculate the torque on the molecule produced by the forces in **(i)**.

torque = ... N m [2]

For Examiner's Use

7 Two oppositely-charged parallel metal plates are situated in a vacuum, as shown in Fig. 7.1.

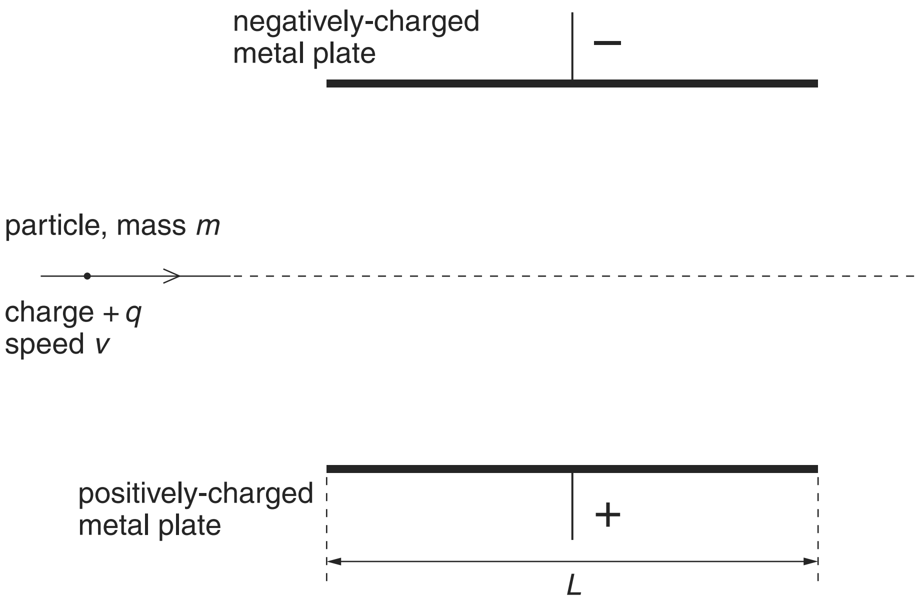


Fig. 7.1

The plates have length *L*.
The uniform electric field between the plates has magnitude *E*. The electric field outside the plates is zero.

A positively-charged particle has mass *m* and charge +*q*. Before the particle reaches the region between the plates, it is travelling with speed *v* parallel to the plates.
The particle passes between the plates and into the region beyond them.

(a) **(i)** On Fig. 7.1, draw the path of the particle between the plates and beyond them. [2]

(ii) For the particle in the region between the plates, state expressions, in terms of *E*, *m*, *q*, *v* and *L*, as appropriate, for

1. the force *F* on the particle,

.... [1]

2. the time *t* for the particle to cross the region between the plates.

.... [1]

For Examiner's Use

(b) (i) State the law of conservation of linear momentum.

....

....

.... [2]

(ii) Use your answers in **(a)(ii)** to state an expression for the change in momentum of the particle.

.... [1]

(iii) Suggest and explain whether the law of conservation of linear momentum applies to the particle moving between the plates.

....

....

.... [2]

For Examiner's Use

4 **(a)** Define *electric field strength*.

....

....[1]

(b) Two horizontal metal plates are 20 mm apart in a vacuum. A potential difference of 1.5 kV is applied across the plates, as shown in Fig. 4.1.

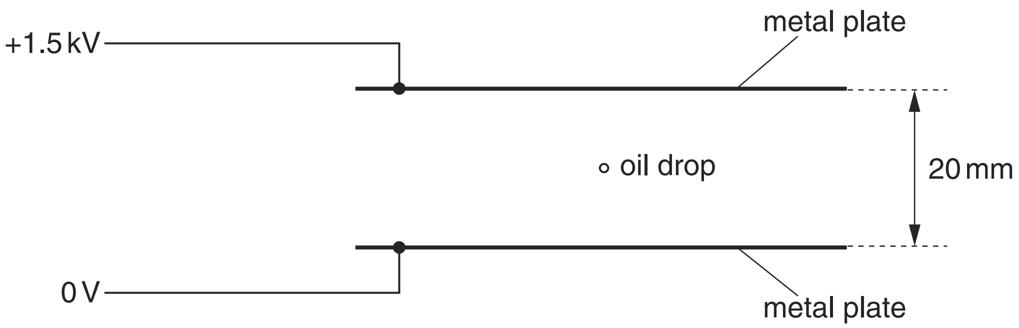


Fig. 4.1

A charged oil drop of mass 5.0×10^{-15} kg is held stationary by the electric field.

(i) On Fig. 4.1, draw lines to represent the electric field between the plates. [2]

(ii) Calculate the electric field strength between the plates.

electric field strength = ... V m^{-1} [1]

(iii) Calculate the charge on the drop.

charge = ... C [4]

(iv) The potential of the upper plate is increased. Describe and explain the subsequent motion of the drop.

....

....

....[2]

6 Two horizontal metal plates are separated by distance d in a vacuum. A potential difference V is applied across the plates, as shown in Fig. 6.1.

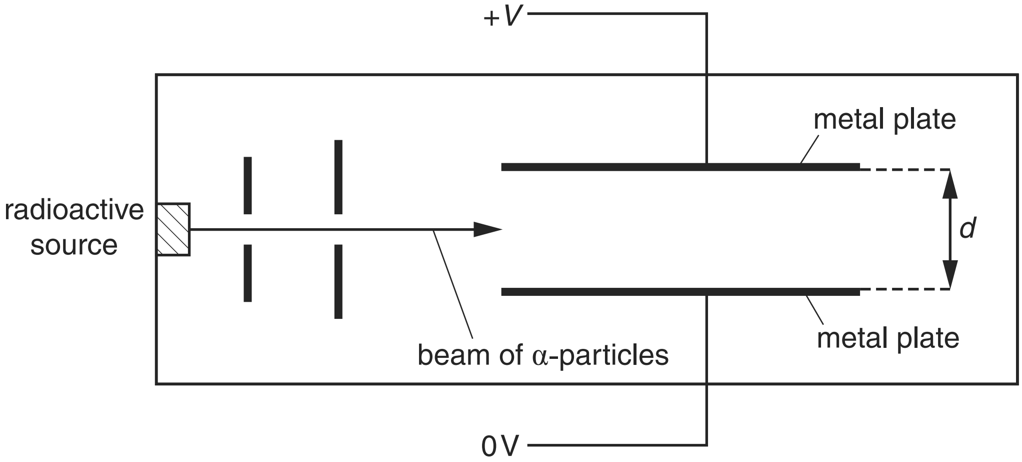


Fig. 6.1

A horizontal beam of α-particles from a radioactive source is made to pass between the plates.

(a) State and explain the effect on the deflection of the α-particles for each of the following changes:

(i) The magnitude of V is increased.

....

.... [1]

(ii) The separation d of the plates is decreased.

....

.... [1]

For Examiner's Use

(b) The source of α-particles is replaced with a source of β-particles.
Compare, with a reason in each case, the effect of each of the following properties on the deflections of α- and β-particles in a uniform electric field:

(i) charge

....

....

.... [2]

(ii) mass

....

....

.... [2]

(iii) speed

....

....

.... [1]

(c) The electric field gives rise to an acceleration of the α-particles and the β-particles. Determine the ratio

$$\frac{\text{acceleration of the } \alpha\text{-particles}}{\text{acceleration of the } \beta\text{-particles}} .$$

ratio = ... [3]

For Examiner's Use

4 **(a)** Define *electric field strength*.

....

.... [1]

(b) A uniform electric field is produced by applying a potential difference of 1200 V across two parallel metal plates in a vacuum, as shown in Fig. 4.1.

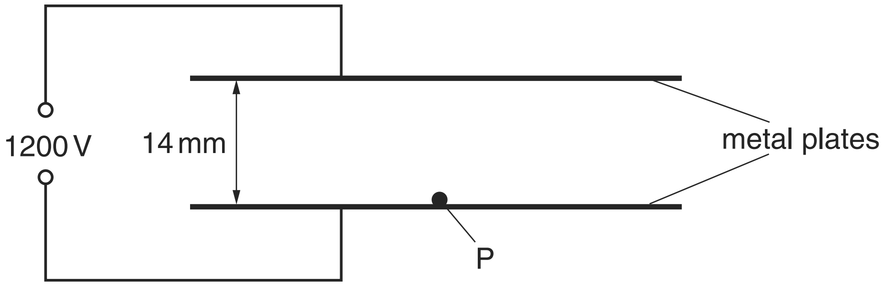


Fig. 4.1

The separation of the plates is 14 mm. A particle P with charge 3.2×10^{-19} C and mass 6.6×10^{-27} kg starts from rest at the lower plate and is moved vertically to the top plate by the electric field.

Calculate

(i) the electric field strength between the plates,

electric field strength = ... V m^{-1} [2]

(ii) the work done on P by the electric field,

work done = ... J [2]

(iii) the gain in gravitational potential energy of P,

gain in potential energy = ... J [2]

For Examiner's Use

(iv) the gain in kinetic energy of P,

gain in kinetic energy = ... J [1]

(v) the speed of P when it reaches the top plate.

speed = ... m s^{-1} [2]

For Examiner's Use

7 **(a)** Two horizontal metal plates are connected to a power supply, as shown in Fig. 7.1.

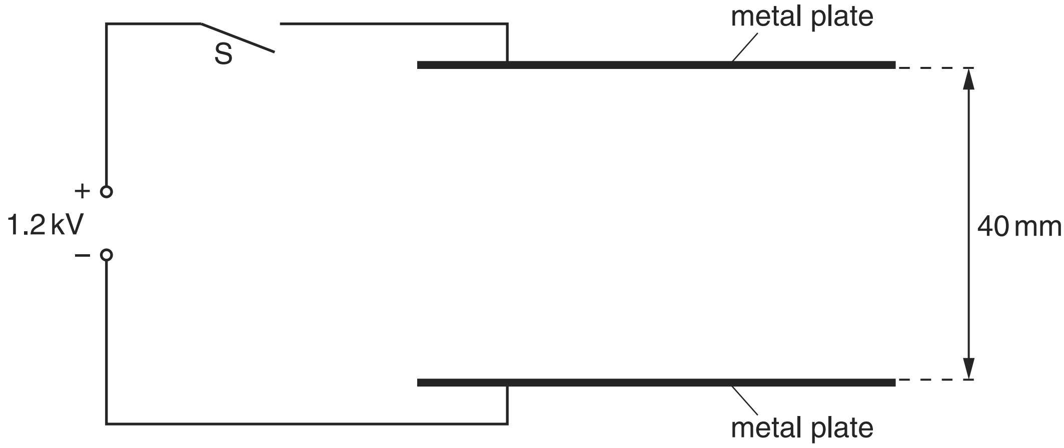


Fig. 7.1

The separation of the plates is 40 mm.

The switch S is then closed so that a potential difference of 1.2 kV is applied across the plates.

(i) On Fig. 7.1, draw six field lines to represent the electric field between the metal plates. [2]

(ii) Calculate the electric field strength E between the plates.

E = ... $\mathrm{V\,m^{-1}}$ [2]

(b) The switch S is opened and the plates lose their charge. Two very small metal spheres A and B joined by an insulating rod are placed between the metal plates as shown in Fig. 7.2.

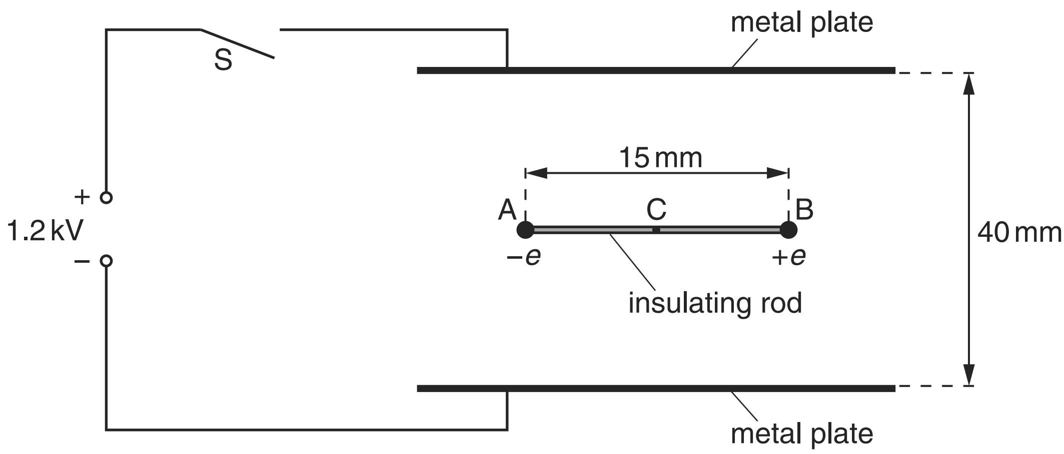


Fig. 7.2

Sphere A has charge $-e$ and sphere B has charge $+e$, where e is the charge of a proton. The length AB is 15 mm. The rod is supported at its centre C so that the rod is horizontal and in equilibrium.

For Examiner's Use

The switch S is then closed so that the potential difference of 1.2 kV is applied across the plates.

(i) There is a force acting on A due to the electric field between the plates. Show that this force is 4.8×10^{-15} N.

[2]

(ii) The insulating rod joining A and B is fixed in the position shown in Fig. 7.2. Calculate the torque of the couple acting on the rod.

torque = ... unit .... [3]

(iii) The insulating rod is now released so that it is free to rotate about C. State and explain the position of the rod when it comes to rest.

....

....

....

.... [2]

3 **(a)** Define *electric field strength*.

....

....[1]

(b) A sphere S has radius 1.2×10^{-6} m and density $930\,\text{kg}\,\text{m}^{-3}$.

Show that the weight of S is 6.6×10^{-14} N.

[2]

(c) Two horizontal metal plates are 14 mm apart in a vacuum. A potential difference (p.d.) of 1.9 kV is applied across the plates, as shown in Fig. 3.1.

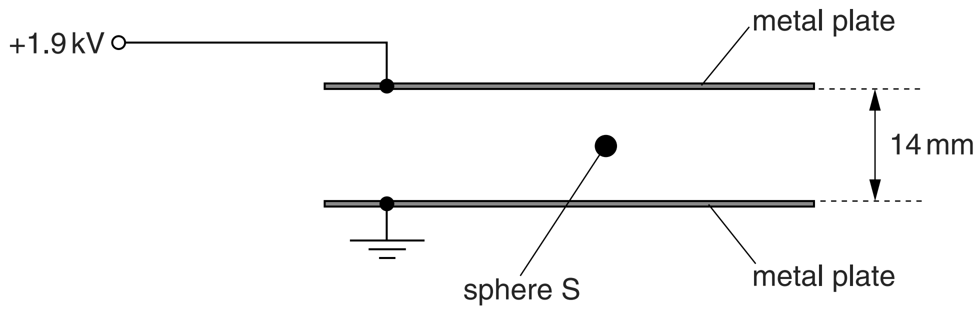


Fig. 3.1

A uniform electric field is produced between the plates.
The sphere S in **(b)** is charged and is held stationary between the plates by the electric field.

(i) Calculate the electric field strength between the plates.

electric field strength = ... $\text{V}\,\text{m}^{-1}$ [2]

(ii) Calculate the magnitude of the charge on S.

charge = ... C [2]

(iii) The magnitude of the p.d. applied to the plates is increased.
Explain why S accelerates towards the top plate.

....

....[2]

7 **(a)** Explain what is meant by an *electric field*.

....

....[1]

(b) A uniform electric field is produced between two vertical metal plates AB and CD, as shown in Fig. 7.1.

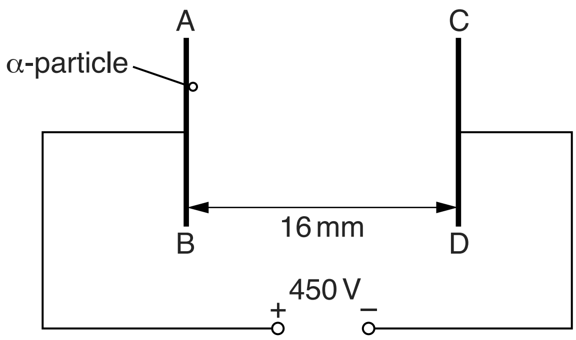


Fig. 7.1

The potential difference between the plates is 450 V and the separation of the plates is 16 mm.

An α-particle is accelerated from plate AB to plate CD.

(i) On Fig. 7.1, draw lines to represent the electric field between the plates. [2]

(ii) Calculate the electric field strength between the plates.

electric field strength = ... $V m^{-1}$ [2]

(iii) Calculate the work done by the electric field on the α-particle as it moves from AB to CD.

work done = ... J [3]

Question 7 continues on page 16.

(iv) A β-particle moves from AB to CD. Calculate the ratio

$$\frac{\text{work done by the electric field on the } \alpha\text{-particle}}{\text{work done by the electric field on the } \beta\text{-particle.}}$$

Show your working.

ratio = ... [1]

1 A student has available some resistors, each of resistance 100 Ω.

(a) Draw circuit diagrams, one in each case, to show how a number of these resistors may be connected to produce a combined resistance of

(i) 200 Ω,

(ii) 50 Ω,

(iii) 40 Ω.

[4]

For Examiner's Use

(b) The arrangement of resistors shown in Fig. 8.1 is connected to a battery.

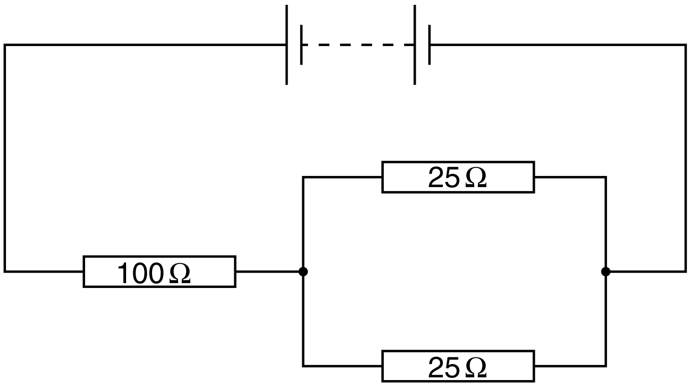


Fig. 8.1

The power dissipation in the 100 Ω resistor is 0.81 W. Calculate

(i) the current in the circuit,

current = ... A

(ii) the power dissipation in each of the 25 Ω resistors.

power = ... W

[4]

2 A household electric lamp is rated as 240 V, 60 W. The filament of the lamp is made from tungsten and is a wire of constant radius 6.0×10^{-6} m. The resistivity of tungsten at the normal operating temperature of the lamp is $7.9 \times 10^{-7}\ \Omega$ m.

(a) For the lamp at its normal operating temperature,

(i) calculate the current in the lamp,

current = ... A

(ii) show that the resistance of the filament is 960 Ω.

[3]

(b) Calculate the length of the filament.

length = ... m [3]

(c) Comment on your answer to **(b)**.

....

.... [1]

3 A thermistor has resistance 3900 Ω at 0 °C and resistance 1250 Ω at 30 °C. The thermistor is connected into the circuit of Fig. 8.1 in order to monitor temperature changes.

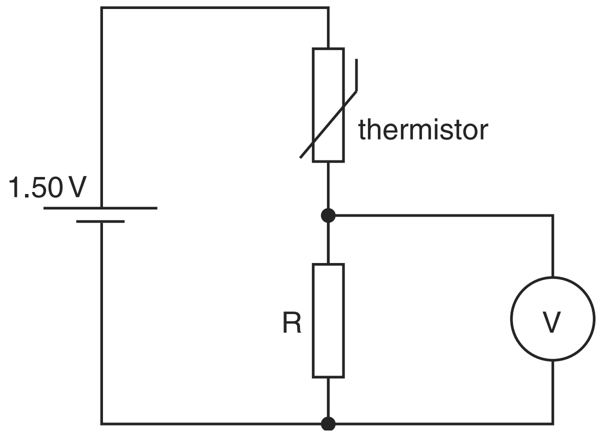


Fig. 8.1

The battery of e.m.f. 1.50 V has negligible internal resistance and the voltmeter has infinite resistance.

(a) The voltmeter is to read 1.00 V at 0 °C. Show that the resistance of resistor R is 7800 Ω.

[2]

(b) The temperature of the thermistor is increased to 30 °C. Determine the reading on the voltmeter.

reading = ... V [2]

For Examiner's Use

(c) The voltmeter in Fig. 8.1 is replaced with one having a resistance of 7800 Ω.
Calculate the reading on this voltmeter for the thermistor at a temperature of 0 °C.

reading = ... V [2]

For Examiner's Use

4 **(a)** Define the *resistance* of a resistor.

....

....[1]

(b) In the circuit of Fig. 7.1, the battery has an e.m.f. of 3.00 V and an internal resistance *r*. R is a variable resistor. The resistance of the ammeter is negligible and the voltmeter has an infinite resistance.

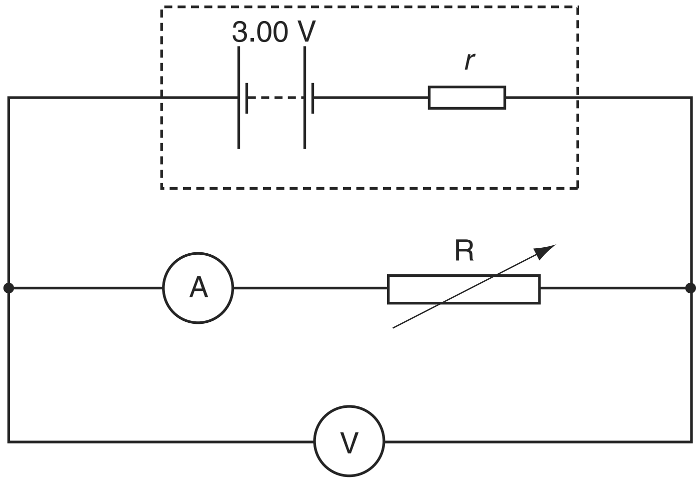


Fig. 7.1

The resistance of R is varied. Fig. 7.2 shows the variation of the power *P* dissipated in R with the potential difference *V* across R.

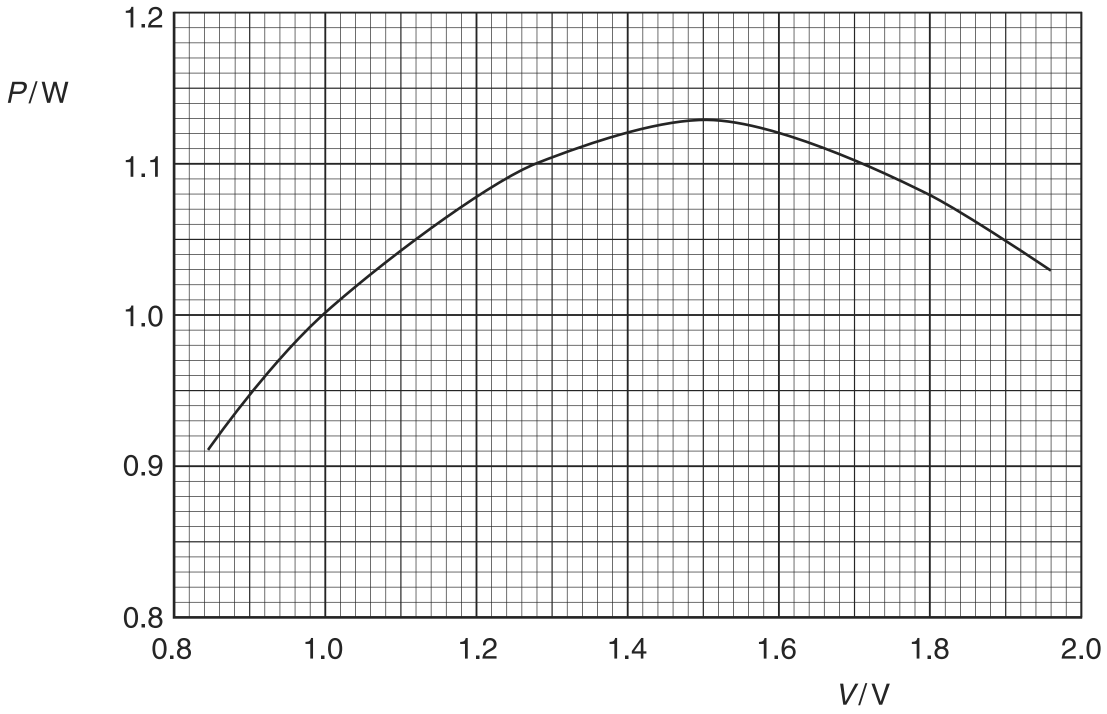


Fig. 7.2

(i) Use Fig. 7.2 to determine

1. the maximum power dissipation in R,

maximum power = ... W

2. the potential difference across R when the maximum power is dissipated.

potential difference = ... V [1]

(ii) Hence calculate the resistance of R when the maximum power is dissipated.

resistance = ... Ω [2]

(iii) Use your answers in **(i)** and **(ii)** to determine the internal resistance r of the battery.

r = ... Ω [3]

(c) By reference to Fig. 7.2, it can be seen that there are two values of potential difference V for which the power dissipation is 1.05 W.
State, with a reason, which value of V will result in less power being dissipated in the internal resistance.

....

....

....

....[3]

For Examiner's Use

5 A circuit contains three similar lamps A, B and C. The circuit also contains three switches, S_1, S_2 and S_3, as shown in Fig. 7.1.

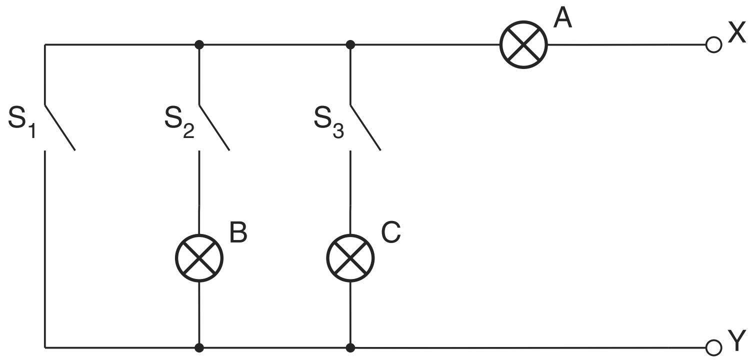


Fig. 7.1

One of the lamps is faulty. In order to detect the fault, an ohm-meter (a meter that measures resistance) is connected between terminals X and Y. When measuring resistance, the ohm-meter causes negligible current in the circuit.

Fig. 7.2 shows the readings of the ohm-meter for different switch positions.

switch S_1	S_2	S_3	meter reading / Ω
open	open	open	∞
closed	open	open	15 Ω
open	closed	open	30 Ω
open	closed	closed	15 Ω

Fig. 7.2

(a) Identify the faulty lamp, and the nature of the fault.

faulty lamp: ....

nature of fault: .... [2]

(b) Suggest why it is advisable to test the circuit using an ohm-meter that causes negligible current rather than with a power supply.

....

.... [1]

(c) Determine the resistance of one of the non-faulty lamps, as measured using the ohm-meter.

resistance = ... Ω [1]

(d) Each lamp is marked 6.0 V, 0.20 A.

Calculate, for one of the lamps operating at normal brightness,

(i) its resistance,

resistance = ... Ω [2]

(ii) its power dissipation.

power = ... W [2]

(e) Comment on your answers to **(c)** and **(d)(i)**.

....

....

....[2]

6 A car battery has an internal resistance of 0.060 Ω. It is re-charged using a battery charger having an e.m.f. of 14 V and an internal resistance of 0.10 Ω, as shown in Fig. 6.1.

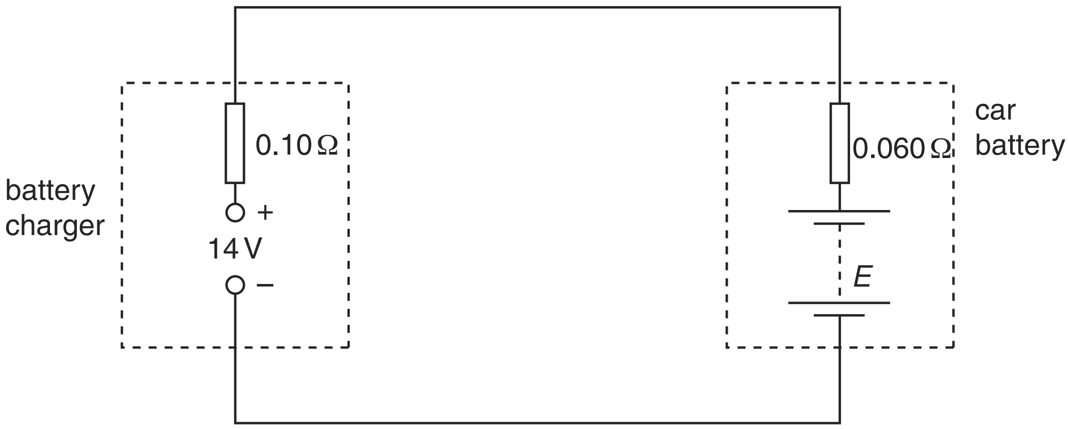


Fig. 6.1

(a) At the beginning of the re-charging process, the current in the circuit is 42 A and the e.m.f. of the battery is *E* (measured in volts).

(i) For the circuit of Fig. 6.1, state

1. the magnitude of the total resistance,

resistance = ... Ω

2. the total e.m.f. in the circuit. Give your answer in terms of *E*.

e.m.f. = ... V
[2]

(ii) Use your answers to **(i)** and data from the question to determine the e.m.f. of the car battery at the beginning of the re-charging process.

e.m.f. = ...V [2]

(b) For the majority of the charging time of the car battery, the e.m.f. of the car battery is 12 V and the charging current is 12.5 A. The battery is charged at this current for 4.0 hours. Calculate, for this charging time,

(i) the charge that passes through the battery,

charge = ... C [2]

(ii) the energy supplied from the battery charger,

energy = ... J [2]

(iii) the total energy dissipated in the internal resistance of the battery charger and the car battery.

energy = ... J [2]

(c) Use your answers in **(b)** to calculate the percentage efficiency of transfer of energy from the battery charger to stored energy in the car battery.

efficiency = ... % [2]

7 An electric heater consists of three similar heating elements A, B and C, connected as shown in Fig. 6.1.

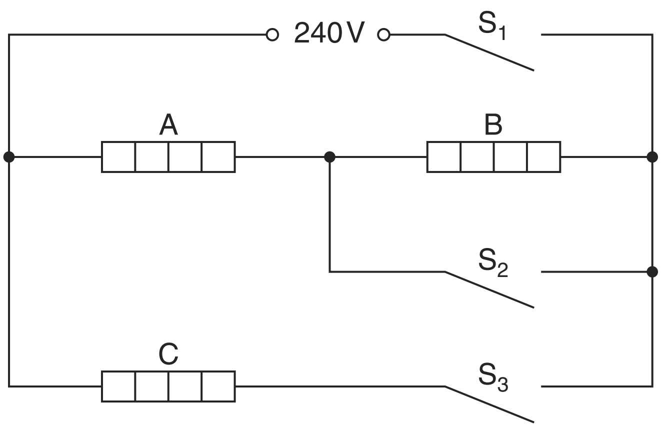


Fig. 6.1

Each heating element is rated as 1.5 kW, 240 V and may be assumed to have constant resistance.
The circuit is connected to a 240 V supply.

(a) Calculate the resistance of one heating element.

resistance = ……………….……….. Ω [2]

(b) The switches S_1, S_2 and S_3 may be either open or closed.

Complete Fig. 6.2 to show the total power dissipation of the heater for the switches in the positions indicated.

S_1	S_2	S_3	total power / kW
open	closed	closed	....
closed	closed	open	....
closed	closed	closed	....
closed	open	open	....
closed	open	closed	....

[5]

Fig. 6.2

For Examiner's Use

8 A network of resistors, each of resistance *R*, is shown in Fig. 7.1.

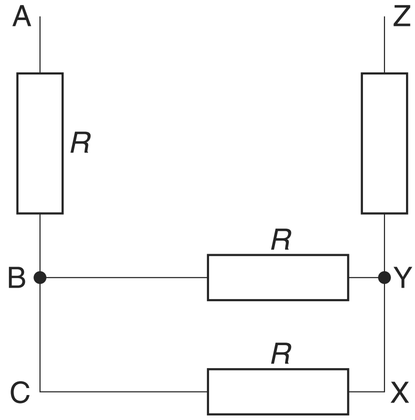


Fig. 7.1

(a) Calculate the total resistance, in terms of *R*, between points

(i) A and C,

resistance = ... [1]

(ii) B and X,

resistance = ... [1]

(iii) A and Z.

resistance = ... [1]

(b) Two cells of e.m.f. E_1 and E_2 and negligible internal resistance are connected into the network in **(a)**, as shown in Fig. 7.2.

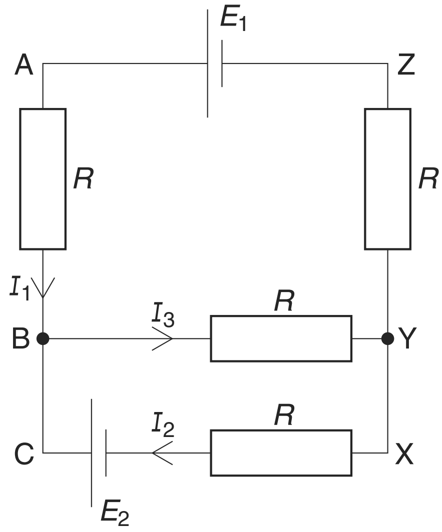


Fig. 7.2

The currents in the network are as indicated in Fig. 7.2.

Use Kirchhoff's laws to state the relation

(i) between currents I_1, I_2 and I_3,

.... [1]

(ii) between E_2, R, I_2 and I_3 in loop BCXYB,

.... [1]

(iii) between E_1, E_2, R, I_1 and I_2 in loop ABCXYZA.

.... [1]

9 **(a)** A student has been asked to make an electric heater. The heater is to be rated as 12 V 60 W, and is to be constructed of wire of diameter 0.54 mm. The material of the wire has resistivity $4.9 \times 10^{-7}\,\Omega\,\text{m}$.

(i) Show that the resistance of the heater will be 2.4 Ω.

[2]

(ii) Calculate the length of wire required for the heater.

length = ... m [3]

(b) Two cells of e.m.f. E_1 and E_2 are connected to resistors of resistance R_1, R_2 and R_3 as shown in Fig. 7.1.

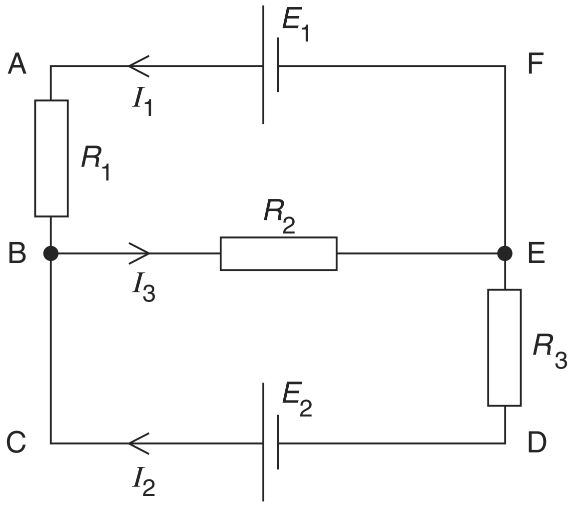


Fig. 7.1

The currents I_1, I_2 and I_3 in the various parts of the circuit are as shown.

(i) Write down an expression relating I_1, I_2 and I_3.

....[1]

(ii) Use Kirchhoff's second law to write down a relation between

1. E_1, R_1, R_2, I_1 and I_3 for loop ABEFA,

....

2. E_1, E_2, R_1, R_3, I_1 and I_2 for loop ABCDEFA.

....
[2]

10 A student set up the circuit shown in Fig. 7.1.

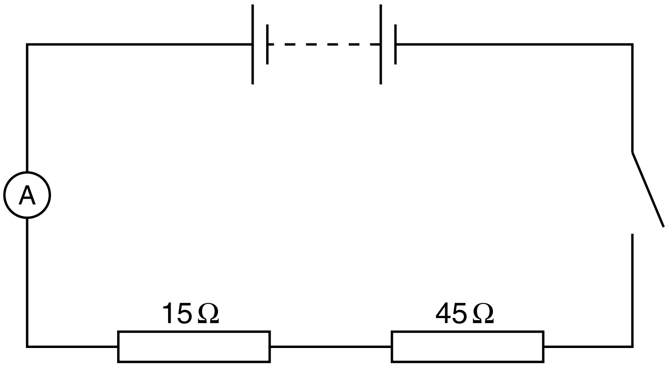


Fig. 7.1

The resistors are of resistance 15 Ω and 45 Ω. The battery is found to provide 1.6×10^5 J of electrical energy when a charge of 1.8×10^4 C passes through the ammeter in a time of 1.3×10^5 s.

(a) Determine

(i) the electromotive force (e.m.f.) of the battery,

e.m.f. = ... V

(ii) the average current in the circuit.

current = ... A
[4]

(b) During the time for which the charge is moving, 1.1×10^5 J of energy is dissipated in the 45 Ω resistor.

(i) Determine the energy dissipated in the 15 Ω resistor during the same time.

energy = ... J

(ii) Suggest why the total energy provided is greater than that dissipated in the two resistors.

....

....

[4]

For Examiner's Use

11 Fig. 6.1 shows the variation with applied potential difference V of the current I in an electrical component C.

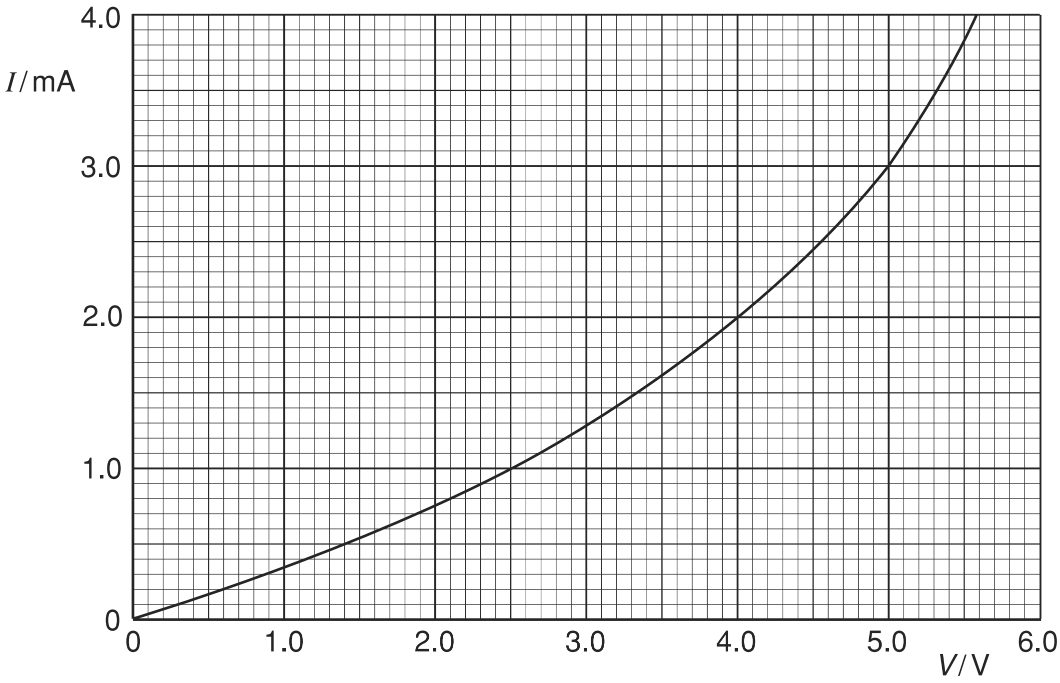


Fig. 6.1

(a) (i) State, with a reason, whether the resistance of component C increases or decreases with increasing potential difference.

....

.... [2]

(ii) Determine the resistance of component C at a potential difference of 4.0 V.

resistance = …………………….. Ω [2]

(b) Component C is connected in parallel with a resistor R of resistance 1500 Ω and a battery of e.m.f. E and negligible internal resistance, as shown in Fig. 6.2.

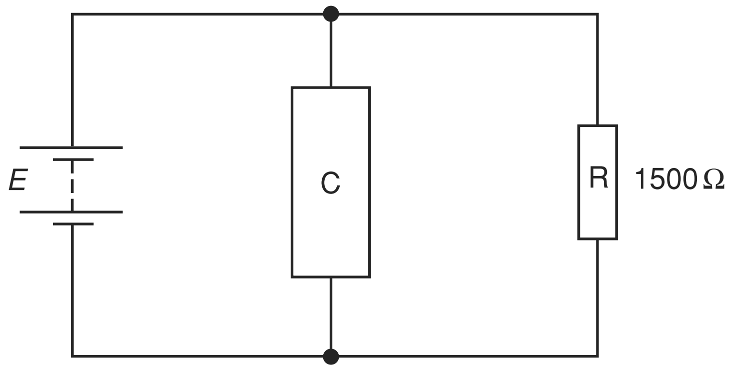


Fig. 6.2

(i) On Fig. 6.1, draw a line to show the variation with potential difference V of the current I in resistor R. [2]

(ii) Hence, or otherwise, use Fig. 6.1 to determine the current in the battery for an e.m.f. of 2.0 V.

current = ... A [2]

(c) The resistor R of resistance 1500 Ω and the component C are now connected in series across a supply of e.m.f. 7.0 V and negligible internal resistance.

Using information from Fig. 6.1, state and explain which component, R or C, will dissipate thermal energy at a greater rate.

....

....

....

.... [3]

12 A battery of e.m.f. 4.50 V and negligible internal resistance is connected in series with a fixed resistor of resistance 1200 Ω and a thermistor, as shown in Fig. 7.1.

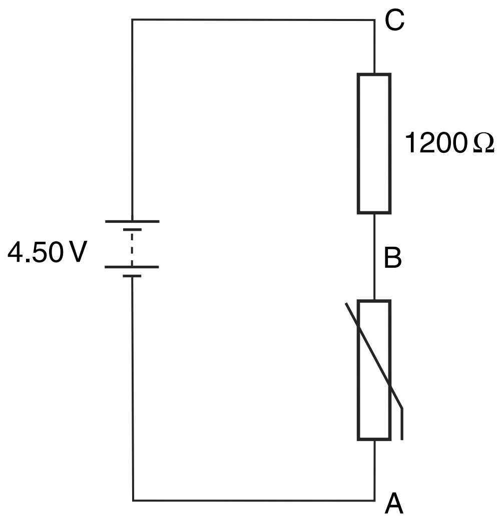


Fig. 7.1

(a) At room temperature, the thermistor has a resistance of 1800 Ω. Deduce that the potential difference across the thermistor (across AB) is 2.70 V.

[2]

(b) A uniform resistance wire PQ of length 1.00 m is now connected in parallel with the resistor and the thermistor, as shown in Fig. 7.2.

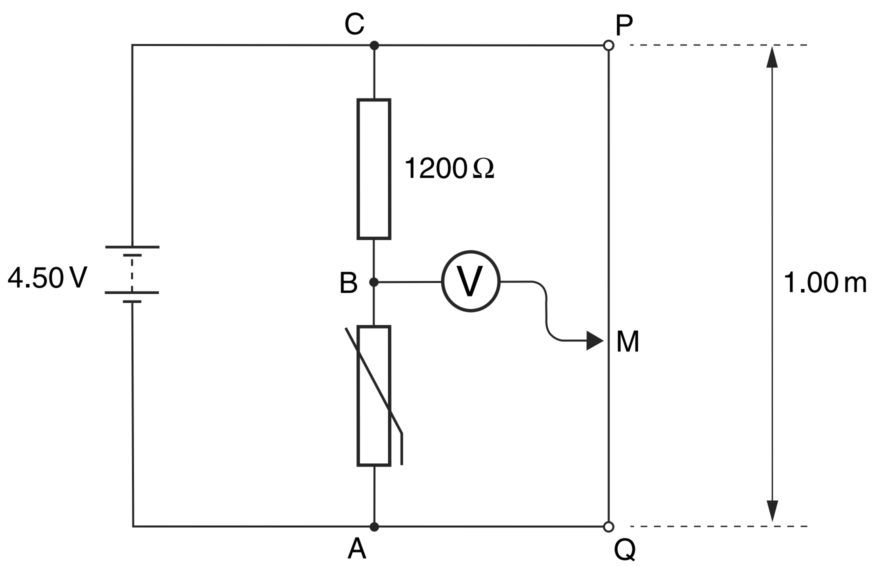


Fig. 7.2

A sensitive voltmeter is connected between point B and a moveable contact M on the wire.

For Examiner's Use

(i) Explain why, for constant current in the wire, the potential difference between any two points on the wire is proportional to the distance between the points.

....

....

....[2]

(ii) The contact M is moved along PQ until the voltmeter shows zero reading.

1. State the potential difference between the contact at M and the point Q.

potential difference = ………………………….. V [1]

2. Calculate the length of wire between M and Q.

length = ………………………….. cm [2]

(iii) The thermistor is warmed slightly. State and explain the effect on the length of wire between M and Q for the voltmeter to remain at zero deflection.

....

....

....[2]

13 **(a)** Distinguish between the electromotive force (e.m.f.) of a cell and the potential difference (p.d.) across a resistor.

....

....

....

.... [3]

(b) Fig. 7.1. is an electrical circuit containing two cells of e.m.f. E_1 and E_2.

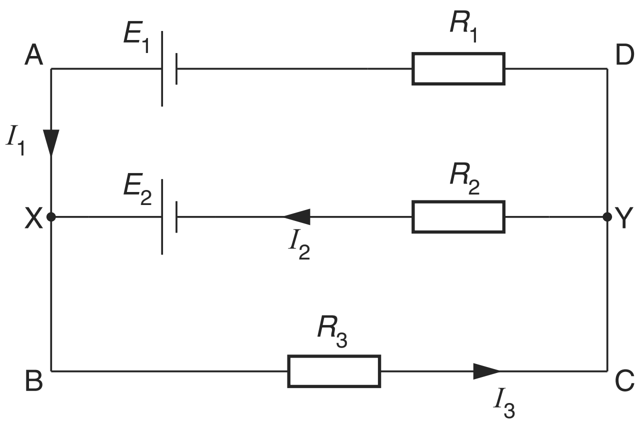


Fig. 7.1

The cells are connected to resistors of resistance R_1, R_2 and R_3 and the currents in the branches of the circuit are I_1, I_2 and I_3, as shown.

(i) Use Kirchhoff's first law to write down an expression relating I_1, I_2 and I_3.

.... [1]

(ii) Use Kirchhoff's second law to write down an expression relating

1. E_2, R_2, R_3, I_2 and I_3 in the loop XBCYX,

.... [1]

2. E_1, E_2, R_1, R_2, I_1 and I_2 in the loop AXYDA.

.... [1]

For Examiner's Use

14 An electric shower unit is to be fitted in a house. The shower is rated as 10.5 kW, 230 V. The shower unit is connected to the 230 V mains supply by a cable of length 16 m, as shown in Fig. 6.1.

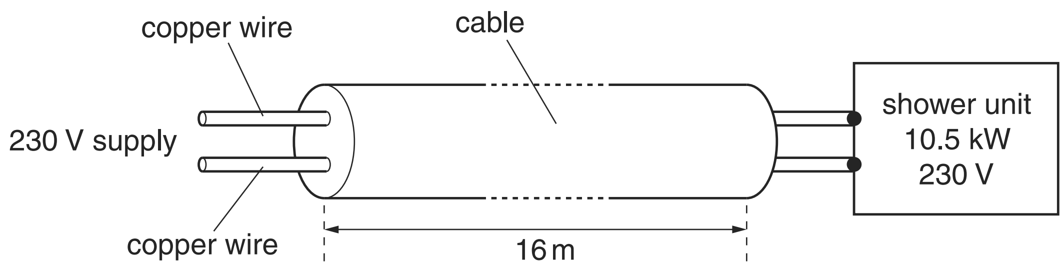


Fig. 6.1

(a) Show that, for normal operation of the shower unit, the current is approximately 46 A.

[2]

(b) The resistance of the two wires in the cable causes the potential difference across the shower unit to be reduced. The potential difference across the shower unit must not be less than 225 V.
The wires in the cable are made of copper of resistivity $1.8 \times 10^{-8}\,\Omega\,\text{m}$.
Assuming that the current in the wires is 46 A, calculate

(i) the maximum resistance of the cable,

resistance = ... Ω [3]

(ii) the minimum area of cross-section of each wire in the cable.

area = ... m^2 [3]

(c) Connecting the shower unit to the mains supply by means of a cable having wires with too small a cross-sectional area would significantly reduce the power output of the shower unit.

(i) Assuming that the shower is operating at 210 V, rather than 230 V, and that its resistance is unchanged, determine the ratio

$$\frac{\text{power dissipated by shower unit at 210 V}}{\text{power dissipated by shower unit at 230 V}}.$$

ratio = ... [2]

(ii) Suggest and explain one further disadvantage of using wires of small cross-sectional area in the cable.

....

....

.... [2]

For Examiner's Use

15 A potential divider circuit consists of two resistors of resistances P and Q, as shown in Fig. 7.1.

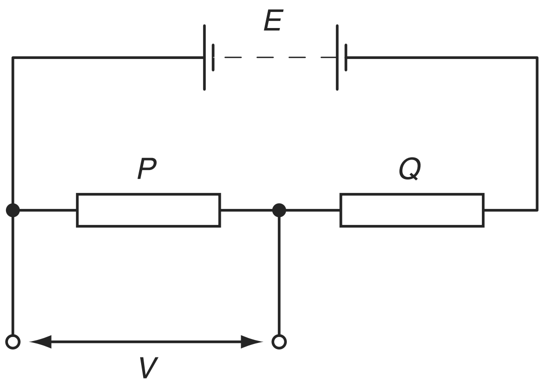


Fig. 7.1

The battery has e.m.f. E and negligible internal resistance.

(a) Deduce that the potential difference V across the resistor of resistance P is given by the expression

$$V = \frac{P}{P + Q} E.$$

[2]

For Examiner's Use

(b) The resistances *P* and *Q* are 2000 Ω and 5000 Ω respectively.
A voltmeter is connected in parallel with the 2000 Ω resistor and a thermistor is connected in parallel with the 5000 Ω resistor, as shown in Fig. 7.2.

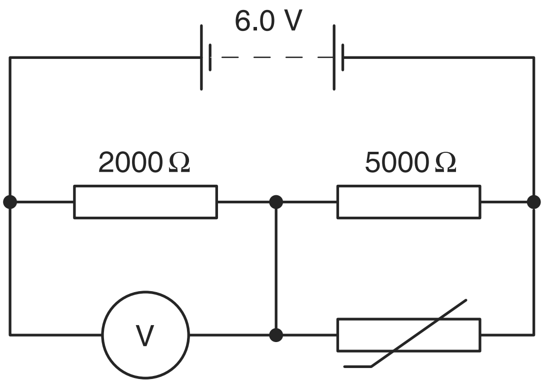


Fig. 7.2

The battery has e.m.f. 6.0 V. The voltmeter has infinite resistance.

(i) State and explain qualitatively the change in the reading of the voltmeter as the temperature of the thermistor is raised.

....

....

....

.... [3]

(ii) The voltmeter reads 3.6 V when the temperature of the thermistor is 19 °C.
Calculate the resistance of the thermistor at 19 °C.

resistance = ... Ω [4]

For Examiner's Use

16 A cell has electromotive force (e.m.f.) E and internal resistance r. It is connected in series with a variable resistor R, as shown in Fig. 6.1.

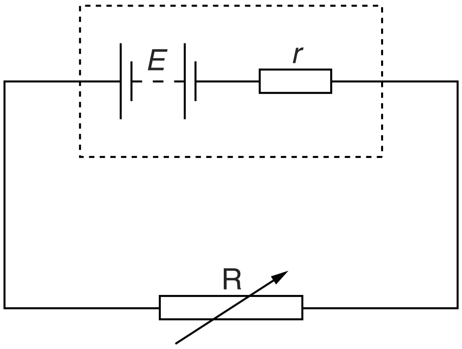


Fig. 6.1

(a) Define electromotive force (e.m.f.).

....

....

.... [2]

(b) The variable resistor R has resistance X. Show that

$$\frac{\text{power dissipated in resistor R}}{\text{power produced in cell}} = \frac{X}{X + r}.$$

[3]

For Examiner's Use

(c) The variation with resistance X of the power P_R dissipated in R is shown in Fig. 6.2.

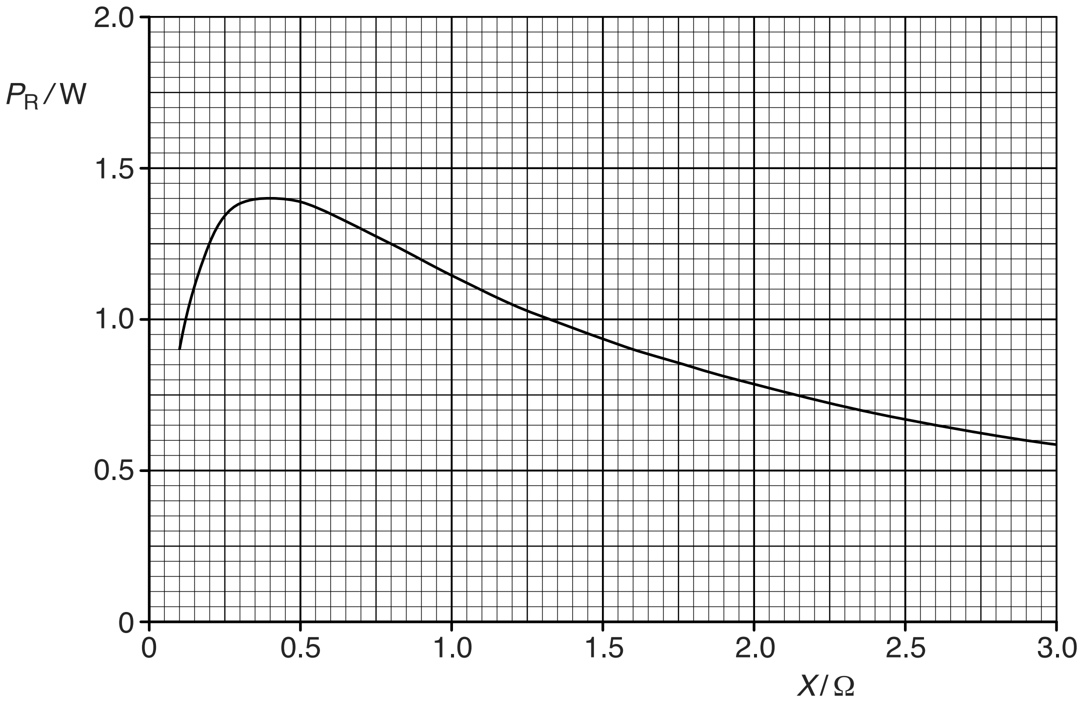


Fig. 6.2

(i) Use Fig. 6.2 to state, for maximum power dissipation in resistor R, the magnitude of this power and the resistance of R.

maximum power = ... W

resistance = ... Ω [2]

(ii) The cell has e.m.f. 1.5V.
Use your answers in **(i)** to calculate the internal resistance of the cell.

internal resistance = ... Ω [3]

(d) In Fig. 6.2, it can be seen that, for larger values of X, the power dissipation decreases. Use the relationship in **(b)** to suggest one advantage, despite the lower power output, of using the cell in a circuit where the resistance X is larger than the internal resistance of the cell.

....

.... [1]

17 **(a)** Two resistors, each of resistance *R*, are connected first in series and then in parallel.

Show that the ratio

$$\frac{\text{combined resistance of resistors connected in series}}{\text{combined resistance of resistors connected in parallel}}$$

is equal to 4.

[1]

(b) The variation with potential difference *V* of the current *I* in a lamp is shown in Fig. 6.1.

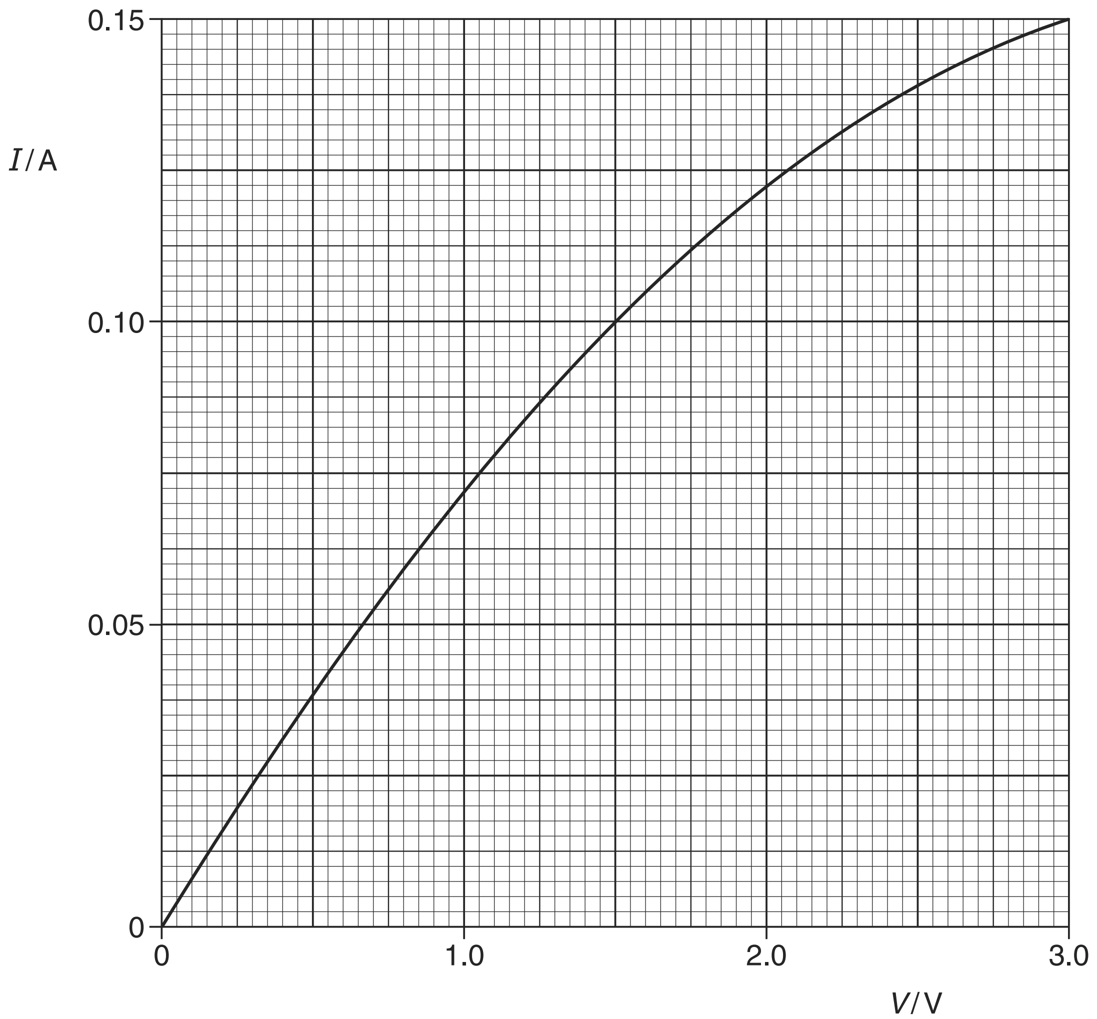


Fig. 6.1

Calculate the resistance of the lamp for a potential difference across the lamp of 1.5 V.

For Examiner's Use

resistance = ... Ω [2]

(c) Two lamps, each having the *I*-*V* characteristic shown in Fig. 6.1, are connected first in series and then in parallel with a battery of e.m.f. 3.0 V and negligible internal resistance.

Complete the table of Fig. 6.2 for the lamps connected to the battery.

	p.d. across each lamp / V	resistance of each lamp / Ω	combined resistance of lamps / Ω
lamps connected in series	....	....	....
lamps connected in parallel	....	....	....

Fig. 6.2

[4]

(d) **(i)** Use data from the completed Fig. 6.2 to calculate the ratio

$$\frac{\text{combined resistance of lamps connected in series}}{\text{combined resistance of lamps connected in parallel}}.$$

ratio = ... [1]

(ii) The ratios in **(a)** and **(d)(i)** are not equal.

By reference to Fig. 6.1, state and explain qualitatively the change in the resistance of a lamp as the potential difference is changed.

....

....

....

.... [3]

For Examiner's Use

18 **(a)** A network of resistors, each of resistance *R*, is shown in Fig. 7.1.

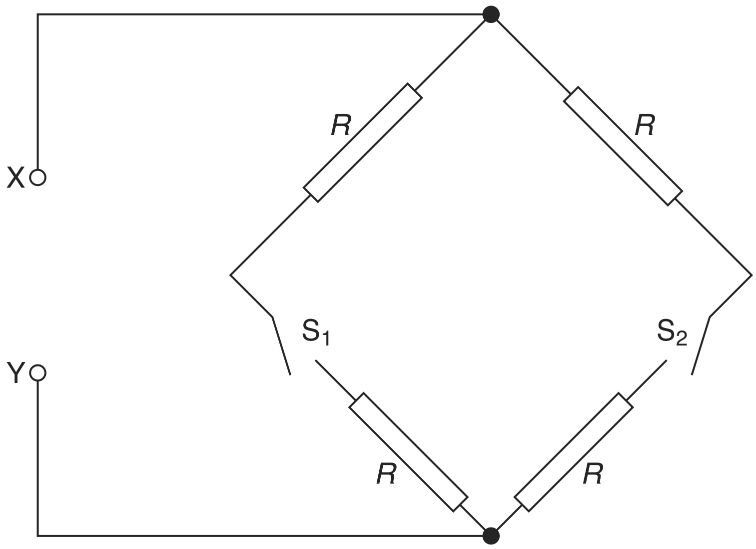


Fig. 7.1

Switches S_1 and S_2 may be 'open' or 'closed'.

Complete Fig. 7.2 by calculating the resistance, in terms of *R*, between points X and Y for the switches in the positions shown.

switch S_1	switch S_2	resistance between points X and Y
open	open	....
open	closed	....
closed	closed	....

Fig. 7.2

[3]

For Examiner's Use

(b) Two cells of e.m.f. E_1 and E_2 and negligible internal resistance are connected into a network of resistors, as shown in Fig. 7.3.

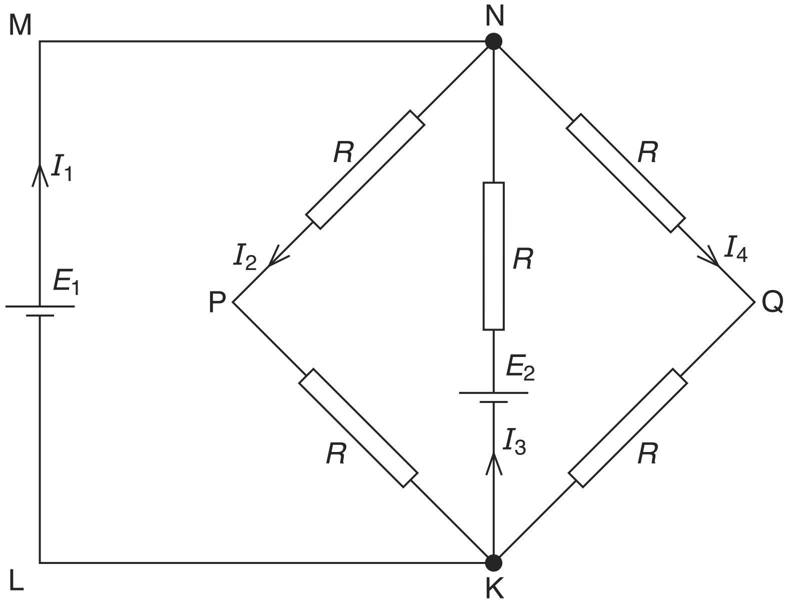


Fig. 7.3

The currents in the network are as indicated in Fig. 7.3.

Use Kirchhoff's laws to state the relation

(i) between currents I_1, I_2, I_3 and I_4,

.... [1]

(ii) between E_1, E_2, R, and I_3 in loop NKLMN,

.... [1]

(iii) between E_2, R, I_3 and I_4 in loop NKQN.

.... [1]

For Examiner's Use

6 An electric heater is to be made from nichrome wire. Nichrome has a resistivity of $1.0 \times 10^{-6}\,\Omega\,m$ at the operating temperature of the heater.
The heater is to have a power dissipation of 60 W when the potential difference across its terminals is 12 V.

(a) For the heater operating at its designed power,

(i) calculate the current,

current = ... A [2]

(ii) show that the resistance of the nichrome wire is 2.4 Ω.

[2]

(b) Calculate the length of nichrome wire of diameter 0.80 mm required for the heater.

length = ... m [3]

For Examiner's Use

(c) A second heater, also designed to operate from a 12 V supply, is constructed using the same nichrome wire but using half the length of that calculated in **(b)**.
Explain quantitatively the effect of this change in length of wire on the power of the heater.

....

....

....

....[3]

For Examiner's Use

6 **(a)** A metal wire of constant resistance is used in an electric heater.
In order not to overload the circuit for the heater, the supply voltage to the heater is reduced from 230V to 220V.

Determine the percentage reduction in the power output of the heater.

reduction = ... % [2]

(b) A uniform wire AB of length 100cm is connected between the terminals of a cell of e.m.f. 1.5V and negligible internal resistance, as shown in Fig. 6.1.

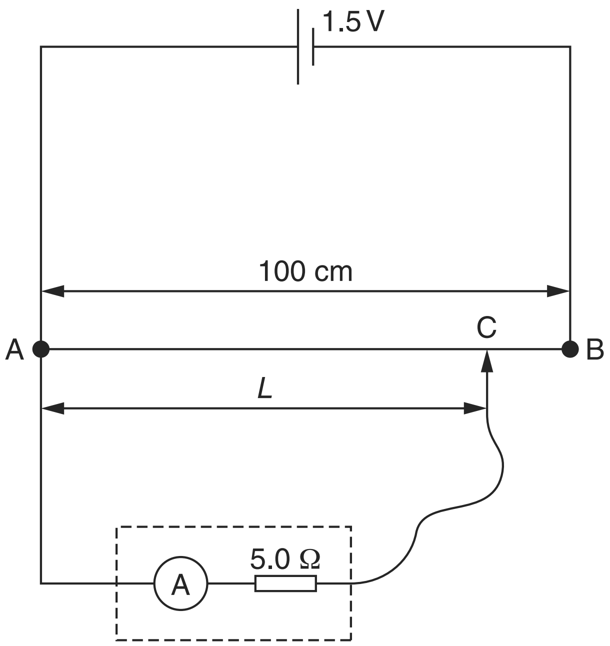


Fig. 6.1

An ammeter of internal resistance 5.0Ω is connected to end A of the wire and to a contact C that can be moved along the wire.

Determine the reading on the ammeter for the contact C placed

(i) at A,

reading = ... A [1]

For Examiner's Use

(ii) at B.

reading = ... A [1]

(c) Using the circuit in **(b)**, the ammeter reading *I* is recorded for different distances *L* of the contact C from end A of the wire. Some data points are shown on Fig. 6.2.

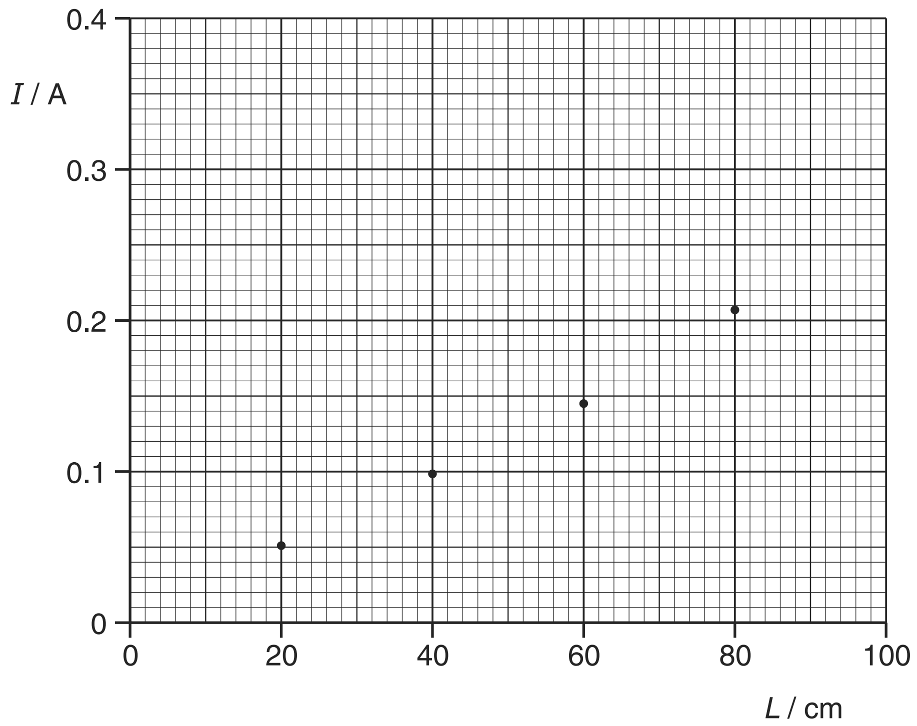


Fig. 6.2

(i) Use your answers in **(b)** to plot data points on Fig. 6.2 corresponding to the contact C placed at end A and at end B of the wire. [1]

(ii) Draw a line of best fit for all of the data points and hence determine the ammeter reading for contact C placed at the midpoint of the wire.

reading = ... A [1]

For Examiner's Use

(iii) Use your answer in **(ii)** to calculate the potential difference between A and the contact C for the contact placed at the midpoint of AB.

potential difference = ... V [2]

(d) Explain why, although the contact C is at the midpoint of wire AB, the answer in **(c)(iii)** is **not** numerically equal to one half of the e.m.f. of the cell.

....

....

....[2]

6 **(a)** **(i)** State what is meant by an *electric current*.

....

....[1]

(ii) Define *electric potential difference*.

....

....[1]

(b) The variation with potential difference V of the current I in a component Y and in a resistor R are shown in Fig. 6.1.

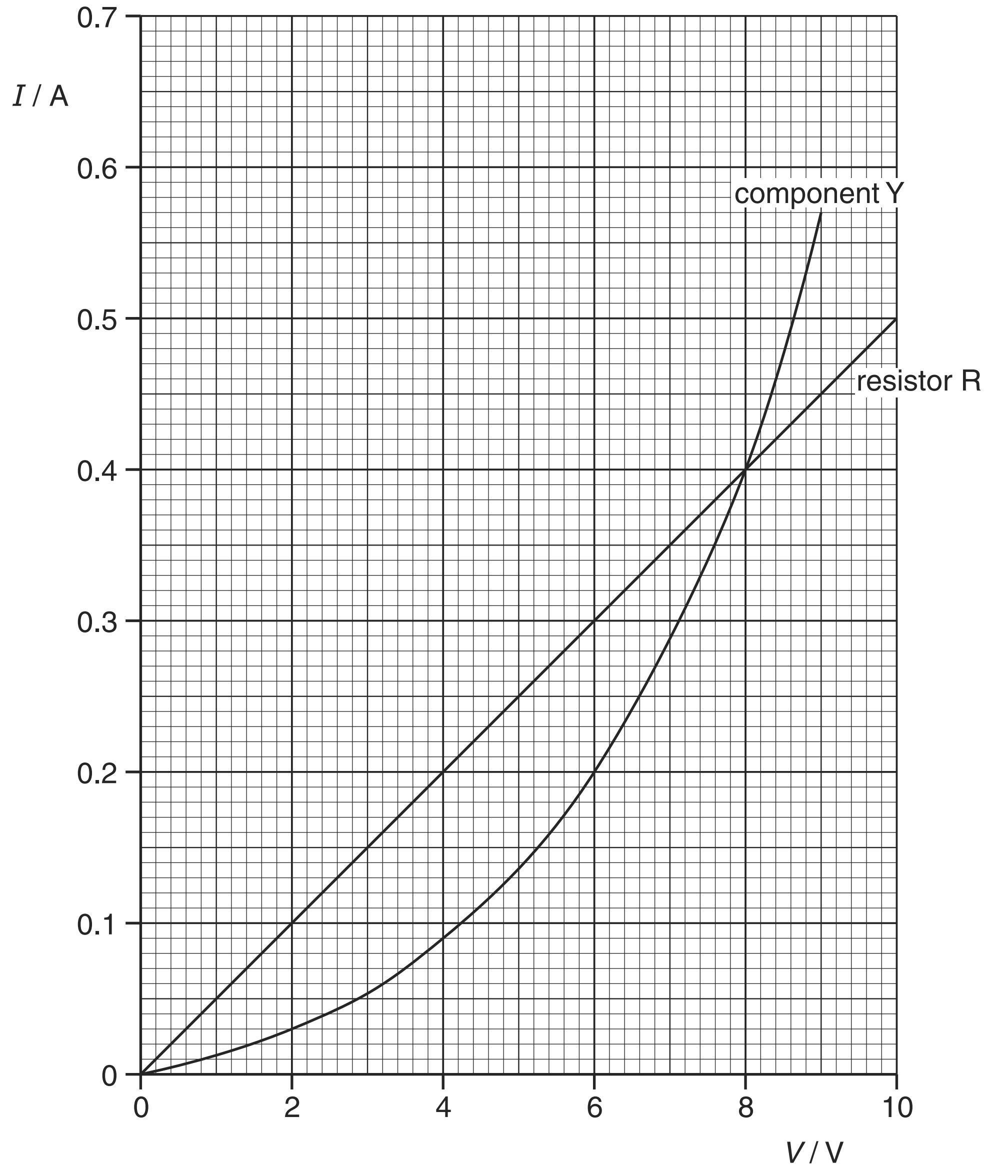


Fig. 6.1

For Examiner's Use

Use Fig. 6.1 to explain how it can be deduced that resistor R has a constant resistance of 20 Ω.

....

....

....[2]

(c) The component Y and the resistor R in **(b)** are connected in parallel as shown in Fig. 6.2.

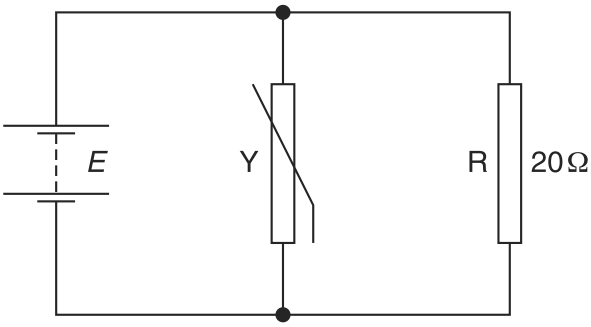


Fig. 6.2

A battery of e.m.f. *E* and negligible internal resistance is connected across the parallel combination.

Use data from Fig. 6.1 to determine

(i) the current in the battery for an e.m.f. *E* of 6.0 V,

current = ...A [1]

(ii) the total resistance of the circuit for an e.m.f. of 8.0 V.

resistance = ... Ω [2]

For Examiner's Use

(d) The circuit of Fig. 6.2 is now re-arranged as shown in Fig. 6.3.

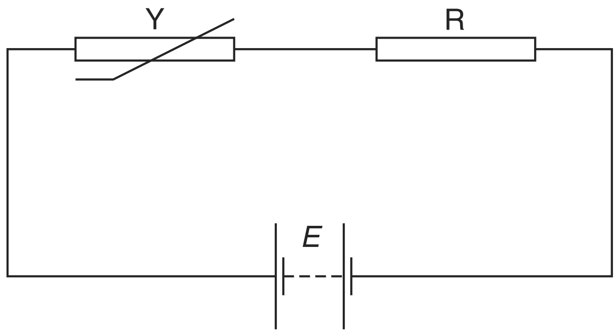


Fig. 6.3

The current in the circuit is 0.20 A.

(i) Use Fig. 6.1 to determine the e.m.f. E of the battery.

E = ...V [1]

(ii) Calculate the total power dissipated in component Y and resistor R.

power = ...W [2]

For Examiner's Use

6 **(a)** A lamp is rated as 12 V, 36 W.

(i) Calculate the resistance of the lamp at its working temperature.

resistance = ... Ω [2]

(ii) On the axes of Fig. 6.1, sketch a graph to show the current-voltage (I–V) characteristic of the lamp. Mark an appropriate scale for current on the y-axis.

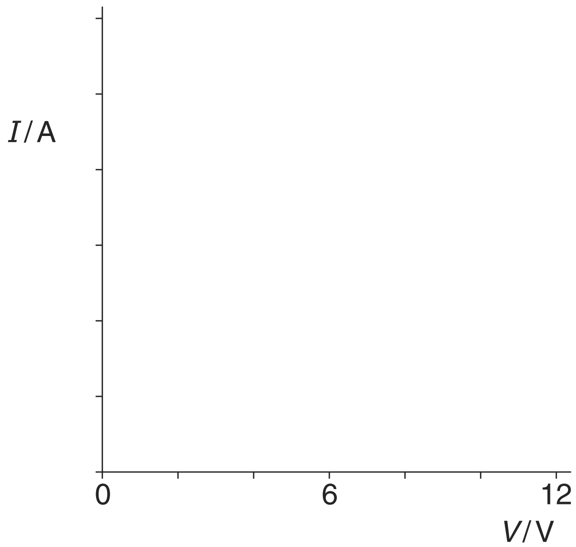


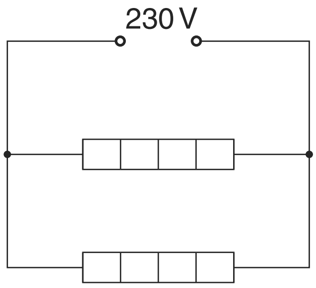
Fig. 6.1

[3]

(b) Some heaters are each labelled 230 V, 1.0 kW. The heaters have constant resistance.

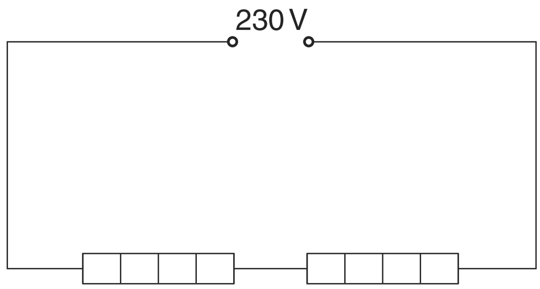
Determine the total power dissipation for the heaters connected as shown in each of the diagrams shown below.

(i)



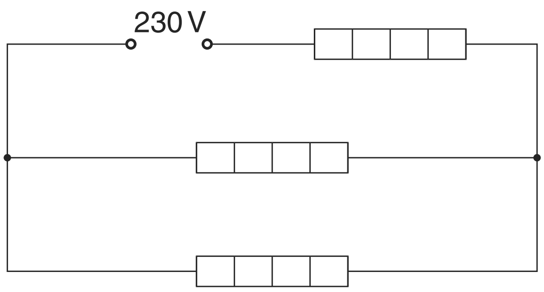
power = ... kW [1]

(ii)



power = ... kW [1]

(iii)



power = ... kW [2]

For Examiner's Use

6 The variation with temperature of the resistance R_T of a thermistor is shown in Fig. 6.1.

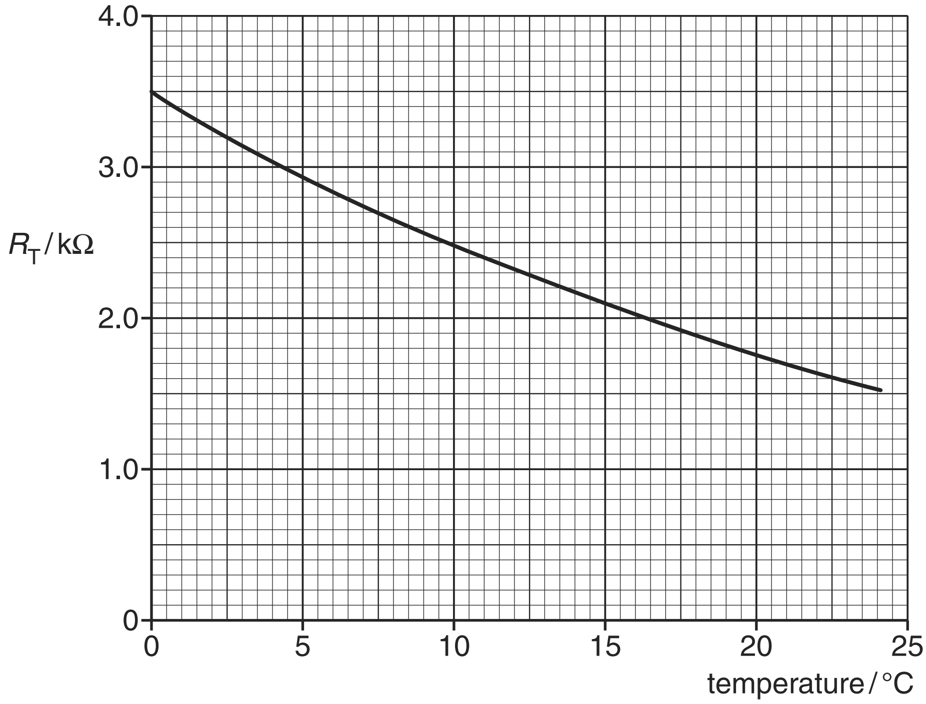


Fig. 6.1

The thermistor is connected into the circuit of Fig. 6.2.

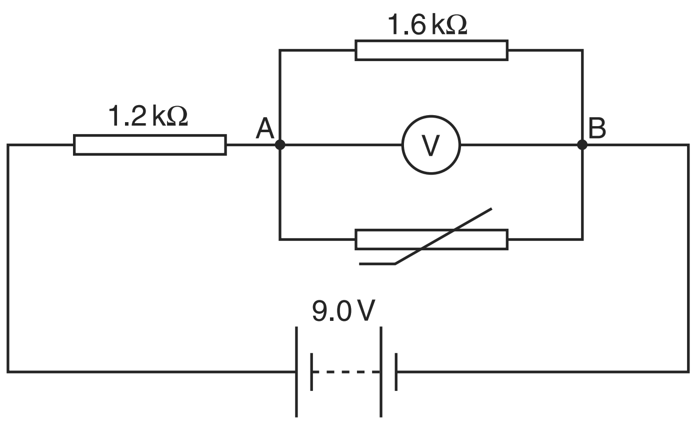


Fig. 6.2

The battery has e.m.f. 9.0V and negligible internal resistance. The voltmeter has infinite resistance.

For Examiner's Use

(a) For the thermistor at 22.5 °C, calculate

(i) the total resistance between points A and B on Fig. 6.2,

resistance = ... Ω [2]

(ii) the reading on the voltmeter.

voltmeter reading = ...V [2]

(b) The temperature of the thermistor is changed. The voltmeter now reads 4.0V. Determine

(i) the total resistance between points A and B on Fig. 6.2,

resistance = ... Ω [2]

(ii) the temperature of the thermistor.

temperature = ... °C [2]

(c) A student suggests that the voltmeter, reading up to 10 V, could be calibrated to measure temperature.

Suggest two disadvantages of using the circuit of Fig. 6.2 with this voltmeter for the measurement of temperature in the range 0 °C to 25 °C.

1. ....

....

2. ....

....
[2]

8 An electric heater has a constant resistance and is rated as 1.20 kW, 230 V.

The heater is connected to a 230 V supply by means of a cable that is 9.20 m long, as illustrated in Fig. 8.1.

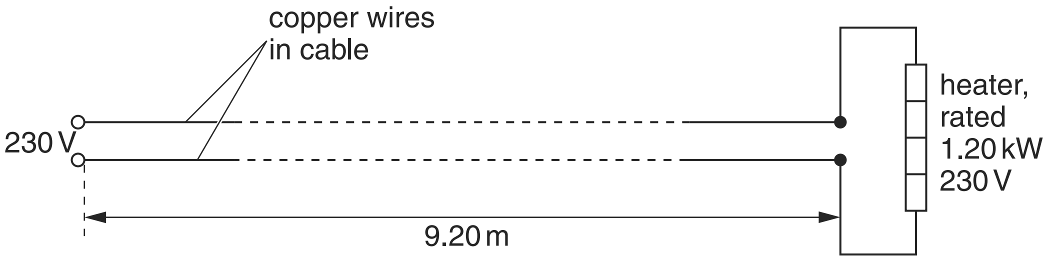


Fig. 8.1

The two copper wires that make up the cable each have a circular cross-section of diameter 0.900 mm. The resistivity of copper is $1.70 \times 10^{-8}\,\Omega\,m$.

(a) Show that

(i) the resistance of the heater is 44.1 Ω,

[2]

(ii) the total resistance of the cable is 0.492 Ω.

[2]

For Examiner's Use

(b) The current in the cable and heater is switched on. Determine, to three significant figures, the power dissipated in the heater.

power = ... W [3]

(c) Suggest two disadvantages of connecting the heater to the 230 V supply using a cable consisting of two thinner copper wires.

1. ....

....

2. ....

....
[2]

For Examiner's Use

5 **(a)** For a cell, explain the terms

(i) *electromotive force* (e.m.f.),

....

.... [1]

(ii) *internal resistance*.

....

.... [1]

(b) The circuit of Fig. 5.1 shows two batteries A and B and a resistor R connected in series.

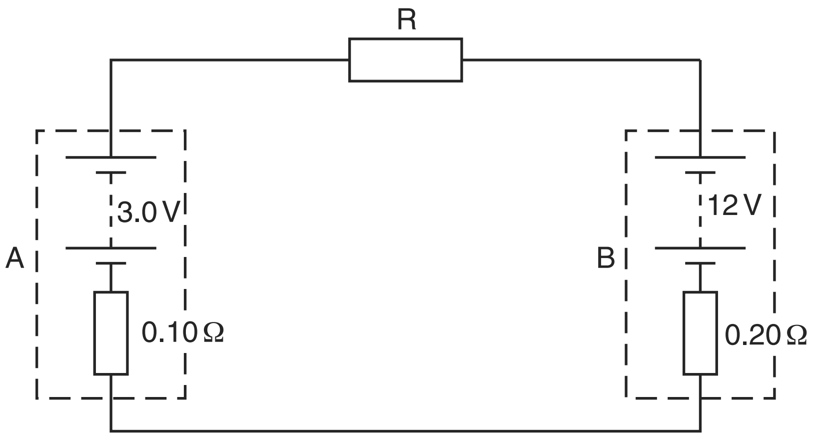


Fig. 5.1

Battery A has an e.m.f. of 3.0 V and an internal resistance of 0.10 Ω. Battery B has an e.m.f. of 12 V and an internal resistance of 0.20 Ω. Resistor R has a resistance of 3.3 Ω.

(i) Apply Kirchhoff's second law to calculate the current in the circuit.

current = ... A [2]

(ii) Calculate the power transformed by battery B.

power = ... W [2]

For Examiner's Use

(iii) Calculate the total energy lost per second in resistor R and the internal resistances.

energy lost per second = ... $J s^{-1}$ [2]

(c) The circuit of Fig. 5.1 may be used to store energy in battery A. Suggest how your answers in **(b)** support this statement.

....

....

.... [1]

For Examiner's Use

5 **(a)** A variable resistor is used to control the current in a circuit, as shown in Fig. 5.1.

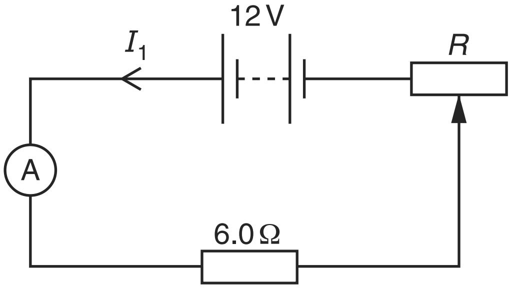


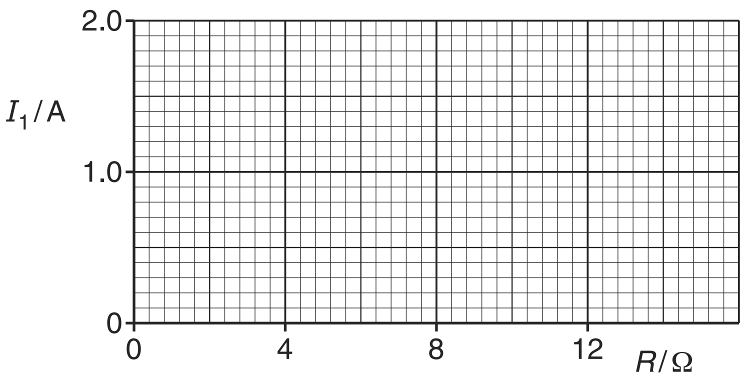
Fig. 5.1

The variable resistor is connected in series with a 12 V power supply of negligible internal resistance, an ammeter and a 6.0 Ω resistor. The resistance R of the variable resistor can be varied between 0 and 12 Ω.

(i) The maximum possible current in the circuit is 2.0 A. Calculate the minimum possible current.

minimum current = ... A [2]

(ii) On Fig. 5.2, sketch the variation with R of current I_1 in the circuit.



[2]

Fig. 5.2

(b) The variable resistor in **(a)** is now connected as a potential divider, as shown in Fig. 5.3.

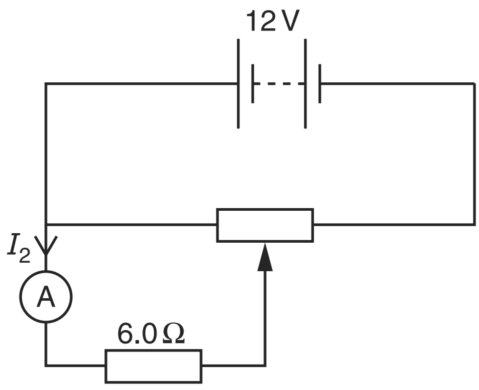


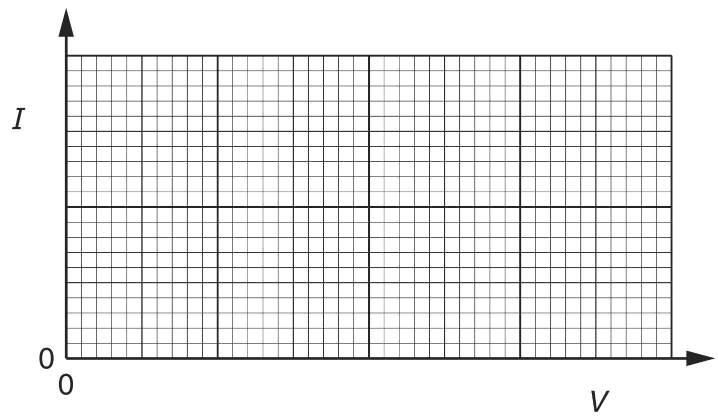
Fig. 5.3

Calculate the maximum possible and minimum possible current I_2 in the ammeter.

maximum I_2 = ... A

minimum I_2 = ... A
[2]

(c) **(i)** Sketch on Fig. 5.4 the I – V characteristic of a filament lamp.



[2]

Fig. 5.4

(ii) The resistor of resistance 6.0 Ω is replaced with a filament lamp in the circuits of Fig. 5.1 and Fig. 5.3. State an advantage of using the circuit of Fig. 5.3, compared to the circuit of Fig 5.1, when using the circuits to vary the brightness of the filament lamp.

....

....

.... [1]

For Examiner's Use

For Examiner's Use

5 **(a)** **(i)** On Fig. 5.1, sketch the I – V characteristic for a filament lamp.

Fig. 5.1

[2]

(ii) Explain how the resistance of the lamp may be calculated for any voltage from its I – V characteristic.

....

.... [1]

(b) Two identical filament lamps are connected first in series, and then in parallel, to a 12 V power supply that has negligible internal resistance. The circuits are shown in Fig. 5.2 and Fig. 5.3 respectively.

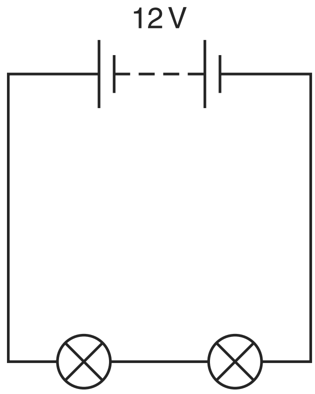


Fig. 5.2

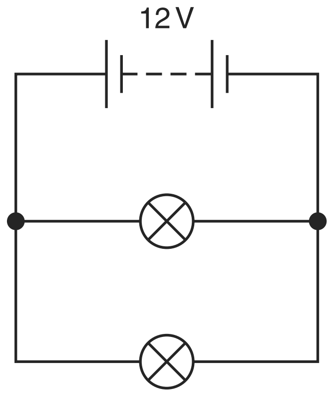


Fig. 5.3

For Examiner's Use

(i) State and explain why the resistance of each lamp when they are connected in series is different from the resistance of each lamp when they are connected in parallel.

....

....

....

....

.... [3]

(ii) Each lamp is marked with a rating '12 V, 50 W'. Calculate the total resistance of the circuit for the two lamps connected such that each lamp uses this power.

total resistance = ... Ω [3]

5 (a) Define the *ohm*.

.... [1]

(b) Determine the SI base units of **resistivity**.

base units of resistivity = ... [3]

(c) A cell of e.m.f. 2.0V and negligible internal resistance is connected to a variable resistor R and a metal wire, as shown in Fig. 5.1.

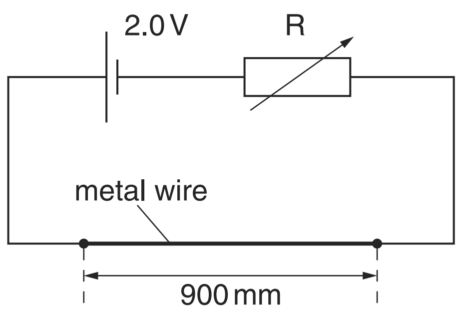


Fig. 5.1

The wire is 900mm long and has an area of cross-section of $1.3 \times 10^{-7}\,\text{m}^2$. The resistance of the wire is 3.4Ω.

(i) Calculate the resistivity of the metal wire.

resistivity = ... [2]

For Examiner's Use

(ii) The resistance of R may be varied between 0 and 1500 Ω.
Calculate the maximum potential difference (p.d.) and minimum p.d. possible across the wire.

maximum p.d. = ... V

minimum p.d. = ...V
[2]

(iii) Calculate the power transformed in the wire when the potential difference across the wire is 2.0 V.

power = ... W [2]

(d) Resistance R in **(c)** is now replaced with a different variable resistor Q. State the power transformed in Q, for Q having

(i) zero resistance,

power = ... W [1]

(ii) infinite resistance.

power = ... W [1]

For Examiner's Use

5 A potentiometer circuit that is used as a means of comparing potential differences is shown in Fig. 5.1.

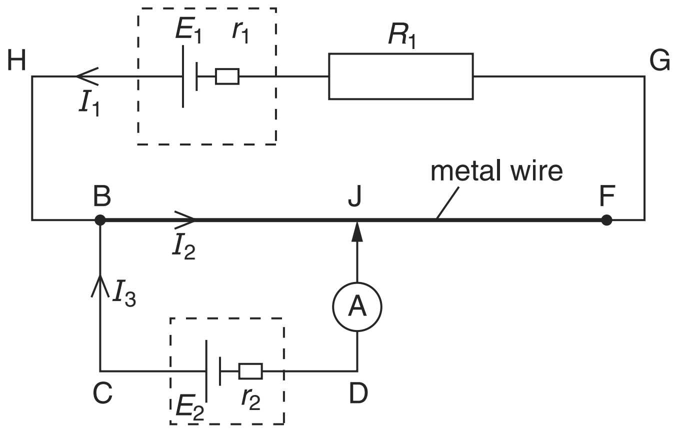


Fig. 5.1

A cell of e.m.f. E_1 and internal resistance r_1 is connected in series with a resistor of resistance R_1 and a uniform metal wire of total resistance R_2.
A second cell of e.m.f. E_2 and internal resistance r_2 is connected in series with a sensitive ammeter and is then connected across the wire at BJ. The connection at J is halfway along the wire. The current directions are shown on Fig. 5.1.

(a) Use Kirchhoff's laws to obtain the relation

(i) between the currents I_1, I_2 and I_3,

.... [1]

(ii) between E_1, R_1, R_2, r_1, I_1 and I_2 in loop HBJFGH,

.... [1]

(iii) between E_1, E_2, r_1, r_2, R_1, R_2, I_1 and I_3 in the loop HBCDJFGH.

.... [2]

(b) The connection at J is moved along the wire. Explain why the reading on the ammeter changes.

....

....

....

.... [2]

For Examiner's Use

4 **(a)** Distinguish between *potential difference* (p.d.) and *electromotive force* (e.m.f.) in terms of energy transformations.

....

....

....

....[2]

(b) Two cells A and B are connected in series with a resistor R of resistance 5.5 Ω, as shown in Fig. 4.1.

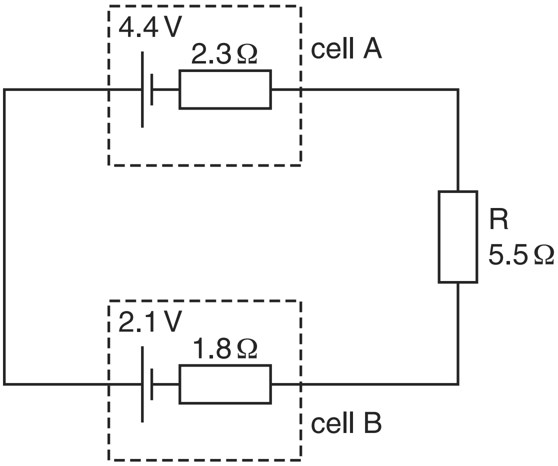


Fig. 4.1

Cell A has e.m.f. 4.4 V and internal resistance 2.3 Ω. Cell B has e.m.f. 2.1 V and internal resistance 1.8 Ω.

(i) State Kirchhoff's second law.

....

....[1]

(ii) Calculate the current in the circuit.

current = ... A [2]

(iii) On Fig. 4.1, draw an arrow to show the direction of the current in the circuit. Label this arrow *I*. [1]

(iv) Calculate

1. the p.d. across resistor R,

p.d. = ... V [1]

2. the terminal p.d. across cell A,

p.d. = ... V [1]

3. the terminal p.d. across cell B.

p.d. = ... V [2]

For Examiner's Use

5 **(a)** **(i)** State Kirchhoff's second law.

....

.... [1]

(ii) Kirchhoff's second law is linked to the conservation of a certain quantity. State this quantity.

.... [1]

(b) The circuit shown in Fig. 5.1 is used to compare potential differences.

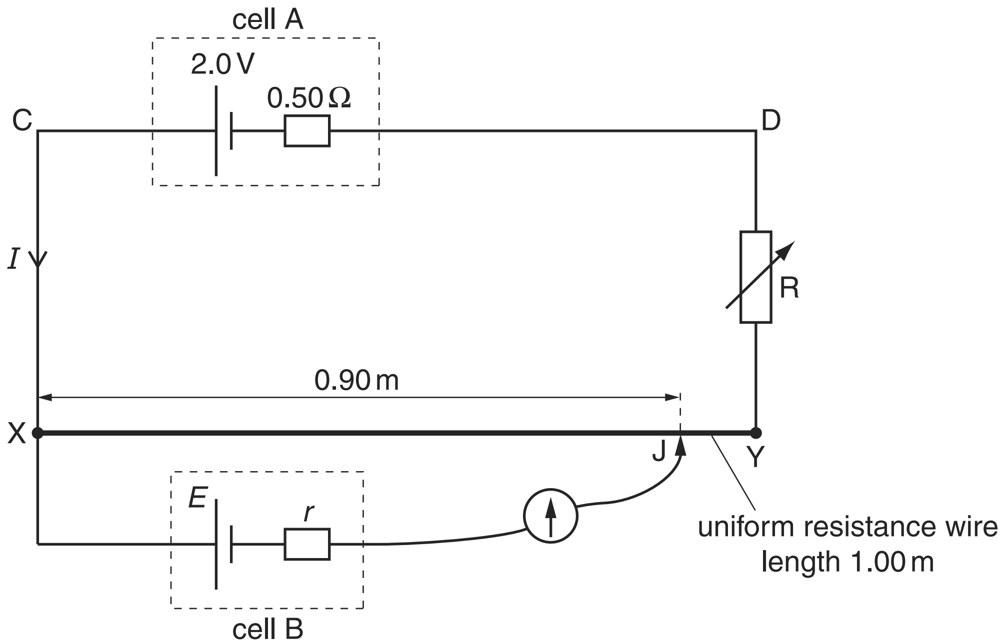


Fig. 5.1

The uniform resistance wire XY has length 1.00 m and resistance 4.0 Ω. Cell A has e.m.f. 2.0 V and internal resistance 0.50 Ω. The current through cell A is *I*. Cell B has e.m.f. *E* and internal resistance *r*.

The current through cell B is made zero when the movable connection J is adjusted so that the length of XJ is 0.90 m. The variable resistor R has resistance 2.5 Ω.

(i) Apply Kirchhoff's second law to the circuit CXYDC to determine the current *I*.

I = ... A [2]

For Examiner's Use

(ii) Calculate the potential difference across the length of wire XJ.

potential difference = ... V [2]

(iii) Use your answer in **(ii)** to state the value of *E*.

E = ... V [1]

(iv) State why the value of the internal resistance of cell B is not required for the determination of *E*.

....

....[1]

For Examiner's Use

4 A battery of electromotive force 12 V and negligible internal resistance is connected to two resistors and a light-dependent resistor (LDR), as shown in Fig. 4.1.

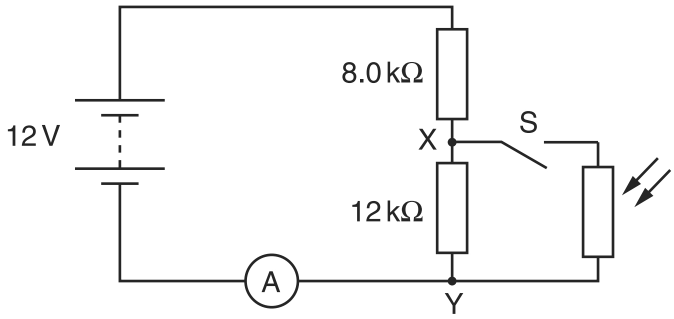


Fig. 4.1

An ammeter is connected in series with the battery. The LDR and switch S are connected across the points XY.

(a) The switch S is open. Calculate the potential difference (p.d.) across XY.

p. d. = ... V [3]

(b) The switch S is closed. The resistance of the LDR is 4.0 kΩ. Calculate the current in the ammeter.

current = ... A [3]

(c) The switch S remains closed. The intensity of the light on the LDR is increased. State and explain the change to

For Examiner's Use

(i) the ammeter reading,

....

....

.... [2]

(ii) the p.d. across XY.

....

....

.... [2]

For Examiner's Use

5 **(a)** **(i)** State Kirchhoff's first law.

....

.... [1]

(ii) Kirchhoff's first law is linked to the conservation of a certain quantity. State this quantity.

.... [1]

(b) A variable resistor of resistance *R* is used to control the current in a circuit, as shown in Fig. 5.1.

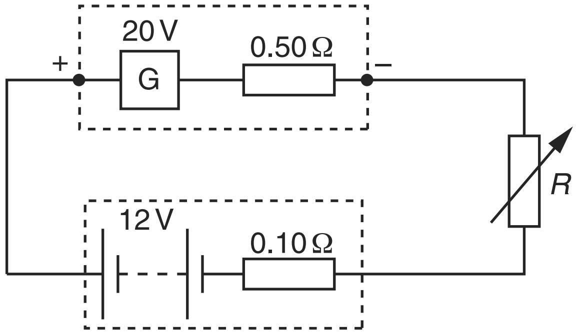


Fig. 5.1

The generator G has e.m.f. 20 V and internal resistance 0.50 Ω. The battery has e.m.f. 12 V and internal resistance 0.10 Ω. The current in the circuit is 2.0 A.

(i) Apply Kirchhoff's second law to the circuit to determine the resistance *R*.

R = ... Ω [2]

(ii) Calculate the total power generated by G.

power = ... W [2]

(iii) Calculate the power loss in the total resistance of the circuit.

power = ... W [2]

(iv) The circuit is used to supply energy to the battery from the generator. Determine the efficiency of the circuit.

efficiency = ... [2]

For Examiner's Use

4 A circuit used to measure the power transfer from a battery is shown in Fig. 4.1. The power is transferred to a variable resistor of resistance *R*.

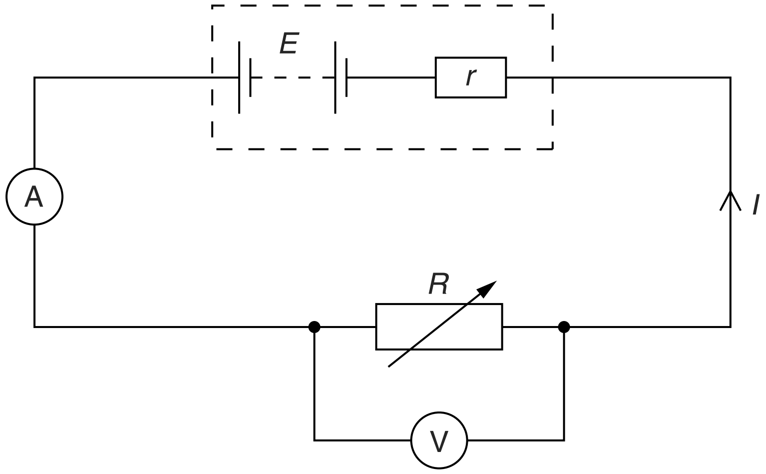


Fig. 4.1

The battery has an electromotive force (e.m.f.) *E* and an internal resistance *r*. There is a potential difference (p.d.) *V* across *R*. The current in the circuit is *I*.

(a) By reference to the circuit shown in Fig. 4.1, distinguish between the definitions of e.m.f. and p.d.

....

....

....

.... [3]

(b) Using Kirchhoff's second law, determine an expression for the current *I* in the circuit.

[1]

For Examiner's Use

(c) The variation with current I of the p.d. V across R is shown in Fig. 4.2.

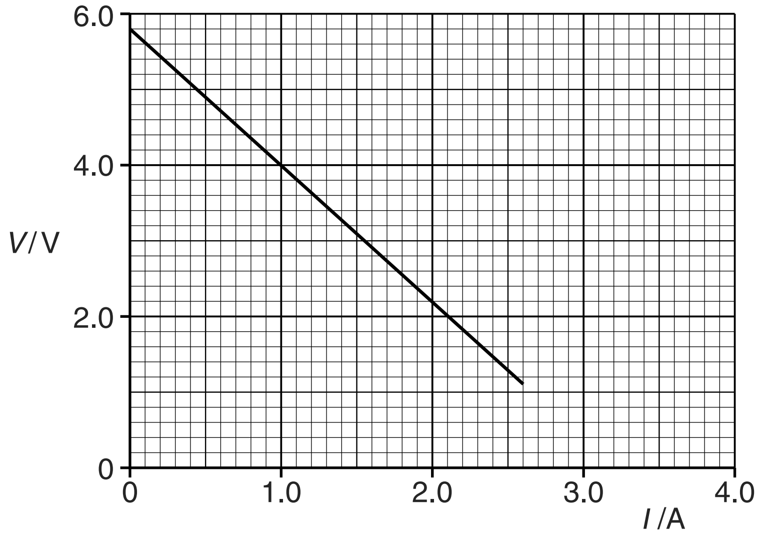


Fig. 4.2

Use Fig. 4.2 to determine

(i) the e.m.f. E,

E = ... V [1]

(ii) the internal resistance r.

r = ... Ω [2]

(d) **(i)** Using data from Fig. 4.2, calculate the power transferred to R for a current of 1.6 A.

power = ... W [2]

(ii) Use your answers from **(c)(i)** and **(d)(i)** to calculate the efficiency of the battery for a current of 1.6 A.

efficiency = ... % [2]

5 Fig. 5.1 shows a 12 V power supply with negligible internal resistance connected to a uniform metal wire AB. The wire has length 1.00 m and resistance 10 Ω. Two resistors of resistance 4.0 Ω and 2.0 Ω are connected in series across the wire.

For Examiner's Use

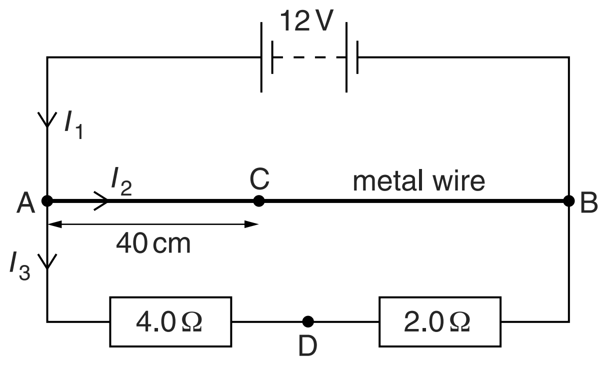


Fig. 5.1

Currents I_1, I_2 and I_3 in the circuit are as shown in Fig. 5.1.

(a) **(i)** Use Kirchhoff's first law to state a relationship between I_1, I_2 and I_3.

.... [1]

(ii) Calculate I_1.

I_1 = ... A [3]

(iii) Calculate the ratio *x*, where

$$x = \frac{\text{power in metal wire}}{\text{power in series resistors}}.$$

x = ... [3]

(b) Calculate the potential difference (p.d.) between the points C and D, as shown in Fig. 5.1. The distance AC is 40 cm and D is the point between the two series resistors.

p.d. = ... V [3]

For Examiner's Use

3 **(a)** With reference to the arrangement of atoms, distinguish between metals, polymers and amorphous solids.

metals: ....

....

polymers: ....

....

amorphous solids: ....

....
[3]

(b) On Fig. 3.1, sketch the variation with extension x of force F to distinguish between a metal and a polymer.

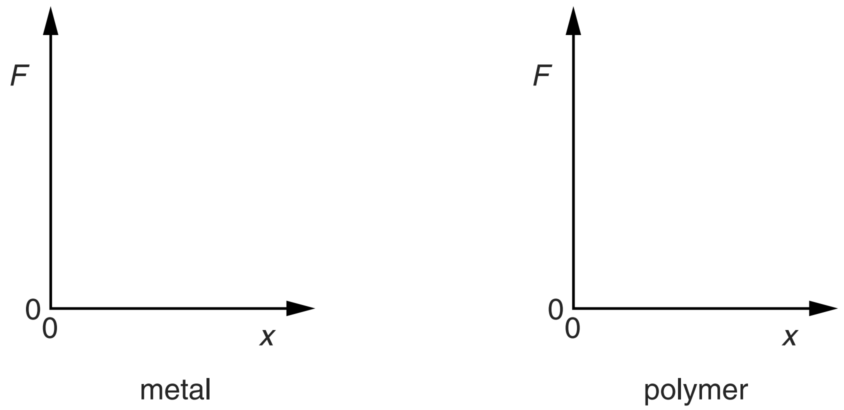


Fig. 3.1

[2]

For Examiner's Use

2 **(a)** Define electrical *resistance*.

....

.... [1]

(b) A circuit is set up to measure the resistance R of a metal wire. The potential difference (p.d.) V across the wire and the current I in the wire are to be measured.

(i) Draw a circuit diagram of the apparatus that could be used to make these measurements.

[3]

(ii) Readings for p.d. V and the corresponding current I are obtained. These are shown in Fig. 2.1.

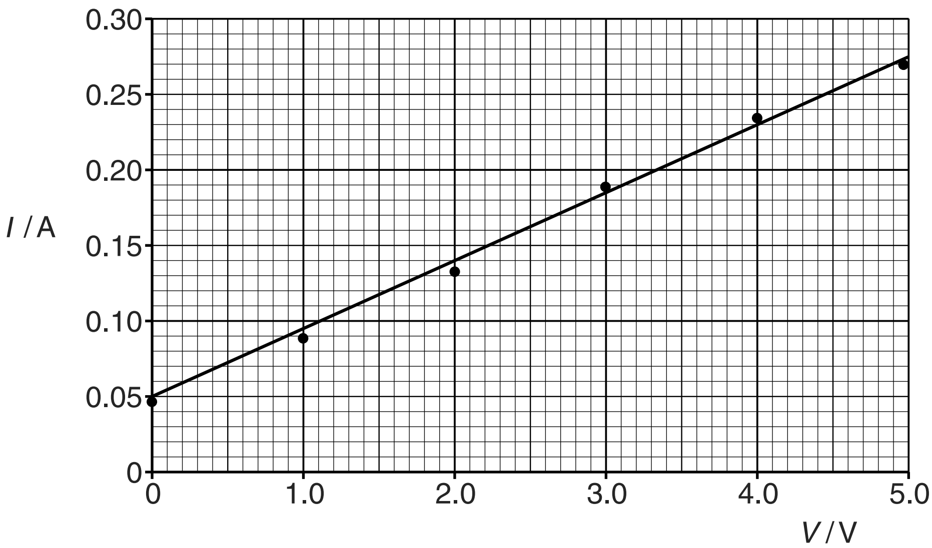


Fig. 2.1

For Examiner's Use

Explain how Fig. 2.1 indicates that the readings are subject to

1. a systematic uncertainty,

....

.... [1]

2. random uncertainties.

....

.... [1]

(iii) Use data from Fig. 2.1 to determine *R*. Explain your working.

R = ... Ω [3]

(c) In another experiment, a value of *R* is determined from the following data:

Current $I = 0.64 \pm 0.01$ A and p.d. $V = 6.8 \pm 0.1$ V.

Calculate the value of *R*, together with its uncertainty. Give your answer to an appropriate number of significant figures.

R = ... ± ....Ω [3]

For Examiner's Use

6 **(a)** Define *potential difference* (p.d.).

.... [1]

(b) A battery of electromotive force 20 V and zero internal resistance is connected in series with two resistors R_1 and R_2, as shown in Fig. 6.1.

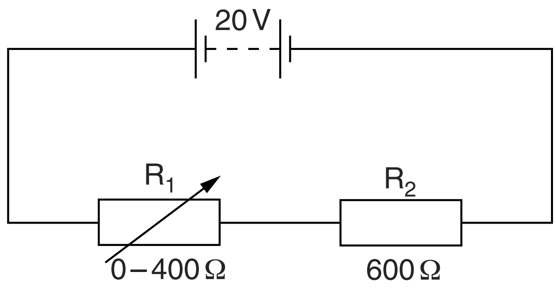


Fig. 6.1

The resistance of R_2 is 600 Ω. The resistance of R_1 is varied from 0 to 400 Ω.

Calculate

(i) the maximum p.d. across R_2,

maximum p.d. = ... V [1]

(ii) the minimum p.d. across R_2.

minimum p.d. = ... V [2]

(c) A light-dependent resistor (LDR) is connected in parallel with R_2, as shown in Fig. 6.2.

For Examiner's Use

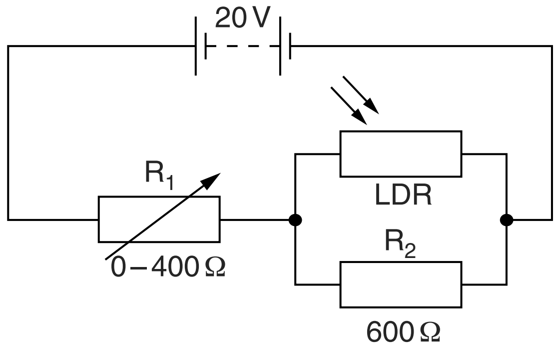


Fig. 6.2

When the light intensity is varied, the resistance of the LDR changes from 5.0 kΩ to 1.2 kΩ.

(i) For the **maximum** light intensity, calculate the total resistance of R_2 and the LDR.

total resistance = ... Ω [2]

(ii) The resistance of R_1 is varied from 0 to 400 Ω in the circuits of Fig. 6.1 and Fig. 6.2. State and explain the difference, if any, between the minimum p.d. across R_2 in each circuit. Numerical values are not required.

....

....

.... [2]

Please turn over for Question 7.

For Examiner's Use

6 **(a)** Define *charge*.

.... [1]

(b) A heater is made from a wire of resistance 18.0 Ω and is connected to a power supply of 240 V. The heater is switched on for 2.60 Ms.

Calculate

(i) the power transformed in the heater,

power = ... W [2]

(ii) the current in the heater,

current = ... A [1]

(iii) the charge passing through the heater in this time,

charge = ... C [2]

(iv) the number of electrons per second passing a given point in the heater.

number = ... s^{-1} [2]

6 Two resistors A and B have resistances R_1 and R_2 respectively. The resistors are connected in series with a battery, as shown in Fig. 6.1.

For Examiner's Use

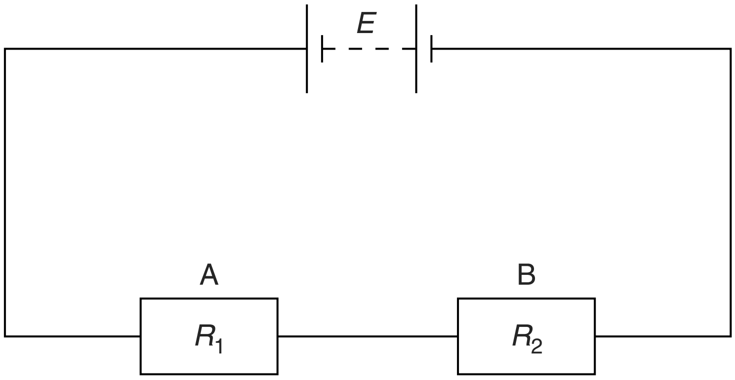


Fig. 6.1

The battery has electromotive force (e.m.f.) E and zero internal resistance.

(a) State the energy transformation that occurs in

(i) the battery,

....

.... [1]

(ii) the resistors.

....

.... [1]

(b) The current in the circuit is I.

State the rate of energy transformation in

(i) the battery,

.... [1]

(ii) the resistor A.

.... [1]

(c) The resistors are made from metal wires. Data for the resistors are given in Fig. 6.2.

resistor	A	B
resistivity of metal	ρ	$\rho/2$
length of wire	l	l
diameter of wire	d	$2d$

Fig. 6.2

Use information from Fig. 6.2 to determine the ratio

$$\frac{\text{power dissipated in A}}{\text{power dissipated in B}}.$$

ratio = ... [3]

(d) The resistors A and B are connected in parallel across the same battery of e.m.f. *E*.
Determine the ratio

$$\frac{\text{power dissipated in A}}{\text{power dissipated in B}}.$$

ratio = ... [2]

For Examiner's Use

6 **(a)** Define *potential difference* (p.d.).

.... [1]

(b) A power supply of e.m.f. 240 V and zero internal resistance is connected to a heater as shown in Fig. 6.1.

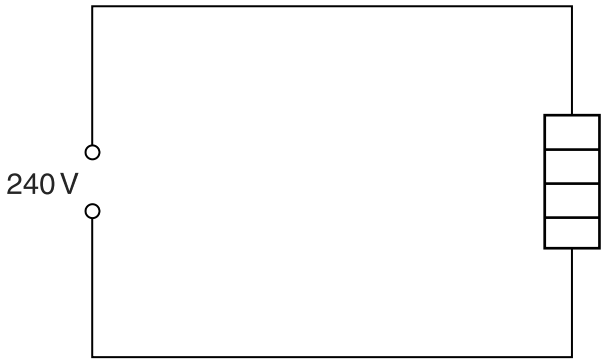


Fig. 6.1

The wires used to connect the heater to the power supply each have length 75 m. The wires have a cross-sectional area 2.5 mm^2 and resistivity 18 nΩ m. The heater has a constant resistance of 38 Ω.

(i) Show that the resistance of each wire is 0.54 Ω.

[3]

(ii) Calculate the current in the wires.

current = ... A [3]

(iii) Calculate the power loss in the wires.

power = ... W [3]

(c) The wires to the heater are replaced by wires of the same length and material but having a cross-sectional area of 0.50 mm^2. Without further calculation, state and explain the effect on the power loss in the wires.

For Examiner's Use

....

....

.... [2]

6 A battery connected in series with a resistor R of resistance 5.0 Ω is shown in Fig. 6.1.

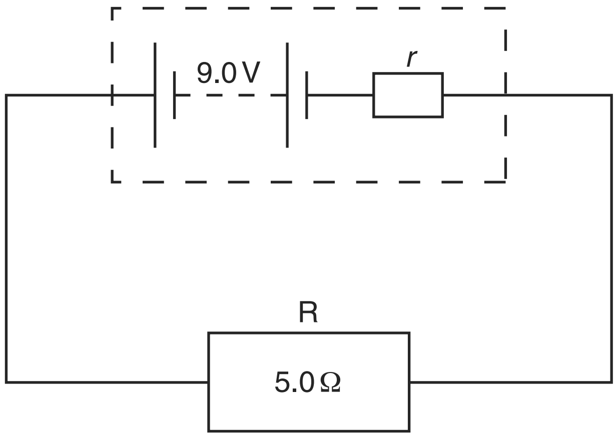


Fig. 6.1

The electromotive force (e.m.f.) of the battery is 9.0 V and the internal resistance is *r*.
The potential difference (p.d.) across the battery terminals is 6.9 V.

(a) Use energy considerations to explain why the p.d. across the battery is not equal to the e.m.f. of the battery.

....

....

.... [2]

(b) Calculate

(i) the current in the circuit,

current = ... A [2]

(ii) the internal resistance *r*.

r = ... Ω [2]

For Examiner's Use

(c) Calculate, for the battery in the circuit,

(i) the total power produced,

power = ... W [2]

(ii) the efficiency.

efficiency = ... [2]

5 **(a)** Explain why the terminal potential difference (p.d.) of a cell with internal resistance may be less than the electromotive force (e.m.f.) of the cell.

....

....

....[2]

(b) A battery of e.m.f. 4.5V and internal resistance *r* is connected in series with a resistor of resistance 6.0Ω, as shown in Fig. 5.1.

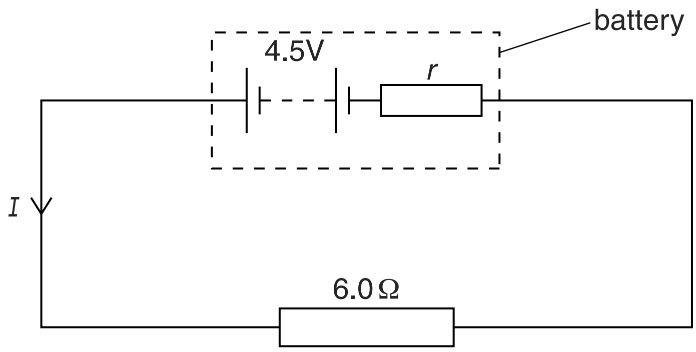


Fig. 5.1

The current I in the circuit is 0.65A.

Determine

(i) the internal resistance *r* of the battery,

r = ... Ω [2]

(ii) the terminal p.d. of the battery,

p.d. = ... V [2]

(iii) the power dissipated in the resistor,

power = ... W [2]

(iv) the efficiency of the battery.

efficiency = ... [2]

(c) A second resistor of resistance 20 Ω is connected in parallel with the 6.0 Ω resistor in Fig. 5.1.

Describe and explain qualitatively the change in the heating effect within the battery.

....

....

....

....[3]

6 A battery is connected in series with resistors X and Y, as shown in Fig. 6.1.

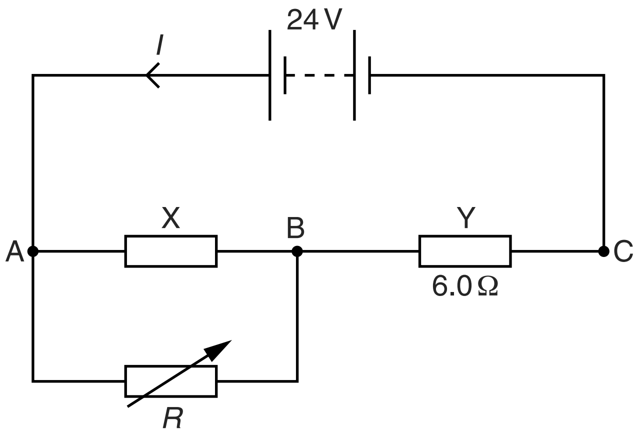


Fig. 6.1

The resistance of X is constant. The resistance of Y is 6.0 Ω. The battery has electromotive force (e.m.f.) 24 V and zero internal resistance. A variable resistor of resistance *R* is connected in parallel with X.

The current I from the battery is changed by varying *R* from 5.0 Ω to 20 Ω. The variation with *R* of I is shown in Fig. 6.2.

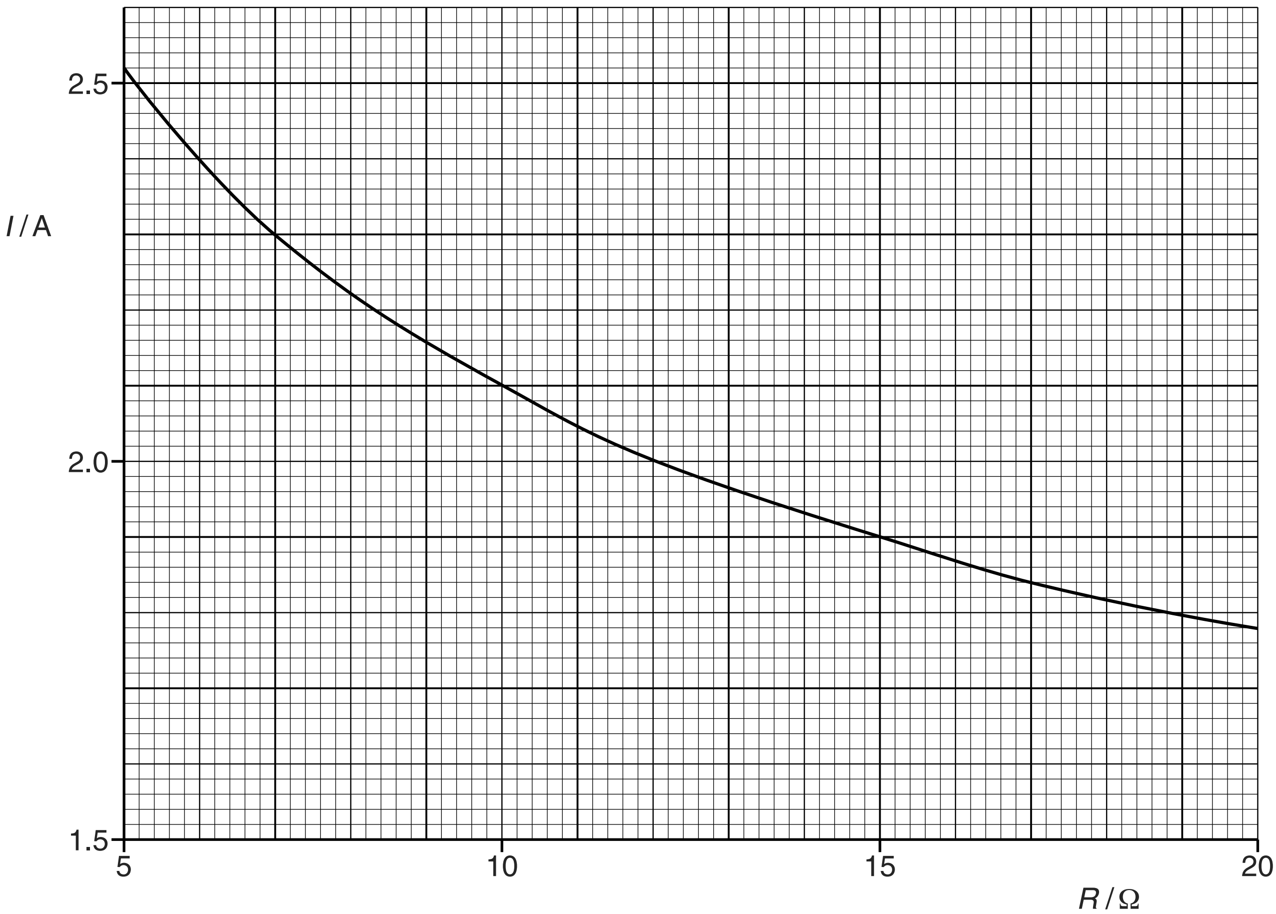


Fig. 6.2

(a) Explain why the potential difference (p.d.) between points A and C is 24 V for all values of R.

....

.... [1]

(b) Use Fig. 6.2 to state and explain the variation of the p.d. across resistor Y as R is increased. Numerical values are not required.

....

....

.... [2]

(c) For $R = 6.0\,\Omega$,

(i) show that the p.d. between points A and B is 9.6 V,

[2]

(ii) calculate the resistance of X,

resistance = ... Ω [3]

(iii) calculate the power provided by the battery.

power = ... W [2]

(d) State and explain qualitatively how the power provided by the battery changes as the resistance R is increased.

....

.... [1]

6 **(a)** Distinguish between *electromotive force* (e.m.f.) and *potential difference* (p.d.).

....

....

.... [2]

(b) A battery of e.m.f. 12 V and internal resistance 0.50 Ω is connected to two identical lamps, as shown in Fig. 6.1.

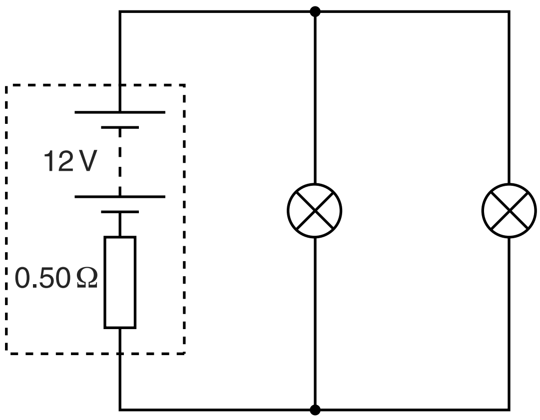


Fig. 6.1

Each lamp has constant resistance. The power rating of each lamp is 48 W when connected across a p.d. of 12 V.

(i) Explain why the power dissipated in each lamp is not 48 W when connected as shown in Fig. 6.1.

....

....

.... [1]

(ii) Calculate the resistance of one lamp.

resistance = ... Ω [2]

(iii) Calculate the current in the battery.

current = ... A [2]

(iv) Calculate the power dissipated in one lamp.

power = ... W [2]

(c) A third identical lamp is placed in parallel with the battery in the circuit of Fig. 6.1. Describe and explain the effect on the terminal p.d. of the battery.

....

....

....

.... [2]

Please turn over for Question 7.

3 The resistance R of a uniform metal wire is measured for different lengths l of the wire. The variation with l of R is shown in Fig. 3.1.

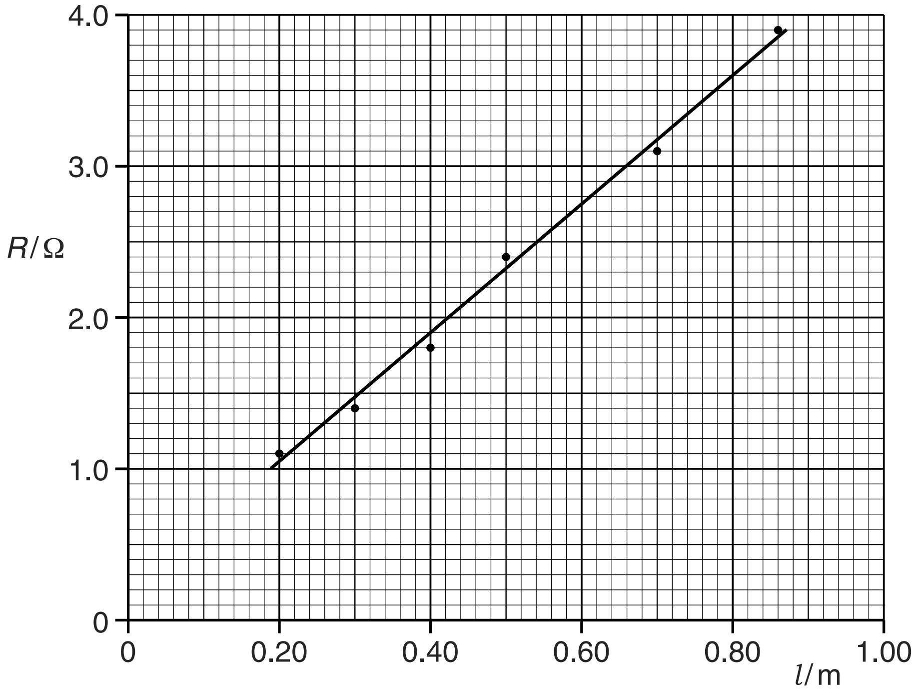


Fig. 3.1

(a) The points shown in Fig. 3.1 do not lie on the best-fit line. Suggest a reason for this.

....

.... [1]

(b) Determine the gradient of the line shown in Fig. 3.1.

gradient = ... [2]

(c) The cross-sectional area of the wire is 0.12 mm^2.

Use your answer in **(b)** to determine the resistivity of the metal of the wire.

resistivity = ... Ω m [3]

(d) The resistance R of different wires is measured. The wires are of the same metal and same length but have different cross-sectional areas A.

On Fig. 3.2, sketch a graph to show the variation with A of R.

Fig. 3.2

[2]

7 **(a)** A cell with internal resistance supplies a current. Explain why the terminal potential difference (p.d.) is less than the electromotive force (e.m.f.) of the cell.

....

....

.... [1]

(b) A battery of e.m.f. 12 V and internal resistance 0.50 Ω is connected to a variable resistor X and a resistor Y of constant resistance, as shown in Fig. 7.1.

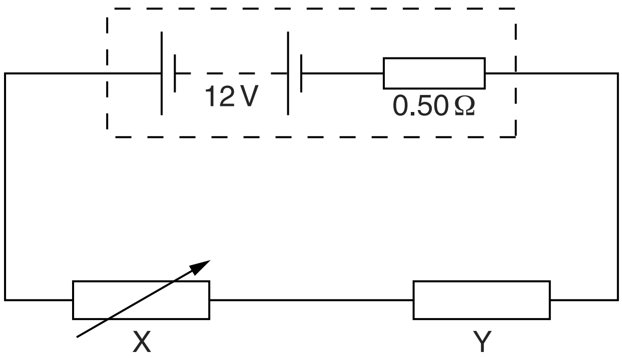


Fig. 7.1

The resistance R of X is increased from 2.0 Ω to 16 Ω. The variation with R of the current I in the circuit is shown in Fig. 7.2.

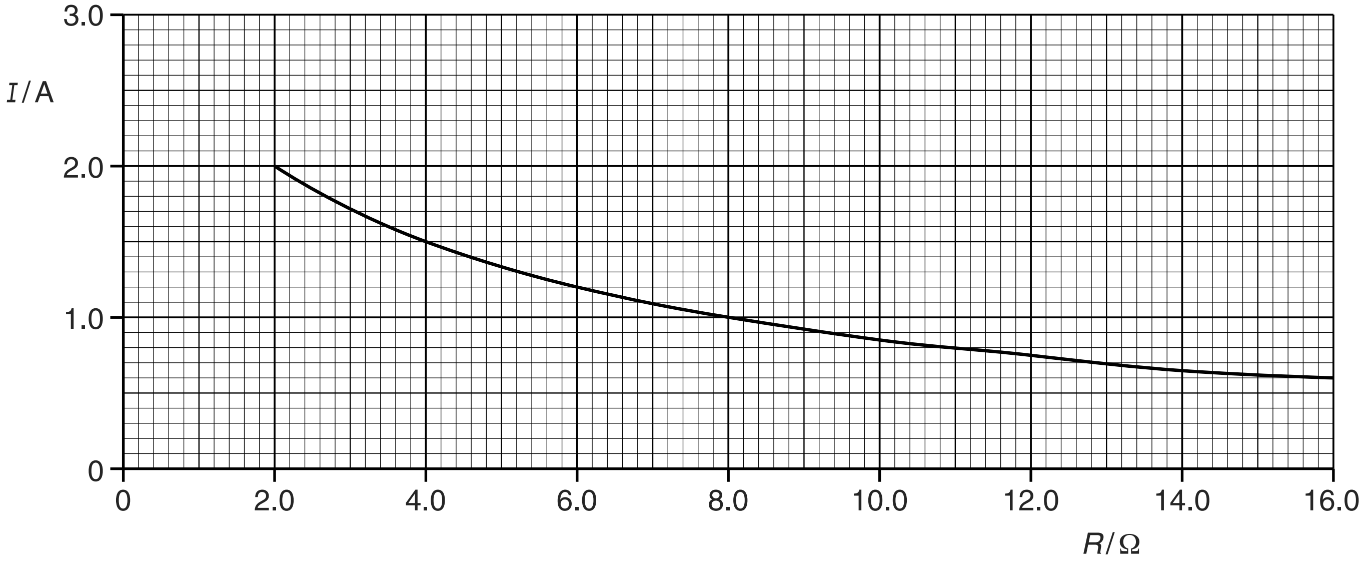


Fig. 7.2

Calculate, for $I = 1.2\,A$,

(i) the p.d. across X,

p.d. = ... V [2]

(ii) the resistance of Y,

resistance = ... Ω [3]

(iii) the power dissipated in the battery.

power = ... W [2]

(c) Use Fig. 7.2 to explain the variation in the terminal p.d. of the battery as the resistance R of X is increased.

....

.... [1]

5 A battery of electromotive force (e.m.f.) 12 V and internal resistance r is connected in series to two resistors, each of constant resistance X, as shown in Fig. 5.1.

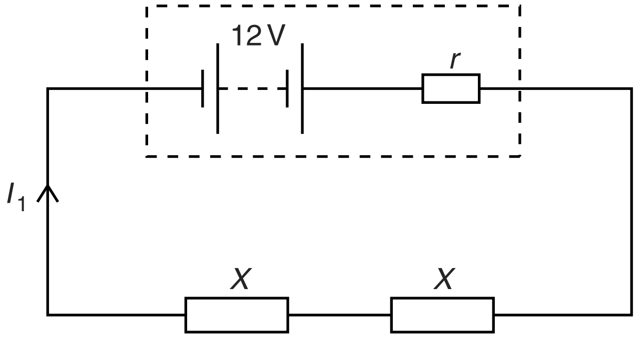


Fig. 5.1

The current I_1 supplied by the battery is 1.2 A.

The same battery is now connected to the same two resistors in parallel, as shown in Fig. 5.2.

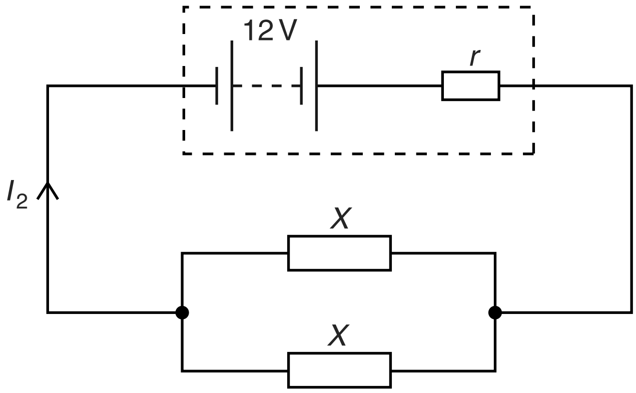


Fig. 5.2

The current I_2 supplied by the battery is 3.0 A.

(a) **(i)** Show that the combined resistance of the two resistors, each of resistance X, is four times greater in Fig. 5.1 than in Fig. 5.2.

[2]

(ii) Explain why I_2 is not four times greater than I_1.

....

....

....[2]

(iii) Using Kirchhoff's second law, state equations, in terms of e.m.f., current, X and r, for

1. the circuit of Fig. 5.1,

....

2. the circuit of Fig. 5.2.

....
[2]

(iv) Use the equations in **(iii)** to calculate the resistance X.

X = ... Ω [1]

(b) Calculate the ratio

$$\frac{\text{power transformed in one resistor of resistance } X \text{ in Fig. 5.1}}{\text{power transformed in one resistor of resistance } X \text{ in Fig. 5.2}}.$$

ratio = ...[2]

(c) The resistors in Fig. 5.1 and Fig. 5.2 are replaced by identical 12 V filament lamps.

Explain why the resistance of each lamp, when connected in series, is not the same as the resistance of each lamp when connected in parallel.

....

....

....

....[2]

6 **(a)** A wire has length 100 cm and diameter 0.38 mm. The metal of the wire has resistivity $4.5 \times 10^{-7}\,\Omega\,\text{m}$.

Show that the resistance of the wire is 4.0 Ω.

[3]

(b) The ends B and D of the wire in **(a)** are connected to a cell X, as shown in Fig. 6.1.

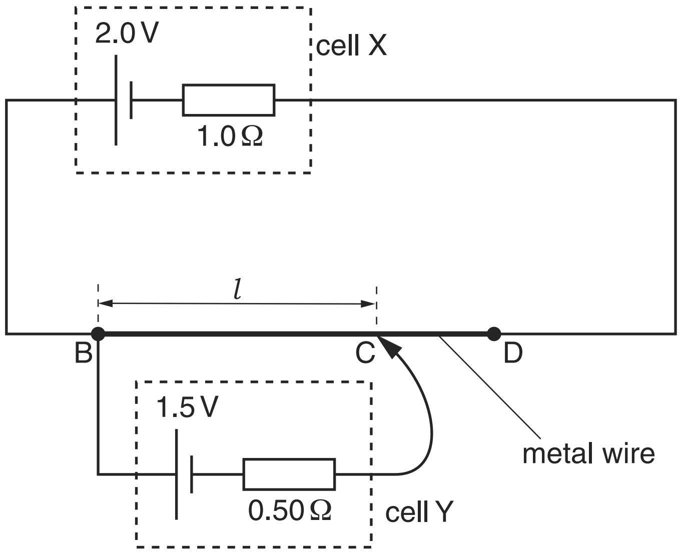


Fig. 6.1

The cell X has electromotive force (e.m.f.) 2.0 V and internal resistance 1.0 Ω.

A cell Y of e.m.f. 1.5 V and internal resistance 0.50 Ω is connected to the wire at points B and C, as shown in Fig. 6.1.

The point C is distance l from point B. The current in cell Y is zero.

Calculate

(i) the current in cell X,

current = ... A [2]

(ii) the potential difference (p.d.) across the wire BD,

p.d. = ... V [1]

(iii) the distance l.

l = ... cm [2]

(c) The connection at C is moved so that l is increased. Explain why the e.m.f. of cell Y is less than its terminal p.d.

....

....

....[2]

5 A uniform resistance wire AB has length 50 cm and diameter 0.36 mm. The resistivity of the metal of the wire is $5.1 \times 10^{-7}\,\Omega\,m$.

(a) Show that the resistance of the wire AB is 2.5 Ω.

[2]

(b) The wire AB is connected in series with a power supply E and a resistor R as shown in Fig. 5.1.

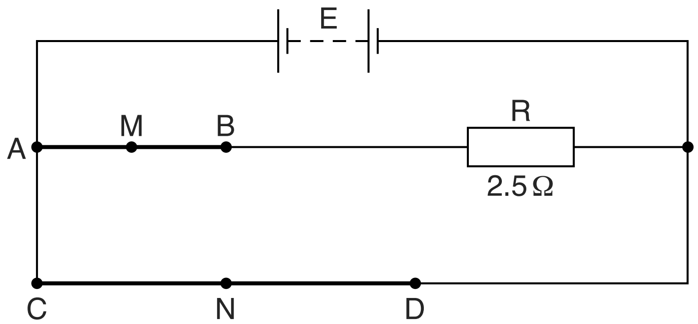


Fig. 5.1

The electromotive force (e.m.f.) of E is 6.0 V and its internal resistance is negligible. The resistance of R is 2.5 Ω. A second uniform wire CD is connected across the terminals of E. The wire CD has length 100 cm, diameter 0.18 mm and is made of the same metal as wire AB.

Calculate

(i) the current supplied by E,

current = ... A [4]

(ii) the power transformed in wire AB,

power = ... W [2]

(iii) the potential difference (p.d.) between the midpoint M of wire AB and the midpoint N of wire CD.

p.d. = ... V [2]

5 **(a)** On Fig. 5.1, sketch the temperature characteristic of a thermistor.

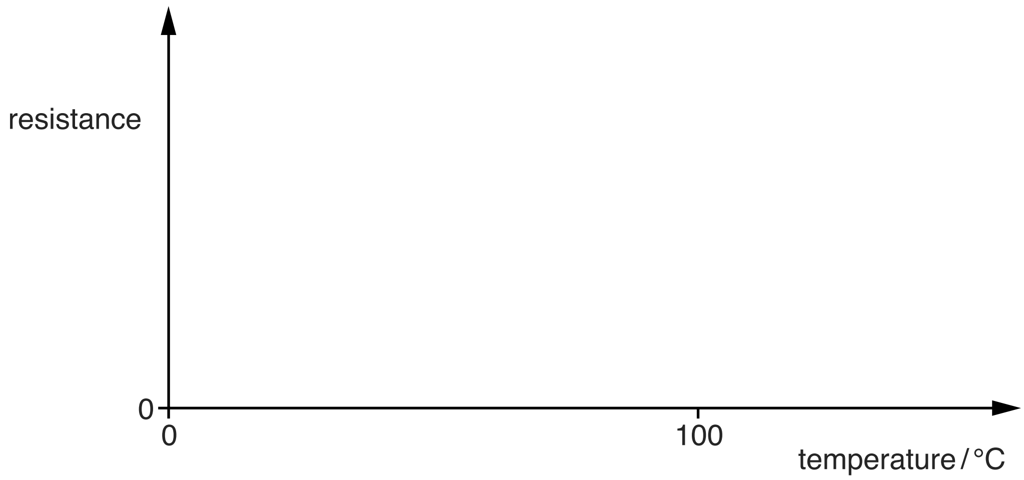


Fig. 5.1

[2]

(b) A potential divider circuit is shown in Fig. 5.2.

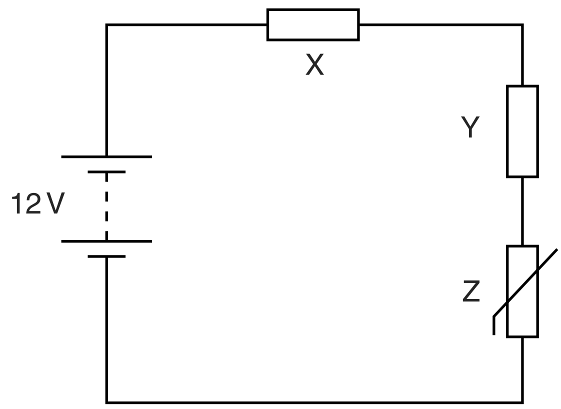


Fig. 5.2

The battery of electromotive force (e.m.f.) 12 V and negligible internal resistance is connected in series with resistors X and Y and thermistor Z. The resistance of Y is 15 kΩ and the resistance of Z at a particular temperature is 3.0 kΩ. The potential difference (p.d.) across Y is 8.0 V.

(i) Explain why the power transformed in the battery equals the total power transformed in X, Y and Z.

.... [1]

(ii) Calculate the current in the circuit.

current = ... A [2]

(iii) Calculate the resistance of X.

resistance = ... Ω [3]

(iv) The temperature of Z is increased.

State and explain the effect on the potential difference across Z.

....

....

....

.... [2]

5 The variation with potential difference (p.d.) V of current I for a semiconductor diode is shown in Fig. 5.1.

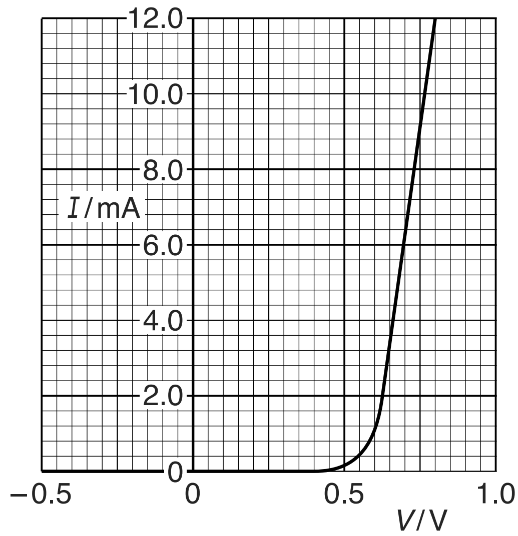


Fig. 5.1

(a) Use Fig. 5.1 to describe the variation of the resistance of the diode between $V = -0.5\,V$ and $V = 0.8\,V$.

....

....

....

....[2]

(b) On Fig. 5.2, sketch the variation with p.d. V of current I for a filament lamp. Numerical values are not required.

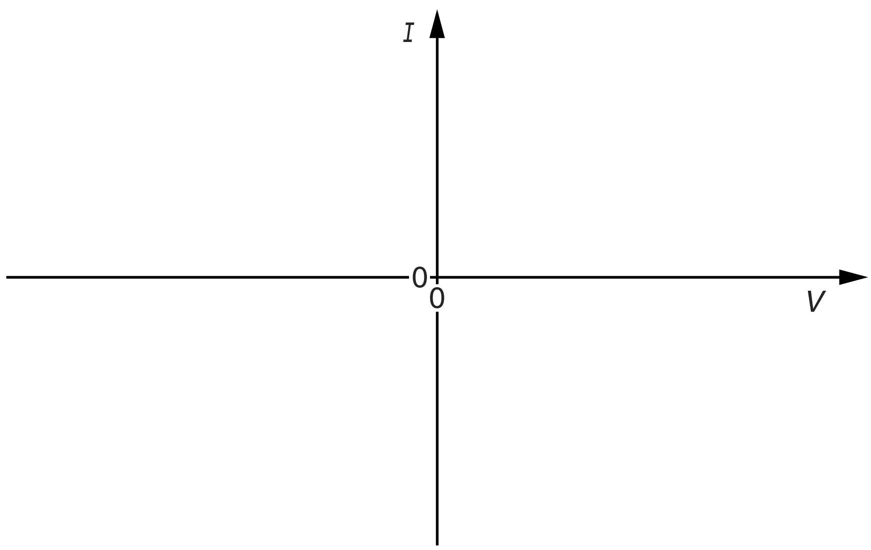


Fig. 5.2

[2]

(c) Fig. 5.3 shows a power supply of electromotive force (e.m.f.) 12 V and internal resistance 0.50 Ω connected to a filament lamp and switch.

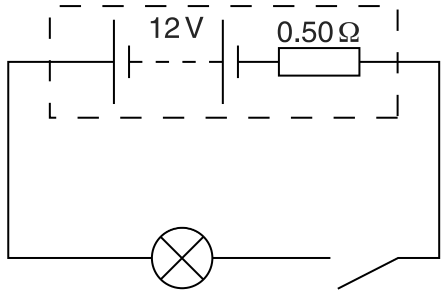


Fig. 5.3

The filament lamp has a power of 36 W when the p.d. across it is 12 V.

(i) Calculate the resistance of the lamp when the p.d. across it is 12 V.

resistance = ... Ω [1]

(ii) The switch is closed and the current in the lamp is 2.8 A. Calculate the resistance of the lamp.

resistance = ... Ω [3]

(d) Explain how the two values of resistance calculated in **(c)** provide evidence for the shape of the sketch you have drawn in **(b)**.

....

....[1]

For Examiner's Use

1 Fig. 2.1 shows the variation with distance x along a wave of its displacement d at a particular time.

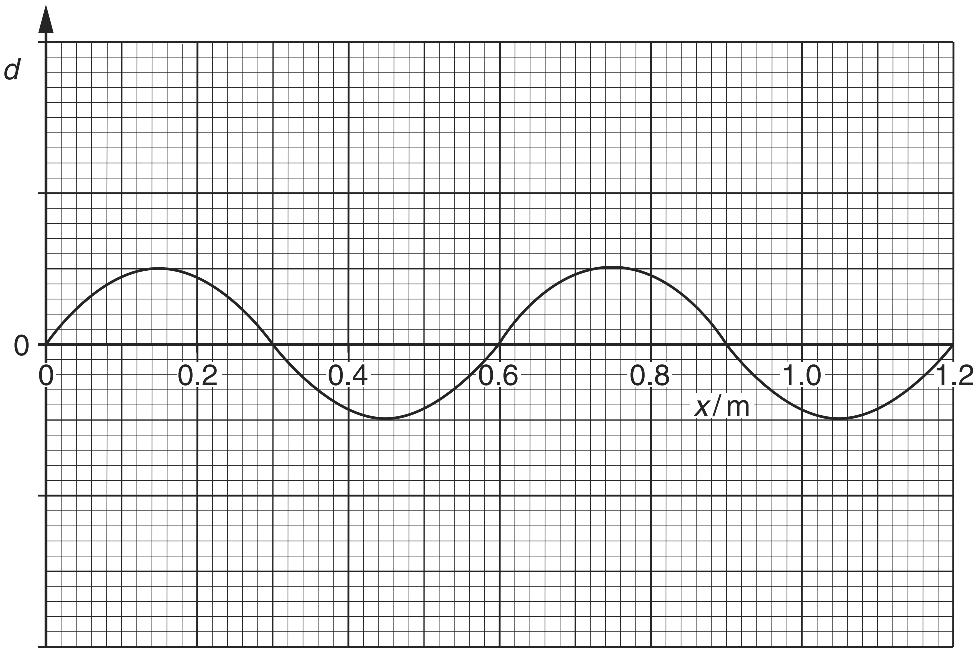


Fig. 2.1

The wave is a progressive wave having a speed of $330\,\text{m}\,\text{s}^{-1}$.

(a) **(i)** Use Fig. 2.1 to determine the wavelength of the wave.

wavelength = ... m

(ii) Hence calculate the frequency of the wave.

frequency = ... Hz

[3]

(b) A second wave has the same frequency and speed as the wave shown in Fig. 2.1 but has double the intensity. The phase difference between the two waves is 180°.

On the axes of Fig. 2.1, sketch a graph to show the variation with distance x of the displacement d of this second wave. [2]

2 A long tube, fitted with a tap, is filled with water. A tuning fork is sounded above the top of the tube as the water is allowed to run out of the tube, as shown in Fig. 6.1.

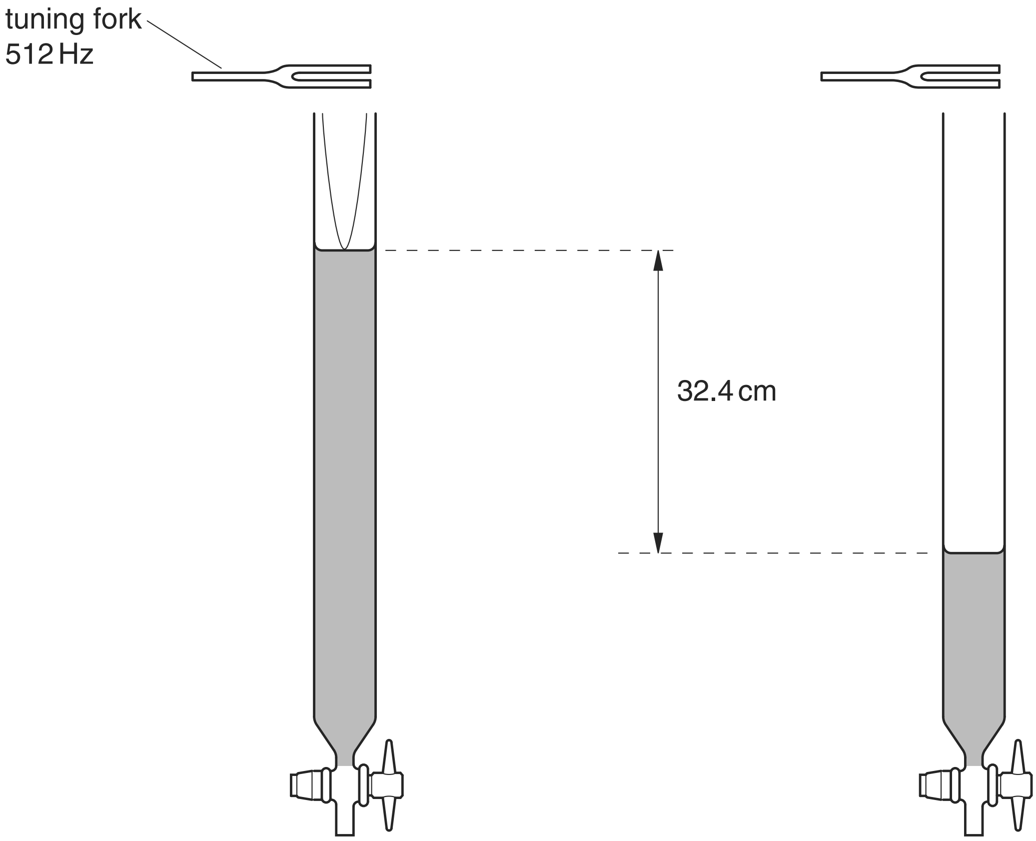


Fig. 6.1 **Fig. 6.2**

A loud sound is first heard when the water level is as shown in Fig. 6.1, and then again when the water level is as shown in Fig. 6.2.

Fig. 6.1 illustrates the stationary wave produced in the tube.

(a) On Fig. 6.2,

(i) sketch the form of the stationary wave set up in the tube, [1]

(ii) mark, with the letter N, the positions of any nodes of the stationary wave. [1]

(b) The frequency of the fork is 512 Hz and the difference in the height of the water level for the two positions where a loud sound is heard is 32.4 cm.

Calculate the speed of sound in the tube.

speed = ... m s^{-1} [3]

(c) The length of the column of air in the tube in Fig. 6.1 is 15.7 cm.

Suggest where the antinode of the stationary wave produced in the tube in Fig. 6.1 is likely to be found.

....

....

.... [2]

3 Light reflected from the surface of smooth water may be described as a polarised transverse wave.

(a) By reference to the direction of propagation of energy, explain what is meant by

(i) a *transverse wave*,

....

....[1]

(ii) *polarisation*.

....

....[1]

(b) A glass tube, closed at one end, has fine dust sprinkled along its length. A sound source is placed near the open end of the tube, as shown in Fig. 5.1.

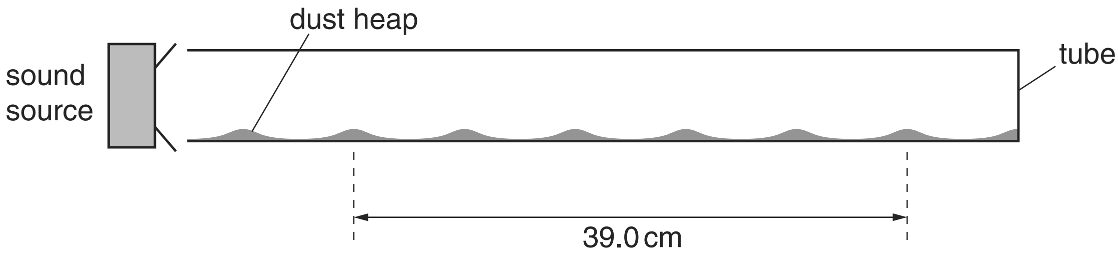


Fig. 5.1

The frequency of the sound emitted by the source is varied and, at one frequency, the dust forms small heaps in the tube.

(i) Explain, by reference to the properties of stationary waves, why the heaps of dust are formed.

....

....

....

....[3]

(ii) One frequency at which heaps are formed is 2.14 kHz.
The distance between six heaps, as shown in Fig. 5.1, is 39.0 cm.
Calculate the speed of sound in the tube.

speed = ... $m\,s^{-1}$ [3]

(c) The wave in the tube is a stationary wave. Explain, by reference to the formation of a stationary wave, what is meant by the speed calculated in **(b)(ii)**.

....

....

....

....[3]

For Examiner's Use

4 **(a)** State what is meant by

(i) the *frequency* of a progressive wave,

....

....

.... [2]

(ii) the *speed* of a progressive wave.

....

.... [1]

(b) One end of a long string is attached to an oscillator. The string passes over a frictionless pulley and is kept taut by means of a weight, as shown in Fig. 5.1.

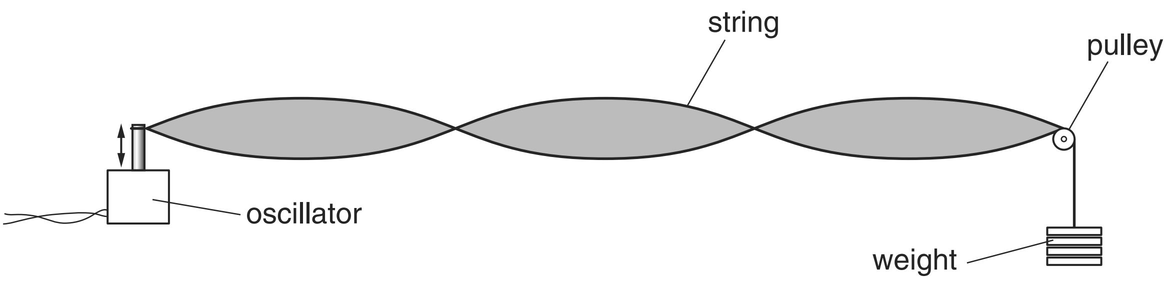


Fig. 5.1

The frequency of oscillation is varied and, at one value of frequency, the wave formed on the string is as shown in Fig. 5.1.

(i) Explain why the wave is said to be a *stationary wave*.

....

.... [1]

(ii) State what is meant by an *antinode*.

....

.... [1]

(iii) On Fig. 5.1, label the antinodes with the letter A. [1]

For Examiner's Use

(c) A weight of 4.00 N is hung from the string in **(b)** and the frequency of oscillation is adjusted until a stationary wave is formed on the string. The separation of the antinodes on the string is 17.8 cm for a frequency of 125 Hz.
The speed *v* of waves on a string is given by the expression

$$v = \sqrt{\frac{T}{m}}\ ,$$

where *T* is the tension in the string and *m* is its mass per unit length.
Determine the mass per unit length of the string.

mass per unit length = ... $kg\,m^{-1}$ [5]

5 The variation with time *t* of the displacement *x* of a point in a transverse wave T_1 is shown in Fig. 5.1.

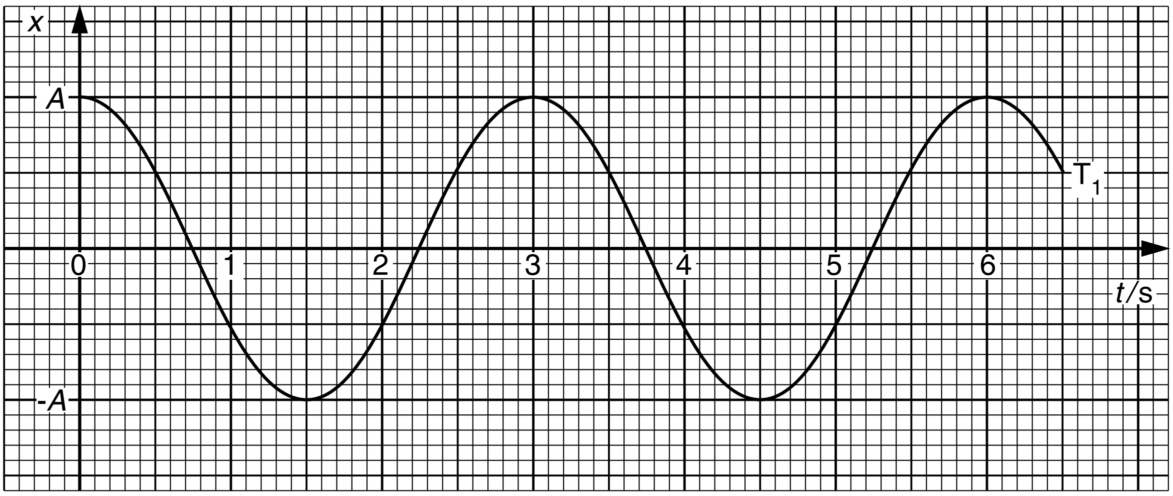


Fig. 5.1

(a) By reference to displacement and direction of travel of wave energy, explain what is meant by a *transverse wave*.

....

....[1]

(b) A second transverse wave T_2, of amplitude *A* has the same waveform as wave T_1 but lags behind T_1 by a phase angle of 60°. The two waves T_1 and T_2 pass through the same point.

(i) On Fig. 5.1, draw the variation with time *t* of the displacement *x* of the point in wave T_2. [2]

(ii) Explain what is meant by the *principle of superposition* of two waves.

....

....

....[2]

(iii) For the time *t* = 1.0 s, use Fig. 5.1 to determine, in terms of *A*,

1. the displacement due to wave T_1 alone,

displacement = ...

2. the displacement due to wave T_2 alone,

displacement = ...

3. the resultant displacement due to both waves.

displacement = ...

[3]

For Examiner's Use

6 The spectrum of electromagnetic waves is divided into a number of regions such as radio waves, visible light and gamma radiation.

(a) State three distinct features of waves that are common to all regions of the electromagnetic spectrum.

1. ....

2. ....

3. .... [3]

(b) A typical wavelength of visible light is 495 nm. Calculate the number of wavelengths of this light in a wave of length 1.00 m.

number = ... [2]

(c) State a typical wavelength for

(i) X-rays,

wavelength = ... m

(ii) infra-red radiation.

wavelength = ... m
[2]

7 A string is stretched between two fixed points. It is plucked at its centre and the string vibrates, forming a stationary wave as illustrated in Fig. 4.1.

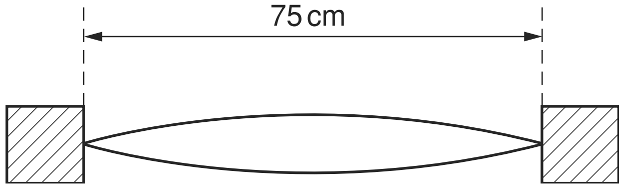


Fig. 4.1

The length of the string is 75 cm.

(a) State the wavelength of the wave.

wavelength = ... m [1]

(b) The frequency of vibration of the string is 360 Hz. Calculate the speed of the wave on the string.

speed = ... m s^{-1} [2]

(c) By reference to the formation of the stationary wave on the string, explain what is meant by the speed calculated in **(b)**.

....

....

.... [3]

8 Fig. 5.1 shows the variation with time t of the displacements x_A and x_B at a point P of two sound waves A and B.

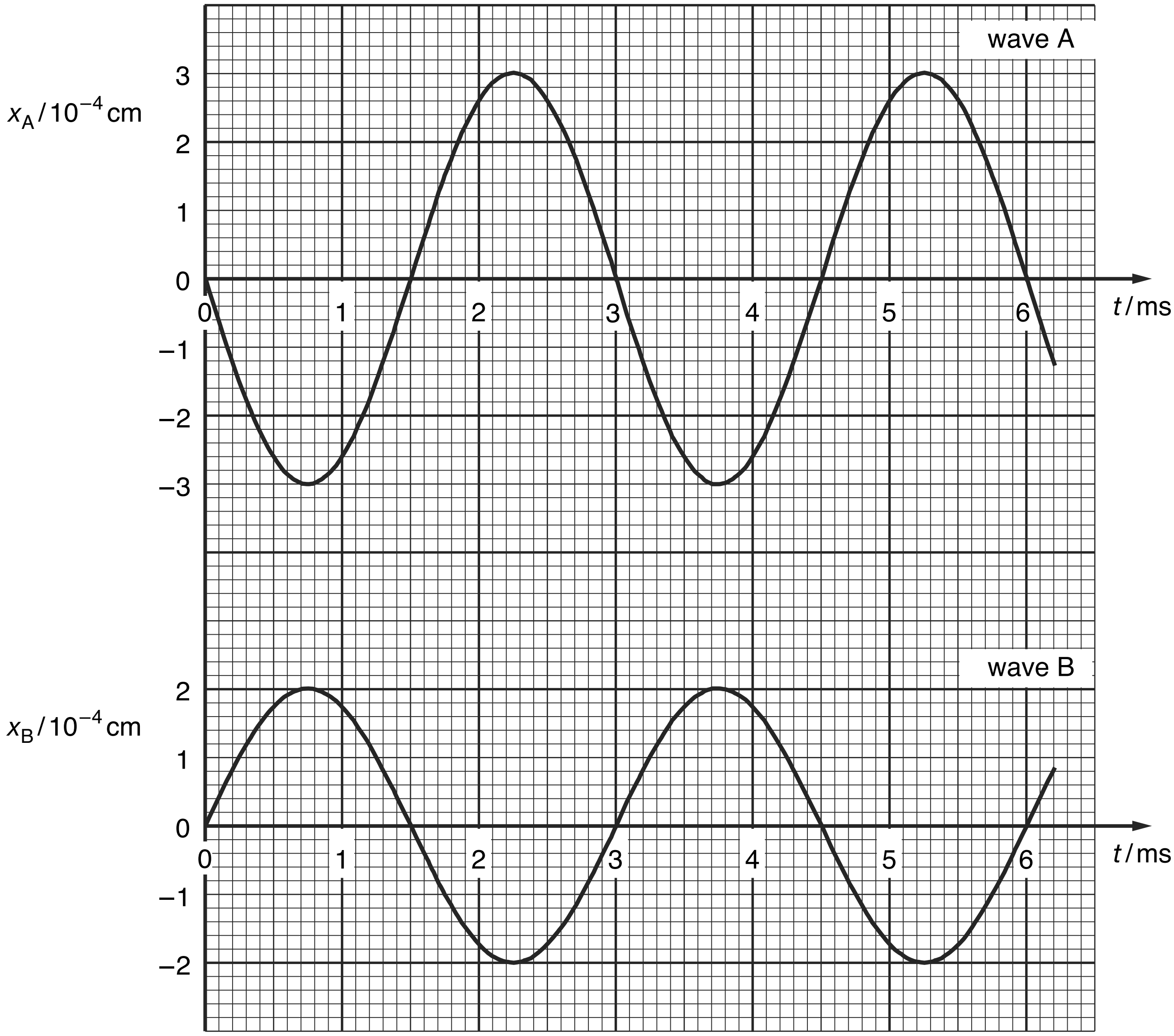


Fig. 5.1

(a) By reference to Fig. 5.1, state one similarity and one difference between these two waves.

similarity: ....

difference: .... [2]

(b) State, with a reason, whether the two waves are coherent.

....

.... [1]

For Examiner's Use

(c) The intensity of wave A alone at point P is I.

(i) Show that the intensity of wave B alone at point P is $\frac{4}{9}I$.

[2]

(ii) Calculate the resultant intensity, in terms of I, of the two waves at point P.

resultant intensity = ... I [2]

(d) Determine the resultant displacement for the two waves at point P

(i) at time t = 3.0 ms,

resultant displacement = ... cm [1]

(ii) at time t = 4.0 ms.

resultant displacement = ... cm [2]

9 A uniform string is held between a fixed point P and a variable-frequency oscillator, as shown in Fig. 5.1.

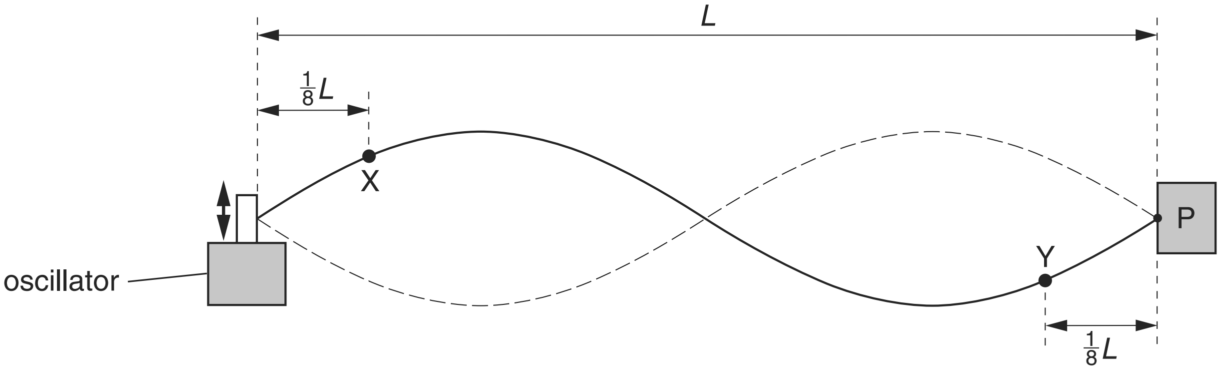


Fig. 5.1

The distance between point P and the oscillator is L.

The frequency of the oscillator is adjusted so that the stationary wave shown in Fig. 5.1 is formed.

Points X and Y are two points on the string.

Point X is a distance $\frac{1}{8}L$ from the end of the string attached to the oscillator. It vibrates with frequency f and amplitude A.

Point Y is a distance $\frac{1}{8}L$ from the end P of the string.

(a) For the vibrations of point Y, state

(i) the frequency (in terms of f),

frequency = ... [1]

(ii) the amplitude (in terms of A).

amplitude = ... [1]

(b) State the phase difference between the vibrations of point X and point Y.

phase difference = ... [1]

For Examiner's Use

(c) **(i)** State, in terms of *f* and *L*, the speed of the wave on the string.

speed = ... [1]

(ii) The wave on the string is a stationary wave.

Explain, by reference to the formation of a stationary wave, what is meant by the speed stated in **(i)**.

....

....

....

....

.... [3]

For Examiner's Use

4 **(a)** State two features of a stationary wave that distinguish it from a progressive wave.

1. ....

....

2. ....

.... [2]

(b) A long tube is open at one end. It is closed at the other end by means of a piston that can be moved along the tube, as shown in Fig. 4.1.

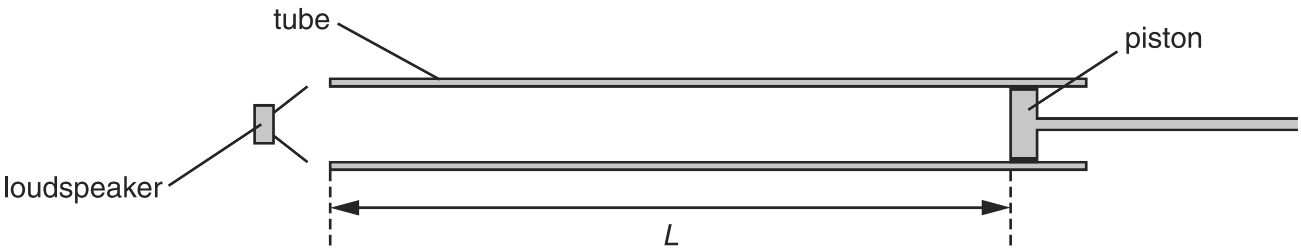


Fig. 4.1

A loudspeaker producing sound of frequency 550 Hz is held near the open end of the tube.
The piston is moved along the tube and a loud sound is heard when the distance L between the piston and the open end of the tube is 45 cm.
The speed of sound in the tube is $330\,m\,s^{-1}$.

(i) Show that the wavelength of the sound in the tube is 60 cm.

[1]

(ii) On Fig. 4.1, mark all the positions along the tube of

1. the displacement nodes (label these with the letter N),

2. the displacement antinodes (label these with the letter A).

[3]

For Examiner's Use

(c) The frequency of the sound produced by the loudspeaker in **(b)** is gradually reduced.

Determine the lowest frequency at which a loud sound will be produced in the tube of length L = 45 cm.

frequency = ... Hz [3]

For Examiner's Use

5 **(a)** A source of sound has frequency *f*. Sound of wavelength λ is produced by the source.

(i) State

1. what is meant by the *frequency* of the source,

....

....[1]

2. the distance moved, in terms of λ, by a wavefront during *n* oscillations of the source.

distance = ...[1]

(ii) Use your answers in **(i)** to deduce an expression for the speed *v* of the wave in terms of *f* and λ.

[2]

(b) The waveform of a sound wave produced on the screen of a cathode-ray oscilloscope (c.r.o.) is shown in Fig. 5.1.

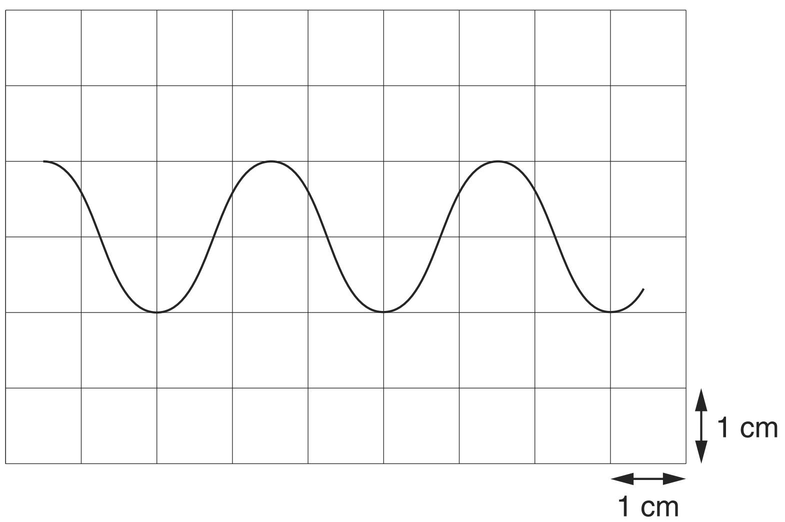


Fig. 5.1

The time-base setting of the c.r.o. is 2.0 ms cm^{-1}.

For Examiner's Use

(i) Determine the frequency of the sound wave.

frequency = ...Hz [2]

(ii) A second sound wave has the same frequency as that calculated in **(i)**. The amplitude of the two waves is the same but the phase difference between them is 90°.

On Fig. 5.1, draw the waveform of this second wave. [1]

For Examiner's Use

5 A student is studying a water wave in which all the wavefronts are parallel to one another. The variation with time t of the displacement x of a particular particle in the wave is shown in Fig. 5.1.

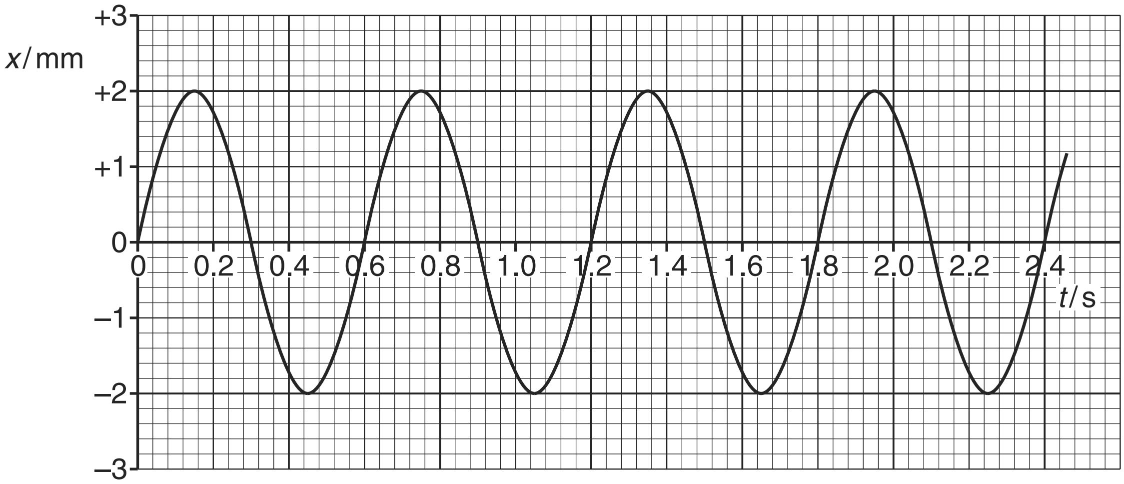


Fig. 5.1

The distance d of the oscillating particles from the source of the waves is measured.
At a particular time, the variation of the displacement x with this distance d is shown in Fig. 5.2.

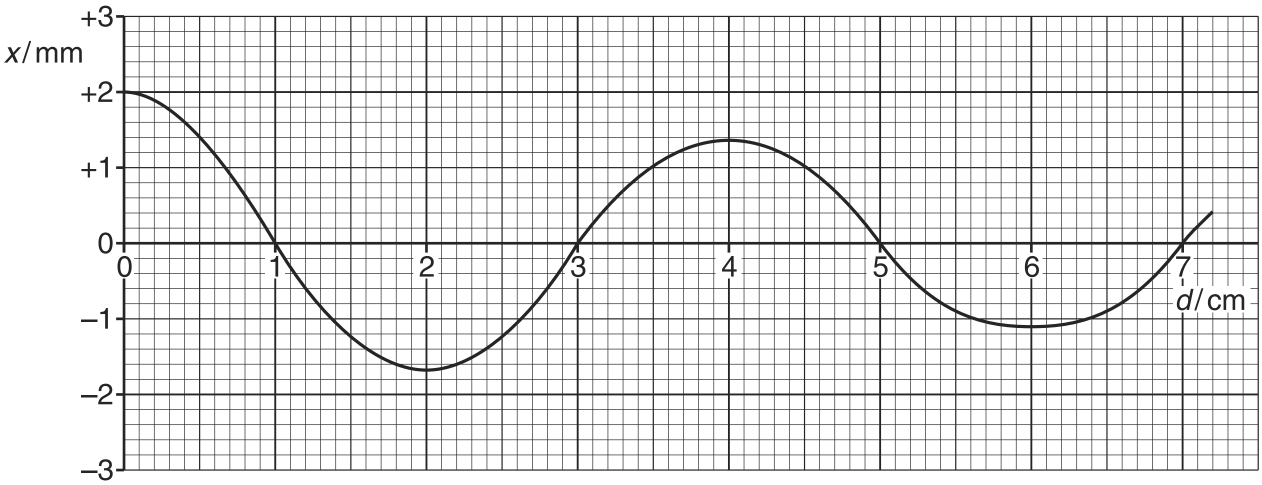


Fig. 5.2

(a) Define, for a wave, what is meant by

(i) *displacement*,

....

....[1]

(ii) *wavelength*.

....

....[1]

(b) Use Figs. 5.1 and 5.2 to determine, for the water wave,

(i) the period *T* of vibration,

T = ... s [1]

(ii) the wavelength λ,

λ = ... cm [1]

(iii) the speed *v*.

v = ... cm s^{-1} [2]

(c) **(i)** Use Figs. 5.1 and 5.2 to state and explain whether the wave is losing power as it moves away from the source.

....

....

....[2]

(ii) Determine the ratio

$$\frac{\text{intensity of wave at source}}{\text{intensity of wave 6.0 cm from source}}.$$

ratio = ... [3]

For Examiner's Use

6 **(a)** A transverse progressive wave travels along a stretched string from left to right. The shape of part of the string at a particular instant is shown in Fig. 6.1.

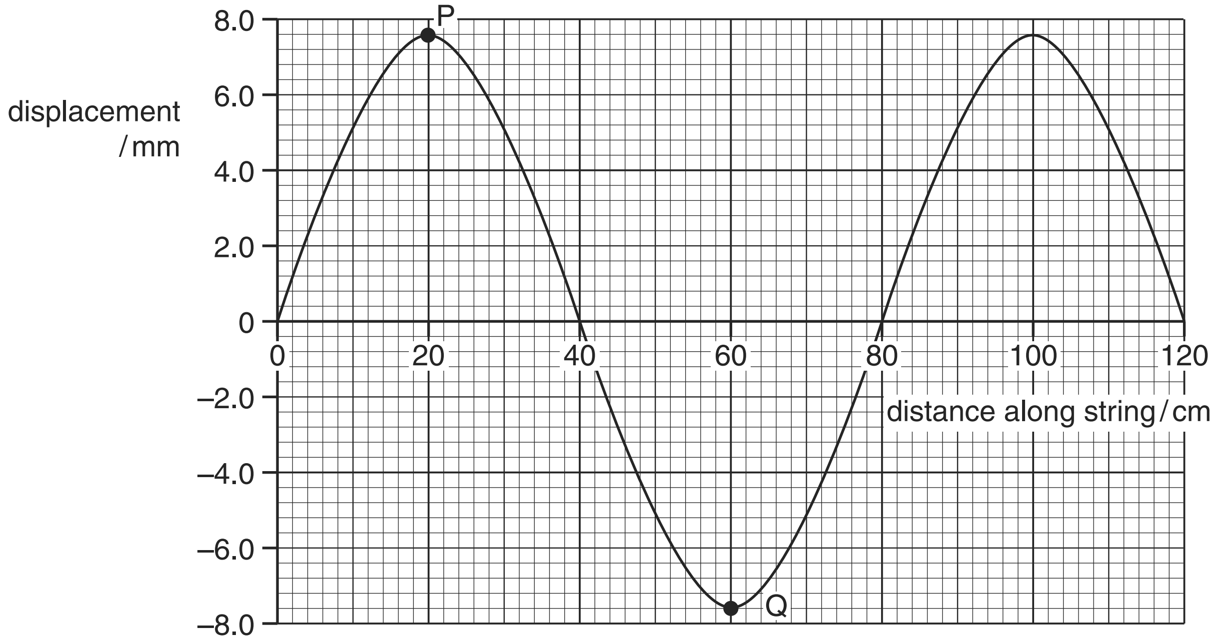


Fig. 6.1

The frequency of the wave is 15 Hz.
For this wave, use Fig. 6.1 to determine

(i) the amplitude,

amplitude = ... mm [1]

(ii) the phase difference between the points P and Q on the string,

phase difference = ... [1]

(iii) the speed of the wave.

speed = ... m s^{-1} [2]

(b) The period of vibration of the wave is T. The wave moves forward from the position shown in Fig 6.1 for a time 0.25 T. On Fig. 6.1, sketch the new position of the wave. [2]

For Examiner's Use

(c) Another stretched string is used to form a stationary wave. Part of this wave, at a particular instant, is shown in Fig. 6.2.

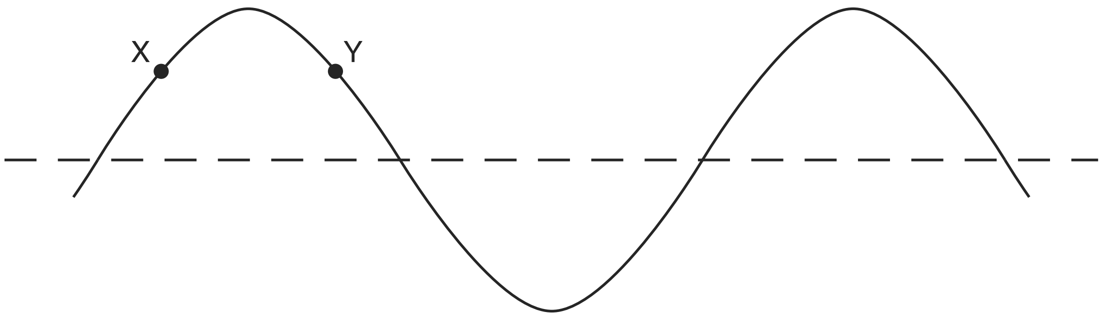


Fig. 6.2

The points on the string are at their maximum displacement.

(i) State the phase difference between the particles labelled X and Y.

phase difference = ... [1]

(ii) Explain the following terms used to describe stationary waves on a string:

antinode: ....

node: ....
[1]

(iii) State the number of antinodes shown on Fig. 6.2 for this wave.

number of antinodes = ... [1]

(iv) The period of vibration of this wave is τ. On Fig. 6.2, sketch the stationary wave 0.25τ after the instant shown in Fig. 6.2. [1]

6 **(a)** State the *principle of superposition*.

....

....

....[2]

(b) An arrangement that can be used to determine the speed of sound in air is shown in Fig. 6.1.

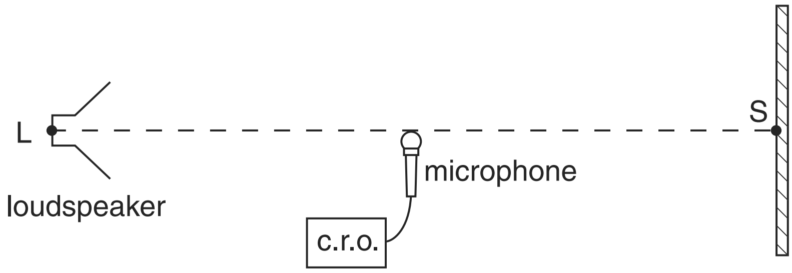


Fig. 6.1

Sound waves of constant frequency are emitted from the loudspeaker L and are reflected from a point S on a hard surface.
The loudspeaker is moved away from S until a stationary wave is produced.

Explain how sound waves from L give rise to a stationary wave between L and S.

....

....

....[2]

(c) A microphone connected to a cathode ray oscilloscope (c.r.o.) is positioned between L and S as shown in Fig. 6.1. The trace obtained on the c.r.o. is shown in Fig. 6.2.

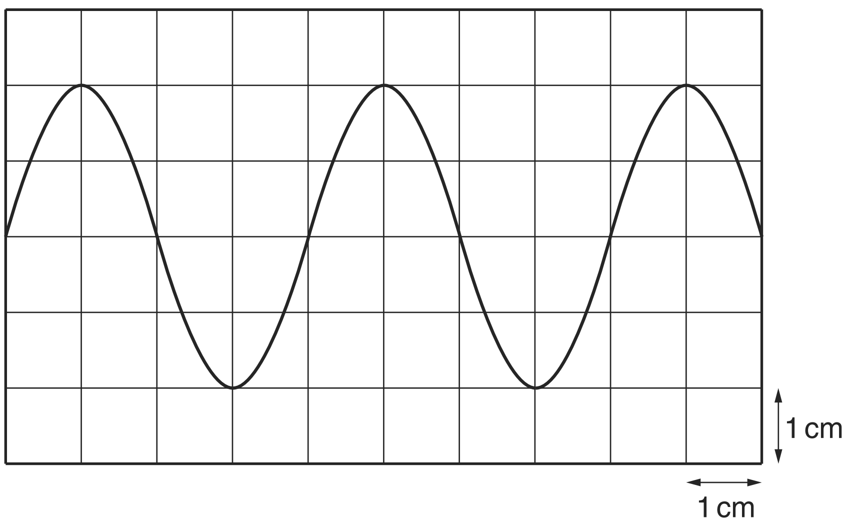


Fig. 6.2

The time-base setting on the c.r.o. is $0.10\,\text{ms}\,\text{cm}^{-1}$.

(i) Calculate the frequency of the sound wave.

frequency = ... Hz [2]

(ii) The microphone is now moved towards S along the line LS. When the microphone is moved 6.7 cm, the trace seen on the c.r.o. varies from a maximum amplitude to a minimum and then back to a maximum.

1. Use the properties of stationary waves to explain these changes in amplitude.

....

....

....[1]

2. Calculate the speed of sound.

speed of sound = ... $m\,s^{-1}$ [3]

Please turn over for Question 7.

For Examiner's Use

5 **(a)** By reference to vibrations of the points on a wave and to its direction of energy transfer, distinguish between transverse waves and longitudinal waves.

....

....

....

.... [2]

(b) Describe what is meant by a *polarised* wave.

....

....

.... [2]

(c) The variation with distance x of the displacement y of a transverse wave is shown in Fig. 5.1.

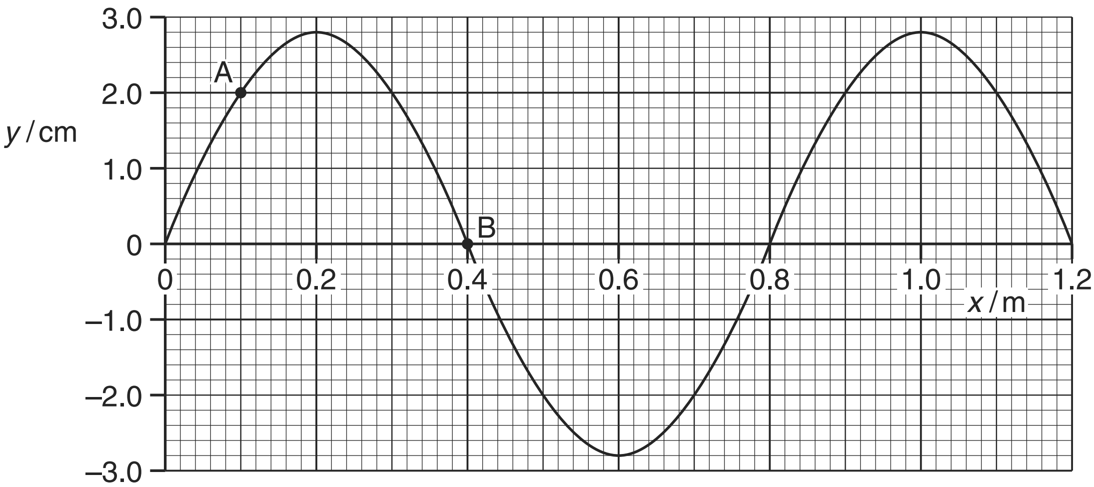


Fig. 5.1

(i) Use Fig. 5.1 to determine

1. the amplitude of the wave,

amplitude = ... cm [1]

2. the phase difference between the points labelled A and B.

phase difference = ... [2]

(ii) Determine the amplitude of a wave with twice the intensity of that shown in Fig. 5.1.

For Examiner's Use

amplitude = ... cm [1]

For Examiner's Use

6 **(a)** Use the principle of superposition to explain the formation of a stationary wave.

....

....

....

....

.... [3]

(b) Describe an experiment to determine the wavelength of sound in air using stationary waves. Include a diagram of the apparatus in your answer.

....

....

....

....

....

....

....

....

....

.... [3]

For Examiner's Use

(c) The variation with distance x of the intensity I of a stationary sound wave is shown in Fig. 6.1.

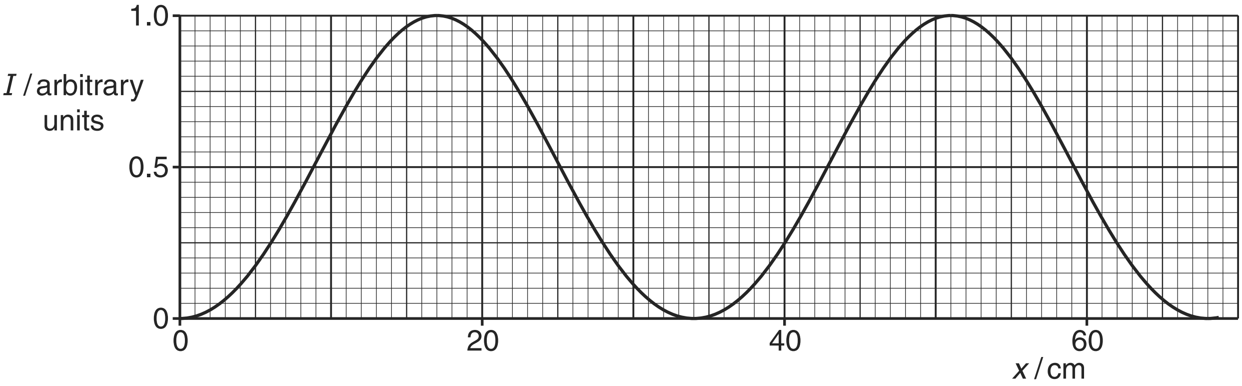


Fig. 6.1

(i) On the x-axis of Fig. 6.1, indicate the positions of all the nodes and antinodes of the stationary wave. Label the nodes **N** and the antinodes **A**. [1]

(ii) The speed of sound in air is 340 m s^{-1}.

Use Fig. 6.1 to determine the frequency of the sound wave.

frequency = ... Hz [3]

Please turn over for Question 7.

5 A long rope is held under tension between two points A and B. Point A is made to vibrate vertically and a wave is sent down the rope towards B as shown in Fig. 5.1.

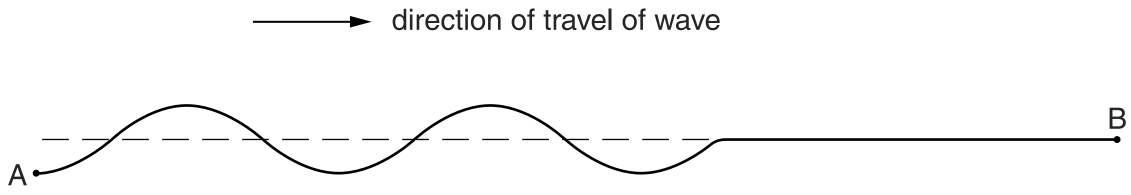


Fig. 5.1 (not to scale)

The time for one oscillation of point A on the rope is 0.20 s. The point A moves a distance of 80 mm during one oscillation. The wave on the rope has a wavelength of 1.5 m.

(a) (i) Explain the term *displacement* for the wave on the rope.

....

.... [1]

(ii) Calculate, for the wave on the rope,

1. the amplitude,

amplitude = ... mm [1]

2. the speed.

speed = ... m s^{-1} [3]

(b) On Fig. 5.1, draw the wave pattern on the rope at a time 0.050 s later than that shown. [2]

(c) State and explain whether the waves on the rope are

(i) progressive or stationary,

....

.... [1]

(ii) longitudinal or transverse.

....

.... [1]

For Examiner's Use

5 **(a)** **(i)** Define, for a wave,

1. wavelength λ,

....

.... [1]

2. frequency *f*.

....

.... [1]

(ii) Use your definitions to deduce the relationship between λ, f and the speed v of the wave.

[1]

(b) Plane waves on the surface of water are represented by Fig. 5.1 at one particular instant of time.

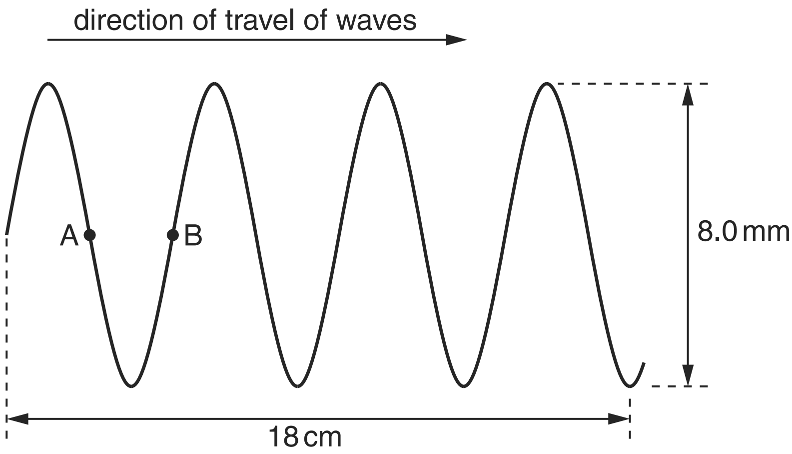


Fig. 5.1 (not to scale)

The waves have frequency 2.5 Hz.

Determine, for the waves,

(i) the amplitude,

amplitude = ... mm [1]

(ii) the speed,

speed = ... $m\,s^{-1}$ [2]

(iii) the phase difference between points A and B.

phase difference = ... unit .... [1]

For Examiner's Use

(c) The wave in **(b)** was produced in a ripple tank. Describe briefly, with the aid of a sketch diagram, how the wave may be observed.

....

....

....

[2]

5 **(a)** Explain what is meant by the following quantities for a wave on the surface of water:

(i) displacement and amplitude,

displacement ....

amplitude ....
[2]

(ii) frequency and time period.

frequency ....

time period ....
[2]

(b) Fig. 5.1 represents waves on the surface of water in a ripple tank at one particular instant of time.

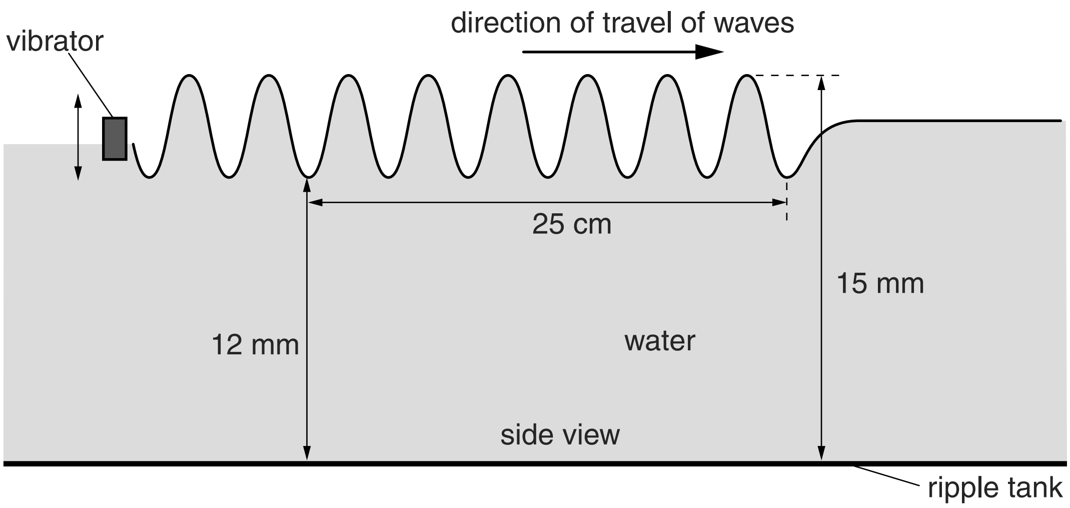


Fig. 5.1 (not to scale)

A vibrator moves the surface of the water to produce the waves of frequency *f*. The speed of the waves is 7.5 cm s^{-1}. Where the waves travel on the water surface, the maximum depth of the water is 15 mm and the minimum depth is 12 mm.

(i) Calculate, for the waves,

1. the amplitude,

amplitude = ... mm [1]

2. the wavelength.

wavelength = ... m [2]

(ii) Calculate the time period of the oscillations of the vibrator.

time period = ... s [2]

(c) State and explain whether the waves on the surface of the water shown in Fig. 5.1 are

(i) progressive or stationary,

....

.... [1]

(ii) transverse or longitudinal.

....

.... [1]

7 **(a)** **(i)** Explain what is meant by a *progressive transverse* wave.

progressive: ....

....

transverse: ....

....
[2]

(ii) Define frequency.

....

....[1]

(b) The variation with distance x of displacement y for a transverse wave is shown in Fig. 7.1.

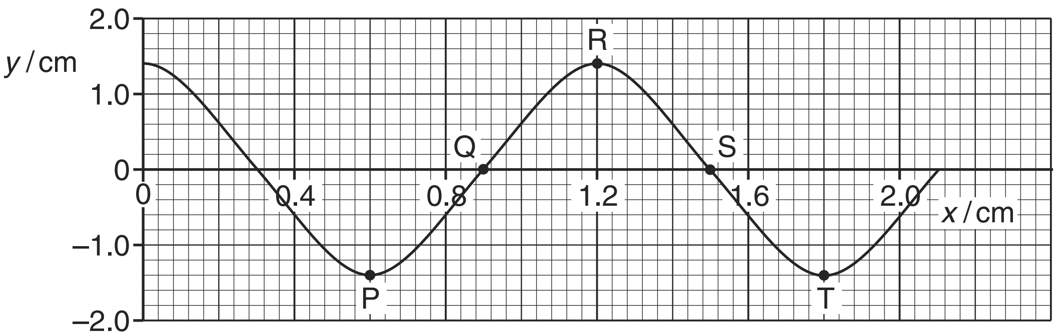


Fig. 7.1

On Fig. 7.1, five points are labelled.

Use Fig. 7.1 to state any two points having a phase difference of

(i) zero,

....[1]

(ii) 270°.

....[1]

(c) The frequency of the wave in **(b)** is 15 Hz.

Calculate the speed of the wave in **(b)**.

speed = ... $m s^{-1}$ [3]

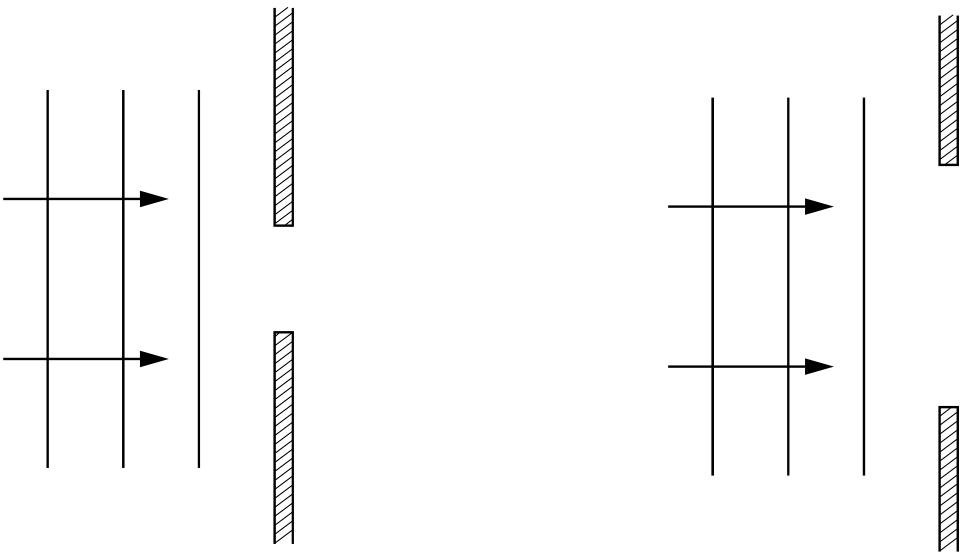
(d) Two waves of the same frequency have amplitudes 1.4 cm and 2.1 cm.

Calculate the ratio

$$\frac{\text{intensity of wave of amplitude 1.4 cm}}{\text{intensity of wave of amplitude 2.1 cm}}.$$

ratio = ... [2]

1 **(a)** Figs. 7.1(a) and (b) show plane wavefronts approaching a narrow gap and a wide gap respectively.



(a) **(b)**

Fig. 7.1

On Figs. 7.1(a) and (b), draw three successive wavefronts to represent the wave after it has passed through each of the gaps. [5]

(b) Light from a laser is directed normally at a diffraction grating, as illustrated in Fig. 7.2.

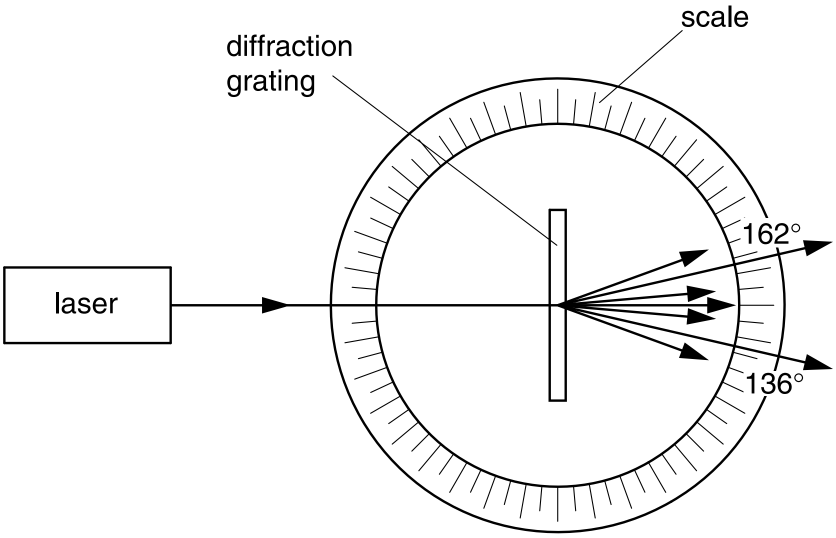


Fig. 7.2

The diffraction grating is situated at the centre of a circular scale, marked in degrees. The readings on the scale for the second order diffracted beams are 136° and 162°.

The wavelength of the laser light is 630 nm.

Calculate the spacing of the slits of the diffraction grating.

spacing = ... m [4]

(c) Suggest one reason why the fringe pattern produced by light passing through a diffraction grating is brighter than that produced from the same source with a double slit.

....

....[1]

For Examiner's Use

2 Fig. 6.1 shows wavefronts incident on, and emerging from, a double slit arrangement.

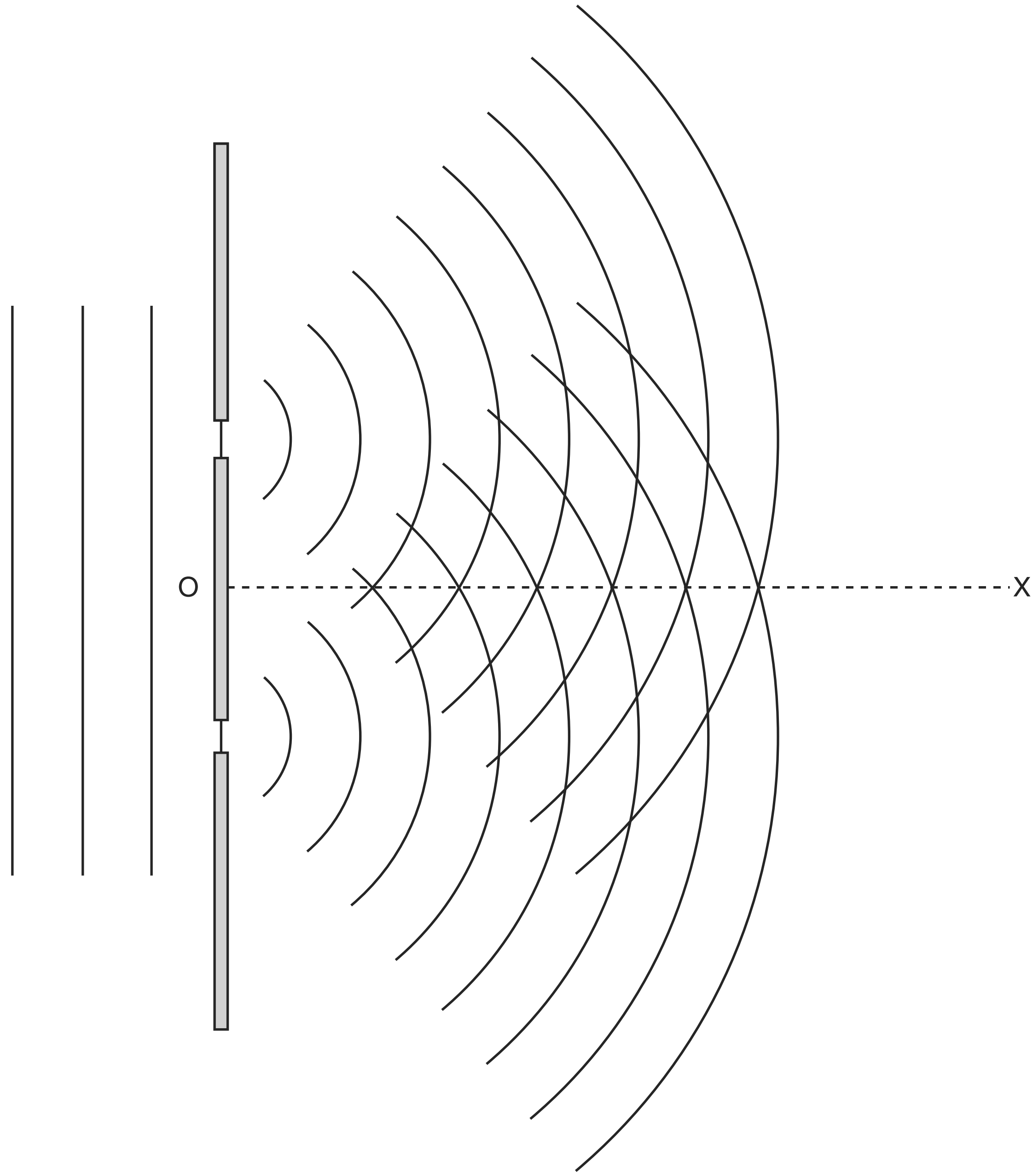


Fig. 6.1

The wavefronts represent successive crests of the wave. The line OX shows one direction along which constructive interference may be observed.

(a) State the principle of superposition.

....

....

.... [3]

(b) On Fig. 6.1, draw lines to show

(i) a second direction along which constructive interference may be observed (label this line CC),

(ii) a direction along which destructive interference may be observed (label this line DD).

[2]

(c) Light of wavelength 650 nm is incident normally on a double slit arrangement. The interference fringes formed are viewed on a screen placed parallel to and 1.2 m from the plane of the double slit, as shown in Fig. 6.2.

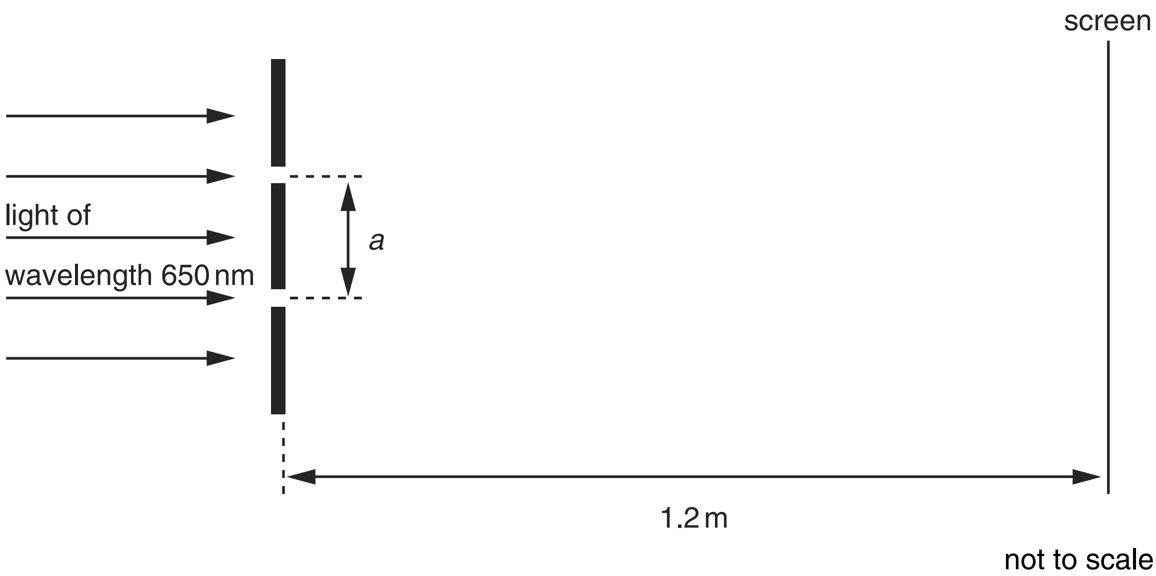


Fig. 6.2

The fringe separation is 0.70 mm.

(i) Calculate the separation *a* of the slits.

separation = ... m [3]

For Examiner's Use

(ii) The width of both slits is increased without changing their separation *a*. State the effect, if any, that this change has on

1. the separation of the fringes,

....

2. the brightness of the light fringes,

....

3. the brightness of the dark fringes.

....
[3]

For Examiner's Use

3 **(a)** Explain what is meant by the *diffraction* of a wave.

....

....

....[2]

(b) Light of wavelength 590 nm is incident normally on a diffraction grating having 750 lines per millimetre.
The diffraction grating formula may be expressed in the form

$$d\sin\theta = n\lambda.$$

(i) Calculate the value of *d*, in metres, for this grating.

d = ... m [2]

(ii) Determine the maximum value of *n* for the light incident normally on the grating.

maximum value of *n* = ... [2]

(iii) Fig. 5.1 shows incident light that is not normal to the grating.

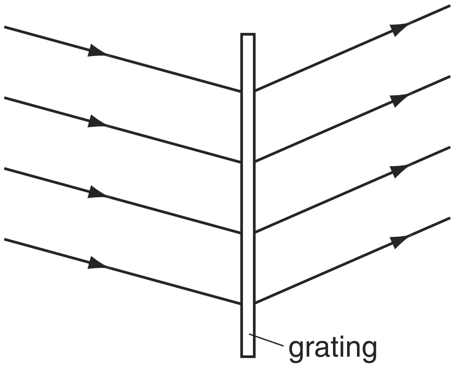


Fig. 5.1

Suggest why the diffraction grating formula, $d\sin\theta = n\lambda$, should **not** be used in this situation.

....

....[1]

(c) Light of wavelengths 590 nm and 595 nm is now incident normally on the grating.
Two lines are observed in the first order spectrum and two lines are observed in the second order spectrum, corresponding to the two wavelengths.
State two differences between the first order spectrum and the second order spectrum.

1. ....

....

2. ....

....[2]

4 A double-slit interference experiment is set up using coherent red light as illustrated in Fig. 5.1.

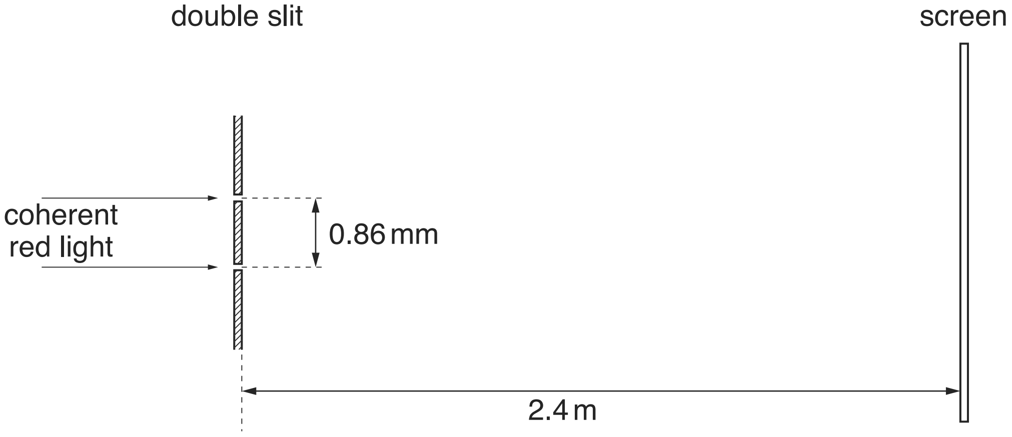


Fig. 5.1 (not to scale)

The separation of the slits is 0.86 mm.
The distance of the screen from the double slit is 2.4 m.
A series of light and dark fringes is observed on the screen.

(a) State what is meant by *coherent* light.

....

.... [1]

(b) Estimate the separation of the dark fringes on the screen.

separation = ... mm [3]

(c) Initially, the light passing through each slit has the same intensity.
The intensity of light passing through one slit is now reduced.
Suggest and explain the effect, if any, on the dark fringes observed on the screen.

....

....

.... [2]

For Examiner's Use

5 Two sources S_1 and S_2 of sound are situated 80 cm apart in air, as shown in Fig. 5.1.

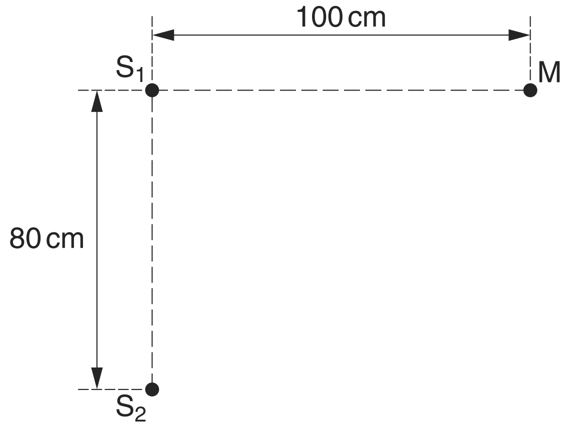


Fig. 5.1

The frequency of vibration can be varied. The two sources always vibrate in phase but have different amplitudes of vibration.

A microphone M is situated a distance 100 cm from S_1 along a line that is normal to S_1S_2.

As the frequency of S_1 and S_2 is gradually increased, the microphone M detects maxima and minima of intensity of sound.

(a) State the two conditions that must be satisfied for the intensity of sound at M to be zero.

1. ....

....

2. ....

....
[2]

(b) The speed of sound in air is 330 m s^{-1}.

The frequency of the sound from S_1 and S_2 is increased. Determine the number of minima that will be detected at M as the frequency is increased from 1.0 kHz to 4.0 kHz.

number = ... [4]

6 Light of frequency 4.8 x 10^{14} Hz is incident normally on a double slit, as illustrated in Fig. 6.1.

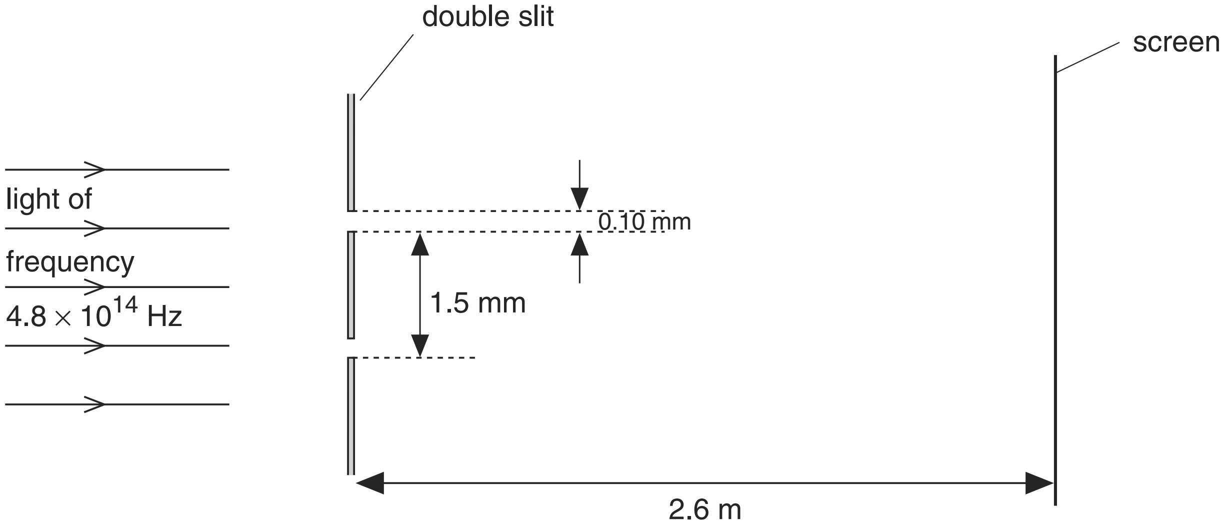


Fig. 6.1 (not to scale)

Each slit of the double slit arrangement is 0.10 mm wide and the slits are separated by 1.5 mm. The pattern of fringes produced is observed on a screen at a distance 2.6 m from the double slit.

(a) (i) Show that the width of each slit is approximately 160 times the wavelength of the incident light.

[3]

(ii) Hence explain why the pattern of fringes on the screen is seen over a *limited* area of the screen.

....

....

....

....[3]

(b) Calculate the separation of the fringes observed on the screen.

separation = ... mm [3]

(c) The intensity of the light incident on the double slit is increased. State the effect, if any, on the separation and on the appearance of the fringes.

....

....

....

....

....[3]

7 **(a)** In order that interference between waves from two sources may be observed, the waves must be coherent.

Explain what is meant by

(i) *interference*,

....

....

.... [2]

(ii) *coherence*.

....

.... [1]

(b) Red light of wavelength 644 nm is incident normally on a diffraction grating having 550 lines per millimetre, as illustrated in Fig. 4.1.

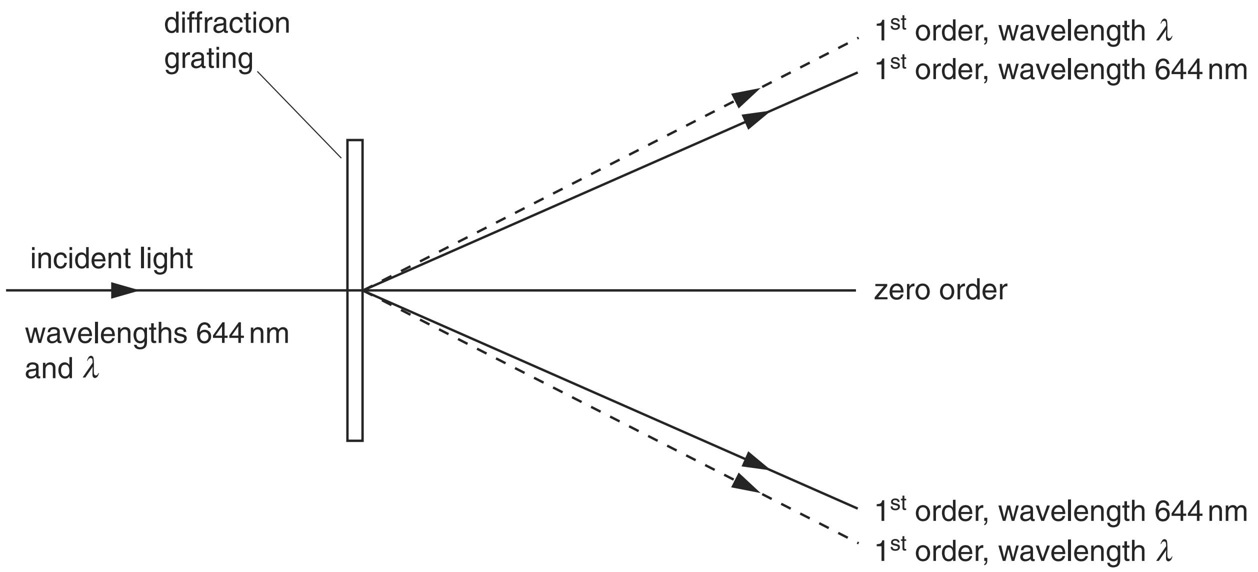


Fig. 4.1

Red light of wavelength λ is also incident normally on the grating. The first order diffracted light of both wavelengths is illustrated in Fig. 4.1.

(i) Calculate the number of orders of diffracted light of wavelength 644 nm that are visible on each side of the zero order.

For Examiner's Use

number = ... [4]

(ii) State and explain

1. whether λ is greater or smaller than 644 nm,

....

.... [1]

2. in which order of diffracted light there is the greatest separation of the two wavelengths.

....

....

.... [2]

8 **(a)** Fig. 5.1 shows the variation with time t of the displacement y of a wave W as it passes a point P. The wave has intensity I.

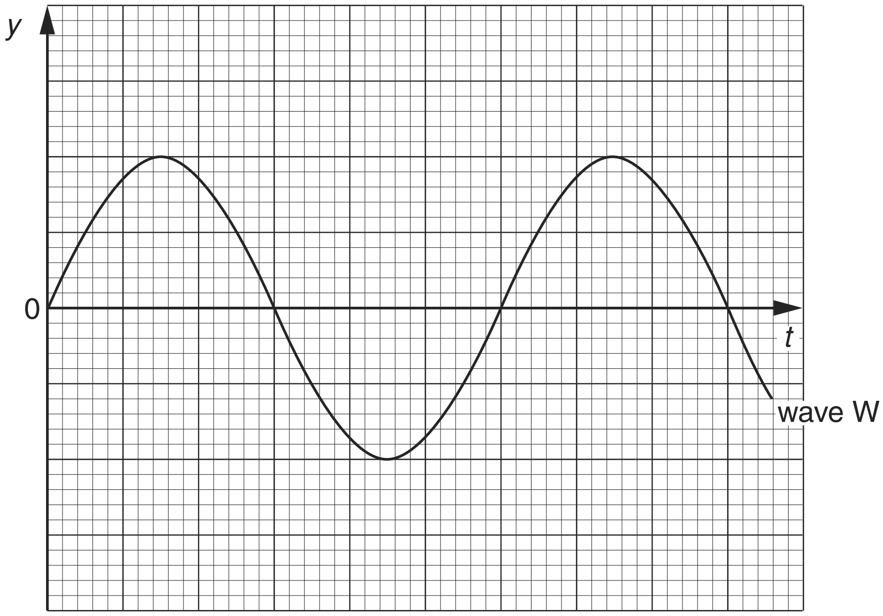


Fig. 5.1

A second wave X of the same frequency as wave W also passes point P.
This wave has intensity $\frac{1}{2}I$. The phase difference between the two waves is 60°.
On Fig. 5.1, sketch the variation with time t of the displacement y of wave X. [3]

(b) In a double-slit interference experiment using light of wavelength 540 nm, the separation of the slits is 0.700 mm. The fringes are viewed on a screen at a distance of 2.75 m from the double slit, as illustrated in Fig. 5.2 (not to scale).

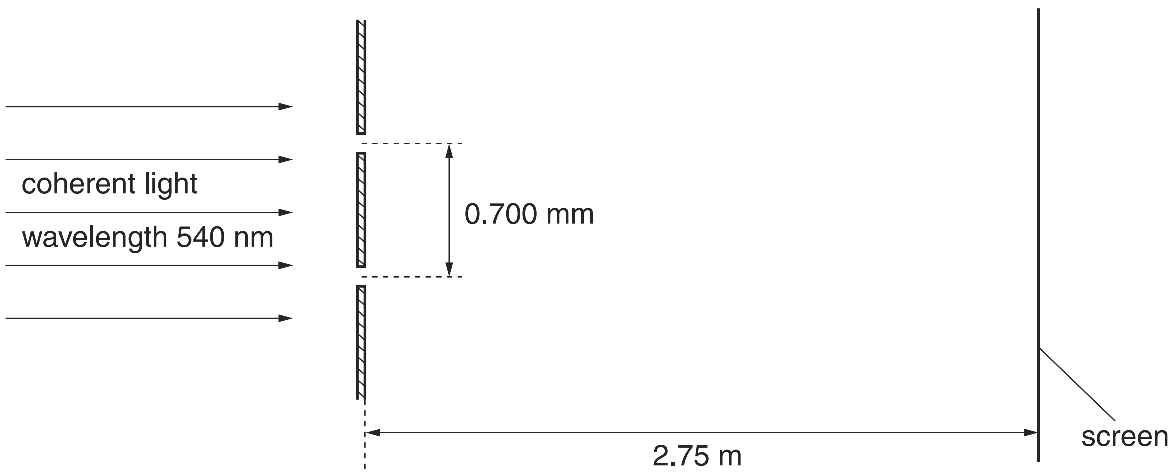


Fig. 5.2

Calculate the separation of the fringes observed on the screen.

separation = ... mm [3]

(c) State the effect, if any, on the appearance of the fringes observed on the screen when the following changes are made, separately, to the double-slit arrangement in **(b).**

(i) The width of each slit is increased but the separation remains constant.

....

....

....

.... [3]

(ii) The separation of the slits is increased.

....

....

.... [2]

For Examiner's Use

9 **(a)** Explain what is meant by the *diffraction* of a wave.

....

....

.... [2]

(b) **(i)** Outline briefly an experiment that may be used to demonstrate diffraction of a transverse wave.

....

....

.... [3]

(ii) Suggest how your experiment in **(i)** may be changed to demonstrate the diffraction of a longitudinal wave.

....

....

.... [3]

For Examiner's Use

10 **(a)** State what is meant by a *progressive wave*.

....

....

.... [2]

(b) The variation with distance x along a progressive wave of a quantity y, at a particular time, is shown in Fig. 5.1.

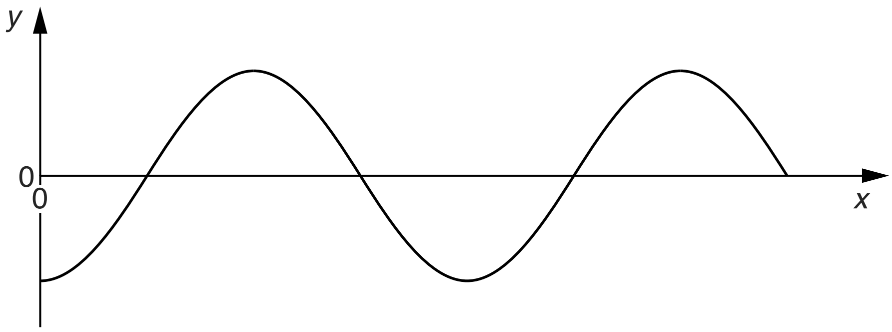


Fig. 5.1

(i) State what the quantity y could represent.

....

.... [1]

(ii) Distinguish between the quantity y for

1. a transverse wave,

....

.... [1]

2. a longitudinal wave.

....

.... [1]

(c) The wave nature of light may be demonstrated using the phenomena of diffraction and interference.

Outline how diffraction and how interference may be demonstrated using light.
In each case, draw a fully labelled diagram of the apparatus that is used and describe what is observed.

diffraction

....

....

....

interference

....

....

....
[6]

For Examiner's Use

4 **(a)** State what is meant by the *diffraction* of a wave.

....

....

.... [2]

(b) A laser produces a narrow beam of coherent light of wavelength 632 nm. The beam is incident normally on a diffraction grating, as shown in Fig. 4.1.

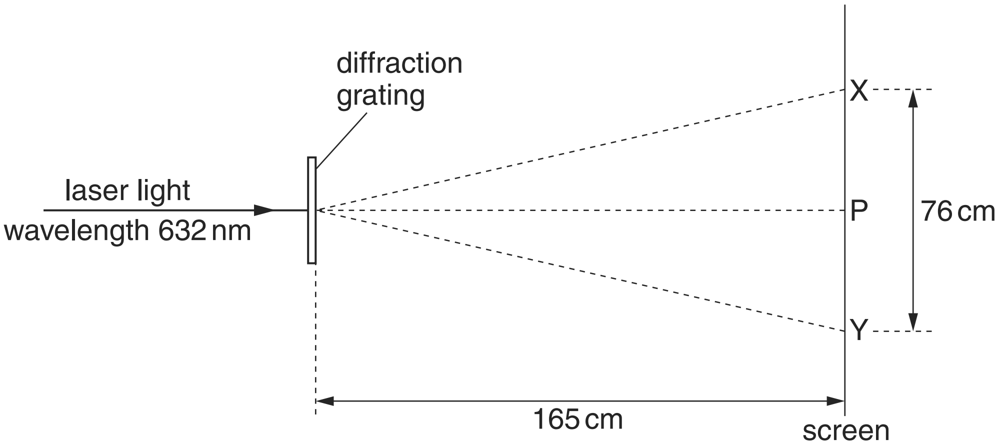


Fig. 4.1

Spots of light are observed on a screen placed parallel to the grating. The distance between the grating and the screen is 165 cm.
The brightest spot is P. The spots formed closest to P and on each side of P are X and Y.
X and Y are separated by a distance of 76 cm.
Calculate the number of lines per metre on the grating.

number per metre = ... [4]

For Examiner's Use

(c) The grating in **(b)** is now rotated about an axis parallel to the incident laser beam, as shown in Fig. 4.2.

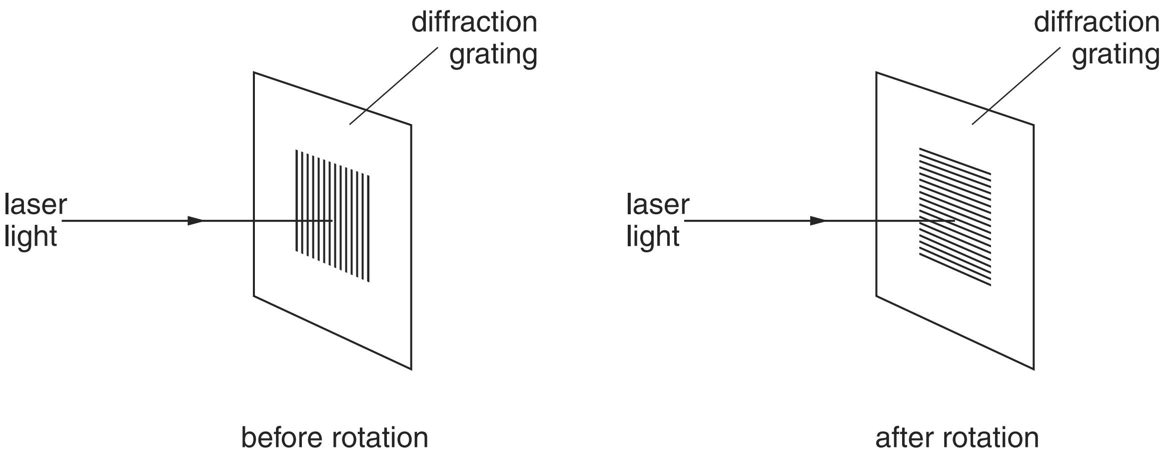


Fig. 4.2

State what effect, if any, this rotation will have on the positions of the spots P, X and Y.

....

....

....

.... [2]

(d) In another experiment using the apparatus in **(b)**, a student notices that the distances XP and PY, as shown in Fig. 4.1, are not equal.
Suggest a reason for this difference.

....

.... [1]

5 **(a)** State what is meant by the *diffraction* of a wave.

....

....

.... [2]

(b) Plane wavefronts are incident on a slit, as shown in Fig. 5.1.

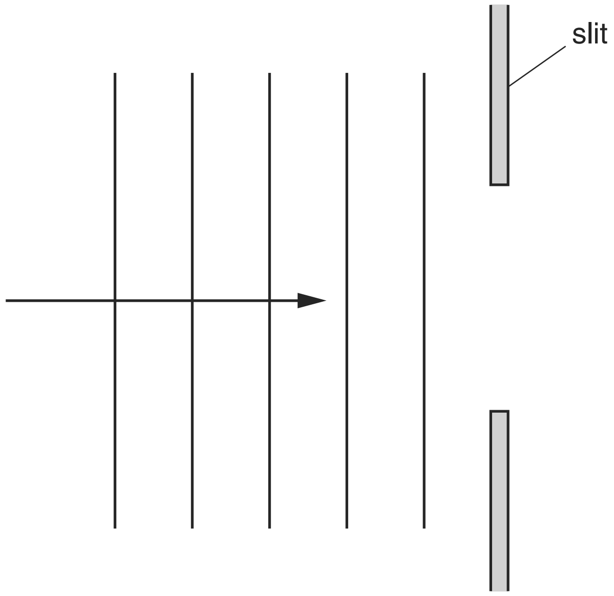


Fig. 5.1

Complete Fig. 5.1 to show four wavefronts that have emerged from the slit. [2]

(c) Monochromatic light is incident normally on a diffraction grating having 650 lines per millimetre, as shown in Fig. 5.2.

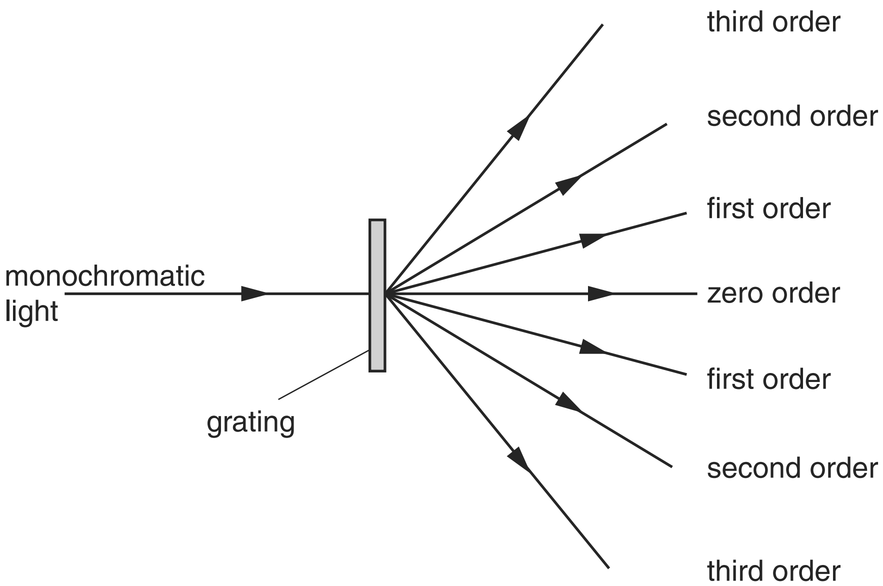


Fig. 5.2

An image (the zero order) is observed for light that has an angle of diffraction equal to zero.

For incident light of wavelength 590 nm, determine the number of orders of diffracted light that can be observed on each side of the zero order.

number = ... [3]

(d) The images in Fig. 5.2 are viewed, starting with the zero order and then with increasing order number.
State how the appearance of the images changes as the order number increases.

....

.... [1]

For Examiner's Use

6 **(a)** State the principle of superposition.

....

....

.... [2]

(b) Coherent light of wavelength 590 nm is incident normally on a double slit, as shown in Fig. 6.1.

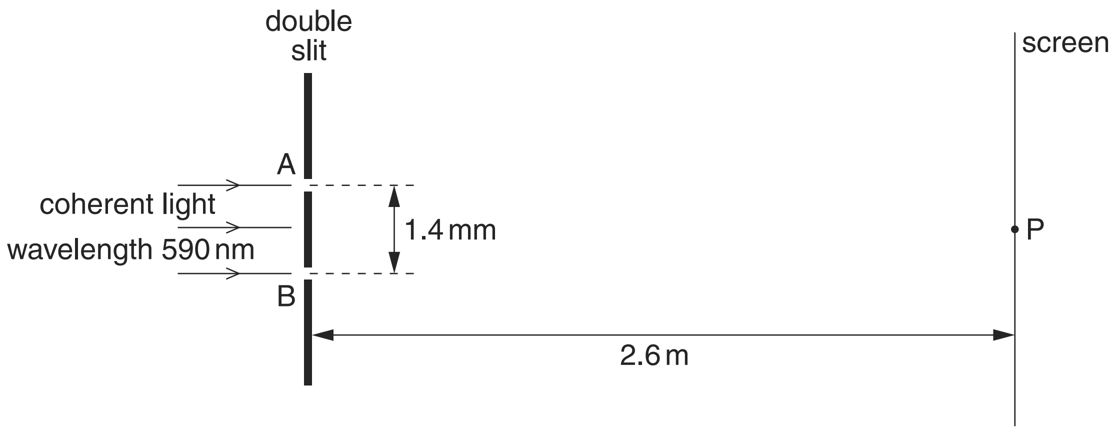


Fig. 6.1 (not to scale)

The separation of the slits A and B is 1.4 mm.
Interference fringes are observed on a screen placed parallel to the plane of the double slit.
The distance between the screen and the double slit is 2.6 m.

At point P on the screen, the path difference is zero for light arriving at P from the slits A and B.

(i) Determine the separation of bright fringes on the screen near to point P.

separation = ... mm [3]

For Examiner's Use

(ii) The variation with time of the displacement x of the light wave arriving at point P on the screen from slit A and from slit B is shown in Fig. 6.2a and Fig. 6.2b respectively.

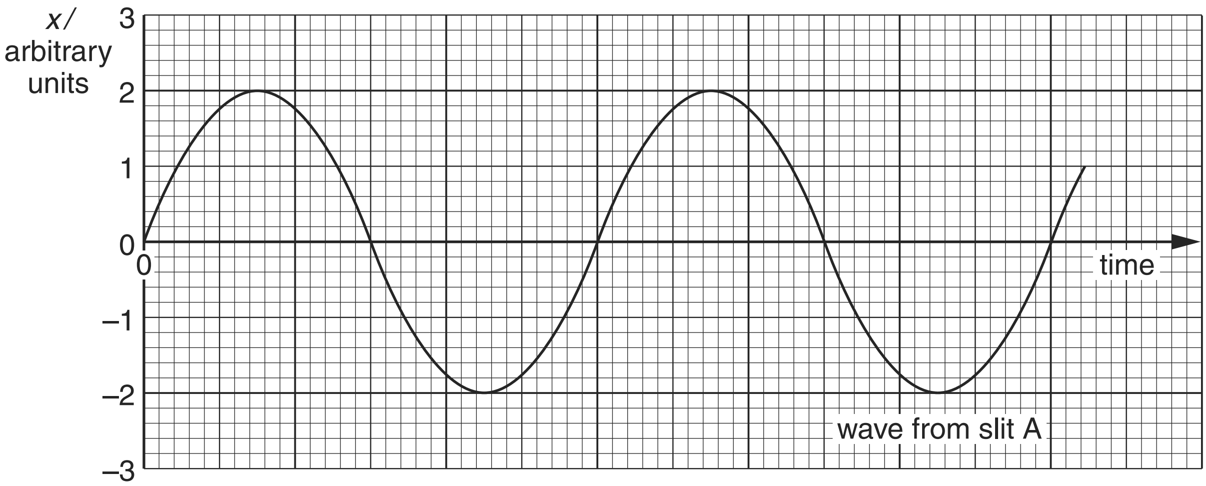


Fig. 6.2a

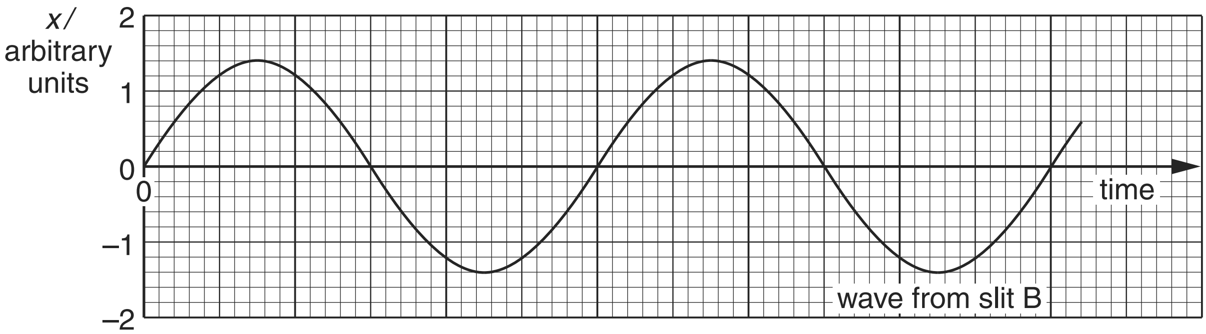


Fig. 6.2b

1. State the phase difference between waves forming the dark fringe on the screen that is next to point P.

phase difference = ... ° [1]

2. Determine the ratio

$$\frac{\text{intensity of light at a bright fringe}}{\text{intensity of light at a dark fringe}}.$$

ratio = ... [3]

6 **(a)** Apparatus used to produce interference fringes is shown in Fig. 6.1. The apparatus is not drawn to scale.

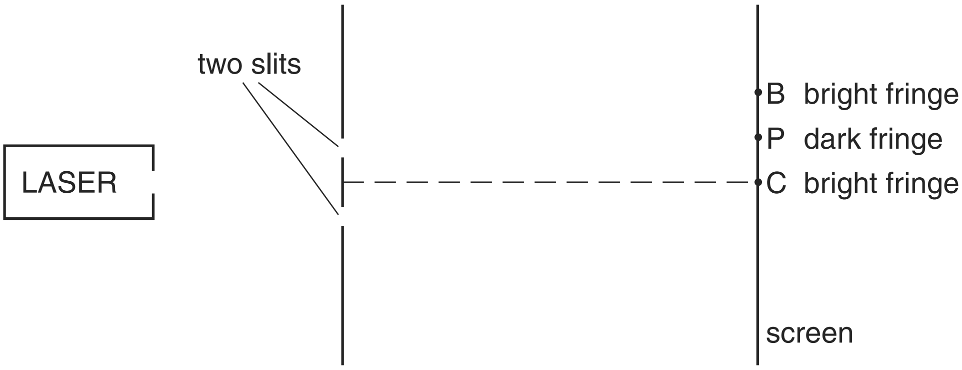


Fig. 6.1 (not to scale)

Laser light is incident on two slits. The laser provides light of a single wavelength. The light from the two slits produces a fringe pattern on the screen. A bright fringe is produced at C and the next bright fringe is at B. A dark fringe is produced at P.

(i) Explain why one laser and two slits are used, instead of two lasers, to produce a visible fringe pattern on the screen.

....

.... [1]

(ii) State the phase difference between the waves that meet at

1. B .... [1]

2. P .... [1]

(iii) **1.** State the *principle of superposition*.

....

....

.... [2]

2. Use the principle of superposition to explain the dark fringe at P.

....

.... [1]

For Examiner's Use

(b) In Fig. 6.1 the distance from the two slits to the screen is 1.8 m. The distance CP is 2.3 mm and the distance between the slits is 0.25 mm.
Calculate the wavelength of the light provided by the laser.

wavelength = ... nm [3]

7 **(a)** Explain the term *interference*.

....

....

.... [1]

(b) A ripple tank is used to demonstrate interference between water waves.

Describe

(i) the apparatus used to produce two sources of coherent waves that have circular wavefronts,

....

....

....

.... [2]

(ii) how the pattern of interfering waves may be observed.

....

....

....

.... [2]

For Examiner's Use

(c) A wave pattern produced in **(b)** is shown in Fig. 7.1.

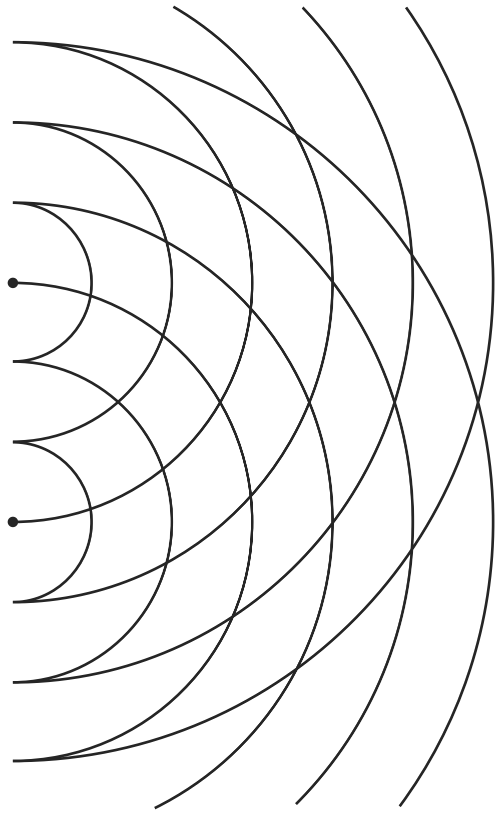


Fig. 7.1

Solid lines on Fig. 7.1 represent crests.

On Fig. 7.1,

(i) draw two lines to show where maxima would be seen (label each of these lines with the letter X), [1]

(ii) draw one line to show where minima would be seen (label this line with the letter N). [1]

For Examiner's Use

6 **(a)** State the *principle of superposition*.

....

....

.... [2]

(b) An arrangement that can be used to determine the speed of sound in air is shown in Fig. 6.1.

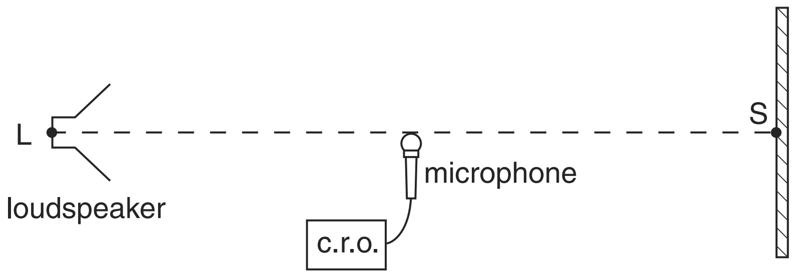


Fig. 6.1

Sound waves of constant frequency are emitted from the loudspeaker L and are reflected from a point S on a hard surface.
The loudspeaker is moved away from S until a stationary wave is produced.

Explain how sound waves from L give rise to a stationary wave between L and S.

....

....

.... [2]

(c) A microphone connected to a cathode ray oscilloscope (c.r.o.) is positioned between L and S as shown in Fig. 6.1. The trace obtained on the c.r.o. is shown in Fig. 6.2.

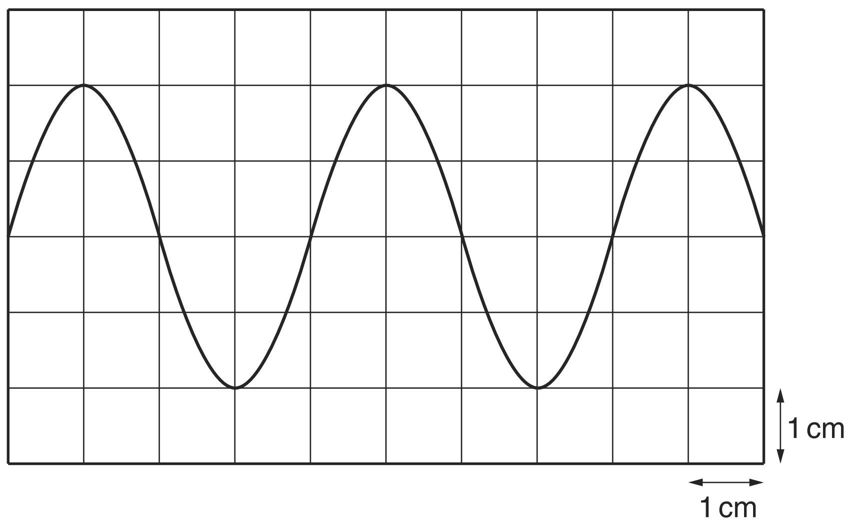


Fig. 6.2

The time-base setting on the c.r.o. is $0.10\,\text{ms}\,\text{cm}^{-1}$.

For Examiner's Use

(i) Calculate the frequency of the sound wave.

frequency = ... Hz [2]

(ii) The microphone is now moved towards S along the line LS. When the microphone is moved 6.7 cm, the trace seen on the c.r.o. varies from a maximum amplitude to a minimum and then back to a maximum.

1. Use the properties of stationary waves to explain these changes in amplitude.

....

....

....[1]

2. Calculate the speed of sound.

speed of sound = ... m s^{-1} [3]

Please turn over for Question 7.

6 **(a)** A laser is used to produce an interference pattern on a screen, as shown in Fig. 6.1.

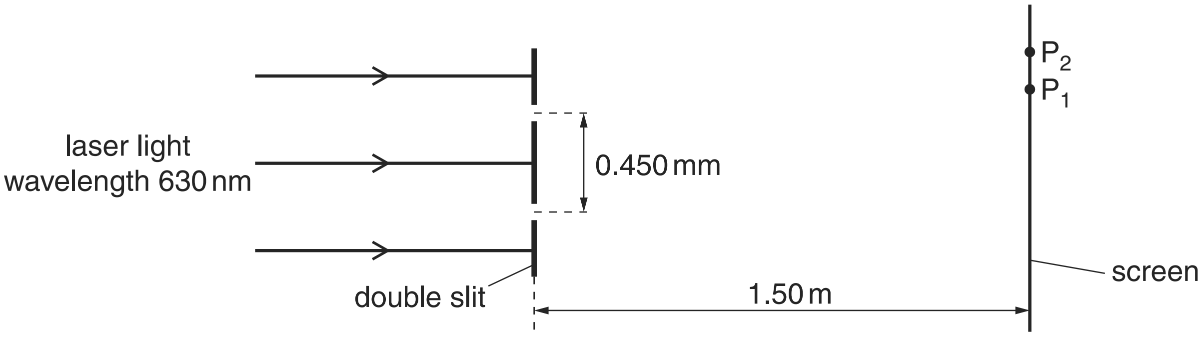


Fig. 6.1 (not to scale)

The laser emits light of wavelength 630 nm. The slit separation is 0.450 mm. The distance between the slits and the screen is 1.50 m. A maximum is formed at P_1 and a minimum is formed at P_2.
Interference fringes are observed only when the light from the slits is coherent.

(i) Explain what is meant by *coherence*.

....

....

.... [2]

(ii) Explain how an interference maximum is formed at P_1.

....

.... [1]

(iii) Explain how an interference minimum is formed at P_2.

....

.... [1]

(iv) Calculate the fringe separation.

fringe separation = ... m [3]

(b) State the effects, if any, on the fringes when the amplitude of the waves incident on the double slits is increased.

....

....

....

.... [3]

For Examiner's Use

6 **(a)** Use the principle of superposition to explain the formation of a stationary wave.

For Examiner's Use

....

....

....

....

.... [3]

(b) Describe an experiment to determine the wavelength of sound in air using stationary waves. Include a diagram of the apparatus in your answer.

....

....

....

....

....

....

....

....

....

.... [3]

For Examiner's Use

(c) The variation with distance x of the intensity I of a stationary sound wave is shown in Fig. 6.1.

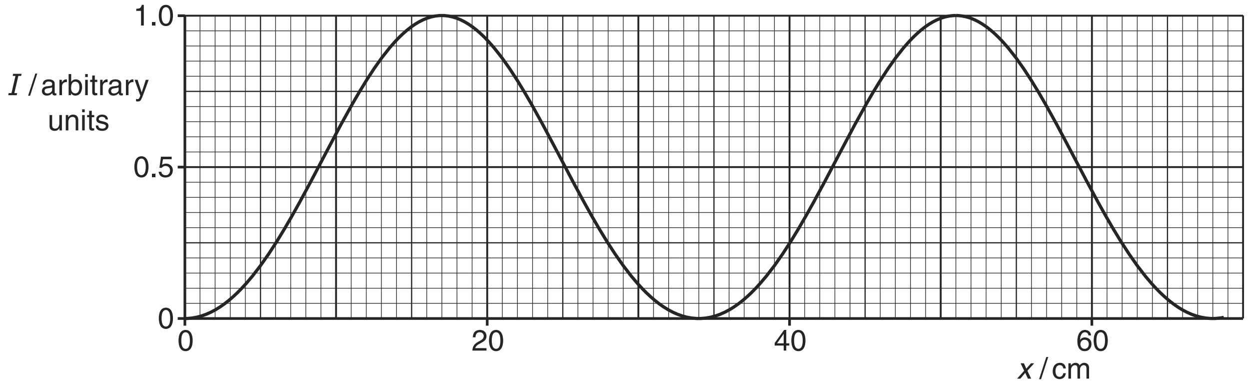


Fig. 6.1

(i) On the x-axis of Fig. 6.1, indicate the positions of all the nodes and antinodes of the stationary wave. Label the nodes **N** and the antinodes **A**. [1]

(ii) The speed of sound in air is $340\,\text{m}\,\text{s}^{-1}$.

Use Fig. 6.1 to determine the frequency of the sound wave.

frequency = ... Hz [3]

Please turn over for Question 7.

For Examiner's Use

6 **(a)** Monochromatic light is diffracted by a diffraction grating. By reference to this, explain what is meant by

(i) diffraction,

....

....

.... [2]

(ii) coherence,

....

....

.... [1]

(iii) superposition.

....

....

.... [1]

(b) A parallel beam of red light of wavelength 630 nm is incident normally on a diffraction grating of 450 lines per millimetre.

Calculate the number of diffraction orders produced.

number of orders = ... [3]

(c) The red light in **(b)** is replaced with blue light. State and explain the effect on the diffraction pattern.

....

....

....

....

.... [3]

For Examiner's Use

4 Fig. 4.1 shows an arrangement for producing stationary waves in a tube that is closed at one end.

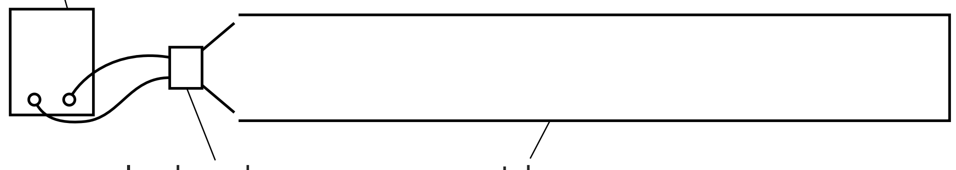


Fig. 4.1

(a) Explain how waves from the loudspeaker produce stationary waves in the tube.

....

....

....

....

.... [3]

(b) One of the stationary waves that may be formed in the tube is represented in Fig. 4.2.

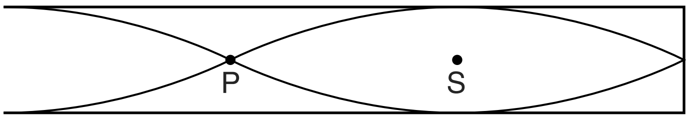


Fig. 4.2

(i) Describe the motion of the air particles in the tube at

1. point P,

.... [1]

2. point S.

.... [1]

(ii) The speed of sound in the tube is $330\,\mathrm{m\,s^{-1}}$ and the frequency of the waves from the loudspeaker is 880 Hz. Calculate the length of the tube.

length = ... m [3]

4 **(a)** Describe the diffraction of monochromatic light as it passes through a diffraction grating.

....

....

.... [2]

(b) White light is incident on a diffraction grating, as shown in Fig. 4.1.

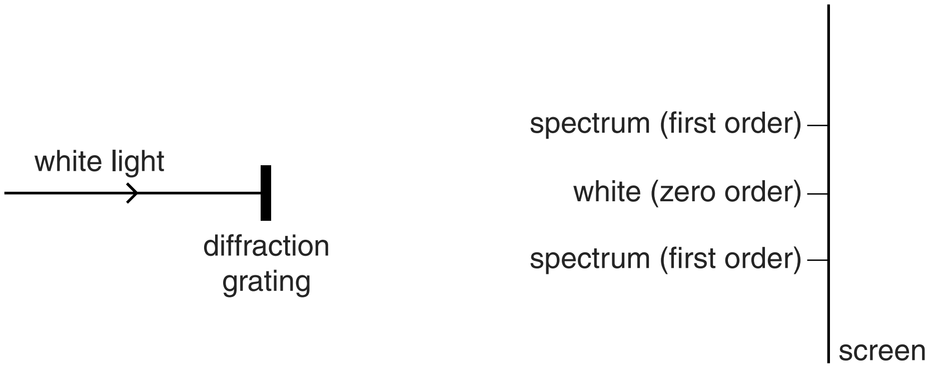


Fig. 4.1 (not to scale)

The diffraction pattern formed on the screen has white light, called zero order, and coloured spectra in other orders.

(i) Describe how the principle of superposition is used to explain

1. white light at the zero order,

....

....

.... [2]

2. the difference in position of red and blue light in the first-order spectrum.

....

....

.... [2]

For Examiner's Use

(ii) Light of wavelength 625 nm produces a second-order maximum at an angle of 61.0° to the incident direction.
Determine the number of lines per metre of the diffraction grating.

number of lines = ... m^{-1} [2]

(iii) Calculate the wavelength of another part of the visible spectrum that gives a maximum for a different order at the same angle as in **(ii)**.

wavelength = ………………………..……..nm [2]

For Examiner's Use

5 **(a)** Explain the principle of superposition.

....

....

.... [2]

(b) Sound waves travel from a source S to a point X along two paths SX and SPX, as shown in Fig. 5.1.

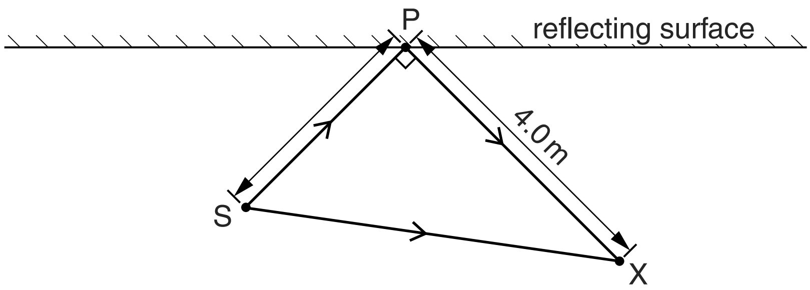


Fig. 5.1

(i) State the phase difference between these waves at X for this to be the position of

1. a minimum,

phase difference = ... unit .... [1]

2. a maximum.

phase difference = ... unit .... [1]

(ii) The frequency of the sound from S is 400 Hz and the speed of sound is 320 m s^{-1}. Calculate the wavelength of the sound waves.

wavelength = ... m [2]

(iii) The distance SP is 3.0 m and the distance PX is 4.0 m. The angle SPX is 90°. Suggest whether a maximum or a minimum is detected at point X. Explain your answer.

....

.... [2]

5 Fig. 5.1 shows a string stretched between two fixed points P and Q.

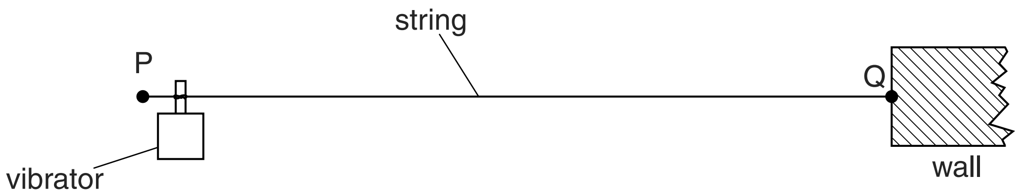


Fig. 5.1

A vibrator is attached near end P of the string. End Q is fixed to a wall. The vibrator has a frequency of 50 Hz and causes a transverse wave to travel along the string at a speed of 40 m s^{-1}.

(a) **(i)** Calculate the wavelength of the transverse wave on the string.

wavelength = ... m [2]

(ii) Explain how this arrangement may produce a stationary wave on the string.

....

....

.... [2]

(b) The stationary wave produced on PQ at one instant of time *t* is shown on Fig. 5.2. Each point on the string is at its maximum displacement.

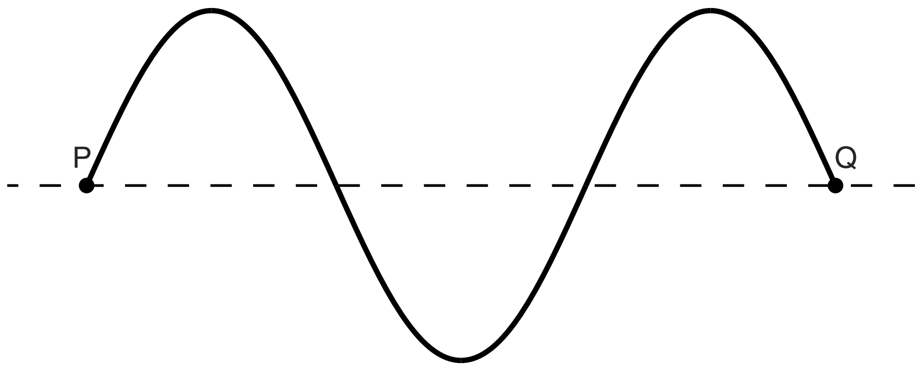


Fig. 5.2 (not to scale)

(i) On Fig. 5.2, label all the nodes with the letter **N** and all the antinodes with the letter **A**. [2]

For Examiner's Use

(ii) Use your answer in **(a)(i)** to calculate the length of string PQ.

length = ... m [1]

(iii) On Fig. 5.2, draw the stationary wave at time (t + 5.0 ms). Explain your answer.

.... [3]

For Examiner's Use

5 **(a)** State three conditions required for maxima to be formed in an interference pattern produced by two sources of microwaves.

1. ....

....

2. ....

....

3. ....

....
[3]

(b) A microwave source M emits microwaves of frequency 12 GHz. Show that the wavelength of the microwaves is 0.025 m.

[3]

(c) Two slits S_1 and S_2 are placed in front of the microwave source M described in **(b)**, as shown in Fig 5.1.

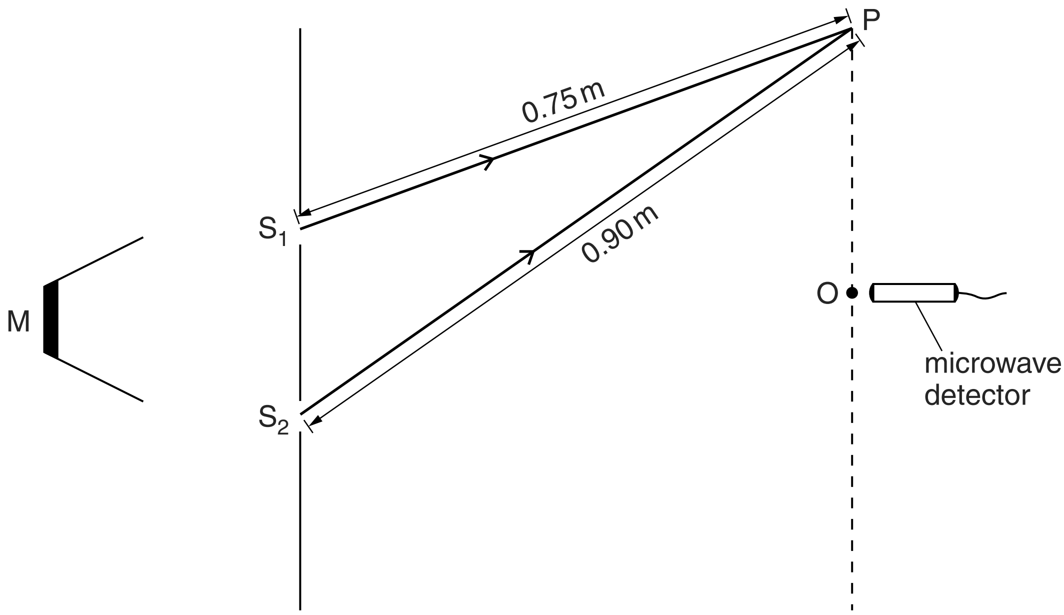


Fig. 5.1 (not to scale)

The distances S_1O and S_2O are equal. A microwave detector is moved from O to P. The distance S_1P is 0.75 m and the distance S_2P is 0.90 m.

For Examiner's Use

The microwave detector gives a maximum reading at O.

State the variation in the readings on the microwave detector as it is moved slowly along the line from O to P.

....

....

....

....

.... [3]

(d) The microwave source M is replaced by a source of coherent light.

State two changes that must be made to the slits in Fig. 5.1 in order to observe an interference pattern.

1. ....

2. ....
[2]

7 A laser is placed in front of a double slit, as shown in Fig. 7.1.

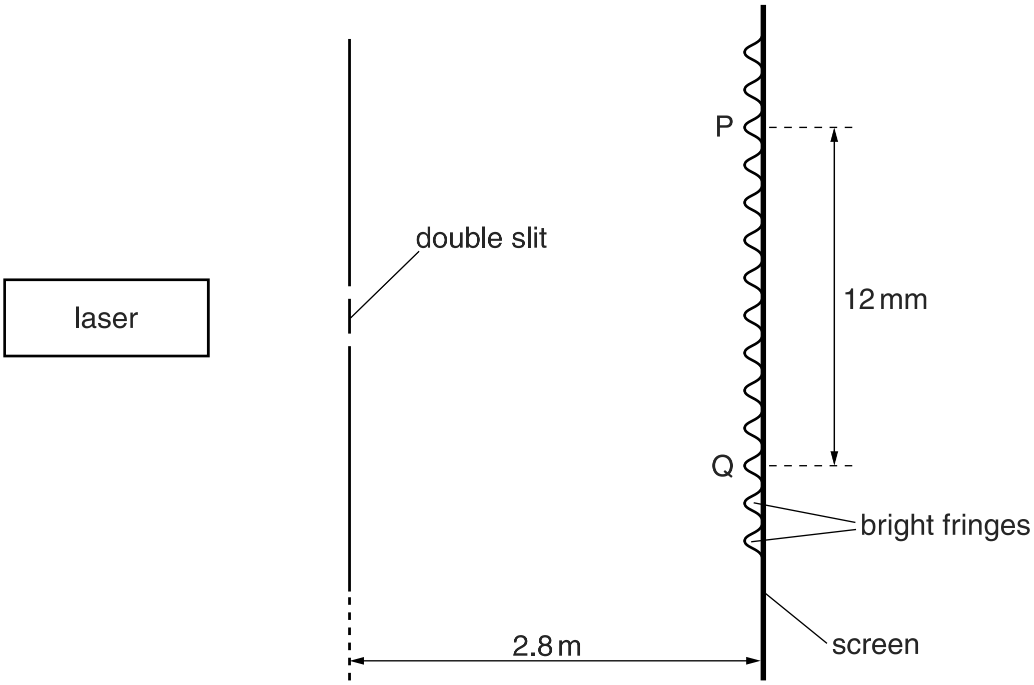


Fig. 7.1 (not to scale)

The laser emits light of frequency 670 THz. Interference fringes are observed on the screen.

(a) Explain how the interference fringes are formed.

....

....

....

....

....

.... [3]

(b) Show that the wavelength of the light is 450 nm.

[2]

(c) The separation of the maxima P and Q observed on the screen is 12 mm. The distance between the double slit and the screen is 2.8 m.

Calculate the separation of the two slits.

separation = ... m [3]

(d) The laser is replaced by a laser emitting red light. State and explain the effect on the interference fringes seen on the screen.

....

....

....

.... [2]

6 A hollow tube is used to investigate stationary waves. The tube is closed at one end and open at the other end. A loudspeaker connected to a signal generator is placed near the open end of the tube, as shown in Fig. 6.1.

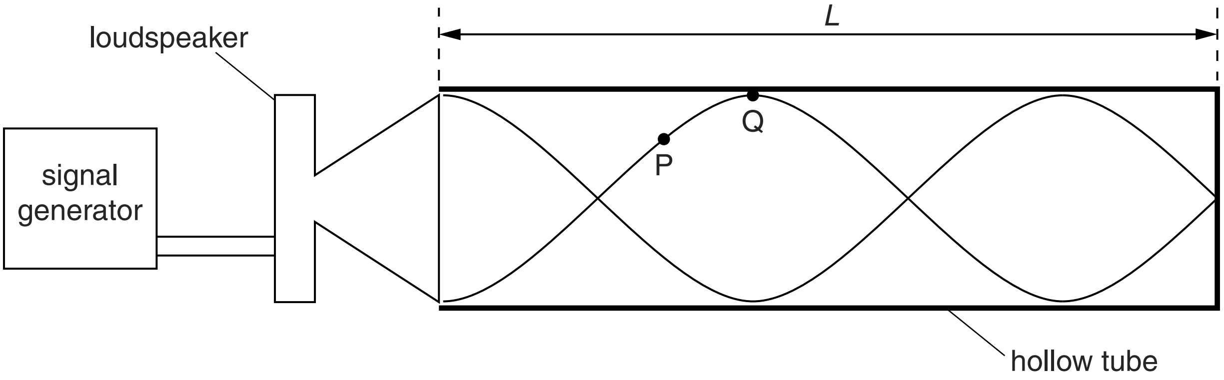


Fig. 6.1

The tube has length L. The frequency of the signal generator is adjusted so that the loudspeaker produces a progressive wave of frequency 440 Hz. A stationary wave is formed in the tube. A representation of this stationary wave is shown in Fig. 6.1.
Two points P and Q on the stationary wave are labelled.

(a) **(i)** Describe, in terms of energy transfer, the difference between a progressive wave and a stationary wave.

....

....[1]

(ii) Explain how the stationary wave is formed in the tube.

....

....

....

....[3]

(iii) State the direction of the oscillations of an air particle at point P.

....

....[1]

(b) On Fig. 6.1 label, with the letter N, the nodes of the stationary wave. [1]

(c) State the phase difference between points P and Q on the stationary wave.

phase difference = ... [1]

(d) The speed of sound in the tube is 330 m s^{-1}.

Calculate

(i) the wavelength of the sound wave,

wavelength = ... m [2]

(ii) the length L of the tube.

length = ... m [2]

8 **(a)** Explain how stationary waves are formed.

....

....

.... [2]

(b) The arrangement of apparatus used to determine the wavelength of a sound wave is shown in Fig. 8.1.

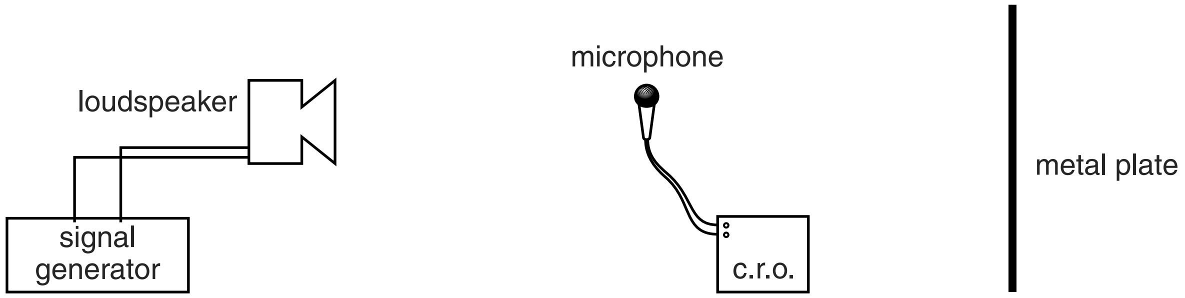


Fig. 8.1

The loudspeaker emits sound of one frequency. The microphone is connected to a cathode-ray oscilloscope (c.r.o.).
The waveform obtained on the c.r.o. for one position of the microphone is shown in Fig. 8.2.

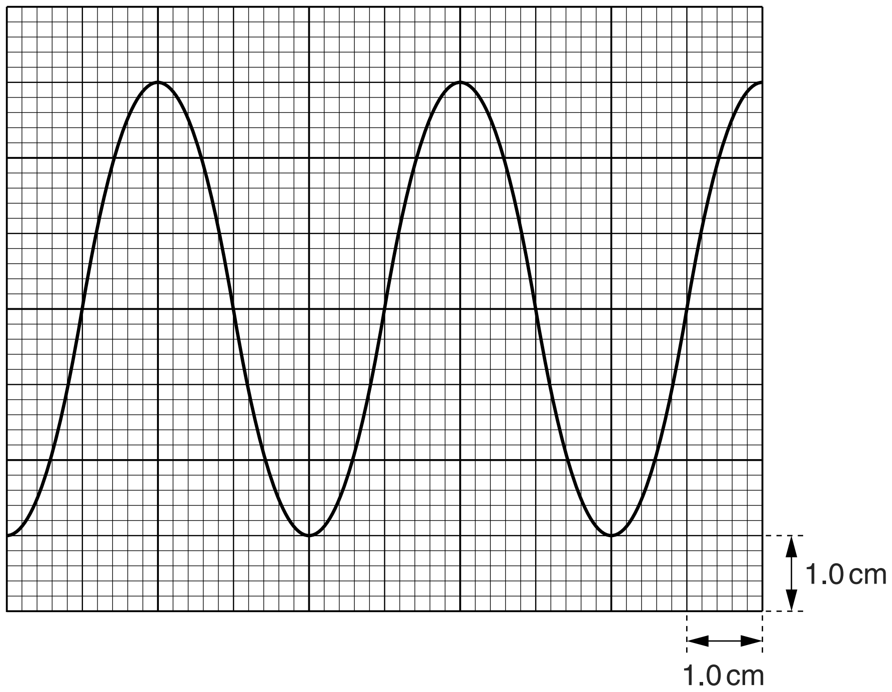


Fig. 8.2

The time-base setting of the c.r.o. is 0.20 ms cm^{-1}.

(i) Use Fig. 8.2 to show that the frequency of the sound is approximately 1300 Hz.

[2]

(ii) Explain how the apparatus is used to determine the wavelength of the sound.

....

....

....

.... [2]

(iii) The wavelength of the sound wave is 0.26 m. Calculate the speed of sound in this experiment.

speed = ... m s^{-1} [2]

6 **(a)** State one difference and one similarity between longitudinal and transverse waves.

difference: ....

....

similarity: ....

.... [2]

(b) A laser is placed in front of two slits as shown in Fig. 6.1.

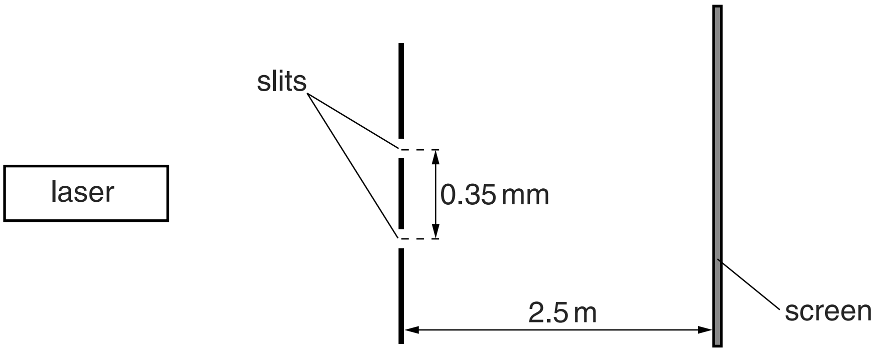


Fig. 6.1 (not to scale)

The laser emits light of wavelength 6.3×10^{-7} m.
The distance from the slits to the screen is 2.5 m. The separation of the slits is 0.35 mm.
An interference pattern of maxima and minima is observed on the screen.

(i) Explain why an interference pattern is observed on the screen.

....

....

....

....[2]

(ii) Calculate the distance between adjacent maxima.

distance = ... m [2]

(c) State and explain the effect, if any, on the distance between adjacent maxima when the laser is replaced by another laser emitting ultra-violet radiation.

....

....[1]

6 **(a)** Two overlapping waves of the same type travel in the same direction. The variation with distance x of the displacement y of each wave is shown in Fig. 6.1.

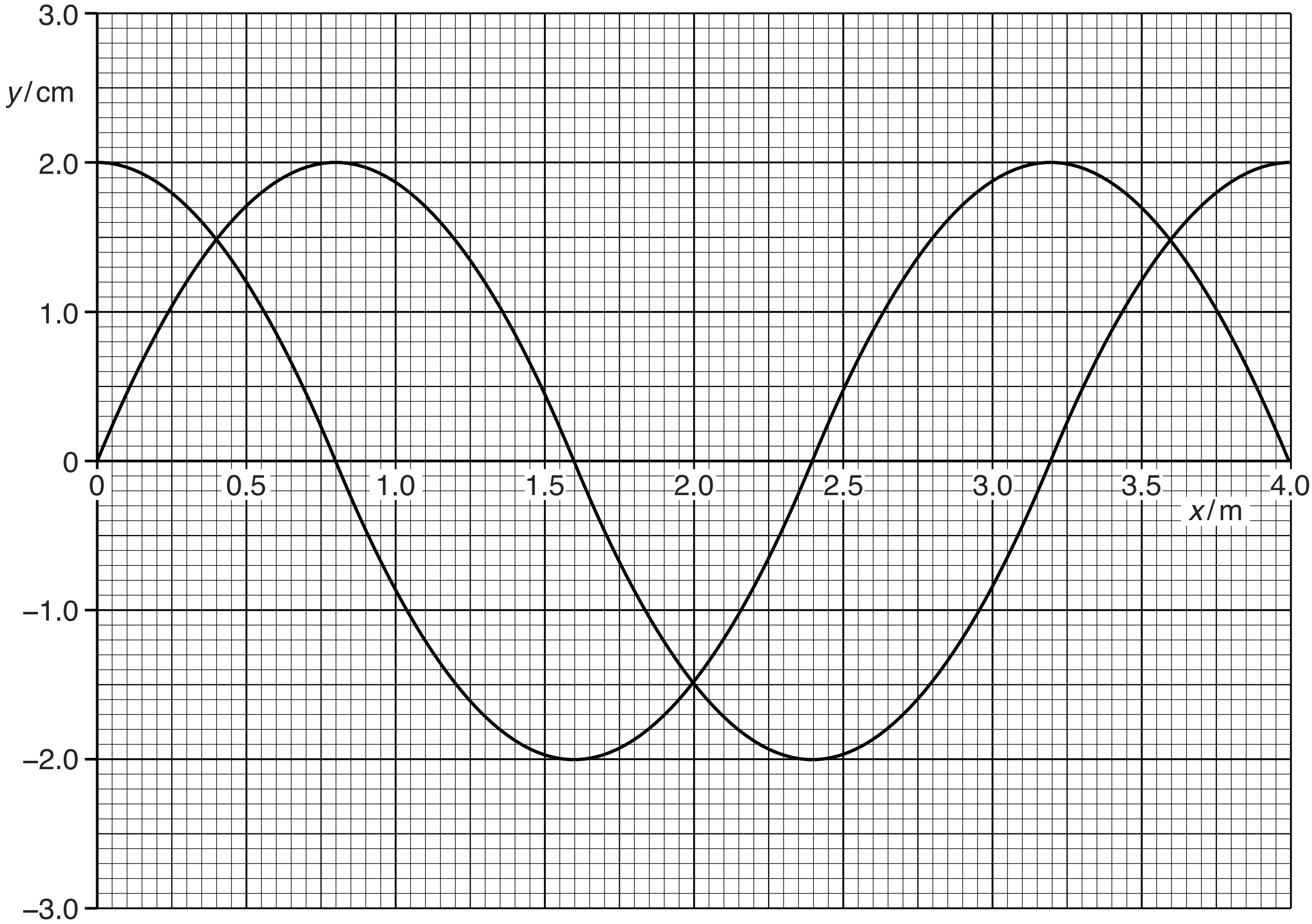


Fig. 6.1

The speed of the waves is $240\,\mathrm{m\,s^{-1}}$. The waves are coherent and produce an interference pattern.

(i) Explain the meaning of *coherence* and *interference*.

coherence: ....

....

interference: ....

.... [2]

(ii) Use Fig. 6.1 to determine the frequency of the waves.

frequency = ... Hz [2]

(iii) State the phase difference between the waves.

phase difference = ... ° [1]

(iv) Use the principle of superposition to sketch, on Fig. 6.1, the resultant wave. [2]

(b) An interference pattern is produced with the arrangement shown in Fig. 6.2.

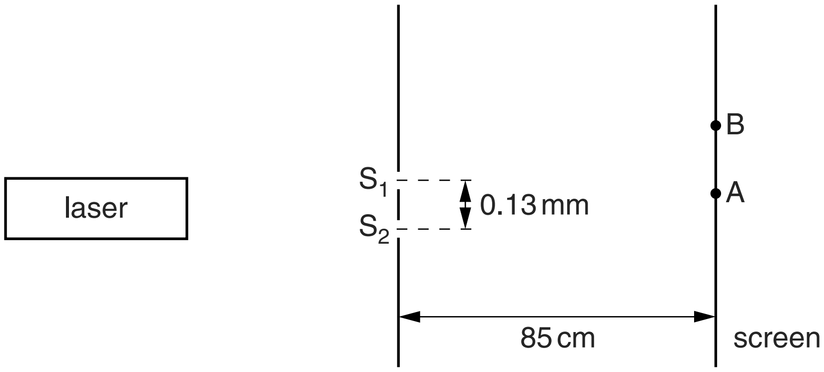


Fig. 6.2 (not to scale)

Laser light of wavelength λ of 546 nm is incident on the slits S_1 and S_2. The slits are a distance 0.13 mm apart. The distance between the slits and the screen is 85 cm.

Two points on the screen are labelled A and B. The path difference between S_1A and S_2A is zero. The path difference between S_1B and S_2B is 2.5λ. Maxima and minima of intensity of light are produced on the screen.

(i) Calculate the distance AB.

distance = ... m [3]

(ii) The laser is replaced by a laser emitting blue light. State and explain the change in the distance between the maxima observed on the screen.

....

....

....[1]

6 **(a)** State two differences between progressive waves and stationary waves.

1. ....

....

2. ....

....
[2]

(b) A source S of microwaves is placed in front of a metal reflector R, as shown in Fig. 6.1.

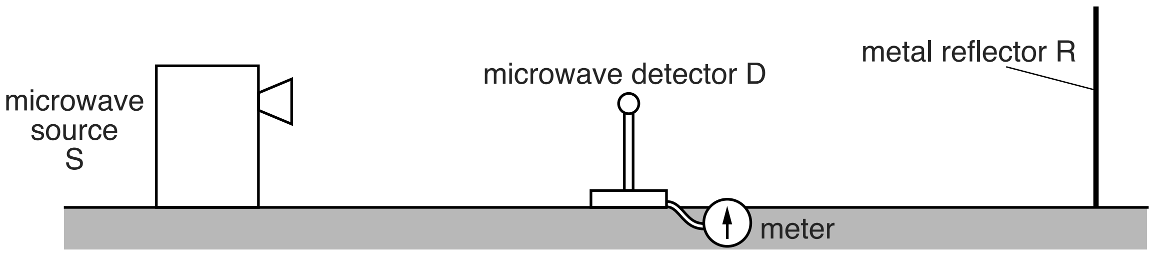


Fig. 6.1

A microwave detector D is placed between R and S.

Describe

(i) how stationary waves are formed between R and S,

....

....

....

.... [3]

(ii) how D is used to show that stationary waves are formed between R and S,

....

....

.... [2]

(iii) how the wavelength of the microwaves may be determined using the apparatus in Fig. 6.1.

....

....

.... [2]

(c) The wavelength of the microwaves in **(b)** is 2.8 cm. Calculate the frequency, in GHz, of the microwaves.

frequency = ... GHz [3]

Please turn over for Question 7.

6 **(a)** State what is meant by *diffraction* and by *interference*.

diffraction: ....

....

interference: ....

.... [3]

(b) Light from a source S_1 is incident on a diffraction grating, as illustrated in Fig. 6.1.

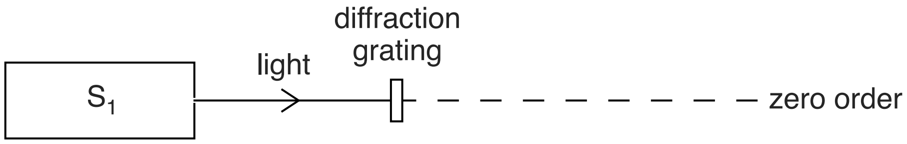


Fig. 6.1 (not to scale)

The light has a single frequency of 7.06×10^{14} Hz. The diffraction grating has 650 lines per millimetre.

Calculate the number of orders of diffracted light produced by the grating. Do not include the zero order.
Show your working.

number = ... [3]

(c) A second source S_2 is used in place of S_1. The light from S_2 has a single frequency lower than that of the light from S_1.

State and explain whether more orders are seen with the light from S_2.

....

....[1]

For Examiner's Use

1 The radiation from a radioactive source is detected using the apparatus illustrated in Fig. 9.1.

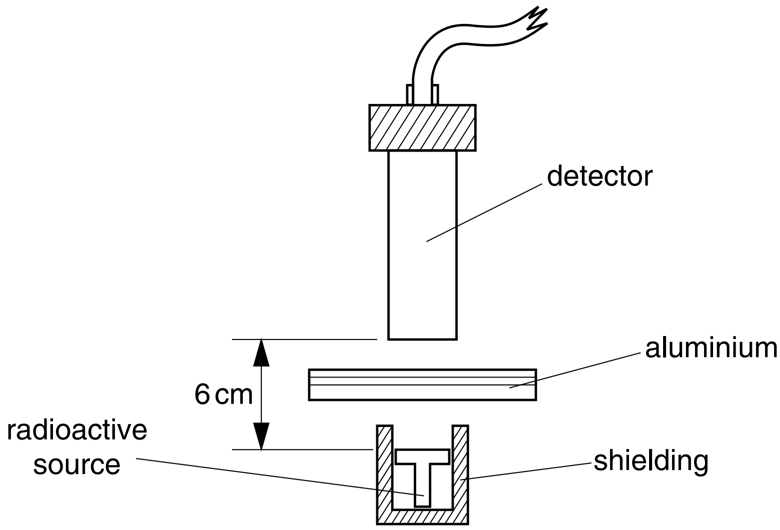


Fig. 9.1

Different thicknesses of aluminium are placed between the source and the detector. The count rate is obtained for each thickness. Fig. 9.2 shows the variation with thickness *x* of aluminium of the count rate.

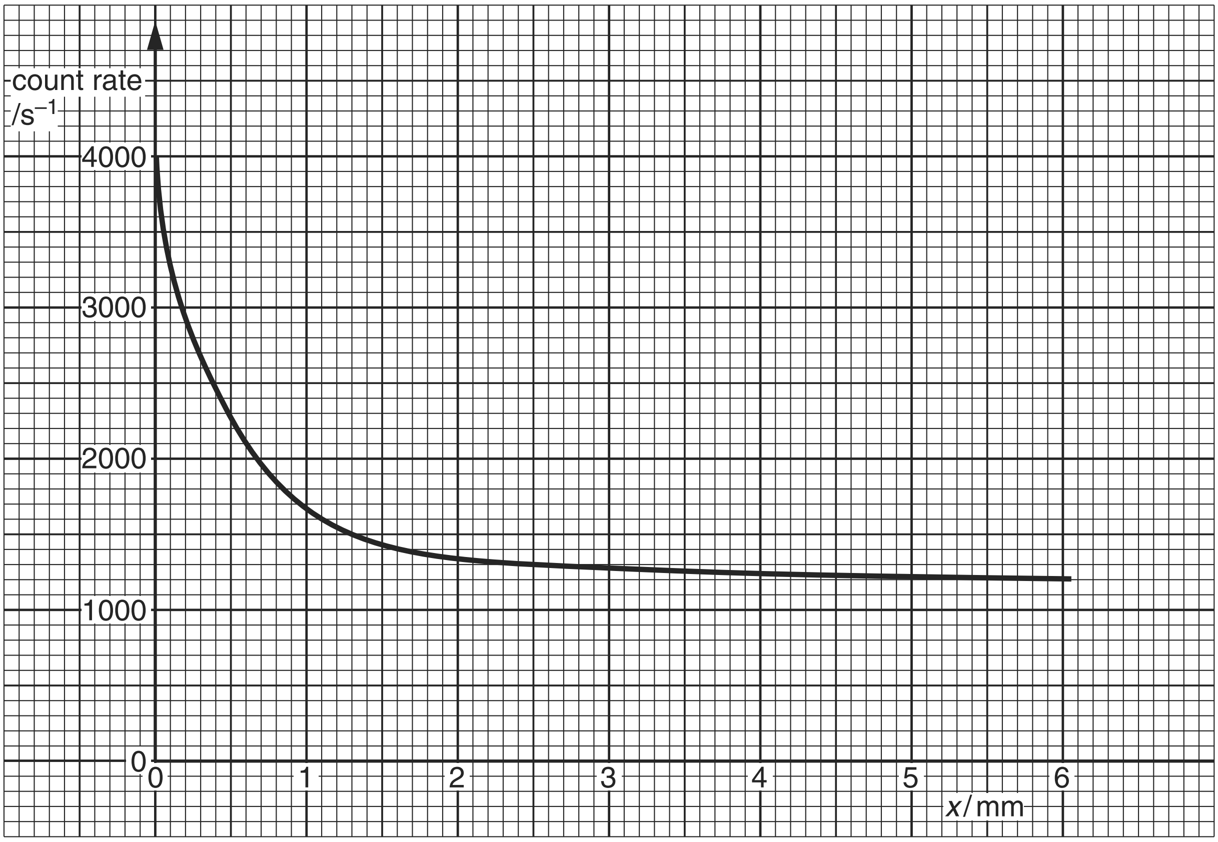


Fig. 9.2

(a) Suggest why it is not possible to detect the presence of the emission of α-particles from the source.

....

....[1]

(b) State the evidence provided on Fig. 9.2 for the emission from the source of

(i) β-particles,

....

....

....

(ii) γ-radiation.

....

....

....

[4]

2 Fig. 8.1 shows the position of Neptunium-231 ($^{231}_{93}Np$) on a diagram in which nucleon number (mass number) *A* is plotted against proton number (atomic number) *Z*.

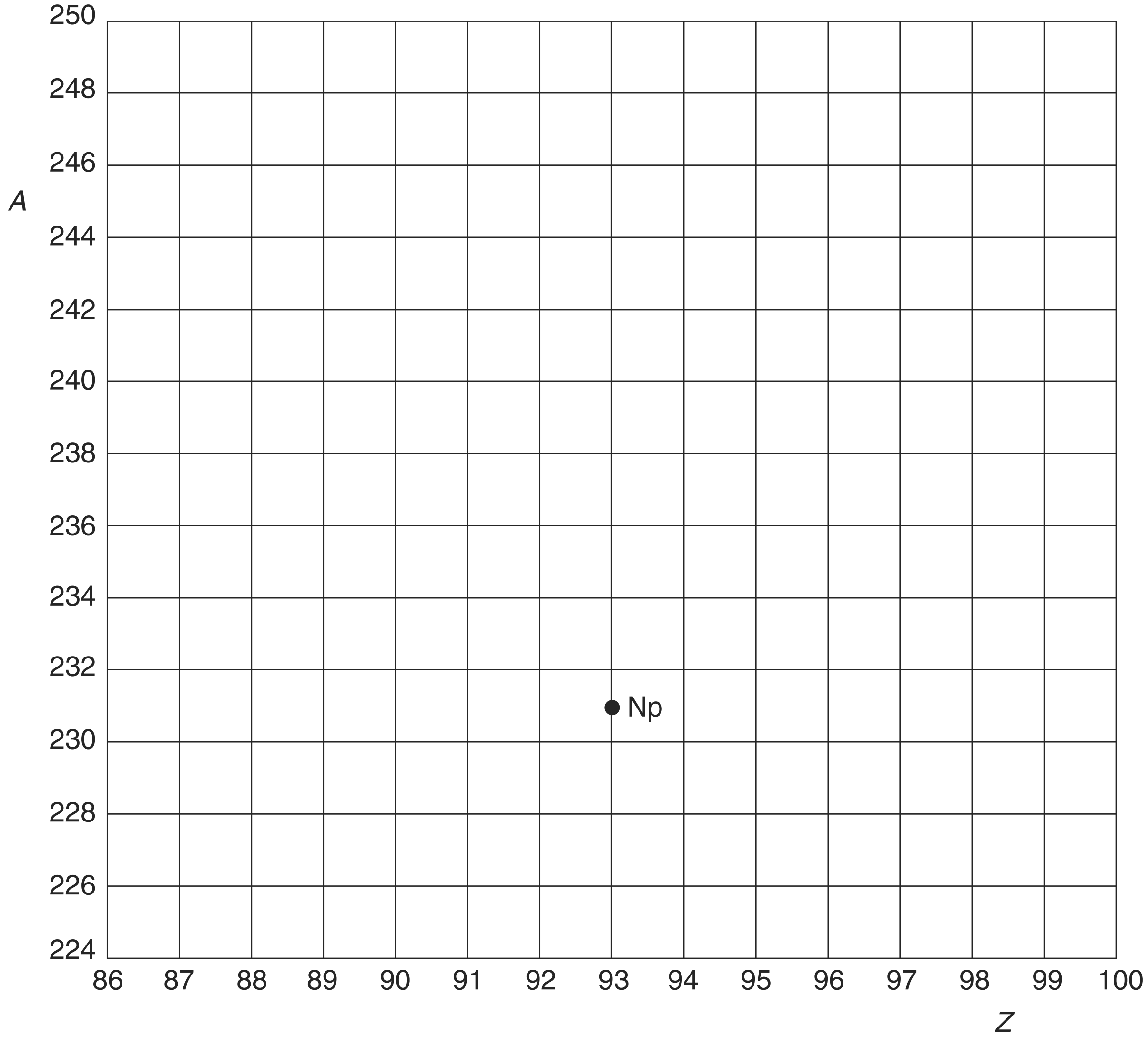


Fig. 8.1

(a) Neptunium-231 decays by the emission of an α-particle to form protactinium. On Fig. 8.1, mark with the symbol Pa the position of the isotope of protactinium produced in this decay. [1]

(b) Plutonium-243 ($^{243}_{94}Pu$) decays by the emission of a β-particle (an electron). On Fig. 8.1, show this decay by labelling the position of Plutonium-243 as Pu and the position of the daughter product as D. [2]

3 The radioactive decay of nuclei is both spontaneous and random.

Explain what is meant by

(a) *radioactive decay* of a nucleus,

....

....

.... [2]

(b) *spontaneous* decay,

....

....

.... [2]

(c) *random* decay.

....

....

.... [2]

4 The radioactive decay of a strontium (Sr) nucleus is represented in Fig. 7.1.

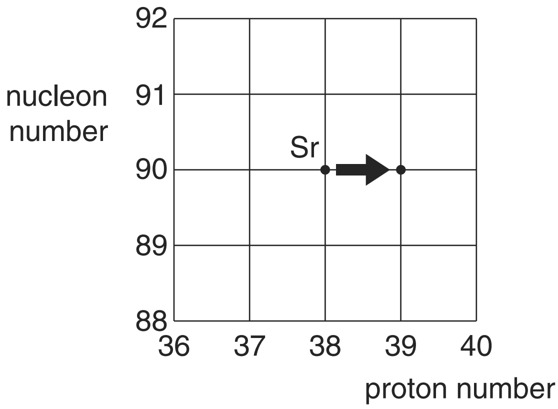


Fig. 7.1

(a) State whether Fig. 7.1 represents α-decay, β-decay or γ-decay.

.... [1]

(b) One type of radioactive decay cannot be represented on Fig. 7.1.
Identify this decay and explain why it cannot be represented.

....

....

.... [2]

5 Uranium-236 ($^{236}_{92}U$) and Uranium-237 ($^{237}_{92}U$) are both radioactive.
Uranium-236 is an α-emitter and Uranium-237 is a β-emitter.

(a) Distinguish between an α-particle and a β-particle.

....

....

....

....

....

....[4]

(b) The grid of Fig. 7.1 shows some proton numbers *Z* on the *x*-axis and the number *N* of neutrons in the nucleus on the *y*-axis.

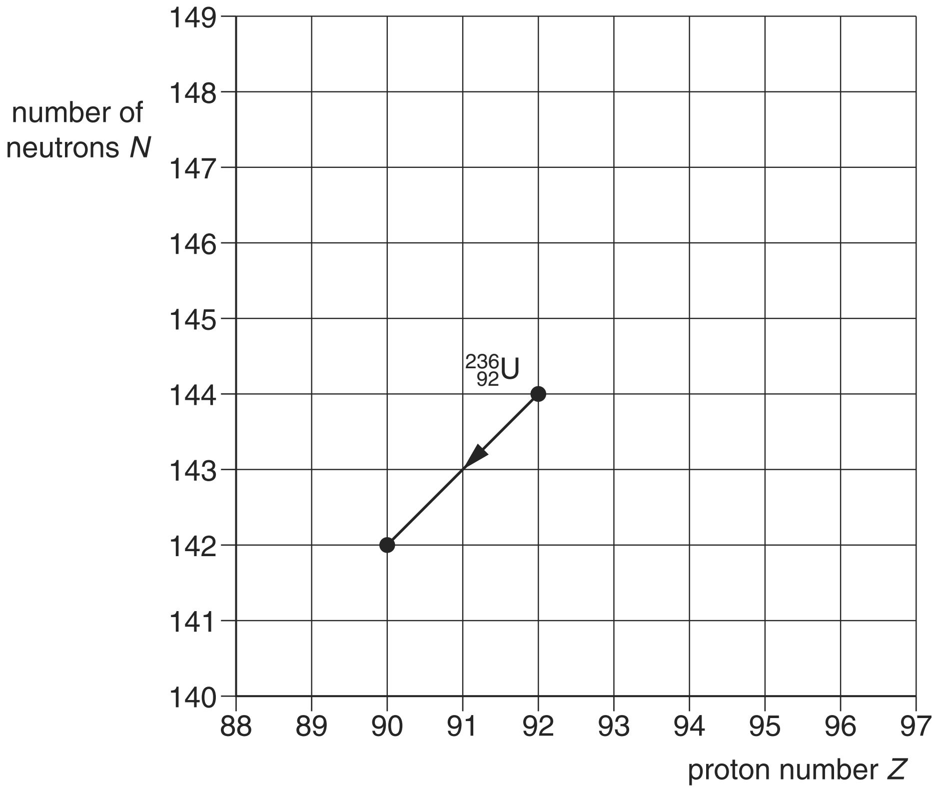


Fig. 7.1

The α-decay of Uranium-236 ($^{236}_{92}U$) is represented on the grid. This decay produces a nucleus of thorium (Th).

For Examiner's Use

(i) Write down the nuclear equation for this α-decay.

.... [2]

(ii) On Fig. 7.1, mark the position for a nucleus of

1. Uranium-237 (mark this position with the letter U),

2. Neptunium, the nucleus produced by the β-decay of Uranium-237 (mark this position with the letters Np). [2]

For Examiner's Use

6 The spontaneous and random decay of a radioactive substance involves the emission of either α-radiation or β-radiation and/or γ-radiation.

(a) Explain what is meant by *spontaneous* decay.

....

....

.... [2]

(b) State the type of emission, one in each case, that

(i) is not affected by electric and magnetic fields,

.... [1]

(ii) produces the greatest density of ionisation in a medium,

.... [1]

(iii) does not directly result in a change in the proton number of the nucleus,

.... [1]

(iv) has a range of energies, rather than discrete values.

.... [1]

7 **(a)** One isotope of gold is represented as

$$^{197}_{79}\text{Au}.$$

State the number of neutrons in one nucleus of this isotope.

number = ... [1]

(b) In an α-particle scattering experiment, an α-particle approaches an isolated gold nucleus, as illustrated in Fig. 8.1.

Fig. 8.1

Complete Fig. 8.1 to show the path of the α-particle as it passes by, and moves away from, the gold nucleus. [2]

(c) The α-particle in **(b)** is replaced by one having greater initial kinetic energy.

State what change, if any, will occur in the final deviation of the α-particle.

....[1]

8 A nucleus of an atom of francium (Fr) contains 87 protons and 133 neutrons.

(a) Write down the notation for this nuclide.

$$^{\cdots\cdots\cdots\cdots}_{\cdots\cdots\cdots\cdots}\mathrm{Fr}$$

[2]

(b) The nucleus decays by the emission of an α-particle to become a nucleus of astatine (At).

Write down a nuclear equation to represent this decay. [2]

9 The α-particle scattering experiment provided evidence for the existence of a nuclear atom.

(a) State what could be deduced from the fact that

(i) most α-particles were deviated through angles of less than 10°,

....

....

.... [2]

(ii) a very small proportion of the α-particles was deviated through angles greater than 90°.

....

....

.... [2]

(b) Fig. 7.1 shows the path AB of an α-particle as it approaches and passes by a stationary gold nucleus.

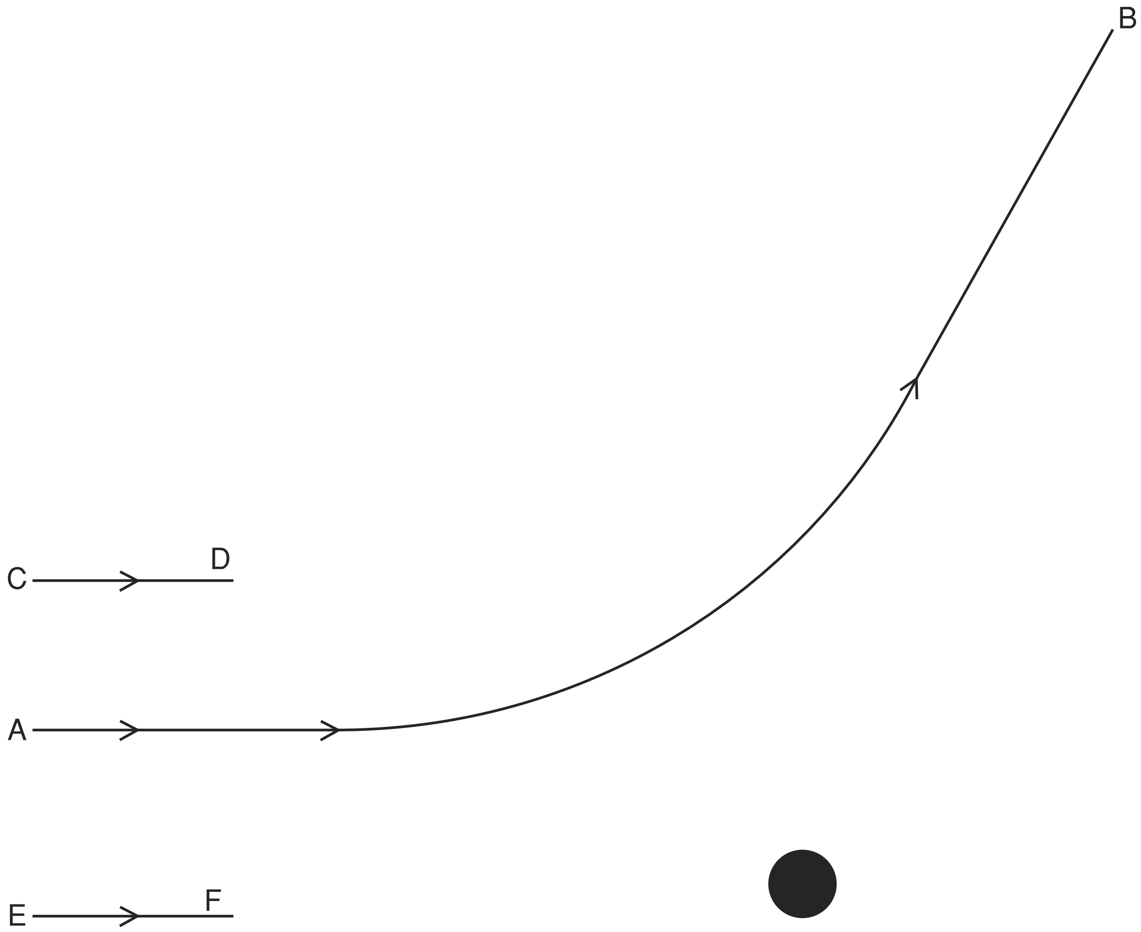


Fig. 7.1

On Fig. 7.1, draw lines (one in each case) to complete the paths of the α-particles passing by the gold nucleus when the initial direction of approach is

(i) along line CD,

(ii) along line EF.

[3]

10 **(a)** Evidence for the nuclear atom was provided by the α-particle scattering experiment. State the results of this experiment.

....

....

....

.... [2]

(b) Give estimates for the diameter of

(i) an atom,

....[1]

(ii) a nucleus.

....[1]

For Examiner's Use

11 Thoron is a radioactive gas. The variation with time t of the detected count rate C from a sample of the gas is shown in Fig. 8.1.

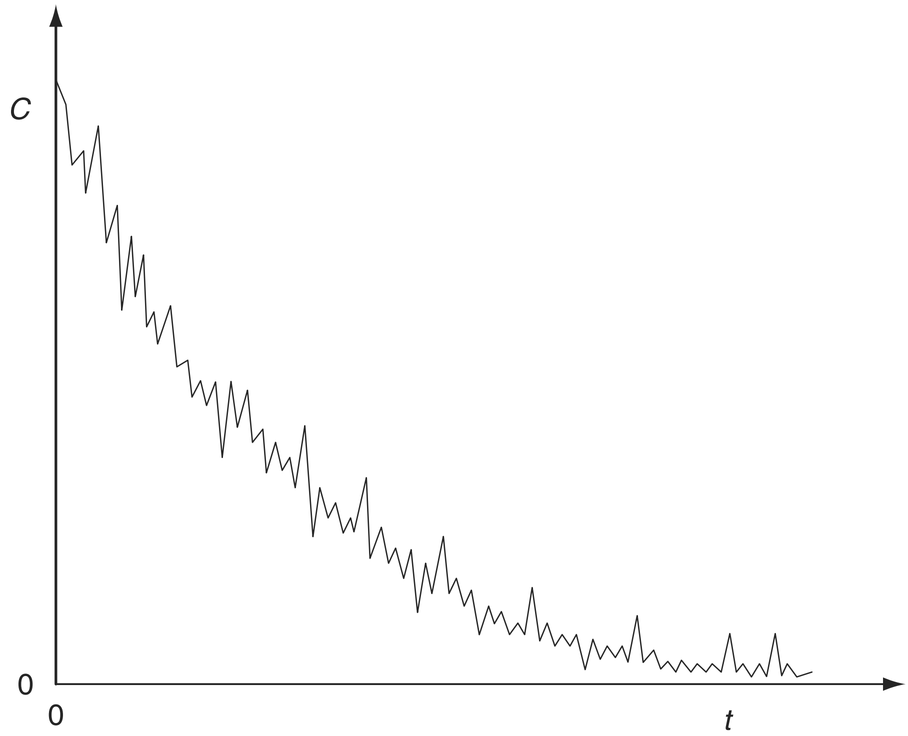


Fig. 8.1

Radioactive decay is said to be a random and spontaneous process.

(a) Explain, by reference to radioactive decay, what is meant by a *random* process.

....

....

.... [2]

(b) State the feature of Fig. 8.1 which indicates that the process is

(i) a decay process,

.... [1]

(ii) random.

.... [1]

For Examiner's Use

(c) A second similar sample of thoron is prepared but it is at a much higher temperature. The variation with time of the count rate for this second sample is determined.
State the feature of the decay curves for the two samples that suggests that radioactive decay is a spontaneous process.

....

.... [1]

12 An α-particle A approaches and passes by a stationary gold nucleus N. The path is illustrated in Fig. 7.1.

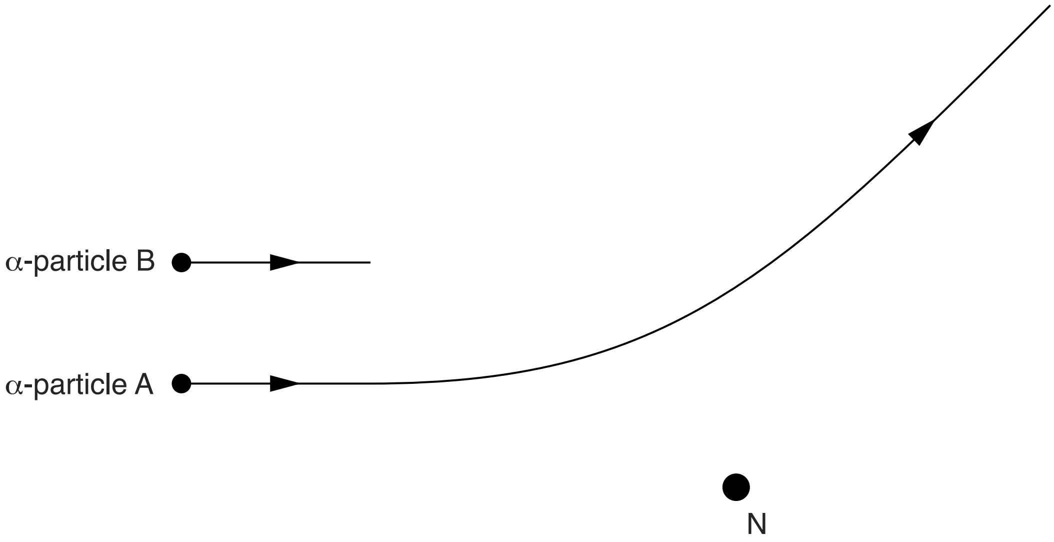


Fig. 7.1

(a) On Fig. 7.1, mark the angle of deviation *D* of this α-particle as a result of passing the nucleus N. [1]

(b) A second α-particle B has the same initial direction and energy as α-particle A. On Fig. 7.1, complete the path of α-particle B as it approaches and passes by the nucleus N. [2]

(c) State what can be inferred about atoms from the observation that very few α-particles experience large deviations.

....

....

.... [2]

(d) The nucleus N could be one of several different isotopes of gold.

Suggest, with an explanation, whether different isotopes of gold would give rise to different deviations of a particular α-particle.

....

....

.... [2]

For Examiner's Use

13 Tungsten-184 ($^{184}_{74}W$) and tungsten-185 ($^{185}_{74}W$) are two isotopes of tungsten.

Tungsten-184 is stable but tungsten-185 undergoes β-decay to form rhenium (Re).

(a) Explain what is meant by *isotopes*.

....

....

....

.... [2]

(b) The β-decay of nuclei of tungsten-185 is spontaneous and random.

State what is meant by

(i) *spontaneous* decay,

....

.... [1]

(ii) *random* decay.

....

.... [1]

(c) Complete the nuclear equation for the β-decay of a tungsten-185 nucleus.

$$^{185}_{74}W \rightarrow \text{...............} + \text{..................}$$ [2]

For Examiner's Use

7 One of the isotopes of uranium is uranium-238 ($^{238}_{92}U$).

(a) State what is meant by *isotopes*.

....

....

....[2]

(b) For a nucleus of uranium-238, state

(i) the number of protons,

number = ... [1]

(ii) the number of neutrons.

number = ... [1]

(c) A uranium-238 nucleus has a radius of 8.9×10^{-15} m.

Calculate, for a uranium-238 nucleus,

(i) its mass,

mass = ... kg [2]

(ii) its mean density.

density = ... kg m^{-3} [2]

For Examiner's Use

(d) The density of a lump of uranium is $1.9 \times 10^4\,\text{kg}\,\text{m}^{-3}$.
Using your answer to **(c)(ii)**, suggest what can be inferred about the structure of the atom.

....

....

....[2]

For Examiner's Use

7 **(a)** The radioactive decay of some nuclei gives rise to the emission of α-particles. State

(i) what is meant by an α-particle,

....[1]

(ii) two properties of α-particles.

1. ....

....

2. ....

....
[2]

(b) One possible nuclear reaction involves the bombardment of a stationary nitrogen-14 nucleus by an α-particle to form oxygen-17 and another particle.

(i) Complete the nuclear equation for this reaction.

$$^{14}_{7}\text{N} + {}^{\dots\dots}_{\dots\dots}\alpha \rightarrow {}^{17}_{8}\text{O} + \dots\dots\dots\dots\dots\dots$$ [2]

(ii) The total mass-energy of the nitrogen-14 nucleus and the α-particle is less than that of the particles resulting from the reaction. This mass-energy difference is 1.1 MeV.

1. Suggest how it is possible for mass-energy to be conserved in this reaction.

....

....[1]

2. Calculate the speed of an α-particle having kinetic energy of 1.1 MeV.

speed = ... m s^{-1} [4]

For Examiner's Use

7 One property of α-particles is that they produce a high density of ionisation of air at atmospheric pressure. In this ionisation process, a neutral atom becomes an ion pair. The ion pair is a positively-charged particle and an electron.

(a) State

(i) what is meant by an α-particle,

....

....[1]

(ii) an approximate value for the range of α-particles in air at atmospheric pressure.

range = ... cm [1]

(b) The energy required to produce an ion pair in air at atmospheric pressure is 31 eV. An α-particle has an initial kinetic energy of 8.5×10^{-13} J.

(i) Show that 8.5×10^{-13} J is equivalent to 5.3 MeV.

[1]

(ii) Calculate, to two significant figures, the number of ion pairs produced as the α-particle is stopped in air at atmospheric pressure.

number = ... [2]

(iii) Using your answer in **(a)(ii)**, estimate the average number of ion pairs produced per unit length of the track of the α-particle as it is brought to rest in air.

For Examiner's Use

number per unit length = ... [2]

For Examiner's Use

7 **(a)** Uranium (U) has at least fourteen isotopes.
Explain what is meant by *isotopes*.

....

....

.... [2]

(b) One possible nuclear reaction involving uranium is

$$^{235}_{92}\text{U} + ^{1}_{0}\text{n} \longrightarrow ^{141}_{56}\text{Ba} + ^{92}_{Z}\text{Kr} + x^{1}_{0}\text{n} + \text{energy.}$$

(i) State three quantities that are conserved in a nuclear reaction.

1. ....

....

2. ....

....

3. ....

....
[3]

(ii) For this reaction, determine the value of

1. *Z*,

Z = ... [1]

2. *x*.

x = ... [1]

For Examiner's Use

7 The results of the α-particle scattering experiment provided evidence for the existence and small size of the nucleus.

(a) State the result that provided evidence for

(i) the small size of the nucleus, compared with the atom,

....

....

.... [2]

(ii) the nucleus being charged and containing the majority of the mass of the atom.

....

....

.... [2]

(b) The α-particles in this experiment originated from the decay of a radioactive nuclide. Suggest two reasons why β-particles from a radioactive source would be inappropriate for this type of scattering experiment.

1. ....

....

2. ....

....

[2]

9 **(a)** Explain what is meant by *radioactive decay*.

....

....

.... [2]

(b) **(i)** State how the random nature of radioactive decay may be inferred from observations of the count rate.

....

.... [1]

(ii) A radioactive source has a long half-life so that, over a period of several days, its rate of decay remains constant.
State the effect, if any, of a rise in temperature on this decay rate.

.... [1]

(iii) Suggest why some radioactive sources are found to contain traces of helium gas.

....

....

.... [2]

For Examiner's Use

7 **(a)** Two isotopes of the element uranium are $^{235}_{92}U$ and $^{238}_{92}U$.

Explain the term *isotope*.

....

....

.... [2]

(b) **(i)** In a nuclear reaction, proton number and neutron number are conserved. Other than proton number and neutron number, state a quantity that is conserved in a nuclear reaction.

.... [1]

(ii) When a nucleus of uranium-235 absorbs a neutron, the following reaction may take place.

$$^{235}_{92}U + ^{a}_{b}n \longrightarrow ^{141}_{x}Ba + ^{y}_{36}Kr + 3\,^{a}_{b}n$$

State the values of *a*, *b*, *x* and *y*.

a = ...

b = ...

x = ...

y = ...

[3]

(c) When the nucleus of $^{238}_{92}U$ absorbs a neutron, the nucleus decays, emitting an α-particle. State the proton number and nucleon number of the nucleus that is formed as a result of the emission of the α-particle.

proton number = ...

nucleon number = ...

[2]

For Examiner's Use

7 **(a)** State the experimental observations that show radioactive decay is

(i) spontaneous,

....

....[1]

(ii) random.

....

....[1]

(b) On Fig. 7.1, complete the charge and mass of α-particles, β-particles and γ-radiation. Give example speeds of α-particles and γ-radiation emitted by a laboratory source.

	α-particle	β-particle	γ-radiation
charge			0
mass	4u		
speed		up to 0.99*c*	

Fig. 7.1

[3]

(c) Explain the process by which α-particles lose energy when they pass through air.

....

....

....[2]

For Examiner's Use

6 Two horizontal metal plates are separated by distance *d* in a vacuum. A potential difference *V* is applied across the plates, as shown in Fig. 6.1.

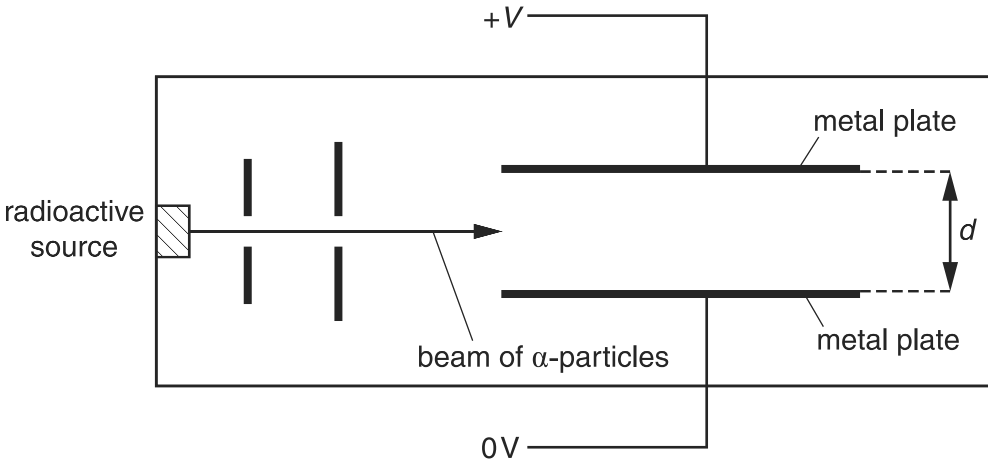


Fig. 6.1

A horizontal beam of α-particles from a radioactive source is made to pass between the plates.

(a) State and explain the effect on the deflection of the α-particles for each of the following changes:

(i) The magnitude of *V* is increased.

....

....[1]

(ii) The separation *d* of the plates is decreased.

....

....[1]

For Examiner's Use

(b) The source of α-particles is replaced with a source of β-particles.
Compare, with a reason in each case, the effect of each of the following properties on the deflections of α- and β-particles in a uniform electric field:

(i) charge

....

....

.... [2]

(ii) mass

....

....

.... [2]

(iii) speed

....

....

.... [1]

(c) The electric field gives rise to an acceleration of the α-particles and the β-particles. Determine the ratio

$$\frac{\text{acceleration of the } \alpha\text{-particles}}{\text{acceleration of the } \beta\text{-particles}}.$$

ratio = ... [3]

For Examiner's Use

7 **(a)** The spontaneous decay of polonium is shown by the nuclear equation

$$^{210}_{84}\text{Po} \rightarrow ^{206}_{82}\text{Pb} + \text{X}.$$

(i) State the composition of the nucleus of X.

....

....[1]

(ii) The nuclei X are emitted as radiation. State two properties of this radiation.

1. ....

....

2. ....

....

[2]

(b) The mass of the polonium (Po) nucleus is greater than the combined mass of the nuclei of lead (Pb) and X. Use a conservation law to explain qualitatively how this decay is possible.

....

....

....[3]

For Examiner's Use

7 **(a)** A nuclear reaction occurs when a uranium-235 nucleus absorbs a neutron. The reaction may be represented by the equation:

$$^{235}_{92}U + ^{W}_{X}n \rightarrow ^{93}_{37}Rb + ^{141}_{Z}Cs + Y^{W}_{X}n$$

State the number represented by the letter

W ....

X ....

Y ....

Z ....

[3]

(b) The sum of the masses on the left-hand side of the equation in **(a)** is not the same as the sum of the masses on the right-hand side.

Explain why mass seems not to be conserved.

....

....

....[2]

For Examiner's Use

7 A radioactive source emits α-radiation and γ-radiation.

Explain how it may be shown that the source does not emit β-radiation using

(a) the absorption properties of the radiation,

....

....

....

....

.... [2]

(b) the effects of a magnetic field on the radiation.

....

....

....

....

.... [2]

6 **(a)** β-radiation is emitted during the spontaneous radioactive decay of an unstable nucleus.

(i) State the nature of a β-particle.

.... [1]

(ii) State two properties of β-radiation.

1. ....

2. ....
[2]

(iii) Explain the meaning of *spontaneous radioactive decay*.

....

.... [1]

(b) The following equation represents the decay of a nucleus of hydrogen-3 by the emission of a β-particle.

Complete the equation.

$$^{3}_{1}\text{H} \rightarrow \,^{\cdots\cdots}_{\cdots\cdots}\text{He} + \,^{\cdots\cdots}_{\cdots\cdots}\beta$$ [2]

(c) The β-particle is emitted with an energy of 5.7×10^3 eV.

Calculate the speed of the β-particle.

speed = ... m s^{-1} [3]

(d) A different isotope of hydrogen is hydrogen-2 (deuterium). Describe the similarities and differences between the atoms of hydrogen-2 and hydrogen-3.

....

....

.... [2]

For Examiner's Use

7 A nuclear reaction between two helium nuclei produces a second isotope of helium, two protons and 13.8 MeV of energy. The reaction is represented by the following equation.

$$^{3}_{2}\text{He} + ^{3}_{2}\text{He} \rightarrow ^{\cdots\cdots}_{\cdots\cdots}\text{He} + 2\,^{\cdots\cdots}_{\cdots\cdots}\text{p} + 13.8\,\text{MeV}$$

(a) Complete the nuclear equation. [2]

(b) By reference to this reaction, explain the meaning of the term *isotope*.

....

....

.... [2]

(c) State the quantities that are conserved in this nuclear reaction.

....

....

....

....

.... [2]

(d) Radiation is produced in this nuclear reaction.

State

(i) a possible type of radiation that may be produced,

.... [1]

(ii) why the energy of this radiation is less than the 13.8 MeV given in the equation.

.... [1]

(e) Calculate the minimum number of these reactions needed per second to produce power of 60 W.

number = ... s^{-1} [2]

For Examiner's Use

6 **(a)** Describe the structure of an atom of the nuclide $^{235}_{92}U$.

....

....

....

.... [2]

(b) The deflection of α-particles by a thin metal foil is investigated with the arrangement shown in Fig. 6.1. All the apparatus is enclosed in a vacuum.

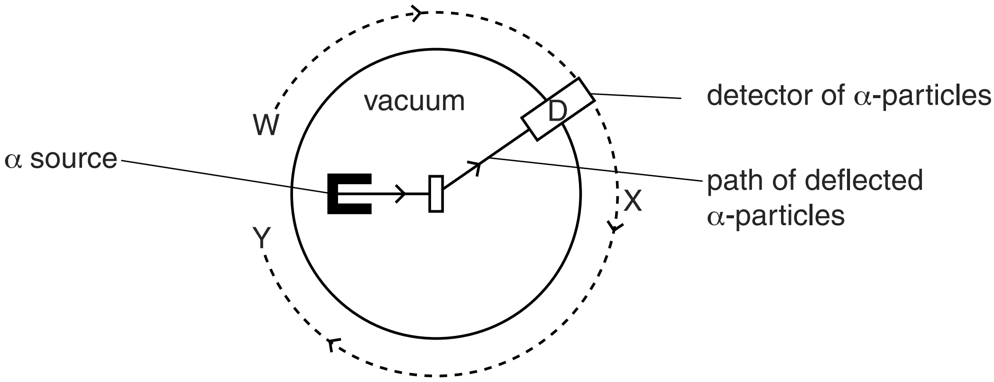


Fig. 6.1

The detector of α-particles, D, is moved around the path labelled WXY.

(i) Explain why the apparatus is enclosed in a vacuum.

....

.... [1]

(ii) State and explain the readings detected by D when it is moved along WXY.

....

....

....

....

....

.... [3]

Question 6 continues on page 16.

(c) A beam of α-particles produces a current of 1.5 pA. Calculate the number of α-particles per second passing a point in the beam.

For Examiner's Use

number = ... s^{-1} [3]

For Examiner's Use

7 **(a)** Two isotopes of uranium are uranium-235 ($^{235}_{92}U$) and uranium-238 ($^{238}_{92}U$).

(i) Describe in detail an atom of uranium-235.

....

....

....

....

.... [4]

(ii) With reference to the two forms of uranium, explain the term *isotopes*.

....

....

.... [2]

(b) When a uranium-235 nucleus absorbs a neutron, the following reaction may occur:

$$^{235}_{92}U + {}^{W}_{X}n \rightarrow {}^{148}_{57}La + {}^{Z}_{Y}Q + 3{}^{W}_{X}n$$

(i) Determine the values of Y and Z.

Y = ...

Z = ...

[2]

(ii) Explain why the sum of the masses of the uranium nucleus and of the neutron does not equal the total mass of the products of the reaction.

....

....

.... [2]

For Examiner's Use

7 **(a)** Describe the two main results of the α-particle scattering experiment.

result 1: ....

....

result 2: ....

....
[3]

(b) Relate each of the results in **(a)** with the conclusions that were made about the nature of atoms.

result 1: ....

....

result 2: ....

....
[3]

For Examiner's Use

7 A polonium nucleus $^{210}_{84}\text{Po}$ is radioactive and decays with the emission of an α-particle. The nuclear reaction for this decay is given by

$$^{210}_{84}\text{Po} \longrightarrow \ ^{W}_{X}\text{Q} + \ ^{Y}_{Z}\alpha.$$

(a) **(i)** State the values of *W* ....

X ....

Y ....

Z ....

[2]

(ii) Explain why mass seems not to be conserved in the reaction.

....

....[2]

(b) The reaction is spontaneous. Explain the meaning of *spontaneous*.

....

....[1]

For Examiner's Use

7 (a) An electric field is set up between two parallel metal plates in a vacuum. The deflection of α-particles as they pass between the plates is shown in Fig. 7.1.

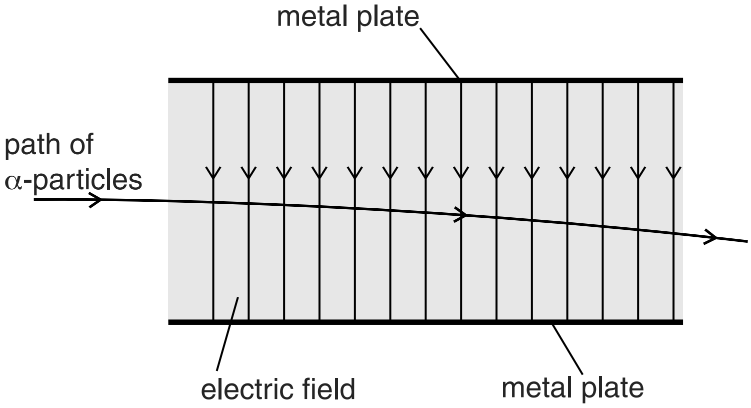


Fig. 7.1

The electric field strength between the plates is reduced. The α-particles are replaced by β-particles. The deflection of β-particles is shown in Fig. 7.2.

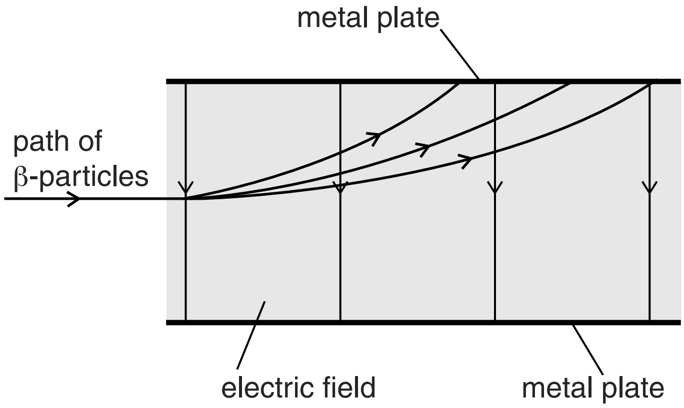


Fig. 7.2

(i) State one similarity of the electric fields shown in Fig. 7.1 and Fig. 7.2.

....

.... [1]

(ii) The electric field strength in Fig. 7.2 is less than that in Fig. 7.1. State two methods of reducing this electric field strength.

1. ....

2. ....

[2]

(iii) By reference to the properties of α-particles and β-particles, suggest three reasons for the differences in the deflections shown in Fig. 7.1 and Fig. 7.2.

1. ....

....

2. ....

....

3. ....

.... [3]

(b) A source of α-particles is uranium-238. The nuclear reaction for the emission of α-particles is represented by

$$^{238}_{92}\text{U} \rightarrow {}^{W}_{X}\text{Q} + {}^{Y}_{Z}\alpha.$$

State the values of *W*...............

X ....

Y ....

Z .... [2]

(c) A source of β-particles is phosphorus-32. The nuclear reaction for the emission of β-particles is represented by

$$^{32}_{15}\text{P} \rightarrow {}^{A}_{B}\text{R} + {}^{C}_{D}\beta.$$

State the values of *A* ....

B ....

C ....

D .... [1]

7 **(a)** State what is meant by

α-particle: ....

β-particle: ....

γ-radiation: ....
[2]

(b) Describe the changes to the proton number and the nucleon number of a nucleus when emission occurs of

(i) an α-particle,

....

.... [1]

(ii) a β-particle,

....

.... [1]

(iii) γ-radiation.

....

.... [1]

7 In the decay of a nucleus of $^{210}_{84}Po$, an α-particle is emitted with energy 5.3 MeV.

The emission is represented by the nuclear equation

$$^{210}_{84}Po \rightarrow {}^{A}_{B}X + \alpha + \text{energy}$$

(a) **(i)** On Fig. 7.1, complete the number and name of the particle, or particles, represented by A and B in the nuclear equation.

	number	name of particle or particles
A		
B		

Fig. 7.1

[1]

(ii) State the form of energy given to the α-particle in the decay of $^{210}_{84}Po$.

....[1]

(b) A sample of polonium $^{210}_{84}Po$ emits 7.1×10^{18} α-particles in one day.

Calculate the mean power output from the energy of the α-particles.

power = ... W [2]

7 The equation represents the spontaneous radioactive decay of a nucleus of bismuth-212.

$$^{212}_{83}\text{Bi} \longrightarrow \text{X} + {}^{208}_{81}\text{T}l + 6.2\,\text{MeV}$$

(a) **(i)** Explain the meaning of *spontaneous* radioactive decay.

....

....[1]

(ii) State the constituent particles of X.

....[1]

(b) **(i)** Use the conservation of mass-energy to explain the release of 6.2 MeV of energy in this reaction.

....

....

....[2]

(ii) Calculate the energy, in joules, released in this reaction.

energy = ... J [1]

7 A uranium-235 nucleus absorbs a neutron and then splits into two nuclei. A possible nuclear reaction is given by

$$^{235}_{92}U + {}^{a}_{b}n \rightarrow {}^{93}_{37}Rb + {}^{c}_{d}X + 2{}^{a}_{b}n + \text{energy.}$$

(a) State the constituent particles of the uranium-235 nucleus.

.... [1]

(b) Complete Fig. 7.1 for this reaction.

	value
a	
b	
c	
d	

[3]

Fig. 7.1

(c) Suggest a possible form of energy released in this reaction.

.... [1]

(d) Explain, using the law of mass-energy conservation, how energy is released in this reaction.

....

....

.... [2]