



Cambridge International AS & A Level

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PHYSICS

9702/21

Paper 2 AS Level Structured Questions

May/June 2025

1 hour 15 minutes

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION

- The total mark for this paper is 60.
- The number of marks for each question or part question is shown in brackets [].

This document has **16** pages. Any blank pages are indicated.



Data

acceleration of free fall	$g = 9.81 \text{ m s}^{-2}$
speed of light in free space	$c = 3.00 \times 10^8 \text{ m s}^{-1}$
elementary charge	$e = 1.60 \times 10^{-19} \text{ C}$
unified atomic mass unit	$1 \text{ u} = 1.66 \times 10^{-27} \text{ kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27} \text{ kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31} \text{ kg}$
Avogadro constant	$N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$
molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
Boltzmann constant	$k = 1.38 \times 10^{-23} \text{ J K}^{-1}$
gravitational constant	$G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
permittivity of free space	$\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$ $(\frac{1}{4\pi\epsilon_0} = 8.99 \times 10^9 \text{ m F}^{-1})$
Planck constant	$h = 6.63 \times 10^{-34} \text{ J s}$
Stefan–Boltzmann constant	$\sigma = 5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
hydrostatic pressure	$\Delta p = \rho g \Delta h$
upthrust	$F = \rho g V$
Doppler effect for sound waves	$f_o = \frac{f_s v}{v \pm v_s}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \dots$
resistors in parallel	$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$





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- 1 (a) Define acceleration.

.....
 [1]

- (b) In an experiment, two objects A and B are released from the side of a building, as shown in Fig. 1.1.

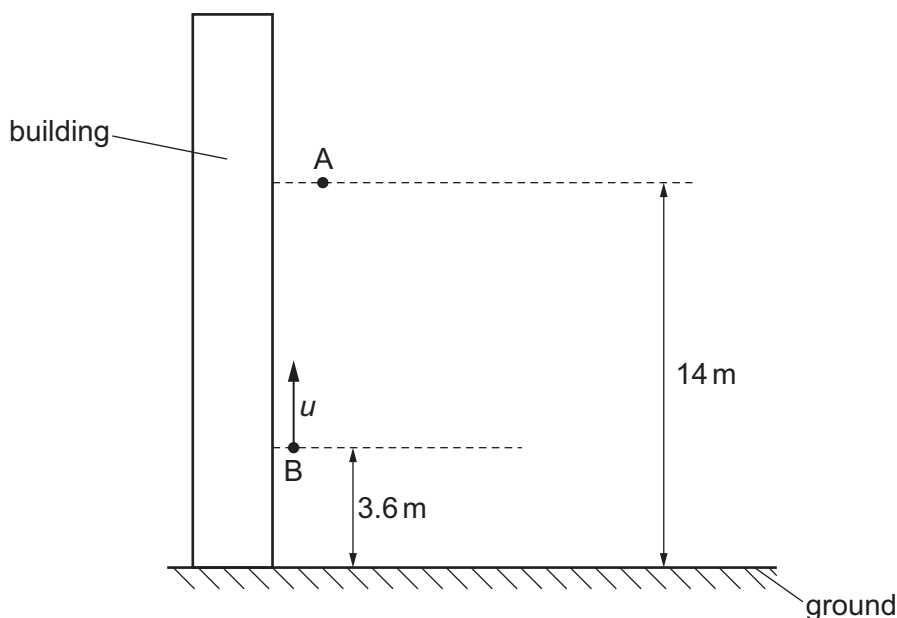


Fig. 1.1 (not to scale)

Object A is released from rest at a height of 14 m above the horizontal ground.
 Object B is released with an initial upwards vertical velocity u at a height of 3.6 m above the ground.
 Both objects take the same time to reach the ground and they do not collide with each other.
 Air resistance is negligible.

- (i) Calculate the time taken for object A to reach the ground.

time = ... s [2]

- (ii) Use your answer in (b)(i) to calculate u .

$u = \dots\dots\dots \text{ms}^{-1}$ [2]



- (c) In a second experiment, object B is released from the same height and given the same initial speed as in (b) but at a release angle θ to the vertical, as shown in Fig. 1.2.

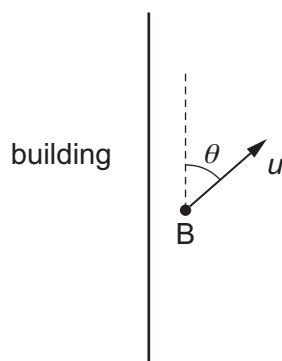


Fig. 1.2

- (i) State and explain whether the time taken for object B to reach the ground is less than, the same as or greater than the time in (b)(i).

.....

 [2]

- (ii) By considering energy, state and explain the effect of the change in release angle on the speed at which B reaches the ground.

.....

 [2]

[Total: 9]



- 2 (a) State the principle of moments.

.....

.....

..... [2]

- (b) Three objects A, B and C are placed on a horizontal beam. The beam is in equilibrium, as shown in Fig. 2.1.

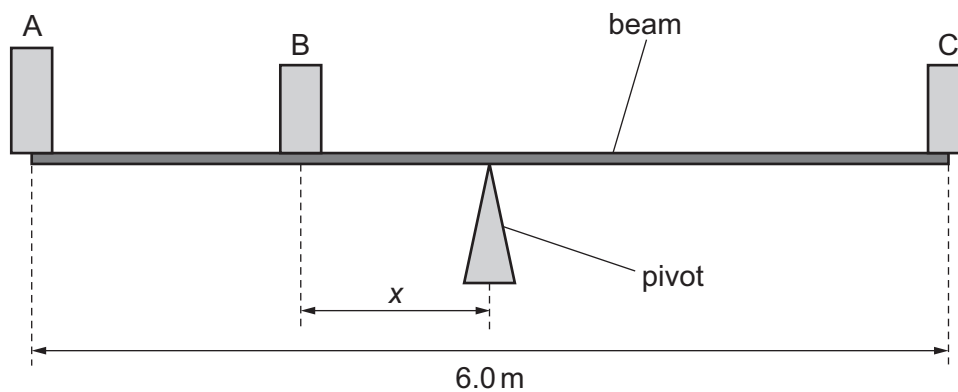


Fig. 2.1 (not to scale)

The beam is uniform and has length 6.0 m.

The pivot is at the midpoint of the beam.

Object A has mass 60 kg and is at one end of the beam.

Object B has mass 45 kg and is at a distance x from the pivot.

Object C has mass 80 kg and is at the other end of the beam.

Calculate x .

$x = \dots\dots\dots \text{ m } [3]$



(c) The beam is 0.80 m above horizontal ground.

Object A is removed and replaced by a spring connected to the ground and the beam, as shown in Fig. 2.2.

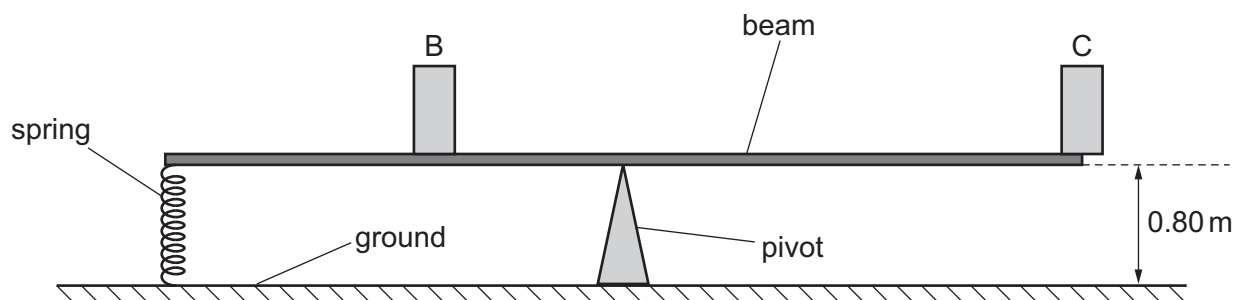


Fig. 2.2

After the change, the beam is again horizontal and in equilibrium. The positions of B and C are unchanged.

The spring has an unstretched length of 0.59 m and obeys Hooke's law.

(i) Calculate the spring constant of the spring.

spring constant = ... Nm^{-1} [3]

(ii) Calculate the elastic potential energy of the spring.

elastic potential energy = ... J [2]

[Total: 10]



3 (a) Define power.

.....
 [1]

(b) An electric car is powered by a motor. The car is travelling at a constant speed of 35 ms^{-1} along a straight horizontal road, as shown in Fig. 3.1.

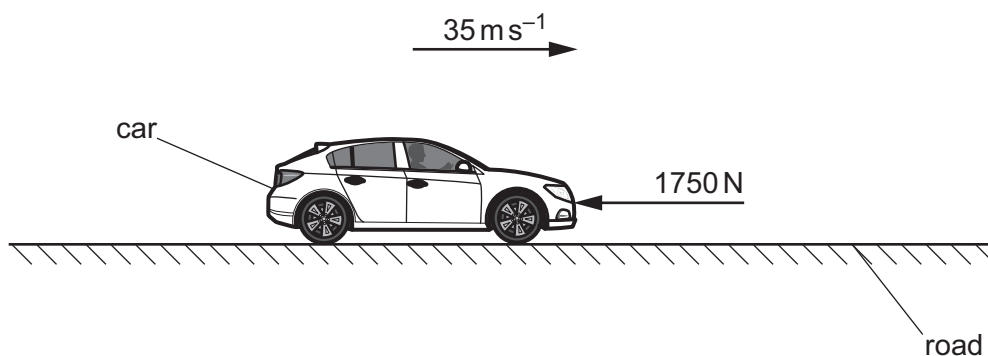


Fig. 3.1

There is a total resistive force of 1750 N acting on the car.

(i) Calculate the power transmitted to the wheels of the car by the motor.

power = ...W [2]

(ii) Calculate the useful work done by the motor when the car travels a distance of 17 km .

work done = ...J [2]



- (iii) The potential difference (p.d.) across the motor has a constant value of 600 V and the motor has an efficiency of 85%.

Calculate the current in the motor.

current = ... A [3]

- (c) The car in (b) now reaches a slope, as shown in Fig. 3.2.

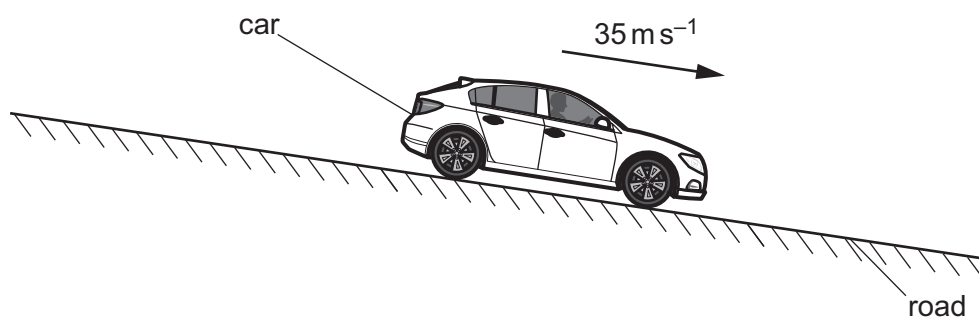


Fig. 3.2

The car continues down the slope at the same speed as in (b).

State and explain the effect, if any, of the slope on:

- (i) the air resistance acting on the car

.....
 [1]

- (ii) the current in the motor.

.....
 [1]

[Total: 10]



- 4 (a) State the principle of superposition.

.....

.....

..... [2]

- (b) Light of wavelength $7.2 \times 10^{-7} \text{ m}$ is incident normally on a double slit, as shown in Fig. 4.1.

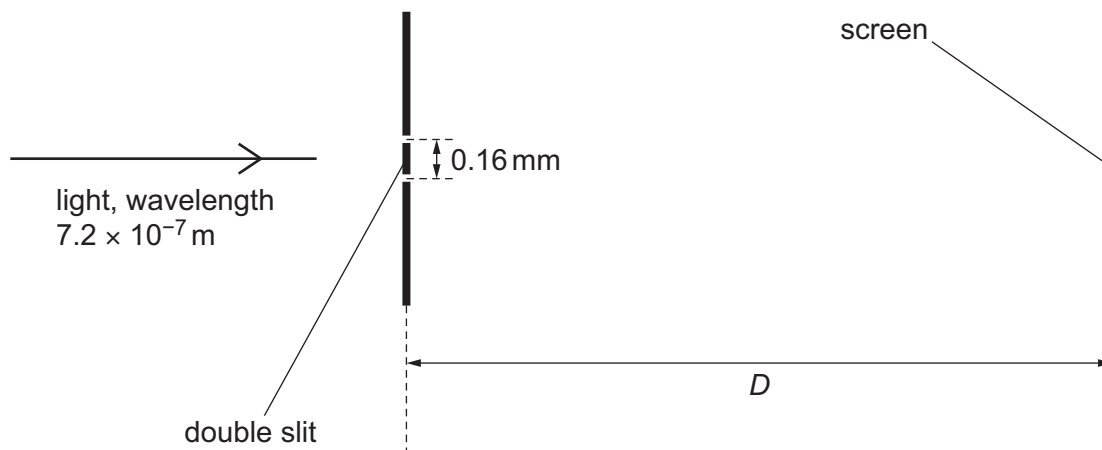


Fig. 4.1 (not to scale)

A screen is at a distance D from the double slit. The double slit and the screen are parallel.

The separation of the slits in the double-slit arrangement is 0.16 mm. The resulting interference pattern on the screen contains nine dark fringes, as shown in Fig. 4.2.

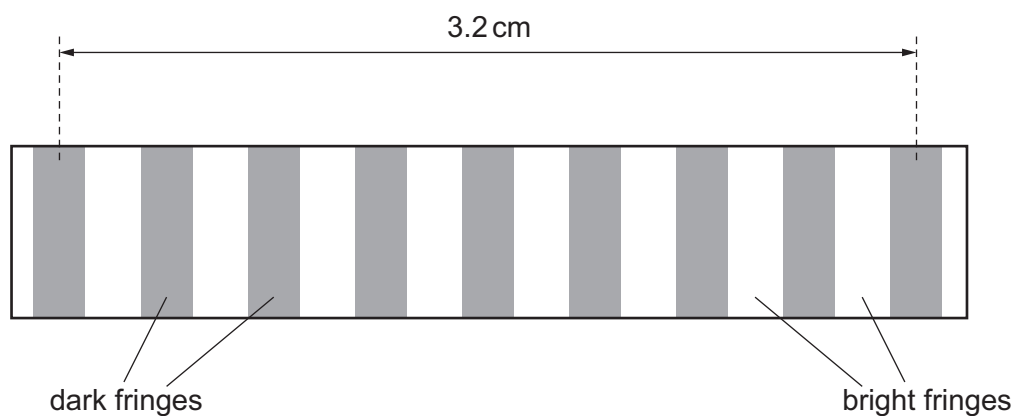


Fig. 4.2 (not to scale)



The distance between the centres of the first and ninth dark fringes is 3.2 cm.

(i) Calculate D .

$D = \dots\dots\dots$ m [3]

(ii) The slit separation is now gradually decreased from 0.16 mm to 0.04 mm. The distance between the centres of adjacent dark fringes is x .

On Fig. 4.3, sketch the variation of x with slit separation.

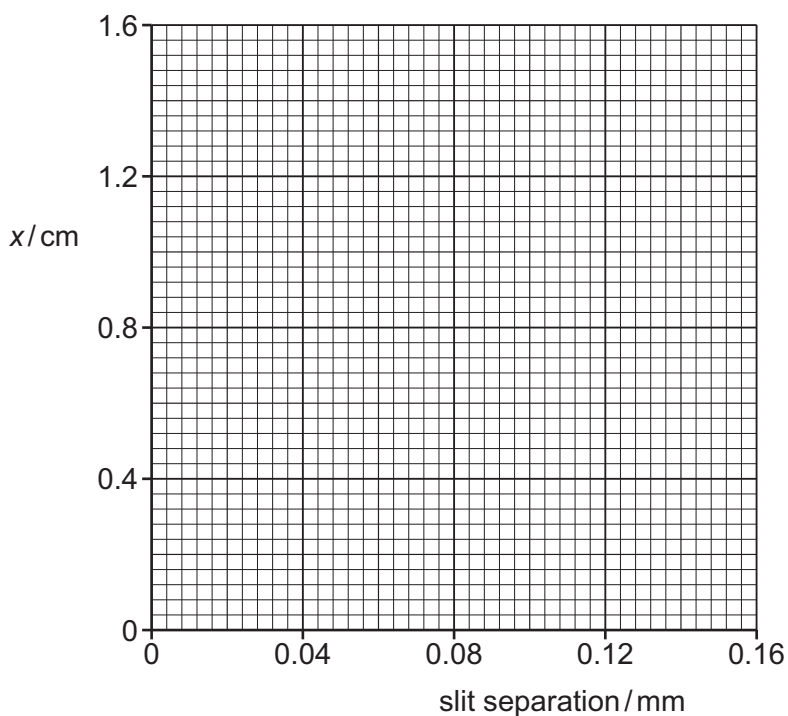


Fig. 4.3

[3]

[Total: 8]



- 5 (a) Use the definitions of speed v , frequency f and wavelength λ to derive the wave equation

$$v = f\lambda.$$

[2]

- (b) A source of sound waves of frequency 236 Hz is travelling at a constant velocity of 20 m s^{-1} .

A stationary observer has a microphone connected to a cathode-ray oscilloscope (CRO). The microphone detects the sound waves as the source moves directly towards the observer.

The resulting trace on the CRO is shown in Fig. 5.1.

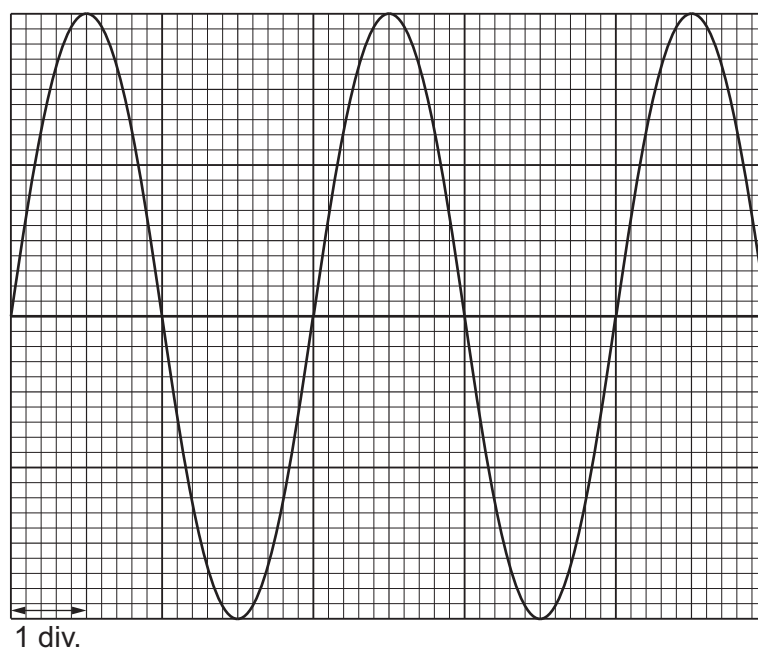


Fig. 5.1

The time-base on the CRO is set to 1.0 ms div^{-1} .



- (i) Calculate the frequency of the sound waves detected by the microphone.

frequency = ... Hz [2]

- (ii) Determine the speed of the sound in air.

speed of sound = ... ms^{-1} [2]

[Total: 6]



- 6 A nichrome wire X of length 45 cm and cross-sectional area $4.7 \times 10^{-7} \text{ m}^2$ is connected into the circuit shown in Fig. 6.1.

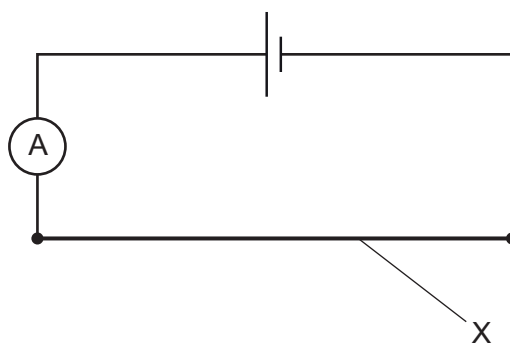


Fig. 6.1

The resistance of X is 1.1Ω . The cell has electromotive force (e.m.f.) 1.3 V and negligible internal resistance.

- (a) (i) Calculate the current in X.

current = ... A [1]

- (ii) The number density of charge carriers (electrons) in nichrome is $8.5 \times 10^{28} \text{ m}^{-3}$.

Calculate the average drift speed of the charge carriers in X.

average drift speed = ... ms^{-1} [2]

- (iii) Calculate the resistivity of the nichrome.

resistivity = ... $\Omega \text{ m}$ [3]



- (b) Wire Y is identical to wire X. Wire Y is added to the circuit in parallel with wire X, as shown in Fig. 6.2.

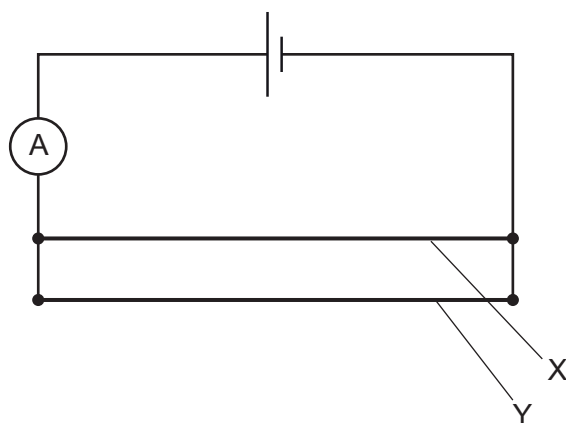


Fig. 6.2

State and explain the effect, if any, of this change on:

- (i) the reading on the ammeter

.....

 [2]

- (ii) the average drift speed of the charge carriers in X.

.....
 [1]

[Total: 9]



- 7 (a) Nitrogen-12 ($^{12}_7\text{N}$) is an unstable isotope of nitrogen that decays by the emission of radiation to carbon-12 ($^{12}_6\text{C}$).

Complete the full nuclear equation for the decay, including all the particles involved.



[3]

- (b) Hydrogen-1 (^1_1H) is an isotope of hydrogen. An atom of hydrogen-1 comprises a proton with an orbiting electron.

An antiparticle equivalent of hydrogen-1 comprises an antiproton with an orbiting positron. The antiquarks in the antiproton are the antiparticles of the quarks in a proton.

- (i) State the charge on the positron in terms of the elementary charge e .

charge = ... e [1]

- (ii) State the group (class) of fundamental particle to which the positron belongs.

..... [1]

- (iii) In Table 7.1, state the flavour and charge of the three antiquarks that comprise the antiproton.

Table 7.1

flavour	charge / e

[3]

[Total: 8]

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electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \dots$
resistors in parallel	$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$





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- 1 (a) Table 1.1 lists some physical quantities. Identify with ticks (✓) which quantities are vectors and which are scalars.

Table 1.1

quantity	scalar	vector
acceleration		
displacement		
gravitational potential energy		
speed		
temperature		

[2]

- (b) A constant resultant force F acts on a car of mass m . The car moves from rest with constant acceleration a along horizontal ground. When the car has displacement s , the speed of the car is v .

- (i) Using the concept of work done on the car, show that the kinetic energy E_K of the car is given by the equation

$$E_K = \frac{1}{2}mv^2.$$

[3]

- (ii) The mass of the car is 920 kg. At time $t = 0$, the car is at rest. At time $t = 5.8$ s, its velocity is 17 m s^{-1} .

Calculate the kinetic energy of the car at time $t = 5.8$ s.

kinetic energy = ... J [1]



- (iii) Between time $t = 0$ and time $t = 5.8$ s, the work done against resistive forces is 4.7×10^4 J.

Determine the average output power of the car during this time.

power = ... W [3]

- (iv) At time $t = 5.8$ s, the speed of the car becomes constant.

State and explain whether the output power of the car is greater than, less than or the same as the output power just before $t = 5.8$ s.

.....
 [1]

[Total: 10]



- 2 (a) Define the moment of a force about a point.

..... [1]

- (b) A tree of mass 270 kg grows out of sloping ground and is supported by a post, as shown in Fig. 2.1.

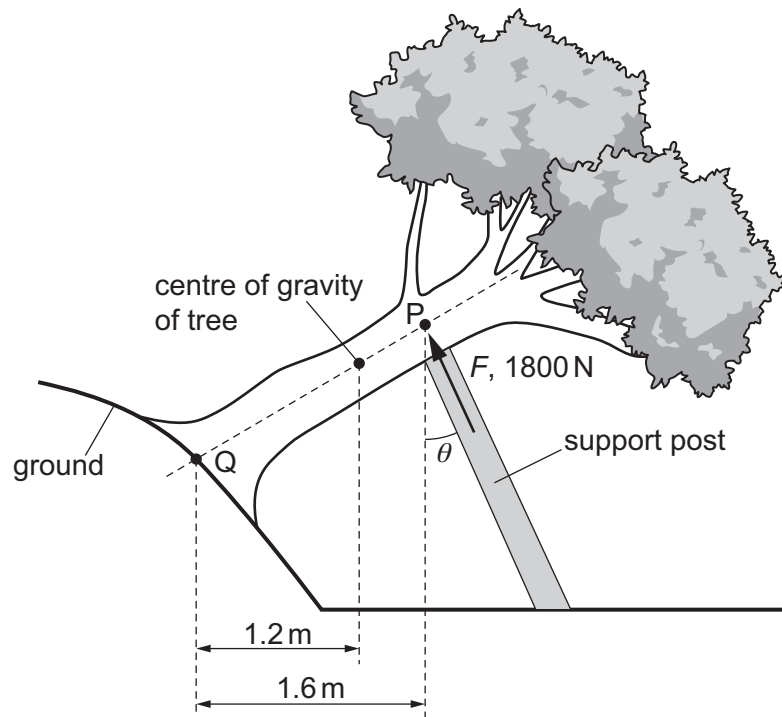


Fig. 2.1 (not to scale)

The ground applies a total force R on the tree at point Q .
 The centre of gravity of the tree is a horizontal distance of 1.2 m from Q .
 The post applies a force F of 1800 N perpendicular to the line PQ . The line of action of F passes through point P at an angle θ to the vertical. P is a horizontal distance of 1.6 m from Q .
 The tree is in equilibrium and all forces act on the tree in the same plane.

- (i) By taking moments about point Q , show that θ is 25° .

[3]



- (ii) On Fig. 2.2, draw a labelled scale vector triangle to represent the forces acting on the tree. The weight of the tree has been drawn to scale.

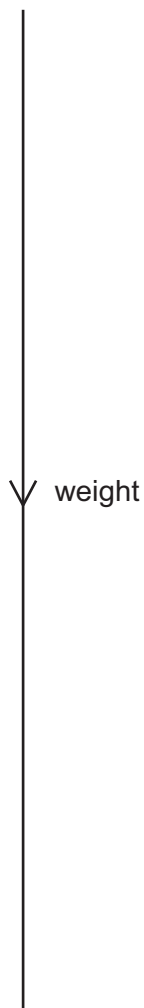


Fig. 2.2

[2]

- (iii) The tree exerts a pressure of 150 kPa on the top of the post.

Determine the surface area of the tree in contact with the post.

area = ... m² [2]

[Total: 8]



- 3 Two progressive water waves X and Y travel along a straight line from point A to point B. The variation of displacement of the waves with distance from A at an instant in time is shown in Fig. 3.1.

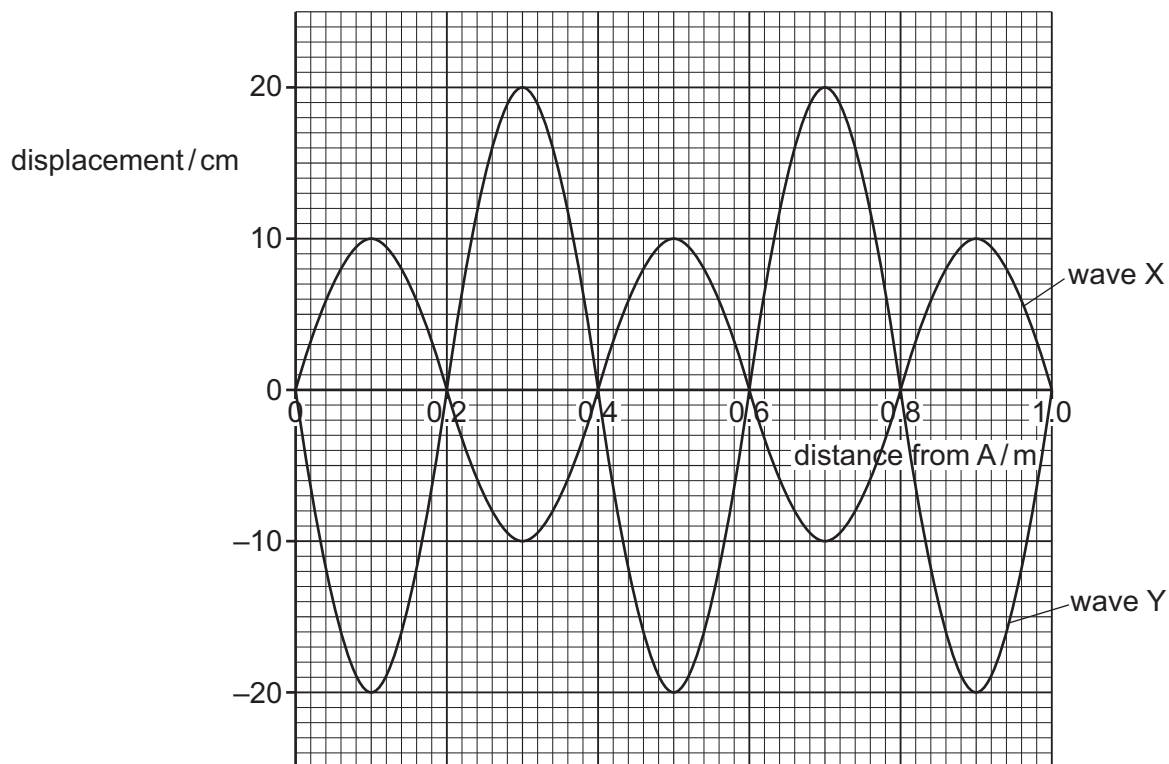


Fig. 3.1

- (a) State the amplitude of wave X.

amplitude = ... cm [1]

- (b) Both waves have frequency 16 Hz.

- (i) Determine the speed of wave X.

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

- (ii) State and explain whether X and Y are coherent.

.....

 [1]



- (c) Wave X and wave Y superpose to form a resultant wave.

On Fig. 3.2, sketch the variation of displacement of the resultant wave with distance from A at the instant of time shown in Fig. 3.1.

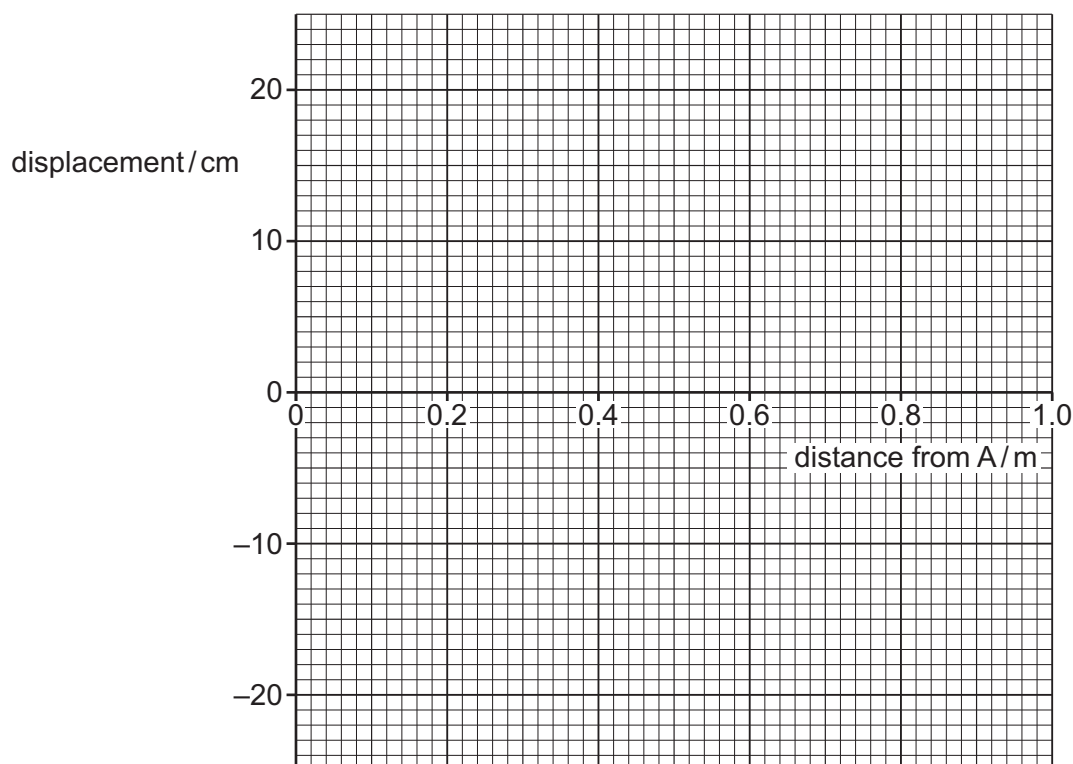


Fig. 3.2

[2]

- (d) The intensity of wave X is I_X . The intensity of wave Y is I_Y .

Use Fig. 3.1 to determine the ratio $\frac{I_X}{I_Y}$.

ratio = ... [2]

[Total: 8]



- 4 A small ball is dropped from rest from height h_1 above the ground and falls vertically downwards. The ball collides with the ground and bounces back vertically upwards, reaching a maximum height h_2 . Fig. 4.1 shows the ball just before and just after hitting the ground.

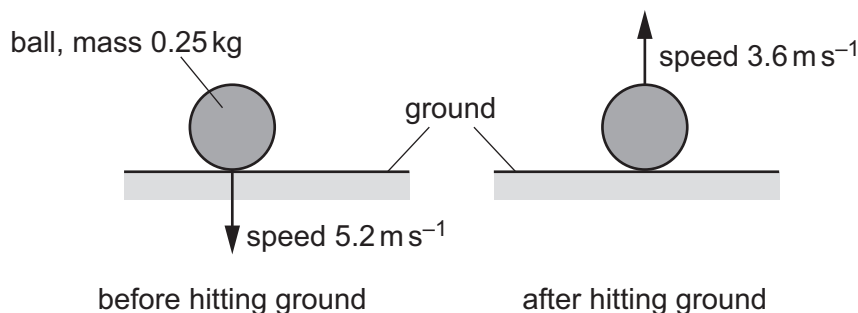


Fig. 4.1

The ball has mass 0.25 kg and is in contact with the ground for a time of 0.18 s. Just before the ball hits the ground, it has speed 5.2 m s⁻¹. Just after it leaves the ground, it has speed 3.6 m s⁻¹. Air resistance acting on the ball is negligible.

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

.....

 [1]

- (b) (i) Calculate the change in momentum of the ball during the collision with the ground.

change in momentum = ... kg m s⁻¹ [2]

- (ii) Determine the average force on the ball during the collision with the ground.

force = ... N [2]





(c) Calculate the ratio $\frac{h_2}{h_1}$.

ratio = ... [3]

[Total: 8]



5 (a) Define the Young modulus.

.....
 [1]

(b) A wire of unstretched length 0.81 m is made of a metal with Young modulus 95 GPa. The wire obeys Hooke's law and has a constant cross-sectional area. Fig. 5.1 shows the force–extension graph for the wire.

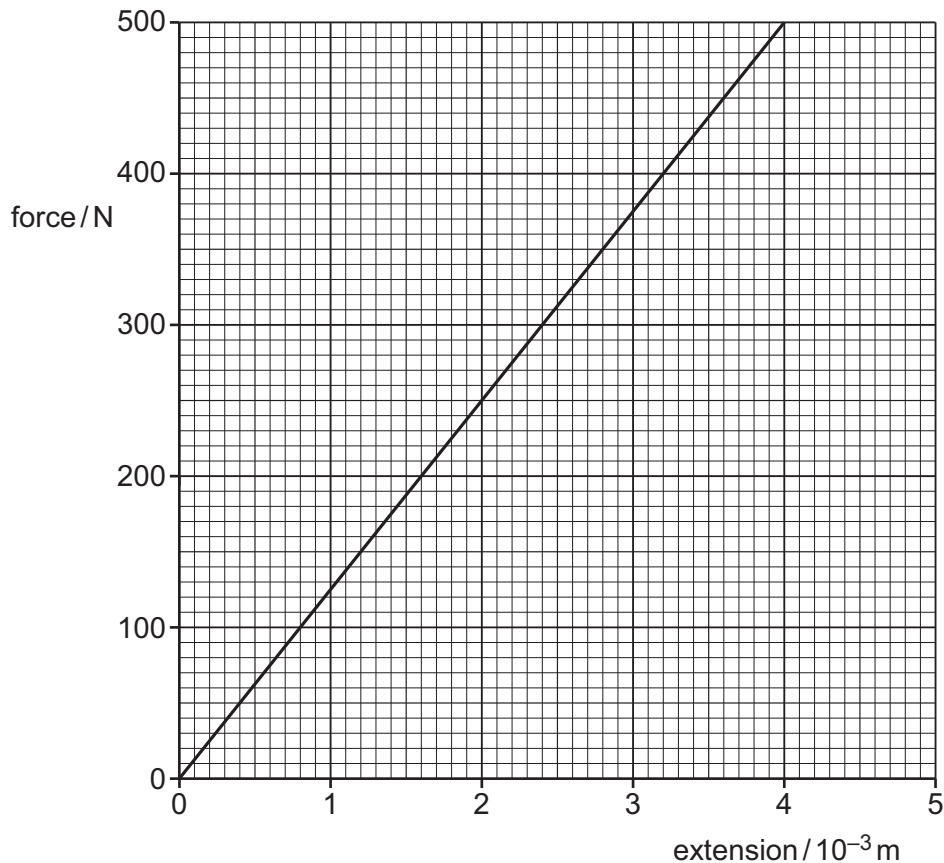


Fig. 5.1

(i) Determine the cross-sectional area of the wire.

area = ... m^2 [3]



(ii) The extension of the wire is initially 2.0×10^{-3} m.

Determine the work done to increase the extension of the wire to 3.0×10^{-3} m.

work done = ... J [3]

[Total: 7]



- 6 (a) Define electric potential difference across a component.

.....
 [1]

- (b) A circuit contains four resistors and a battery of electromotive force (e.m.f.) 8.0 V with negligible internal resistance. When the variable resistor has resistance R , the currents in the circuit are 0.030 A , I_1 and I_2 , as shown in Fig. 6.1.

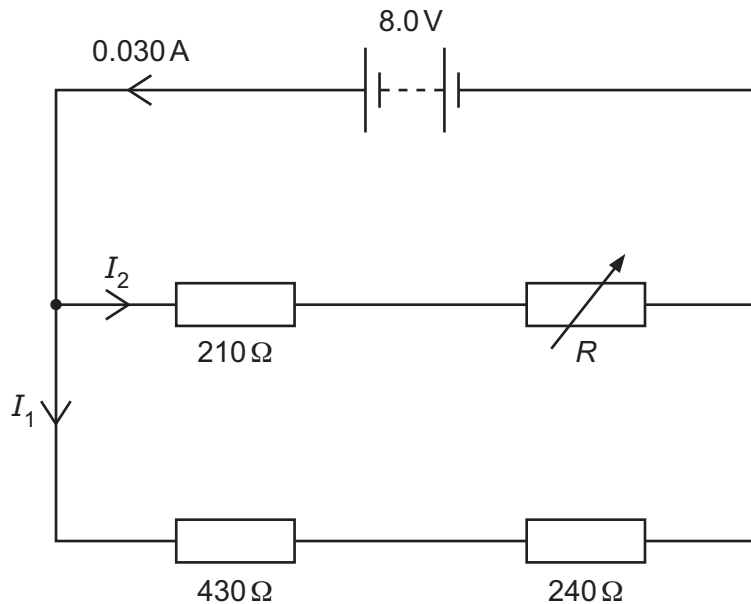


Fig. 6.1

- (i) Determine the charge passing through the battery in a time of 4.0 minutes.

charge = ... C [2]

- (ii) Calculate I_1 .

I_1 = ... A [2]





(iii) Calculate I_2 .

$I_2 = \dots\dots\dots$ A [1]

(iv) Determine R .

$R = \dots\dots\dots$ Ω [2]



- (c) The variable resistor in (b) is fitted with a scale so that its resistance can be accurately determined.

The resistor of resistance $240\ \Omega$ is now replaced by a new resistor X of unknown resistance. A galvanometer is connected as shown in Fig. 6.2.

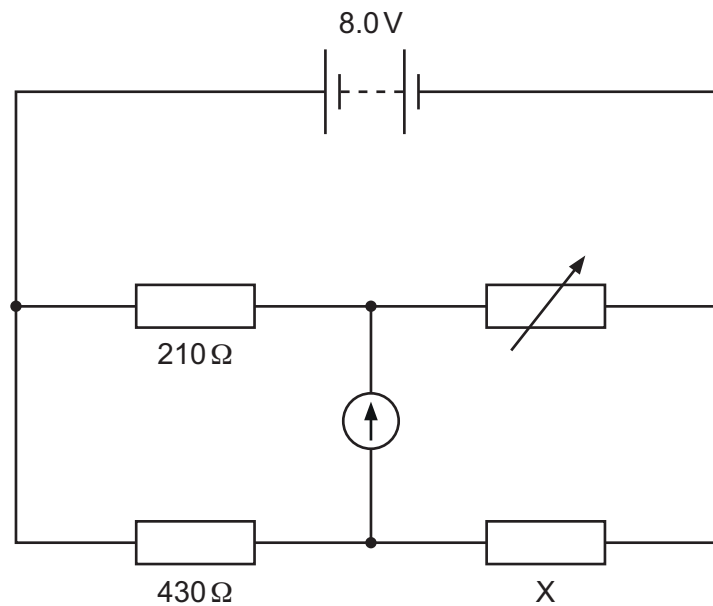


Fig. 6.2

With reference to ratios of resistances, explain how this circuit can be used to determine the resistance of X.

.....

.....

.....

.....

..... [2]

[Total: 10]



- 7 (a) State what is meant by a fundamental particle.

.....
 [1]

- (b) A nucleus X has 14 nucleons and p protons. The ratio of charge to mass for nucleus X is $4.1 \times 10^7 \text{ C kg}^{-1}$.

- (i) Determine p .

$p =$ [3]

- (ii) Nucleus X undergoes β^- decay to form nucleus Z.

Complete the equation representing this decay.



[3]

- (c) A sample of a radioactive substance emits particles that are positively charged and have a continuous range of kinetic energies.

State and explain whether the nuclei in the sample are undergoing α -decay, β^+ decay or β^- decay.

.....

 [2]

[Total: 9]









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rest mass of electron	$m_e = 9.11 \times 10^{-31} \text{ kg}$
Avogadro constant	$N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$
molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
Boltzmann constant	$k = 1.38 \times 10^{-23} \text{ J K}^{-1}$
gravitational constant	$G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
permittivity of free space	$\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$ $(\frac{1}{4\pi\epsilon_0} = 8.99 \times 10^9 \text{ m F}^{-1})$
Planck constant	$h = 6.63 \times 10^{-34} \text{ J s}$
Stefan–Boltzmann constant	$\sigma = 5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
hydrostatic pressure	$\Delta p = \rho g \Delta h$
upthrust	$F = \rho g V$
Doppler effect for sound waves	$f_o = \frac{f_s v}{v \pm v_s}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \dots$
resistors in parallel	$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$





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- 1 (a) Define velocity.

.....
 [1]

- (b) In an experiment, two objects A and B are released from the side of a building, as shown in Fig. 1.1.

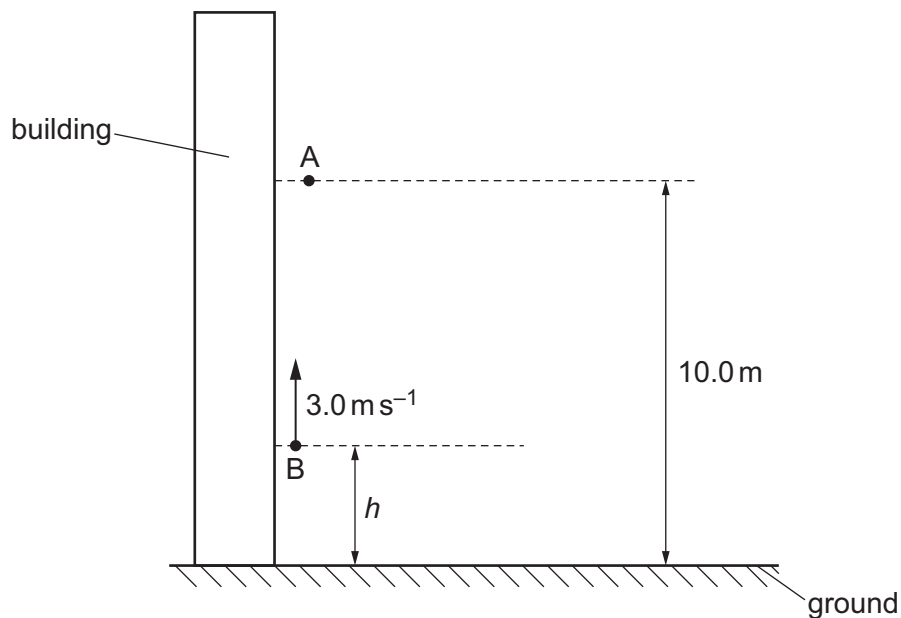


Fig. 1.1 (not to scale)

Object A is released from rest at a height of 10.0 m above horizontal ground.
 Object B is released with an initial upward velocity of 3.0 ms^{-1} at a height h above the ground.
 Both objects take the same time to reach the ground and they do not collide with each other.
 Air resistance is negligible.

Calculate h .

$h = \dots\dots\dots \text{ m [3]}$



- (c) In a second experiment, object B is released from the same height as in (b) but with a speed of 6.0 ms^{-1} at an angle of 60° to the vertical, as shown in Fig. 1.2.

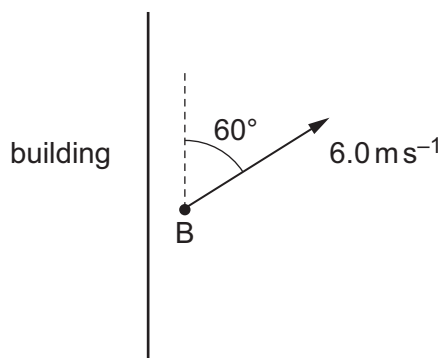


Fig. 1.2

- (i) State and explain whether the time taken for object B to reach the ground is less than, the same as, or greater than the time taken in the first experiment.

.....

 [2]

- (ii) By considering energy, state and explain whether the speed at which object B reaches the ground is less than, the same as, or greater than in the first experiment.

.....

 [2]

[Total: 8]



- 2 (a) Define the moment of a force about a pivot.

.....
 [1]

- (b) Three objects A, B and C are placed on a horizontal beam. The beam is in equilibrium, as shown in Fig. 2.1.

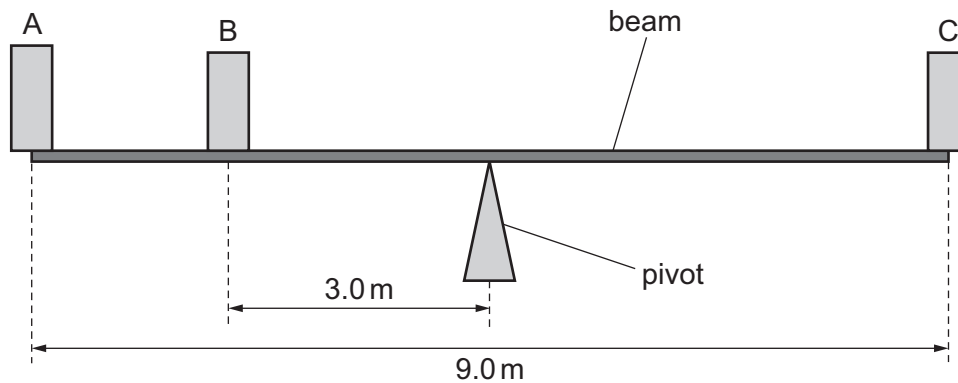


Fig. 2.1 (not to scale)

The beam is uniform and has length 9.0 m.

A pivot is at the midpoint of the beam.

Object A has mass 90 kg and is at one end of the beam.

Object B has mass m and is a distance of 3.0 m from the pivot.

Object C has mass 150 kg and is at the other end of the beam.

- (i) Calculate m .

$m = \dots\dots\dots$ kg [3]



- (ii) Object A is removed and replaced by a wire fixed to the end of the beam and to the ground, as shown in Fig. 2.2.

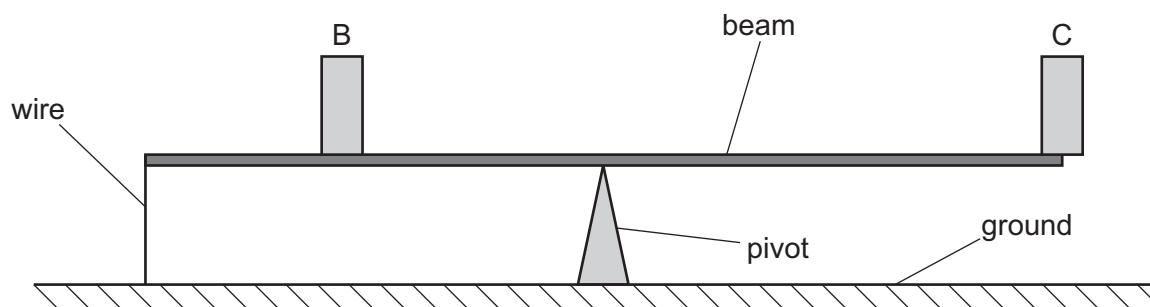


Fig. 2.2

After the change, the beam is again horizontal and in equilibrium. The positions of B and C are unchanged.

The wire has a diameter of $1.8 \times 10^{-3} \text{ m}$ and has a strain of 1.2×10^{-3} .
The wire is not extended beyond its limit of proportionality.

Calculate the Young modulus of the wire.

Young modulus = ... Pa [3]

- (iii) Object B is now moved to a new position closer to the pivot without passing it. The beam is again horizontal and in equilibrium.

State and explain the effect, if any, that this has on the strain in the wire.

.....

 [2]

[Total: 9]



- 3 A car of mass 1500 kg is travelling along a straight horizontal road at constant velocity v . The car is subject to a total resistive force F , as shown in Fig. 3.1.

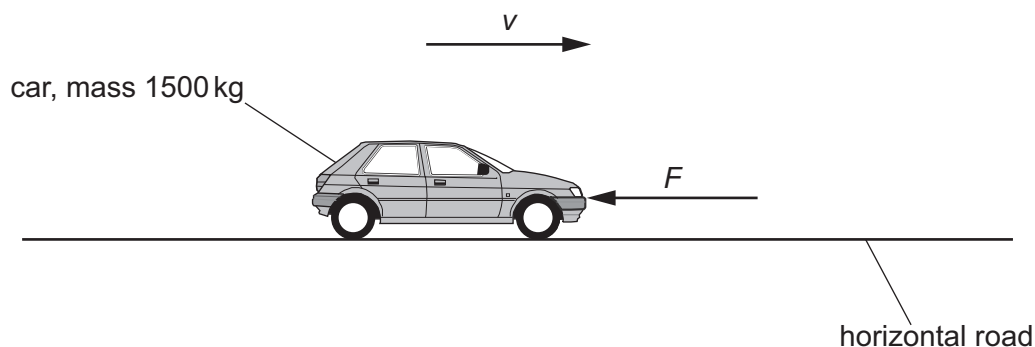


Fig. 3.1

- (a) Show that the power P developed by the engine in overcoming the total resistive force is given by the equation

$$P = Fv.$$

[2]

- (b) The car now moves up a slope at a constant speed of 30 m s^{-1} . The slope is at an angle to the horizontal of 6.0° , as shown in Fig. 3.2.

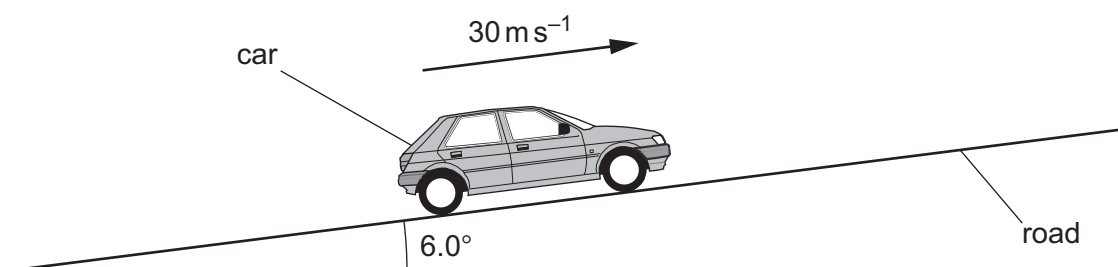


Fig. 3.2

The total resistive force acting on the car is 1600 N.



- (i) Show that the increase in gravitational potential energy of the car in a time of 1.0 s is 46 000 J.

[2]

- (ii) Use the information in (b)(i) to determine the power developed by the engine to move the car up the slope.

power = ... W [2]

- (c) The car picks up a passenger and then continues up the slope at the same speed as in (b).

State and explain the effect, if any, that the passenger has on:

- (i) the air resistance acting on the car

.....
 [1]

- (ii) the power developed by the engine.

.....
 [1]

[Total: 8]





- 4 (a) State the principle of conservation of momentum.

.....

.....

..... [2]

- (b) An object A of mass 4.0 kg travels at a velocity of 6.0 ms^{-1} to the right on a horizontal frictionless surface. It moves towards a second object B of mass 2.0 kg that is moving at a velocity of 3.0 ms^{-1} in the same direction as A, as shown in Fig. 4.1.

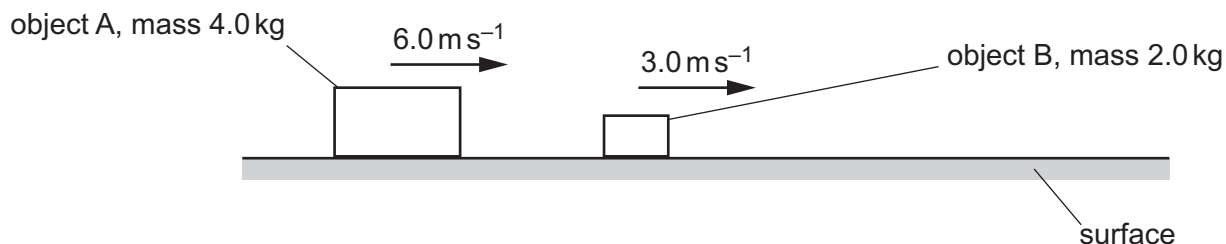


Fig. 4.1

Object A collides with object B. The two objects join and move off together with velocity v .

Calculate:

- (i) velocity v

$$v = \dots\dots\dots \text{ms}^{-1} \quad [2]$$

- (ii) the percentage of the total initial kinetic energy of the two objects that is transferred to other forms of energy during the collision.

$$\text{percentage} = \dots\dots\dots \% \quad [2]$$

[Total: 6]



- 5 (a) State why sound waves **cannot** be polarised.

.....
 [1]

- (b) A plane-polarised light wave is incident on a polarising filter as shown in Fig. 5.1.

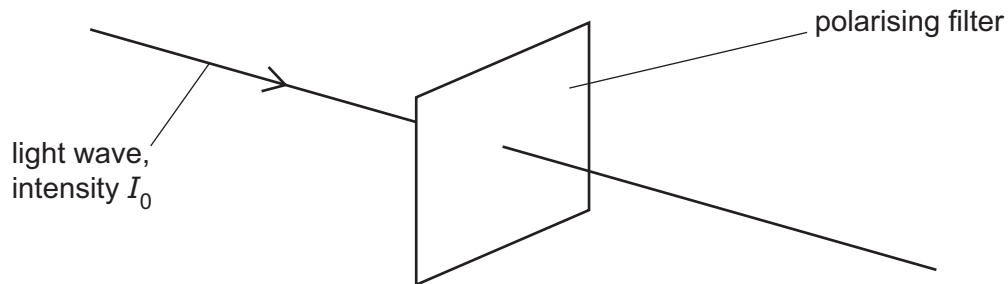


Fig. 5.1

The intensity of the light incident on the filter is I_0 .

The light is incident normally on the filter and the transmission axis of the filter is initially perpendicular to the plane of polarisation of the light.

The filter is now rotated through 360° about the direction of travel of the light wave.

- (i) On Fig. 5.2, sketch the variation of the intensity I of the transmitted light with the angle of rotation α as the filter is rotated through 360° from its initial position.

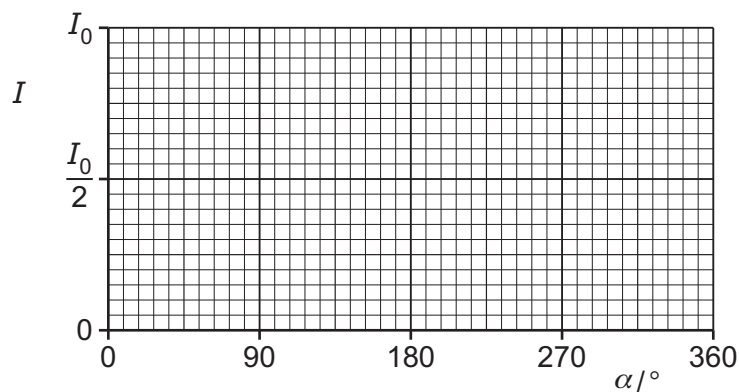


Fig. 5.2

[3]



- (ii) The amplitude of the incident light wave is A_0 when the intensity of the wave is I_0 .

Use Malus's law to determine, in terms of A_0 , the amplitude of the transmitted wave when $\alpha = 20^\circ$.

amplitude = ... A_0 [4]

[Total: 8]



- 6 (a) State what is meant by diffraction.

.....
 [1]

- (b) Light of wavelength 720 nm in a vacuum is incident normally on a diffraction grating as shown in Fig. 6.1.

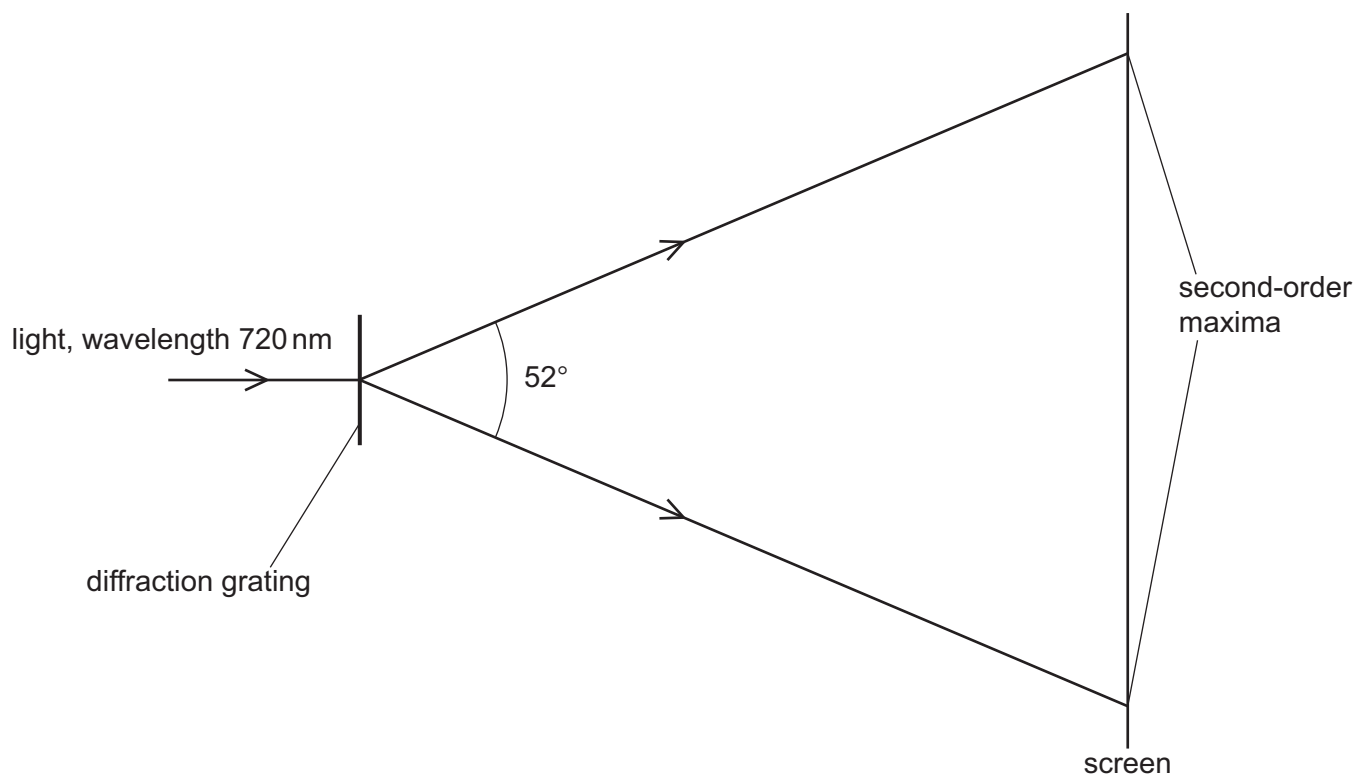


Fig. 6.1 (not to scale)

A screen is parallel to the grating. An interference pattern is seen on the screen and the angle between the **second-order** maxima is 52° .

- (i) Calculate the frequency of the light.

frequency = ... Hz [2]



- (ii) Calculate the number of lines per unit length in the diffraction grating.

number per unit length = ... m^{-1} [3]

- (iii) The light in Fig. 6.1 is now replaced with light of a different wavelength λ . It is observed that the third-order maxima of this light are at the same positions as the second-order maxima of the light in Fig. 6.1.

Calculate, in nm, the wavelength λ .

$\lambda = \dots\dots\dots \text{nm}$ [2]

[Total: 8]



- 7 A nichrome resistance wire has length 150 cm, cross-sectional area $2.45 \times 10^{-7} \text{ m}^2$ and resistivity $1.12 \times 10^{-6} \Omega \text{ m}$.

(a) Calculate, to three significant figures, the resistance of the wire.

resistance = ... Ω [3]

- (b) The nichrome wire forms part of a potentiometer circuit together with a cell of electromotive force (e.m.f.) 1.2 V and negligible internal resistance, as shown in Fig. 7.1.

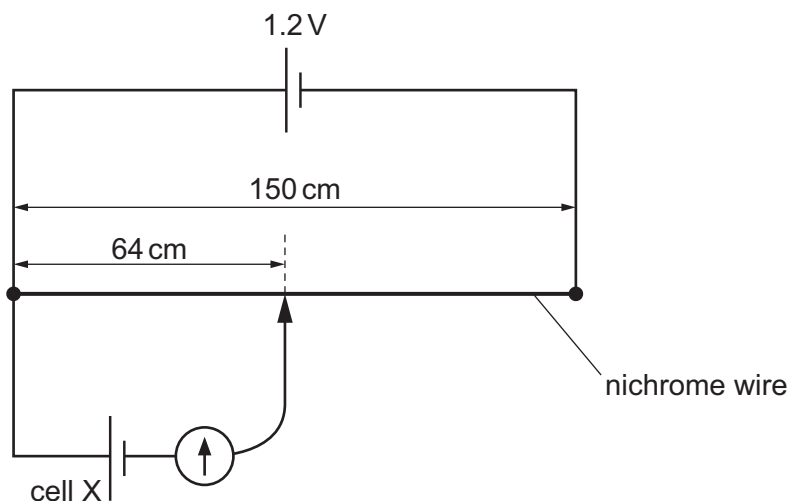


Fig. 7.1 (not to scale)

The circuit is used to determine the e.m.f. of cell X.

The galvanometer is used in a null method to find the null point 64 cm from the left-hand end of the nichrome wire.

- (i) Explain what is meant by a null method.

.....
 [1]





(ii) Calculate the e.m.f. of cell X.

e.m.f. = ... V [2]

- (iii) The cell of e.m.f. 1.2V is replaced by a new cell with the same e.m.f. but with an internal resistance that is **not** negligible.

State and explain the effect, if any, of the internal resistance of the new cell on the position of the null point.

.....
.....
.....
..... [2]

[Total: 8]



- 8 (a) An antiparticle equivalent of the neutron is called the antineutron. The quarks in the antineutron are the antiparticles of the quarks in a neutron.

The elementary charge is e .

In Table 8.1, state the flavour and charge of the three antiquarks that comprise the antineutron.

Table 8.1

flavour	charge / e

[3]

- (b) In β^- decay, a neutron decays to form a proton.

Theory predicts that an antineutron should decay to form an antiproton. A particle and an antiparticle should also be observed.

Suggest the names of the particle and the antiparticle.

particle:

antiparticle:

[2]

[Total: 5]







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PHYSICS

9702/24

Paper 2 AS Level Structured Questions

May/June 2025

1 hour 15 minutes

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION

- The total mark for this paper is 60.
- The number of marks for each question or part question is shown in brackets [].

This document has **16** pages. Any blank pages are indicated.

**Data**

acceleration of free fall	$g = 9.81 \text{ m s}^{-2}$
speed of light in free space	$c = 3.00 \times 10^8 \text{ m s}^{-1}$
elementary charge	$e = 1.60 \times 10^{-19} \text{ C}$
unified atomic mass unit	$1 \text{ u} = 1.66 \times 10^{-27} \text{ kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27} \text{ kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31} \text{ kg}$
Avogadro constant	$N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$
molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
Boltzmann constant	$k = 1.38 \times 10^{-23} \text{ J K}^{-1}$
gravitational constant	$G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
permittivity of free space	$\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$ $(\frac{1}{4\pi\epsilon_0} = 8.99 \times 10^9 \text{ m F}^{-1})$
Planck constant	$h = 6.63 \times 10^{-34} \text{ J s}$
Stefan–Boltzmann constant	$\sigma = 5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
hydrostatic pressure	$\Delta p = \rho g \Delta h$
upthrust	$F = \rho g V$
Doppler effect for sound waves	$f_o = \frac{f_s v}{v \pm v_s}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \dots$
resistors in parallel	$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$



- 1 (a) Define the moment of a force.

.....
 [1]

- (b) A trapdoor has a hinge at end A, as shown in Fig. 1.1.

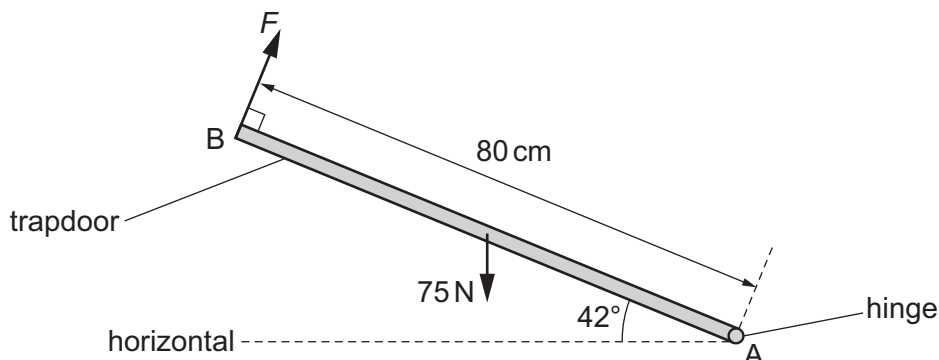


Fig. 1.1 (not to scale)

The trapdoor has length 80 cm and weight 75 N. The mass of the trapdoor is uniformly distributed along its length.

A force F acts at right angles to the trapdoor at end B so that the trapdoor is held in equilibrium at an angle of 42° to the horizontal.

- (i) State the principle of moments.

.....

 [2]

- (ii) Calculate the component of the weight that is perpendicular to the trapdoor.

component of weight = ... N [1]

- (iii) Calculate the magnitude of the force F .

$F =$ N [2]

[Total: 6]



- 2 An object of constant mass moves in a straight line. The variation with time t of the momentum p of the object is shown in Fig. 2.1.

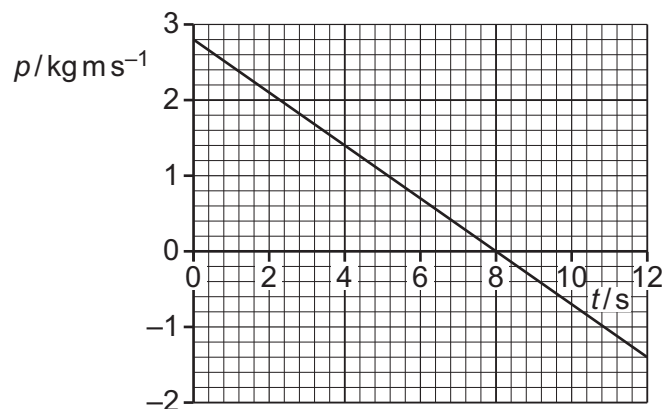


Fig. 2.1

- (a) Define momentum.

.....
 [1]

- (b) Calculate the change in momentum of the object from time $t = 0$ to $t = 12$ s.

change in momentum = ... kg m s⁻¹ [1]

- (c) Calculate the magnitude of the resultant force acting on the object.

force = ... N [2]





- (d) Describe the variation of the speed of the object from time $t = 0$ to $t = 8.0$ s.

.....
 [1]

- (e) By reference to Fig. 2.1, explain why the resultant force acting on the object during the first 8.0 s of its motion cannot be due to air resistance.

.....

 [2]

- (f) At time $t = 0$ the displacement d of the object is zero.

On Fig. 2.2, sketch the variation of d with time t from $t = 0$ to $t = 12$ s.

Numerical values of d are not required.

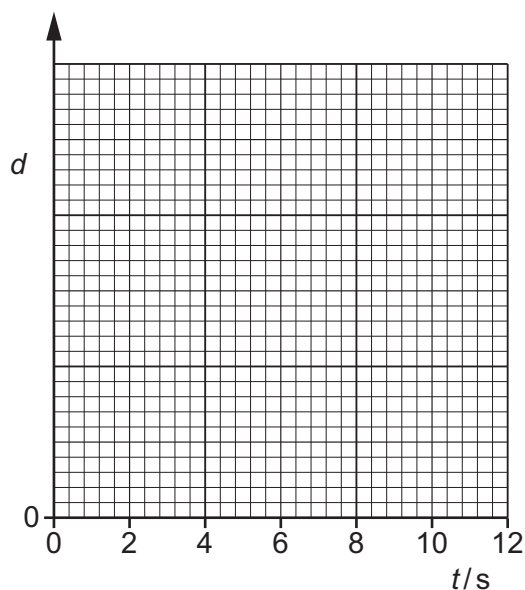


Fig. 2.2

[3]

[Total: 10]



- 3 The lower end of a vertical spring is fixed to a horizontal surface, as shown in Fig. 3.1.

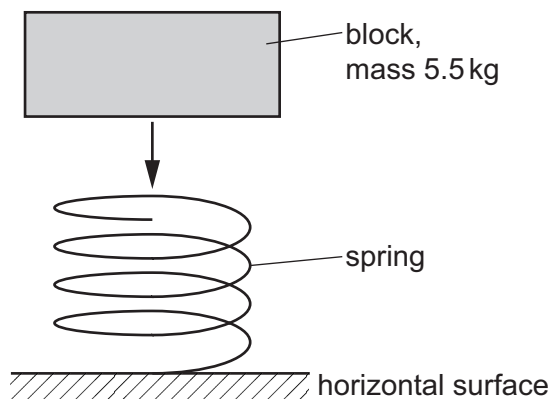


Fig. 3.1

The mass of the spring is negligible. A block of mass 5.5 kg drops vertically onto the spring and is brought to rest as the spring is compressed.

- (a) The block has kinetic energy 110 J as it makes contact with the spring.

Calculate the speed of the block as it makes contact with the spring.

speed = ... ms^{-1} [2]

- (b) The gravitational potential energy of the block decreases by 20 J as the spring is compressed to its maximum compression x_0 .

Show that x_0 is 0.37 m.

[2]

- (c) Assume that, as the spring compresses, all of the energy lost by the block is converted into the elastic potential energy of the spring.

Use the data from (a) and (b) to determine the maximum elastic potential energy of the spring.

Show your working.

maximum elastic potential energy = ... J [1]



- (d) The variation of the force F acting on the spring with the compression x of the spring is shown in Fig. 3.2.

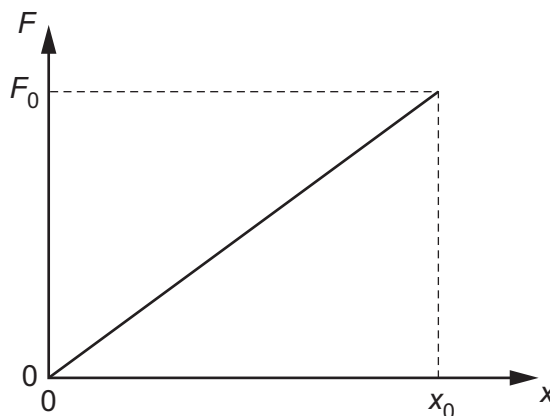


Fig. 3.2

Use the information in (b) and your answer in (c) to show that the maximum force F_0 exerted on the spring by the block is 700 N.

[2]

- (e) Use the information in (d) to determine, for the instant that the block is first brought to rest by the spring, the magnitude of:

- (i) the resultant force acting on the block

resultant force = ... N [2]

- (ii) the acceleration of the block.

acceleration = ... ms^{-2} [2]

[Total: 11]



- 4 (a) A source oscillates with frequency f to produce a progressive wave of wavelength λ . The source takes time t to produce n complete oscillations.

(i) State what is meant by a progressive wave.

.....
 [1]

(ii) State expressions, in terms of some or all of f , λ and n , for:

- the distance moved by a wavefront in time t

distance = ...

- time t .

time t = ... [2]

(iii) Use your answers in (ii) to determine an expression for the speed v of the wave in terms of f and λ .

[1]

- (b) Two identical microwave sources X and Y emit waves in phase. The sources are separated by a distance of 30 cm, as shown in Fig. 4.1.

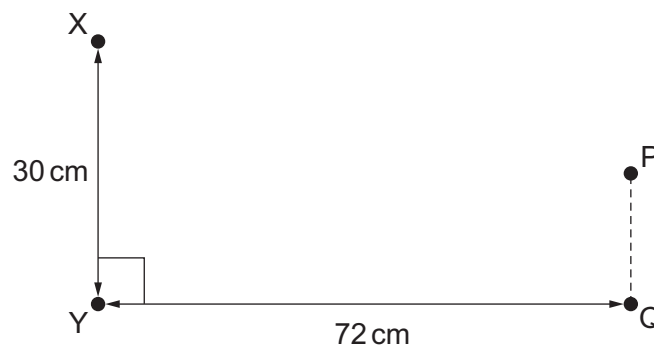


Fig. 4.1 (not to scale)

The intensity of the microwaves is to be investigated at points P and Q.

Line PQ is parallel to line XY. Distance XP is equal to distance YP. Distance YQ is 72 cm and angle XYQ is 90° .

The wavelength of the microwaves is 4.0 cm.



- (i) Calculate the frequency, in GHz, of the microwaves.

frequency = ... GHz [2]

- (ii) Show that the difference between the path lengths XQ and YQ is 6 cm.

[1]

- (iii) State and explain what may be deduced about the intensity of the microwaves at point Q.

.....

 [3]

- (iv) A microwave detector is positioned at P and connected to a cathode-ray oscilloscope (CRO). The controls of the CRO are adjusted so that a waveform is shown on the screen.

Describe the changes to the amplitude of the waveform as the detector is moved from P to Q.

.....

 [2]

[Total: 12]





- 5 (a) (i) State and explain the effect, if any, on the resistance of a filament wire in a lamp as the current in the wire decreases.

.....
 [1]

- (ii) On Fig. 5.1, sketch the I - V characteristic of a filament lamp.

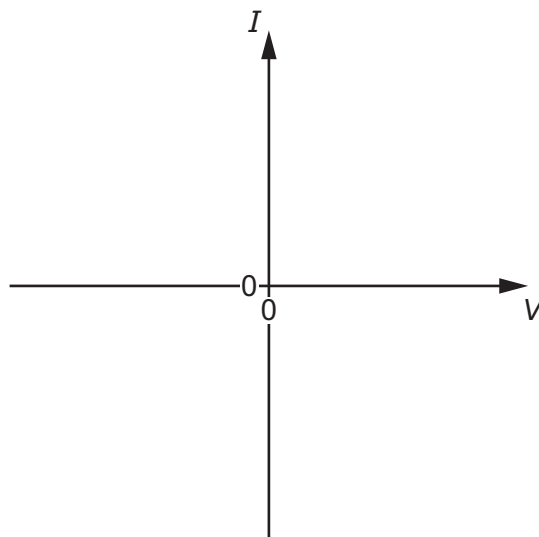


Fig. 5.1

[2]

- (b) A battery of electromotive force (e.m.f.) E and negligible internal resistance is connected in parallel with two filament lamps A and B, as shown in Fig. 5.2.

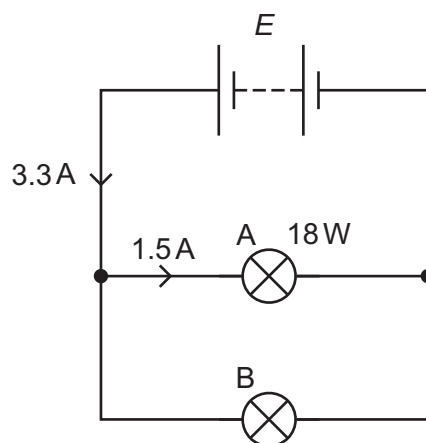


Fig. 5.2

The current in the battery is 3.3 A and the current in lamp A is 1.5 A. The power dissipated in lamp A is 18 W.





- (i) Calculate the e.m.f. E of the battery.

$$E = \dots\dots\dots \text{ V [2]}$$

- (ii) The filament wire of lamp B has a cross-sectional area of $1.4 \times 10^{-9} \text{ m}^2$. The number of free (conduction) electrons per unit volume in the metal of the filament wire is $3.4 \times 10^{28} \text{ m}^{-3}$.

Calculate the average drift speed of the free electrons in the filament wire of lamp B.

$$\text{average drift speed} = \dots\dots\dots \text{ ms}^{-1} \text{ [3]}$$

[Total: 8]



- 6 A battery of electromotive force (e.m.f.) 6.0 V and negligible internal resistance is connected in series with a variable resistor and a uniform resistance wire XY, as shown in Fig. 6.1.

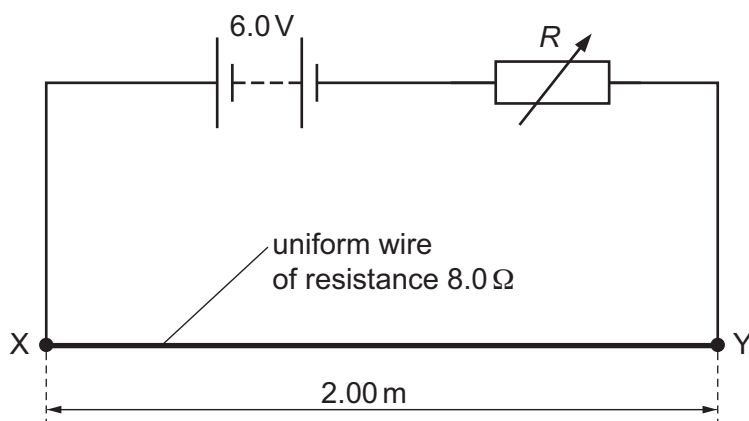


Fig. 6.1

Wire XY has length 2.00 m and resistance $8.0\ \Omega$. The resistance R of the variable resistor is adjusted so that the potential difference across wire XY is 2.4 V .

- (a) Determine R .

$R = \dots\dots\dots \Omega$ [2]

- (b) Explain why the potential difference V between any two points on wire XY is proportional to the distance L between those points.

.....

 [2]



(c) A cell of e.m.f. E and internal resistance r is connected to the circuit, as shown in Fig. 6.2.

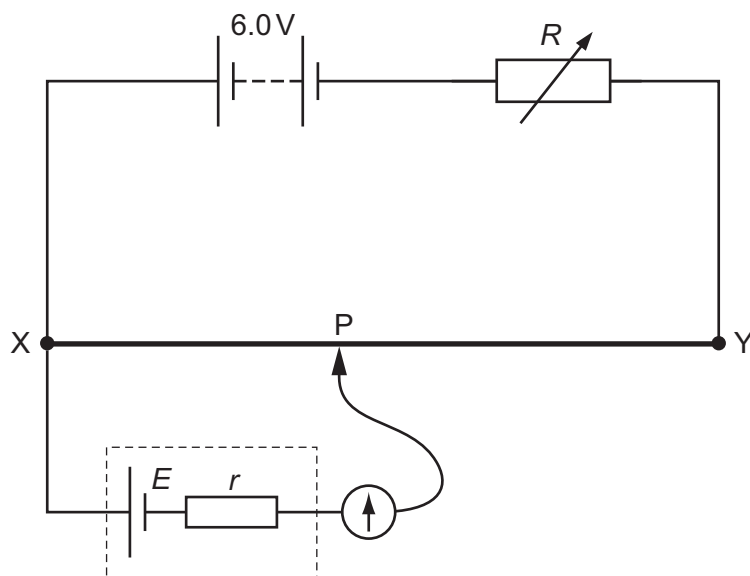


Fig. 6.2

Resistance R is unchanged.

The movable connection P is positioned on wire XY so that the galvanometer reading is zero. Distance XP is 1.24 m.

(i) Calculate E .

$$E = \dots\dots\dots \text{ V [2]}$$

(ii) The value of R is now decreased.

State and explain the change that must be made to the position of P on wire XY so that the galvanometer reads zero again.

.....

 [2]

[Total: 8]







7 (a) State the names of **two** different leptons.

1

2

[2]

(b) In the following list, underline all the particles that are hadrons.

antineutrino beta-plus meson neutron

[1]

(c) By reference to quark composition, show that the charge of a proton is $+1.6 \times 10^{-19} \text{ C}$.

[2]

[Total: 5]





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