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9702/21

May/June 2013

1 hour

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

DO **NOT** WRITE IN ANY BARCODES.

You may lose marks if you do not show your working or if you do not use appropriate units.

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For Examiner's Use	
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Total	

This document consists of **13** printed pages and **3** blank pages.

Data

speed of light in free space,	$c = 3.00 \times 10^8 \text{ m s}^{-1}$
permeability of free space,	$\mu_0 = 4\pi \times 10^{-7} \text{ H m}^{-1}$
permittivity of free space,	$\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$
	$(\frac{1}{4\pi\epsilon_0} = 8.99 \times 10^9 \text{ m F}^{-1})$
elementary charge,	$e = 1.60 \times 10^{-19} \text{ C}$
the Planck constant,	$h = 6.63 \times 10^{-34} \text{ J s}$
unified atomic mass constant,	$u = 1.66 \times 10^{-27} \text{ kg}$
rest mass of electron,	$m_e = 9.11 \times 10^{-31} \text{ kg}$
rest mass of proton,	$m_p = 1.67 \times 10^{-27} \text{ kg}$
molar gas constant,	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
the Avogadro constant,	$N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$
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gravitational constant,	$G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
acceleration of free fall,	$g = 9.81 \text{ m s}^{-2}$

Formulae

uniformly accelerated motion,

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

$$v^2 = u^2 + 2as$$

work done on/by a gas,

$$W = p\Delta V$$

gravitational potential,

$$\phi = -\frac{Gm}{r}$$

hydrostatic pressure,

$$p = \rho gh$$

pressure of an ideal gas,

$$p = \frac{1}{3} \frac{Nm}{V} \langle c^2 \rangle$$

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$$a = -\omega^2 x$$

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$$V = \frac{Q}{4\pi\epsilon_0 r}$$

capacitors in series,

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capacitors in parallel,

$$C = C_1 + C_2 + \dots$$

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$$x = x_0 \sin \omega t$$

radioactive decay,

$$x = x_0 \exp(-\lambda t)$$

decay constant,

$$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$$

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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 $\text{kg m}^{-1} \text{s}^{-2}$.

[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]

- 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.

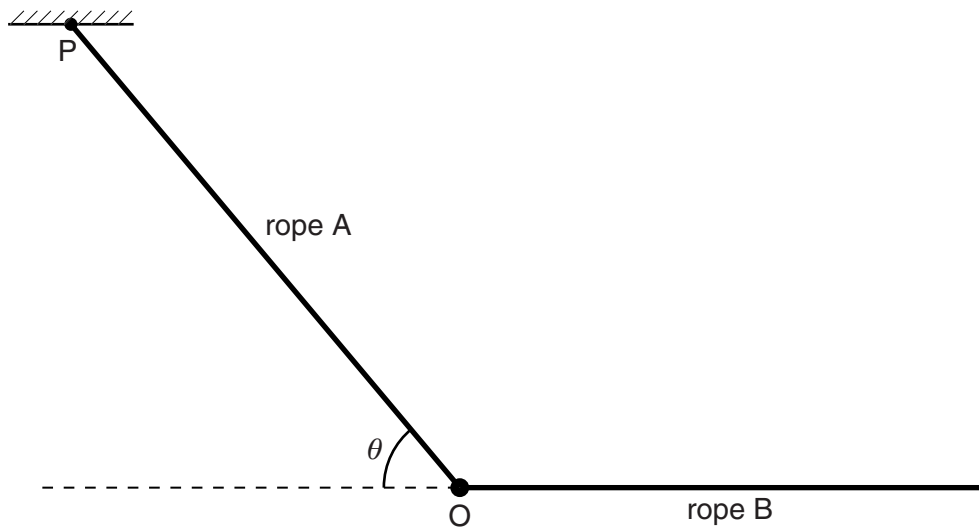


Fig. 2.1

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 ,

For
Examiner's
Use

$\theta = \dots\dots\dots^\circ$ [3]

2. the tension T .

$T = \dots\dots\dots$ N [2]

- 3 (a)** An object falls vertically from rest through air. State and explain the energy conversions that occur as the object falls.

For
Examiner's
Use

.....

.....

.....

..... [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]

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]

- 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.

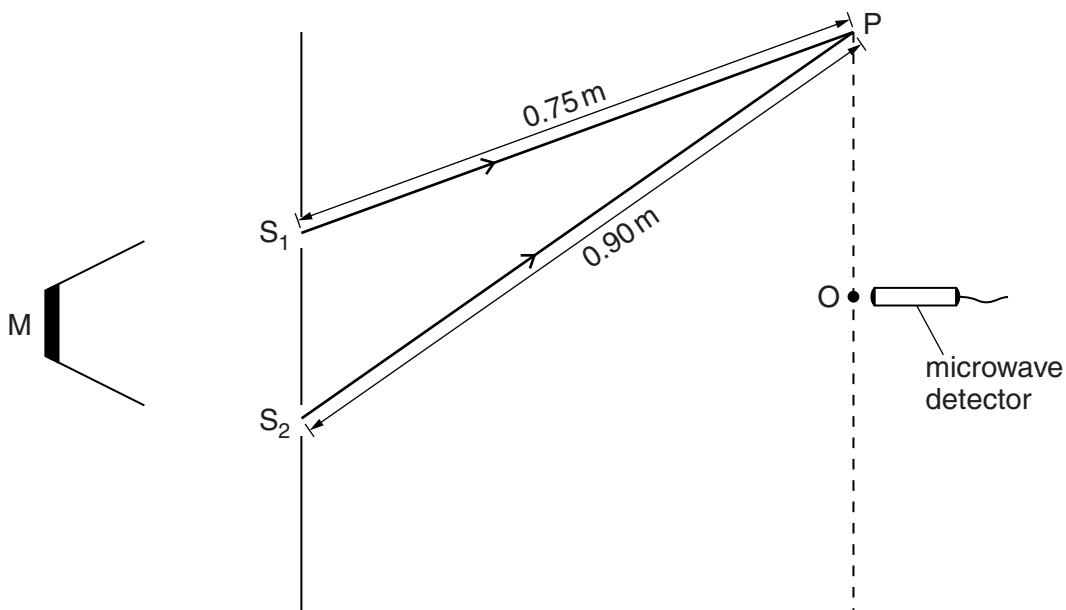


Fig. 5.1 (not to scale)

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.

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]

- 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.

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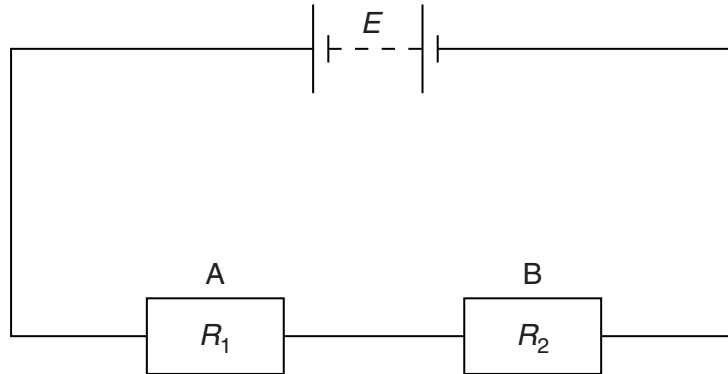


Fig. 6.1

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]

- 7 (a) Describe the two main results of the α -particle scattering experiment.

For
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Use

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:

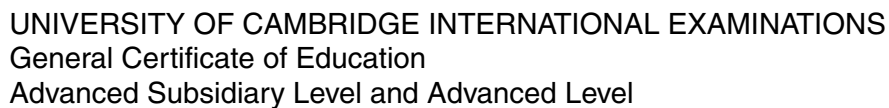
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[3]

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decay constant,

$$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$$

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

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- 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.

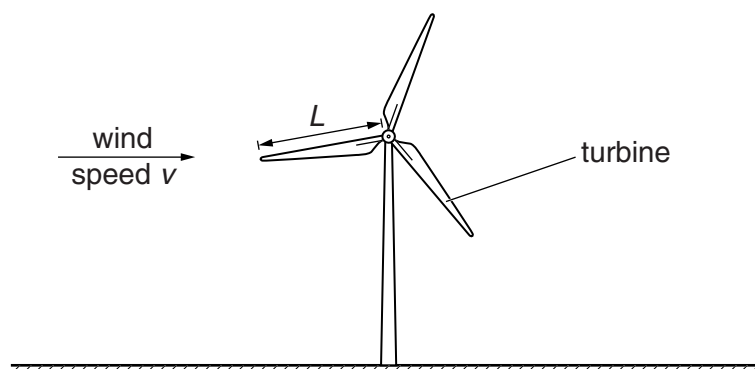


Fig. 1.1

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]

- (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 $3.50 \times 10^5 \text{ W}$.

Calculate the wind speed.

wind speed = ... ms^{-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]

For
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Use

- 2 (a) Define *force*.

..... [1]

For
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Use

- (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.

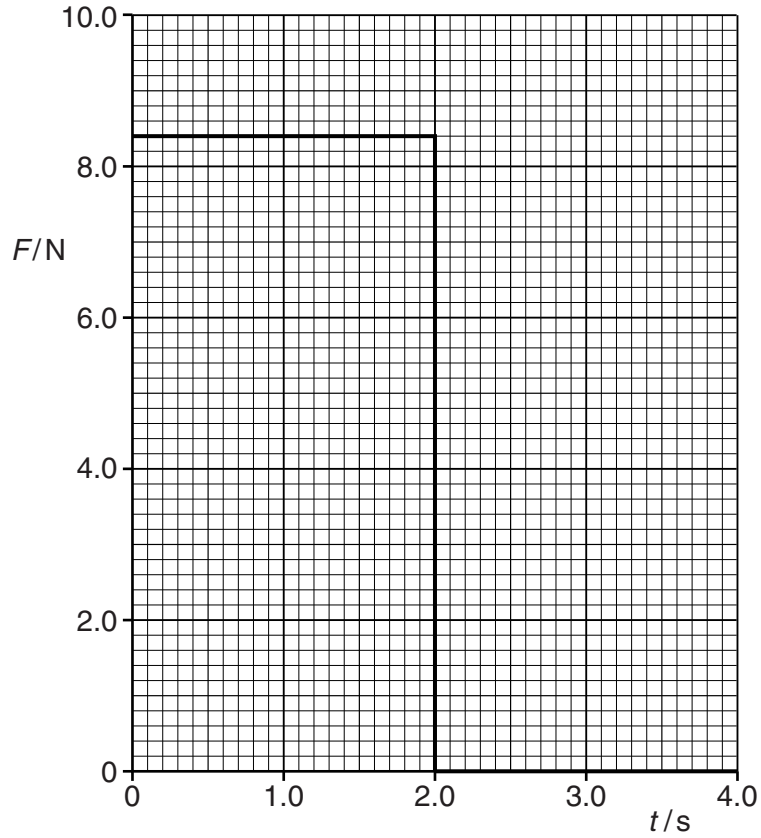


Fig. 2.1

The object starts from rest.

- (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.

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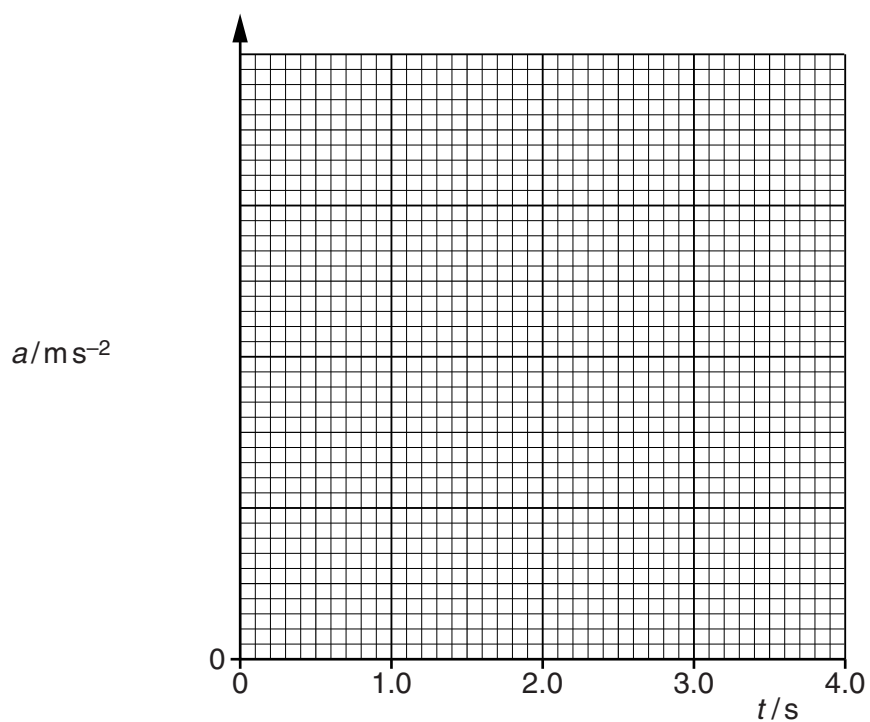


Fig. 2.2

[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.

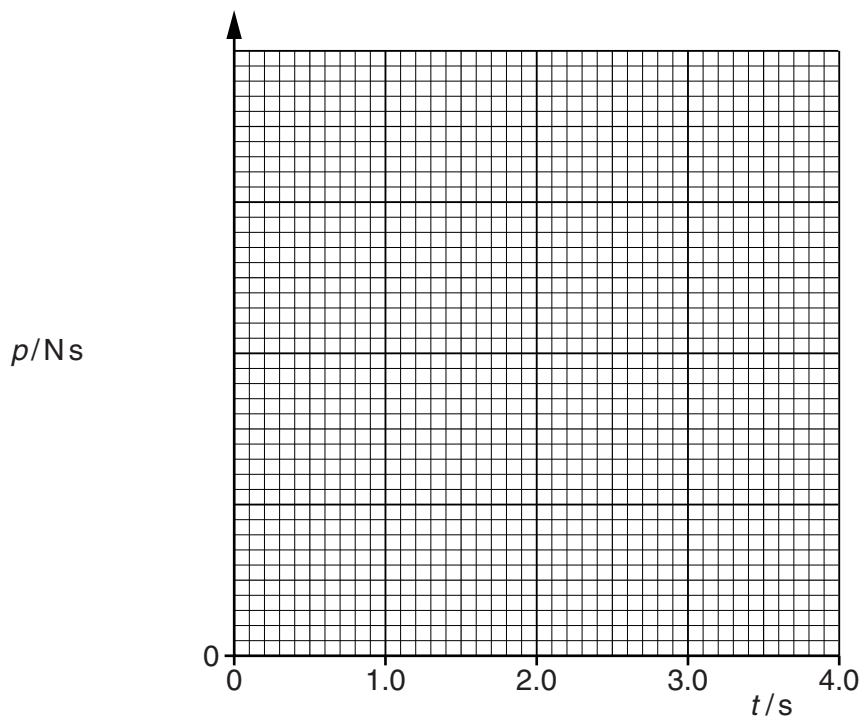


Fig. 2.3

[5]

- 3 (a) Define *centre of gravity*.

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.....
.....[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.

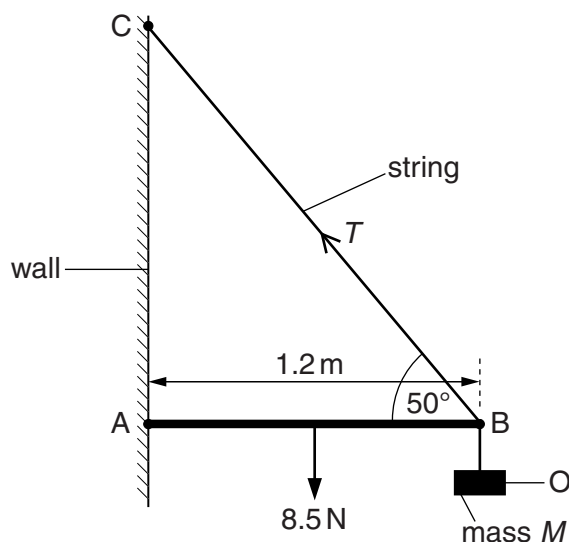


Fig. 3.1

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 $T = \dots\dots\dots$ 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.

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Use

[3]

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

$M = \dots\dots\dots$ kg [1]

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

.....

 [2]

- 4 (a) Describe apparatus that demonstrates Brownian motion. Include a diagram.

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Examiner's
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.....
.....
.....
.....
.....[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]

- 5 Fig. 5.1 shows a string stretched between two fixed points P and Q.

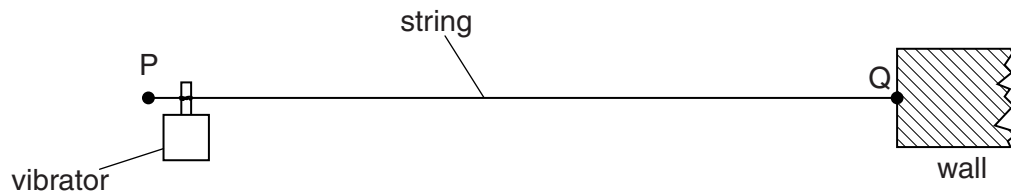


Fig. 5.1

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 ms^{-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.

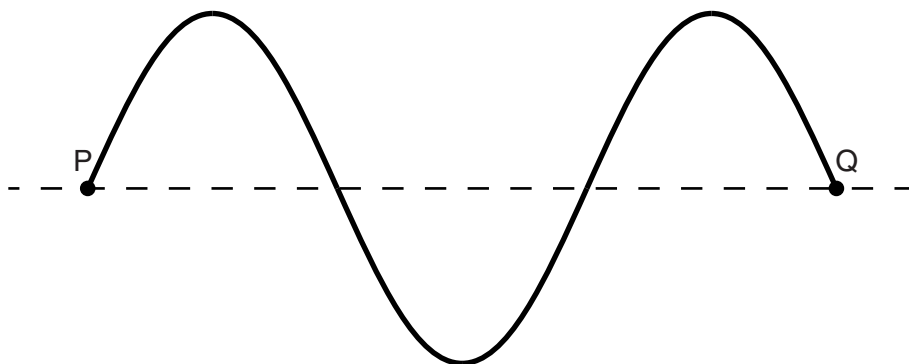


Fig. 5.2 (not to scale)

- (i) On Fig. 5.2, label all the nodes with the letter **N** and all the antinodes with the letter **A**. [2]

- (ii) Use your answer in (a)(i) to calculate the length of string PQ.

For
Examiner's
Use

length = ... m [1]

- (iii) On Fig. 5.2, draw the stationary wave at time $(t + 5.0 \text{ ms})$. Explain your answer.

..... [3]

- 6 (a) Define *charge*.

..... [1]

- (b) A heater is made from a wire of resistance $18.0\ \Omega$ 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]

- 7 A polonium nucleus ${}_{84}^{210}\text{Po}$ is radioactive and decays with the emission of an α -particle. The nuclear reaction for this decay is given by

For
Examiner's
Use



- (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*.

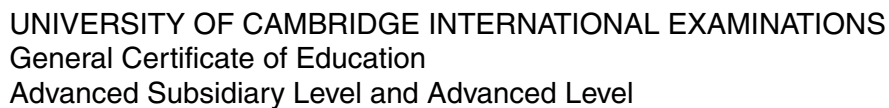
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9702/23

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Do not use staples, paper clips, highlighters, glue or correction fluid.
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Electronic calculators may be used.

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Use

- 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.

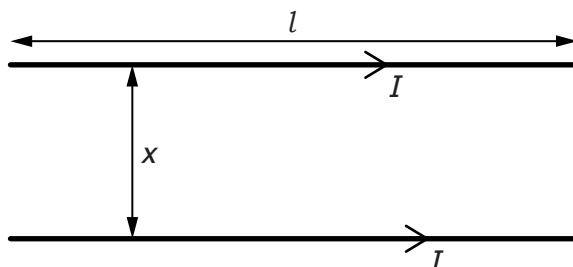


Fig. 1.1

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

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

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.

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Fig. 1.3

[1]

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

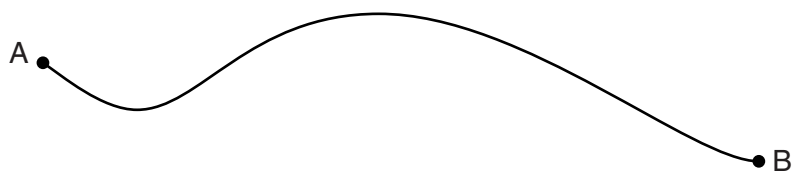


Fig. 2.1

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]

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

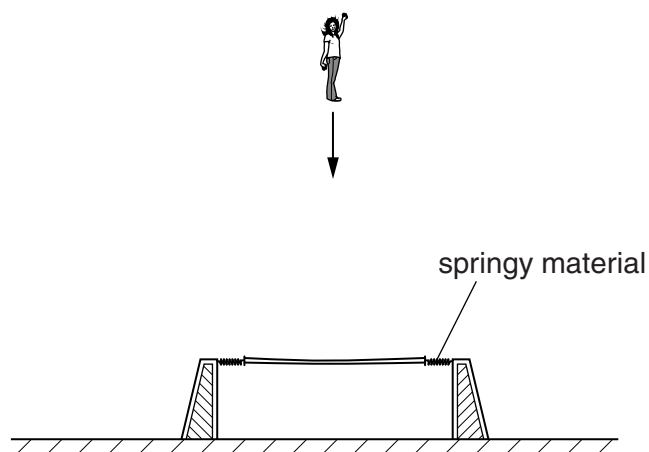


Fig. 2.2

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.

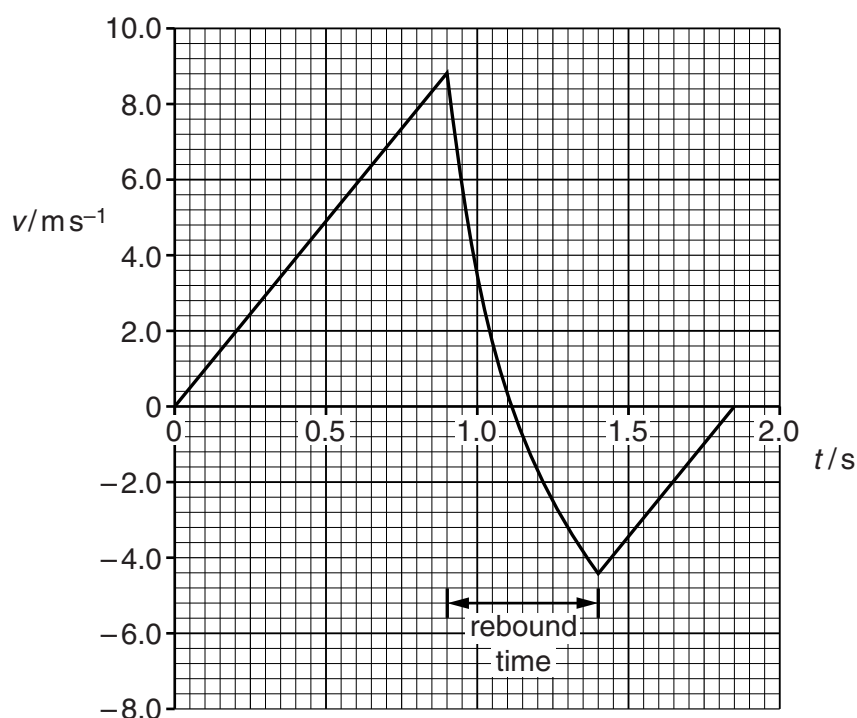


Fig. 2.3

For the motion of the girl, calculate

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

distance = ... m [2]

- (ii) the average acceleration during the rebound.

acceleration = ... ms^{-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 $t = 1.85\text{ s}$. Explain your answer.

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

- 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.

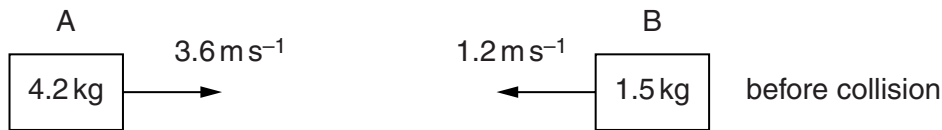


Fig. 3.1

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.

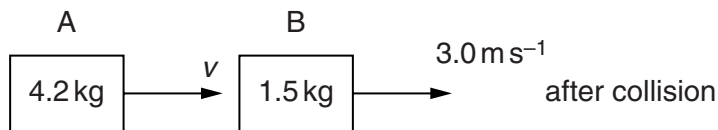


Fig. 3.2

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]

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]

- 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.

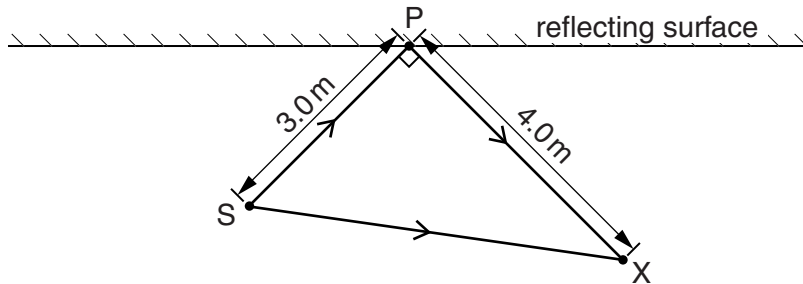


Fig. 5.1

- (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]

- 6 (a) Define *potential difference* (p.d.).

..... [1]

For
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Use

- (b) A battery of electromotive force 20V and zero internal resistance is connected in series with two resistors R_1 and R_2 , as shown in Fig. 6.1.

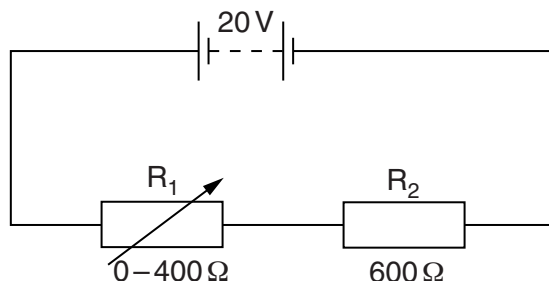


Fig. 6.1

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

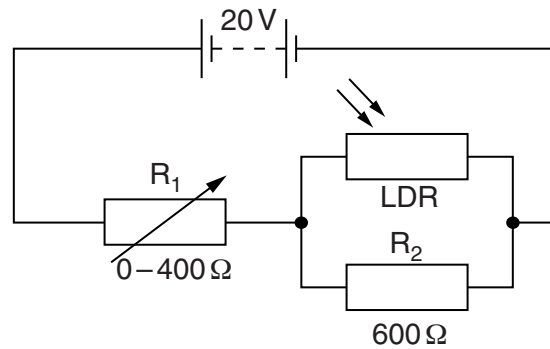


Fig. 6.2

When the light intensity is varied, the resistance of the LDR changes from $5.0\text{ k}\Omega$ to $1.2\text{ k}\Omega$.

- (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 400Ω 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.

- 7 (a) Two isotopes of uranium are uranium-235 ($^{235}_{92}\text{U}$) and uranium-238 ($^{238}_{92}\text{U}$).

(i) Describe in detail an atom of uranium-235.

.....

.....

.....

.....

..... [4]

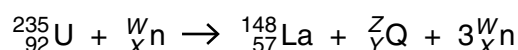
(ii) With reference to the two forms of uranium, explain the term *isotopes*.

.....

.....

..... [2]

- (b) When a uranium-235 nucleus absorbs a neutron, the following reaction may occur:



(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]

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