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9702/21

May/June 2011

1 hour

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Write in dark blue or black pen.
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Answer **all** questions.

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Total	

This document consists of **16** printed 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,	$\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$
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,	$N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$
the Boltzmann constant,	$k = 1.38 \times 10^{-23} \text{ J K}^{-1}$
gravitational constant,	$G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
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,	$p = \frac{1}{3} \frac{Nm}{V} \langle c^2 \rangle$
simple harmonic motion,	$a = -\omega^2 x$
velocity of particle in s.h.m.,	$v = v_0 \cos \omega t$ $v = \pm \omega \sqrt{(x_0^2 - x^2)}$
electric potential,	$V = \frac{Q}{4\pi\epsilon_0 r}$
capacitors in series,	$1/C = 1/C_1 + 1/C_2 + \dots$
capacitors in parallel,	$C = C_1 + C_2 + \dots$
energy of charged capacitor,	$W = \frac{1}{2} QV$
resistors in series,	$R = R_1 + R_2 + \dots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \dots$
alternating current/voltage,	$x = x_0 \sin \omega t$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

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

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

quantity	measurement	uncertainty
length	1750 mm	$\pm 3 \text{ mm}$
diameter	0.38 mm	$\pm 0.01 \text{ mm}$
resistance	7.5Ω	$\pm 0.2 \Omega$

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 $4.86 \times 10^{-7} \Omega \text{ m}$.

[2]

- (ii)** Calculate the uncertainty in the resistivity.

uncertainty = $\pm$ $\Omega \text{ m}$ [4]

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

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resistivity = ... $\pm$ Ωm [1]

- 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.

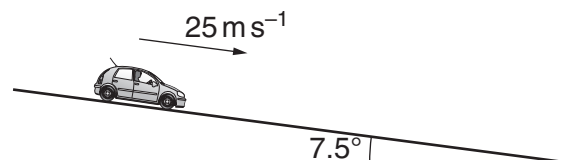


Fig. 2.1

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 ms^{-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 ms^{-2} .

[2]

- (ii) Calculate the distance the car travels from when the brakes are applied until the car comes to rest.

distance = ... m [2]

(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]

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

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

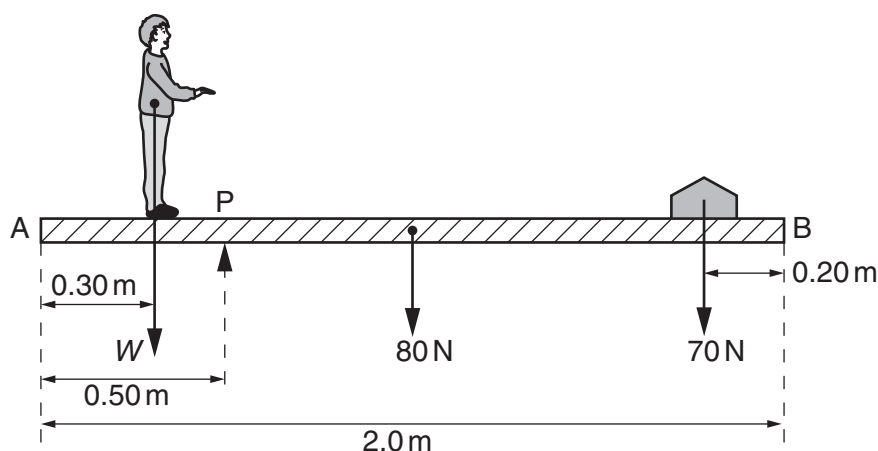


Fig. 3.1 (not to scale)

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.

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Use

$W = \dots\dots\dots$ 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]

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.

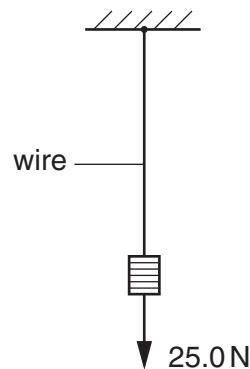


Fig. 4.1

The wire has cross-sectional area $5.74 \times 10^{-8} \text{ m}^2$ and is made of a material that has a Young modulus of $1.60 \times 10^{11} \text{ Pa}$. 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]

- 5 (a) A variable resistor is used to control the current in a circuit, as shown in Fig. 5.1.

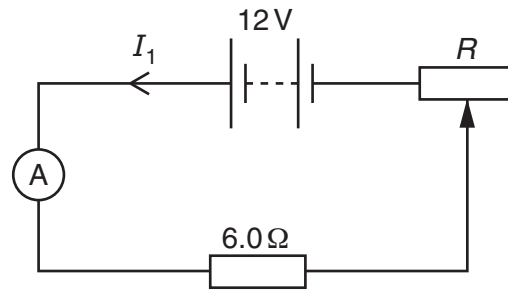


Fig. 5.1

The variable resistor is connected in series with a 12V power supply of negligible internal resistance, an ammeter and a 6.0Ω resistor. The resistance R of the variable resistor can be varied between 0 and 12Ω .

- (i) The maximum possible current in the circuit is 2.0A. 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.

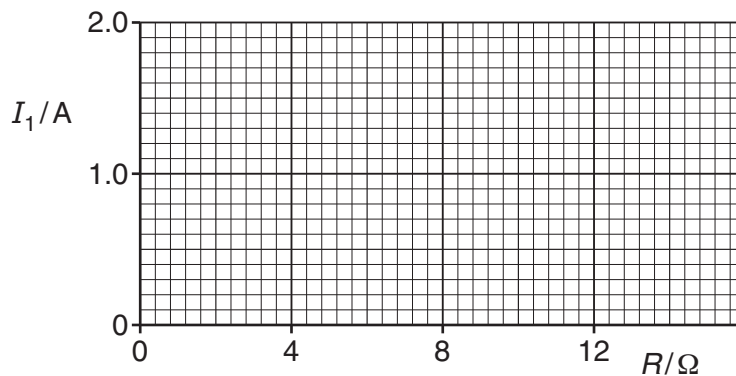


Fig. 5.2

[2]

(b) The variable resistor in (a) is now connected as a potential divider, as shown in Fig. 5.3.

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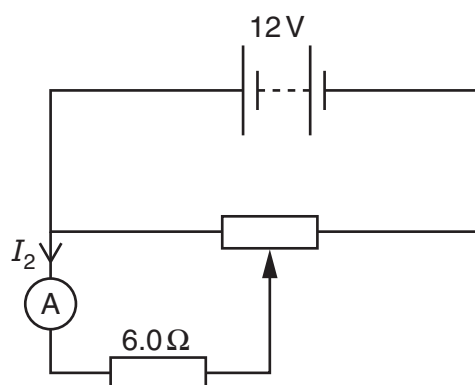


Fig. 5.3

Calculate the maximum possible and minimum possible current I_2 in the ammeter.

maximum $I_2 = \dots\dots\dots$ A

minimum $I_2 = \dots\dots\dots$ A
[2]

(c) (i) Sketch on Fig. 5.4 the $I - V$ characteristic of a filament lamp.

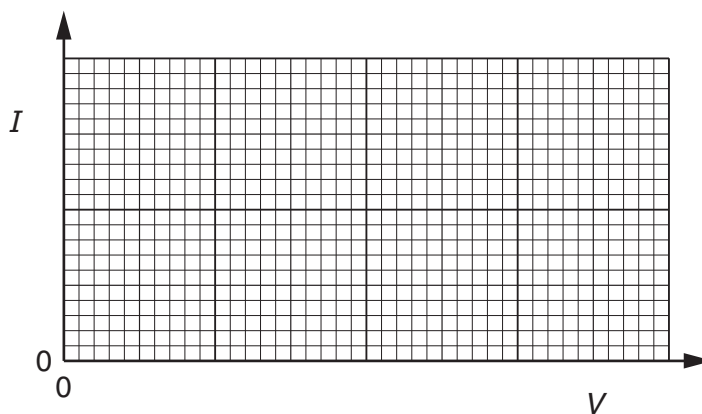


Fig. 5.4

[2]

- (ii) The resistor of resistance 6.0Ω 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.

*For
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Use*

.....
.....
..... [1]

- 6 (a) State two assumptions of the simple kinetic model of a gas.

For
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Use

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]

- 7 (a) Explain the term *interference*.

For
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Use

.....

.....

..... [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]

(c) A wave pattern produced in (b) is shown in Fig. 7.1.

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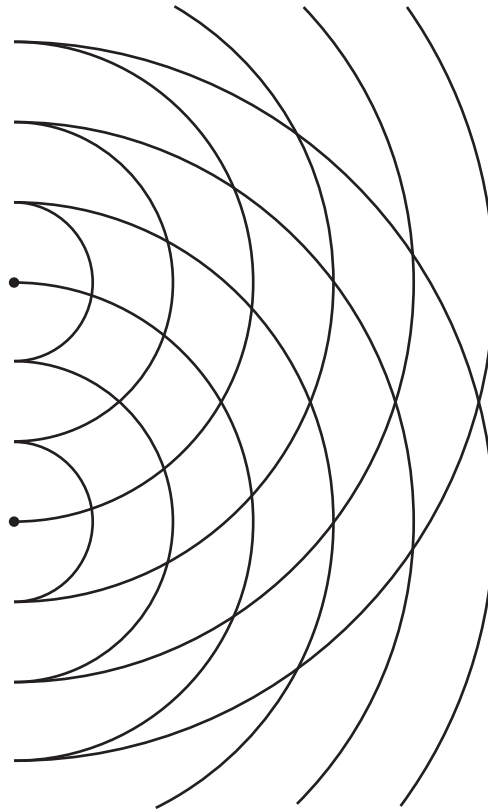


Fig. 7.1

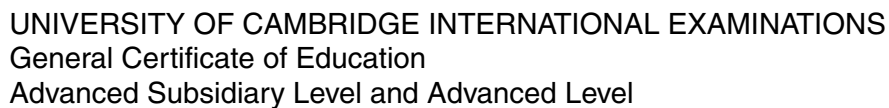
Solid lines on Fig. 7.1 represent crests.

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]

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- 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 m s^{-1} from the top of a cliff 15 m high. The path of the stone is shown in Fig. 1.1.

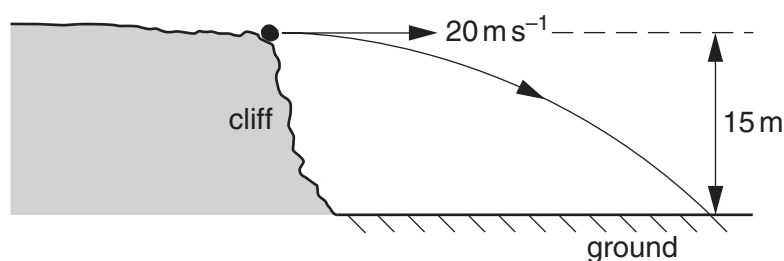


Fig. 1.1

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

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

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Use*

.....

.....

..... [2]

- 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

$$F = 6\pi DRv$$

where D depends on the fluid.

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

[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 $6.6 \times 10^{-4} \text{ kg m}^{-1} \text{s}^{-1}$. The density of water is 1000 kg m^{-3} .

Calculate

1. the magnitude of the frictional force F ,

$$F = \dots\dots\dots \text{ N [1]}$$

2. the acceleration of the raindrop.

$$\text{acceleration} = \dots\dots\dots \text{ m s}^{-2} [3]$$

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

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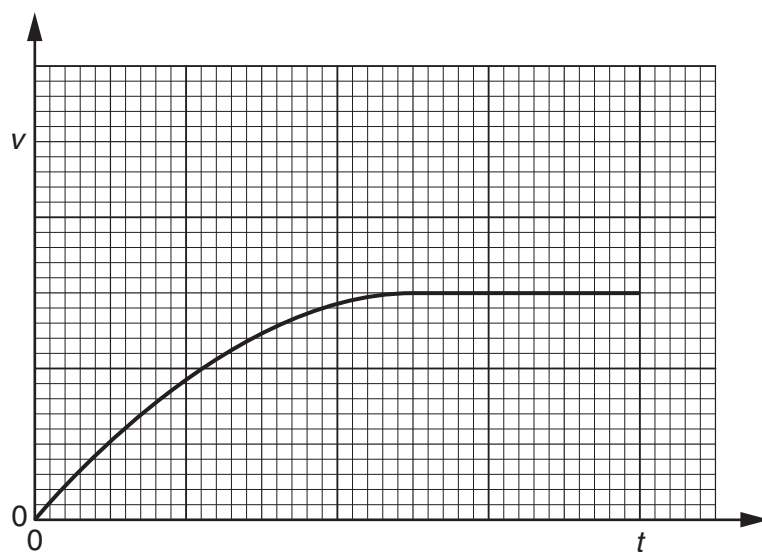


Fig. 2.1

(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]

- 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.

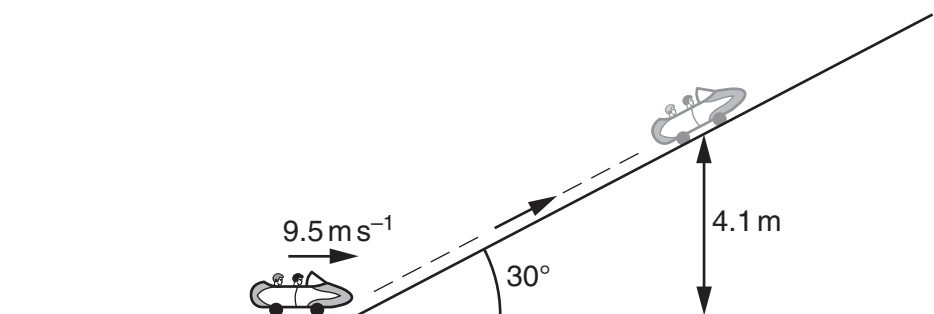


Fig. 3.1

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]

- (iii) Calculate the work done against the resistive force as the carriage moves up the slope.

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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]

4 A student measures the Young modulus of a metal in the form of a wire.

For
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Use

(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
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Use*

.....

.....

.....

.....

.....

.....

.....

.....

.....

..... [4]

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.

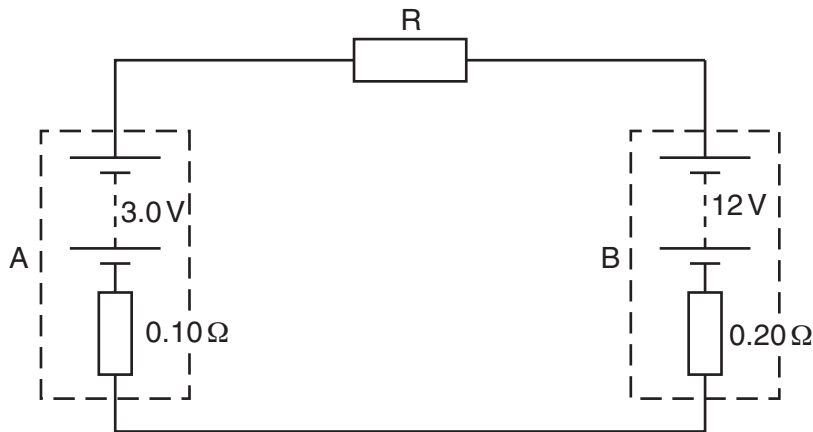


Fig. 5.1

Battery A has an e.m.f. of 3.0V and an internal resistance of 0.10Ω. Battery B has an e.m.f. of 12V and an internal resistance of 0.20Ω. Resistor R has a resistance of 3.3Ω.

(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]

- (iii) Calculate the total energy lost per second in resistor R and the internal resistances.

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Use

energy lost per second = ... Js^{-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]

- 6 (a) Apparatus used to produce interference fringes is shown in Fig. 6.1. The apparatus is not drawn to scale.

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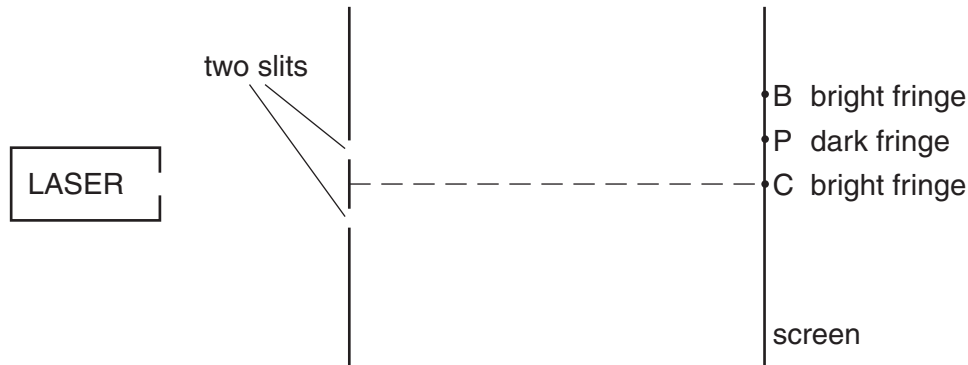


Fig. 6.1 (not to scale)

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]

- (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.

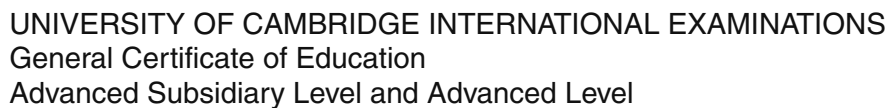
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wavelength = ... nm [3]

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resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \dots$
alternating current/voltage,	$x = x_0 \sin \omega t$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

- 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.

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	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.

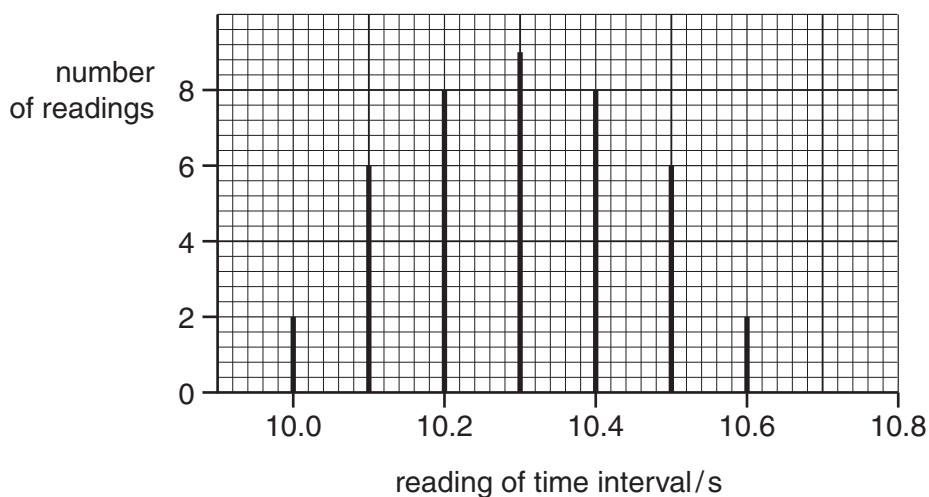


Fig. 1.1

The true value of the time interval is 10.1 s.

(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]

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

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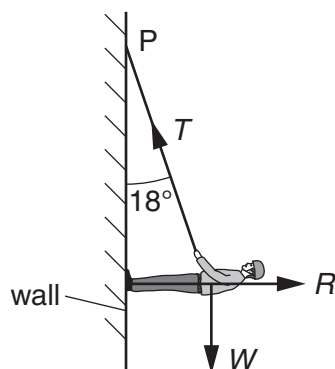


Fig. 2.1

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]

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

(i) the tension T in the rope,

$$T = \dots\dots\dots \text{ N [2]}$$

(ii) the reaction force R .

$$R = \dots\dots\dots \text{ N [1]}$$

(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]

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

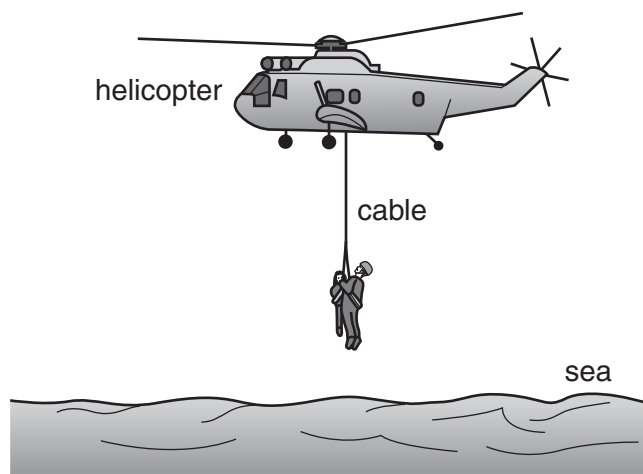


Fig. 3.1

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]

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

For
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Use

deceleration = ... ms^{-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.

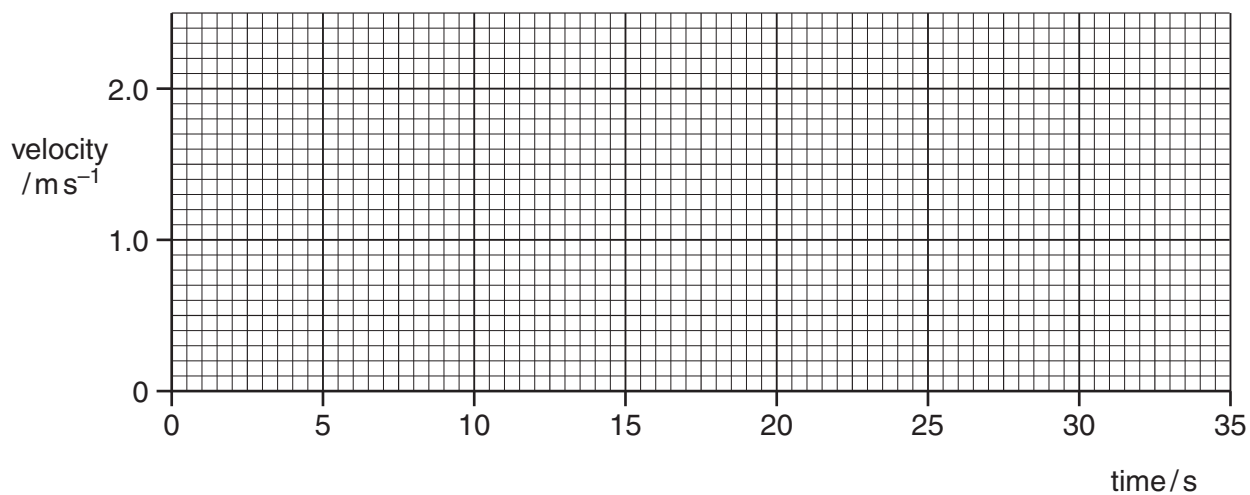


Fig. 3.2

[2]

- 4 (a) State Hooke's Law.

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Use

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

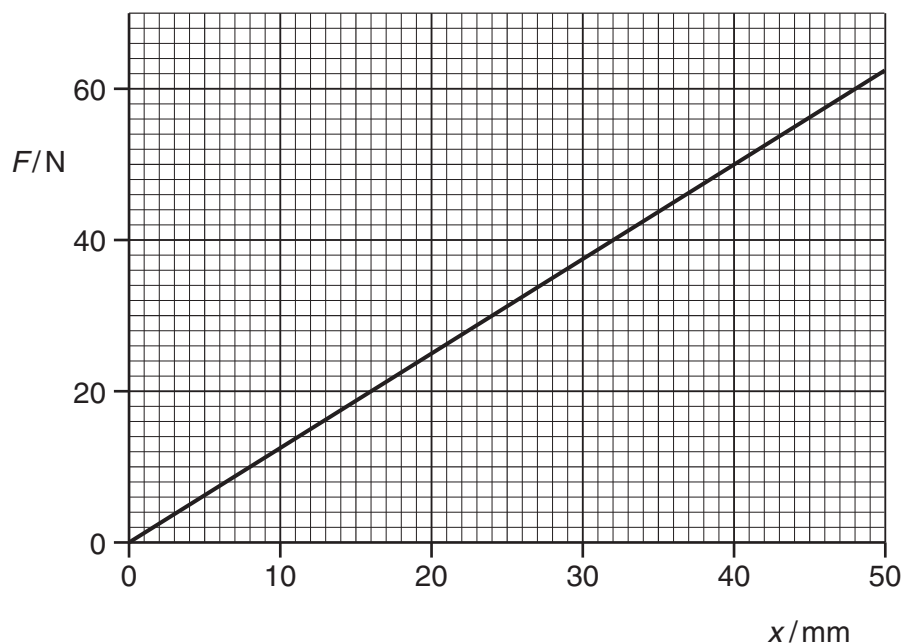


Fig. 4.1

- (i) Calculate the spring constant.

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

- (ii) Show that the work done in compressing the spring by 36 mm is 0.81 J.

[2]

- (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.

For
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Use

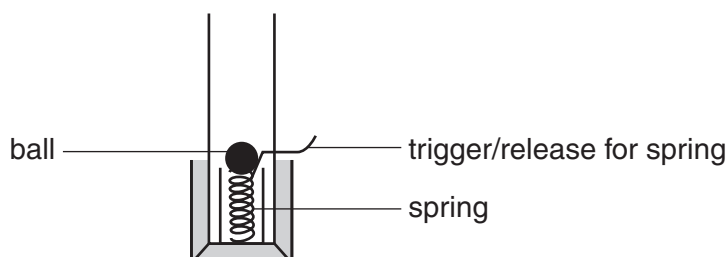


Fig. 4.2

- (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 = ... ms^{-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]

- 5 (a) (i) On Fig. 5.1, sketch the $I - V$ characteristic for a filament lamp.

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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 12V power supply that has negligible internal resistance. The circuits are shown in Fig. 5.2 and Fig. 5.3 respectively.

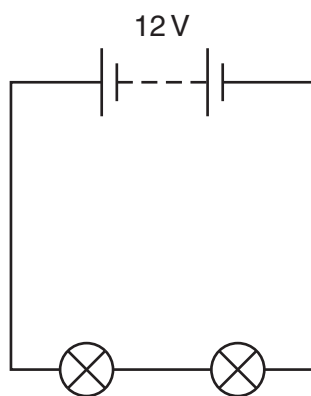


Fig. 5.2

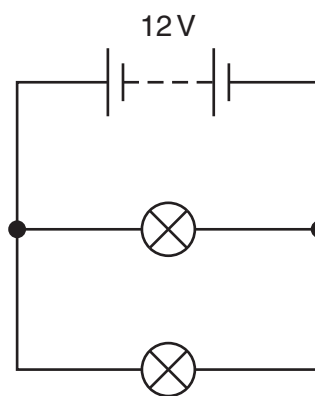


Fig. 5.3

- (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 '12V, 50W'. Calculate the total resistance of the circuit for the two lamps connected such that each lamp uses this power.

total resistance = ... Ω [3]

- 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.

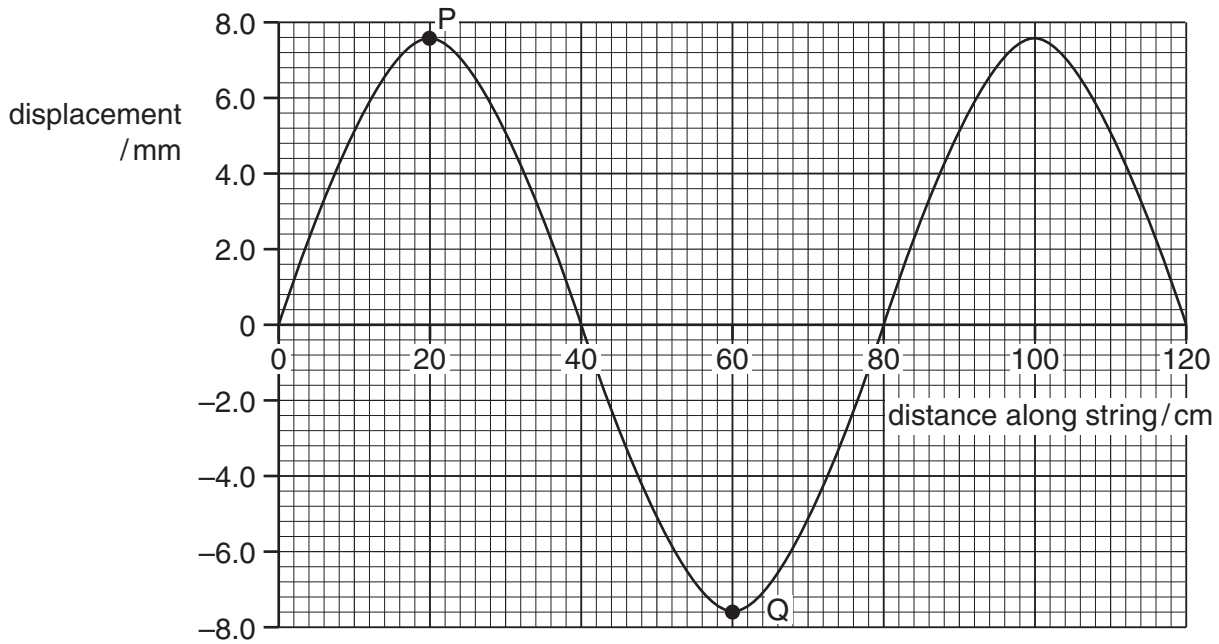


Fig. 6.1

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 = ... ms^{-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]

- (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.

For
Examiner's
Use

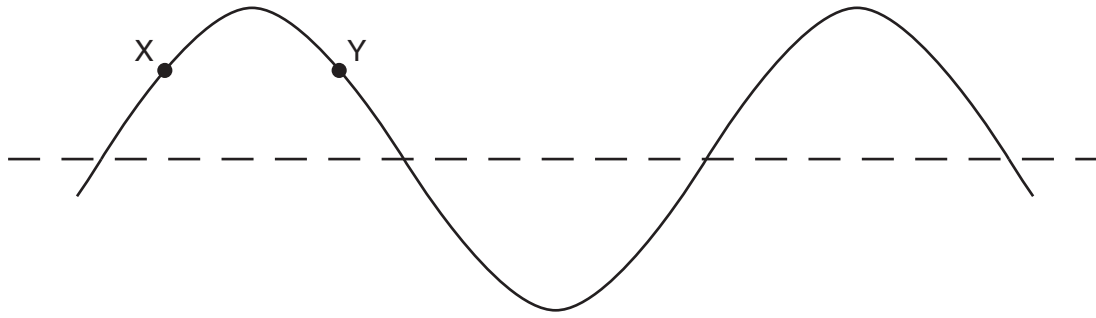


Fig. 6.2

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]

- 7 (a) Explain the difference in densities in solids, liquids and gases using ideas of the spacing between molecules.

For
Examiner's
Use

.....

.....

.....

.....

.....

.....

.....

..... [3]

- (b) A hydrogen nucleus (proton) may be assumed to be a sphere of radius $1 \times 10^{-15} \text{ m}$. 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]

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