



CANDIDATE
NAME

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CENTRE
NUMBER

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CANDIDATE
NUMBER

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9702/21

May/June 2023

1 hour 15 minutes

You must answer on the question paper.

No additional materials are needed.

- 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.

- 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 **20** 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) (i) Define power.

.....
 [1]

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

[1]

- (b) The intensity I of a sound wave moving through a gas is given by

$$I = f^2 A^2 v k$$

where f is the frequency of the wave,
 A is the amplitude of the wave,
 v is the speed of the wave
 and k is a constant that depends on the gas.

Determine the SI base units of k .

SI base units [3]

[Total: 5]

- 2 A rigid uniform beam of weight W is connected to a fixed support by a hinge, as shown in Fig. 2.1.

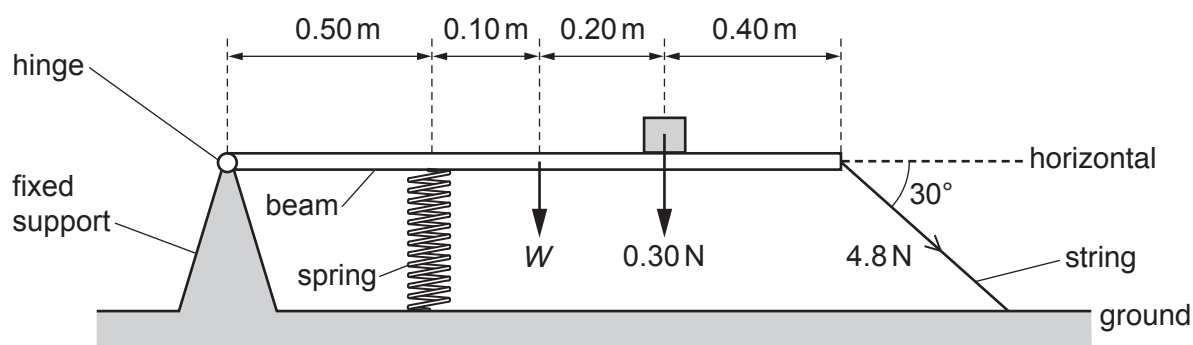


Fig. 2.1 (not to scale)

A compressed spring exerts a total force of 8.2 N vertically upwards on the horizontal beam. A block of weight 0.30 N rests on the beam. The right-hand end of the beam is connected to the ground by a string at an angle of 30° to the horizontal. The tension in the string is 4.8 N. The distances along the beam are shown in Fig. 2.1.

The beam is in equilibrium. Assume that the hinge is frictionless.

- (a) (i) Show that the vertical component of the tension in the string is 2.4 N.

[1]

- (ii) By taking moments about the hinge, determine the weight W of the beam.

$$W = \dots\dots\dots \text{ N } [3]$$

- (iii) Calculate the horizontal component of the force exerted on the beam by the hinge.

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

- (b) The spring obeys Hooke's law and has an elastic potential energy of 0.32 J.

Calculate the compression of the spring.

compression = ...m [2]

- (c) The string is cut so that the spring extends upwards. This causes the beam to rotate and launch the block into the air. The block reaches its maximum height and then falls back to the ground.

Fig. 2.2 shows part of the path of the block in the air shortly before it hits the horizontal ground.

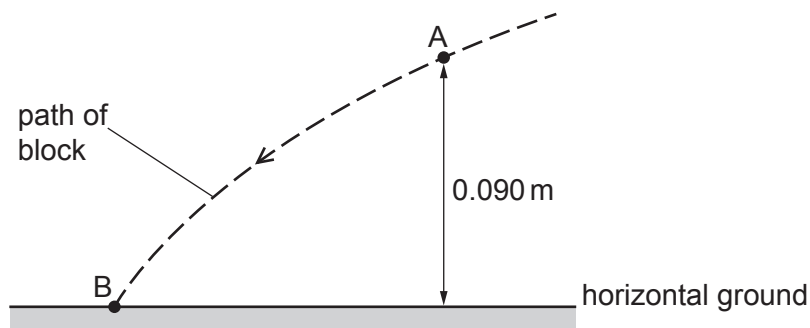


Fig. 2.2 (not to scale)

The block is at a height of 0.090 m above the ground when it passes through point A. The block has a kinetic energy of 0.044 J when it hits the ground at point B. Air resistance is negligible.

- (i) Calculate the decrease in the gravitational potential energy of the block for its movement from A to B.

decrease in gravitational potential energy = ... J [2]

- (ii) Use your answer in (c)(i) and conservation of energy to determine the speed of the block at point A.

speed = ... ms^{-1} [3]

- (iii) By reference to the force on the block, explain why the horizontal component of the velocity of the block remains constant as it moves from A to B.

.....
 [1]

- (iv) The block passes through point A at time t_A and arrives at point B at time t_B .

On Fig. 2.3, sketch a graph to show the variation of the magnitude of the vertical component v_Y of the velocity of the block with time t from $t = t_A$ to $t = t_B$.
 Numerical values of v_Y are not required.

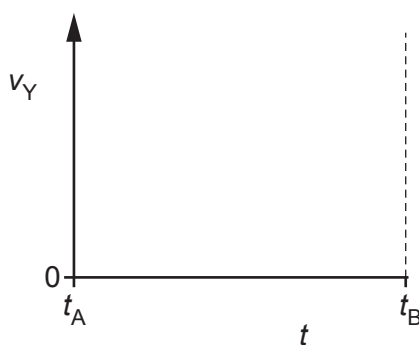


Fig. 2.3

[1]

[Total: 14]

- 3 A block is pulled in a straight line along a rough horizontal surface by a varying force X , as shown in Fig. 3.1.

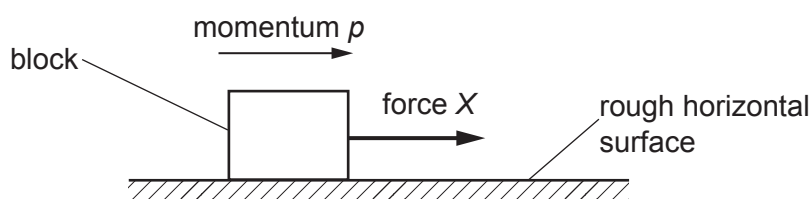


Fig. 3.1

Air resistance is negligible. Assume that the frictional force exerted on the block by the surface is constant and has magnitude 2.0 N .

The variation with time t of the momentum p of the block is shown in Fig. 3.2.

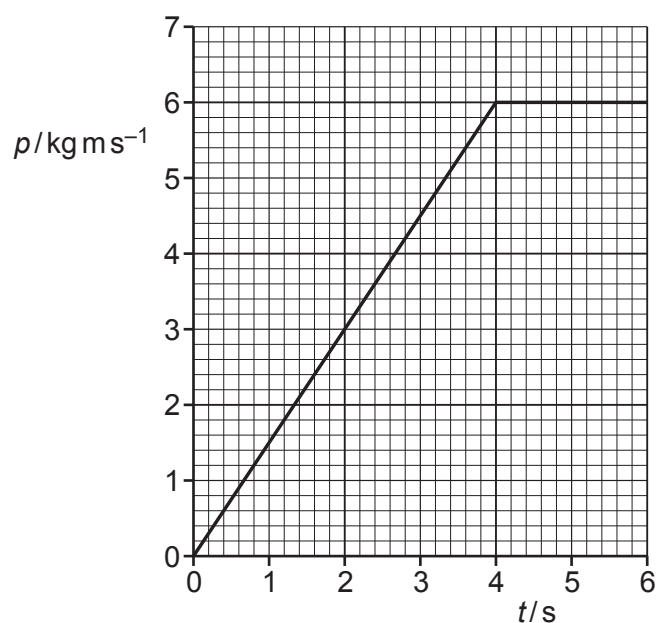


Fig. 3.2

- (a) State Newton's second law of motion.

.....
 [1]

(b) Use Fig. 3.2 to determine, for the block at time $t = 2.0\text{ s}$, the magnitude of:

(i) the resultant force on the block

resultant force = ... N [1]

(ii) the force X .

$X =$ N [1]

(c) On Fig. 3.3, sketch a graph to show the variation of force X with time t from $t = 0$ to $t = 6.0\text{ s}$.

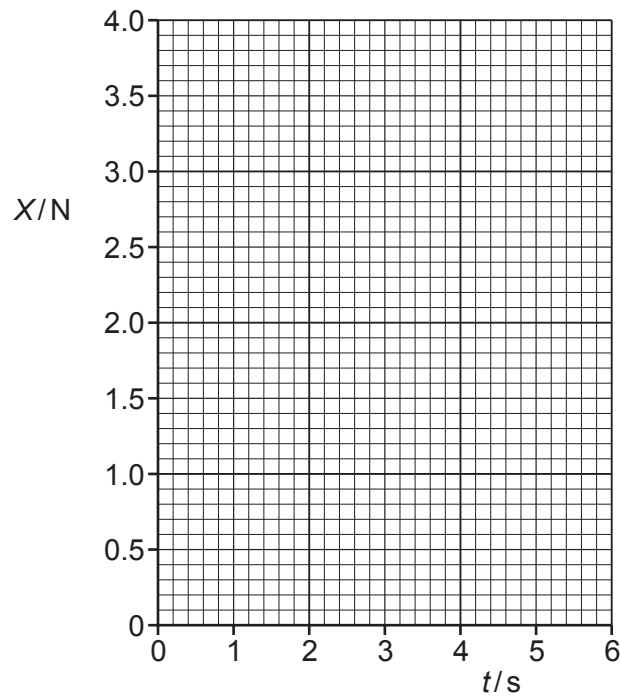


Fig. 3.3

[3]

[Total: 6]

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- 4 A beaker in air contains a liquid. The base of the beaker is in contact with the liquid and has area A , as shown in Fig. 4.1.

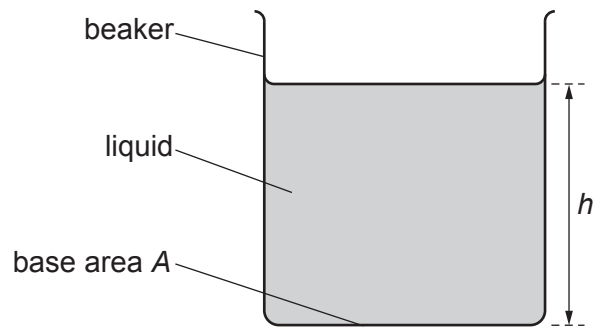


Fig. 4.1

The liquid has density ρ and fills the beaker to a depth h .

- (a) By using the definitions of pressure and density, show that

$$p = \rho gh$$

where p is the pressure due to the liquid that is exerted on the base of the beaker and g is the acceleration of free fall.

[3]

- (b) Suggest why the equation in (a) does not give the total pressure on the base of the beaker.

.....
 [1]

- (c) Fig. 4.2 shows the variation of the total pressure inside the liquid with depth x below the surface.

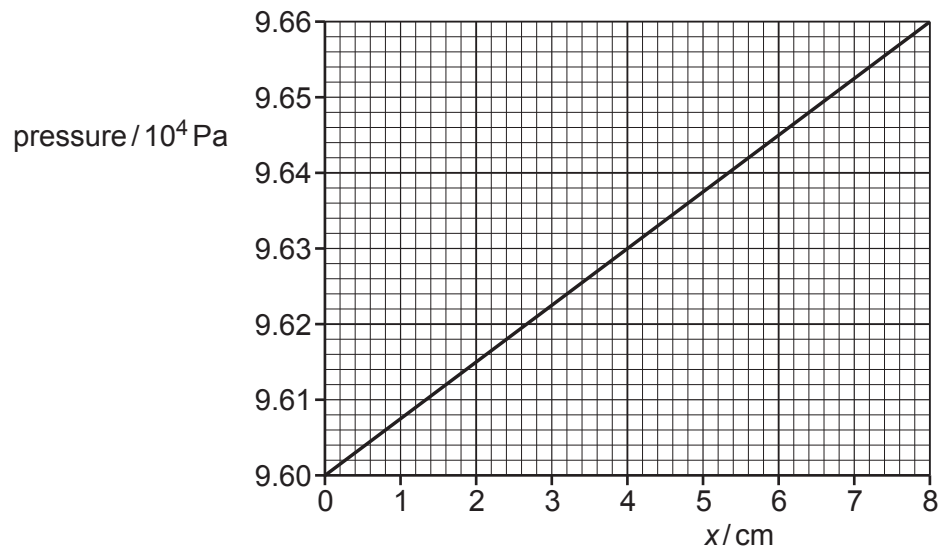


Fig. 4.2

Determine the density of the liquid.

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

- (d) A solid cylinder is held stationary by a wire so that the base of the cylinder is level with the surface of the liquid, as shown in Fig. 4.3.

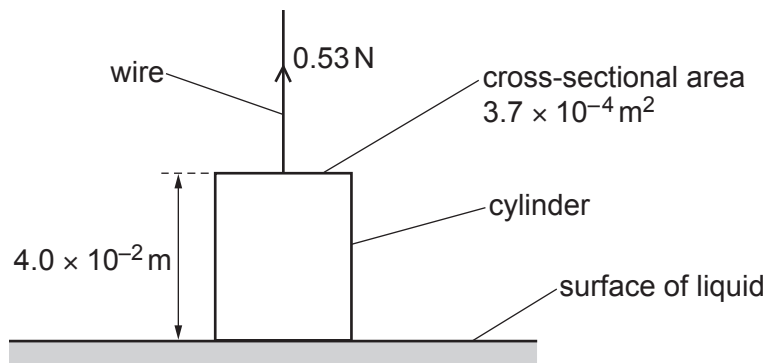


Fig. 4.3 (not to scale)

The cylinder has length $4.0 \times 10^{-2} \text{ m}$ and cross-sectional area $3.7 \times 10^{-4} \text{ m}^2$. The tension in the wire is 0.53 N .

The cylinder is now lowered and then held stationary by the wire so that the top of the cylinder is level with the surface of the liquid.

Calculate the new tension in the wire.

tension = ... N [2]

[Total: 8]

- 5 (a) An electromagnetic wave in a vacuum has a wavelength of $8.4 \times 10^{-6} \text{ m}$.

(i) State the name of the principal region of the electromagnetic spectrum for the wave.

..... [1]

(ii) Calculate the frequency, in THz, of the wave.

frequency = ... THz [2]

- (b) An arrangement that uses a double slit to demonstrate the interference of light from a laser is shown in Fig. 5.1.

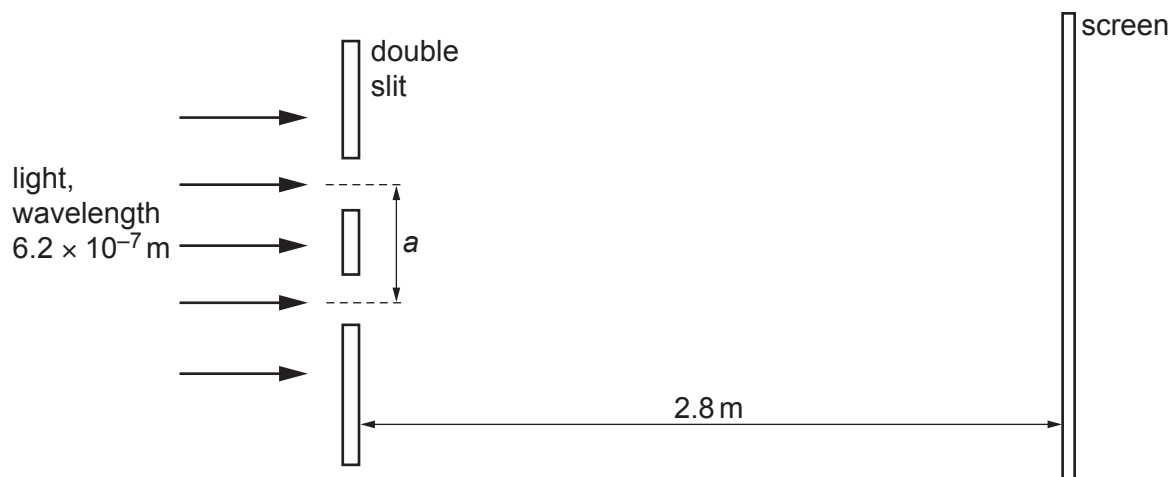


Fig. 5.1 (not to scale)

The light from the laser has a wavelength of $6.2 \times 10^{-7} \text{ m}$ and is incident normally on the slits. The separation of the two slits is a . The slits and screen are parallel and separated by a distance of 2.8 m.

An interference pattern of bright fringes and dark fringes is formed on the screen. The distance on the screen across 8 bright fringes is 22 mm, as illustrated in Fig. 5.2.

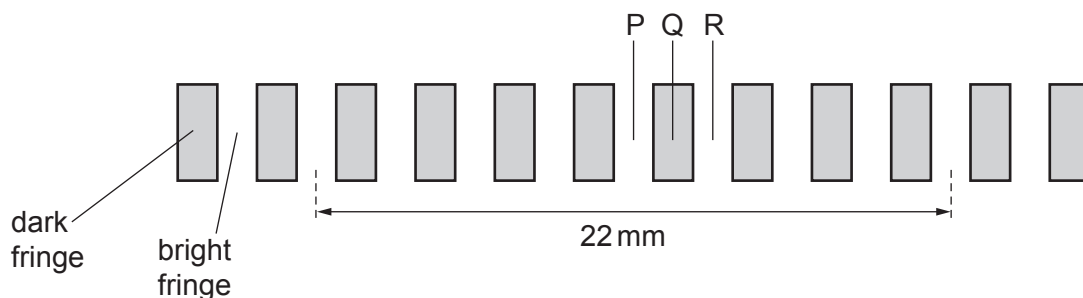


Fig. 5.2

- (i) The light waves emerging from the two slits are coherent.

State what is meant by coherent.

.....
 [1]

- (ii) Calculate the separation a of the slits.

$a =$ m [3]

- (c) Fringe P is the central bright fringe of the interference pattern in (b). Fringe Q and fringe R are the nearest dark fringe and the nearest bright fringe respectively to the right of fringe P, as shown in Fig. 5.2.

- (i) Calculate the difference in the distances (the path difference) from each slit to the centre of fringe Q.

difference in the distances = ... m [1]

- (ii) State the phase difference between the light waves meeting at the centre of fringe R.

phase difference = ...° [1]

[Total: 9]

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- 6 A metal wire in a circuit has a length of 1.8 m and a cross-sectional area of $1.5 \times 10^{-6} \text{ m}^2$. The total number of free electrons (charge carriers) in the wire is 2.3×10^{23} .

There is a current in the wire so that a charge of 172 C moves past a fixed point in the wire in a time of 2.5 minutes.

- (a) Show that the number density of the free electrons in the wire is $8.5 \times 10^{28} \text{ m}^{-3}$.

[1]

- (b) Calculate the average drift speed of the free electrons.

average drift speed = ... ms^{-1} [3]

[Total: 4]

- 7 A battery of electromotive force (e.m.f.) 9.6 V and negligible internal resistance is connected in series with two fixed resistors and a thermistor, as shown in Fig. 7.1.

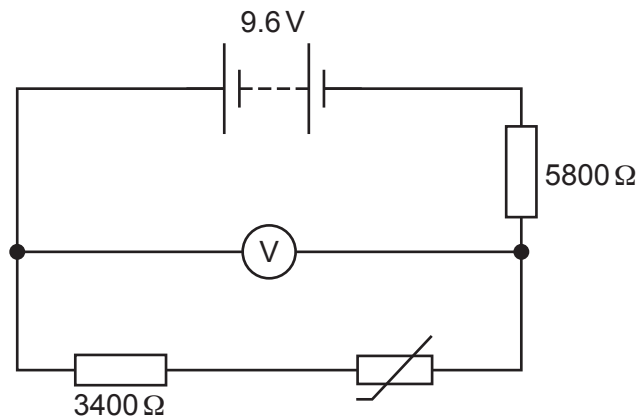


Fig. 7.1

The fixed resistors have resistances of $3400\ \Omega$ and $5800\ \Omega$. The reading on the voltmeter in the circuit is 6.0 V.

- (a) Calculate the current in the resistor of resistance $5800\ \Omega$.

current = ... A [2]

- (b) Calculate the resistance of the thermistor.

resistance = ... Ω [2]

- (c) The initial energy stored in the battery is $2.6 \times 10^4 \text{ J}$.

Assume that the e.m.f. of the battery is constant.

Determine the final energy stored in the battery after a charge of 330 C has moved through it.

final stored energy = ... J [2]

- (d) The environmental conditions change causing an increase in the resistance of the thermistor.

State whether there is a decrease, increase or no change to:

- (i) the temperature of the thermistor

..... [1]

- (ii) the current in the thermistor

..... [1]

- (iii) the potential difference across the thermistor.

..... [1]

[Total: 9]

- 8 An isolated stationary nucleus X decays by emitting an α -particle to form a nucleus Y.

Nucleus Y and nucleus Z are isotopes of the same element.

- (a) By comparing the number of protons in each nucleus, state and explain whether the charge of nucleus Y is less than, greater than or the same as the charge of:

(i) nucleus Z

.....
 [1]

(ii) nucleus X.

.....

 [2]

- (b) Use the principle of conservation of momentum to explain why nucleus Y cannot be stationary immediately after the decay of nucleus X.

.....

 [2]

[Total: 5]

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molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
Boltzmann constant	$k = 1.38 \times 10^{-23} \text{ J K}^{-1}$
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Formulae

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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) (i) Define pressure.

.....
 [1]

- (ii) Use the answer to (a)(i) to show that the SI base units of pressure are $\text{kg m}^{-1} \text{s}^{-2}$.

[1]

- (b) A horizontal pipe has length L and a circular cross-section of radius R . A liquid of density ρ flows through the pipe. The mass m of liquid flowing through the pipe in time t is given by

$$m = \frac{\pi(p_2 - p_1)R^4 \rho t}{8kL}$$

where p_1 and p_2 are the pressures at the ends of the pipe and k is a constant.

Determine the SI base units of k .

SI base units [3]

- (c) An experiment is performed to determine the value of k by measuring the values of the other quantities in the equation in (b).

The values of L and R each have a percentage uncertainty of 2%.

State and explain, quantitatively, which of these two quantities contributes more to the percentage uncertainty in the calculated value of k .

.....

 [1]

[Total: 6]

- 2 (a) State what is meant by the centre of gravity of an object.

.....
 [1]

- (b) Two blocks are on a horizontal beam that is pivoted at its centre of gravity, as shown in Fig. 2.1.

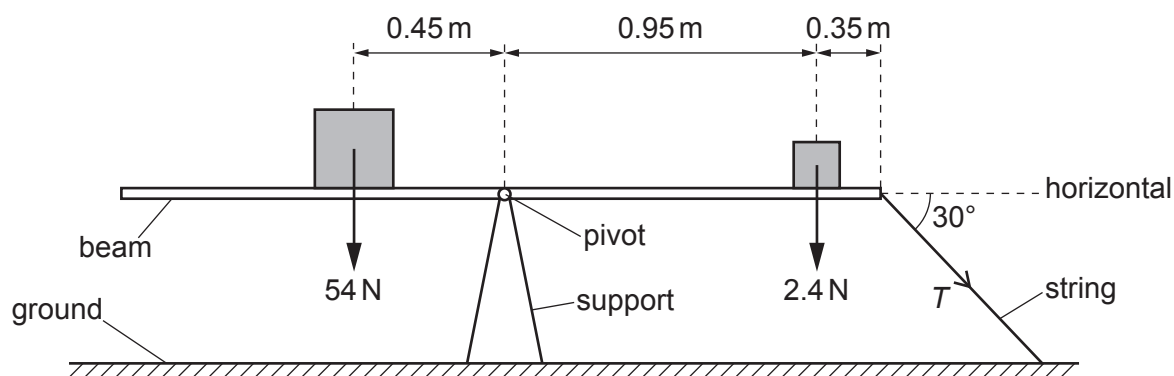


Fig. 2.1 (not to scale)

A large block of weight 54 N is a distance of 0.45 m from the pivot. A small block of weight 2.4 N is a distance of 0.95 m from the pivot and a distance of 0.35 m from the right-hand end of the beam.

The right-hand end of the beam is connected to the ground by a string that is at an angle of 30° to the horizontal. The beam is in equilibrium.

- (i) By taking moments about the pivot, calculate the tension T in the string.

$T = \dots\dots\dots$ N [3]

- (ii) The string is cut so that the beam is no longer in equilibrium.

Calculate the magnitude of the resultant moment about the pivot acting on the beam immediately after the string is cut.

resultant moment = $\dots\dots\dots$ Nm [1]

- (c) The beam in (b) rotates when the string is cut and the small block of weight 2.4 N is projected through the air. Fig. 2.2 shows the last part of the path of the block before it hits the ground at point Y.

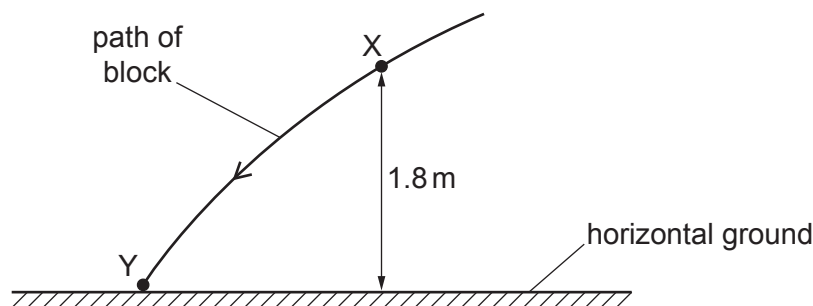


Fig. 2.2 (not to scale)

At point X on the path, the block has a speed of 3.4 m s^{-1} and is at a height of 1.8 m above the horizontal ground. Air resistance is negligible.

- (i) Calculate the decrease in the gravitational potential energy of the block for its movement from X to Y.

decrease in gravitational potential energy = ... J [2]

- (ii) Use your answer to (c)(i) and conservation of energy to determine the kinetic energy of the block at Y.

kinetic energy = ... J [3]

- (iii) State the variation, if any, in the direction of the acceleration of the block as it moves from X to Y.

..... [1]

- (iv) The block passes point X at time t_X and arrives at point Y at time t_Y .

On Fig. 2.3, sketch a graph to show the variation of the magnitude of the horizontal component of the velocity of the block with time from t_X to t_Y . Numerical values are not required.

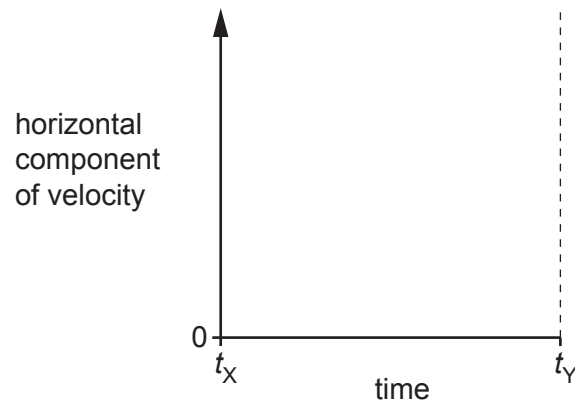


Fig. 2.3

[1]

[Total: 12]

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- 3 A block is pulled by a force X in a straight line along a rough horizontal surface, as shown in Fig. 3.1.

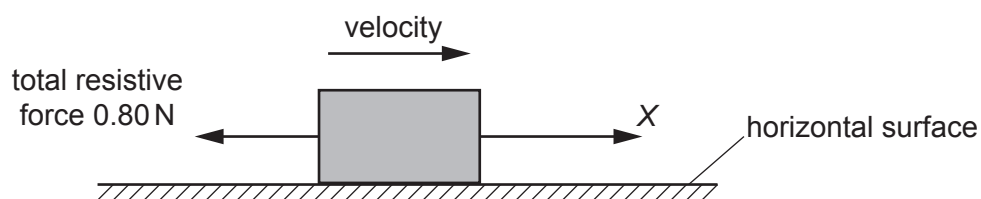


Fig. 3.1

Assume that the total resistive force opposing the motion of the block is 0.80 N at all speeds of the block.

The variation with time t of the magnitude of the force X is shown in Fig. 3.2.

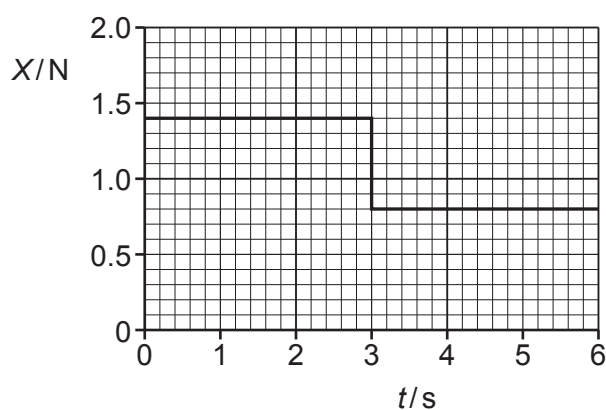


Fig. 3.2

- (a) (i) Define force.

.....
 [1]

- (ii) Determine the change in momentum of the block from time $t = 0$ to time $t = 3.0$ s.

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

- (b) (i) Describe and explain the motion of the block between time $t = 3.0\text{ s}$ and time $t = 6.0\text{ s}$.

.....

.....

.....

..... [2]

- (ii) Force X produces a total power of 2.0 W when moving the block between time $t = 3.0\text{ s}$ and time $t = 6.0\text{ s}$.

Calculate the distance moved by the block during this time interval.

distance = ... m [3]

- (c) The block is at rest at time $t = 0$.

On Fig. 3.3, sketch a graph to show the variation of the momentum of the block with time t from $t = 0$ to $t = 6.0\text{ s}$.

Numerical values of momentum are not required.

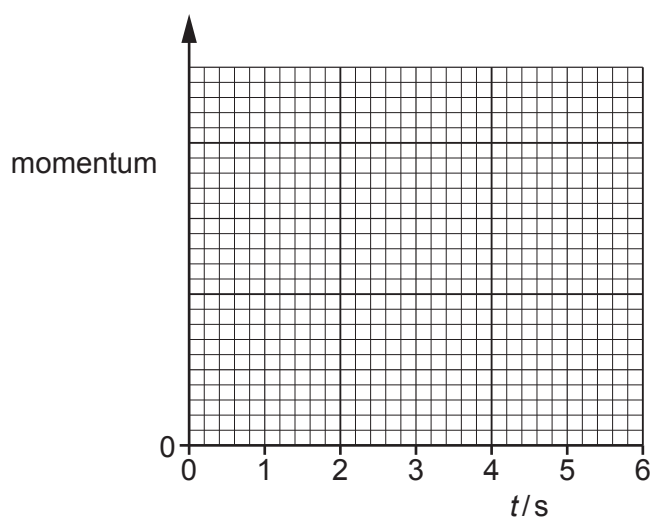


Fig. 3.3

[2]

[Total: 10]

- 4 A spring is suspended from a fixed point at one end. The spring is extended by a vertical force applied to the other end. The variation of the applied force F with the length L of the spring is shown in Fig. 4.1.

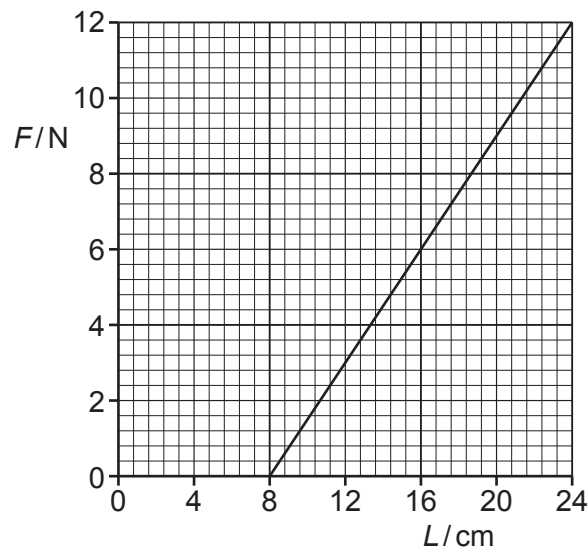


Fig. 4.1

For the spring:

- (a) state the name of the law that gives the relationship between the force and the extension

..... [1]

- (b) determine the spring constant, in N m^{-1}

spring constant = ... N m^{-1} [2]

- (c) determine the elastic potential energy when $F = 6.0 \text{ N}$.

elastic potential energy = ... J [2]

[Total: 5]

- 5 (a) A progressive wave travels through a medium. The wave causes a particle of the medium to vibrate along a line P. The energy of the wave propagates along a line Q.

Compare the directions of lines P and Q if the wave is:

- (i) a transverse wave

..... [1]

- (ii) a longitudinal wave.

..... [1]

- (b) A tube is closed at one end. A loudspeaker is placed near the other end of the tube, as shown in Fig. 5.1.

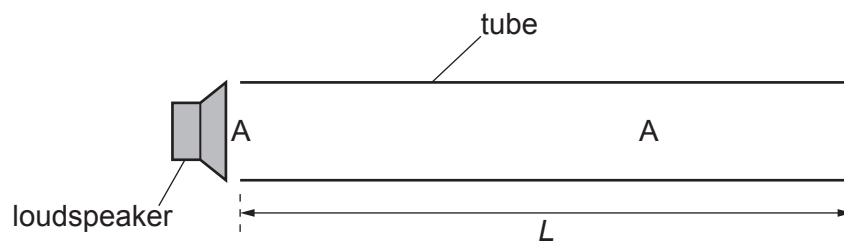


Fig. 5.1 (not to scale)

The loudspeaker emits sound of frequency 1.7 kHz . The speed of sound in the air in the tube is 340 m s^{-1} . A stationary wave is formed with an antinode A at the open end of the tube. There is only one other antinode A inside the tube, as shown in Fig. 5.1.

Determine:

- (i) the wavelength of the sound

wavelength = ... m [2]

- (ii) the length L of the tube

$L =$ m [1]

- (iii) the maximum wavelength of the sound from the loudspeaker that can produce a stationary wave in the tube.

maximum wavelength = ... m [1]

- (c) Two polarising filters are arranged so that their planes are vertical and parallel. The first filter has its transmission axis at an angle of 35° to the vertical and the second filter has its transmission axis at angle α to the vertical, as shown in Fig. 5.2.

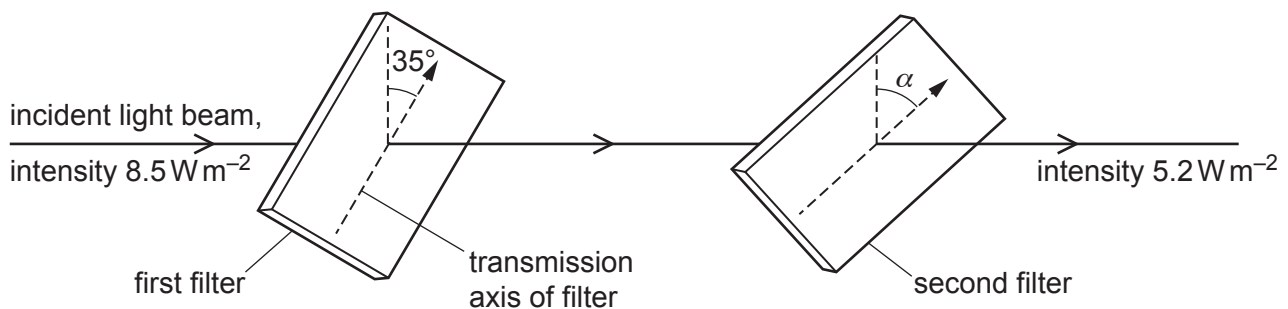


Fig. 5.2

Angle α is greater than 35° and less than 90° . A beam of vertically polarised light of intensity 8.5 W m^{-2} is incident normally on the first filter.

- (i) Show that the intensity of the light transmitted by the first filter is 5.7 W m^{-2} .

[1]

- (ii) The intensity of the light transmitted by the second filter is 5.2 W m^{-2} .

Calculate angle α .

$\alpha = \dots\dots\dots^\circ$ [2]

[Total: 9]

- 6 (a) The current in a filament lamp decreases.

State and explain how the resistance of the lamp changes.

.....
 [1]

- (b) A cylindrical wire has length L and resistance R . The **total** number of free electrons (charge carriers) contained in the volume of the wire is N . Each free electron has charge e . The potential difference between the ends of the wire is V .

Determine expressions, in terms of some or all of the symbols e , L , N , R and V for:

- (i) the current in the wire

current = ... [1]

- (ii) the average drift speed of the free electrons

average drift speed = ... [2]

- (iii) the average time taken for a free electron to move along the full length of the wire.

time taken = ... [1]

[Total: 5]

- 7 (a) A battery of electromotive force (e.m.f.) 9.0 V and negligible internal resistance is connected to a light-dependent resistor (LDR) and a fixed resistor, as shown in Fig. 7.1.

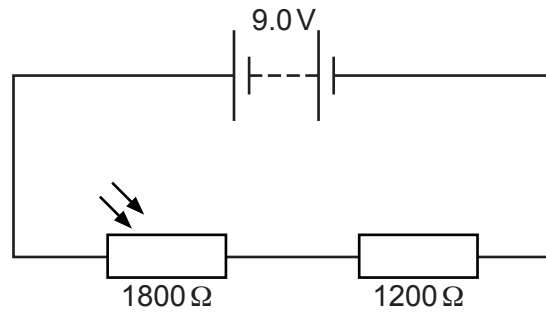


Fig. 7.1

The LDR and fixed resistor have resistances of $1800\ \Omega$ and $1200\ \Omega$ respectively.

Calculate the potential difference across the LDR.

potential difference = ... V [2]

- (b) The circuit in (a) is now modified by adding a uniform resistance wire XY and a galvanometer, as shown in Fig. 7.2.

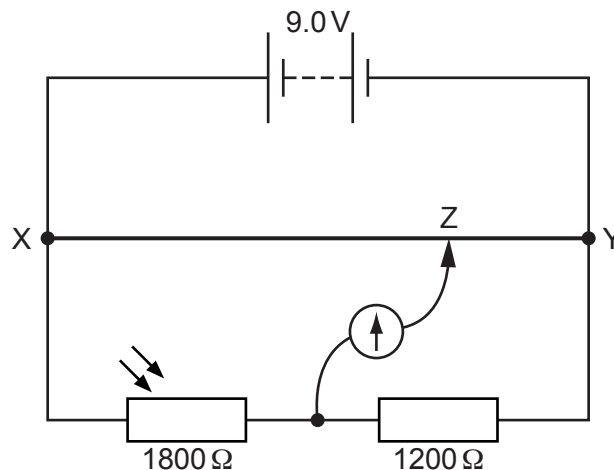


Fig. 7.2 (not to scale)

The length of the wire XY is 1.2 m. The movable connection Z is positioned on the wire XY so that the galvanometer reading is zero.

- (i) Calculate the length XZ along the resistance wire.

length XZ = ...m [2]

- (ii) The environmental conditions change causing a decrease in the resistance of the LDR. The temperature of the LDR remains constant.

State whether there is a decrease, increase or no change to:

- the intensity of the light illuminating the LDR

.....

- the total power produced by the battery

.....

- the length XZ so that the galvanometer reads zero.

.....

[3]

[Total: 7]

- 8 (a) Nucleus P and nucleus Q are isotopes of the same element.

Nucleus Q is unstable and emits a β^- particle to form nucleus R.

- (i) For nuclei P and Q, compare:

- the number of protons

.....

- the number of neutrons.

.....

[2]

- (ii) When nucleus Q decays to form nucleus R, the quark composition of a nucleon changes.

State the change to the quark composition of the nucleon.

..... [1]

- (iii) State the name of another particle that must be emitted from nucleus Q in addition to the β^- particle.

..... [1]

- (b) A hadron consists of two charm quarks and one bottom quark.

Determine, in terms of the elementary charge e , the charge of the hadron.

charge = ... e [2]

[Total: 6]

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9702/23

May/June 2023

1 hour 15 minutes

You must answer on the question paper.

No additional materials are needed.

- 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.

- 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 **20** 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 well has a depth of 36 m from ground level to the surface of the water in the well, as shown in Fig. 1.1.

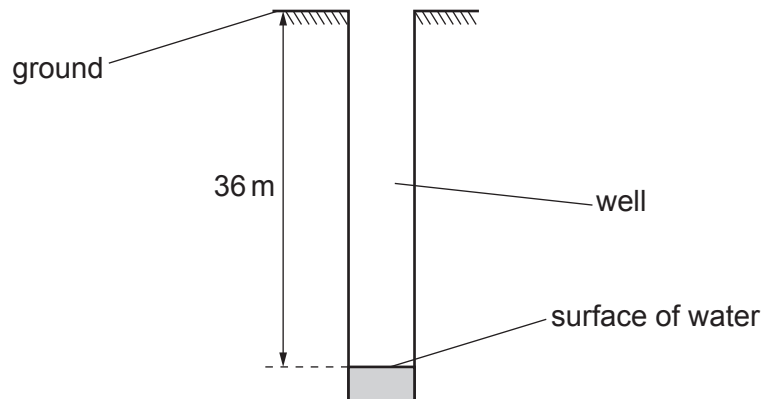


Fig. 1.1 (not to scale)

A student wishes to find the depth of the well. The student plans to drop a stone down the well and record the time taken from releasing the stone to hearing the splash made by the stone as it enters the water.

- (a) Assume that air resistance is negligible and that the stone is released from rest.

Calculate the time taken for the stone to fall from ground level to the surface of the water.

time = ... s [2]

- (b) The time recorded by the student using a stop-watch is not equal to the time in (a).

Suggest **three** possible reasons, other than the effect of air resistance, for this difference.

1

.....

2

.....

3

.....

[3]

- (c) The student repeats the experiment three times and uses the results to calculate the depth of the well. The values are shown in Table 1.1.

Table 1.1

	1st experiment	2nd experiment	3rd experiment
depth/m	54.4	53.9	54.1

The true depth of the well is 36.0 m. Explain why these results may be described as precise but not accurate.

.....

.....

.....

..... [2]

[Total: 7]

- 2 A sphere floats in equilibrium on the surface of sea water of density 1050 kg m^{-3} , as shown in Fig. 2.1.

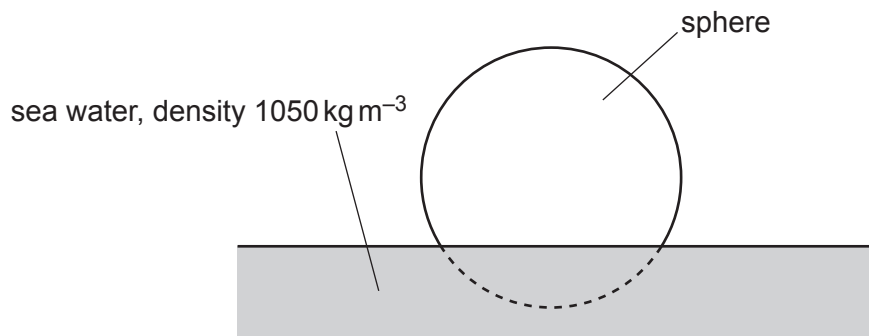


Fig. 2.1

- (a) 21% of the volume of the sphere is below the surface of the water.

Calculate the density of the sphere.

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

- (b) The sphere is now held so that its entire volume is below the surface of the water. The sphere is then released.

- (i) Calculate the initial acceleration of the sphere.

acceleration = ... ms^{-2} [3]

- (ii) The sphere accelerates upwards but remains entirely below the surface of the water.

State and explain what happens to the acceleration of the sphere as its velocity begins to increase.

.....

.....

.....

..... [3]

[Total: 8]

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

.....

 [2]

- (b) A firework is initially stationary. It explodes into three fragments A, B and C that move in a horizontal plane, as shown in the view from above in Fig. 3.1.

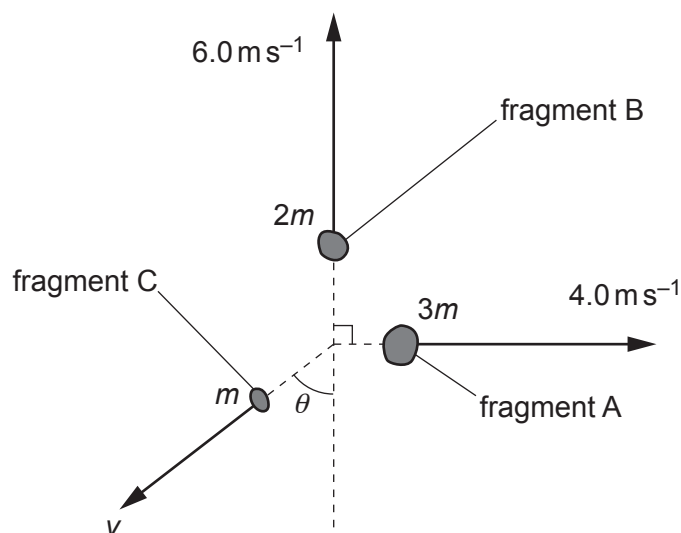


Fig. 3.1

Fragment A has a mass of $3m$ and moves away from the explosion at a speed of 4.0 ms^{-1} .

Fragment B has a mass of $2m$ and moves away from the explosion at a speed of 6.0 ms^{-1} at right angles to the direction of A.

Fragment C has a mass of m and moves away from the explosion at a speed v and at an angle θ as shown in Fig. 3.1.

Calculate:

- (i) the angle θ

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

(ii) the speed v .

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

- (c) The firework in (b) contains a chemical that has mass 5.0 g and has chemical energy per unit mass 700 J kg^{-1} . When the firework explodes, all of the chemical energy is transferred to the kinetic energy of fragments A, B and C.

(i) Show that the total chemical energy in the firework is 3.5 J.

[1]

(ii) Calculate the mass m .

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

[Total: 11]

- 4 (a) For a progressive wave, state what is meant by the frequency.

.....
 [1]

- (b) A loudspeaker, microphone and cathode-ray oscilloscope (CRO) are arranged as shown in Fig. 4.1.

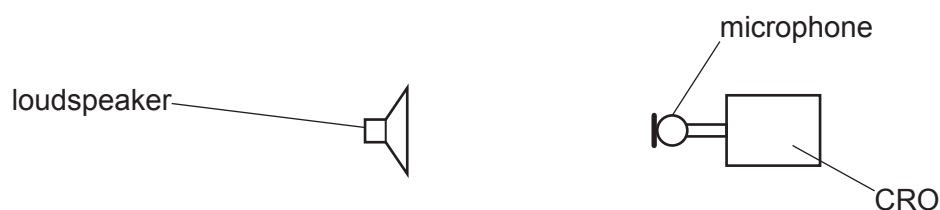


Fig. 4.1

The loudspeaker is emitting a sound wave which is detected by the microphone and displayed on the screen of the CRO as shown in Fig. 4.2.

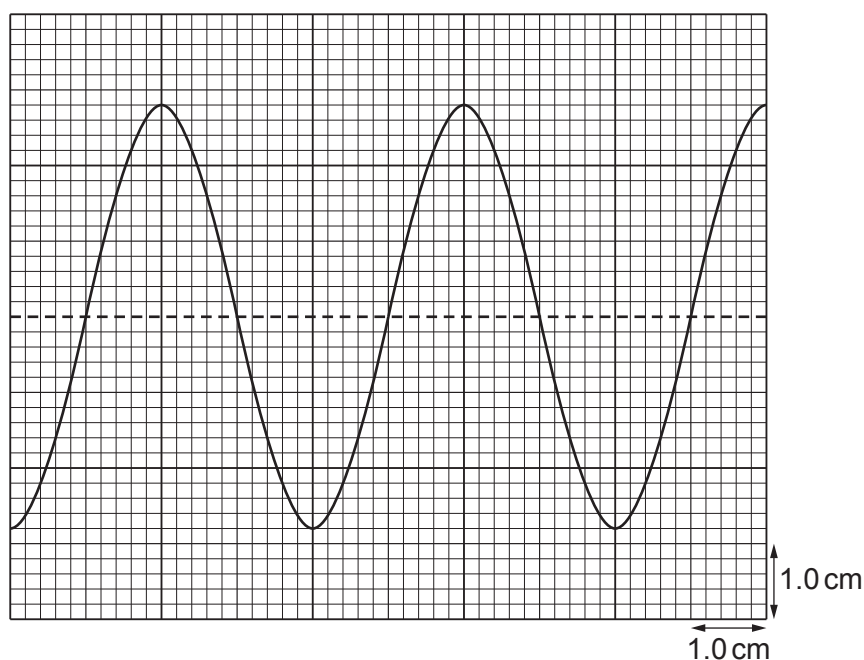


Fig. 4.2

The time-base on the CRO is set to 0.50 ms cm^{-1} and the y-gain is set to 0.20 V cm^{-1} .

Calculate:

- (i) the frequency of the sound wave

frequency = ... Hz [2]

- (ii) the amplitude of the signal received by the CRO.

amplitude = ... V [1]

- (c) The intensity of the sound wave in (b) is reduced to a quarter of its original intensity without a change in frequency. Assume that the amplitude of the signal received by the CRO is proportional to the amplitude of the sound wave.

On Fig. 4.2, sketch the trace that is now seen on the screen of the CRO. [3]

(d) A metal sheet is now placed in front of the loudspeaker in (b), as shown in Fig. 4.3.

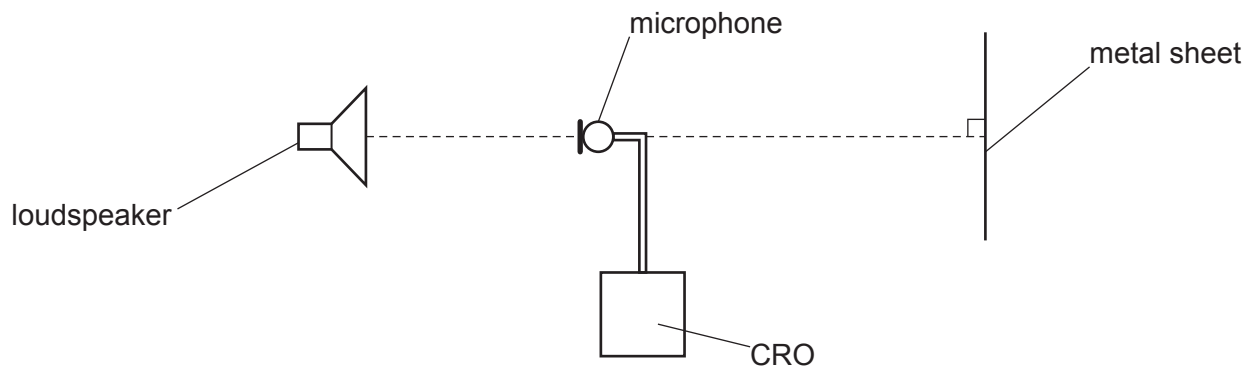


Fig. 4.3

A stationary wave is formed between the loudspeaker and the metal sheet.

(i) State the principle of superposition.

.....

 [2]

(ii) The initial position of the microphone is such that the trace on the CRO has an amplitude minimum. It is now moved a distance of 1.05 m away from the loudspeaker along the line joining the loudspeaker and metal sheet.

As the microphone moves, it passes through three positions where the trace has an amplitude maximum before ending at a position where the trace has an amplitude minimum.

Determine the wavelength of the sound wave.

wavelength = ... m [2]

- (iii) Use your answers in (b)(i) and (d)(ii) to determine the speed of the sound in the air.

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

[Total: 13]

- 5 A student sets up a circuit with a battery, an ammeter, a heater and a light-dependent resistor (LDR) all in series.

The battery has negligible internal resistance.

A voltmeter is connected across (in parallel with) the heater.

- (a) On Fig. 5.1, complete the circuit diagram of this arrangement.

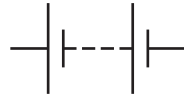


Fig. 5.1

[3]

- (b) The heater is a wire made of metal of resistivity $1.1 \times 10^{-6} \Omega \text{ m}$. The wire has length 2.0 m and cross-sectional area $3.8 \times 10^{-7} \text{ m}^2$.

The reading on the voltmeter is 4.8 V.

Calculate:

- (i) the resistance of the heater

resistance = ... Ω [2]

- (ii) the reading on the ammeter.

reading on ammeter = ... A [1]

- (c) The heater is replaced by a new wire. The new wire is made of the same metal as the wire in (b) and has the same length but a larger diameter.

The resistance of the LDR remains constant.

- (i) State and explain whether the new wire has a resistance that is greater than, less than or the same as that of the wire in (b).

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

- (ii) State and explain whether the new reading on the voltmeter is greater than, less than or equal to 4.8V.

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

[Total: 10]

- 6 (a) Define the Young modulus.

.....
 [1]

- (b) A uniform wire is suspended from a fixed support. Masses are added to the other end of the wire, as shown in Fig. 6.1.

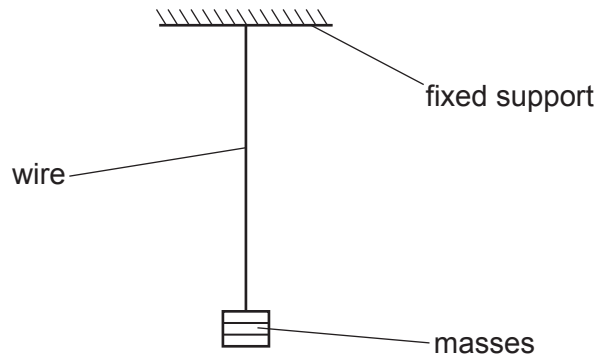


Fig. 6.1 (not to scale)

The variation of the length l of the wire with the force F applied to the wire by the masses is shown in Fig. 6.2.

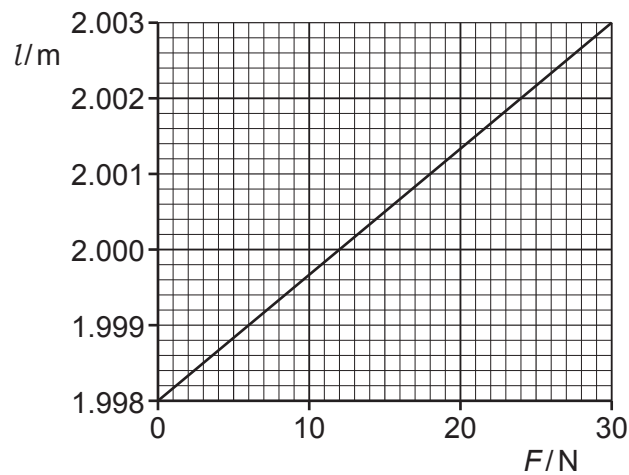


Fig. 6.2

The cross-sectional area of the wire is 0.95 mm^2 .

- (i) Determine the unstretched length of the wire.

unstretched length = ... m [1]

(ii) For an applied force F of 30 N, determine:

- the stress in the wire

stress = ... Pa

- the strain of the wire.

strain = ...
[3]

[Total: 5]

- 7 (a) Table 7.1 shows incomplete data for three flavours (types) of quark. The elementary charge is e .

Table 7.1

flavour	quark		antiquark	
	symbol	charge/ e	symbol	charge/ e
up	u	$+\frac{2}{3}$	$\bar{u}$	
down	d		$\bar{d}$	
charm	c		$\bar{c}$	

Complete Table 7.1 by inserting the missing charges.

[2]

- (b) Using the symbols given in Table 7.1, state a possible quark combination for the following hadrons:

- (i) a neutral baryon

..... [1]

- (ii) a meson with a charge of $+e$.

..... [1]

- (c) Quarks are fundamental particles.

Electrons are in another group (class) of fundamental particle.

- (i) State the name of this group.

..... [1]

- (ii) State the name of another particle in this group.

..... [1]

[Total: 6]

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