



CANDIDATE
NAME

--

CENTRE
NUMBER

--	--	--	--	--

CANDIDATE
NUMBER

--	--	--	--

9702/21

October/November 2020

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 **16** pages. Blank pages are indicated.

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 unit	$1 \text{ u} = 1.66 \times 10^{-27} \text{ kg}$
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.	$v = v_0 \cos \omega t$ $v = \pm \omega \sqrt{(x_0^2 - x^2)}$
Doppler effect	$f_o = \frac{f_s v}{v \pm v_s}$
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	$W = \frac{1}{2} QV$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \dots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \dots$
Hall voltage	$V_H = \frac{BI}{ntq}$
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.

- 1 (a) (i) Define the *moment* of a force about a point.

.....
 [1]

- (ii) Determine the SI base units of the moment of a force.

base units [1]

- (b) A uniform rigid rod of length 2.4 m is shown in Fig. 1.1.

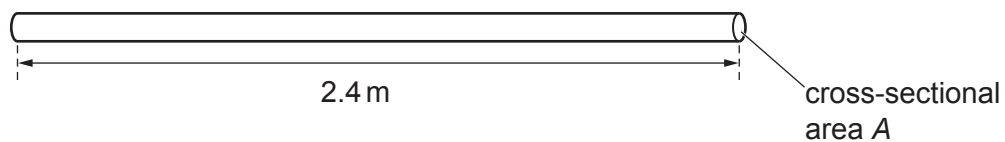


Fig. 1.1

The rod has a weight of 5.2 N and is made of wood of density 790 kg m^{-3} .

Calculate the cross-sectional area A , in mm^2 , of the rod.

$A = \dots\dots\dots \text{mm}^2$ [3]

(c) A fishing rod AB, made from the rod in (b), is shown in Fig. 1.2.

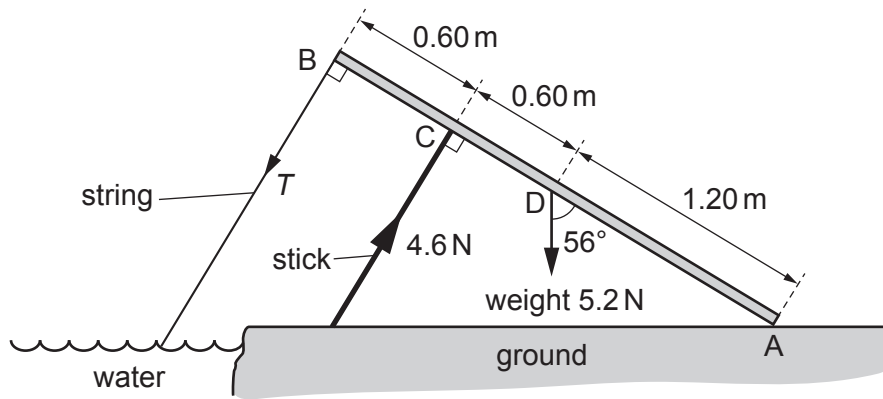


Fig. 1.2 (not to scale)

End A of the rod rests on the ground and a string is attached to the other end B. A support stick exerts a force perpendicular to the rod at point C. The weight of the rod acts at point D.

The tension T in the string is in a direction perpendicular to the rod. The rod is in equilibrium and inclined at an angle of 56° to the vertical.

The forces and the distances along the rod of points A, B, C and D are shown in Fig. 1.2.

(i) Show that the component of the weight that is perpendicular to the rod is 4.3 N.

[1]

(ii) By taking moments about end A of the rod, calculate the tension T .

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

[Total: 9]

- 2 A small block is lifted vertically upwards by a toy aircraft, as illustrated in Fig. 2.1.

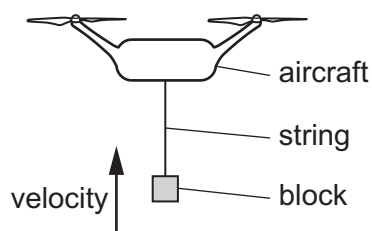


Fig. 2.1

As the block is moving upwards, the string breaks at time $t = 0$. The block initially continues moving upwards and then falls and hits the ground at time $t = 0.90\text{ s}$. The variation with time t of the velocity v of the block is shown in Fig. 2.2.

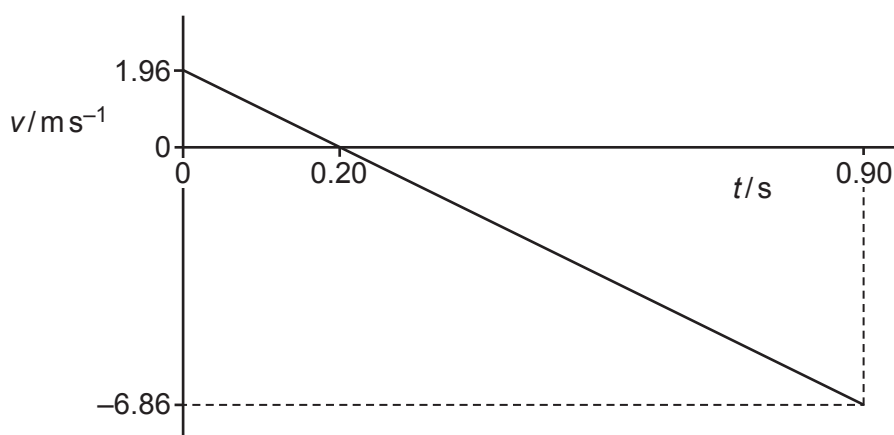


Fig. 2.2

Air resistance is negligible.

- (a) State the feature of the graph in Fig. 2.2 that shows the block has a constant acceleration.
 [1]
- (b) Use Fig. 2.2 to determine the height of the block above the ground when the string breaks at time $t = 0$.

height = ... m [3]

- (c) The block has a weight of 0.86 N.

Calculate the difference in gravitational potential energy of the block between time $t = 0$ and time $t = 0.90$ s.

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

- (d) On Fig. 2.3, sketch a line to show the variation of the distance moved by the block with time t from $t = 0$ to $t = 0.20$ s. Numerical values of distance are not required.

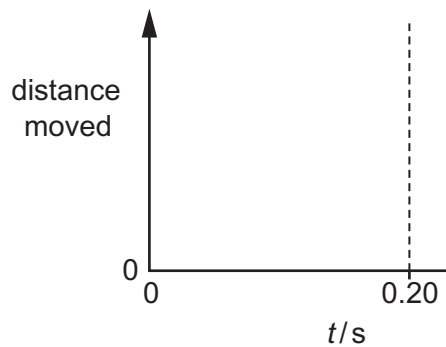


Fig. 2.3

[2]

- (e) A block of greater mass is now released from the same height with the same upward velocity. Air resistance is still negligible.

State and explain the effect, if any, of the increased mass on the speed with which the block hits the ground.

.....
 [1]

[Total: 9]

- 3 (a) Define *force*.

.....
 [1]

- (b) A ball falls vertically downwards towards a horizontal floor and then rebounds along its original path, as illustrated in Fig. 3.1.

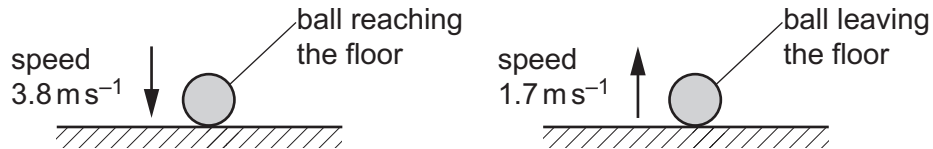


Fig. 3.1

The ball reaches the floor with speed 3.8 m s^{-1} . The ball is then in contact with the floor for a time of 0.081 s before leaving it with speed 1.7 m s^{-1} . The mass of the ball is 0.062 kg .

- (i) Calculate the loss of kinetic energy of the ball during the collision.

loss of kinetic energy = ... J [2]

- (ii) Determine the magnitude of the change in momentum of the ball during the collision.

change in momentum = ... Ns [2]

- (iii) Show that the magnitude of the average resultant force acting on the ball during the collision is 4.2 N .

[1]

(iv) Use the information in (iii) to calculate the magnitude of:

1. the average force of the floor on the ball during the collision

average force = ... N

2. the average force of the ball on the floor during the collision.

average force = ... N
[2]

[Total: 8]

4 (a) Define, for a wire:

(i) *stress*

.....
 [1]

(ii) *strain*.

.....
 [1]

(b) (i) A school experiment is performed on a metal wire to determine the Young modulus of the metal. A force is applied to one end of the wire which is fixed at the other end. The variation of the force F with extension x of the wire is shown in Fig. 4.1.

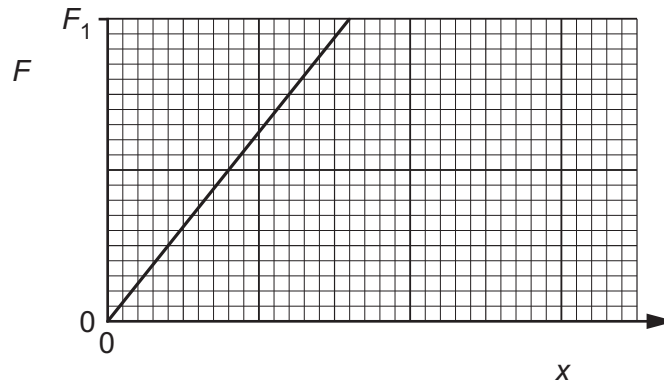


Fig. 4.1

The maximum force applied to the wire is F_1 .

The gradient of the graph line in Fig. 4.1 is G . The wire has initial length L and cross-sectional area A .

Determine an expression, in terms of A , G and L , for the Young modulus E of the metal.

$E =$ [2]

- (ii) A student repeats the experiment in **(b)(i)** using a new wire that has twice the diameter of the first wire. The initial length of the wire and the metal of the wire are unchanged.

On Fig. 4.1, draw the graph line representing the new wire for the force increasing from $F = 0$ to $F = F_1$. [2]

- (iii) Another student repeats the original experiment in **(b)(i)**, increasing the force beyond F_1 to a new maximum force F_2 . The new graph obtained is shown in Fig. 4.2.

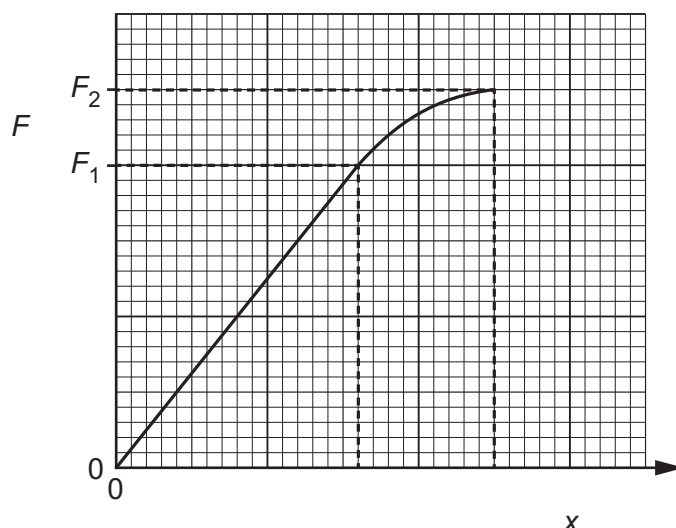


Fig. 4.2

- On Fig. 4.2, shade an area that represents the work done to extend the wire when the force is increased from F_1 to F_2 . [1]
- Explain how the student can check that the elastic limit of the wire was not exceeded when force F_2 was applied.

.....

.....

..... [1]

- (iv) Each student in the class performs the experiment in **(b)(i)**. The teacher describes the values of the Young modulus calculated by the students as having high accuracy and low precision.

Explain what is meant by *low precision*.

.....

..... [1]

[Total: 9]

- 5 A progressive wave Y passes a point P. The variation with time t of the displacement x for the wave at P is shown in Fig. 5.1.

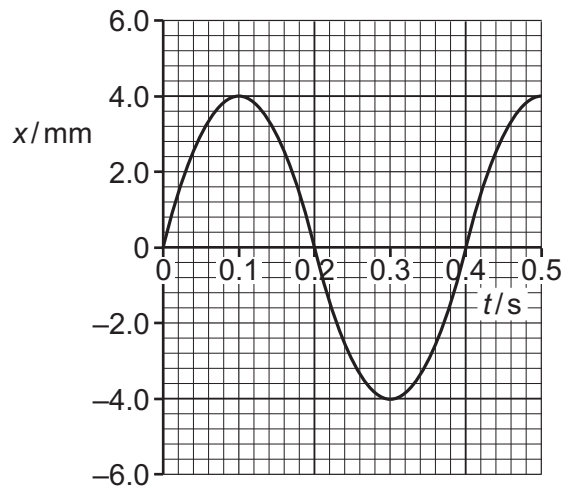


Fig. 5.1

The wave has a wavelength of 8.0 cm.

- (a) Determine the speed of the wave.

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

- (b) A second wave Z has wavelength 8.0 cm and amplitude 2.0 mm at point P. Waves Y and Z have the same speed.

For the waves at point P, calculate the ratio

$$\frac{\text{intensity of wave Z}}{\text{intensity of wave Y}}.$$

ratio = ... [3]

[Total: 5]

- 6 (a) Describe the conditions required for two waves to be able to form a stationary wave.

.....

.....

.....

..... [2]

- (b) A stationary wave on a string has nodes and antinodes. The distance between a node and an adjacent antinode is 6.0 cm.

- (i) State what is meant by a *node*.

..... [1]

- (ii) Calculate the wavelength of the two waves forming the stationary wave.

wavelength = ... cm [1]

- (iii) State the phase difference between the particles at two adjacent antinodes of the stationary wave.

phase difference = ... ° [1]

[Total: 5]

- 7 (a) Define the *ohm*.

.....
 [1]

- (b) A uniform wire has resistance $3.2\ \Omega$. The wire has length 2.5 m and is made from metal of resistivity $460\text{ n}\Omega\text{ m}$.

Calculate the cross-sectional area of the wire.

cross-sectional area = ... m^2 [3]

- (c) A cell of electromotive force (e.m.f.) E and internal resistance r is connected to a variable resistor of resistance R , as shown in Fig. 7.1.

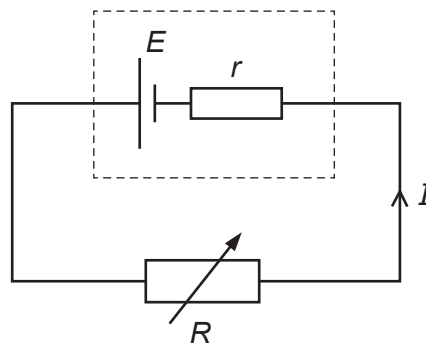


Fig. 7.1

The current in the circuit is I .

- (i) State, in terms of energy, why the potential difference across the variable resistor is less than the e.m.f. of the cell.

.....
 [1]

- (ii) State an expression for E in terms of I , R and r .

$$E = \dots\dots\dots [1]$$

- (iii) The resistance R of the variable resistor is changed so that it is equal to r .

Determine an expression, in terms of only E and r , for the power P dissipated in the variable resistor.

$$P = \dots\dots\dots [2]$$

[Total: 8]

- 8 (a) State a similarity and a difference between a down quark and a down antiquark.

similarity:

difference: [2]

(b) For a nucleus of aluminium-25 ($^{25}_{13}\text{Al}$):

(i) state the number of protons and the number of neutrons

number of protons = ...

number of neutrons = ...

[1]

(ii) show that the charge is $2.1 \times 10^{-18} \text{ C}$.

[1]

(c) The nucleus in (b) is moved along a straight line from point A to point B in a uniform horizontal electric field in a vacuum, as shown in Fig. 8.1.

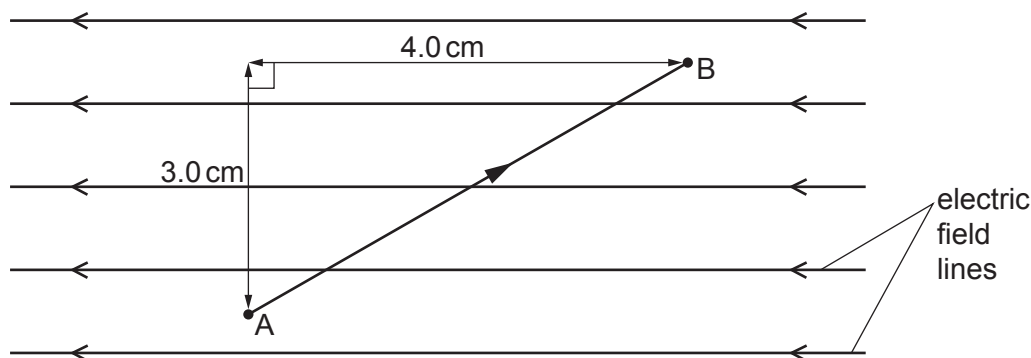


Fig. 8.1

The electric field strength is 11 kV m^{-1} .

Calculate the work done to move the charge from A to B.

work done = ... J [3]

[Total: 7]



CANDIDATE
NAME

--

CENTRE
NUMBER

--	--	--	--	--

CANDIDATE
NUMBER

--	--	--	--

9702/22

October/November 2020

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. Blank pages are indicated.

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 unit	$1 \text{ u} = 1.66 \times 10^{-27} \text{ kg}$
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.	$v = v_0 \cos \omega t$ $v = \pm \omega \sqrt{(x_0^2 - x^2)}$
Doppler effect	$f_o = \frac{f_s v}{v \pm v_s}$
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	$W = \frac{1}{2} QV$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \dots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \dots$
Hall voltage	$V_H = \frac{BI}{ntq}$
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.

- 1 (a) Complete Table 1.1 by putting a tick (✓) in the appropriate column to indicate whether the listed quantities are scalars or vectors.

Table 1.1

quantity	scalar	vector
acceleration		
density		
temperature		
momentum		

[2]

- (b) A toy train moves along a straight section of track. Fig. 1.1 shows the variation with time t of the distance d moved by the train.

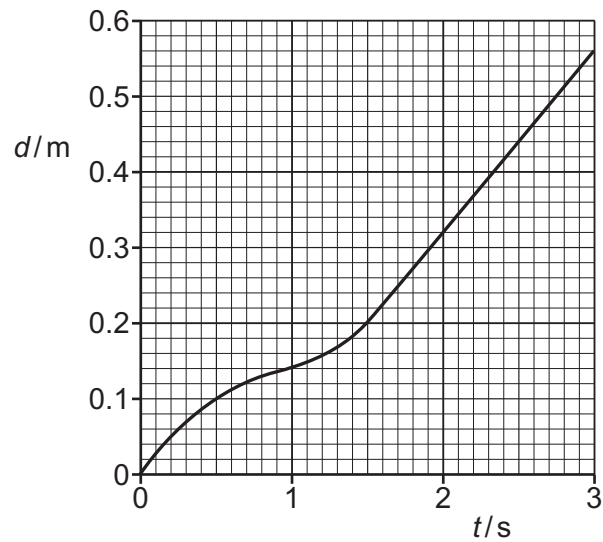


Fig. 1.1

- (i) Describe qualitatively the motion of the train between time $t = 0$ and time $t = 1.0$ s.

.....
 [1]

- (ii) Determine the speed of the train at time $t = 2.0$ s.

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

- (c) The straight section of track in (b) is part of the loop of track shown in Fig. 1.2.

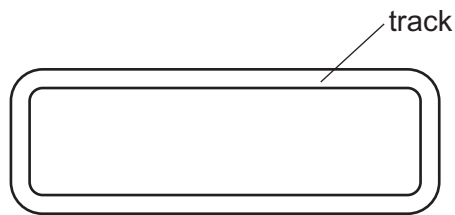


Fig. 1.2

The train completes exactly one lap of the loop.

State and explain the average velocity of the train over the one complete lap.

.....

 [1]

[Total: 6]

- 2 (a) A cylinder is suspended from the end of a string. The cylinder is stationary in water with the axis of the cylinder vertical, as shown in Fig. 2.1.

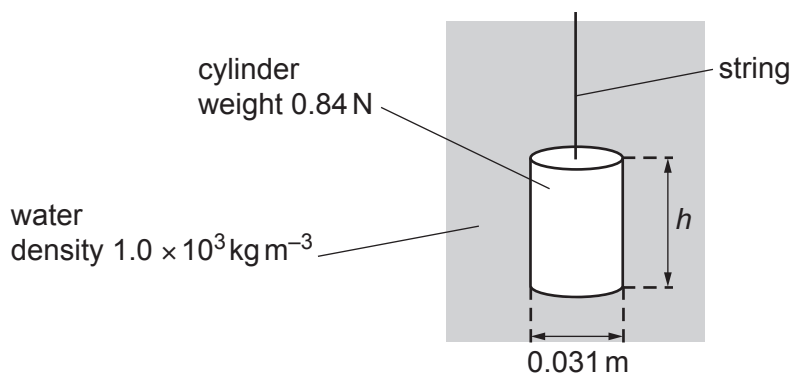


Fig. 2.1 (not to scale)

The cylinder has weight 0.84 N, height h and a circular cross-section of diameter 0.031 m. The density of the water is $1.0 \times 10^3 \text{ kg m}^{-3}$. The difference between the pressures on the top and bottom faces of the cylinder is 520 Pa.

- (i) Calculate the height h of the cylinder.

$h = \dots\dots\dots \text{ m}$ [2]

- (ii) Show that the upthrust acting on the cylinder is 0.39 N.

[2]

- (iii) Calculate the tension T in the string.

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

- (b) The string is now used to move the cylinder in (a) vertically upwards through the water. The variation with time t of the velocity v of the cylinder is shown in Fig. 2.2.

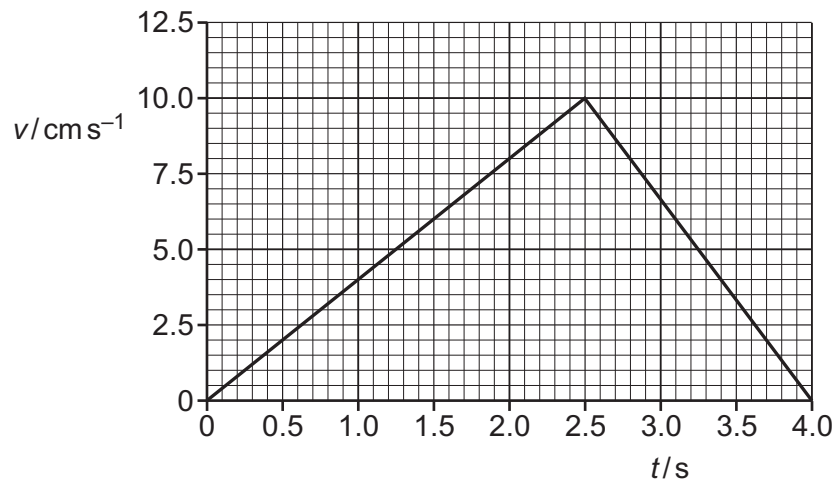


Fig. 2.2

- (i) Use Fig. 2.2 to determine the acceleration of the cylinder at time $t = 2.0$ s.

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

- (ii) The top face of the cylinder is at a depth of 0.32 m below the surface of the water at time $t = 0$.

Use Fig. 2.2 to determine the depth of the top face below the surface of the water at time $t = 4.0$ s.

depth = ... m [2]

(c) The cylinder in (b) is released from the string at time $t = 4.0\text{ s}$. The cylinder falls, from rest, vertically downwards through the water. Assume that the upthrust acting on the cylinder remains constant as it falls.

- (i) State the name of the force that acts on the cylinder when it is moving and does not act on the cylinder when it is stationary.

..... [1]

- (ii) State and explain the variation, if any, of the acceleration of the cylinder as it falls downwards through the water.

.....

.....

..... [2]

[Total: 12]

BLANK PAGE

- 3 (a) A spring is fixed at one end and is compressed by applying a force to the other end. The variation of the force F acting on the spring with its compression x is shown in Fig. 3.1.

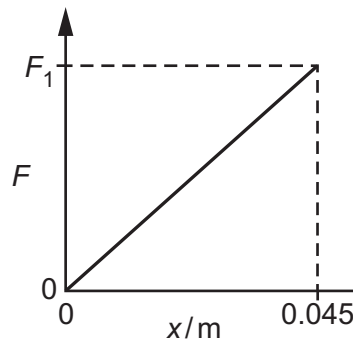


Fig. 3.1

A compression of 0.045 m is produced when a force F_1 acts on the spring. The spring has a spring constant of 800 N m^{-1} .

- (i) Determine F_1 .

$$F_1 = \dots\dots\dots \text{ N [2]}$$

- (ii) Use Fig. 3.1 to show that, for a compression of 0.045 m, the elastic potential energy of the spring is 0.81 J.

[2]

- (b) A child's toy uses the spring in (a) to launch a ball of mass 0.020 kg vertically into the air. The ball is initially held against one end of the spring which has a compression of 0.045 m. The spring is then released to launch the ball. The kinetic energy of the ball as it leaves the toy is 0.72 J.

- (i) The toy converts the elastic potential energy of the spring into the kinetic energy of the ball. Use the information in (a)(ii) to calculate the percentage efficiency of this conversion.

$$\text{efficiency} = \dots\dots\dots \% [1]$$

- (ii) Determine the initial momentum of the ball as it leaves the toy.

momentum = ... N s [3]

- (c) The ball in (b) leaves the toy at point A and moves vertically upwards through the air. Point B is the position of the ball when it is at maximum height h above point A, as illustrated in Fig. 3.2.

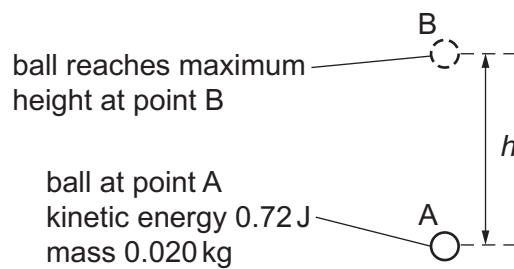


Fig. 3.2 (not to scale)

The gravitational potential energy of the ball increases by 0.60 J as it moves from A to B.

- (i) Calculate h .

$h =$ m [2]

- (ii) Determine the average force due to air resistance acting on the ball for its movement from A to B.

average force = ... N [2]

- (iii) When there is air resistance, the ball takes time T to move from A to B.

State and explain whether the time taken for the ball to move from A to its maximum height will be more than, less than or equal to time T if there is **no** air resistance.

.....

..... [1]

[Total: 13]

- 4 A rigid plank is used to make a ramp between two different horizontal levels of ground, as shown in Fig. 4.1.

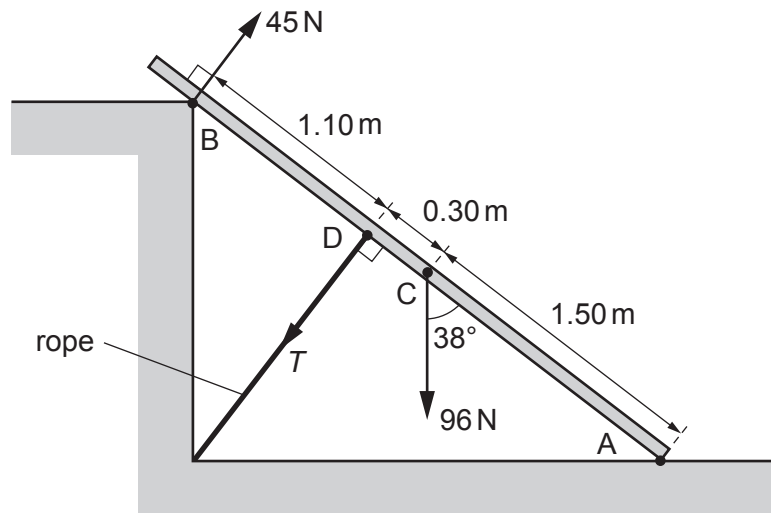


Fig. 4.1 (not to scale)

Point A at one end of the plank rests on the lower level of the ground. A force acts on, and is perpendicular to, the plank at point B. The plank is held in equilibrium by a rope that connects point D on the plank to the ground. The plank has a weight that may be considered to act from its centre of gravity C.

The rope is perpendicular to the plank and has tension T . The plank is at an angle of 38° to the vertical.

The forces and the distances along the plank of points A, B, C and D are shown in Fig. 4.1.

- (a) Show that the component of the weight that is perpendicular to the plank is 59 N.

[1]

- (b) By taking moments about end A of the plank, calculate the tension T .

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

[Total: 4]

[Turn over]

- 5 Microwaves with the same wavelength and amplitude are emitted in phase from two sources X and Y, as shown in Fig. 5.1.

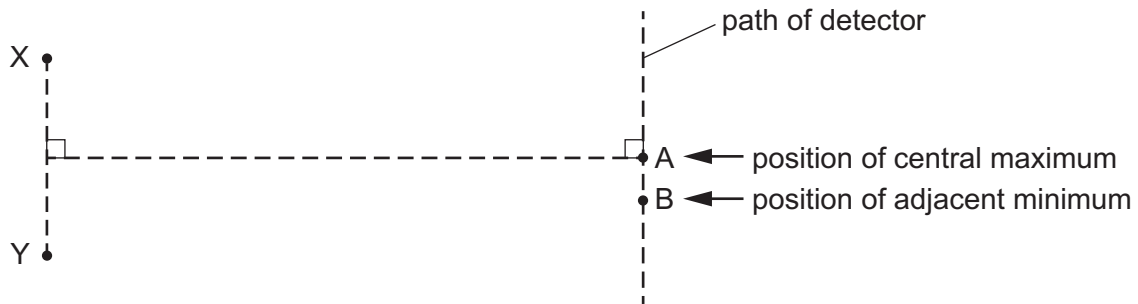


Fig. 5.1 (not to scale)

A microwave detector is moved along a path parallel to the line joining X and Y. An interference pattern is detected. A central intensity maximum is located at point A and there is an adjacent intensity minimum at point B. The microwaves have a wavelength of 0.040 m.

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

frequency = ... GHz [3]

- (b) For the waves arriving at point B, determine:

- (i) the path difference

path difference = ... m [1]

- (ii) the phase difference.

phase difference = ...° [1]

- (c) The amplitudes of the waves from the sources are changed. This causes a change in the amplitude of the waves arriving at point A. At this point, the amplitude of the wave arriving from source X is doubled and the amplitude of the wave arriving from source Y is also doubled.

Describe the effect, if any, on the intensity of the central maximum at point A.

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

- (d) Describe the effect, if any, on the positions of the central intensity maximum and the adjacent intensity minimum due to the following separate changes.

- (i) The separation of the sources X and Y is increased.

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

- (ii) The phase difference between the microwaves emitted by the sources X and Y changes to 180° .

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

[Total: 9]

- 6 (a) A network of three resistors of resistances R_1 , R_2 and R_3 is shown in Fig. 6.1.

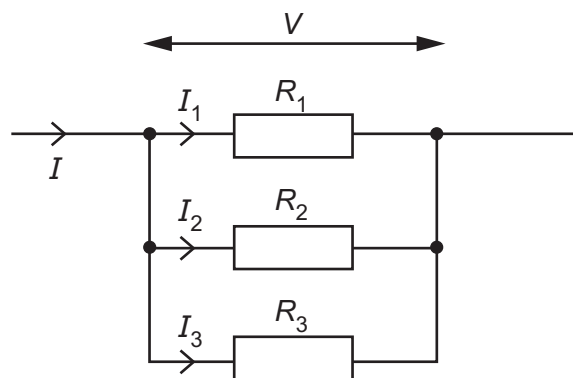


Fig. 6.1

The individual currents in the resistors are I_1 , I_2 and I_3 . The total current in the combination of resistors is I and the potential difference across the combination is V .

Show that the combined resistance R of the network is given by

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}.$$

[2]

- (b) A battery of electromotive force (e.m.f.) 8.0V and internal resistance r is connected to three resistors X, Y and Z, as shown in Fig. 6.2.

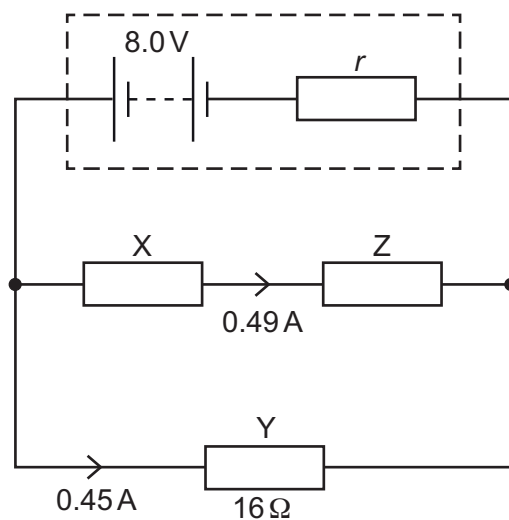


Fig. 6.2

Resistor Y has a resistance of $16\ \Omega$. The current in resistor X is 0.49 A and the current in resistor Y is 0.45 A .

Calculate:

- (i) the current in the battery

current = ... A [1]

- (ii) the internal resistance r of the battery.

$r =$ Ω [2]

- (c) Resistors X and Y in Fig. 6.2 are made from wires of the same material and cross-sectional area. The average drift speed of the free electrons in X is $2.1 \times 10^{-4}\text{ m s}^{-1}$.

Calculate the average drift speed v of the free electrons in Y.

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

- (d) Resistor Z in Fig. 6.2 is replaced by a new resistor of smaller resistance.

State and explain the effect, if any, on the terminal potential difference of the battery.

.....

 [2]

[Total: 9]

- 7 (a) State a similarity and a difference between an up quark and an up antiquark.

similarity:

difference:

[2]

- (b) Fig. 7.1 shows an electron in an electric field, in a vacuum, at an instant when the electron is stationary.

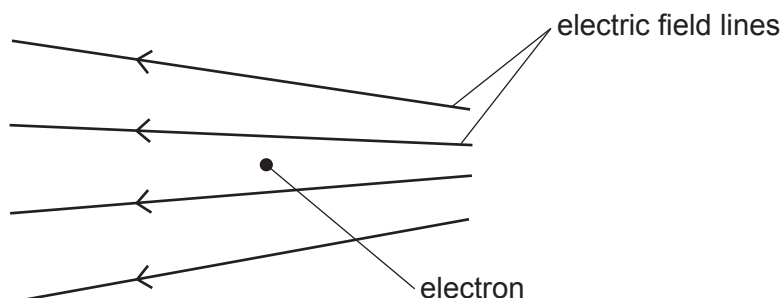


Fig. 7.1

- (i) On Fig. 7.1, draw an arrow to show the direction of the electric force acting on the stationary electron. [1]

- (ii) The electric field causes the electron to move from its initial position.

Describe and explain the acceleration of the electron due to the field, as the electron moves through the field.

.....

 [2]

- (iii) A stationary α -particle is now placed in the same electric field at the same initial position that was occupied by the electron.

Compare the initial electric force acting on the α -particle with the initial electric force that acted on the electron.

.....

 [2]

[Total: 7]

BLANK PAGE

BLANK PAGE

Permission to reproduce items where third-party owned material protected by copyright is included has been sought and cleared where possible. Every reasonable effort has been made by the publisher (UCLES) to trace copyright holders, but if any items requiring clearance have unwittingly been included, the publisher will be pleased to make amends at the earliest possible opportunity.

To avoid the issue of disclosure of answer-related information to candidates, all copyright acknowledgements are reproduced online in the Cambridge Assessment International Education Copyright Acknowledgements Booklet. This is produced for each series of examinations and is freely available to download at www.cambridgeinternational.org after the live examination series.

Cambridge Assessment International Education is part of the Cambridge Assessment Group. Cambridge Assessment is the brand name of the University of Cambridge Local Examinations Syndicate (UCLES), which itself is a department of the University of Cambridge.



CANDIDATE
NAME

--

CENTRE
NUMBER

--	--	--	--	--

CANDIDATE
NUMBER

--	--	--	--

9702/23

October/November 2020

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 **16** pages. Blank pages are indicated.

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 unit	$1 \text{ u} = 1.66 \times 10^{-27} \text{ kg}$
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.	$v = v_0 \cos \omega t$ $v = \pm \omega \sqrt{(x_0^2 - x^2)}$
Doppler effect	$f_o = \frac{f_s v}{v \pm v_s}$
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	$W = \frac{1}{2} QV$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \dots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \dots$
Hall voltage	$V_H = \frac{BI}{ntq}$
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.

- 1 (a) An electromagnetic wave has a wavelength of $85\ \mu\text{m}$.

(i) State the wavelength, in m, of the wave.

wavelength = ... m [1]

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

frequency = ... THz [2]

(iii) State the name of the region of the electromagnetic spectrum that contains this wave.

..... [1]

- (b) The current I in a coil of wire produces a magnetic field. The energy E stored in the magnetic field is given by

$$E = \frac{I^2 L}{2}$$

where L is a constant.

The manufacturer of the coil states that the value of L , in SI base units, is $7.5 \times 10^{-6} \pm 5\%$.
The current I in the coil is measured as $(0.50 \pm 0.02)\text{ A}$.

The values of L and I are used to calculate E .

Determine the percentage uncertainty in the value of E .

percentage uncertainty = ... % [2]

[Total: 6]

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

.....

 [2]

- (b) A uniform wooden post AB of weight 45 N stands in equilibrium on hard ground, as shown in Fig. 2.1.

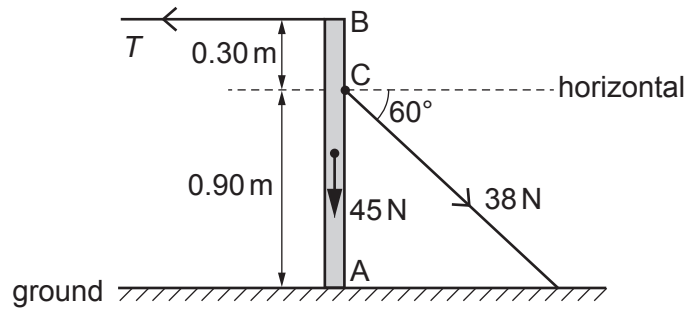


Fig. 2.1 (not to scale)

End A of the vertical post is supported by the ground. A horizontal wire with tension T is attached to end B of the post. Another wire, attached to the post at point C, is at an angle of 60° to the horizontal and has tension 38 N. The distances along the post of points A, B and C are shown in Fig. 2.1.

- (i) Calculate the horizontal component of the force exerted on the post by the wire connected to point C.

horizontal component of force = ... N [1]

- (ii) By considering moments about end A, determine the tension T .

$T =$ N [2]

- (iii) Calculate the vertical component of the force exerted on the post at end A.

force = ... N [1]

[Total: 6]

- 3 A ball is fired horizontally with a speed of 41.0 m s^{-1} from a stationary cannon at the top of a hill. The ball lands on horizontal ground that is a vertical distance of 57 m below the cannon, as shown in Fig. 3.1.

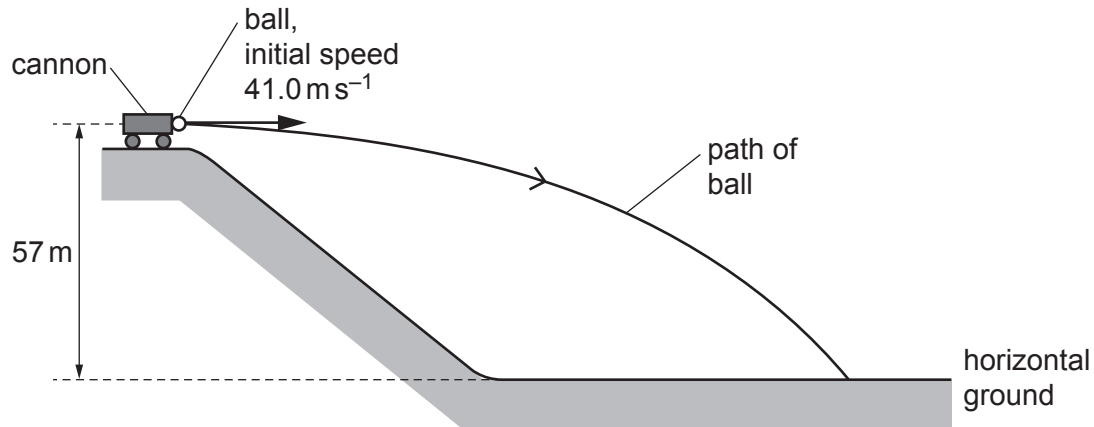


Fig. 3.1 (not to scale)

Assume air resistance is negligible.

- (a) Show that the time taken for the ball to reach the ground, after being fired, is 3.4 s.

[2]

- (b) Calculate the horizontal distance of the ball from the cannon at the point where the ball lands on the ground.

horizontal distance = ... m [1]

- (c) Determine the magnitude of the displacement of the ball from the cannon at the point where the ball lands on the ground.

displacement = ... m [2]

- (d) The ball leaves the cannon at time $t = 0$.

On Fig. 3.2, sketch a graph to show the variation of the magnitude v of the vertical component of the velocity of the ball with time t from $t = 0$ to $t = 3.4$ s. Numerical values are not required.

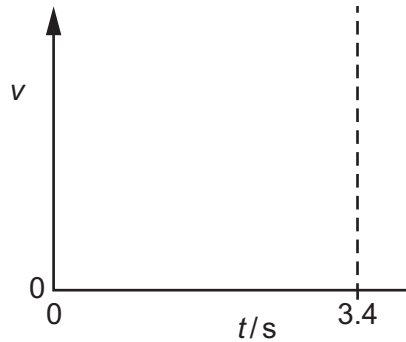


Fig. 3.2

[1]

- (e) The cannon recoils horizontally with a speed of 0.340 ms^{-1} when it fires the ball. The total mass of the ball and the cannon is 1480 kg . Assume that no external horizontal forces act on the ball-cannon system.

Determine, to three significant figures, the mass of the ball.

mass = ... kg [2]

- (f) The cannon now fires a ball of smaller mass. Assume that air resistance is still negligible.

State and explain the change, if any, to the graph in Fig. 3.2 due to the decreased mass of the ball.

.....

 [2]

[Total: 10]

- 4 (a) State Hooke's law.

.....
 [1]

- (b) A spring is fixed at one end. A compressive force F is applied to the other end. The variation of the force F with the compression x of the spring is shown in Fig. 4.1.

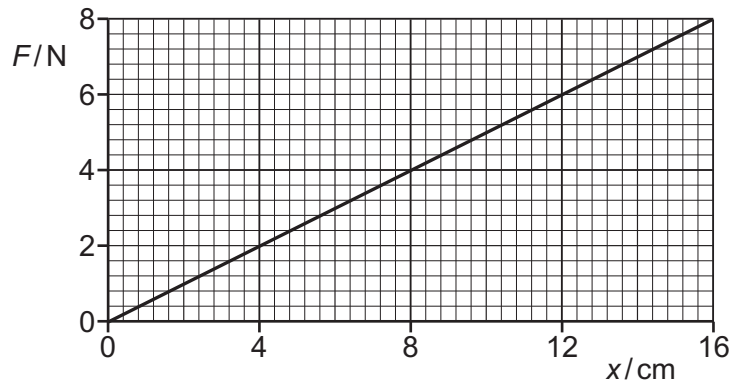


Fig. 4.1

Show that the elastic potential energy of the spring is 0.64 J when its compression is 16.0 cm.

[2]

- (c) The spring in (b) is used to project a toy car along a track from point X to point Y, as illustrated in Fig. 4.2.

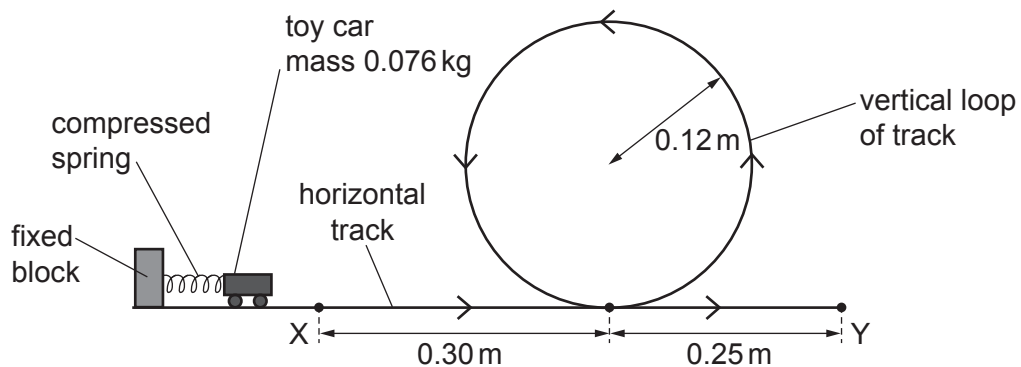


Fig. 4.2 (not to scale)

The spring is initially given a compression of 16.0 cm. The car of mass 0.076 kg is held against one end of the compressed spring. When the spring is released it projects the car forward. The car leaves the spring at point X with kinetic energy that is equal to the initial elastic potential energy of the compressed spring.

The car follows the track around a vertical loop of radius 0.12 m and then passes point Y. Assume that friction and air resistance are negligible.

Calculate:

- (i) the speed of the car at X

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

- (ii) the kinetic energy of the car when it is at the top of the loop

kinetic energy = ... J [3]

- (iii) the speed of the car at Y.

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

- (d) In practice, a resistive force due to friction and air resistance acts on the car so that its kinetic energy at Y is 0.23 J less than its kinetic energy at X.

Determine the average resistive force acting on the car for its movement from X to Y.

average resistive force = ... N [3]

[Total: 12]

- 5 (a) A sound wave is detected by a microphone that is connected to a cathode-ray oscilloscope (CRO). The trace on the screen of the CRO is shown in Fig. 5.1.

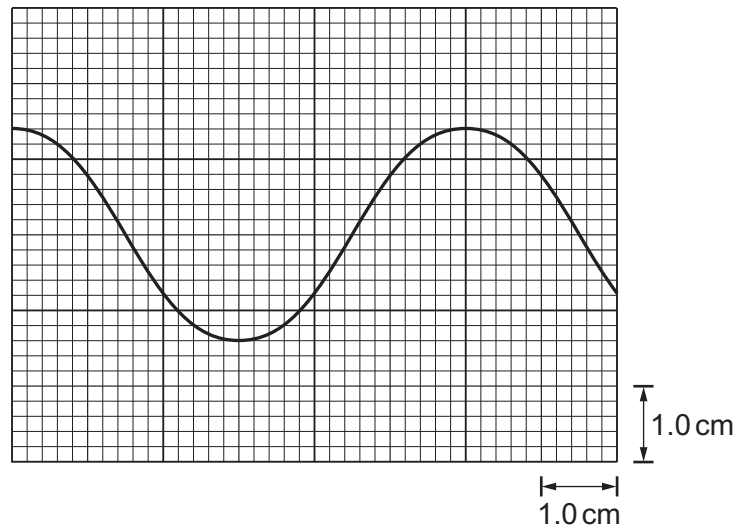


Fig. 5.1

The time-base setting of the CRO is $2.0 \times 10^{-5} \text{ s cm}^{-1}$.

- (i) Determine the frequency of the sound wave.

frequency = ... Hz [2]

- (ii) The intensity of the sound wave is now doubled. The frequency is unchanged. Assume that the amplitude of the trace is proportional to the amplitude of the sound wave.

On Fig. 5.1, sketch the new trace shown on the screen. [2]

- (iii) The time-base is now switched off.

Describe the trace seen on the screen.

.....
 [1]

- (b) A beam of light of a single wavelength is incident normally on a diffraction grating, as illustrated in Fig. 5.2.

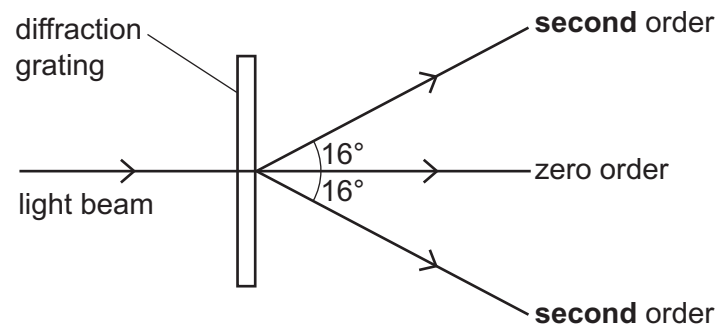


Fig. 5.2 (not to scale)

Fig. 5.2 does not show all of the emerging beams from the grating. The angle between the **second**-order emerging beam and the central zero-order beam is 16° . The grating has a line spacing of $3.4 \times 10^{-6} \text{ m}$.

- (i) Calculate the wavelength of the light.

wavelength = ... m [2]

- (ii) Determine the highest order of emerging beam from the grating.

highest order = ... [2]

[Total: 9]

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

.....
 [1]

- (b) A wire of cross-sectional area A is made from metal of resistivity ρ . The wire is extended. Assume that the volume V of the wire remains constant as it extends.

Show that the resistance R of the extending wire is inversely proportional to A^2 .

[2]

- (c) A battery of electromotive force (e.m.f.) E and internal resistance r is connected to a variable resistor of resistance R , as shown in Fig. 6.1.

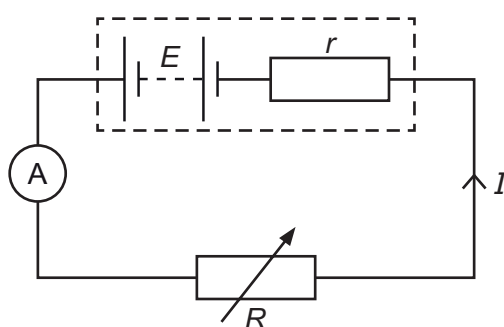


Fig. 6.1

The current in the circuit is I .

Use Kirchhoff's second law to show that

$$R = \left(\frac{E}{I} \right) - r.$$

[1]

- (d) An ammeter is used in the circuit in (c) to measure the current I as resistance R is varied. Fig. 6.2 is a graph of R against $\frac{1}{I}$.

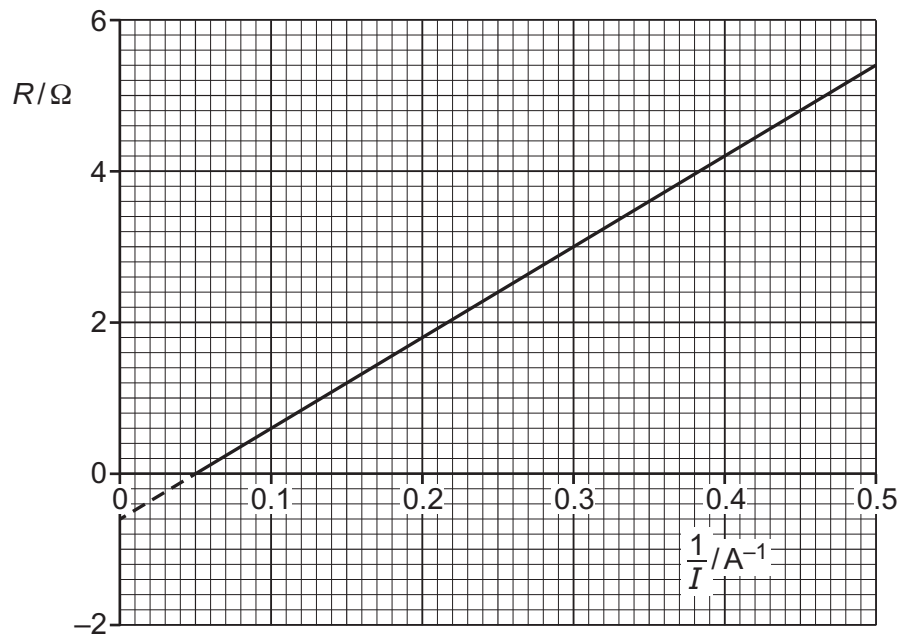


Fig. 6.2

- (i) Use Fig. 6.2 to determine the power dissipated in the variable resistor when there is a current of 2.0 A in the circuit.

power = ... W [3]

- (ii) Use Fig. 6.2 and the equation in (c) to:

1. state the internal resistance r of the battery

$r =$ Ω

2. determine the e.m.f. E of the battery.

$E =$ V
[3]

[Total: 10]

- 7 Two vertical metal plates are separated by a distance d in a vacuum, as shown in Fig. 7.1.

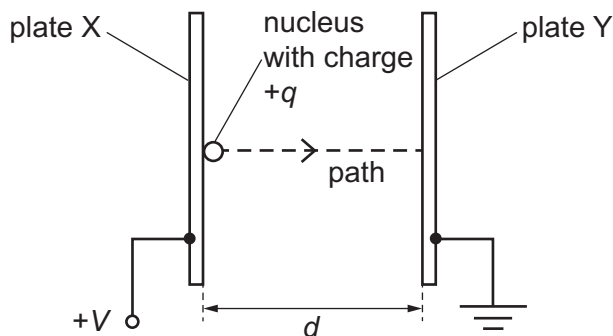


Fig. 7.1 (not to scale)

The potential difference (p.d.) between the plates is V . A nucleus with charge $+q$ is initially at rest on plate X. The nucleus is accelerated by the uniform electric field from plate X along a horizontal path to plate Y.

- (a) State expressions, in terms of some or all of d , q and V , for:

- (i) the magnitude of the electric field strength

electric field strength = ... [1]

- (ii) the magnitude of the electric force acting on the nucleus

force = ... [1]

- (iii) the kinetic energy of the nucleus when it reaches plate Y.

kinetic energy = ... [1]

- (b) State the change, if any, in the kinetic energy of the nucleus on reaching plate Y when the following separate changes are made.

- (i) The distance d is halved, but the p.d. V remains the same.

..... [1]

- (ii) The nucleus is replaced by a different nucleus that is an isotope of the original nucleus with fewer neutrons.

..... [1]

- (c) The nucleus is carbon-14 ($^{14}_6\text{C}$). This nucleus decays to form a new nucleus by releasing a β^- particle and only one other particle of negligible mass.

- (i) Calculate the nucleon number and the proton number of the **new** nucleus.

nucleon number = ...

proton number = ...

[1]

- (ii) State the name of the particle of negligible mass.

..... [1]

[Total: 7]

BLANK PAGE

Permission to reproduce items where third-party owned material protected by copyright is included has been sought and cleared where possible. Every reasonable effort has been made by the publisher (UCLES) to trace copyright holders, but if any items requiring clearance have unwittingly been included, the publisher will be pleased to make amends at the earliest possible opportunity.

To avoid the issue of disclosure of answer-related information to candidates, all copyright acknowledgements are reproduced online in the Cambridge Assessment International Education Copyright Acknowledgements Booklet. This is produced for each series of examinations and is freely available to download at www.cambridgeinternational.org after the live examination series.

Cambridge Assessment International Education is part of the Cambridge Assessment Group. Cambridge Assessment is the brand name of the University of Cambridge Local Examinations Syndicate (UCLES), which itself is a department of the University of Cambridge.