

CANDIDATE
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PHYSICS

9702/21

Paper 2 AS Level Structured Questions

October/November 2019

1 hour 15 minutes

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your centre number, candidate number and name on all the work you hand in.

Write in dark blue or black pen.

You may use an HB pencil for any diagrams or graphs.

Do not use staples, paper clips, glue or correction fluid.

DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.

Electronic calculators may be used.

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

At the end of the examination, fasten all your work securely together.

The number of marks is given in brackets [] at the end of each question or part question.

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

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

1 (a) Make estimates of:

(i) the mass, in g, of a new pencil

mass = ... g [1]

(ii) the wavelength of ultraviolet radiation.

wavelength = ... m [1]

(b) The period T of the oscillations of a mass m suspended from a spring is given by

$$T = 2\pi\sqrt{\frac{m}{k}}$$

where k is the spring constant of the spring.

The manufacturer of a spring states that it has a spring constant of $25 \text{ N m}^{-1} \pm 8\%$. A mass of $200 \times 10^{-3} \text{ kg} \pm 4 \times 10^{-3} \text{ kg}$ is suspended from the end of the spring and then made to oscillate.

(i) Calculate the period T of the oscillations.

$T =$ s [1]

(ii) Determine the value of T , with its absolute uncertainty, to an appropriate number of significant figures.

$T =$ $\pm$ s [3]

[Total: 6]

- 2 A small charged glass bead of weight $5.4 \times 10^{-5} \text{ N}$ is initially at rest at point A in a vacuum. The bead then falls through a uniform horizontal electric field as it moves in a straight line to point B, as illustrated in Fig. 2.1.

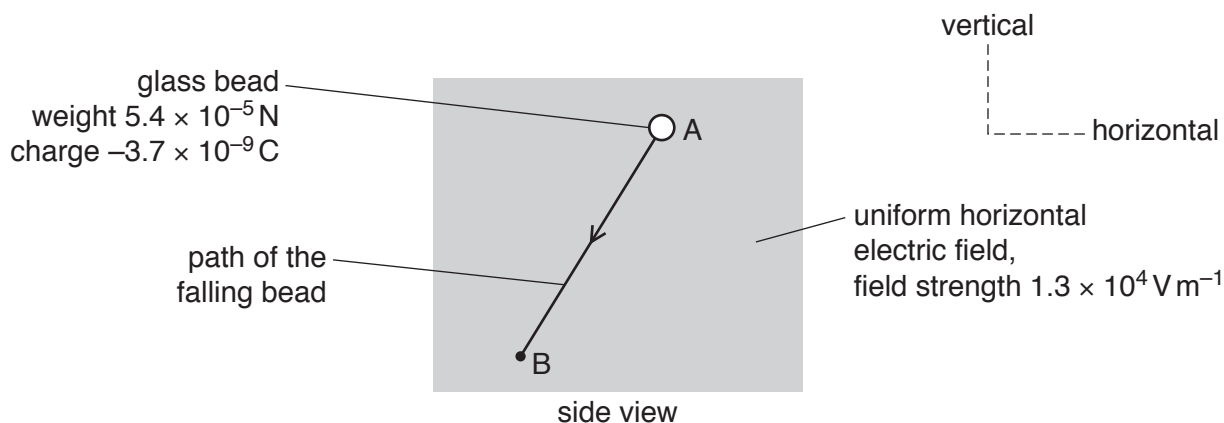


Fig. 2.1 (not to scale)

The electric field strength is $1.3 \times 10^4 \text{ V m}^{-1}$. The charge on the bead is $-3.7 \times 10^{-9} \text{ C}$.

- (a) Describe how two metal plates could be used to produce the electric field. Numerical values are not required.

.....

.....

..... [2]

- (b) Determine the magnitude of the electric force acting on the bead.

electric force = ... N [2]

- (c) Use your answer in (b) and the weight of the bead to show that the resultant force acting on it is $7.2 \times 10^{-5} \text{ N}$.

[1]

- (d) Explain why the resultant force on the bead of $7.2 \times 10^{-5} \text{ N}$ is constant as the bead moves along path AB.

.....

.....

.....

..... [2]

- (e) (i) Calculate the magnitude of the acceleration of the bead along the path AB.

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

- (ii) The path AB has length 0.58 m.

Use your answer in (i) to determine the speed of the bead at point B.

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

[Total: 11]

- 3 A small remote-controlled model aircraft has two propellers, each of diameter 16 cm. Fig. 3.1 is a side view of the aircraft when hovering.

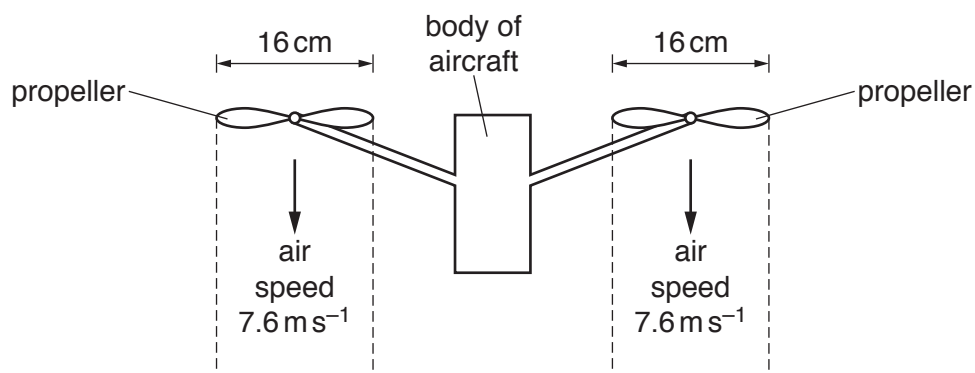


Fig. 3.1

Air is propelled vertically downwards by each propeller so that the aircraft hovers at a fixed position. The density of the air is 1.2 kg m^{-3} . Assume that the air from each propeller moves with a constant speed of 7.6 m s^{-1} in a uniform cylinder of diameter 16 cm. Also assume that the air above each propeller is stationary.

- (a) Show that, in a time interval of 3.0 s, the mass of air propelled downwards by **one** propeller is 0.55 kg.

[3]

- (b) Calculate:

- (i) the increase in momentum of the mass of air in (a)

increase in momentum = ... N s [1]

- (ii) the downward force exerted on this mass of air by the propeller.

force = ... N [1]

(c) State:

- (i) the upward force acting on **one** propeller

force = ... N [1]

- (ii) the name of the law that explains the relationship between the force in **(b)(ii)** and the force in **(c)(i)**.

..... [1]

(d) Determine the mass of the aircraft.

mass = ... kg [1]

- (e) In order for the aircraft to hover at a very high altitude (height), the propellers must propel the air downwards with a greater speed than when the aircraft hovers at a low altitude. Suggest the reason for this.

.....
 [1]

- (f) When the aircraft is hovering at a high altitude, an electric fault causes the propellers to stop rotating. The aircraft falls vertically downwards. When the aircraft reaches a constant speed of 22 m s^{-1} , it emits sound of frequency 3.0 kHz from an alarm. The speed of the sound in the air is 340 m s^{-1} .

Determine the frequency of the sound heard by a person standing vertically below the falling aircraft.

frequency = ... Hz [2]

[Total: 11]

- 4 The variation with extension x of the force F applied to a spring is shown in Fig. 4.1.

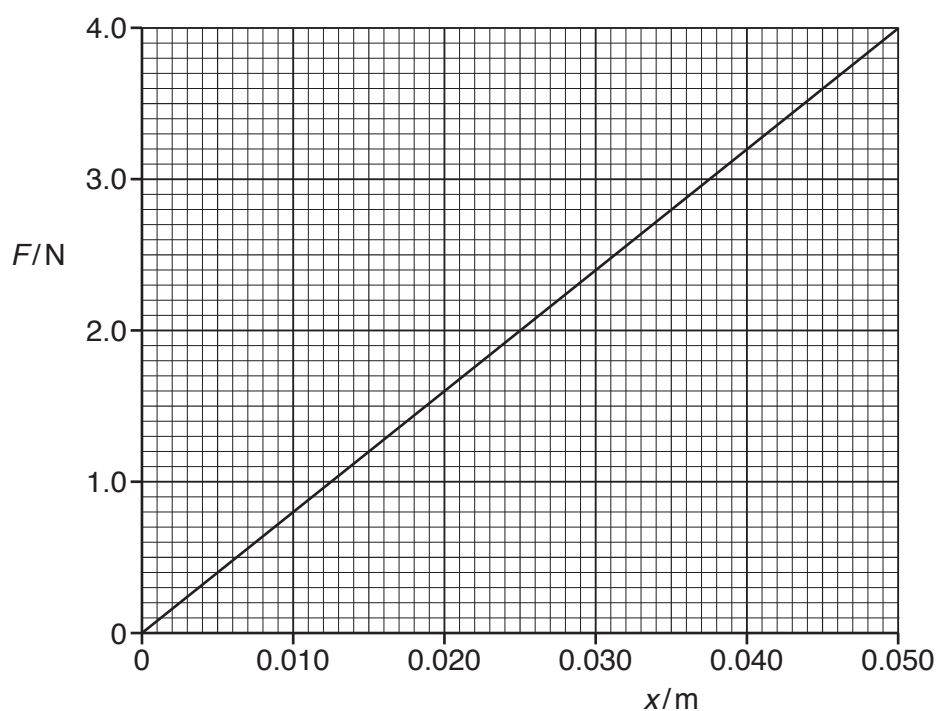


Fig. 4.1

The spring has an unstretched length of 0.080 m and is suspended vertically from a fixed point, as shown in Fig. 4.2.

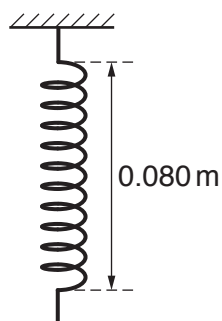


Fig. 4.2

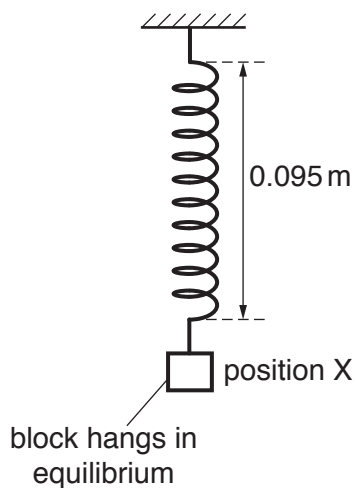


Fig. 4.3

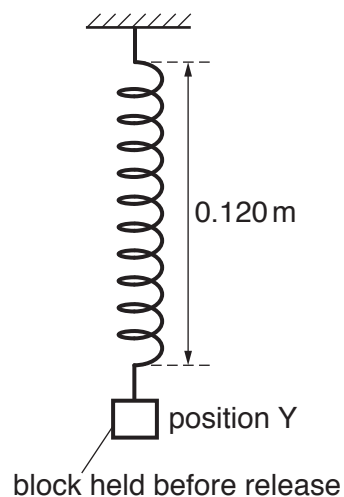


Fig. 4.4

A block is attached to the lower end of the spring. The block hangs in equilibrium at position X when the length of the spring is 0.095 m, as shown in Fig. 4.3.

The block is then pulled vertically downwards and held at position Y so that the length of the spring is 0.120 m, as shown in Fig. 4.4. The block is then released and moves vertically upwards from position Y back towards position X.

- (a) Use Fig. 4.1 to determine the spring constant of the spring.

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

- (b) Use Fig. 4.1 to show that the decrease in elastic potential energy of the spring is 0.055 J when the block moves from position Y to position X.

[2]

- (c) The block has a mass of 0.122 kg. Calculate the increase in gravitational potential energy of the block for its movement from position Y to position X.

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

- (d) Use the decrease in elastic potential energy stated in (b) and your answer in (c) to determine, for the block, as it moves through position X:

- (i) its kinetic energy

kinetic energy = ... J [1]

- (ii) its speed.

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

[Total: 9]

- 5 A ripple tank is used to demonstrate the interference of water waves. Two dippers D1 and D2 produce coherent waves that have circular wavefronts, as illustrated in Fig. 5.1.

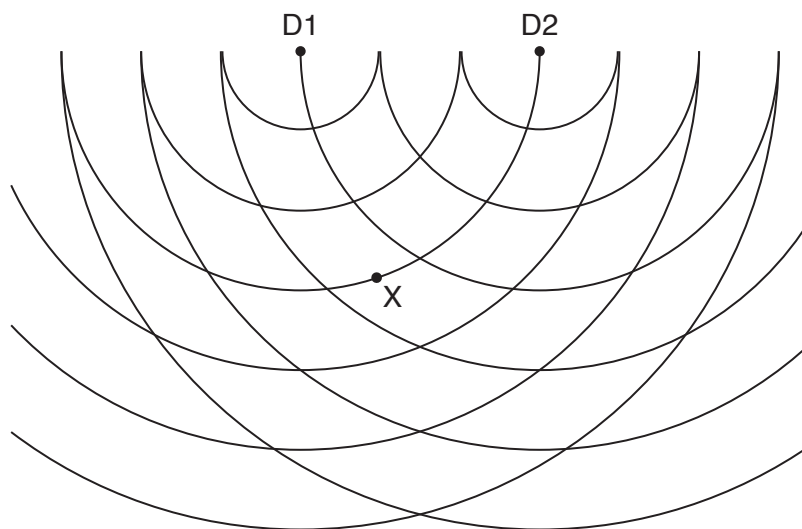


Fig. 5.1

The lines in the diagram represent crests. The waves have a wavelength of 6.0 cm.

- (a) One condition that is required for an observable interference pattern is that the waves must be coherent.

- (i) Describe how the apparatus is arranged to ensure that the waves from the dippers are coherent.

.....
 [1]

- (ii) State one other condition that must be satisfied by the waves in order for the interference pattern to be observable.

.....
 [1]

- (b) Light from a lamp above the ripple tank shines through the water onto a screen below the tank. Describe one way of seeing the illuminated pattern more clearly.

.....
 [1]

- (c) The speed of the waves is 0.40 m s^{-1} . Calculate the period of the waves.

period = ... s [2]

- (d) Fig. 5.1 shows a point X that lies on a crest of the wave from D1 and midway between two adjacent crests of the wave from D2.

For the waves at point X, state:

- (i) the path difference, in cm

path difference = ... cm [1]

- (ii) the phase difference.

phase difference = ... ° [1]

- (e) On Fig. 5.1, draw **one** line, at least 4 cm long, which joins points where only maxima of the interference pattern are observed. [1]

[Total: 8]

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

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

- (b) The variation with potential difference V of the current I in a semiconductor diode is shown in Fig. 6.1.

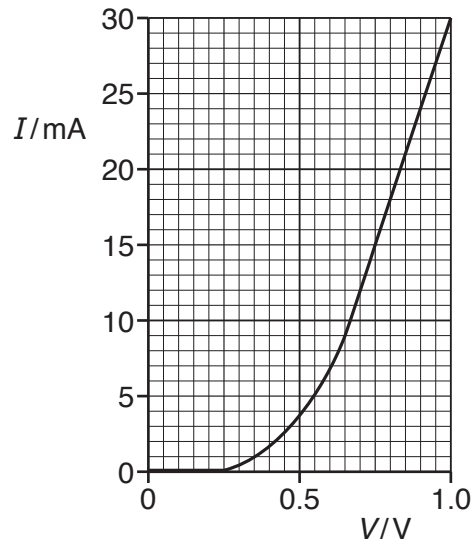


Fig. 6.1

Use Fig. 6.1 to describe qualitatively the variation of the resistance of the diode as V increases from 0 to 1.0 V.

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

(c) The diode in (b) is part of the circuit shown in Fig. 6.2.

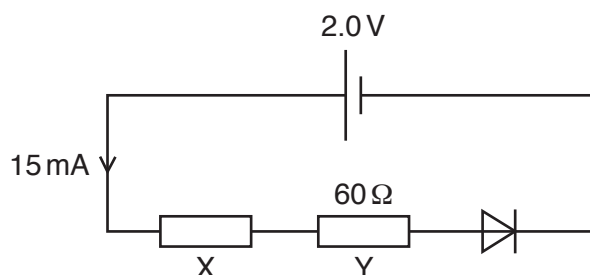


Fig. 6.2

The cell of electromotive force (e.m.f.) 2.0 V and negligible internal resistance is connected in series with the diode and resistors X and Y. The resistance of Y is $60\ \Omega$. The current in the cell is 15 mA.

(i) Use Fig. 6.1 to determine the resistance of the diode.

resistance = ... Ω [3]

(ii) Calculate:

1. the resistance of X

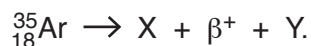
resistance = ... Ω [3]

2. the ratio

$$\frac{\text{power dissipated in resistor Y}}{\text{total power produced by the cell}}$$

ratio = ... [2]

- 7 (a) The decay of a nucleus ${}^{35}_{18}\text{Ar}$ by β^+ emission is represented by



A nucleus X and two particles, β^+ and Y, are produced by the decay.

State:

- (i) the proton number and the nucleon number of nucleus X

proton number = ...

nucleon number = ...

[1]

- (ii) the name of the particle represented by the symbol Y.

..... [1]

- (b) A hadron consists of two down quarks and one strange quark.

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

charge = ... [2]

[Total: 4]

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9702/22

October/November 2019

1 hour 15 minutes

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Data

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

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

- 1 (a) Distinguish between vector and scalar quantities.

.....

.....

..... [2]

- (b) The electric field strength E at a distance x from an isolated point charge Q is given by the equation

$$E = \frac{Q}{x^2 b}$$

where b is a constant.

- (i) Use the definition of electric field strength to show that E has SI base units of $\text{kg m A}^{-1} \text{s}^{-3}$.

[2]

- (ii) Use the units for E given in (b)(i) to determine the SI base units of b .

SI base units of b [2]

[Total: 6]

- 2 (a) Define *acceleration*.

..... [1]

- (b) A steel ball of diameter 0.080 m is released from rest and falls vertically in air, as illustrated in Fig. 2.1.

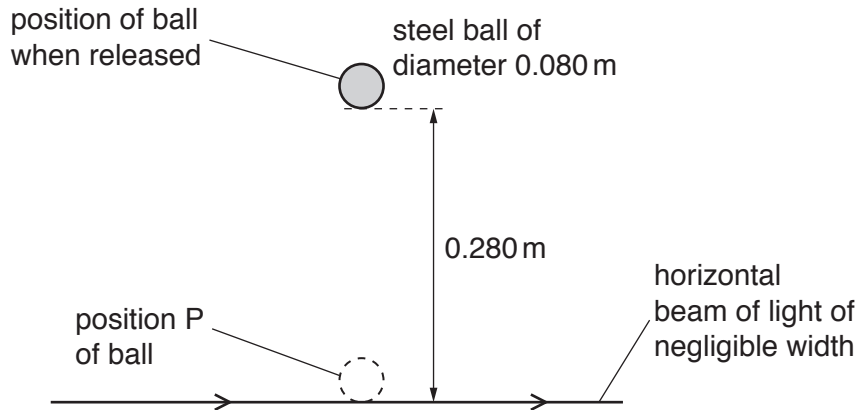


Fig. 2.1 (not to scale)

A horizontal beam of light of negligible width is a vertical distance of 0.280 m below the bottom of the ball when it is released. The ball falls through and breaks the beam of light.

- (i) Explain why the force due to air resistance acting on the ball may be neglected when calculating the time taken for the ball to reach the beam of light.

..... [1]

- (ii) Calculate the time taken for the ball to fall from rest to position P where the bottom of the ball touches the beam of light.

time taken = ... s [2]

- (iii) Determine the time interval during which the beam of light is broken by the ball.

time interval = ... s [2]

- (c) A different ball is released from the same position as the steel ball in (b). This ball has the same diameter but a much lower density. For this ball, the force due to air resistance cannot be neglected as the ball falls.

State and explain the change, if any, to the time interval during which the beam of light is broken by the ball.

.....

 [2]

[Total: 8]

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

.....

.....

..... [2]

- (b) A block X of mass m_X slides in a straight line along a horizontal frictionless surface, as shown in Fig. 3.1.

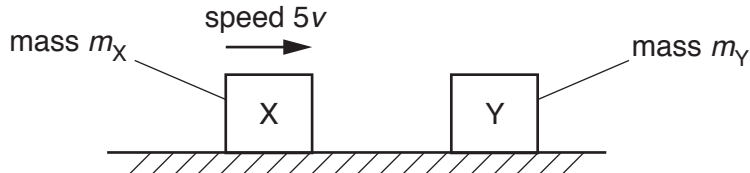


Fig. 3.1

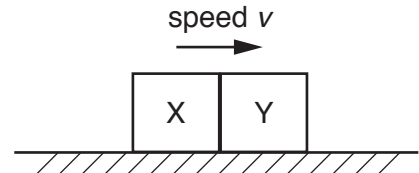


Fig. 3.2

The block X, moving with speed $5v$, collides head-on with a stationary block Y of mass m_Y . The two blocks stick together and then move with common speed v , as shown in Fig. 3.2.

- (i) Use conservation of momentum to show that the ratio $\frac{m_Y}{m_X}$ is equal to 4.

[2]

- (ii) Calculate the ratio

$$\frac{\text{total kinetic energy of X and Y after collision}}{\text{total kinetic energy of X and Y before collision}}.$$

ratio = ... [3]

(iii) State the value of the ratio in (ii) for a perfectly elastic collision.

ratio = ... [1]

(c) The variation with time t of the momentum of block X in (b) is shown in Fig. 3.3.

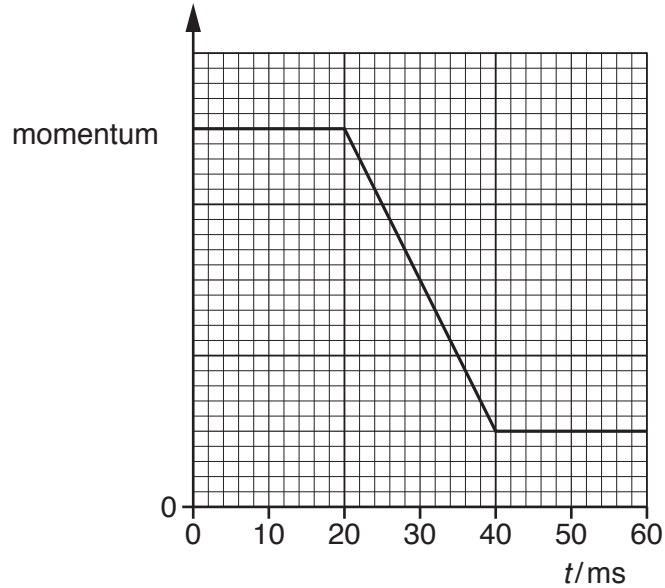


Fig. 3.3

Block X makes contact with block Y at time $t = 20$ ms.

(i) Describe, qualitatively, the magnitude and direction of the resultant force, if any, acting on block X in the time interval:

1. $t = 0$ to $t = 20$ ms

.....

2. $t = 20$ ms to $t = 40$ ms.

.....

.....

[3]

(ii) On Fig. 3.3, sketch the variation of the momentum of block Y with time t from $t = 0$ to $t = 60$ ms. [3]

[Total: 14]

- 4 (a) A sphere in a liquid accelerates vertically downwards from rest. For the viscous force acting on the moving sphere, state:

(i) the direction

..... [1]

(ii) the variation, if any, in the magnitude.

..... [1]

- (b) A man of weight 750 N stands a distance of 3.6 m from end D of a horizontal uniform beam AD, as shown in Fig. 4.1.

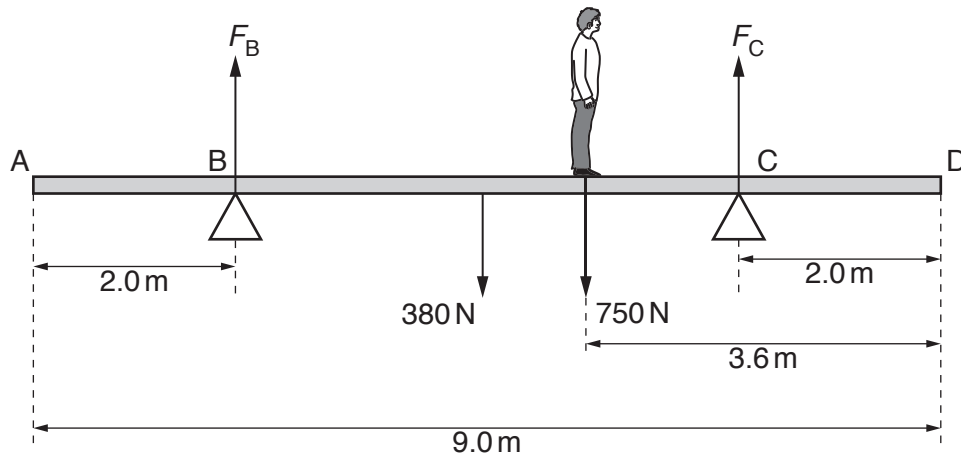


Fig. 4.1 (not to scale)

The beam has a weight of 380 N and a length of 9.0 m. The beam is supported by a vertical force F_B at pivot B and a vertical force F_C at pivot C. Pivot B is a distance of 2.0 m from end A and pivot C is a distance of 2.0 m from end D. The beam is in equilibrium.

(i) State the principle of moments.

.....

 [2]

- (ii) By using moments about pivot C, calculate F_B .

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

- (iii) The man walks towards end D. The beam is about to tip when F_B becomes zero.

Determine the minimum distance x from end D that the man can stand without tipping the beam.

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

[Total: 8]

- 5 (a) State what is meant by the *wavelength* of a progressive wave.

.....
 [1]

- (b) A cathode-ray oscilloscope (CRO) is used to analyse a sound wave. The screen of the CRO is shown in Fig. 5.1.

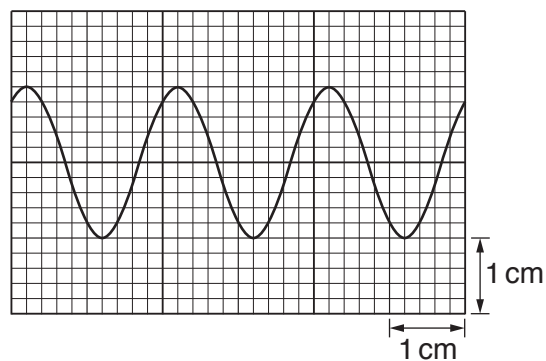


Fig. 5.1

The time-base setting of the CRO is 2.5 ms cm^{-1} .

Determine the frequency of the sound wave.

frequency = ... Hz [2]

- (c) The source emitting the sound in (b) is at point A. Waves travel from the source to point C along two different paths, AC and ABC, as shown in Fig. 5.2.

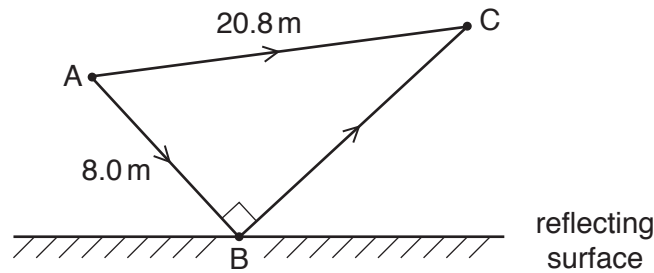


Fig. 5.2 (not to scale)

Distance AB is 8.0 m and distance AC is 20.8 m. Angle ABC is 90° . Assume that there is no phase change of the sound wave due to the reflection at point B. The wavelength of the waves is 1.6 m.

- (i) Show that the waves meeting at C have a path difference of 6.4 m.

[1]

- (ii) Explain why an intensity maximum is detected at point C.

.....

 [2]

- (iii) Determine the difference between the times taken for the sound to travel from the source to point C along the two different paths.

time difference = ... s [2]

- (iv) The wavelength of the sound is gradually increased. Calculate the wavelength of the sound when an intensity maximum is next detected at point C.

wavelength = ... m [1]

[Total: 9]

[Turn over]

- 6 (a) State Kirchhoff's first law.

.....
 [1]

- (b) The variations with potential difference V of the current I for a resistor X and for a semiconductor diode are shown in Fig. 6.1.

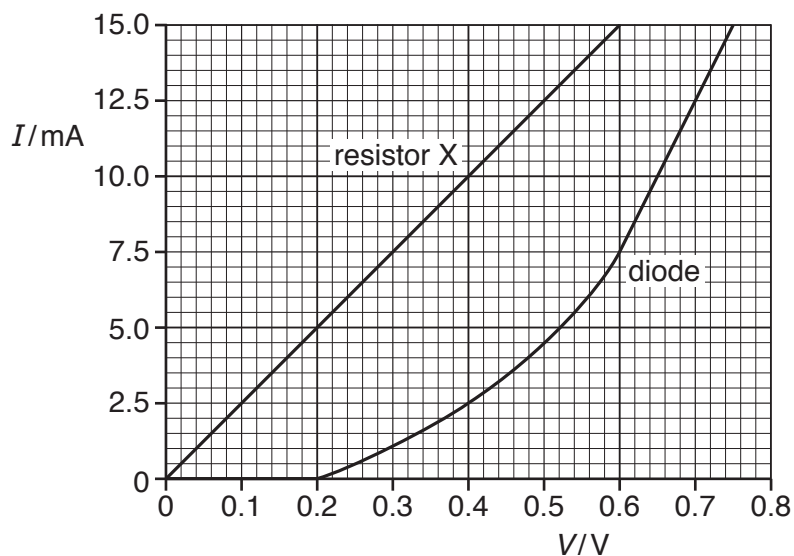


Fig. 6.1

- (i) Determine the resistance of the diode for a potential difference V of 0.60 V.

resistance = ... Ω [3]

- (ii) Describe, qualitatively, the variation of the resistance of the diode as V increases from 0.60 V to 0.75 V.

..... [1]

- (c) The diode and the resistor X in (b) are connected into the circuit shown in Fig. 6.2.

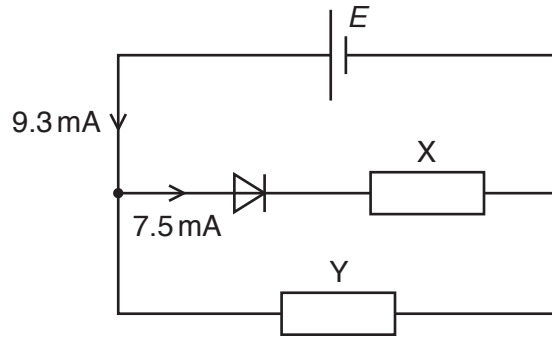


Fig. 6.2

The cell has electromotive force (e.m.f.) E and negligible internal resistance. Resistor Y is connected in parallel with resistor X and the diode. The current in the cell is 9.3 mA and the current in the diode is 7.5 mA .

- (i) Use Fig. 6.1 to determine E .

$$E = \dots\dots\dots\text{V} \quad [1]$$

- (ii) Determine the resistance of resistor Y.

$$\text{resistance} = \dots\dots\dots\Omega \quad [2]$$

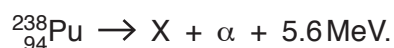
- (iii) Calculate the power dissipated in the diode.

$$\text{power} = \dots\dots\dots\text{W} \quad [2]$$

- (iv) The cell is now replaced by a new cell of e.m.f. 0.50 V and negligible internal resistance. Use Fig. 6.1 to determine the new current in the diode.

$$\text{current} = \dots\dots\dots\text{mA} \quad [1]$$

- 7 A nucleus of plutonium-238 ($^{238}_{94}\text{Pu}$) decays by emitting an α -particle to produce a new nucleus X and 5.6 MeV of energy. The decay is represented by



- (a) Determine the number of protons and the number of neutrons in nucleus X.

number of protons = ...

number of neutrons = ...

[2]

- (b) Calculate the number of plutonium-238 nuclei that must decay in a time of 1.0 s to produce a power of 0.15 W.

number = ... [2]

[Total: 4]

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9702/23

October/November 2019

1 hour 15 minutes

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your centre number, candidate number and name on all the work you hand in.

Write in dark blue or black pen.

You may use an HB pencil for any diagrams or graphs.

Do not use staples, paper clips, glue or correction fluid.

DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.

Electronic calculators may be used.

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

At the end of the examination, fasten all your work securely together.

The number of marks is given in brackets [] at the end of each question or part question.

This document consists of **17** printed pages and **3** blank pages.

Data

speed of light in free space	$c = 3.00 \times 10^8 \text{ m s}^{-1}$
permeability of free space	$\mu_0 = 4\pi \times 10^{-7} \text{ H m}^{-1}$
permittivity of free space	$\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$ ($\frac{1}{4\pi\epsilon_0} = 8.99 \times 10^9 \text{ m F}^{-1}$)
elementary charge	$e = 1.60 \times 10^{-19} \text{ C}$
the Planck constant	$h = 6.63 \times 10^{-34} \text{ J s}$
unified atomic mass 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) Determine the SI base units of the moment of a force.

SI base units [1]

- (b) A uniform square sheet of card ABCD is freely pivoted by a pin at a point P. The card is held in a vertical plane by an external force in the position shown in Fig. 1.1.

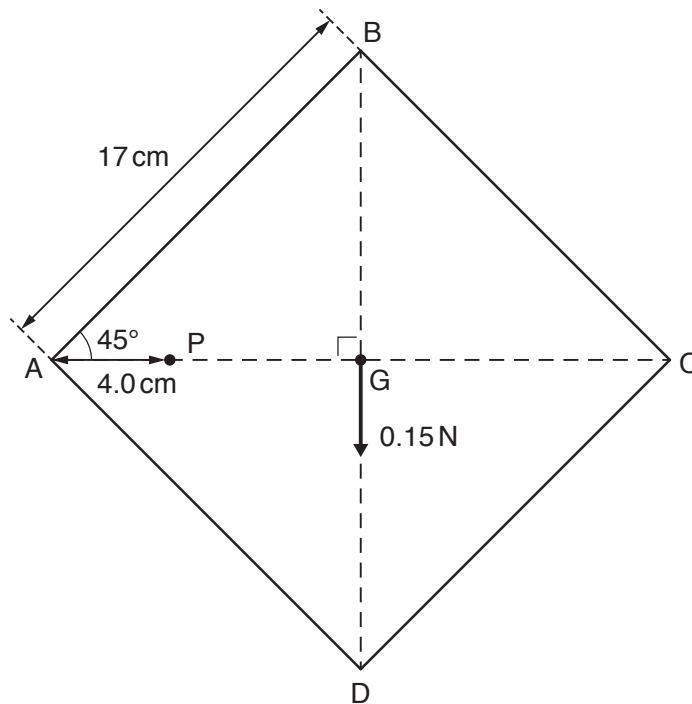


Fig. 1.1 (not to scale)

The card has weight 0.15 N which may be considered to act at the centre of gravity G. Each side of the card has length 17 cm. Point P lies on the horizontal line AC and is 4.0 cm from corner A. Line BD is vertical.

The card is released by removing the external force. The card then swings in a vertical plane until it comes to rest.

- (i) Calculate the magnitude of the resultant moment about point P acting on the card immediately after it is released.

moment = ... Nm [2]

- (ii) Explain why, when the card has come to rest, its centre of gravity is vertically below point P.

.....

.....

.....

..... [2]

[Total: 5]

- 2 (a) State what is meant by *work done*.

.....
 [1]

- (b) A lift (elevator) of weight 13.0 kN is connected by a cable to a motor, as shown in Fig. 2.1.

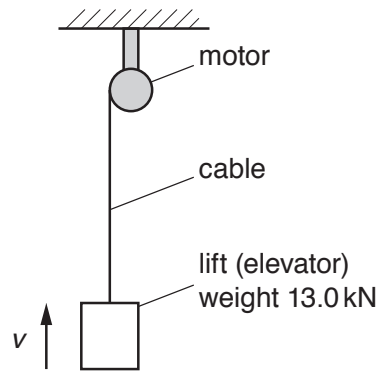


Fig. 2.1

The lift is pulled up a vertical shaft by the cable. A constant frictional force of 2.0 kN acts on the lift when it is moving. The variation with time t of the speed v of the lift is shown in Fig. 2.2.

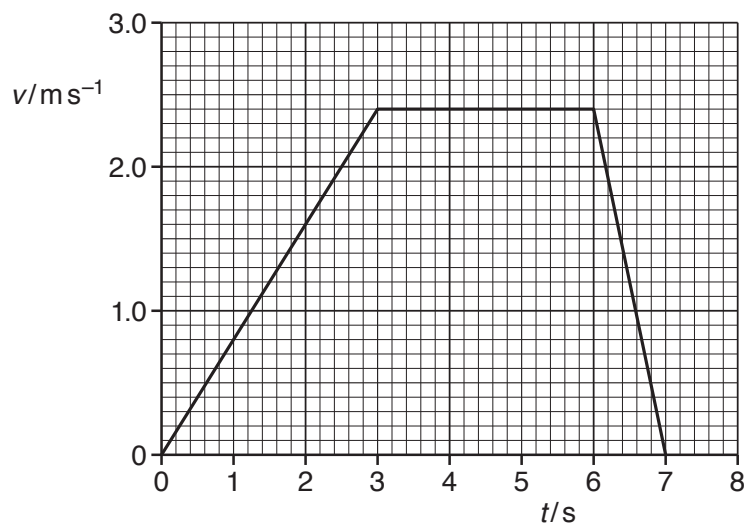


Fig. 2.2

(i) Use Fig. 2.2 to determine:

1. the acceleration of the lift between time $t = 0$ and $t = 3.0$ s

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

2. the work done by the motor to raise the lift between time $t = 3.0$ s and $t = 6.0$ s.

work done = ... J [2]

(ii) The motor has an efficiency of 67%. The tension in the cable is $1.6 \times 10^4 \text{ N}$ at time $t = 2.5$ s.

Determine the input power to the motor at this time.

input power = ... W [3]

(iii) State and explain whether the increase in gravitational potential energy of the lift from time $t = 0$ to $t = 7.0$ s is less than, the same as, or greater than the work done by the motor. A calculation is not required.

.....
 [1]

[Total: 9]

3 (a) State the property of an object that experiences a force when the object is placed in:

(i) a gravitational field

..... [1]

(ii) an electric field.

..... [1]

(b) A potential difference of $1.2 \times 10^3 \text{ V}$ is applied between a pair of horizontal metal plates in a vacuum, as shown in Fig. 3.1.

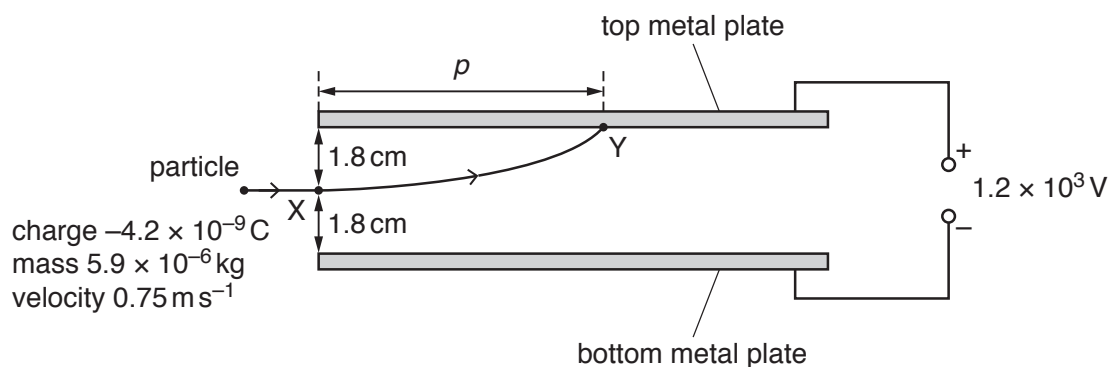


Fig. 3.1 (not to scale)

The separation of the plates is 3.6 cm. The electric field between the plates is uniform.

A particle of mass $5.9 \times 10^{-6} \text{ kg}$ and charge $-4.2 \times 10^{-9} \text{ C}$ enters the field at point X with a horizontal velocity of 0.75 m s^{-1} along a line midway between the two plates. The particle is deflected by the field and hits the top plate at point Y.

(i) Calculate the magnitude of the electric force acting on the particle in the field.

electric force = ... N [3]

- (ii) By considering the resultant vertical force acting on the particle, show that the acceleration of the particle in the electric and gravitational fields is 14 m s^{-2} .

[4]

- (iii) Determine:

- the time taken for the particle to move from X to Y

time taken = ... s [2]

- the distance p of point Y from the left-hand edge of the top plate.

$p = \dots\dots\dots \text{m}$ [1]

[Total: 12]

- 4 A ball X moves along a horizontal frictionless surface and collides with another ball Y, as illustrated in Fig. 4.1.

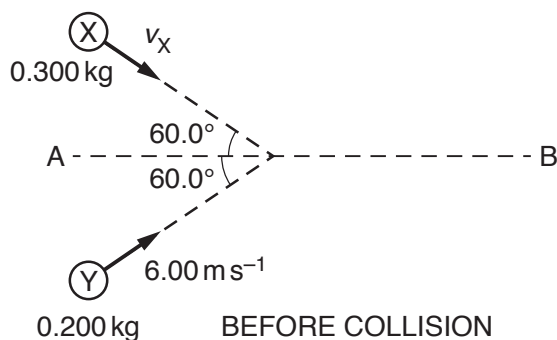


Fig. 4.1 (not to scale)

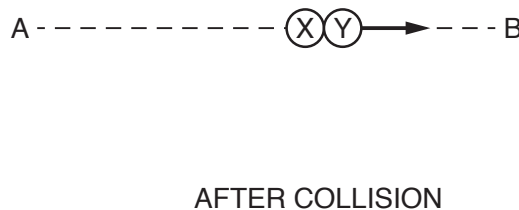


Fig. 4.2 (not to scale)

Ball X has mass 0.300 kg and initial velocity v_X at an angle of 60.0° to line AB.
 Ball Y has mass 0.200 kg and initial velocity 6.00 m s^{-1} at an angle of 60.0° to line AB.
 The balls stick together during the collision and then travel along line AB, as illustrated in Fig. 4.2.

- (a) (i) Calculate, to three significant figures, the component of the initial momentum of ball Y that is perpendicular to line AB.

component of momentum = ... kg m s^{-1} [2]

- (ii) By considering the component of the initial momentum of each ball perpendicular to line AB, calculate, to three significant figures, v_X .

$v_X = \dots\dots\dots \text{m s}^{-1}$ [1]

- (iii) Show that the speed of the two balls after the collision is 2.4 m s^{-1} .

[2]

- (b) The two balls continue moving together along the horizontal frictionless surface towards a spring, as illustrated in Fig. 4.3.

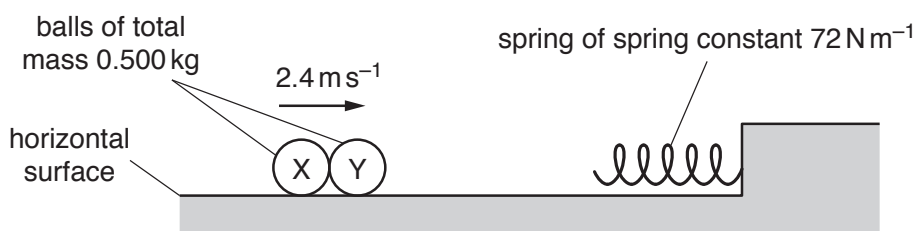


Fig. 4.3

The balls hit the spring and remain stuck together as they decelerate to rest. All the kinetic energy of the balls is converted into elastic potential energy of the spring. The energy E stored in the spring is given by

$$E = \frac{1}{2}kx^2$$

where k is the spring constant of the spring and x is its compression. The spring obeys Hooke's law and has a spring constant of 72 N m^{-1} .

- (i) Determine the maximum compression of the spring caused by the two balls.

maximum compression = ...m [3]

(ii) On Fig. 4.4, sketch graphs to show the variation with compression x of the spring, from zero to maximum compression, of:

1. the magnitude of the deceleration a of the balls
2. the kinetic energy E_k of the balls.

Numerical values are not required.

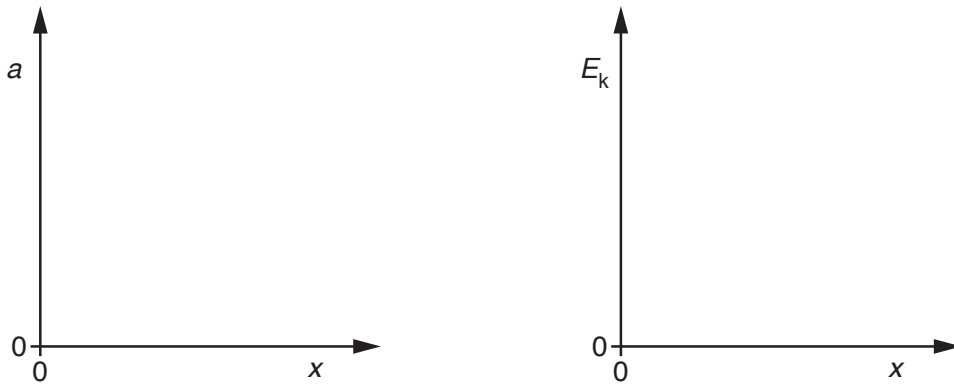


Fig. 4.4

[3]

[Total: 11]

- 5 (a) Light waves emerging from the slits of a diffraction grating are coherent and produce an interference pattern.

Explain what is meant by:

- (i) *coherence*

.....
 [1]

- (ii) *interference*.

.....
 [1]

- (b) A narrow beam of light from a laser is incident normally on a diffraction grating, as shown in Fig. 5.1.

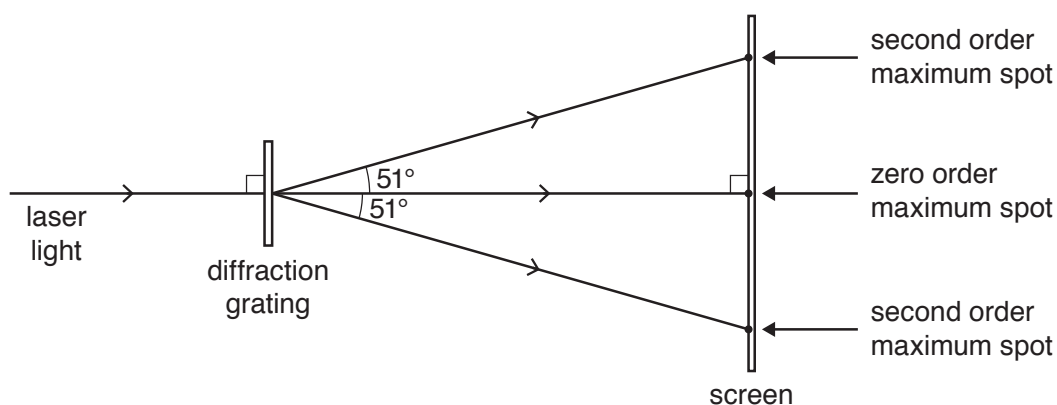


Fig. 5.1 (not to scale)

Spots of light are seen on a screen positioned parallel to the grating. The angle corresponding to each of the **second** order maxima is 51° . The number of lines per unit length on the diffraction grating is $6.7 \times 10^5 \text{ m}^{-1}$.

- (i) Determine the wavelength of the light.

wavelength = ... m [2]

- (ii) State and explain the change, if any, to the distance between the second order maximum spots on the screen when the light from the laser is replaced by light of a shorter wavelength.

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

[Total: 5]

- 6 A battery of electromotive force (e.m.f.) 12 V and negligible internal resistance is connected to a network of two lamps and two resistors, as shown in Fig. 6.1.

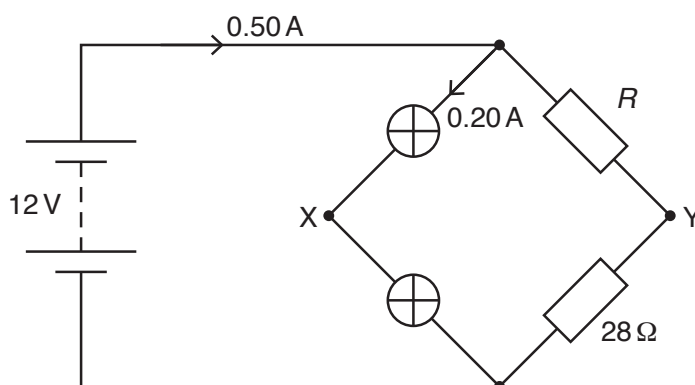


Fig. 6.1

The two lamps in the circuit have equal resistances. The two resistors have resistances R and 28Ω . The lamps are connected at junction X and the resistors are connected at junction Y. The current in the battery is 0.50 A and the current in the lamps is 0.20 A.

(a) Calculate:

- (i) the resistance of each lamp

resistance = ... Ω [2]

- (ii) resistance R .

$R =$ Ω [2]

(b) Determine the potential difference V_{XY} between points X and Y.

$V_{XY} =$ V [3]

(c) Calculate the ratio

$$\frac{\text{total power dissipated by the lamps}}{\text{total power produced by the battery}}$$

ratio = ... [2]

(d) The resistor of resistance R is now replaced by another resistor of lower resistance.

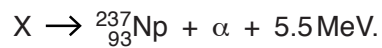
State and explain the effect, if any, of this change on the ratio in (c).

.....

 [2]

[Total: 11]

- 7 A stationary nucleus of a radioactive isotope X decays by emitting an α -particle to produce a nucleus of neptunium-237 and 5.5 MeV of energy. The decay is represented by



- (a) Calculate the number of protons and the number of neutrons in a nucleus of X.

number of protons = ...

number of neutrons = ...

[2]

- (b) Explain why the energy transferred to the α -particle as kinetic energy is less than the 5.5 MeV of energy released in the decay process.

.....

..... [1]

- (c) A sample of X is used to produce a beam of α -particles in a vacuum. The number of α -particles passing a fixed point in the beam in a time of 30 s is 6.9×10^{11} .

- (i) Calculate the average current produced by the beam of α -particles.

current = ... A [2]

- (ii) Determine the total power, in W, that is produced by the decay of 6.9×10^{11} nuclei of X in a time of 30 s.

power = ... W [2]

[Total: 7]

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