Anglo-Chinese Junior College

Physics Preliminary Examination
Higher 2

A Methodist Institution
(Founded 1886)

PHYSICS **9749/01**

Paper 1 Multiple Choice

18 September 2020
1 hour

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your name and index number on the Answer Sheet provided.

There are **thirty** questions in this section. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this Question Paper.
The use of an approved scientific calculator is expected, where appropriate.

DATA AND FORMULAE

Data

speed of light in free space,	c	=	3.00×10^{8} m s^{-1}
permeability of free space,	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_o	=	8.85×10^{-12} F m^{-1}
			$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	e	=	1.60×10^{-19} C
the Planck constant,	h	=	6.63×10^{-34} J s
unified atomic mass constant,	u	=	1.66×10^{-27} kg
rest mass of electron,	m_e	=	9.11×10^{-31} kg
rest mass of proton,	m_p	=	1.67×10^{-27} kg
molar gas constant,	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant,	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant,	k	=	1.38×10^{-23} J K^{-1}
gravitational constant,	G	=	6.67×10^{-11} N m^{2} kg^{-2}
acceleration of free fall,	g	=	9.81 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	=	$p \Delta V$
hydrostatic pressure,	p	=	$\rho g h$
gravitational potential,	ϕ	=	$-\frac{Gm}{r}$
temperature	T/K	=	$T/°C + 273.15$
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of of an ideal gas molecule,	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.,	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.,	v	=	$v_o \cos \omega t$
		=	$\pm \omega \sqrt{x_o^2 - x^2}$
electric current	I	=	$A n v q$
resistors in series,	R	=	$R_1 + R_2 + \ldots$
resistors in parallel,	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential,	V	=	$\frac{Q}{4\pi\varepsilon_o r}$
alternating current/voltage,	x	=	$x_o \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\frac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\frac{\mu_o N I}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_o n I$
radioactive decay,	x	=	$x_o \exp(-\lambda t)$
decay constant,	λ	=	$\frac{\ln 2}{t_{1/2}}$

[Turn over

1 A student hypothesizes that the period of an oscillating mass-spring system T is related to its mass m and spring constant k. In an experiment, the student obtains the relationship

$$T = Cm^{1/2}k^{-1/2}$$

where C is a constant.

Which of the following gives the unit of C?

A s
B s $N^{1/2}$ $m^{-1/2}$
C kg^{-1}
D C does not have a unit.

2 An object, dropped from a building, is timed to take (2.0 ± 0.1) s to fall to the ground.

Assuming that acceleration of free fall is constant, what is the height of the building with its associated uncertainty?

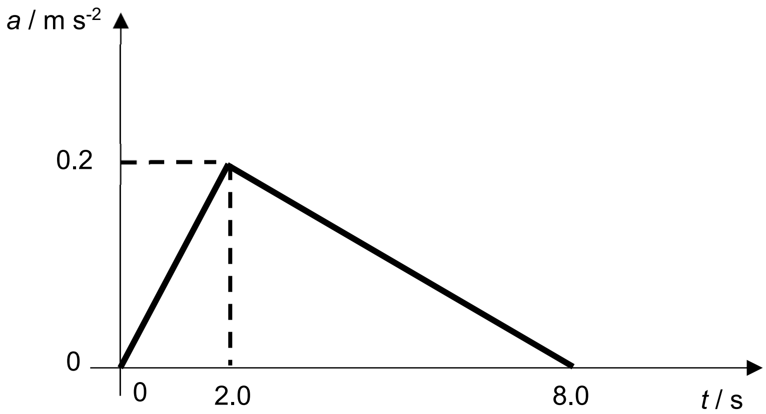
A (19.6 ± 0.1) m

B (19.6 ± 0.2) m

C (19.62 ± 1.96) m

D (20 ± 2) m

3 The graph below shows the variation with time t of acceleration a of a battery operated toy car.



If the toy car has a velocity of -1.0 m s^{-1} at t = 0 s, what is the final velocity of the car?

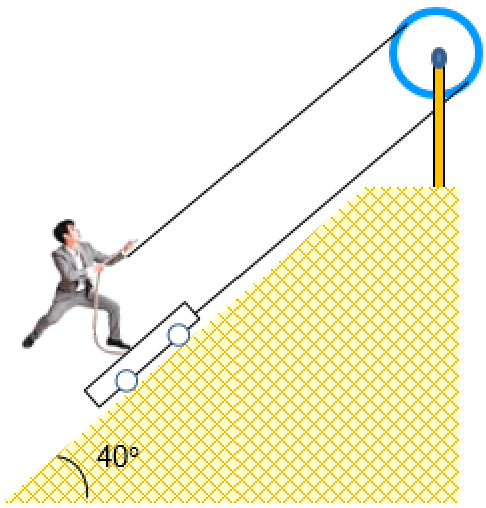
A -1.4 m s^{-1} **B** -0.4 m s^{-1} **C** -0.2 m s^{-1} **D** 0.8 m s^{-1}

4 A rock is thrown with an initial kinetic energy of 15 J at an angle of 30° to the horizontal.

What is its kinetic energy at the highest point of its trajectory?

A 0 J **B** 3.8 J **C** 7.5 J **D** 11 J

5 In the figure below, Tom loosens his grip on a rope slightly to allow the rope to slip through his hands, and this enables him and the trolley to accelerate down an inclined plane together at 0.50 m s^{-2}. Tom and the trolley have a mass of 70 kg and 10 kg respectively and there is no relative motion between Tom and the trolley. The incline is 40° to the horizontal and the pulley is frictionless.



What is the tension in the rope?

A 230 N **B** 280 N **C** 370 N **D** 460 N

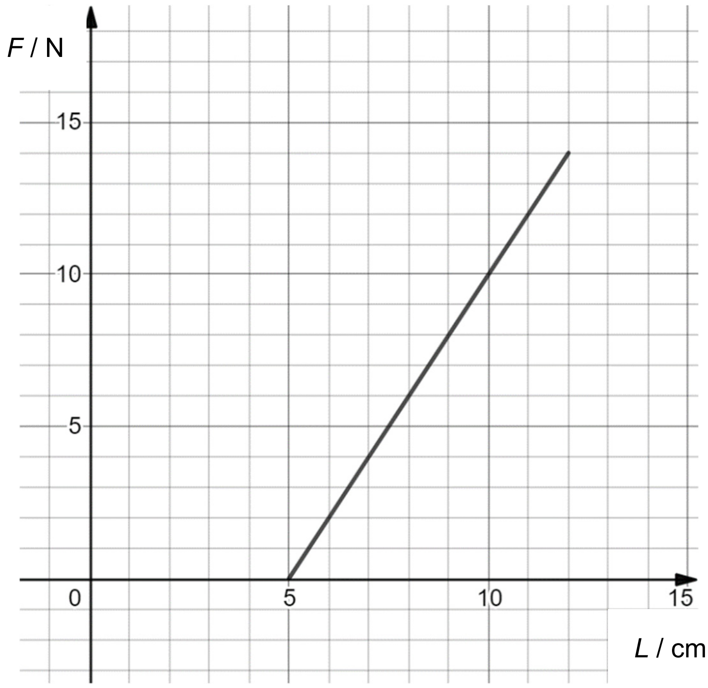
6 A sphere X of mass 2.0 kg makes a head-on collision with sphere Y of mass 3.0 kg. The two spheres separate after the collision.

What is the ratio of $\dfrac{\text{change in speed of X}}{\text{change in speed of Y}}$?

A $\frac{4}{9}$ **B** $\frac{2}{3}$ **C** 1 **D** $\frac{3}{2}$

[Turn over

7 The figure below shows the variation with length L of a spring with varying loads F applied on it.



What is the increase in elastic potential energy of the spring when L is increased from 8.0 cm to 9.0 cm?

A 0.010 J **B** 0.070 J **C** 0.14 J **D** 0.17 J

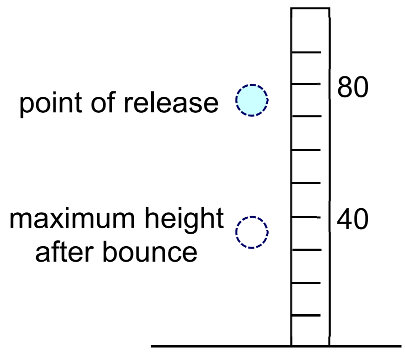
8 An incompressible object is fully submerged in a fluid.

Which of the following quantities is the upthrust experienced by the object independent of?

(i) depth of the object in the fluid
(ii) density of the fluid
(iii) density of the object
(iv) gravitational field strength

A (i) only
B (i) and (iii) only
C (ii) and (iv) only
D None of the above

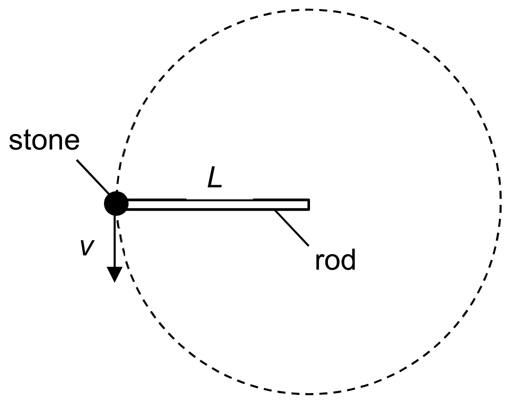
9 A rubber ball has a diameter of 10 cm. It is released from rest with the top of the ball 80 cm above a horizontal surface. It falls vertically and then bounces back up so that the maximum height reached by the top of the ball is 40 cm, as shown in the diagram below.



If the kinetic energy of the ball is 0.80 J just before it strikes the surface, what is the kinetic energy just after it leaves the surface?

A 0.34 J **B** 0.37 J **C** 0.40 J **D** 0.46 J

10 A stone attached to a rigid rod of length L undergoes uniform circular motion in a vertical plane as shown below.



Which one of the following statements is **incorrect**?

A The net work done on the stone by the rod is zero.

B The contact force on the rod is changing all the time.

C The angular velocity of the stone does not change.

D The centripetal acceleration of the stone is given by $\frac{v^2}{L}$.

11 Two identical satellites, A and B, are orbiting around Earth. The distance between Satellite A and Earth is shorter than that between Satellite B and Earth.

Which of the following correctly compares the total energies (TE), gravitational potential energies (GPE) and kinetic energies (KE) of Satellites A and B?

	Total energy	Gravitational potential energy	Kinetic energy
A	$TE_A = TE_B$	$GPE_A > GPE_B$	$KE_A < KE_B$
B	$TE_A = TE_B$	$GPE_A < GPE_B$	$KE_A > KE_B$
C	$TE_A < TE_B$	$GPE_A > GPE_B$	$KE_A < KE_B$
D	$TE_A < TE_B$	$GPE_A < GPE_B$	$KE_A > KE_B$

12 A 150 g insulated pewter flask contains 100 g water at 30 °C. Ice cubes of mass 400 g at -40 °C is placed into the flask.

Given that
specific latent heat of fusion of water is 3.4×10^5 J kg^{-1}
specific latent heat of vaporization of water is 2.3×10^6 J kg^{-1}
specific heat capacity of water is 4.2×10^3 J kg^{-1} K^{-1}
specific heat capacity of ice is 2.1×10^3 J kg^{-1} K^{-1}
specific heat capacity of pewter is 170 J kg^{-1} K^{-1}

At the final equilibrium temperature, which of the following is correct?

A All water has formed ice.
B All ice has melted.
C Water and ice coexist at 0°C.
D Water and ice coexist at above 0°C.

13 What is the approximate number of atoms in a cubic metre of an ideal monatomic gas at the temperature of 27 °C and a pressure of 1×10^5 Pa?

A 1×10^{22} **B** 6×10^{23} **C** 2×10^{25} **D** 3×10^{26}

14 A fixed mass of monatomic ideal gas at a volume *V* at temperature *T* and pressure *P* has a root mean square speed of $\sqrt{\langle c^2 \rangle}$. After absorbing heat, its final volume is *V* and final pressure is 2*P.*

What is the new root mean square speed of the ideal gas?

A $0.50\sqrt{\langle c^2 \rangle}$ **B** $0.71\sqrt{\langle c^2 \rangle}$ **C** $1.4\sqrt{\langle c^2 \rangle}$ **D** $2.0\sqrt{\langle c^2 \rangle}$

15 Which of the following quantities will remain constant for a particle undergoing simple harmonic motion?

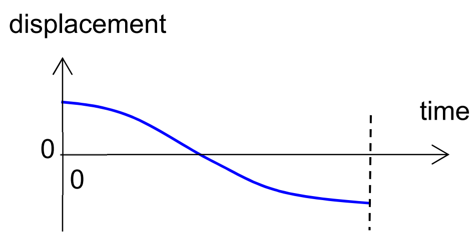
(i) amplitude
(ii) angular frequency
(iii) total energy

A (iii) only
B (i) and (iii) only
C (ii) and (iii) only
D (i), (ii) and (iii)

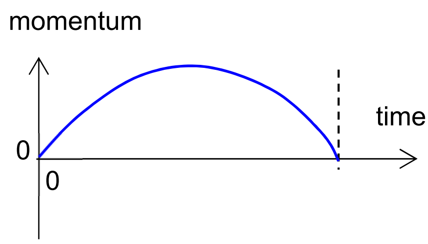
16 A body undergoes simple harmonic motion. The graphs below show the variation with time of displacement, kinetic energy, momentum and force during part of the motion.

Which one of the following graphs is not consistent with the others?

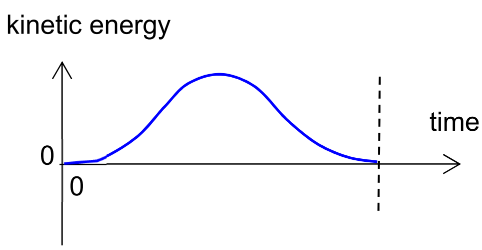
A



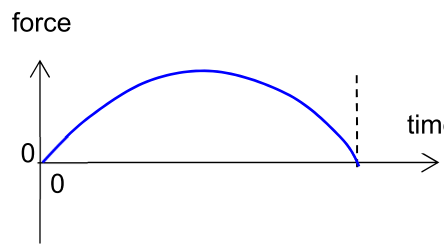
B



C



D



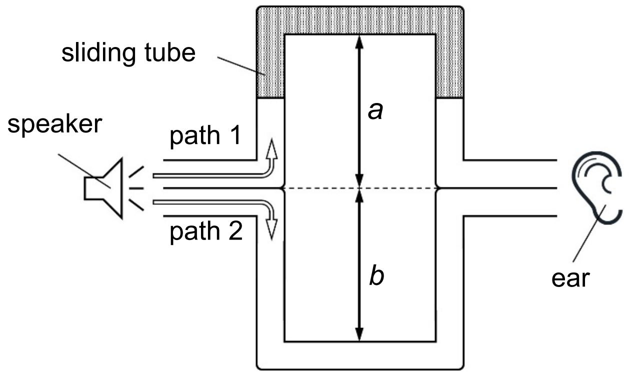
[Turn over

17 The intensity of a beam of light is nine times smaller than its initial intensity after passing through two polarisers.

What is the angle between the polarisation axes of the two polarisers if the initial beam of light is unpolarised?

A 35° **B** 41° **C** 62° **D** 71°

18 Sound energy produced by a speaker is divided equally when it enters into two paths through an arrangement of tubes as shown below.



The sound waves have wavelength λ and are detected by a listener's ear at the end of the paths. Initially, distances a and b are equal. The distance a can be increased by raising the sliding tube.

What is the increase in a when the ear first detects a minimum in the sound received?

A 0.25λ **B** 0.5λ **C** λ **D** 2λ

19 Three telescopes of different diameters are designed to observe an astronomical object at different wavelengths as shown below.

telescope	diameter / m	observation wavelength / nm
(i)	1.0	500
(ii)	2.0	100
(iii)	3.0	1000

Which of the following ranks the telescopes from the one with the worst resolution to the one with the best resolution?

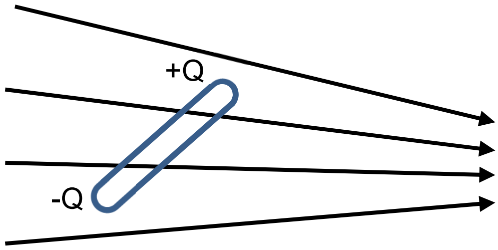
A (i), (ii), (iii)

B (i), (iii), (ii)

C (ii), (iii), (i)

D (iii), (ii), (i)

20 A wooden rod is charged with equal and opposite charges at its ends and placed in a non-uniform electric field as shown below.



Which statement best describes what the rod experiences?

A A resultant force to the left, and an anticlockwise moment.

B A resultant force to the left, and a clockwise moment.

C A resultant force to the right, and an anticlockwise moment.

D A resultant force to the right, and a clockwise moment.

21 Two electrons which are initially very far apart are projected towards each other at a speed of 2.0×10^{6} m s^{-1} each.

What is the minimum distance between the two electrons?

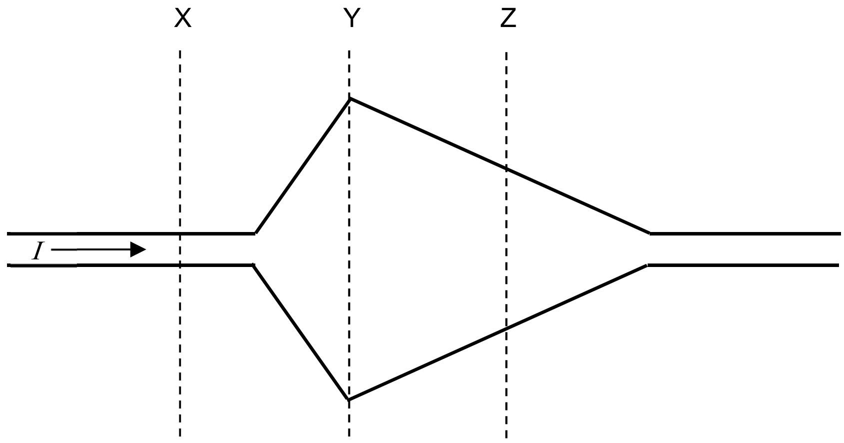
A 3.2×10^{-11} m

B 6.3×10^{-11} m

C 1.3×10^{-10} m

D 2.5×10^{-10} m

22 An electric current I flows through a flat metal specimen of uniform thickness and of the shape shown below.



Which of the following statements about the magnitude of the current I and drift velocity v at sections X, Y and Z is correct?

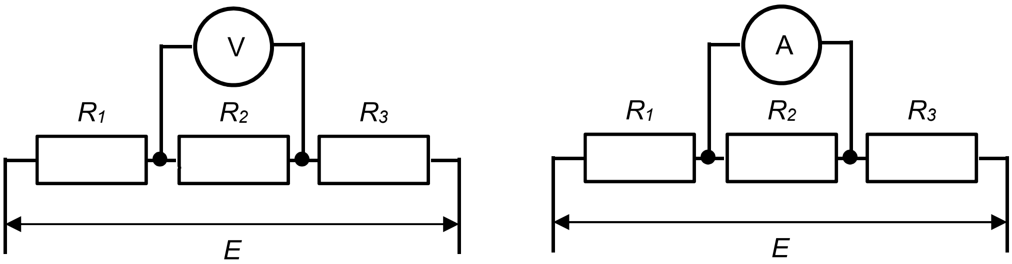
A $I_X = I_Y = I_Z$; $v_X > v_Z > v_Y$

B $I_X > I_Z = I_Y$; $v_X = v_Y = v_Z$

C $I_X = I_Y = I_Z$; $v_X = v_Y = v_Z$

D $I_X > I_Z > I_Y$; $v_X > v_Z > v_Y$

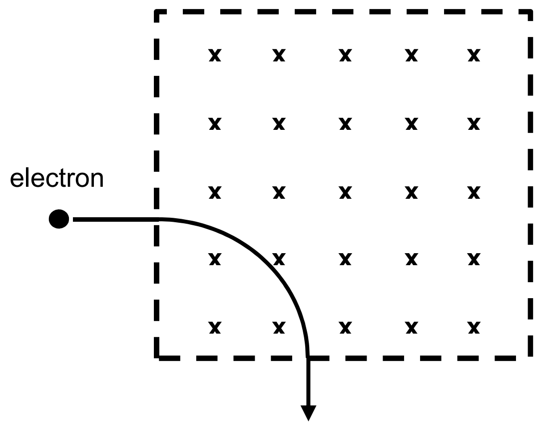
23 Three identical resistors of resistance 10 Ω are connected in series with a constant voltage supply *E*. The reading on an ideal voltmeter connected across R_2 is 5.0 V.



What will be the reading on an ideal ammeter if it is connected across R_2?

A 0.25 A **B** 0.50 A **C** 0.75 A **D** 1.5 A

24 An electron with speed 3.0×10^6 m s^{-1} moves through a magnetic field of magnetic flux density 2.0 mT perpendicular to its direction of motion. The electron turns through an angle of 90° along a circular path as shown.

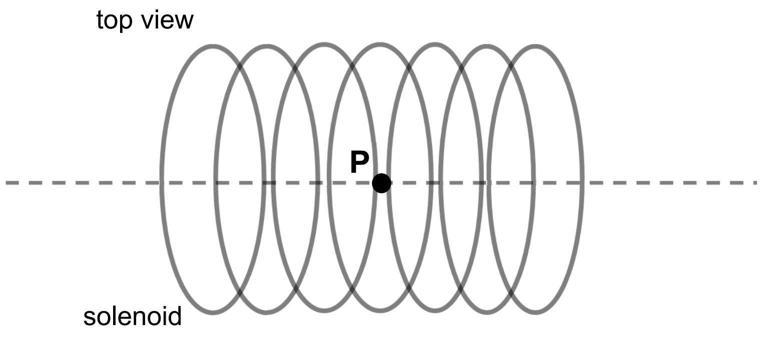


Which of the following statement/s is/are correct?

(i) The force on the electron is 9.6×10^{-16} N.
(ii) The gain in kinetic energy of the electron is zero.
(iii) The change in momentum of the electron is zero.

A (i) only
B (i) and (ii) only
C (i) and (iii) only
D (iii) only

25 A solenoid with 300 turns and a length of 20 cm is shown below. The diameter of the cross-section of the solenoid is 2.0 cm.

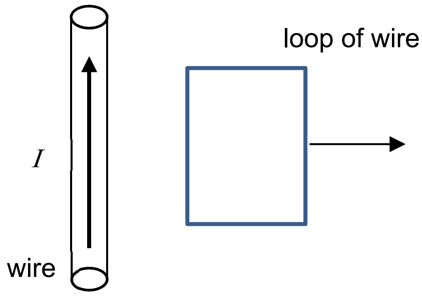


What is the magnetic flux density at point P on the axis of the solenoid when a current of 0.50 A is passed through the solenoid?

A 9.4×10^{-6} T **B** 1.9×10^{-4} T **C** 9.4×10^{-4} T **D** 9.4×10^{-3} T

[Turn over

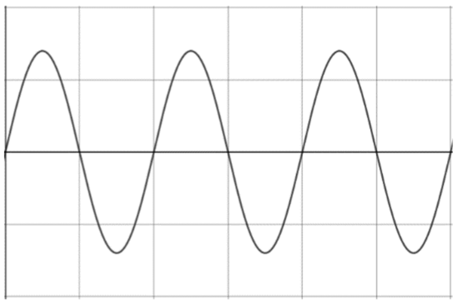
26 A rectangular loop of wire is held coplanar with a long wire carrying current I in the direction indicated below. The loop is then pulled to the right as shown.



What are the directions of the induced current in the loop and the net magnetic force on the loop as it is being pulled?

	induced current	**net magnetic force**
A	anticlockwise	to the left
B	clockwise	to the left
C	anticlockwise	to the right
D	clockwise	to the right

27 An alternating voltage is applied across the Y-plates of a cathode-ray oscilloscope (c.r.o.) and produces the trace as shown below.



Scale: 1 div = 1 cm

If the peak voltage of the alternating voltage is 2.8 V and its frequency is 50 Hz, what are the time-base and Y-gain settings of the c.r.o.?

	time-base	**Y-gain**
A	10 μs cm^{-1}	2.0 V cm^{-1}
B	20 μs cm^{-1}	1.0 V cm^{-1}
C	10 ms cm^{-1}	2.0 V cm^{-1}
D	20 ms cm^{-1}	1.0 V cm^{-1}

28 The minimum intensity of light that the human eye can detect is 2.0×10^{-11} W m^{-2}.

Given that the pupil of the eye has a diameter of 4 mm, how many photons per second of wavelength 550 nm must enter the eye for a distant star to be visible?

A 695 **B** 2780 **C** 1.26×10^9 **D** 5.10×10^9

29 A very slow moving electron has a kinetic energy E and de Broglie wavelength λ.

If the electron's kinetic energy is $4E$, what is its corresponding de Broglie wavelength?

A $\frac{\lambda}{4}$ **B** $\frac{\lambda}{2}$ **C** 2λ **D** 4λ

30 A beam of electrons with a speed 10^6 m s^{-1} is directed towards an aperture of diameter of 10^{-10} m. Due to the Heisenberg uncertainty principle, the transmitted electrons are observed to diffract within 1 m diameter on the screen.

What is the order of magnitude of the distance between the aperture and the screen?

A 10^{-2} m **B** 10^{-1} m **C** 10^0 m **D** 10^1 m

End of Paper

Anglo-Chinese Junior College
Physics Preliminary Examination
Higher 2

A Methodist Institution
(Founded 1886)

CANDIDATE NAME		CLASS	
CENTRE NUMBER	S 3 0 0 4	INDEX NUMBER	

PHYSICS **9749/02**

Paper 2 Structured Questions

27 August 2020

2 hours

Candidates answer on the Question Paper.
No Additional Materials are required

READ THESE INSTRUCTIONS FIRST

Write your Name, Class and Index number in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Answer **all** questions.

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.

For Examiners' use only	
1	/ 8
2	/ 12
3	/ 10
4	/ 14
5	/ 16
6	/ 20
Total	/ 80

DATA AND FORMULAE

Data

speed of light in free space,	c	=	3.00×10^{8} m s^{-1}
permeability of free space,	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_o	=	8.85×10^{-12} F m^{-1}
			$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	e	=	1.60×10^{-19} C
the Planck constant,	h	=	6.63×10^{-34} J s
unified atomic mass constant,	u	=	1.66×10^{-27} kg
rest mass of electron,	m_e	=	9.11×10^{-31} kg
rest mass of proton,	m_p	=	1.67×10^{-27} kg
molar gas constant,	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant,	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant,	k	=	1.38×10^{-23} J K^{-1}
gravitational constant,	G	=	6.67×10^{-11} N m^{2} kg^{-2}
acceleration of free fall,	g	=	9.81 m s^{-2}

For Examiner's Use

Formulae

uniformly accelerated motion,	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas,	W	=	$p \Delta V$
hydrostatic pressure,	p	=	$\rho g h$
gravitational potential,	ϕ	=	$-\frac{Gm}{r}$
temperature	T / K	=	T / °C + 273.15
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of of an ideal gas molecule,	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.,	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.,	v	=	$v_o \cos \omega t$
		=	$\pm \omega \sqrt{x_o^2 - x^2}$
electric current	I	=	$A n v q$
resistors in series,	R	=	$R_1 + R_2 + \ldots$
resistors in parallel,	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential,	V	=	$\frac{Q}{4\pi\varepsilon_o r}$
alternating current/voltage,	x	=	$x_o \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\frac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\frac{\mu_o N I}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_o n I$
radioactive decay,	x	=	$x_o \exp(-\lambda t)$
decay constant,	λ	=	$\frac{\ln 2}{t_{1/2}}$

[Turn over

For Examiner's Use

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

1 An experiment is performed to determine the period of an oscillating system. It involves two objects connected by a light spring sliding on a smooth surface as shown in Fig. 1.1. The two objects are pushed towards the spring before being released to start the oscillation.

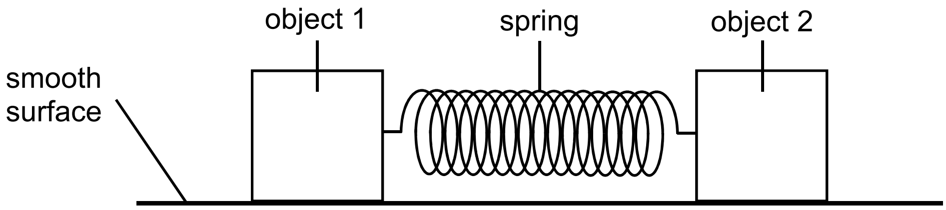


Fig. 1.1

The following equation describes the period of the oscillation, T .

$$T = 2\pi\sqrt{\frac{m_1 m_2}{k\left(m_1 + m_2\right)}}$$

where

mass of object 1, $m_1 = (500 \pm 1)$ g ,

mass of object 2, $m_2 = (1167 \pm 1)$ g , and

spring constant, $k = (8.0 \pm 0.2)$ N m^{-1}.

(a) **(i)** State the absolute uncertainty of $m_1 + m_2$.

absolute uncertainty = ……………………… g [1]

(ii) Hence, or otherwise, determine the percentage uncertainty of T.

percentage uncertainty = ……………………… % [3]

For Examiner's Use

(b) A student plans to measure the total time for 20 oscillations before calculating the average time for one oscillation. The total time recorded on the stopwatch is 26.30 s and the uncertainty in the measurement is estimated to be ± 0.4 s.

(i) Explain, with calculations, the advantage of calculating the average time from 20 oscillations instead of measuring the time for one oscillation.

……………………………………………………………………………………………

……………………………………………………………………………………………

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

(ii) In reality, the student mistook the time for half an oscillation to be one period.

State the percentage error in the measurement of the period due to this mistake.

percentage error = ……………………… % [1]

(iii) Explain whether calculating the average time from the total time taken for multiple oscillations will reduce the error committed in **(b)(ii)**.

……………………………………………………………………………………………

……………………………………………………………………………………………

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

[Turn over

For Examiner's Use

2 **(a)** An object of mass 1.5 kg is released vertically downwards from a stationary hot air balloon in mid air. Fig. 2.1 shows how the velocity of the object varies with time.

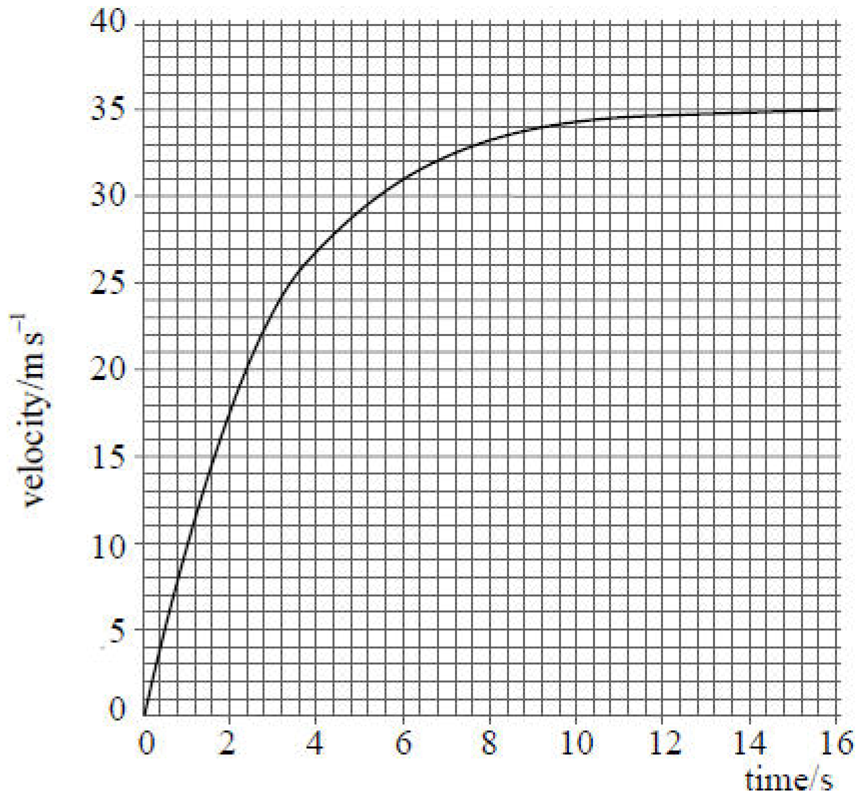


Fig. 2.1

(i) Define *acceleration*.

……………………………………………………………………………………………

…………………………………………………………………………………………… [1]

(ii) Using Fig. 2.1, explain how the acceleration of the object changes with time.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

…………………………………………………………………………………………… [2]

For Examiner's Use

(iii) Determine the magnitude of the viscous force acting on the object at time = 5.0 s.

viscous force = ……………………… N [3]

(b) Fig. 2.2 shows two blocks A and B of mass 3.0 kg and 4.0 kg respectively connected by a light inextensible cord passing over a light frictionless pulley. When both blocks are released, block A starts to move from rest along a smooth plane inclined at 40° to the horizontal while block B starts to move from rest along a smooth plane inclined at 20° to the horizontal.

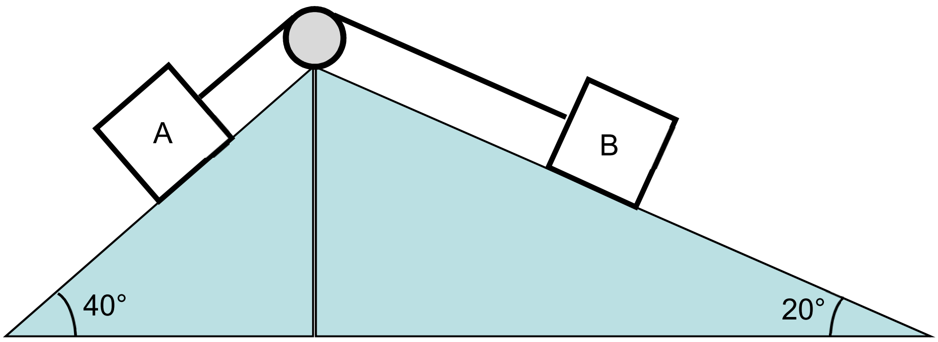


Fig. 2.2 (not to scale)

(i) Calculate the magnitude of the acceleration of the two blocks when the blocks are released and the tension in the cord.

acceleration = ……………………… m s^{-2} [2]

tension = ……………………… N [1]

[Turn over

For Examiner's Use

(ii) If both planes in contact with blocks A and B are rough and the total frictional force between the surfaces in contact is 4.0 N, determine the speed of block A when it has moved 2.0 m along the plane from rest.

speed of block A = ……………………… m s^{-1} [3]

For Examiner's Use

3 **(a)** Define *angular velocity* for an object travelling in a circle.

....

.... [1]

(b) A smooth hollow sphere of radius 20.0 cm rotates steadily about its vertical axis with a period of 0.75 s as shown in Fig. 3.1. A bead is encased in the sphere and is able to slide while in contact with the inner surface of the sphere.

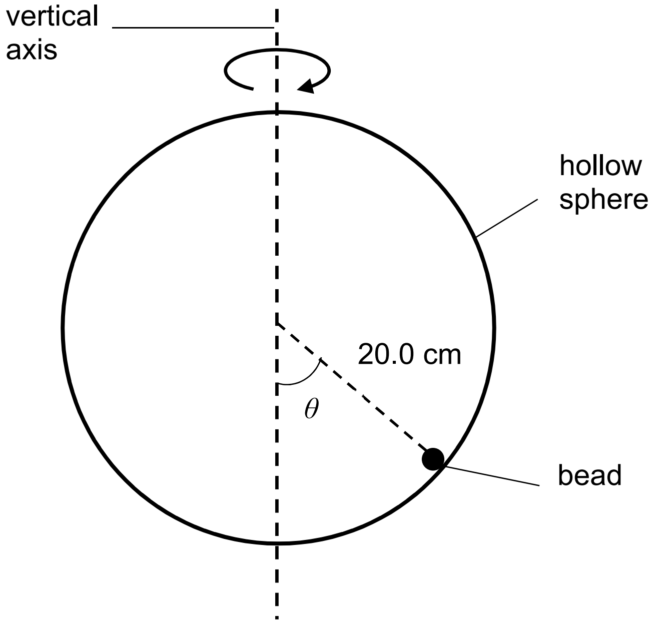


Fig. 3.1

There are two possible positions that the bead can remain in position when the sphere is rotating. One position is when the bead is at the bottom of the sphere and the other is when the bead is at an angle θ relative to the vertical axis as shown in Fig. 3.1.

(i) By considering the forces on the bead, calculate the value of θ.

θ = ...° [3]

[Turn over

For Examiner's Use

(ii) Explain why the value of θ increases when the sphere is rotating at a faster rate.

……………………………………………………………………………………………

……………………………………………………………………………………………

…………………………………………………………………………………… [1]

(c) A satellite of mass 6200 kg at point X is orbiting about the Sun together with the Earth as shown in Fig. 3.2. The satellite, the Earth and the Sun are in line with each other at all times.

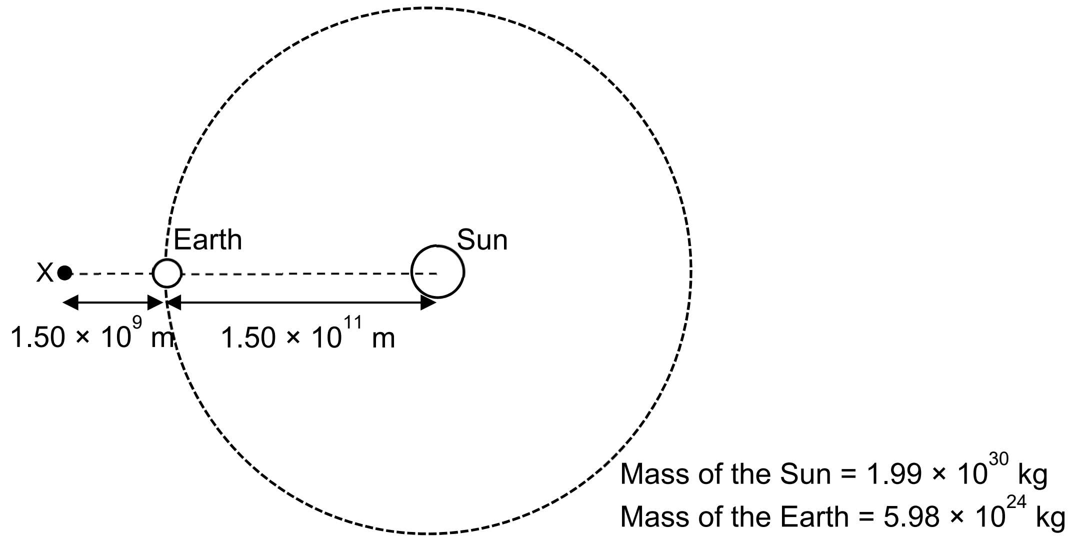


Fig. 3.2 (not to scale)

(i) Calculate the resultant force acting on the satellite due to the Sun and the Earth.

resultant force = ……………………… N [3]

For Examiner's Use

(ii) Hence, calculate the angular velocity of the satellite.

angular velocity = ……………………… rad s^{-1} [2]

[Turn over

For Examiner's Use

4 (a) A light-dependent resistor (LDR) with power rating 0.50 W is placed in parallel with a 600 Ω resistor and connected to a 12.0 V cell of internal resistance 30 Ω, as shown in Fig. 4.1.

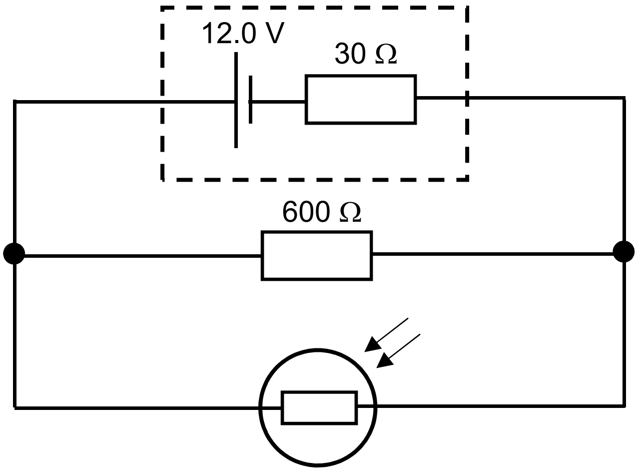


Fig. 4.1

(i) In conditions of low intensity light, the resistance of the LDR is 3000 Ω.

1. Show that the current through the LDR is 3.8 mA.

[2]

2. Hence or otherwise, determine the power dissipated in the LDR.

power = ……………………… W [2]

(ii) Accidentally, the LDR is exposed to sunlight and its resistance falls to 100 Ω. Discuss whether the LDR, which is marked 0.50 W, will be damaged.

....

....

.... [2]

(iii) The circuit in Fig. 4.1 is used to turn on a light bulb in conditions of low intensity light.

Draw on Fig. 4.1 where the light bulb should be placed in the circuit. Explain your answer.

....

....

....

.... [2]

(b) Fig. 4.2 below shows a simplified structure of a silicon solar cell. When sunlight is incident on the top surface of the cell, loosely bound electrons are liberated, generating current flow to the external circuit.

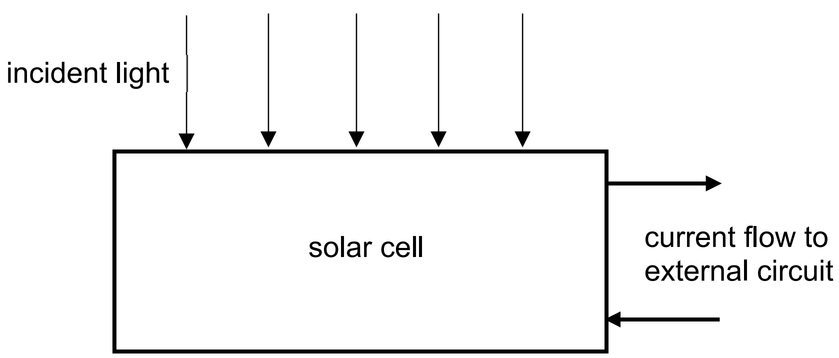


Fig. 4.2

For Examiner's Use

Fig. 4.3 shows the variation with terminal p.d. across the cell of output current for one such solar cell with sunlight of power 90 mW incident on it.

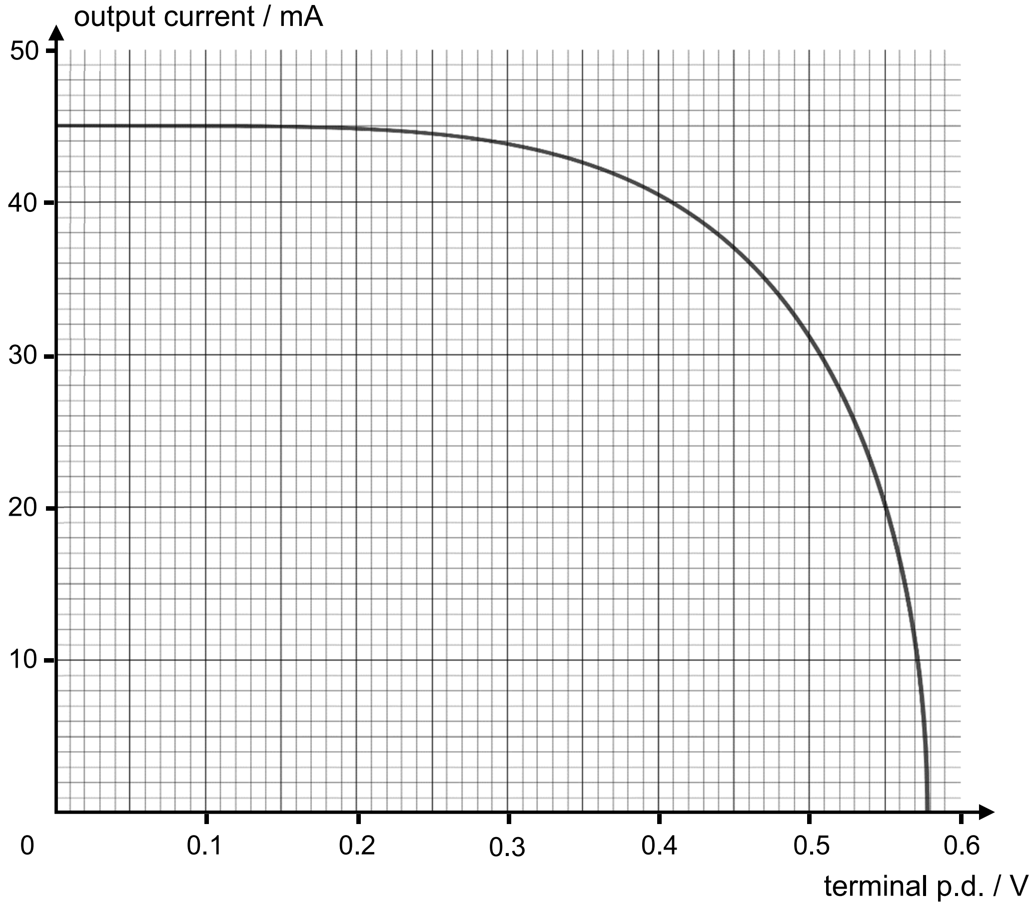


Fig. 4.3

(i) Draw a labelled diagram of an electrical circuit which could be used to obtain the graph in Fig. 4.3.

[2]

For Examiner's Use

(ii) For the incident power of 90 mW, calculate

1. the e.m.f. of the solar cell *E*,

E = ……………………… V [1]

2. the resistance of the external circuit *R* when the output current is 20 mA,

R = ……………………… Ω [1]

3. the internal resistance of the cell *r* when the output current is 20 mA.

r = ……………………… Ω [2]

For Examiner's Use

5 (a) (i) A progressive wave of frequency f and wavelength λ has speed v.

Using the definitions for speed, frequency and wavelength, deduce the equation $v = f\lambda$.

[2]

(ii) The speed of sound in air at $20°C$ is 344 m s^{-1}.

Determine the wavelength of a 262 Hz sound wave travelling in air at $20°C$.

wavelength = ……………………… m [1]

(iii) The sound wave in **(a)(ii)** travels from the left to the right and has an amplitude of 44 nm.

On Fig. 5.1, sketch the variation with distance x of the displacement of the air molecules y over two cycles if $x = 0$ m is the centre of a region of compression and the displacement to the right is taken to be positive.

Fig. 5.1

[1]

For Examiner's Use

(b) Stationary waves can be produced by the superposition of progressive waves when a guitar string is plucked.

(i) State the *principle of superposition*.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

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

(ii) The guitar string can be shortened to produce different musical notes by pressing a finger at a distance d from the near end as shown in Fig. 5.2.

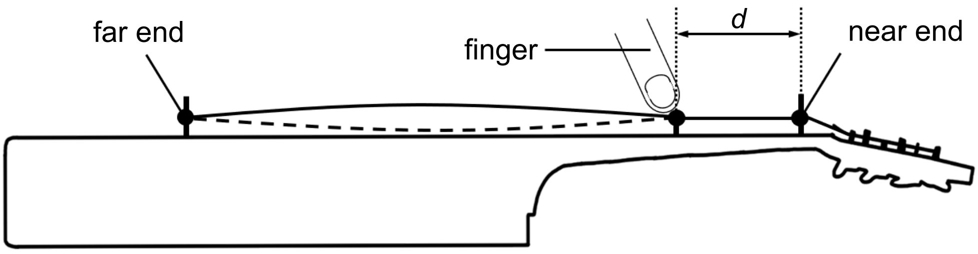


Fig. 5.2

Assuming that the speed of the wave remains constant at 425 m s^{-1}, calculate the change in d when a guitarist changes from playing a note with a fundamental frequency of 247 Hz to a note with a fundamental frequency of 262 Hz.

change in d = ……………………… m [3]

[Turn over

For Examiner's Use

(c) (i) Explain the meaning of the term *diffraction*.

……………………………………………………………………………………………

……………………………………………………………………………………………

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

(ii) Laser light is incident normally on a grating with three slits, as illustrated in Fig. 5.3.

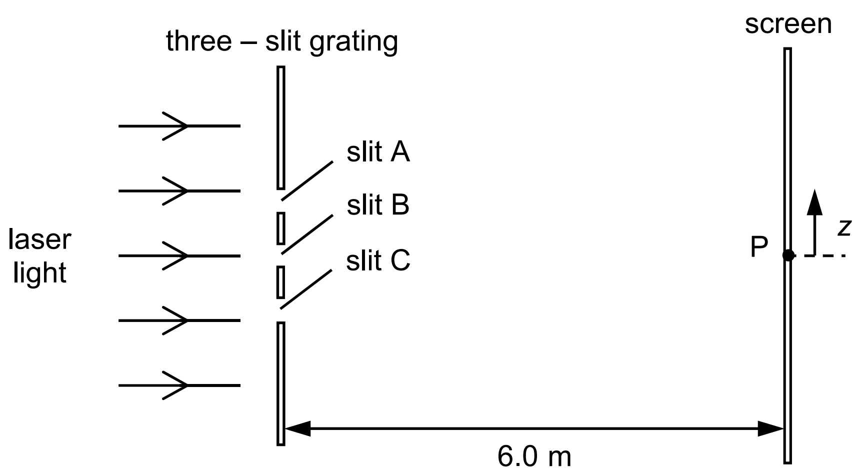


Fig. 5.3 (not to scale)

The three slits are rectangular with equal widths. A screen is placed parallel to the plane of the grating at a distance of 6.0 m from the grating.

The centre of the interference pattern formed on the screen is at P.

Describe the changes to the first order bright fringes when the number of slits per unit length of the grating increases.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

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

(iii) Fig. 5.4 shows the variation with displacement z from point P of the intensity I of the light on the screen in Fig. 5.3 when only slit B is covered. On the other hand, Fig. 5.5 shows this variation when only slits A and C are covered.

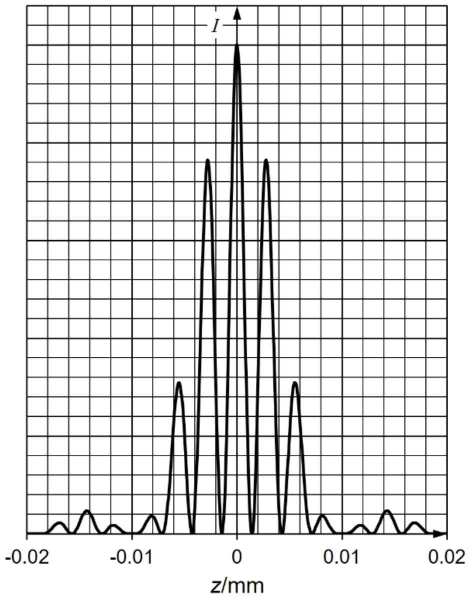


Fig. 5.4

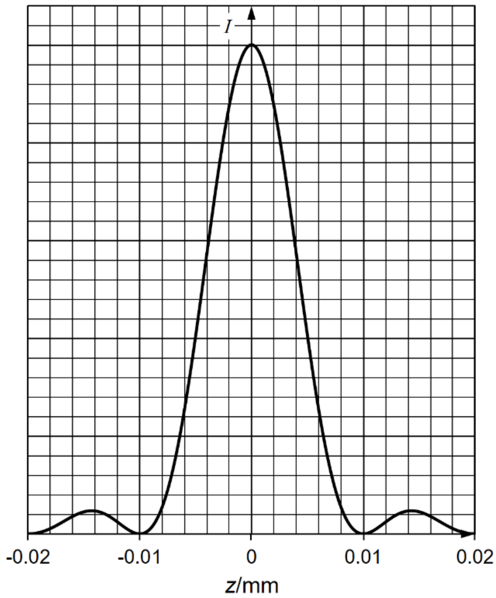


Fig. 5.5

Determine the ratio,

$$\frac{\text{separation between slits A and C}}{\text{width of one slit}}.$$

ratio = ……………………… [3]

(iv) Only slits A and B are now covered.

State the width of the central bright maximum produced by diffraction through slit C.

width = ……………………… mm [1]

For Examiner's Use

6 Read the following passages and answer the questions that follow.

Earth's Atmosphere

The Earth's atmosphere is a thin gaseous envelope that surrounds our planet and its presence contribute to the greenhouse effect which sustains life on Earth.

Warming the Earth begins with the Sun which has a radius of 6.96×10^5 km. With a temperature of about 5778 K, the Sun emits electromagnetic waves known as thermal radiation that travels an average distance of 1.5×10^8 km to reach the Earth as shown in Fig. 6.1. The solar power per unit area that reaches the Earth is known as the solar constant S_0. Incoming solar radiation emits mainly in the visible light wavelengths.

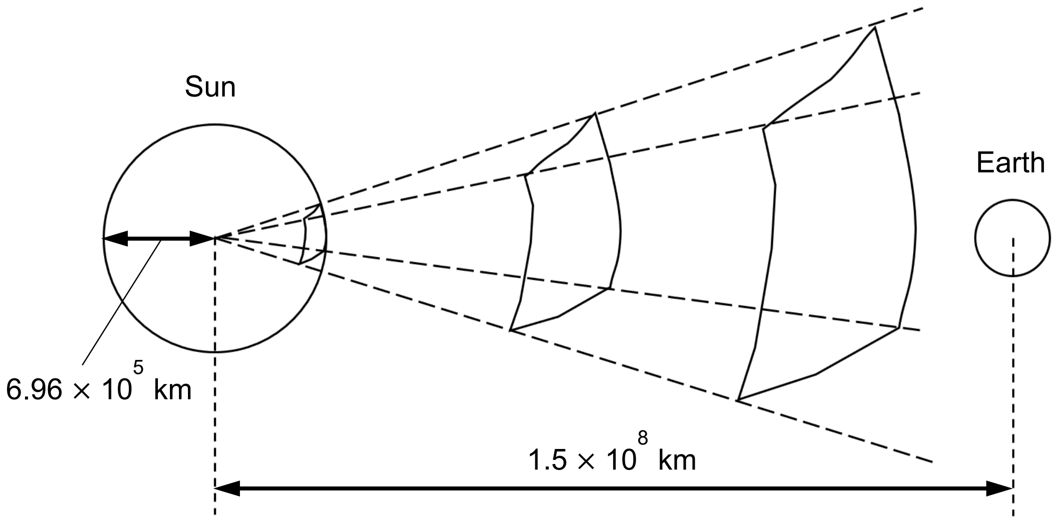


Fig. 6.1

In general, an object with temperature T emits thermal radiation of power per unit area, I. T and I are related by the following equation:

$$I = \varepsilon \sigma T^4$$

where ε is the emissivity of the object and σ is the Stefan-Boltzmann constant 5.67×10^{-8} W m^{-2} K^{-4}. The emissivity quantifies the effectiveness of the object in emitting thermal radiation and it ranges between zero and one. The emissivity of the Sun is one.

When incoming solar radiation reaches the atmosphere, the subsequent exchanges of thermal radiation can be analysed in three phases using a single-layer atmosphere model as shown in Fig. 6.2.

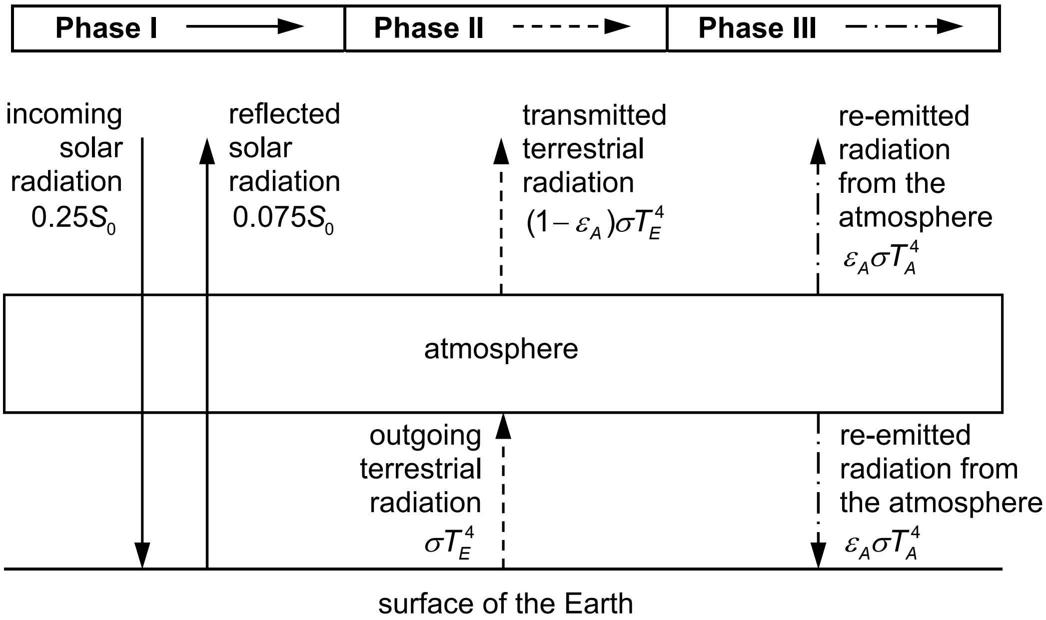


Fig. 6.2

In Phase I, the incoming solar power per unit area averaged over the surface of the Earth enters the atmosphere. Some of the incoming solar radiation is reflected by surfaces in the Earth-atmosphere system. The remaining solar radiation is absorbed by the Earth's surface as the atmosphere is assumed to be transparent to solar radiation.

In Phase II, the surface of the Earth of temperature T_E emits thermal radiation mainly in the infra-red wavelengths. Some of the outgoing terrestrial radiation is absorbed by the atmosphere. In Phase III, the atmosphere of temperature T_A and emissivity ε_A re-emits radiation in all directions. The emissivity of the atmosphere is 0.8.

The percentage absorption of thermal radiation for major natural greenhouse gases in the Earth's atmosphere is shown in Fig. 6.3.

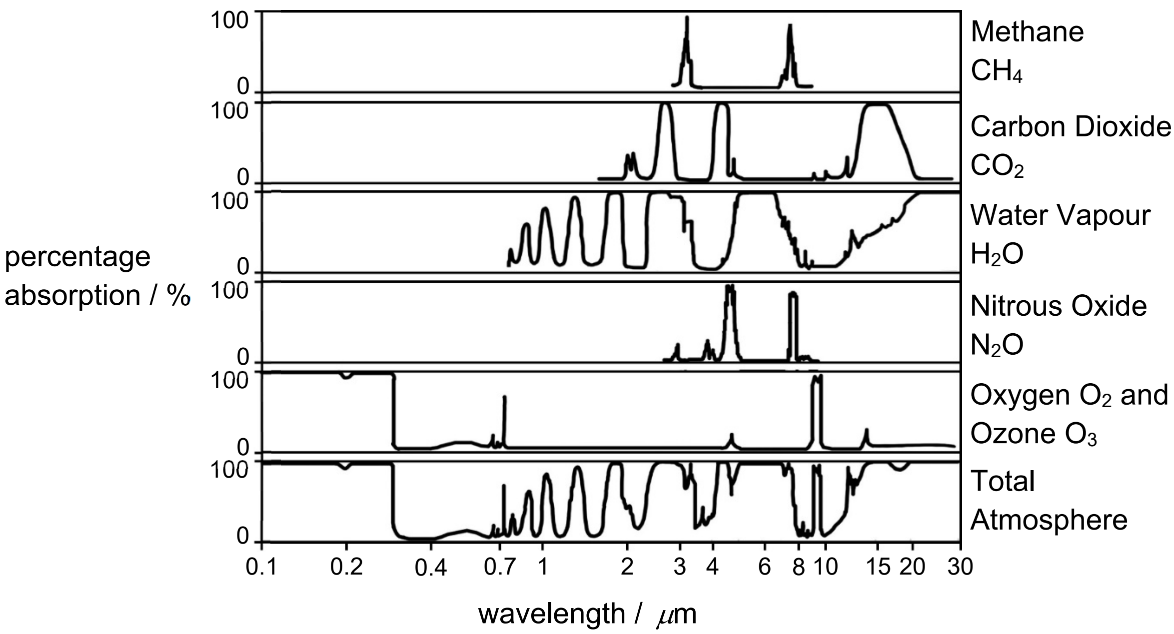


Fig. 6.3

For Examiner's Use

(a) **(i)** Determine the power of the thermal radiation produced by the Sun.

power = ……………………… W [2]

(ii) Assuming that the Sun emits as a point source, show that the solar constant S_0 is 1360 W m^{-2}.

[1]

(b) With reference to the wavelengths of visible light, explain why in the single-layer atmosphere model, it is reasonable to assume that the atmosphere is transparent to solar radiation.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

……………………………………………………………………………………………… [2]

For Examiner's Use

(c) In thermal equilibrium, the absorbed radiation is equal to the emitted radiation. Hence, at the surface of the Earth, the radiative balance equation is given by

$$\left(0.25-0.075\right)S_0+\varepsilon_A\sigma T_A^4=\sigma T_E^4.$$

(i) With reference to Fig. 6.2, show that the equation that represents the radiative balance at the atmosphere reduces to

$$T_E^4=2T_A^4.$$

[1]

(ii) Hence, determine the temperature of the surface of the Earth.

temperature = ……………………… K [2]

(d) With reference to the wavelengths of infra-red radiation, explain why an increase in the concentration of carbon dioxide in the atmosphere leads to global warming.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

…………………………………………………………………………………………… [2]

[Turn over

For Examiner's Use

When an air parcel near the surface of the Earth is heated, its density decreases to become less than the density of the surrounding air. This causes it to rise upwards as shown in Fig. 6.4.

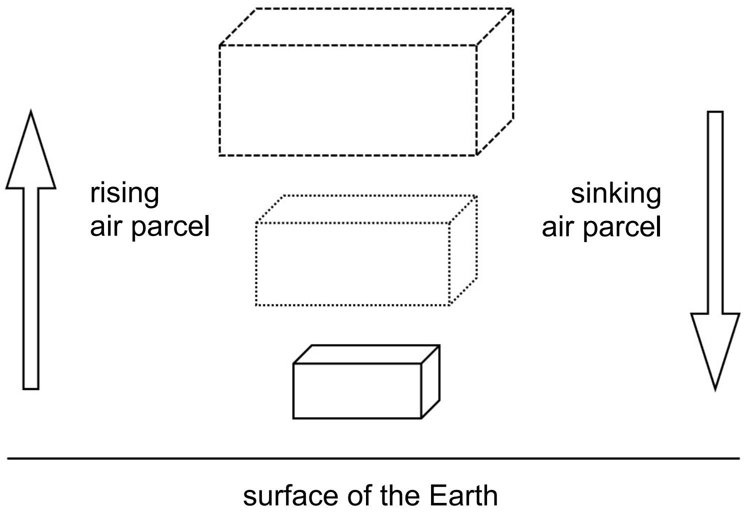


Fig. 6.4

The rate of decrease of temperature T with respect to altitude z for an air parcel moving vertically in the atmosphere is known as the adiabatic lapse rate L and is given by the following equation:

$$L = -\frac{dT}{dz}.$$

In reality, the atmosphere is divided into different layers. The lowest layer is known as the troposphere and extends from the surface of the Earth to an altitude of 16 km. In the troposphere, temperature decreases with increasing altitude as represented by the line drawn in Fig. 6.5. The data points representing the variation with temperature of altitude for an air parcel are also plotted in Fig. 6.5.

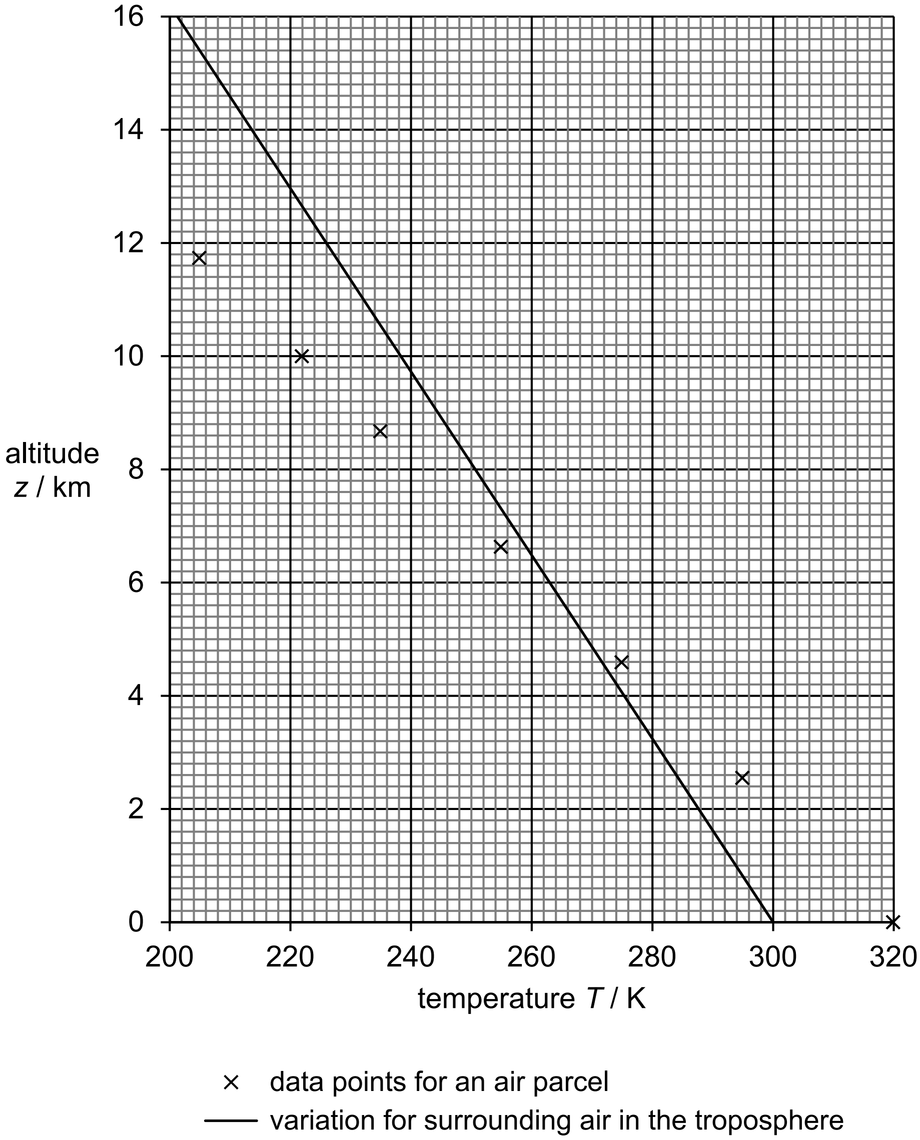


Fig. 6.5

(e) **(i)** Complete Fig. 6.5 by drawing the line of best fit for the variation with temperature of altitude for the air parcel. [1]

(ii) Determine the adiabatic lapse rate for the air parcel.

adiabatic lapse rate = ……………………… K km^{-1} [2]

[Turn over

For Examiner's Use

(iii) When the air parcel rises, thermal energy from the particles in the air parcel is used to do work against gravitational force.

Use your answer in **(e)(ii)** to determine the specific heat capacity of the air parcel.

specific heat capacity = ……………………… J kg^{-1} K^{-1} [3]

(f) **(i)** The line drawn in **(e)(i)** intersects the variation with temperature of altitude for the surrounding air in the troposphere at the altititude z_0.

State the value of z_0.

z_0 = ……………………… km [1]

(ii) An air parcel initially at z_0 is being lifted upwards as it passes a mountain.

Use Fig. 6.5 to explain why the air parcel will subsequently oscillate about z_0 .

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………..…..... [3]

End of Paper

Anglo-Chinese Junior College

Physics Preliminary Examination
Higher 2

A Methodist Institution
(Founded 1886)

CANDIDATE NAME		CLASS	

CENTRE NUMBER	S	3	0	0	4	INDEX NUMBER	

PHYSICS **9749/03**

Paper 3 Longer Structured Questions

2 September 2020

2 hours

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your Name, Class and Index number in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Section A
Answer **all** questions.

Section B
Answer **one** question only.

You are advised to spend one and a half hours on Section A and half an hour on Section B.

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.

For Examiners' use only	
Section A	
1	/ 8
2	/ 13
3	/ 14
4	/ 12
5	/ 13
Total	/ 60
Section B	
6	/ 20
7	/ 20
Grand Total	/ 80

DATA AND FORMULAE

Data

speed of light in free space,	c	=	3.00×10^{8} m s^{-1}
permeability of free space,	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_o	=	8.85×10^{-12} F m^{-1}
			$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	e	=	1.60×10^{-19} C
the Planck constant,	h	=	6.63×10^{-34} J s
unified atomic mass constant,	u	=	1.66×10^{-27} kg
rest mass of electron,	m_e	=	9.11×10^{-31} kg
rest mass of proton,	m_p	=	1.67×10^{-27} kg
molar gas constant,	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant,	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant,	k	=	1.38×10^{-23} J K^{-1}
gravitational constant,	G	=	6.67×10^{-11} N m^{2} kg^{-2}
acceleration of free fall,	g	=	9.81 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	=	$p\,\Delta V$
hydrostatic pressure,	p	=	$\rho g h$
gravitational potential,	ϕ	=	$-\frac{Gm}{r}$
temperature	T / K	=	T / °C + 273.15
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of of an ideal gas molecule,	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.,	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.,	v	=	$v_o \cos \omega t$
		=	$\pm\,\omega\sqrt{x_o^2 - x^2}$
electric current	I	=	$A\,n\,v\,q$
resistors in series,	R	=	$R_1 + R_2 + \ldots$
resistors in parallel,	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential,	V	=	$\frac{Q}{4\pi\varepsilon_o r}$
alternating current/voltage,	x	=	$x_o \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\frac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\frac{\mu_o N I}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_o n I$
radioactive decay,	x	=	$x_o \exp(-\lambda t)$
decay constant,	λ	=	$\frac{\ln 2}{t_{1/2}}$

[Turn over

Section A

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

1 A street lamp is pulled by a truck using a cable as shown in Fig. 1.1 below.

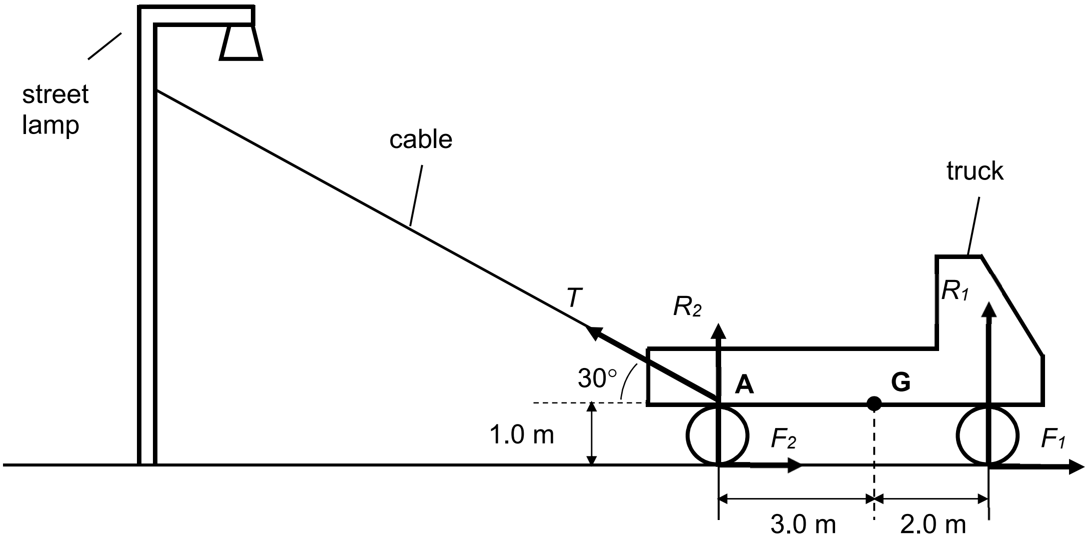


Fig. 1.1 (not to scale)

G is the centre of gravity of the truck which is 1.0 m above the ground. The cable is tied to a point **A** which is the same height as **G** and directly above the rear wheel. The truck is in equilibrium and the cable is in tension. The weight W of the truck is 20000 N and the tension T in the cable is 7000 N.

(a) Explain what is meant by the *centre of gravity* of the truck.

....

....

.... [1]

For Examiner's Use

(b) Describe the nature of forces F_1 and F_2 and suggest how they might arise.

…………………………………………………………………………………………………..

…………………………………………………………………………………………………..

…………………………………………………………………………………………………..

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

(c) Determine the normal contact force exerted by the ground on the rear wheels R_2.

R_2 = ………………………….. N [3]

(d) Hence, find the normal contact force exerted by the ground on the front wheels R_1.

R_1 = ………………………….. N [2]

For Examiner's Use

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

………………………………………………………………………………………………..

………………………………………………………………………………………………..

……………………………………………………………………………………………… [1]

(b) A magician demonstrates that the beaker <u>can remain at the position shown</u> despite its weight, when he pushes the block with a force *F* on a smooth horizontal surface as shown in Fig. 2.1. The masses of the beaker and the block are 0.10 kg and 2.00 kg respectively.

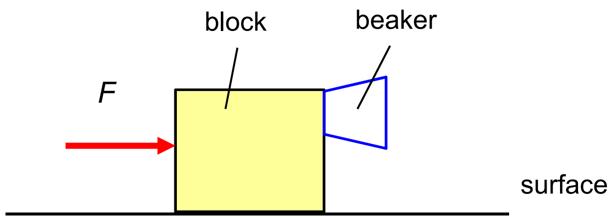
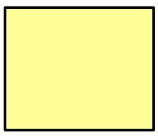


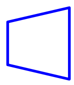
Fig. 2.1 (not to scale)

(i) Draw the free-body diagrams of the

1. block



2. beaker



[4]

For Examiner's Use

(ii) The relationship between the frictional force f and normal contact force N on the beaker by the block is given by the expression,

$$f = \mu N,$$

where the coefficient of static friction between block and beaker, μ is 0.40.

Show that the minimum acceleration of the beaker is 24.6 m s^{-2} for the beaker to remain in the position shown in Fig. 2.1.

[3]

For Examiner's Use

(iii) The system is released on a smooth slope at an angle 50° from the horizontal.

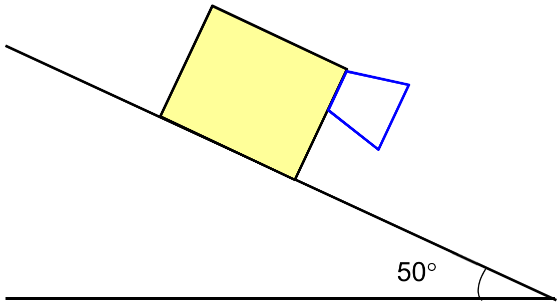


Fig. 2.2 (not to scale)

1. Determine the normal contact force on the beaker for it to remain in the position shown in Fig. 2.2.

normal contact force = ………………………….. N [2]

2. Comment if the beaker is able to remain in the position as it moves down the slope in Fig. 2.2. Show calculations to support your comments.

……………………………………………………………………………..

……………………………………………..……………………………

…………………………………………………………….………… [3]

For Examiner's Use

3 **(a)** Define *electric potential* at a point.

....

....

....[2]

(b) Two long parallel positively charged plates are placed a distance 5.0 cm apart. A conducting plate of width 1.5 cm is placed a distance 1.0 cm from the left plate as shown in Fig. 3.1.

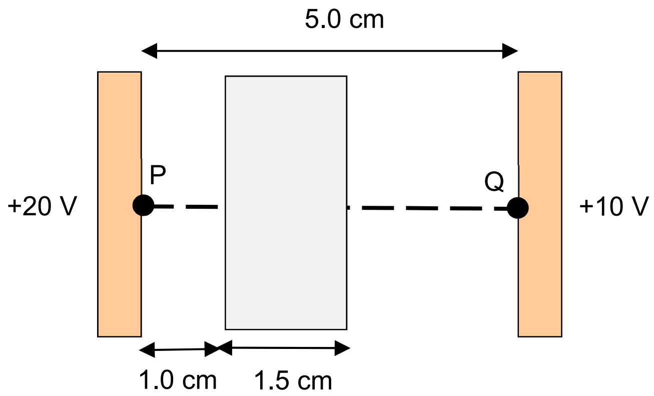


Fig. 3.1

(i) Sketch a fully labelled graph on the axes provided to show the variation with distance *x* of the electric potential *V* from P to Q.

[2]

(ii) Hence, sketch a fully labelled graph on the axes provided to show the variation with distance *x* of the electric field strength *E* from P to Q

[2]

For Examiner's Use

(c) A charged conducting spherical balloon is attached to a valve and is connected to the Earth through a resistor as shown in Fig. 3.2. The balloon is discharging through the resistor and losing gas through the valve. The valve is continuously adjusted so that the current in the resistor is kept constant.

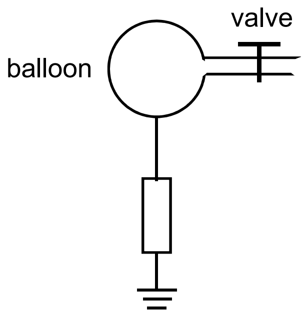


Fig. 3.2

The resistor has a value of 5.0 Ω and the balloon has an initial charge of 1.5×10^{-11} C on its surface and a radius of 2.5 cm.

(i) Show that the constant current *I* through the resistor is 1.08 A.

[2]

(ii) Explain why the rate of decrease of the balloon's radius is directly proportional to the rate of decrease in the balloon's charge for a constant current to flow through the resistor.

…………………………………………………………………………………………..

…………………………………………………………………………………………..

…………………………………………………………………………………………..

…………………………………………………………………………………………[2]

For Examiner's Use

(iii) Show that the rate of decrease of the balloon's radius R_{radius} and constant current I is given by the following expression,

$$R_{radius} = 1.7 \times 10^{9} I .$$

[1]

(iv) Determine the time taken for the balloon to lose all its charge.

time taken = ……………………… s [1]

(v) The balloon can be considered to be fully deflated when its radius is 0.5 cm.

By calculating the time it takes for the radius of the balloon to reach 0.5 cm, determine if the balloon would lose all its charge first or be fully deflated first.

[2]

For Examiner's Use

4 **(a)** State what is meant by *internal energy of an ideal gas.*

....

....

.... [1]

(b) The variation of pressure with volume for an ideal gas is as shown in Fig. 4.1 below.

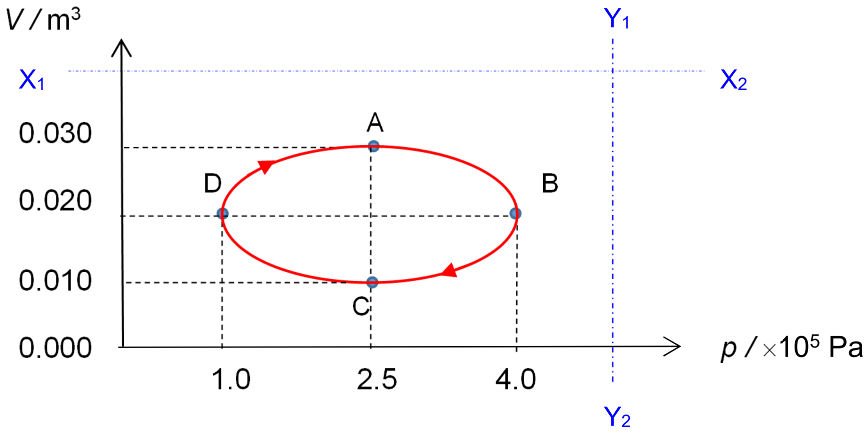


Fig. 4.1

(i) The temperatures T_A , T_B , T_C and T_D at states A, B, C and D respectively are as follows

$$T_D < T_C < T_A < T_B.$$

Show that the relationship between the temperatures is as stated above.

[2]

For Examiner's Use

(ii) Sketch the four isotherms that pass through states A, B, C and D. Each isotherm must extend to touch lines X_1X_2 and Y_1Y_2. [1]

(iii) Explain why there is no change in internal energy of the gas after one complete cycle from A → B → C → D → A.

....

....

.... [1]

(iv) The *first law of thermodynamics* may be expressed in the form

$$+\Delta U = (+q) + (+w).$$

Hence, complete the table in Fig. 4.2 with '+' and '–'.

Process	$+\Delta U$	$+q$	$+w$
A → B		–	
B → C			+
C → D		+	
D → A			–
After one complete cycle	0		

Fig. 4.2

[3]

For Examiner's Use

(v) Determine the net heat gain after one complete cycle.

Hint: Area of an ellipse, $A = \pi ab$

where *a* and *b* are the large and small radii respectively.

net heat gain = …………………………….... J [2]

(c) A relationship between the average translational kinetic energy and thermal energy is given by the expression

$$\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT.$$

Explain if the above expression is applicable to the ideal gas in **(b)**.

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

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

For Examiner's Use

5 A helium balloon is attached to a toy of mass m, and a string of mass per unit length μ hangs under the toy as shown in Fig. 5.1.

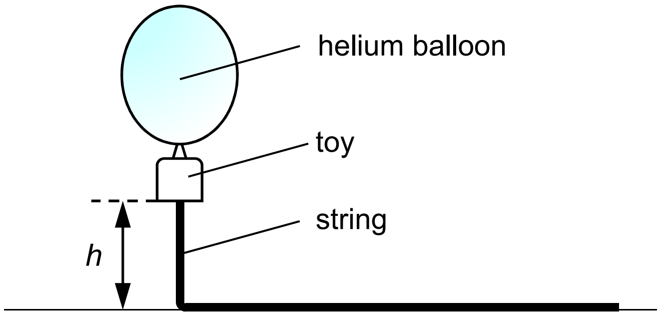


Fig. 5.1

The balloon exerts a constant upward force T on the toy where T is greater than the weight of the toy.

(a) When the toy is at a height h from the ground, it is in equilibrium.

Explain why the relationship between T, m, μ, h and the acceleration of free fall g is given by the expression

$$T = mg + \mu hg .$$

…………………………………………………………………………………………...

…………………………………………………………………………………………...

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

(b) Subsequently, the toy is displaced downwards by a small distance A_0, and then it is released. Throughout the oscillation, the tail of the string is always in contact with the ground.

Assuming that there are no dissipative forces and taking the mass of the oscillating system to be constant and equal to m, show that the acceleration a of the toy at displacement z from the equilibrium position is given by the expression

$$a = -\left(\frac{\mu g}{m}\right) z .$$

[3]

[Turn over

For Examiner's Use

(c) The mass of the toy is 50 g and the string has a mass per unit length of 5.8 g m^{-1}.

Calculate the period of oscillation of the toy.

period = ……………………… s [3]

(d) Air resistance can cause the oscillation to be lightly damped. Fig. 5.2 shows this variation with time *t* of the amplitude *A* of the oscillations of the toy.

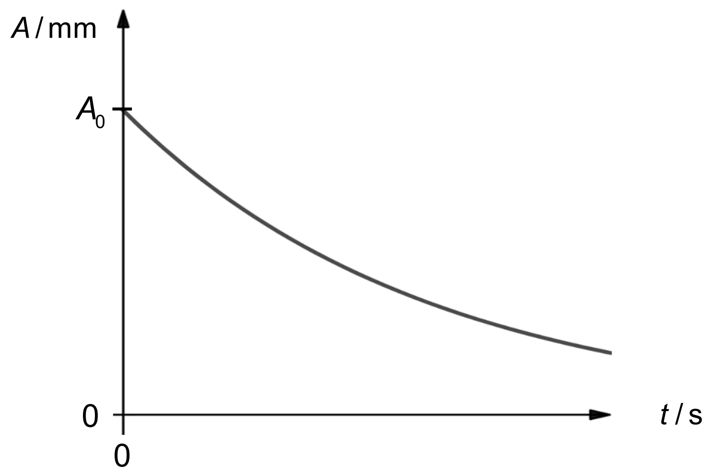


Fig. 5.2

(i) Describe the variation with *t* of *A*.

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………… [1]

(ii) On Fig. 5.2, sketch the variation with *t* of *A* when the toy is replaced by another toy with a smaller base surface area. [1]

For Examiner's Use

(iii) Suggest why experimental results for both toys show that the extent of damping is greater than what Fig. 5.2 predicts.

....

....

....

.... [2]

(e) The toy is displaced downwards by a small distance A_0 from the equilibrium position and released at time $t = 0$ s.

(i) On Fig. 5.3, sketch the variation with time t of displacement from the equilibrium position d of the toy when the mass of the string is negligible and there are no dissipative forces.

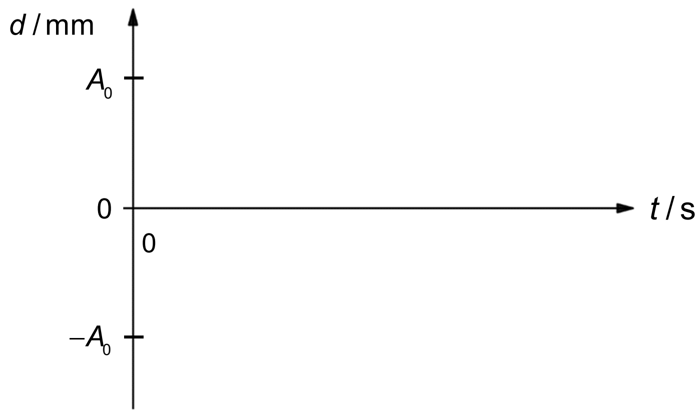


Fig. 5.3

[1]

(ii) Explain the variation with t of d drawn in **(e)(i)**.

....

....

....[1]

For Examiner's Use

Section B

Answer **one** question from this Section in the spaces provided.

6 (a) In an experiment to determine the specific charge (e / m) for an electron, a beam of electrons, travelling horizontally in a vacuum with uniform speed v, enters a region R where uniform electric and magnetic fields can be applied. The electric field strength has a magnitude E and acts into the plane of the paper as shown in Fig. 6.1 below.

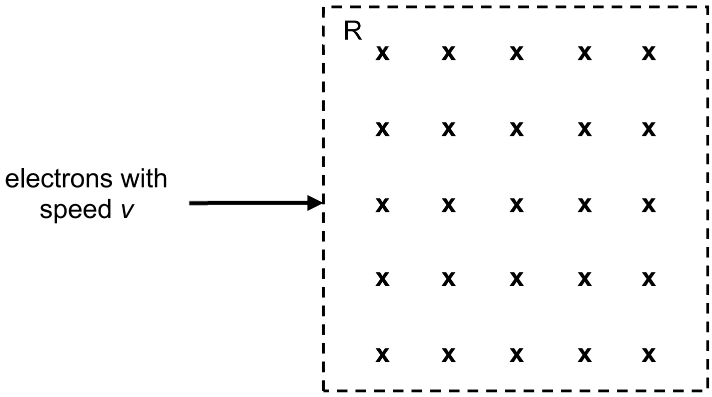


Fig. 6.1

The strength of the fields, when applied in combination, can be adjusted such that the beam remains undeflected when passing through R.

(i) Draw on Fig. 6.1 the magnetic field in region R so that the electron beam can pass through undeflected. Explain your answer.

………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

……………………………………………………………………………………… [3]

(ii) Electrons with speed of 3.3×10^7 m s^{-1} are produced using an electron gun. The magnetic flux density of the magnetic field is 3.0×10^{-3} T.

1. Determine the electric field strength E required to produce an undeflected beam.

E = ………………………… N C^{-1} [2]

For Examiner's Use

2. When the electric field is switched off, the electrons move in an arc of radius 6.0 x 10^{-2} m.

Deduce a value for the specific charge of an electron.

specific charge = ………………………… C kg^{-1} [3]

(b) A pair of concentric coils A and B is shown in Fig. 6.2.

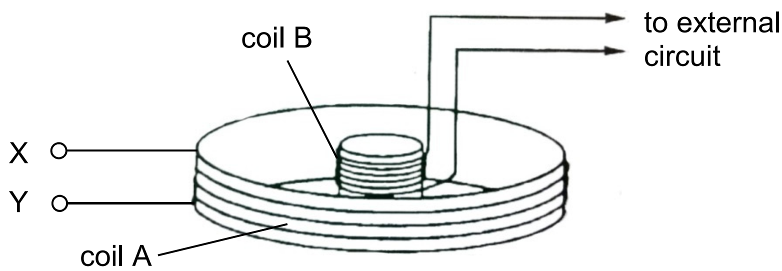


Fig. 6.2

The outer coil A is connected to a variable power supply by the terminals XY. The variation with time *t* of the current I in coil A is shown in Fig. 6.3.

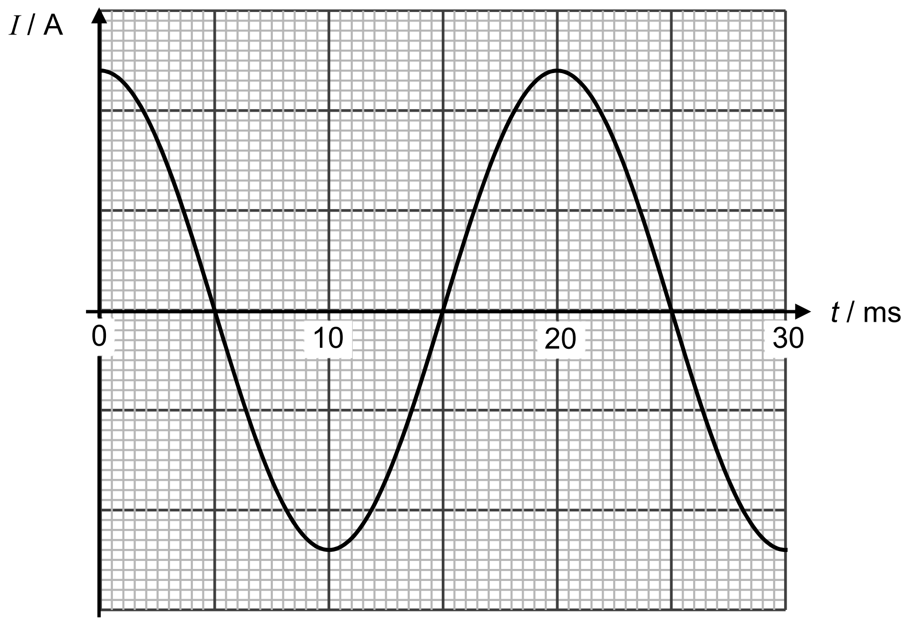


Fig. 6.3

[Turn over

For Examiner's Use

(i) Using Faraday's law, explain why an e.m.f. is induced in coil B.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

…………………………………………………………………………………………… [2]

(ii) At t = 25.0 ms, the induced e.m.f. in coil B is at its maximum value.

Using Fig. 6.3, explain why this is so.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………[1]

(iii) State the phase difference between the current in coil B and the current in coil A. Explain your answer.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………[3]

(iv) On Fig. 6.3, sketch the variation with time t of the induced current I_B in coil B. Values of the current are not required. [1]

(c) A graph of the input voltage V to an ideal transformer is shown in Fig. 6.4. The frequency of the input voltage is 50 Hz and the mean input power is 20 W. The turns ratio of the primary coil to the secondary coil is 50:1.

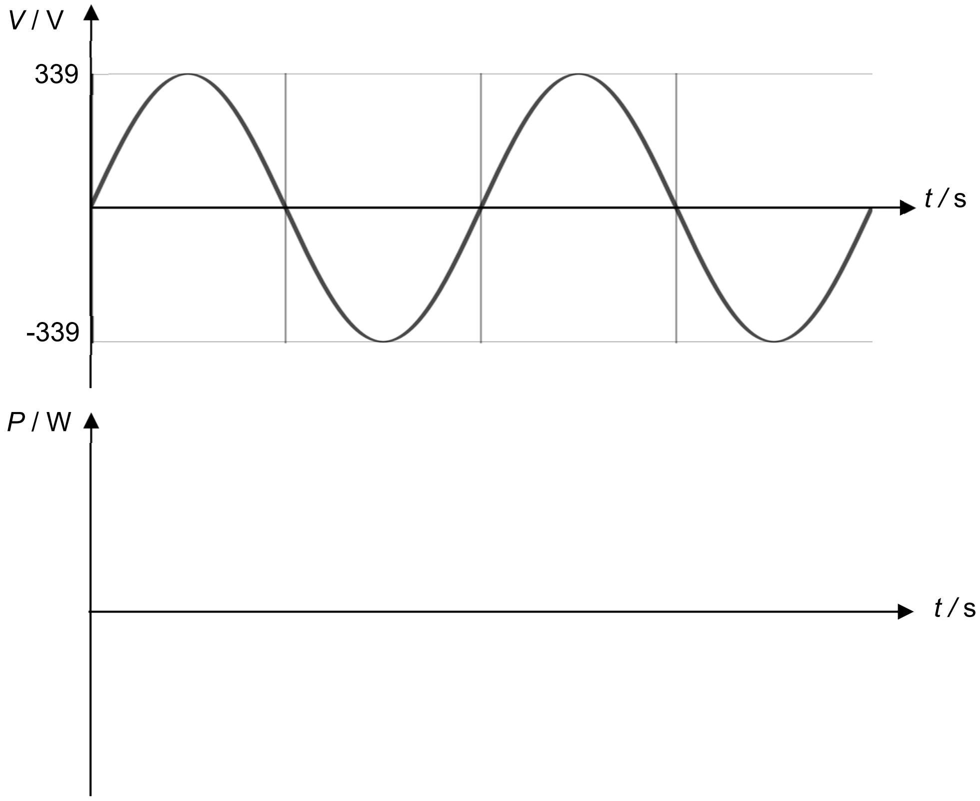


Fig. 6.4

(i) Sketch the variation with time of the input power to the transformer for two complete cycles in Fig. 6.4. [3]

(ii) Calculate the r.m.s. value of the output voltage V_s.

V_s = ………………………… V [2]

For Examiner's Use

7 **(a)** Photoelectric emission experiments are carried out in a dark room.

(i) The circuit in Fig. 7.1a shows electrodes X and Y which are made of zinc.

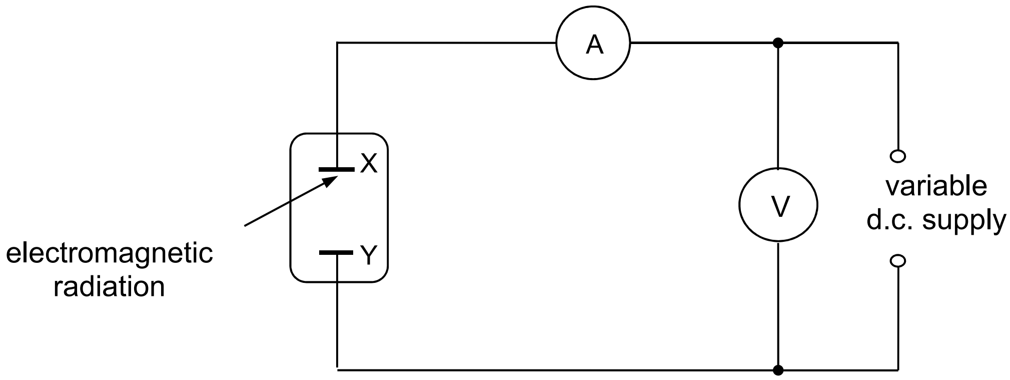


Fig. 7.1a

Current-voltage (I-V) characteristics in Fig. 7.1b is obtained when **only** electrode X is illuminated with light of wavelength 250 nm.

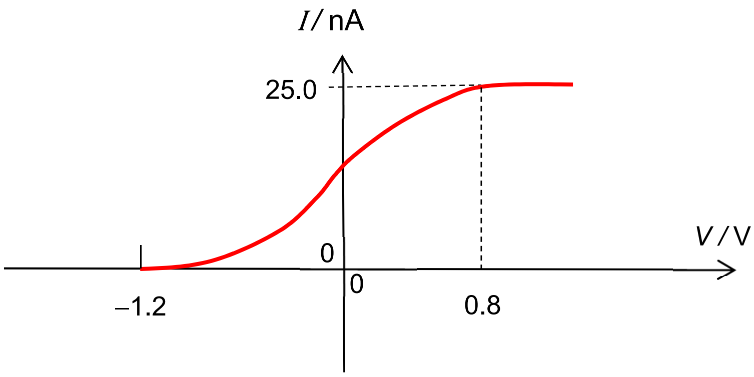


Fig. 7.1b

1. Show that the work function of zinc is 3.8 eV.

[2]

For Examiner's Use

2. Explain why the stopping potential remains the same even when the intensity of the light is changed.

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

…………………………………………………………………………………… [3]

(ii) The circuit in Fig. 7.2a shows electrodes X and Z. Electrode X is made of zinc, and electrode Z is made of nickel.

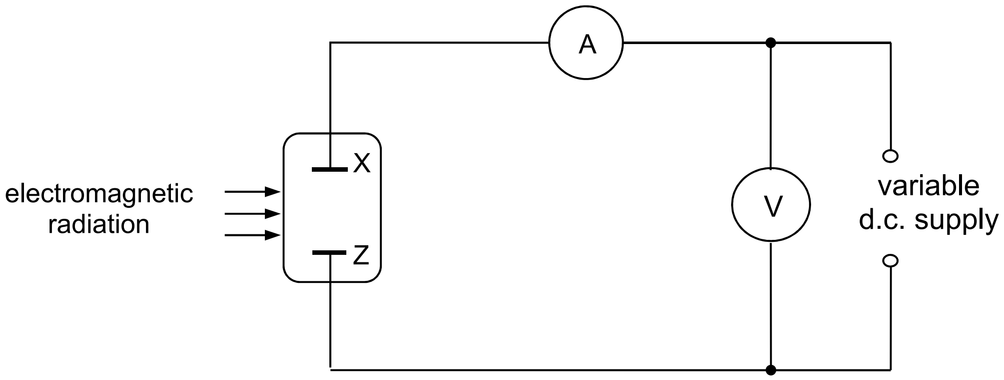


Fig. 7.2a

Current-voltage (I-V) characteristics is obtained when **both** electrodes are illuminated with a monochromatic light.

1. When the light has a wavelength of 250 nm, the I-V characteristics is as shown in Fig. 7.2b.

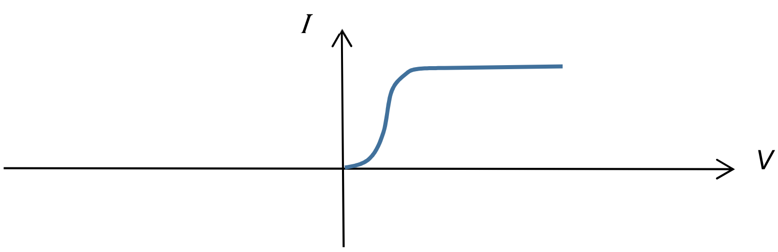


Fig. 7.2b

For Examiner's Use

Explain why the photocurrent has positive values only.

....

....

....

.... [2]

2. When the light has a wavelength of 100 nm, the *I*-*V* characteristics is as shown in Fig. 7.2c.

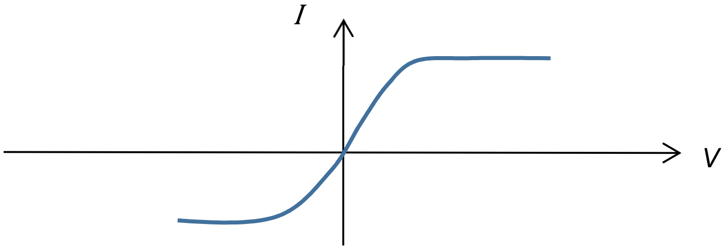


Fig. 7.2c

Explain why the photocurrent has both positive and negative values.

....

....

....

.... [2]

(b) The X-ray spectrum consists of a broad continuous spectrum and a series of sharp lines known as the characteristic peaks.

Fig. 7.3 shows two X-ray spectra lines produced during X-ray emissions.

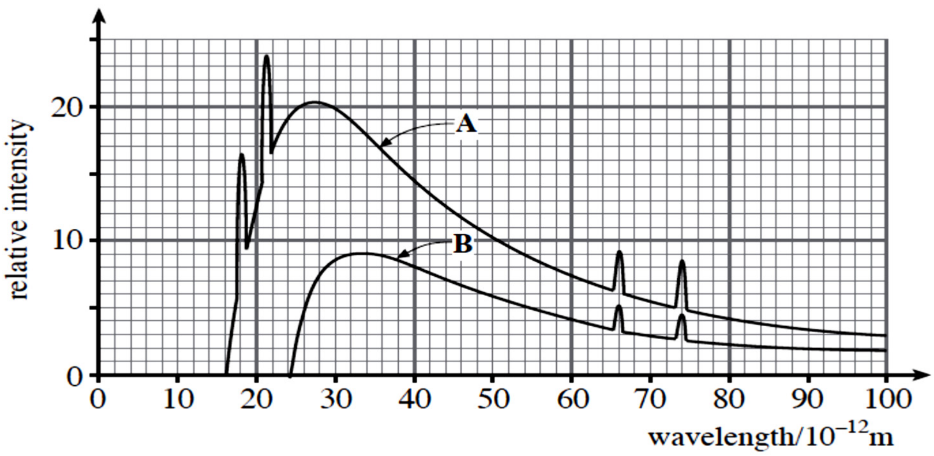


Fig. 7.3

For Examiner's Use

(i) State and explain

1. one **similarity** between graphs A and B.

…………………………………………………………………………………..

………………………………………………………………………………….. [1]

2. one **difference** between graphs A and B.

…………………………………………………………………………………..

………………………………………………………………………………….. [1]

(ii) Determine the potential difference to accelerate the bombarding electrons in graph A.

potential difference = ……………………… V [3]

Fig. 7.4 shows three sets of X-ray spectra produced by different accelerating potentials 100 kV, 80 kV and 50 kV with the same target.

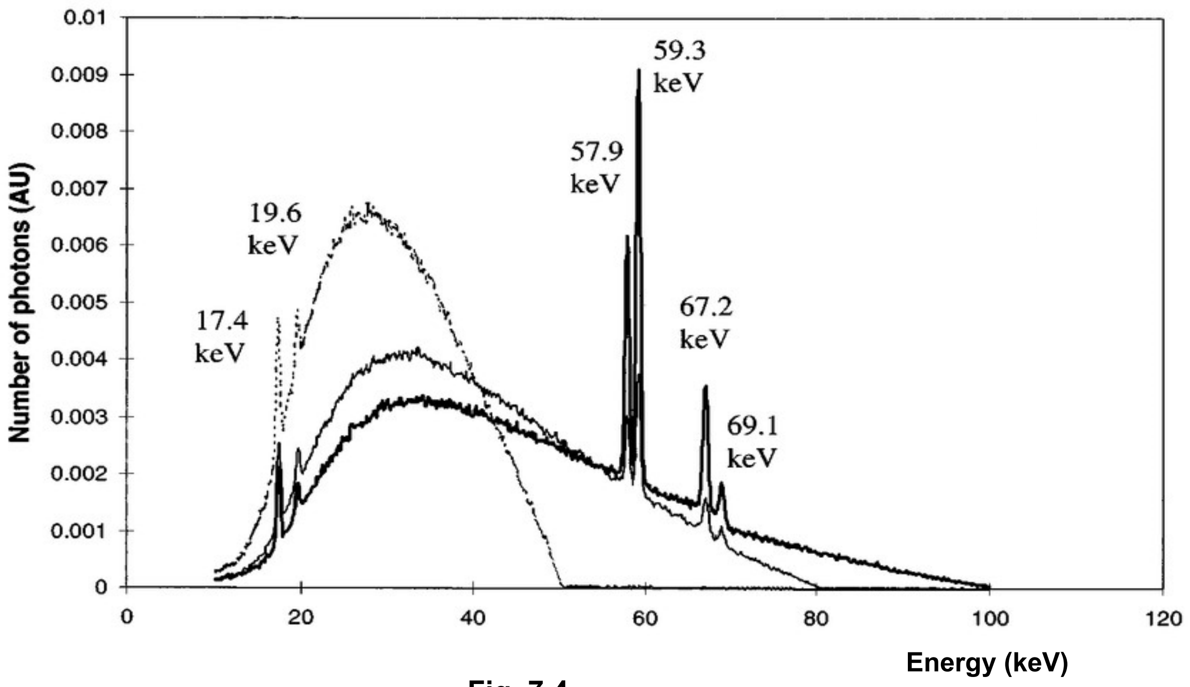


Fig. 7.4

[Turn over

For Examiner's Use

A simplified set of energies of levels K, L, M, and N of tungsten and molybdenum are provided in Fig. 7.5. For a more detailed analysis, Level L is split into 2 levels L_I and L_{II}.

level	energy of level of tungsten / eV	energy of level of molybdenum / eV
N	- 594.1	- 63.2
M	- 2820	- 506.3
L_{II}	- 10207	- 2520
L_I	- 12100	- 2625
K	- 69525	- 20000

Fig. 7.5

(iii) Use the table in Fig. 7.5 to determine the **two** least energetic photons (K_α lines) produced when electrons transit to level K

1. in tungsten, and

energies of photons = ………….. keV, …………. keV

2. in molybdenum.

energies of photons = ………….. keV, …………. keV [2]

(iv) Comment on the element(s) used to make the target based on your calculations in **(iii)** and Fig. 7.4.

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

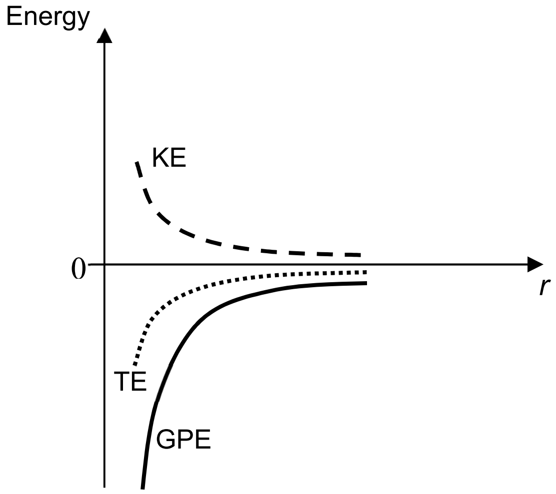
…………………………………………………………………………………………

…………………………………………………………………………………………

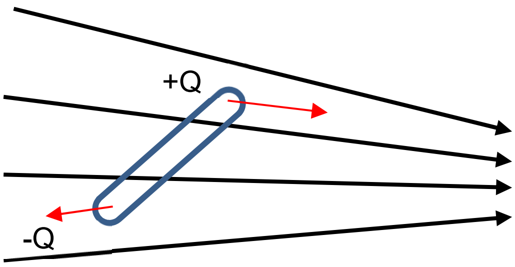
………………………………………………………………………………………… [4]

End of Paper

1	**D**	Rearranging, $C = \frac{Tk^{1/2}}{m^{1/2}}$. Unit of the numerator is s (N $m^{-1})^{1/2}$ = s (kg m s^{-2} $m^{-1})^{1/2}$ = $kg^{1/2}$ Unit of the denominator is = $kg^{1/2}$ Hence unit of *C* is 1 or does not have a unit.
2	**D**	$s = ut + 1/2at^2$ $= 0 + 1/2at^2$ $= 1/2(9.81)(2.0)^2$ = 19.62 m $\pm\frac{\Delta s}{s} = \pm\frac{2\Delta t}{t}$ $\pm\Delta s = \pm\frac{2\Delta t}{t}\times s$ $= \pm\frac{2(0.1)}{2.0}\times 19.62$ $= \pm 1.962$ $= \pm 2$ (1sf) $s \pm \Delta s = (20 \pm 2)$ m
3	**C**	Area under *a-t* graph gives change in velocity. Area under graph = 1/2(8.0)(0.2) = 0.8 m s^{-1} Final velocity = -1.0 + 0.8 = -0.2 m s^{-1}
4	**D**	At maximum height, $v_y = 0$ while $v_x = v\cos\theta$ $\therefore$ K.E. at maximum height = $m(v\cos\theta)^2/2$ $= \text{K.E.}_{\text{initial}}\cos^2\theta$ $= 15\cos^2 30^\circ$ = 11 J (2sf)
5	**A**	$(M+m)a = (M+m)g\sin\theta - 2T$ $(70+10)0.50 = (70+10)9.81\sin 40 - 2T$ $T = 230$ N (2sf)
6	**D**	Since there is no net force on X and Y, $\Delta p_X = -\Delta p_Y \quad \cdots\cdots(1)$ $\frac{\Delta p_X}{\Delta p_Y} = \frac{m_X(-v_X - u_X)}{m_Y(v_Y - (-u_Y))} \quad \cdots\cdots(2)$ $-1 = \frac{-2.0}{3.0}\frac{(v_X + u_X)}{(v_Y + u_Y)}$ $= -\left(\frac{2}{3}\right)\frac{(v_X + u_X)}{(v_Y + u_Y)}$ $\frac{(v_X + u_X)}{(v_Y + u_Y)} = \frac{3}{2}$

7	**B**	Increase in EPE = difference in area under the graph = ½ (8.0)(4.0 x 10^{-2}) – ½ (6.0)(3.0 x 10^{-2}) = 0.070 J (2sf)
8	**B**	Upthrust = weight of fluid displaced by the object = $\rho_{fluid}V_{fluid}g$ So it depends on density of the fluid and gravitational field strength. It is independent of density of the object as that would only affect the weight of the object. It is independent of the depth of the object as upthrust arises from the pressure difference between the top and bottom of the object.
9	**A**	By COE, Gain in KE = Loss in GPE KE just before ball strikes surface = initial GPE $KE_1 = mgh_1$ --- (1) KE just after ball strikes surface = final GPE $KE_2 = mgh_2$ --- (2) Taking the bottom of the ball as reference, (2)/(1): $KE_2 = h_2 / h_1 (KE_1)$ = 30/70 x 0.80 = 0.34 J (2sf)
10	**A**	As the stone is moving up and down vertically, by conservation of energy, its GPE will be changing and hence KE will be changing. So work must be done on the stone via the rod to ensure that KE is kept constant since it is in uniform circular motion.
11	**D**	 As satellite B is in higher orbit, TE_B is greater than TE_A, GPE_B is also greater than GPE_A. Therefore KE_B is lower than KE_A.

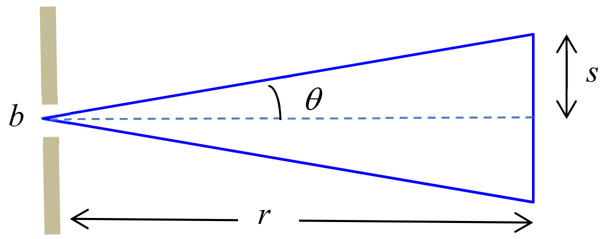
12	C	*heat gained by ice [to melt] to reach 0°C* $= m_{ice}c_{ice}(40)$ [+ $m_w L_f$] $= (0.400)(2100)(40)$ [+ $(0.400)(340000)$] $= 33600$ [+ $136\,000$] $=$ [$169\,600\ J$] *heat lost by water [to form ice] to reach 0°C* $= m_w c_w(30) + m_p c_p(30)$ [+ $m_w L_f$] $= (0.100)(4200)(30) + (0.150)(170)(30)$ [+ $(0.100)(340000)$] $= 12\,600 + 765$ [+ 34000] $= 13\,365$ [+ 34000] $=$ [$47\,365\ J$] At 0 °C, 1. Heat required for ALL ice to melt >> heat loss when ALL water has formed ice. 2. This means, that water and ice co-exist.
13	C	$pV = NkT$ $(1\times10^5)(1) = N(1.38\times10^{-23})(27+273.15)$ $N = 2.41\times10^{25}$ $\approx 2\times10^{25}$
14	C	$PV = nRT$ $2P(V) = nR(2T) \quad \cdots\cdots(1)$ $\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$ $\frac{1}{2}m\langle c_f^2\rangle = \frac{3}{2}k(2T) \quad \cdots\cdots(2)$ $\sqrt{\langle c_f^2\rangle} = \sqrt{2}\sqrt{\langle c^2\rangle}$ $= 1.4\sqrt{\langle c^2\rangle}$
15	D	Amplitude is constant for a particle in simple harmonic motion; it is displacement that changes. Angular frequency = $2\pi f$ and is constant. Total energy is constant as there is no dissipative force present.
16	D	Based on the SHM equations, know the variation of time with *x, v, p, a, and KE*. At $x = 0$, v = maximum, $a = 0$.
17	C	Let the intensity of the initial beam of light be I_0. Let the intensity of the beam of light after passing through the first polariser be I_1. Let the intensity of the beam of light passing through the second polariser be I_2. Given $\frac{I_2}{I_0} = \frac{1}{9}$. Since initial beam of light is unpolarised, $\frac{I_1}{I_0} = \frac{1}{2}$. Hence, $\frac{I_2}{I_1} = \frac{2}{9}$. Applying Malus' Law, $I_2 = I_1\cos^2\theta$. Hence, $\frac{2}{9}I_1 = I_1\cos^2\theta$ and $\theta = 61.9° \approx 62°$ (2sf).

18	**A**	For destructive interference to first occur, the path difference of the two waves must be half of a wavelength. When the sliding tube is raised, the difference between paths 1 and 2 is the additional vertical sections on both sides of the tube above. Hence, the path difference is $2(a_1 - b)$ where a_1 is the distance a when the first minimum is detected. Hence, $0.5\lambda = 2(a_1 - b)$ and $a_1 = 0.25\lambda + b$. Since the initial distance of a is equal to b, a has increased by 0.25λ.
19	**B**	Using Rayleigh's criterion, $\theta_R \approx \frac{\lambda}{d}$ The smaller the value of θ_R, the better the resolution because smaller details can be resolved. Therefore, the telescope with the best resolution is the telescope with the smallest ratio of $\frac{\lambda}{d}$. **telescope** — λ/d — **resolution** (i) — 5.0×10^{-7} — Worst (ii) — 5.0×10^{-8} — Best (iii) — 3.3×10^{-7} Hence, in the order from the worst resolution to the best resolution, it will be (i), (iii), (ii).
20	**D**	 Q exists in a region where electric field strength is weaker (as seen from the line concentration), hence left ward force is smaller than right ward force. Forces create a clockwise moments.
21	**B**	Loss in KE = Gain in EPE $(\frac{1}{2}mv^2 + \frac{1}{2}mv^2) - 0 = \frac{Qq}{4\pi\varepsilon_0 r} - 0$ $r = \frac{Qq}{4m\pi\varepsilon_0 v^2}$ $r = \frac{(1.60\times10^{-19})^2}{4(9.11\times10^{-31})\pi(8.85\times10^{-12})(2.0\times10^6)^2}$ $= 6.3\times10^{-10}$ m (2sf)

22	**A**	Since current is flowing through the specimen, current must be the same in each section. $I_X = I_Y = I_Z$ Since $I = nevA$, as I, n and e are constant, v is inversely related to A. $v_X > v_Z > v_Y$
23	**C**	When voltmeter connected, $\mathrm{I} = \frac{5.0}{10} = 0.50$ A $E = 0.50 \times 30 \quad = 15$ V When ammeter is connected, R_2 will not have current passing through as ammeter has no resistance. Total resistance = 20 Ω $\mathrm{I} = \frac{15}{20} = 0.75$ A
24	**B**	Force on electron $= Bqv \sin\theta$ $= (2.0 \times 10^{-3})(1.60 \times 10^{-19})(3.0 \times 10^{6}) \sin 90° \quad = 9.6 \times 10^{-16}$ N Electron undergoes uniform circular motion in magnetic field as magnetic force provides centripetal force. So magnitude of velocity does not change, and hence kinetic energy does not change. Gain in kinetic energy is zero. Velocity of electron changes as direction changes. Hence, change in momentum is not zero.
25	**C**	$B = \frac{\mu_o NI}{L}$ $= \frac{(4\pi \times 10^{-7})(300)(0.50)}{(20 \times 10^{-2})}$ $= 9.4 \times 10^{-4}$ T (2sf)
26	**B**	By RHGR, magnetic field due to long wire cuts loop wire into the page. When the loop is pulled to the right, magnetic flux linkage decreases as the magnetic field becomes weaker. By Faraday's Law, e.m.f. is induced in the loop of wire. By Lenz's law, induced current will flow in a direction to oppose the change causing it (to increase the magnetic flux linkage into the page). Induced current will flow in a clockwise direction. The vertical sections of the loop of wire will experience a magnetic force due to the magnetic field of the long wire, with a force to the left on the left side of the loop and a force to the right on the right side of the loop. Since the left side of the loop is nearer to the long wire, it experiences a greater magnetic force. Hence, the net force acting on the loop will be to the left.

27	**C**	1.4 x (Y-gain) = 2.8 V Y-gain = 2.0 V cm^{-1} $T = \frac{1}{f}$ $= \frac{1}{50} = 0.02$ s 2.0 x (time-base) = 0.02 s time-base = 0.01 s cm^{-1} = 10 ms cm^{-1}
28	**A**	$I = \frac{P}{A}$ $= \frac{\frac{N}{t} h f}{\pi r^2} = \frac{\frac{N}{t} h \frac{c}{\lambda}}{\pi r^2}$ $2.0 \times 10^{-11} = \frac{\frac{N}{t}\left(6.63 \times 10^{-34}\right) \frac{3.00 \times 10^{8}}{550 \times 10^{-9}}}{\pi \left(0.002\right)^2}$ $\frac{N}{t} = 695$ (3sf)
29	**B**	$E = \frac{p^2}{2m} = \frac{\left(h/\lambda\right)^2}{2m}$ $E \propto \frac{1}{\lambda^2}$ $\frac{4E}{E} \propto \left(\frac{\lambda}{\lambda_f}\right)^2 \Rightarrow \lambda_f = \frac{\lambda}{2}$

30 **A**



<u>Method 1: Using HUP,</u>

- If assume $\Delta x = b$, then $r \le 0.069m$

$$\Delta x\,\Delta p \ge h$$

$$(b)\,p\sin\theta \ge h \quad \text{where} \quad \sin\theta = \frac{\Delta p}{p}, \quad \sin\theta = \frac{s}{r}$$

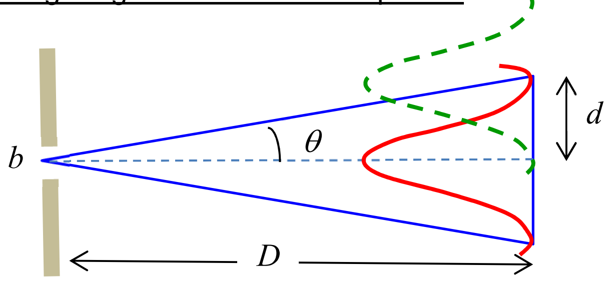
$$(b)\,mv\left(\frac{s}{r}\right) \ge h$$

$$\left(10^{-10}\right)\left(9.11\times10^{-31}\right)\left(10^{6}\right)\frac{0.5}{r} \ge h$$

$$r \le 0.069m$$

- If assume $\Delta x = \dfrac{b}{2}$, then $r \le 0.035m$

<u>Method 2: Using Single Slit Diffraction Equation</u>



$$\textit{For single slit difrraction,} \quad \sin\theta = m\frac{\lambda}{b} \quad \text{where} \quad m = 1, 2, 3, .. \quad \cdots\cdots(1)$$

$$\textit{By Rayleigh Criterion,} \quad \tan\theta \approx \frac{d}{D} \quad \cdots\cdots(2)$$

$$\textit{For small angles,} \quad \frac{d}{D} \approx \frac{\lambda}{b} \quad \text{where } p = \frac{h}{\lambda}$$

$$\approx \frac{h/p}{b}$$

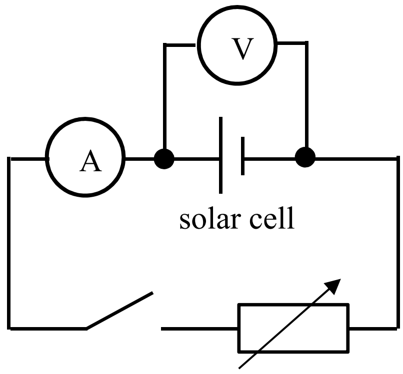
$$\frac{0.5}{D} \approx \frac{h/\left(9.11\times10^{-31}\right)\left(10^{6}\right)}{10^{-10}}$$

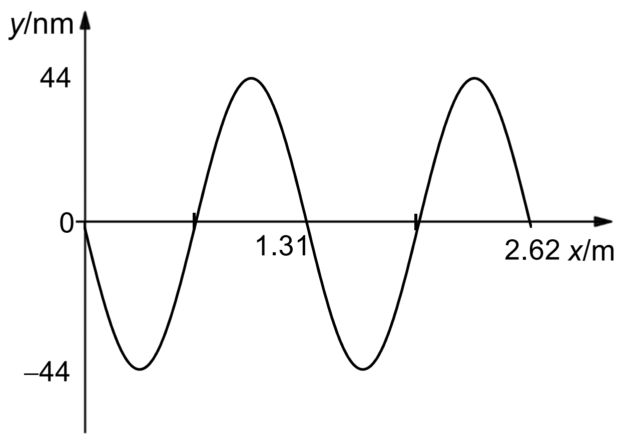
$$r \approx 0.069m$$

Qn	Suggested Answer
1	
(a)(i)	$\Delta(m_1+m_2)=\Delta m_1+\Delta m_2$ $=(\pm 1)+(\pm 1)$
	$=\pm 2$ g
(a)(ii)	$\dfrac{\Delta T}{T}\times 100\%=\dfrac{1}{2}\left(\dfrac{\Delta m_1}{m_1}+\dfrac{\Delta m_2}{m_2}+\dfrac{\Delta k}{k}+\dfrac{\Delta(m_1+m_2)}{m_1+m_2}\right)\times 100\%$
	$\dfrac{\Delta T}{T}\times 100\%=\pm\dfrac{1}{2}\left(\dfrac{1}{500}+\dfrac{1}{1167}+\dfrac{0.2}{8.0}+\dfrac{2}{500+1167}\right)\times 100\%$
	$\dfrac{\Delta T}{T}\times 100\%=\pm 1.45$ $=\pm 1.5\%$ (2sf)
	Alternative solution using max/min method
	$T_{max}=2\pi\sqrt{\dfrac{(501\times 10^{-3})(1168\times 10^{-3})}{(7.8)\left[(501\times 10^{-3})+(1168\times 10^{-3})\right]}}$ $=1.332$ s $T_{min}=2\pi\sqrt{\dfrac{(499\times 10^{-3})(1166\times 10^{-3})}{(8.2)\left[(499\times 10^{-3})+(1166\times 10^{-3})\right]}}$ $=1.297$ s
	$\dfrac{\Delta T}{T}\times 100\%=\dfrac{0.5(1.332-1.297)}{0.5(1.332+1.297)}\times 100\%$
	$\dfrac{\Delta T}{T}\times 100\%=\pm 1.33$ $=\pm 1.3\%$ (2sf)
(b)(i)	Uncertainty of T averaged from 20 oscillations $=\dfrac{\pm 0.4}{20}$ $=\pm 0.02$ s
	Uncertainty of T if the time for one oscillation is recorded is ± 0.4 s. Hence, finding the average time from 20 oscillations will reduce the uncertainty of T.
(b)(ii)	The time recorded as the period would have been for half an oscillation. $\text{percentage error}=\dfrac{\text{wrong value}-\text{correct value}}{\text{correct value}}\times 100\%$ $=\dfrac{0.5T-T}{T}\times 100\%$
	percentage error $=-50\%$
(b)(iii)	The human error in **(ii)** is a systematic error. Systematic errors cannot be reduced by finding the average time from multiple oscillations.

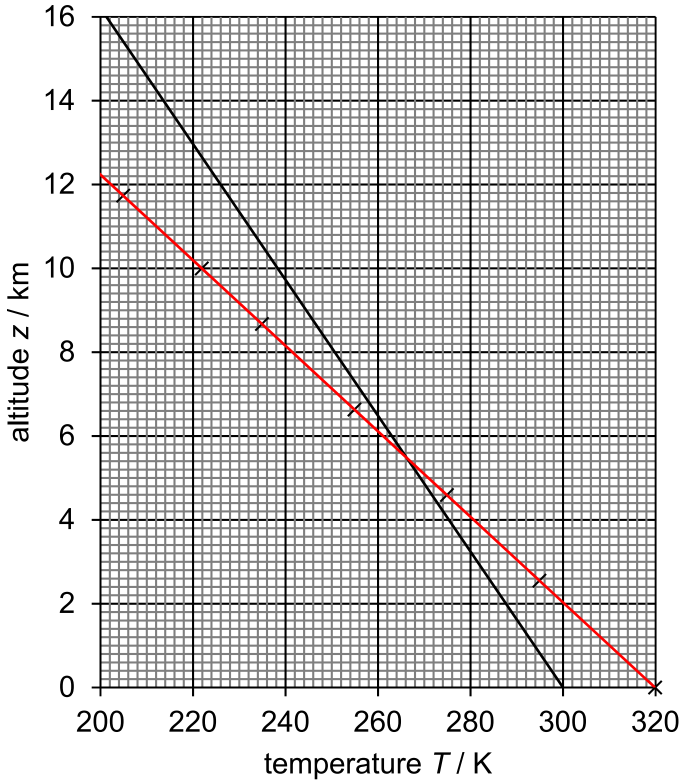
2	
(a)(i)	Acceleration is the rate of change of velocity.
(a)(ii)	The gradient of the tangent to the v-t graph gives the acceleration.
	Acceleration decreases continuously to zero (or near zero) at 16.0 s.
(a)(iii)	Finding gradient of tangent drawn at 5.0 s (accept reasonable tangent)
	$F = ma$ = weight – F_v $1.5(a) = 1.5(9.81) - F_v$
	F_v = 11.2 - 11.9 N
	Alternative solution using formula for F_v
	At 16.0 s, $v = 35.0$ m s^{-1} and object is at terminal velocity. $mg = F_v$ Assuming $F_v = kv^n$, $1.5(9.81) = k35.0^n$
	At 5.0 s, $v = 29.0$ m s^{-1}. $F = ma = mg - F_v$ $1.5(a) = 1.5(9.81) - k29.0^n$ Solving, $k = 0.198$ and $n = 1.21$
	$F_v = 0.198(29.0)^{1.21} = 11.6$ N
(b)(i)	Assuming block A moves down the plane, $(3.0)(9.81)\sin 40° - T = (3.0)a$ $T - (4.0)(9.81)\sin 20° = (4.0)a$
	Solving both equations, $a = 0.785$ m s^{-2} (3sf)
	$(3.0)(9.81)\sin 40° - T = (3.0)(0.785)$ $T = 16.6$ N (3sf)
(b)(ii)	Loss in GPE_A = Gain in GPE_B + Gain in KE_{A+B} + Work done against friction $m_A g h_A = m_B g h_B + \frac{1}{2}(m_A + m_b)v^2 + fs$
	$(3.0)(9.81)(2.0\sin 40°) = (4.0)(9.81)(2.0\sin 20°) + \frac{1}{2}(3.0 + 4.0)v^2 + (4.0)(2.0)$
	$v = 0.925$ m s^{-1} (3sf)
	Alternative solution using dynamics and kinematics
	$(3.0)(9.81)\sin 40° - (4.0)(9.81)\sin 20° - 4.0 = (7.0)a$ $a = 0.214$ m s^{-1}
	$v^2 = u^2 + 2as$ $v^2 = 0 + 2(0.214)(2.0)$
	$v = 0.925$ m s^{-1} (3sf)

3	
(a)	The <u>rate of change of angular displacement</u> of the object about the centre of the circle.
(b)(i)	Horizontal component of normal contact force N provides centripetal force. $N\sin\theta = F_c = mr\omega^2$ $N\cos\theta = mg$
	$\frac{\sin\theta}{\cos\theta} = \frac{0.200\sin\theta\left(\frac{2\pi}{0.75}\right)^2}{9.81}$
	$\theta = 45.7°$ (1dp)
(b)(ii)	<u>Centripetal force will increase</u> thus <u>the horizontal component of the normal contact force will be greater</u>. Bead will move higher and value of θ will increase.
(c)(i)	Resultant force = gravitational force by the Earth + gravitational force by the Sun
	$F_{Earth} = \frac{GMm}{r^2} = \frac{6.67\times10^{-11}(5.98\times10^{24})6200}{(1.50\times10^9)^2} = 1.10$ N $F_{Sun} = \frac{GMm}{r^2} = \frac{6.67\times10^{-11}(1.99\times10^{30})6200}{(1.50\times10^9+1.50\times10^{11})^2} = 35.9$ N
	Resultant force = 1.10 + 35.9 = 37.0 N
(c)(ii)	Gravitational force by the Earth and the Sun provides centripetal force. $F_{net} = mr\omega^2$ $37.0 = 6200(1.515\times10^{11})\omega^2$
	$\omega = 1.98\times10^{-7}$ rad s^{-1} (3sf)
4	
(a)(i)1.	effective resistance $= (\frac{1}{600}+\frac{1}{3000})^{-1}+30$ $= 530\ \Omega$
	terminal p.d. $= \varepsilon - Ir$ $= 12.0 - (\frac{12.0}{530})(30)$ $= 11.3$ V $I_{LDR} = \frac{11.3}{3000}$ $= 3.37$ mA
	$= 3.8$ mA (2sf) (shown)
(a)(i)2.	$P_{LDR} = I_{LDR}{}^2R$ $= (3.8\times10^{-3})^2(3000)$
	$= 0.043$ W (2sf)
(a)(ii)	new effective resistance $= (\frac{1}{600}+\frac{1}{100})^{-1}+30$ $= 116\ \Omega$

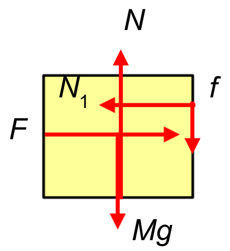
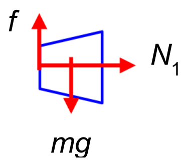
	new terminal p.d. $= \varepsilon - Ir$ $= 12.0 - (\frac{12.0}{116})(30)$ $= 8.90$ V
	new $P_{LDR} = \frac{V_{LDR}{}^2}{R}$ $= \frac{8.90^2}{100}$ $= 0.79$ W (2sf) Since P_{LDR} > 0.50 W, it will be damaged.
(a)(iii)	Light bulb drawn • in series with 600 Ω resistor OR • parallel to LDR and 600 Ω resistor.
	When light intensity is low, resistance of LDR is high. Total resistance in circuit will increase, leading to a smaller total current. This would lead to a smaller drop in p.d. across the internal resistance and a higher p.d. across light bulb.
(b)(i)	 Solar cell, voltmeter and ammeter drawn and connected correctly. Variable resistor to vary resistance in circuit.
(b)(ii)1.	When output current is zero, output p.d. = E = 0.580 V
(b)(ii)2.	$R = \frac{V}{I}$ $= \frac{0.550}{20.0 \times 10^{-3}}$ $= 27.5$ Ω (3sf)
(b)(ii)3.	$V = E - Ir$ $r = \frac{E - V}{I}$ $= \frac{0.580 - 0.550}{20.0 \times 10^{-3}}$
	$= 1.5$ Ω

5	
(a)(i)	Definition of speed: speed $= \frac{\text{distance}}{\text{time}}$, $v = \frac{d}{t}$ Definition of frequency: frequency $= \frac{1}{\text{period}}$, $f = \frac{1}{T}$ In one cycle of a wave, the time taken is one period and the distance covered is one wavelength.
	Hence, $v = \frac{\lambda}{T}$ and $v = f\lambda$ (shown)
(a)(ii)	$\lambda = \frac{v}{f}$ $= \frac{344}{262}$
	$\lambda = 1.31$ m (3sf)
(a)(iii)	 Negative sine graph for 2 cycles.
(b)(i)	The principle of superposition states that the net displacement at a given place and time caused by two or more waves which transverse the same space and meet
	is the vector sum of the displacement which would have been produced by the individual waves separately at that position and instant of time.
(b)(ii)	Let the distance between the finger and the far end be L. $L = \frac{\lambda}{2} = \frac{v}{2f}$
	change in d = change in L change in $L = \frac{v}{2}\left(\frac{1}{f_1} - \frac{1}{f_2}\right)$
	change in $L = \frac{425}{2}\left(\frac{1}{247} - \frac{1}{262}\right)$
	$= 0.0493$ m (3sf)
(c)(i)	Diffraction is the bending/spreading of a wave into its geometrical shadow when it is incident on an edge of an obstacle or aperture/opening.

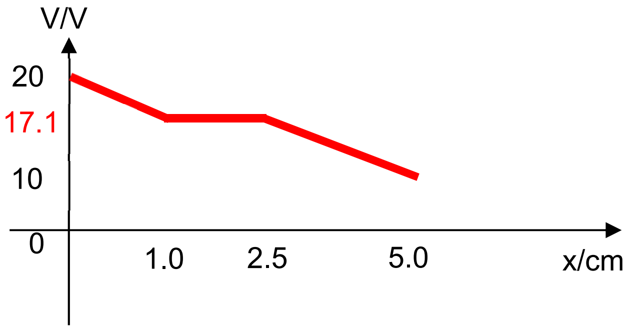
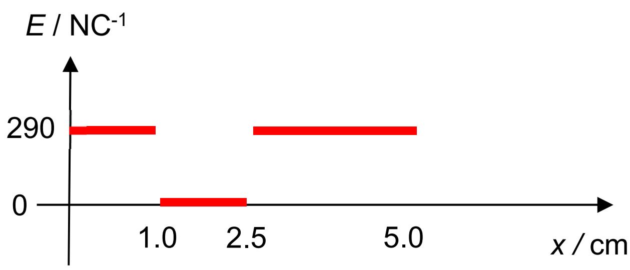
(c)(ii)	The first order bright fringes will • be <u>brighter</u> / have <u>greater intensity</u>. • be spaced <u>further</u> from the central maximum. • the <u>width</u> of the fringes will <u>decrease</u>.
(c)(iii)	When only slits A and C are covered, the fringe pattern is that of a single slit diffraction pattern through slit B. When only slit B is covered, the fringe pattern is that of a double slit pattern through slits A and C.
	<u>Single Slit (ss) Diffraction</u> $\frac{z_{ss}}{D} = \frac{\lambda}{b}$ so $b = \frac{\lambda D}{z_{ss}}$ <u>Double Slit (ds) Interference</u> $\frac{z_{ds}}{D} = \frac{\lambda}{a}$ so $a = \frac{\lambda D}{z_{ds}}$ Where *D* is the distance from the slit to the screen, *b* is the width of each slit, *a* is the separation between slits A and C and λ is the wavelength of incident light.
	$\frac{a}{b} = \frac{z_{ss}}{z_{ds}}$
	Hence, for the single slit diffraction pattern, the distance from P to the first minimum is $z_{ss} = 0.01$ mm. For the double slit interference pattern, the distance from P to the first maximum is $z_{ds} = \frac{0.01}{3.5}$ mm
	$\frac{a}{b} = \left(\frac{0.01}{0.01/3.5} \right)$
	= 3.5
(c)(iv)	Width of central bright maximum of the diffraction pattern through slit C is the same as the width of central bright maximum of the diffraction pattern through slit B.
	0.02 mm
6	
(a)(i)	$I = \varepsilon\sigma T_{sun}^4$ $= (1)(5.67 \times 10^{-8})(5778^4)$
	Power $= I \times 4\pi r_{sun}^2$ $= \varepsilon\sigma T_{sun}^4 \times 4\pi r_{sun}^2$ $= (1)(5.67 \times 10^{-8})(5778^4) \times 4\pi(6.96 \times 10^8)^2$ $= 3.85 \times 10^{26}$ W (3sf)
(a)(ii)	intensity $= \frac{\text{power}}{\text{area over which power is distributed}}$ $S_0 = \frac{3.847 \times 10^{26}}{4\pi(1.5 \times 10^{11})^2}$

	$= 1361 \text{ W m}^{-2}$
	$= 1360 \text{ W m}^{-2}$ (3sf) (shown)
(b)	The incoming solar radiation emits mainly in the visible light wavelengths between $\underline{0.4\ \mu\text{m}}$ and $\underline{0.7\ \mu\text{m}}$.
	From Fig. 6.3, the absorption of thermal radiation by the atmosphere at these wavelengths is small relative to that absorbed at other wavelengths (UV and Infra-red).
(c)(i)	Absorbed radiation = Emitted radiation $\sigma T_E^4 - (1-\varepsilon_A)\sigma T_E^4 = 2\varepsilon_A \sigma T_A^4$
	$\varepsilon_A \sigma T_E^4 = 2\varepsilon_A \sigma T_A^4$
	$T_E^4 = 2T_A^4$ (shown)
(c)(ii)	Substituting the equation in **(c)(i)** into the given equation for the radiative balance at the surface of the Earth, $(0.25-0.075)1360 + (0.8)(5.67\times10^{-8})\frac{1}{2}T_E^4 = (5.67\times10^{-8})T_E^4$
	$T_E = 289$ K (3sf)
(d)	From Fig. 6.3, carbon dioxide absorbs in the infra-red wavelengths. Outgoing terrestrial radiation emits mainly in the infra-red wavelengths.
	An increase in carbon dioxide concentrations will cause the atmosphere to absorb and re-emit more radiation leading to global warming.
(e)(i)	

(e)(ii)	gradient $= \dfrac{11.0-0.2}{212-318}$ $= -0.102$ km K^{-1}
	adiabatic lapse rate $= -\dfrac{1}{\text{gradient}}$ $= -\dfrac{1}{(-0.102)}$ $= 9.81$ K km^{-1} Accept 9.64 - 10.0 K km^{-1}
(e)(iii)	loss in thermal energy = work done against gravity $-mc\Delta T = mg\Delta z$
	$c = g\left(-\dfrac{\Delta z}{\Delta T}\right)$ $= 9.81\left(\dfrac{1}{9.81\times10^{-3}}\right)$
	$c = 1000$ J kg^{-1} K^{-1}
(f)(i)	$z_0 = 5.4 - 5.6$ km
(f)(ii)	Above z_0, the air parcel cools faster than the surrounding air while below z_0, the surrounding air cools faster than the air parcel.
	Above z_0, the air parcel will contract more and become denser than the surrounding air and sinks.
	Below z_0, the air parcel will expand more and become less dense than the surrounding air and rises.

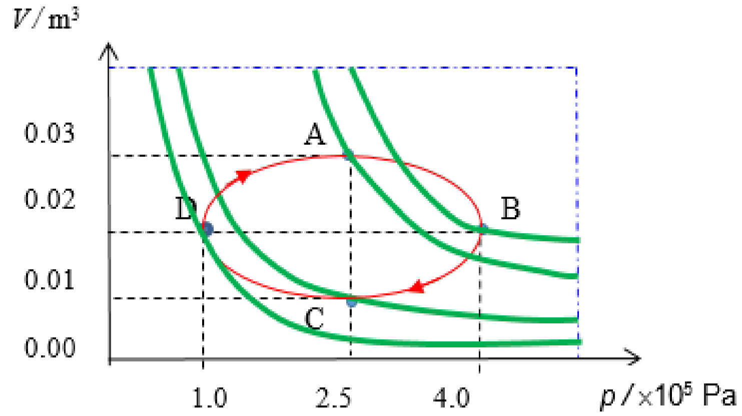
Qn	Suggested Answer
1	
(a)	Point where the weight / gravitational force appears to act through.
(b)	F_1 and F_2 are frictional forces.
	They arise because the tyres exert a force backwards on the ground.
(c)	Taking moments about the bottom of the front wheels,
	$\text{Sum of clockwise moments} = \text{sum of anticlockwise moments}$ $(R_2 \times 5.0) + (T\sin 30° \times 5.0) = (T\cos 30° \times 1.0) + (W \times 2.0)$ $(R_2 \times 5.0) + (7000\sin 30° \times 5.0) = (7000\cos 30° \times 1.0) + (20000 \times 2.0)$
	$R_2 = 5710$ N (3sf)
(d)	Sum of forces vertically = 0 $R_1 + R_2 + T\sin 30° = W$ $R_1 + 5710 + 7000\sin 30° = 20000$
	$R_1 = 10800$ N (3sf)
2	
(a)	Newton's 2nd law states that the rate of change of momentum is directly proportional to the net external force and is in the direction of this force.
(b)(i)1	
	Label type of forces N – normal contact force on block by surface N_1 – normal contact force on block by beaker f – frictional force on block by beaker Mg – gravitational force/weight on block by earth
	4 correct points of application Correct length of arrows • $F > N_1$ • $N = Mg + f$
(b)(i)2	
	Label type of forces N_1 – normal contact force on beaker by block f – frictional force on beaker by block mg – gravitational force/weight on beaker by earth

	3 correct points of application (line of action of N_1 is below the CG) Correct length of arrows • $f = mg$ • N_1 on block = N_1 on beaker • f on block = f on beaker
(b)(ii)	*Given* $f = \mu N_1$ $= 0.40\,N_1 \quad \cdots\cdots(1)$ *By Newton's 2nd law*, $ma = N_1 \quad \cdots\cdots(2)$
	As in vertical equilibrium, $f = mg \quad \cdots\cdots(3)$
	$0.40\,N_1 = mg$ $0.40\,ma = mg$ $a = \frac{g}{0.40} = \frac{9.81}{0.40}$ $= 24.53\ \text{m s}^{-2}$ (4 sf) $= 24.5\ \text{m s}^{-2}$ (3 sf)
(b)(iii)1	For beaker to be in equilibrium (in position) normal to the slope, $f_2 = mg\cos 50°$ $\mu N_2 = mg\cos 50°$ $(0.40)\,N_2 = (0.10)(9.81)\cos 50°$
	$N_2 = 1.58\ \text{N}$ (3sf)
(b)(iii)2	<u>Actual acceleration</u> down the slope due to weight, $a_p = g\sin 50°$ $= 7.51\ \text{m s}^{-2}$
	Acceleration along the slope for beaker to be in position <u>required</u>, $m\,a_2 = m\,g\sin 50° + N_2$ $(0.10)\,a_2 = (0.10)(9.81)\sin 50° + 1.58$ $a_2 = 23.3\ \text{m s}^{-2}$ (3sf)
	Since $a_p << a_2$, the beaker cannot remain in the position.
	OR
	To remain in position, there must be frictional force $f_2 = mg\cos 50°$
	The block and beaker are both accelerating along the slope due to their weight $a_p = g\sin 50°$ $= 7.51\ \text{m s}^{-2}$
	As both have the same acceleration, their normal contact force N_2 must be 0, and hence frictional force f_2 is also 0.
	Hence, the beaker cannot remain in the position.

3	
(a)	Electric potential V at a point is defined as the work done per unit charge
	by an external agent in bringing a small positive point test charge from infinity to that point, without acceleration.
(b)(i)	
	$E = \frac{\Delta V}{\Delta d} = \frac{20-10}{3.5} = 2.86 = 2.9\ \text{V cm}^{-1}\ (\text{NC}^{-1})$ Decrease in V per cm $=$ 2.9 V Potential at horizontal line $= 20 - 2.9 = 17.1$ V
	Gradient is the same for both lines.
(b)(ii)	
	Taking to the right as positive. E is negative potential gradient ($E = -\frac{dV}{dr}$)
	$E\ =\ 2.9\ V\,cm^{-1}\ =\ 290\ V\,m^{-1}$
(c)(i)	$V = \frac{1.5\times10^{-11}}{4\pi\varepsilon_0(2.5\times10^{-2})}$ $V = 5.395$ V
	$I = \frac{5.395}{5.0}$ $I = 1.079$ A
	$=$ 1.08 A (3sf)
(c)(ii)	$I = \frac{V}{R}$ Since I and R are constants, V must be constant.
	$V = \frac{Q}{4\pi\varepsilon_0 r}$ $r \propto Q$ Since Q is decreasing, r also decreases to maintain constant V.

(c)(iii)	$V = \dfrac{Q}{4\pi\varepsilon_0 r}$ $r = \dfrac{Q}{4\pi\varepsilon_0 V}$ $r = 1.67\times10^9\ Q$ $\dfrac{dr}{dt} = 1.67\times10^9\ \dfrac{dQ}{dt}$ Hence $R_{radius} = 1.7 \times 10^9\ I$
(c)(iv)	$t = \dfrac{Q}{I}$ $t = \dfrac{1.5\times10^{-11}}{1.08}$ $t = 1.39\times10^{-11}\text{s}$ (3sf)
(c)(v)	$R_{radius} = 1.7\times10^9\ I$ $\dfrac{dr}{dt} = 1.7\times10^9\ I$ $dt = \dfrac{dr}{1.7\times10^9\ I}$ $t_r = \dfrac{(2.5-0.5)\times10^{-2}}{\left(1.7\times10^9\right)1.08}$ $t_r = 1.09\times10^{-11}$ s (3sf)
	Since 1.09×10^{-11} s is smaller than 1.39×10^{-11} s, the balloon will be fully deflated first.
4	
(a)	Internal energy of an ideal gas is equal to the random distribution of microscopic kinetic energy OR random distribution of molecular kinetic energy OR random distribution of kinetic energy of molecules
(b)(i)	$T \propto pV$
	$pV = nRT$ $\left(2.5\times10^5\right)0.03 = nRT_A = 7500$ $\left(4.0\times10^5\right)0.02 = nRT_B = 8000$ $\left(2.5\times10^5\right)0.01 = nRT_C = 2500$ $\left(1.0\times10^5\right)0.02 = nRT_D = 2000$
	$T_D < T_C < T_A < T_B$

(b)(ii)



All 4 isotherms drawn correctly.

(b)(iii)

After one complete cycle, the gas has the

- <u>same temperature</u>, hence the
- same random distribution of molecular kinetic energy, hence
- same internal energy (no change in internal energy).

(b)(iv)

Process	$+\Delta U$	$+q$	$+w$
A → B	+	–	+
B → C	–	–	+
C → D	–	+	–
D → A	+	+	–
After one complete cycle	0	–	+

(b)(v)

$w = \left[\pi(0.01)(1.5\times10^{5})\right]$

$$\Delta U = q + w$$

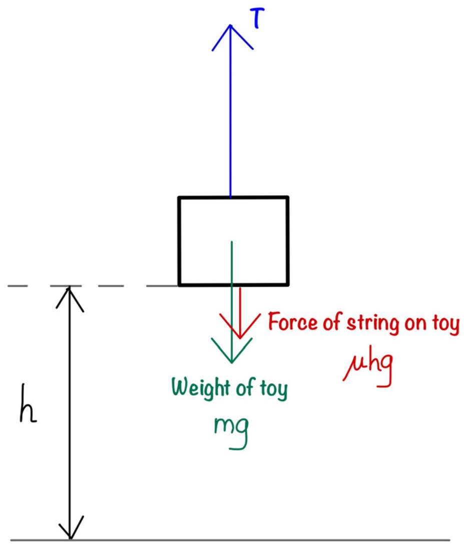
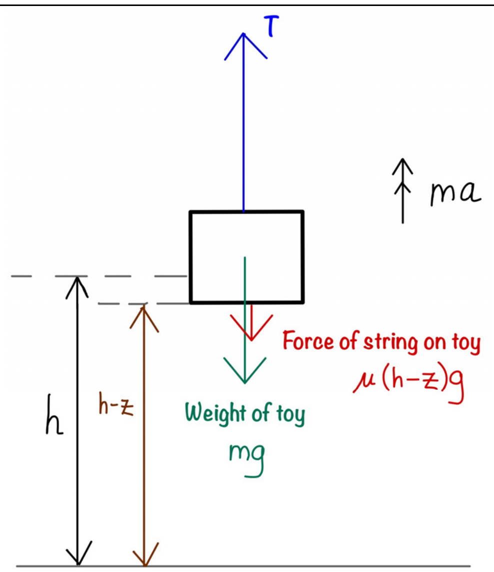
$$0 = q + \left[\pi(0.01)(1.5\times10^{5})\right]$$

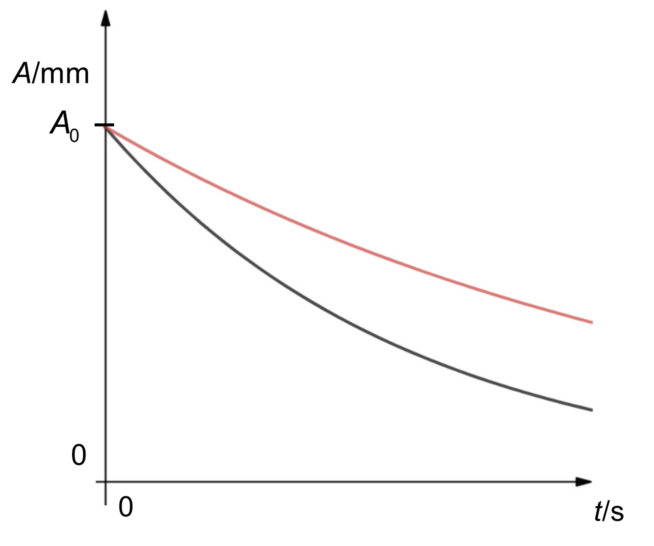
$$q = -4710 \text{ J}$$

(c)

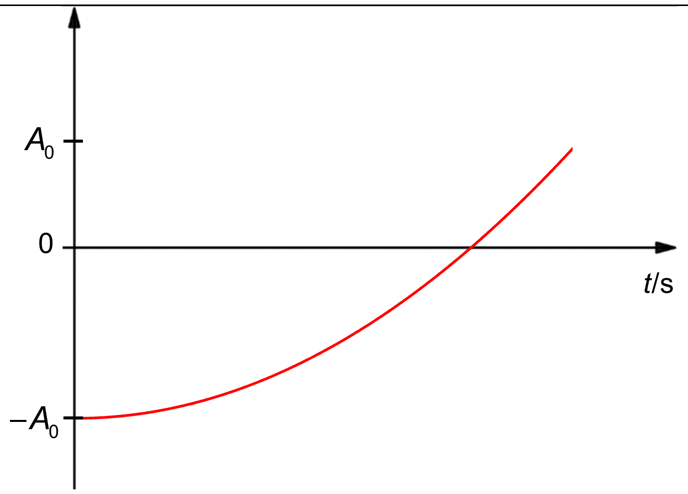
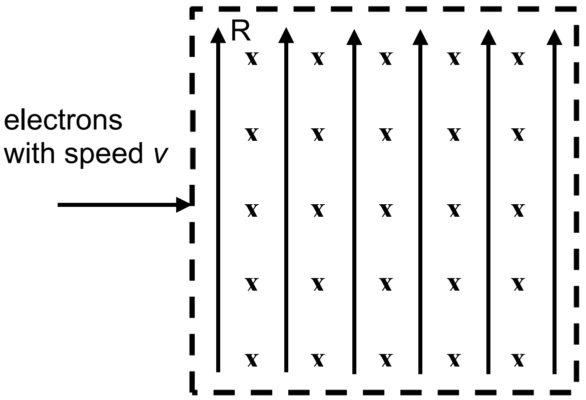
Yes. The expression is derived from

1. <u>ideal gases</u> (hence $PV = NkT$)
2. which obey the <u>Kinetic Theory of Gases</u> (hence $P = \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$)

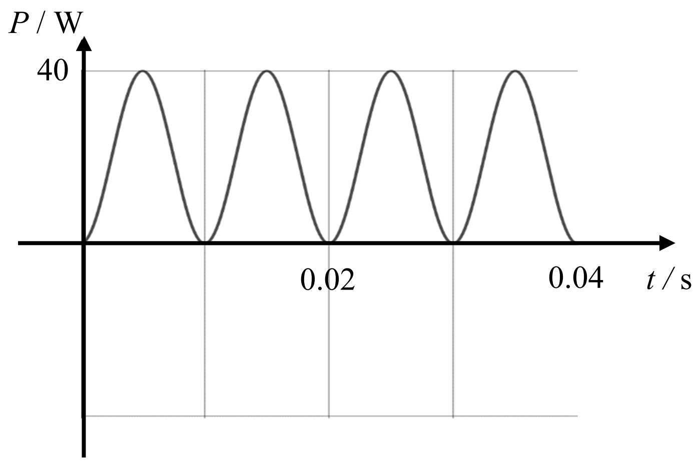
5	
(a)	
	In vertical equilibrium, the upward force (by balloon) is equal to the total downward forces. The downward forces on the toy are the weight of the toy and the tension due to the string on the toy. The tension is equal to the weight of the vertical part of the string.
(b)	
	Define upwards to be positive.
	Net force acting on the toy at the instant the toy is displaced downwards, $F_{net} = T - mg - \mu(h-z)g$ Applying Newton's second law, $ma = T - mg - \mu(h-z)g$
	Substituting the expression for T from (a), $ma = mg + \mu gh - mg - \mu(h-z)g$ $a = \frac{\mu g}{m} z$
	When the toy is displaced downwards, it experiences a net force and hence acceleration upwards.

	Therefore, acceleration is in opposite direction to displacement.
	$a = -\left(\frac{\mu g}{m}\right)z$
	OR
	Define downwards to be positive.
	Net force acting on the toy at the instant the toy is displaced downwards, $F_{\text{net}} = mg + \mu(h - z)g - T$ Applying Newton's second law, $ma = mg + \mu(h - z)g - T$
	Substituting the expression for T from (a), $ma = mg + \mu(h - z)g - mg + \mu gh$
	$a = -\frac{\mu g}{m}z$
(c)	$\omega^2 = \frac{\mu g}{m}$ $T = 2\pi\sqrt{\frac{m}{\mu g}}$
	$T = 2\pi\sqrt{\frac{50}{5.8 \times 9.81}}$
	$T = 5.89$ s (3sf)
(d)(i)	A decreases exponentially over time.
(d)(ii)	A smaller base surface area means the extent of damping is lesser. 
(d)(iii)	Each time the system is displaced downwards, the string collides inelastically with the ground.
	The system needs to do work against the force of the ground on the system resulting in further energy dissipated from the system.
	OR
	Air currents may drag the system across horizontally.
	The system needs to do work against frictional force resulting in further energy dissipated from the system.

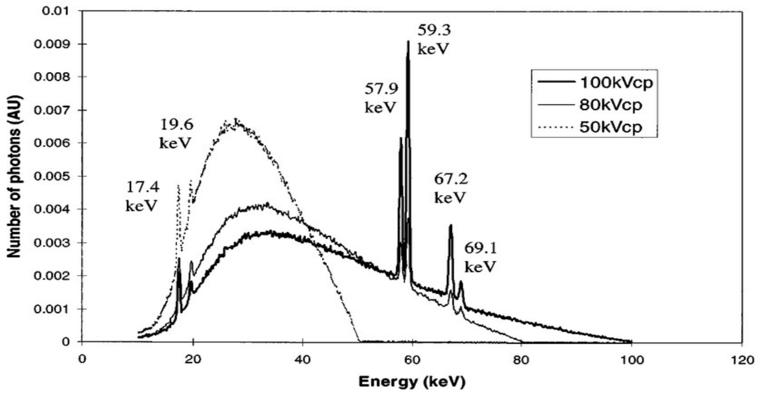
d/mm

	OR
	There is frictional force between the ground and the string.
	The system needs to do work against frictional force resulting in further energy dissipated from the system.
(e)(i)	
(e)(ii)	The only forces acting on the system are the upthrust on the balloon and the weight of the system. These are constant. Hence, the net upwards force is constant and the system will move upwards with constant acceleration.
6	
(a)(i)	 • evenly spaced arrows (5 lines) , • throughout region directed upwards, and • must be drawn with a ruler.
	For the electrons to be undelfected, • Resultant force on electrons = 0, • Electric force on electrons is directed out of the page.
	• Magnetic force must be into the page. By Fleming's left hand rule, magnetic field must be directed upwards.

(a)(ii)	For an undeflected beam, electric force = magnetic force $qE = Bqv\sin\theta$ $E = Bv\sin 90°$ $= (3.0\times10^{-3})(3.3\times10^{7})$
	$= 9.9\times10^{4}$ N C^{-1} (2sf)
(a)(iii)	Magnetic force provides centripetal force.
	$Bqv\sin\theta = \dfrac{mv^2}{r}$ $Bev\sin 90° = \dfrac{mv^2}{r}$ $\dfrac{e}{m} = \dfrac{v}{rB}$ $= \dfrac{3.3\times10^{7}}{(6.0\times10^{-2})(3.0\times10^{-3})}$
	$= 1.8\times10^{11}$ C kg^{-1} (2sf)
(b)(i)	• The alternating current in coil A produces a changing magnetic field experienced by coil B.
	• Hence, coil B experiences a rate of change of magnetic flux linkage, and • by Faraday's law, e.m.f. is induced in coil B.
(b)(ii)	The gradient of the tangent at this point is the largest, thus corresponds to the largest rate of change of magnetic flux linkage.
(b)(iii)	• Current in coil A varies with a cosine function, • magnetic flux density by coil A at coil B varies with a cosine function, $B = \mu_o n\,(I_o\cos\omega t)$ • magnetic flux linkage experienced by coil B varies with cosine function $\Phi = NBA = NA\mu_o n\,(I_o\cos\omega t)$
	By Lenz's law, the induced current in coil B will vary in a sinusoidal manner following a sine function following the variation of induced e.m.f. in coil B. $\varepsilon = -\dfrac{d\Phi}{dt}$ $= -NA\mu_o n\dfrac{d(I_o\cos\omega t)}{dt}$ $\varepsilon = +\,\varepsilon_0\sin\omega t$ $I = +\,I_0\sin\omega t$
	Therefore, phase difference between current in coil B and A is 1.57 rad OR 90° OR π/2 rad.

	OR
	According to the laws of EMI, $\varepsilon = -\frac{d\Phi}{dt}$ ➢ when gradient $\frac{d\Phi}{dt}$ is +ve, e.m.f. is –ve ➢ when the gradient $\frac{d\Phi}{dt}$ is –ve, e.m.f is +ve Hence, $\varepsilon = \varepsilon_\partial \sin\omega t$
(b)(iv)	Positive sine graph with the same period as current in coil A.
(c)(i)	 $P = \frac{V^2}{R} = \frac{(V_0 \sin\omega t)^2}{R}$ sine^2 graph for 2 complete cycles.
	Period = 0.02 s indicated.
	$P_{mean} = \frac{P_0}{2}$ $P_0 = 2(P_{mean}) = 2(20) = 40\,W$
(c)(ii)	$\frac{V_s}{V_p} = \frac{N_s}{N_p}$ $V_s = \frac{N_s}{N_p} V_p$ $= \frac{1}{50}(339)$ $= 6.78$ V
	$V_{rms} = \frac{V_s}{\sqrt{2}}$ $= \frac{6.78}{\sqrt{2}}$ $= 4.79$ V (3sf)

7	
(a)(i)1.	$E = hf = h\dfrac{c}{\lambda}$ $= \dfrac{6.63\times10^{-34}\left(3.00\times10^{8}\right)}{250\times10^{-9}}$ $= 7.96\times10^{-19}$ J $= 4.97$ eV
	$hf = hf_0 + eV_S$ $4.97 = hf_0 + 1.20$ $hf_0 = 3.77\ eV$
	$= 3.8\ eV$
(a)(i)2.	If <u>frequency/energy/wavelength of photon remains constant</u>,
	when <u>intensity changes</u>, implies that ONLY the <u>number of photons per unit time</u> arriving at the emitter <u>changes</u>.
	Using $hf = hf_0 + eV_S$ • As the electrode is the same, work function ϕ is constant. • Each photon imparts the same energy *hf* to each electron • eV_S remains the same, hence V_S remains the same.
(a)(ii)1.	Only one electrode is emitting photoelectrons.
	In (a)(i), there is current only the positive direction, implies only one electrode is emitting electrons. As work function of zinc (electrode X) is lower than 250 nm, electrons must be <u>emitted from X only</u>.
(a)(ii)2.	As the current flows in 2 directions, both <u>electrodes are emiting electrons</u>, which implies that photon energy is greater than the work functions of X and Z.
	<u>Negative values</u> of photocurrent is caused by photoemission <u>from Z</u>.
(b)(i)1.	Same characteristic peaks at higher wavelength.
	Same target (same element).
(b)(i)2.	More photons are produced over the continuous spectrum and peaks (higher intensity). OR A has a lower minimum wavelength.
	A has higher accelerating potential (electrons of A has higher kinetic energies).
(b)(ii)	From the graph, $\lambda_{min} = 16\times10^{-12}$ m
	$\frac{1}{2}mv^2 - 0 = qV \quad \cdots\cdots(1)$ $\frac{1}{2}mv^2 - 0 = hf_{max} \cdots\cdots(2)$ $qV = h\dfrac{c}{\lambda_{min}}$ $\left(1.60\times10^{-19}\right)V = \dfrac{6.63\times10^{-34}\left(3.00\times10^{8}\right)}{16\times10^{-12}}$
	$V = 77700\ V$

(b)(iii)	
	Energy difference of levels Tungsten : **A (57.4 keV), B (59.3 keV)** Molybdenum: **P (17.4 keV), Q (17.5 keV)**
(b)(iv)	In Fig. 7.4, The taller peaks **(57.9, 59.3)** is <u>similar to the energy difference of levels</u> of tungsten. (There is a small difference between calculations and the peaks in the graph due to uncertainties in measurements.) ➢ Target contains tungsten.
	The shorter peaks **(17.4)** <u>matches with the energy difference of levels</u> of molybdenum. (But the peak **(17.5)** is not shown. It is because the difference between 17.4 and 17.5 is very small and hence both may be <u>represented by just one peak</u>.) ➢ Target contains molybdenum.
	Since peaks due to tungsten is much taller than that of molybdenum, ➢ the targer is made of <u>mainly</u> tungsten and <u>less</u> molybdenum.