Anglo-Chinese Junior College

JC 2 Physics Preliminary Examination
Higher 2

A Methodist Institution
(Founded 1886)

PHYSICS **9749/01**

Paper 1 Multiple Choice

28 August 2018

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 in the spaces provided unless this has been done for you.

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 circle 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	=	$-\dfrac{Gm}{r}$
temperature,	T/K	=	$T/^{o}C + 273.15$
pressure of an ideal gas,	p	=	$\dfrac{1}{3}\dfrac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of of an ideal gas molecule,	E	=	$\dfrac{3}{2}kT$
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	=	$Anvq$
resistors in series,	R	=	$R_1 + R_2 + \ldots$
resistors in parallel,	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential,	V	=	$\dfrac{Q}{4\pi\varepsilon_o r}$
alternating current/voltage,	x	=	$x_o \sin \omega t$
magnetic flux density due to a long straight wire,	B	=	$\dfrac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil,	B	=	$\dfrac{\mu_o N I}{2r}$
magnetic flux density due to a long solenoid,	B	=	$\mu_o n I$
radioactive decay,	x	=	$x_o \exp(-\lambda t)$
decay constant.	λ	=	$\dfrac{\ln 2}{t_{1/2}}$

[Turn over

1 Anglo-Chinese Junior College's digital clock tower was restored in 2017.

What is its approximate height above the ground?

A 10 m **B** 30 m **C** 50 m **D** 100 m

2 Due to the random nature of radioactive decay, the count rate recorded by a Geiger-Muller tube is subject to statistical fluctuations. When the total count recorded from a source in a given time is *N*, the uncertainty is $\sqrt{N}$.

What is the number of counts taken to obtain a mean count rate precise to 0.1 %?

A 100

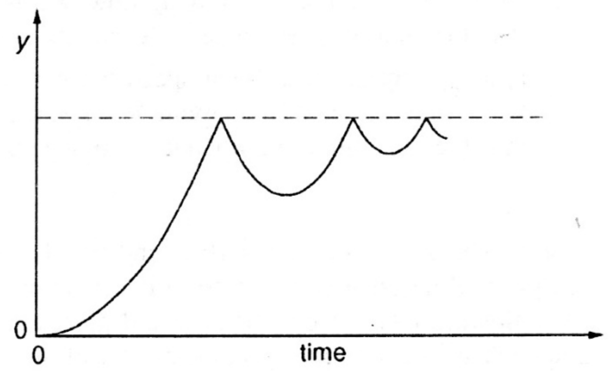
B 1000

C 10000

D 1000000

3 A ball is released from rest above a horizontal surface and bounces several times.

The graph shows the variation with time of quantity *y* for the ball.



What is quantity *y*?

A displacement from horizontal surface; taking upwards as positive

B displacement from horizontal surface; taking downwards as positive

C displacement from where ball is released; taking upwards as positive

D displacement from where ball is released; taking downwards as positive

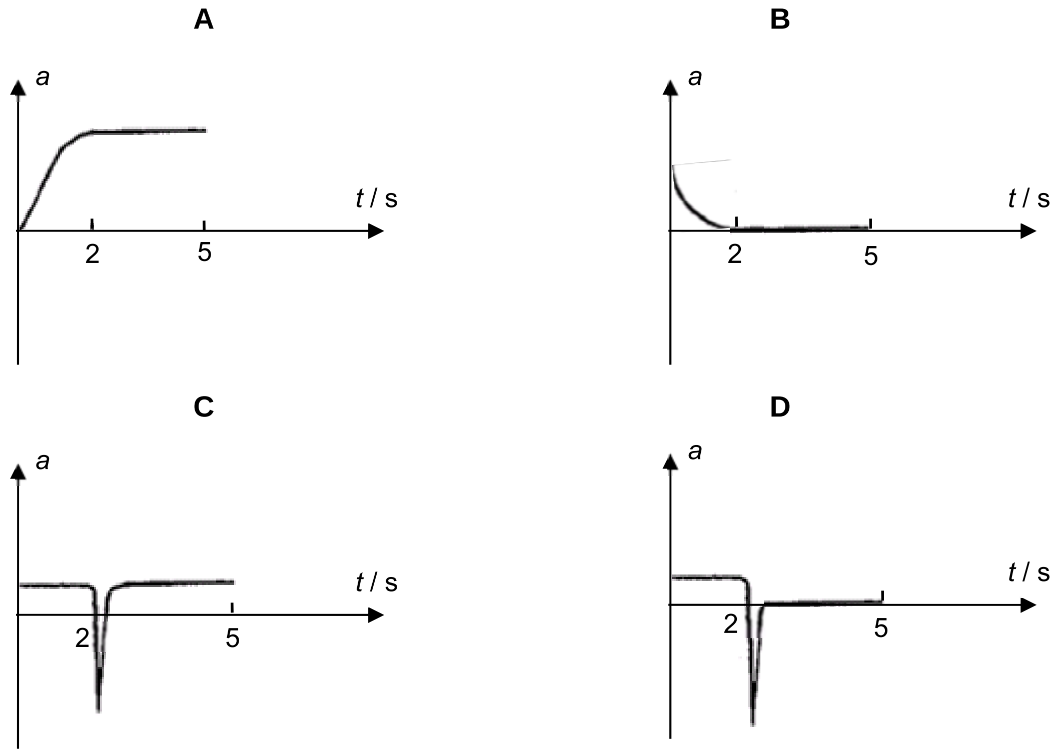
4 A student, standing on the platform of an MRT train station, notices that the first two carriages of an arriving train passes her in 2.00 s, and the next two carriages in another 2.40 s. The train is decelerating uniformly and each carriage is 20.0 m long.

What is the deceleration of the MRT train?

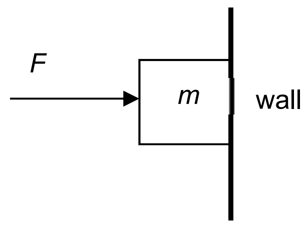
A 1.38 m s^{-2} **B** 1.52 m s^{-2} **C** 1.67 m s^{-2} **D** 3.33 m s^{-2}

5 A parachutist steps out from an aircraft, falls without air resistance for 2 s and then opens his parachute.

Which graph best represents the variation with time *t* of his vertical acceleration *a* during the first 5 s of his decent?



6 A block of mass *m* is held at rest by pushing it with a force *F* to prevent it from slipping.



What is the magnitude of the contact force exerted by the wall on the block?

A F

B mg

C $\sqrt{F^2 - (mg)^2}$

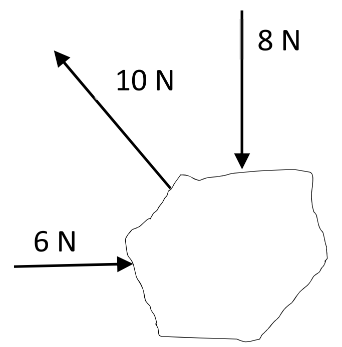
D $\sqrt{F^2 + (mg)^2}$

[Turn over

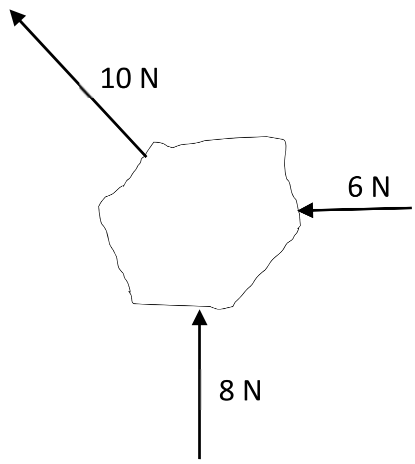
7 Three coplanar forces 10 N, 8 N and 6 N act on a flat object.

Which one of the following shows the flat object in equilibrium under the action of the forces?

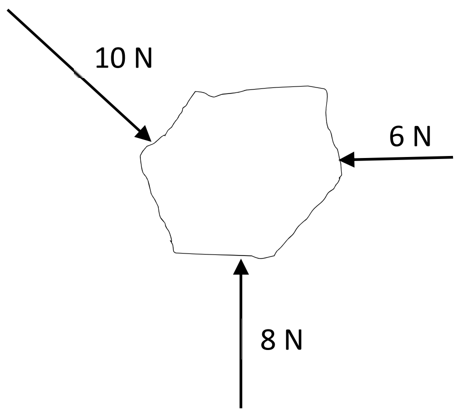
A



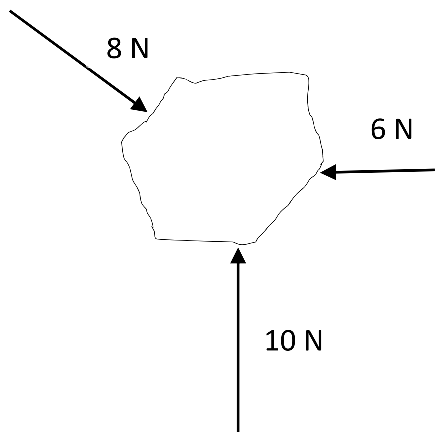
B



C

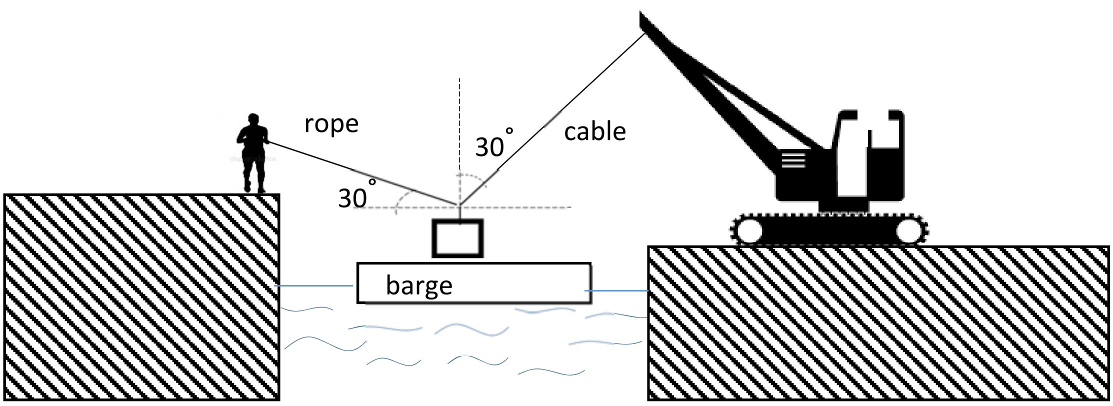


D



8 A mini-crane is used to load a crate weighing 600 N onto a barge. The man uses a rope and applies a force of 300 N to the rope.

What is the tension in the cable from the crane?

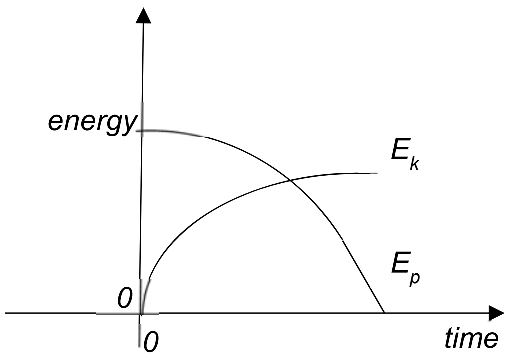


A 300 N **B** 520 N **C** 600 N **D** 690 N

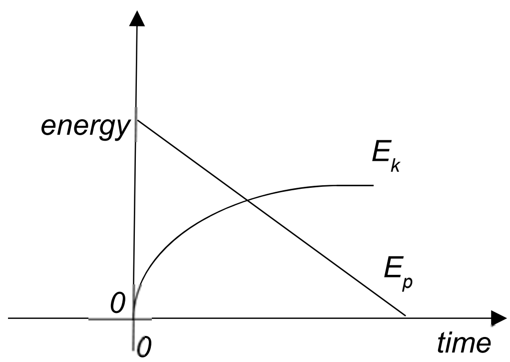
9 A steel ball is released at rest from the surface of oil in a tall cylinder so that it falls to the bottom of the cylinder.

Which graph shows variation with time of the gravitational potential energy, E_p and the kinetic energy, E_k of the ball?

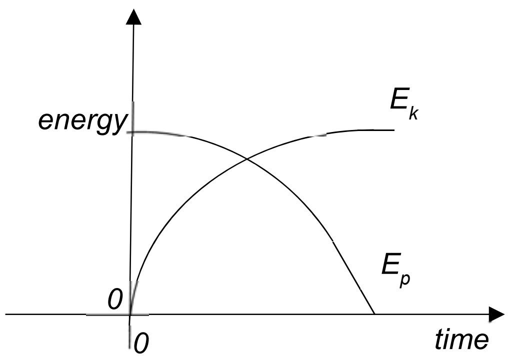
A



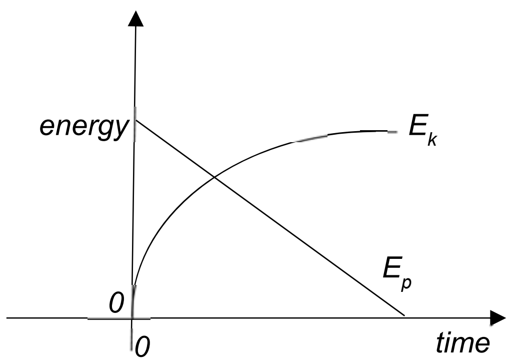
B



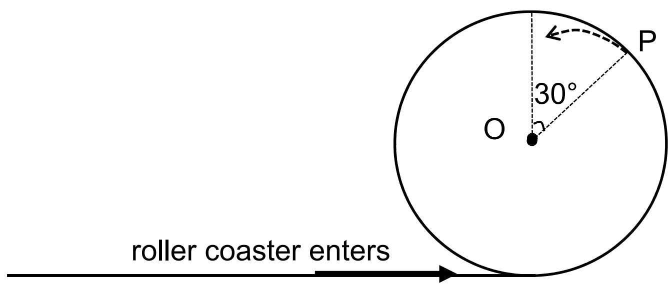
C



D



10 A toy roller coaster attempts a loop-a-loop. It enters the bottom of loop of radius 1.0 m with insufficient speed. It loses contact at the point P as shown. The line joining P and the centre of the loop O makes an angle 30° with the vertical.

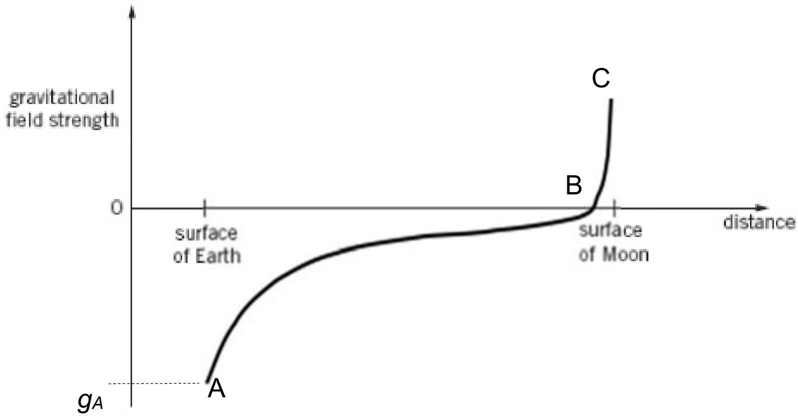


What is the speed at P which the roller coaster just loses contact with the loop?

A 0 m s^{-1} **B** 2.2 m s^{-1} **C** 2.9 m s^{-1} **D** 3.1 m s^{-1}

[Turn over

11 The diagram below shows the variation with distance between the surface of the Earth A and the surface of the Moon C of gravitational field strength. A mass m is at different positions between the Earth and Moon surface.



Which of the following statement is true?

A At A, mg_A gives the gravitational force due to Earth on m on Earth's surface.

B At B, the gravitational potential energy of m is maximum.

C At B, no force acts on mass m.

D At C, the gravitational potential energy of m is positive.

12 Escape velocity from a planet surface is the minimum speed needed for an object at the planet surface to be projected to leave the gravitational influence of the planet.

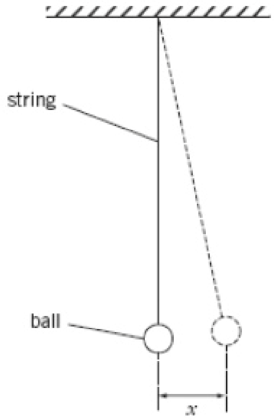
Given that:

$\dfrac{\text{mass of Earth}}{\text{mass of Moon}} = 81, \quad \dfrac{\text{radius of Earth}}{\text{radius of Moon}} = 3.7$

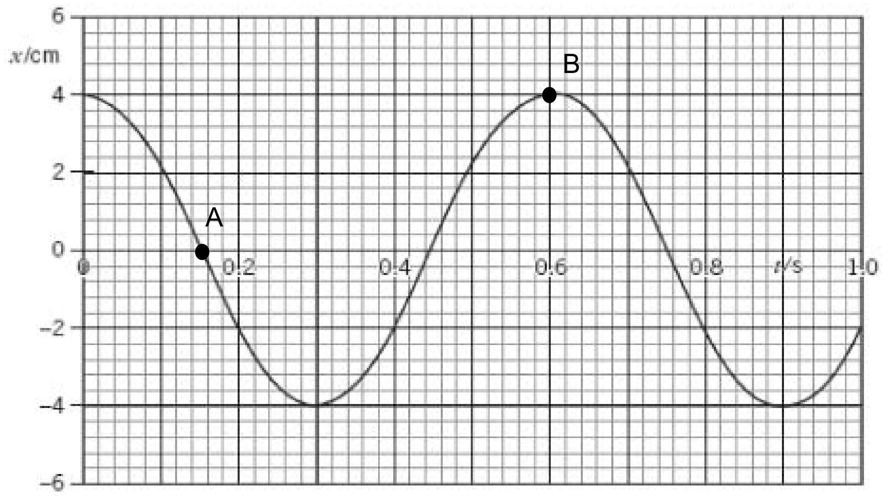
What is the ratio of $\dfrac{\text{escape velocity from Earth surface}}{\text{escape velocity from Moon surface}}$?

A 0.21 **B** 4.7 **C** 22 **D** 480

13 A small metal ball is suspended from a fixed point using a string as shown.



The ball is pulled a small distance to one side and then released. The variation with time *t* of the horizontal distance displacement *x* of the ball is shown below.



Which of the following statement is not true?

A At A, the kinetic energy of the ball is maximum.

B At A, the tension on the string is minimum.

C At B, the ball is instantaneously at rest.

D At B, the ball experiences the greatest restoring force.

14 An ideal gas is contained in a metal box. Which is not true?

A Increasing the temperature of the gas will increase the rate of collision of the gas molecules with the wall.

B Decreasing the internal energy of the gas will decrease the change of momentum of the gas molecules when it hit the walls.

C Increasing the dimensions of the box will increase the frequency of collision of the gas molecules with the walls.

D The speeds of the gas molecules are different but the pressure of the gas on the walls for the same temperature is constant.

[Turn over

15 Which property of a substance takes into account atmospheric pressure significantly?

A specific latent heat of fusion

B specific latent heat of vapourisation

C specific heat capacity of solid

D specific heat capacity of liquid

16 Two coherent waves from a double-slit meet on the screen to form an interference pattern.

What is the phase difference of the two waves at the second-order minima?

A 0 rad

B 3.14 rad

C 6.28 rad

D 9.42 rad

17 The following observations are recorded:

Intensity of unpolarised light = *X*
Intensity of polarised light after passing through first polaroid = *Y*
Intensity of polarised light after passing through second polaroid whose polarising axis is 30° to the first polaroid = *Z*

Which row give the correct intensity of *X*, *Y* and *Z*?

	X	*Y*	*Z*
A	I_o	I_o / 2	0.75 I_o
B	I_o	I_o	0.75 I_o
C	$2I_o$	I_o	0.75 I_o
D	$2I_o$	I_o / 2	0.375 I_o

18 Two blue dots of 5 mm diameter are projected on a screen. The distance between the two dots is 7 mm. A student who is facing the screen takes a few steps backwards and stops walking when she could just resolve the two dots.

The student wishes to still resolve the two dots by standing further back from the screen. What should she do?

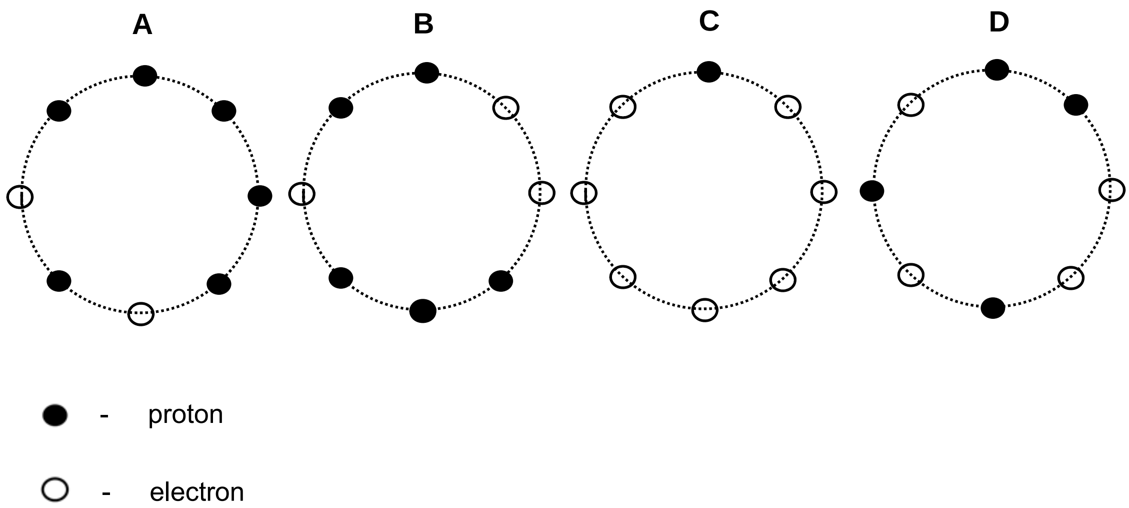
A darken the room to increase the size of the pupil of the eye.

B change the colour of the two dots from blue to red.

C make the blue dots slightly brighter.

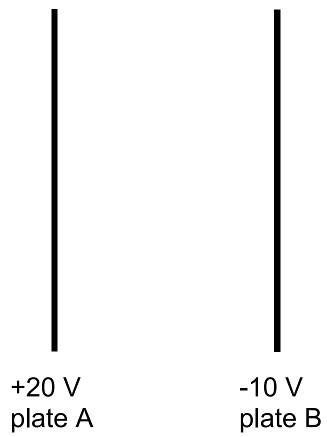
D make the two dots closer.

19 A combination of eight electrons and protons are fixed in place and evenly spread along the circumference of circle as shown.



Which of the above combinations has the smallest magnitude of resultant electric field strength at the centre of the circle?

20 Two long parallel plates spaced a distance 30 cm apart have electric potential of +20 V and –10 V respectively as shown.



Which statement is correct?

A At any point which is 20 cm to the right of plate A, work done by external agent per unit charge to bring a small positive test point charge from infinity to that point is non-zero.

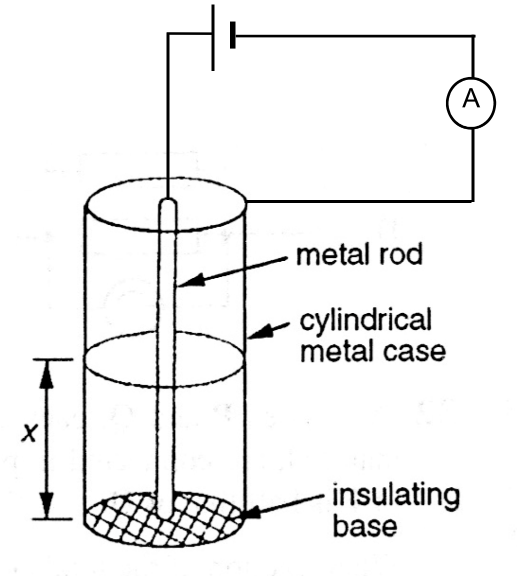
B The electric field strength within the two plates is 1 V m^{-1} and it is directed towards plate B.

C An electron placed at 10 cm to the left of plate B will gain 20 eV of electric potential energy when it reaches plate A.

D When the plates are connected to both ends of a resistor, the electric field strength within the two plates will become zero.

[Turn over

21 An electrical circuit is connected to a cylindrical metal case with an insulating base as shown. Conducting liquid fills the case to a depth of x.



How does the current I in the ammeter vary as x changes?

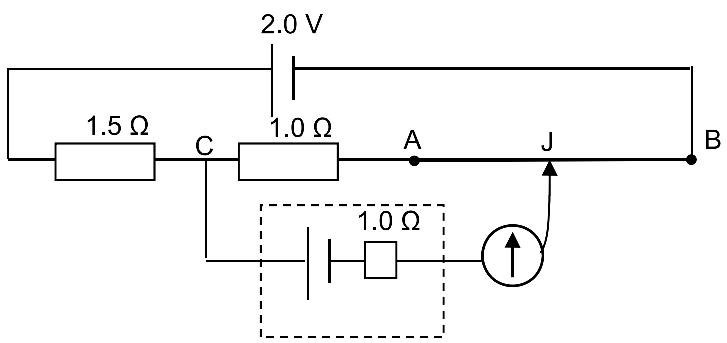
A $I \propto x$

B $I \propto x^2$

C $I \propto \frac{1}{x}$

D $I \propto \frac{1}{x^2}$

22 The diagram below shows a potentiometer circuit in which the wire AB is 100.0 cm long and has a resistance of 5.0 Ω. The e.m.f of the driver cell is 2.0 V and e.m.f of the cell with an internal resistance 1.0 Ω of connected between C and J is 1.5 V. At point J, there is no deflection in the galvanometer.

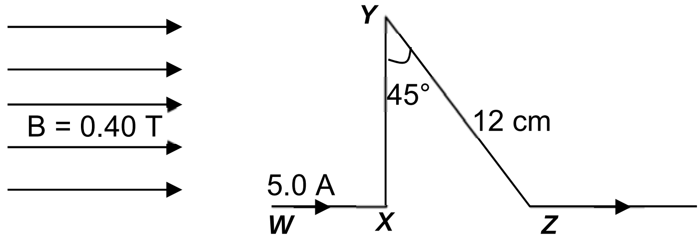


What is the balance length AJ?

A 7.5 cm **B** 20.0 cm **C** 80.0 cm **D** 92.5 cm

23 A current of 5.0 A is flowing in the wire as shown in the diagram below.

Given that the magnetic flux density is 0.40 T, what is the force on the portion YZ of the wire?



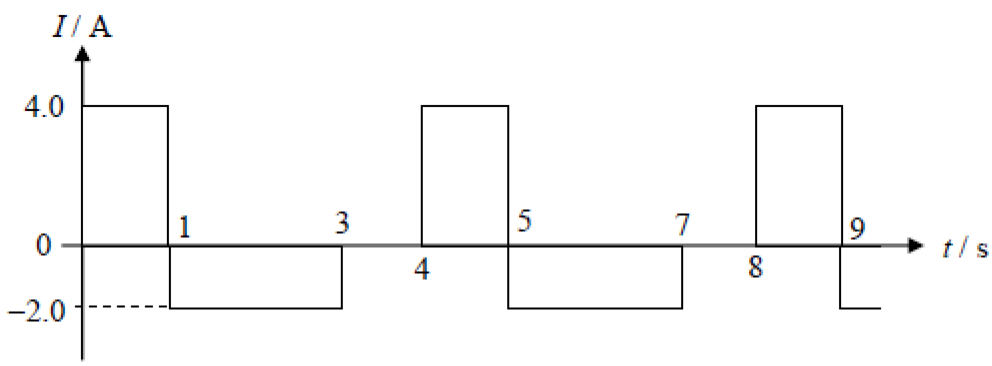
	Force	Direction
A	0.17 N	Into the page
B	0.17 N	Out of the page
C	0.24 N	Into the page
D	0.24 N	Out of the page

24 A particle X of charge 2*q* is moving in a uniform magnetic field of flux density *B* in a circle of radius *r* at a speed *v*. Another particle Y of charge *q* has the same mass as X and moves at the same speed as X.

What is the flux density required for Y to move in a circle which has half the radius of the circle moved by X?

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

25 An alternating current with a rectangular waveform as shown below flows through an 11 Ω resistor.

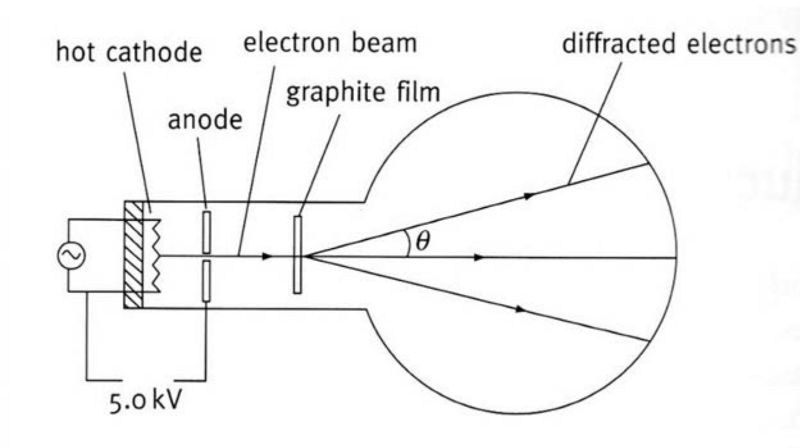


What is the average power dissipated by the resistor?

A 0 W **B** 44 W **C** 66 W **D** 88 W

[Turn over

26 A diagram shows a simplified setup of electron tube to demonstrate electron diffraction. The electrons are diffracted by angle θ. Diffraction rings appear on the screen.



The potential difference between the cathode and anode is increased from 5.0 kV to 10 kV.

Which of the following statement is false?

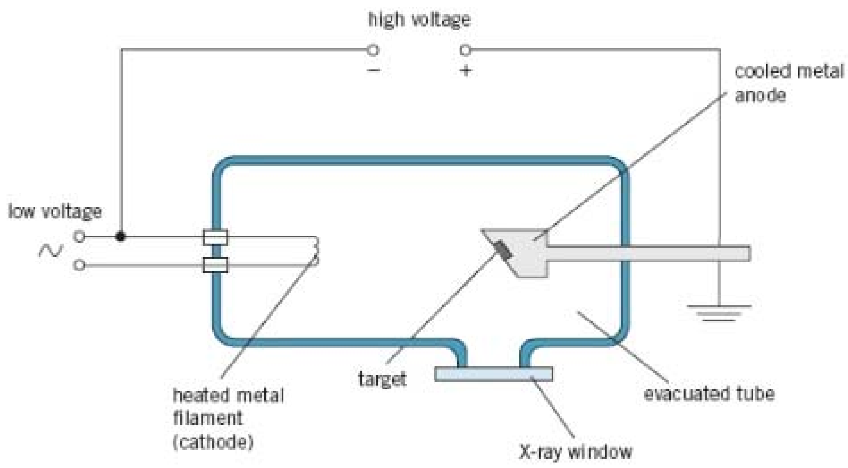
A The velocity of electrons hitting the graphite film increases.

B The diffracted angle θ decreases.

C The brightness of the central ring increases.

D The de Broglie wavelength of the electrons from the anode increases.

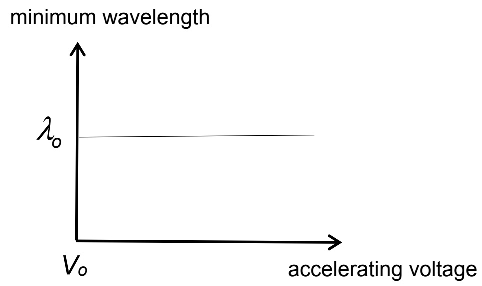
27 In an X-ray tube shown, the high voltage supply accelerates the electrons towards the target. X-rays with a range of wavelengths are emitted from the target.



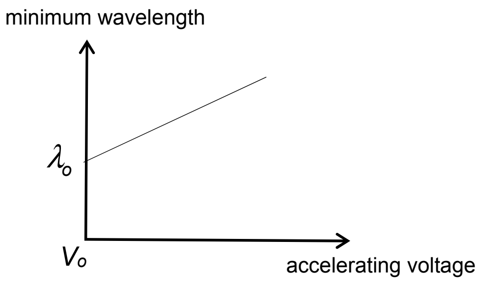
When the high voltage supply is V_o, the minimum wavelength of the x-ray emitted is λ_o.

Which of the following graph shows the variation with accelerating voltage of the minimum wavelength emitted?

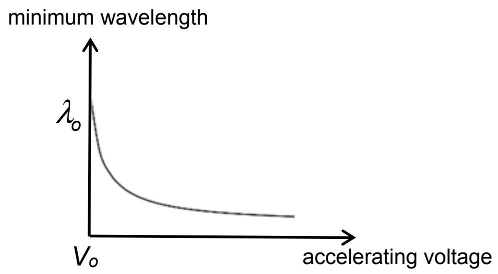
A



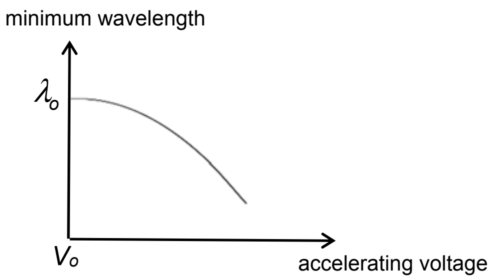
B



C



D



[Turn over

28 In a photoelectric emission experiment, ultra-violet radiation of 210 nm is incident on a piece of metal of surface area 2.0 cm^{2}. A photocurrent of 2.1 μA is detected at the electrode.

If, on average, one electron is ejected for every 10^5 photons reaching the surface, what is the intensity of the ultra-violet radiation incident on the surface?

A 2.5×10^{-4} W m^{-2}

B 6.2×10^{-2} W m^{-2}

C 1.2 W m^{-2}

D 6.2×10^{3} W m^{-2}

29 Uranium – 238 $^{238}_{92}U$ undergoes a series of radioactive decay to form various daughter products. X is produced after Uranium – 238 emitted 4 α and 2 β decays.

What is the number of neutrons and protons in X?

	Neutron number	Proton number
A	136	86
B	136	94
C	222	86
D	222	94

30 After 100 days, 10 % of a radioactive sample of $^{232}_{90}Th$ has decayed.

How many half-lives have elapsed?

A 0.15 **B** 0.20 **C** 3.3 **D** 660

1	2	3	4	5	6	7	8	9	10
B	D	D	B	D	D	A	B	A	C
11	12	13	14	15	16	17	18	19	20
B	B	B	C	B	D	C	A	D	D
21	22	23	24	25	26	27	28	29	30
A	D	B	D	C	D	C	D	A	A

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 **9749/04**

Paper 4 Practical

1 August 2018

2 hours 30 mins

Candidates answer on the Question Paper.
Additional Materials: as listed In the Confidential Instructions

READ THESE INSTRUCTIONS FIRST

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

Answer **all** questions.

Write your answers in the spaces provided on the question paper.
The use of an approved scientific calculator is expected, where appropriate. You may lose marks if you do not show your working or if you do not use the appropriate units.

Give details of your practical shift and laboratory, where appropriate, in the boxes provided.

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.

Shift
Laboratory

For Examiners' use only	
1	/ 11
2	/ 10
3	/ 22
4	/ 12
Total	/ 55

For Examiner's Use

1 In this experiment, you will investigate how the time of swing of masses depends on its distance from the pivot.

(a) **(i)** Measure the length l of the PVC tube.
Use the vernier caliper for this measurement.

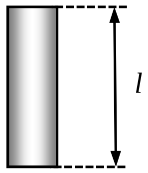


Fig. 1.1

l = ……………………………. [1]

(ii) Explain how you have made this measurement as accurate as possible.

……………………………………………………………………………………

……………………………………………………………………………………

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

(b) Set up the apparatus as shown in Fig. 1.2.

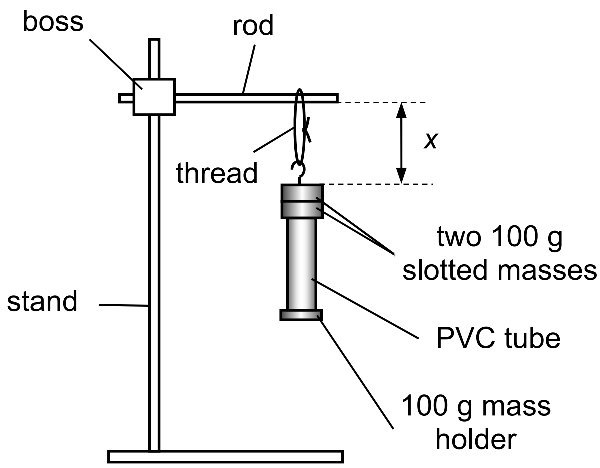


Fig. 1.2

For Examiner's Use

(i) Using the half-metre rule, measure the length x.

x = …………………………….. [1]

(ii) Estimate the percentage uncertainty in your value of x.

percentage uncertainty = …………………………….. [1]

(c) Displace the mass holder, as shown in Fig. 1.3. Ensure that the plane of oscillation is parallel to the rod on which the string pivots.

Release the tube.

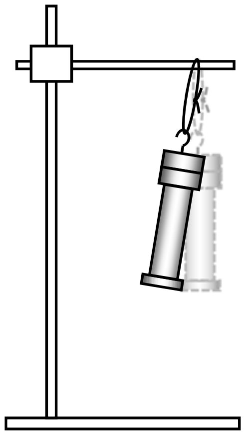


Fig. 1.3

Determine a value for the period of oscillation T.

T = …………………………….. [2]

[Turn over

For Examiner's Use

(d) Remove the PVC tube from the setup while keeping the two 100 g slotted masses on the mass holder as shown in Fig. 1.4.

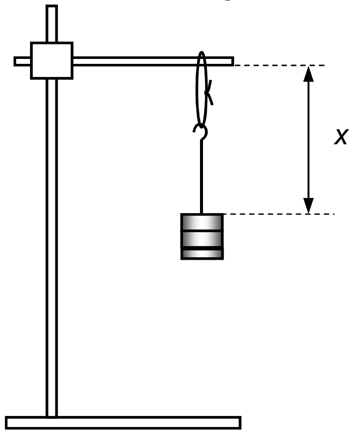


Fig. 1.4

(i) Using the value in **(a)(i)**, calculate x as shown in Fig. 1.4. Give your answer to an appropriate number of decimal places.

x = ……………………………….. [1]

(ii) Repeat **(c)** to obtain a second value of T.

T = ……………………………….. [1]

For Examiner's Use

(e) It is suggested that T and x are related by the equation

$$T^5 = k\,x$$

where k is a constant.

(i) Use your values from **(b)(i)**, **(c)** and **(d)** to determine two values for k. Give your values for k to an appropriate number of significant figures.

first value for k = ……………………………......

second value for k = …………………………………
[1]

(ii) State whether the results of your experiment support the suggested relationship.

Justify your conclusion by referring to your value in **(b)(ii)**.

……………………………………………………………………………………

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……………………………………………………………………………………

…………………………………………………………………………………… [2]

[Total: 11 marks]

For Examiner's Use

2 In this experiment you will investigate how the current flowing through a semiconductor diode varies as the potential difference across it and the temperature are changed.

(a) **(i)** Set up the circuit as shown in Fig. 2.1. The rheostat, 2 V cell and switch has been set up for you.

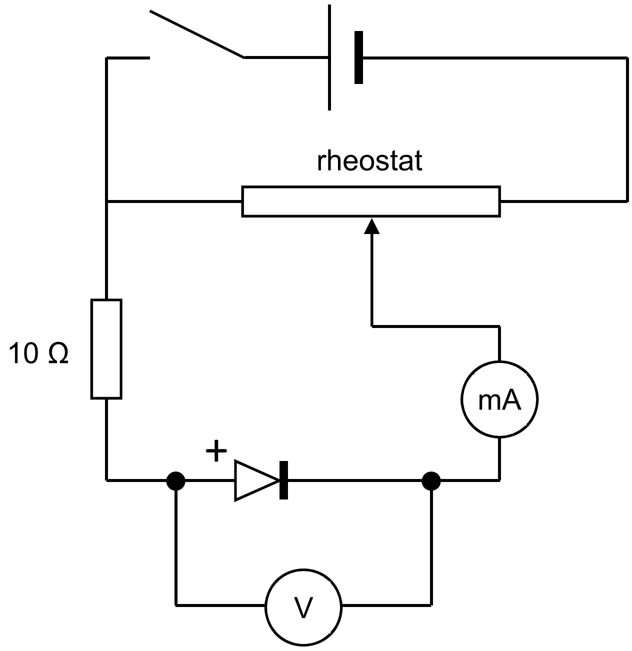


Fig. 2.1

(ii) Place one of the foam cups into the glass beaker. Use this to collect hot water from the water boiler.

(ii) Pour the hot water into the other foam cup until it is about a quarter filled.

(iii) Add some tap water until the temperature of the water is about 65 °C.

Record the temperature of the water *T*.

T = …………………………….. [1]

(b) **(i)** Place the diode in the water.

(ii) Close the switch.

For Examiner's Use

(iii) Adjust the rheostat such that the potential difference across the diode is 0.70 V.

Measure and record the current I flowing through the circuit.

I = ………………………….. [1]

(iv) Open the switch.

(c) **(i)** Pour away the hot water and fill the foam cup with tap water.

Record the temperature of the water, T.

T = ……………………………...

(ii) Repeat **(b)**.

I = ………………………….. [1]

(d) When the experiment is conducted with constant temperature, current I is related to the potential difference V by the expression,

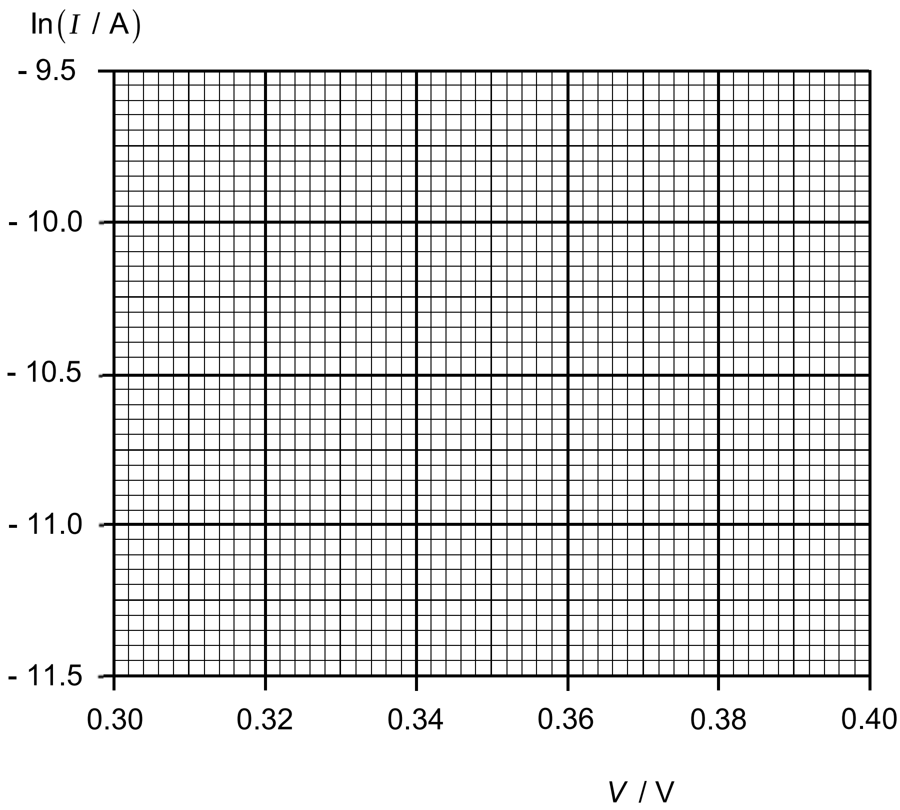
$$I = I_0 \exp\left\{\frac{eV}{kT}\right\}$$

where k is the Boltzmann constant (=1.38 x 10^{-23} J K^{-1}), e is the elementary charge, T is the temperature in kelvin, and I_0 is a constant.

The table shows the results from an experiment done with the diode kept at 60 °C.

V / V	I / x 10^{-6} A	$\ln(I$ / A$)$
0.31	10.3	- 11.48
0.33	17.4	- 10.96
0.34	22.3	- 10.71
0.35	27.7	- 10.49
0.36	37.6	- 10.19
0.37	47.1	- 9.96

(i) Plot the points on the grid and draw a straight line of best fit. [2]



For Examiner's Use

(ii) Determine the gradient and y-intercept of the line.

gradient = ...

y-intercept = ...

[3]

(iii) Determine the value I_0 and *e*.

I_0 = ...

e = ...

[1]

(iv) The experiment is repeated at a higher temperature.

Assuming that I_0 remains the same, sketch a new line in part **(d)(i)** that would represent this set of results. [1]

[Total: 10 marks]

[Turn over

For Examiner's Use

3 In this experiment, you will investigate the equilibrium of a rod supported by a spring.

(a) Measure and record the length l_0 of the unstretched spring, as shown in Fig. 3.1.

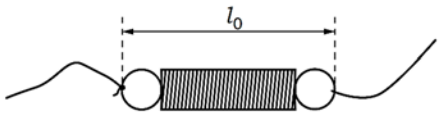


Fig. 3.1

l_0 = …………………………….. [1]

(b) Set up the apparatus as shown in Fig. 3.2.

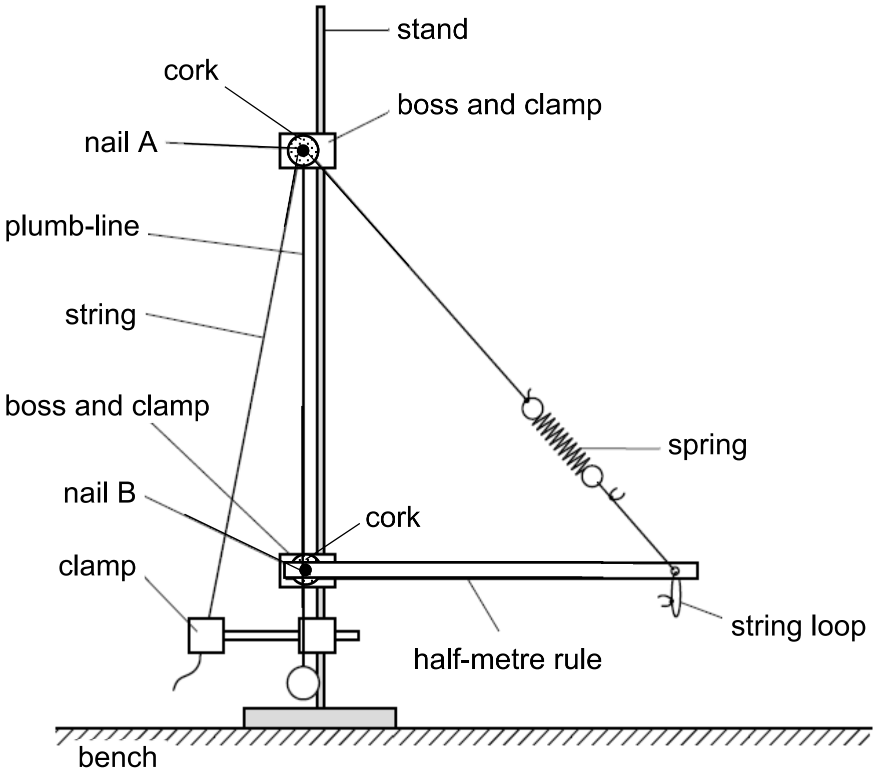


Fig. 3.2

The string loop, spring and string has been connected to one end of the half-metre rule. Nail B and a cork are already attached to the other end of the half-metre rule.

For Examiner's Use

(c) **(i)** Suspend the mass holder *M* from the string loop.

(ii) Adjust the string in the clamp such that the half-metre rule is horizontal again.

(iii) Use the plumb-line to ensure that nail B is vertically below nail A, as shown in Fig. 3.3.

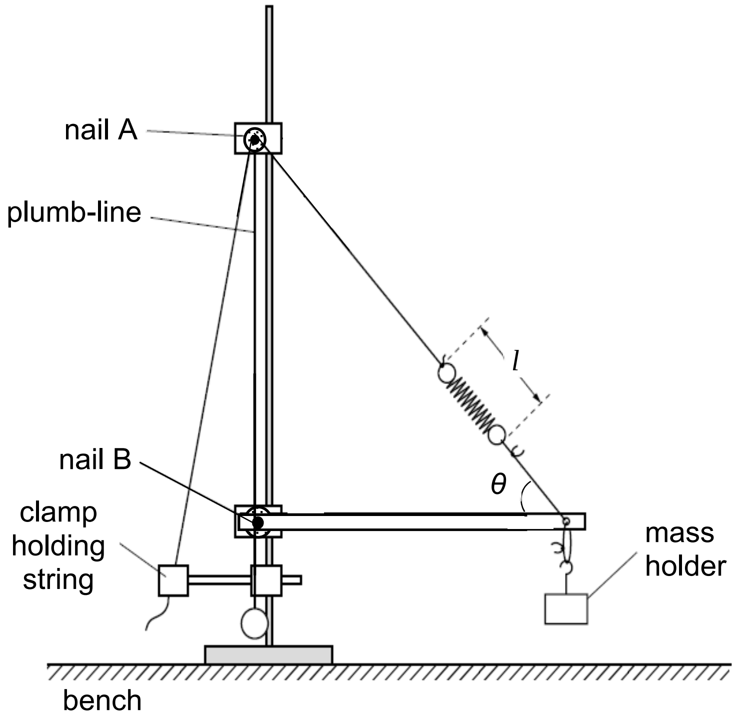


Fig. 3.3

(iv) Measure and record the angle θ between the half metre-rule and the string, and the length l of the spring.

θ = ...

l = ...

(v) Calculate e where $e = l - l_0$.

e = ... [1]

[Turn over

For Examiner's Use

(d) **(i)** Raise nail B by shifting the boss and repeat **(c)** to obtain further values of θ and *e*.

Include the values for $\tan\theta$.

[6]

(ii) Plot a graph of *e* against $\tan\theta$. Draw a curve through your points. [3]

(iii) Determine the gradient of the curve at θ = 30°.

gradient = ……………………………… [2]

For Examiner's Use

For Examiner's Use

(e) **(i)** Suggest **two** significant sources of error in this experiment.

1 ………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

2 ………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

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

(ii) Suggest **two** improvements that could be made to the experiment to address the errors identified in **(e)(i)**. You may suggest the use of other apparatus or different procedure.

1 ………………………………………………………………………………………

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………………………………………………………………………………………

2 ………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

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

For Examiner's Use

(f) An engineer is designing a draw bridge that has a similar design to the set up in **(b)**, where a rope is used to support the bridge. The engineer has access to various materials and wants to determine the most suitable material for the rope.

Plan an investigation to determine which material can withstand the highest tension before breaking.

Your account should include:

- your experimental procedure
- details of the table of measurements with appropriate units
- how you would determine the highest tension before breaking.

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…………………………………………………………………………………………. [5]

[Total: 22 marks]

For Examiner's Use

4 Glass has a resistivity of the order of $10^{14}\ \Omega\ \text{m}$ which is very large.

A student wishes to investigate how the resistance of glass varies with its dimensions. It is suggested that the resistance *R* of the glass is related to its cross-sectional area *A* and its length *l* by the equation

$$R = k A^x l^y$$

where *k, x* and *y* are constants.

You are provided with sheets of glass of varying dimensions.

Design an experiment to determine the values of *k, x* and *y.*

You should draw a diagram showing the arrangement of your apparatus and you should pay particular attention to

(a) the procedure to be followed
(b) the control of variables
(c) how the data would be analysed
(d) any precautions that should be taken to improve the accuracy and safety of the experiment.

Diagram

For Examiner's Use

[Turn over

For Examiner's Use

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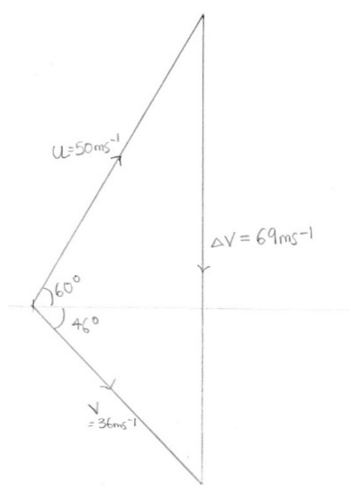
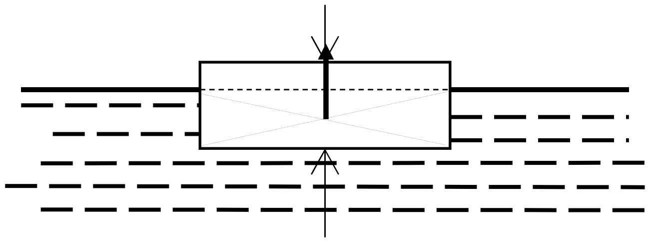
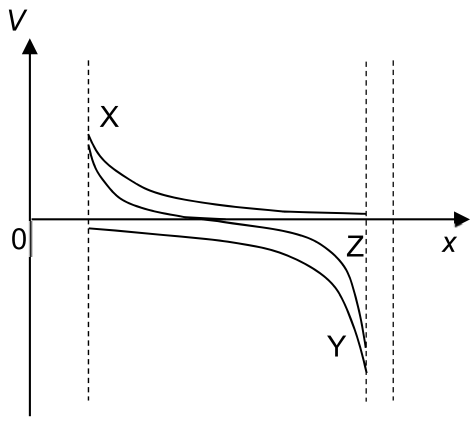
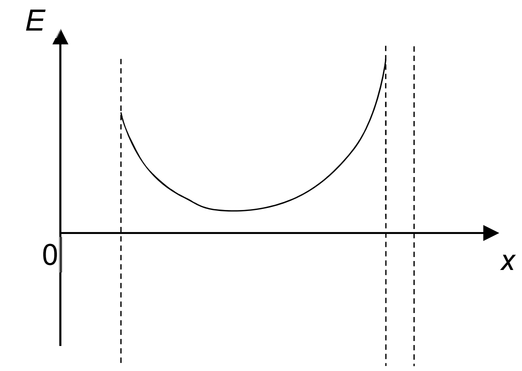
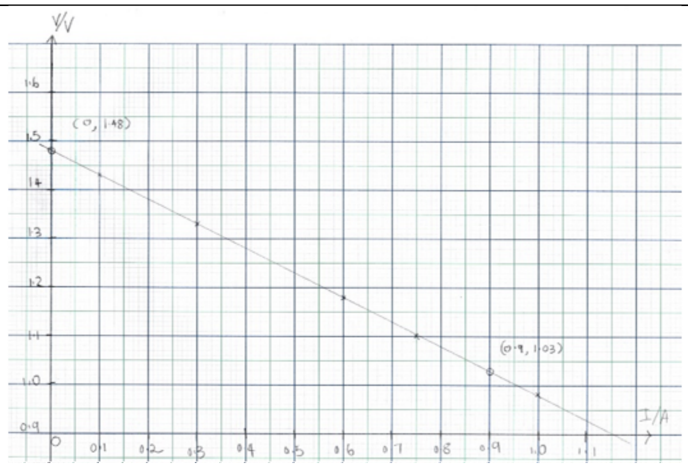
…….. [12]

[Total: 12 marks]

1	
(a)	Random errors: Above and below true value / no fixed pattern / different sign Systematic errors: Above or below true value / with a fixed pattern / same sign
	Random errors: Different magnitude / amount Systematic errors: Same magnitude / amount
(b)(i)	T = 1.41923 s
	$\pm\Delta T = \pm 0.01008$
	T = 1.42 ± 0.01 s
(b)(ii)	There is error due to human reaction time, large number of oscillations will reduce the effect of the (absolute) uncertainty on the calculation of T.
(b)(iii)	• Uneven radius of the Earth • Non-uniform density of the Earth (circulating magma current in the Earth core)
2	
(a)	$u_x = \frac{220}{8.8} = 25 \text{ m s}^{-1}$
	$u_y = 43.164 \text{ m s}^{-1}$
	$\tan\theta = \frac{43.164}{25}$ $\theta = 59.9^\circ \ (1dp)$
	$u = 50 \text{ m s}^{-1} \ (2sf)$
(b)(i)	*change in velocity*, Δv $= 69 \text{ m s}^{-1} \ (2sf)$
	
(b)(ii)	magnitude of v = $(36 \pm 2) \text{ m s}^{-1}$ direction: $(46 \pm 2)^\circ$ below horizontal

3	
(a)	Any object immersed in a fluid will experience an upthrust whose magnitude is equal to the weight of the fluid displaced by the object.
(b)(i)	Resultant force = upthrust
	= 1165.428 N = 1200 N (2sf)
(b)(ii)	 Correct point of origin and having magnitude equal to difference in length of the two arrows
(b)(iii)	By Principle of floatation, $\rho_{block} V_{block} g = \rho_{water} V_{disp} g$
	ρ_{block} = 730 kg m^{-3} (2sf)
(b)(iv)1	$r_{water}V_{block}g - r_{block}V_{block}g = r_{block}V_{block}a$
	a = 4.9 m s^{-2} (2sf)
(b)(iv)2	$s = \frac{1}{2}at^2$
	= 0.20 s (2sf)
(b)(iv)3	As block moves up, viscous drag acts on the block downwards,
	reducing the net force / acceleration upwards on the block. Time taken is longer.
4	
(a)(i) **(a)(ii)** **(a)(iii)**	
	Correct general shape for X and Y
	Show an understanding that the resultant potential is a **scalar** sum of the potential due to the individual charges.

(b)	
	U shaped graph
	Show an understanding that the resultant field strength is the **negative gradient** of the potential graph.
(c)	For charge to be stationary, net force = 0 $\lvert E_{+q} \rvert = \lvert E_{-2q} \rvert$
	Let the distance of the point from +*q* charge be *r*. $\frac{q}{4\pi\varepsilon_0 r^2} = \frac{2q}{4\pi\varepsilon_0 (d+r)^2}$
	$r = 2.41\ d$ (3sf)
5	
(a)(i)	current = $\frac{\text{total charge}}{\text{time}}$
	$= \frac{\text{n x A} \times L \text{ x } e}{\text{time}}$
	$= nAve$
(a)(ii)	$I = nAve,\ v \propto \frac{1}{n(\text{diameter})^2}$
	= 0.24 m s^{-1} (2sf)
(b)(i)	
	
	Since, $V = E - Ir$, $V = -rI + E$ intercept = E = 1.48 V
	gradient = $\frac{1.48 - 1.03}{0.00 - 0.90} = -0.50$
	$r = 0.50\ \Omega$

(b)(ii)	As temperature increases, resistance of thermistor decreases.
	The effective resistance of the circuit decreases. Current increases, causing terminal potential difference to decrease.
	Since $P = \frac{V^2}{R}$, power output of resistor R decreases.
6	
(a)	Nucleus is very small compared to atom.
	The nucleus is positively charged.
	Only a small proportion of α-particles approach close to the nucleus. Electrostatic repulsion gives a large deflection.
(b)(i)	A: nucleon number = 1; proton number = 1
	B: nucleon number = 3; proton number = 1
(b)(ii)	Slow moving nuclides would not have sufficient kinetic energy to overcome large/strong electrostatic repulsion between the two nuclides.
(b)(iii)	Mass defect = 0.00240 *u*
	Binding energy = 3.5856×10^{-13}
	Binding energy per nucleon = 1.7928×10^{-13} J
	= 1.1 MeV (2sf)
(c)(i)	Mean time taken for half the number of Sodium-24 present to decay / disintegrate.
(c)(ii)	$A = A_o e^{-\lambda t}$
	A = 1979.26187 disintegrations per minute Volume of blood = 1979.26187 / 0.50
	= 4000 cm^3 (2sf)
	OR $A = A_o e^{-\lambda t}$
	A_o = 3.03143 disintegrations per minute Volume of blood = 12000 / 3.03143
	= 4000 cm^3 (2sf)
(c)(iii)	Short half-life of Sodium-24 makes it suitable for use as it does not stay in the body for a long period of time.
7	
(a)	• Lower emission of greenhouse gases • Does not require petrol as fuel (use less non-renewable energy sources) • Quieter engines
(b)(i)	$a = v - u / t$ $= 2.72166$
	$s = v^2 - u^2 / 2a$ = 320 m (2 sf)
(b)(ii)1.	Units of C_d = Units of $(F_d / \rho v^2 A)$ = 1

(b)(ii)2.	Power = *Fv*
	= 1000 W (2 sf)
(c)(i)	0.28
(c)(ii)	Kinetic energy of car to electrical energy of generator to (chemical) potential energy of battery
(c)(iii)	Increase in efficiency = (0.08 * 0.80 * 0.90)
	= 0.06 (1sf)
(d)(i)	Energy stored per unit mass of the battery
(d)(ii)	Mass of battery = (30 x 1000 / 140) / 48 x 4 1.1 kg (2sf)
(d)(iii)	Time = Energy / Power = 4.3 hours (2sf)
(d)(iv)1	69.86 %
(d)(iv)2	Point plotted to half smallest square
(d)(iv)3	Best-fit line drawn
(d)(iv)4	*P* = 77.75 - 78.25 %
(e)(i)	• Electric cars consume electricity in charging which produces CO_2 at the point of power generation • Production of components of car may produce CO_2
(e)(ii)	CO_2 emission in 1 charge = 0.4 x 30 x 1000 = 12000 g
	Emission rate = 12000 / 172 = 69.76744 g km^{-1} Band A1

Anglo-Chinese Junior College

JC 2 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

23 August 2018

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.
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 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	/ 16
2	/ 12
3	/ 10
4	/ 8
5	/ 14
Total	/ 60
Section B	
6	/ 20
7	/ 20
Grand Total	/ 80

For Examiner's Use

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

Section A

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

1 (a) A soldier fires his semi-automatic rifle in a stationary position as shown in Fig. 1.1. Each bullet has a mass of 15 g and it leaves the gun with a velocity of 700 m s^{-1}.

Fig. 1.1

(i) If the rifle weighs 4.5 kg, calculate the velocity of the rifle when he fires a single shot.

velocity = ……………………….. m s^{-1} [2]

(ii) If the soldier now fires 10 bullets horizontally in 2.0 s, calculate the average force exerted by the bullets on the rifle.

average force = ……………………….. N [3]

For Examiner's Use

(b) Two balls X and Y having the same mass of 160 g collide head-on with each other as shown in Fig. 1.2.

Fig. 1.2

The graph in Fig. 1.3 shows the momentum of the balls before, during and after the collision.

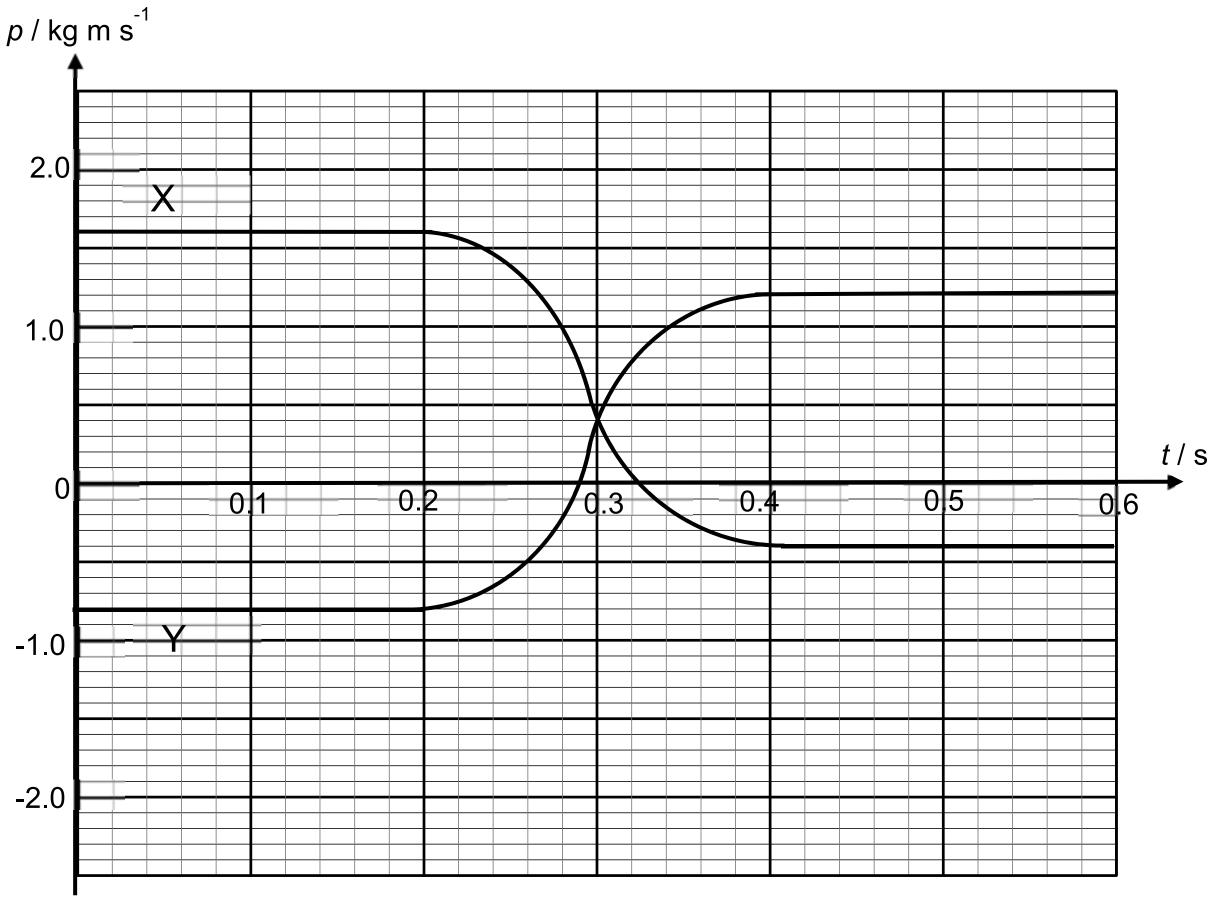


Fig. 1.3

(i) Show that the collision is inelastic.

[2]

[Turn over

For Examiner's Use

(ii) Calculate the impulse experienced by ball X due to the collision.

impulse = ………………………. N s [2]

(iii) Explain why both balls cannot lose all their kinetic energy at the same time during the collision.

…………………………………………………………………………………..

…………………………………………………………………………………..

…………………………………………………………………………………..

…………………………………………………………………………………..

……………………………………………………………………………………. [2]

For Examiner's Use

(c) Block B of mass 8.0 kg rests on a smooth 30° incline and is connected to block A of mass 12.0 kg via a frictionless pulley using an inextensible string as shown in Fig. 1.4. The blocks are released from rest and come to rest again momentarily when the spring is compressed by 1.2 m. The spring has a spring constant *k*.

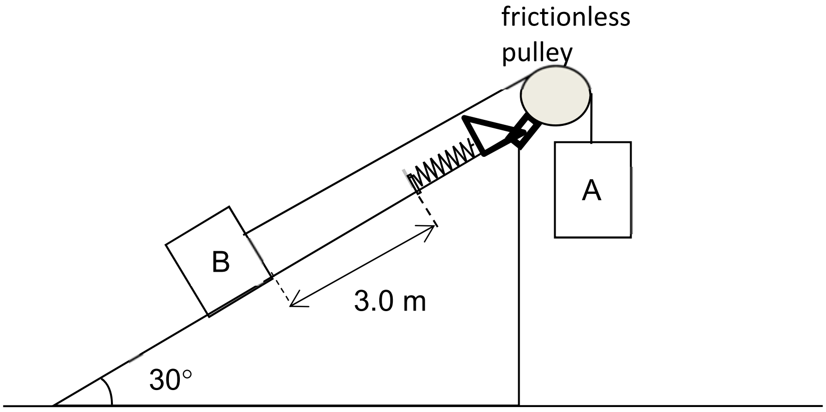


Fig. 1.4

(i) Describe the energy transformation from the time the blocks are released to the time when the blocks first come to rest.

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……………………………………………………………………………………………..

……………………………………………………………………………………………..

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

(ii) Calculate the value of *k.*

k = ……………………… N m^{-1} [2]

[Turn over

For Examiner's Use

2 A satellite of mass 1 200 kg is launched from the Earth's surface into a circular orbit at a height of 35 600 km directly above the equator. The radius of the Earth is 6 400 km.

Fig. 2.1 shows the variation with distance from Earth's centre r of gravitational potential Φ due to Earth.

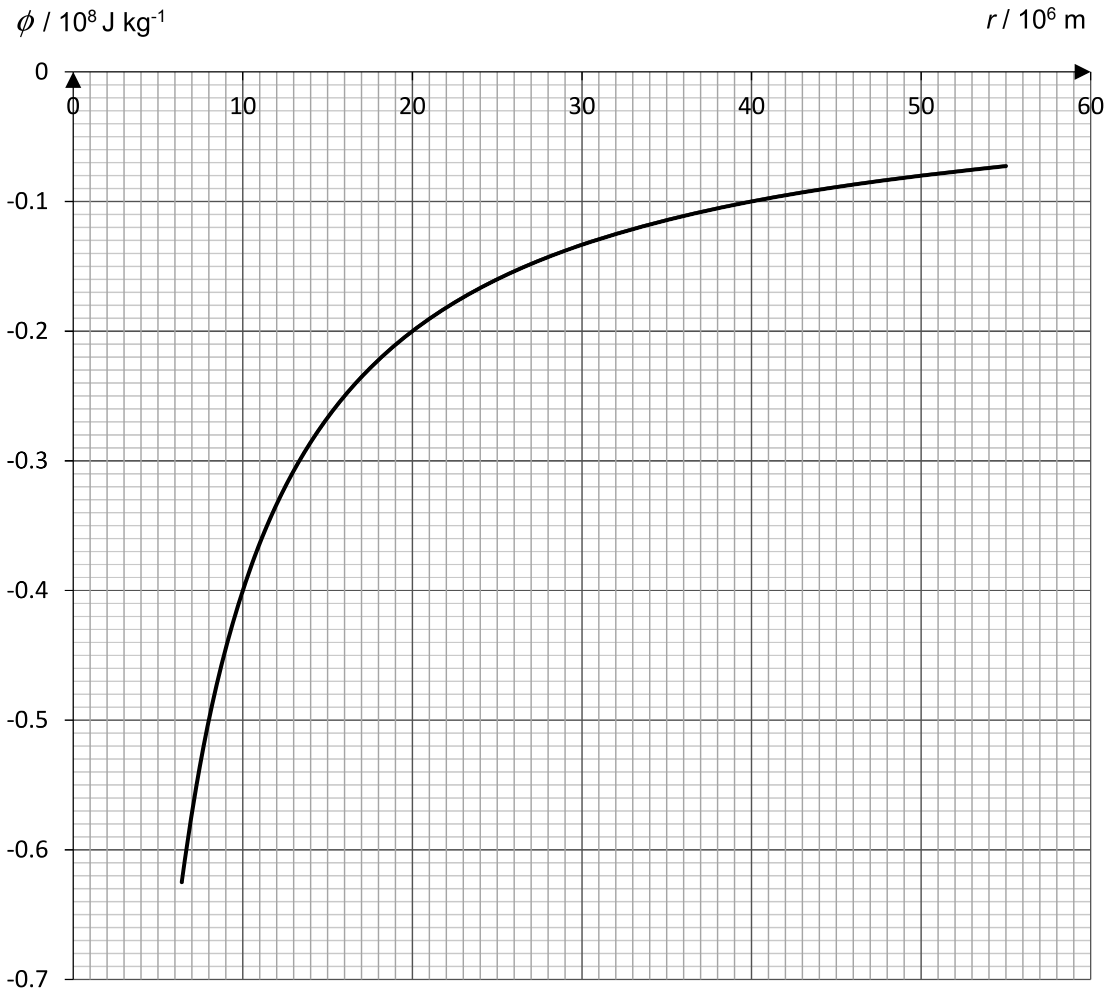


Fig. 2.1

(a) Explain why the gravitational potential graph is always negative.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

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

For Examiner's Use

(b) Using Fig. 2.1, show that the gravitational force acting on the satellite by the Earth when it is in orbit is about 270 N.

[3]

(c) Hence or otherwise, calculate the kinetic energy of the satellite when it is at the orbit.

kinetic energy = ………………………. J [3]

For Examiner's Use

(d) Use Fig. 2.1 and your answer in **(c)** to determine the minimum amount of energy required to launch the satellite to the orbit. Assume that the kinetic energy of the satellite at the surface of Earth is 0 J.

energy = ………………………. J [3]

(e) The actual energy required to send the satellite to the orbit is different from the energy calculated in **(d)**.

Suggest a reason why.

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

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

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

For Examiner's Use

3 **(a)** State what is meant by *internal energy* of a gas.

……………………………………………………………………………………………

……………………………………………………………………………………………

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

(b) 1.2×10^{-5} mol of ideal monoatomic gas is held in a container which allows heat to be freely exchanged between the gas, a regenerator and the surroundings. The regenerator acts as a type of heat storage that allows the gas to transfer heat to and from the regenerator as the gas cycles through the 4 states. The gas is made to undergo the following thermodynamic cycle as shown in Fig. 3.1.

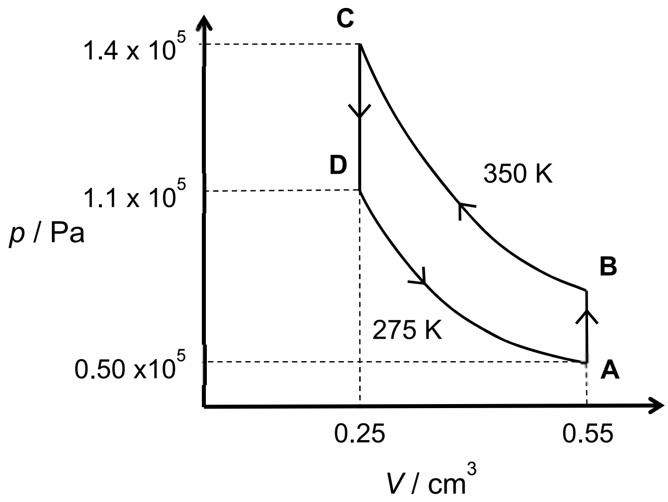


Fig. 3.1

A→B: the gas absorbs heat from the regenerator and its pressure increases.

B→C: the gas contracts isothermally at 350 K

C→D: the gas supplies heat to the regenerator and its pressure decreases

D→A: the gas expands isothermally at 275 K

For Examiner's Use

(i) Determine the pressure at B.

pressure at B = ……………………… Pa [2]

(ii) Show that the change in internal energy from C → D is -11.2 x 10^{-3} J.

[1]

(iii) Fig. 3.2 shows the energy changes for the transitions from A → B → C → D → A.

Complete the table. Show your working clearly.

	Heat supplied / x 10^{-3} J	work done on the gas / x 10^{-3} J	change in internal energy / x 10^{-3} J
A → B			
B → C		27.5	0
C → D			- 11.2
D → A		- 21.6	0

Fig 3.2

[3]

For Examiner's Use

(iv) The above cycle can be used to draw heat out from the surroundings by doing work on the gas. The coefficient of performance (COP) is a measure of how efficient this process is. The COP for such a system is defined as

$$\frac{Q_{in}}{W_{net}}$$

where Q_{in} is the heat energy absorbed by the gas from the surroundings and W_{net} is the **net** work done on the system for one cycle.

1. State which isothermal transition the gas absorbs heat energy from the surroundings.

……… → ……… [1]

2. Hence, determine the COP for this cycle.

COP = ………………………. [2]

For Examiner's Use

4 A mass damper can be used to stabilize a building during earthquakes. A mass-spring system shown in Fig 4.1 can be used to model a mass damper.

A 600 g mass is placed on a smooth surface and is attached horizontally to two unstretched identical springs X and Y with a spring constant of 20 N m^{-1}.

When the mass is displaced by 5.0 cm from its equilibrium position and released from rest as shown in Fig. 4.2, it undergoes simple harmonic motion.

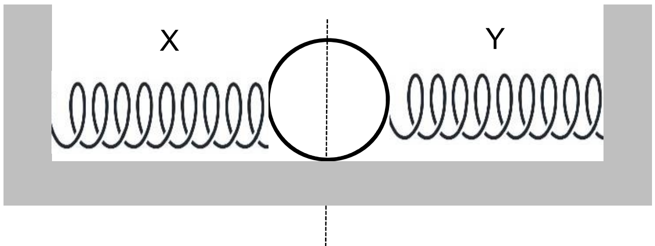


Fig. 4.1

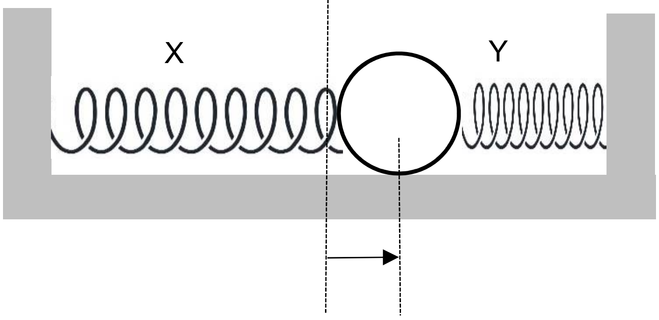


Fig. 4.2

(a) **(i)** Using energy consideration, calculate the maximum velocity of the mass.

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

(ii) Hence, determine the period of the oscillating spring-mass system.

period = ……………………… s [2]

(iii) Sketch on Fig 4.3 the variation with time *t* from the point of release of the mass

1. of the kinetic energy of the mass. Label this graph M.

2. of the elastic potential energy of spring Y. Label this graph S.

Show 1 complete oscillation. [2]

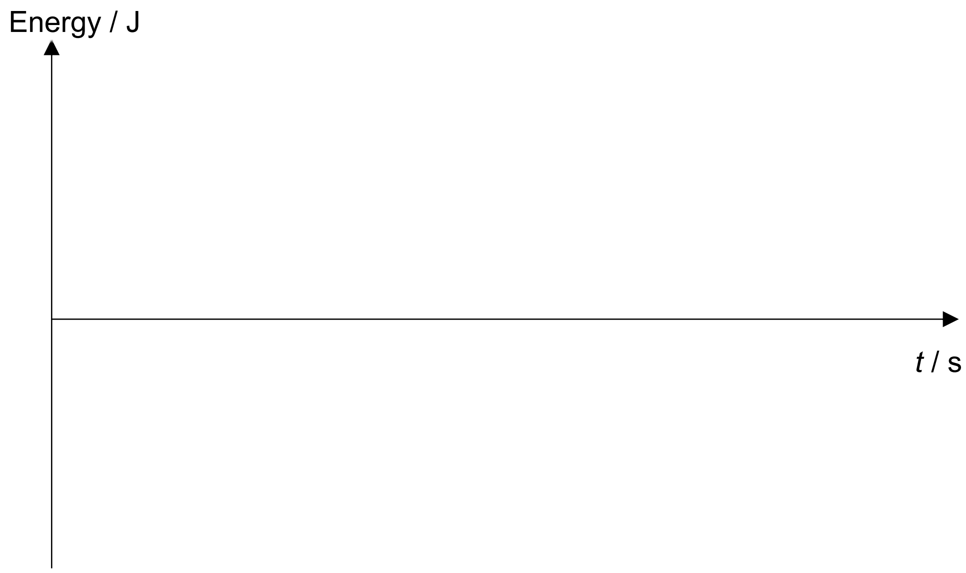


Fig. 4.3

(b) Suggest how the mass damper can help stabilize a building during an earthquake.

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

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

[Turn over

5 **(a)** Fig. 5.1 shows a gold-leaf electroscope. The gold leaf is deflected because the electroscope is negatively-charged.

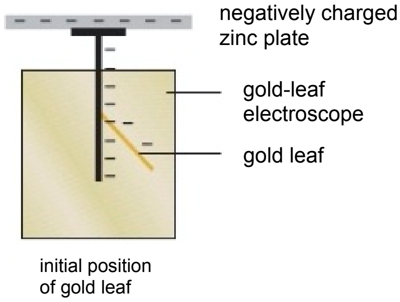


Fig. 5.1

(i) When red light is incident on the electroscope, the gold leaf remains deflected as shown in Fig. 5.2 a.

When ultra-violet radiation is incident on the electroscope, the gold leaf falls as shown in Fig. 5.2 b. This is due to a decrease in the negative charge of the gold leaf.

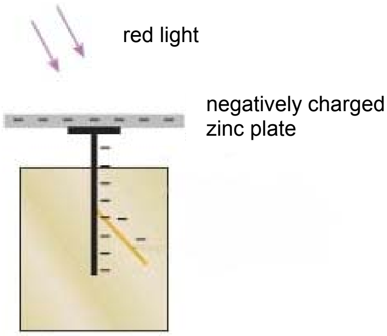


Fig. 5.2 a

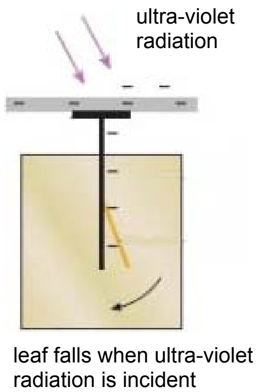


Fig. 5.2 b

Using Fig. 5.2 a and Fig. 5.2 b, explain how this is a demonstration of the photoelectric effect.

....

....

....

....

.... [2]

For Examiner's Use

(ii) When the intensity of the red light that is incident on the electroscope in Fig. 5.2 a is increased, the deflection of the gold leaf remains the same.

Explain how this is an evidence for the particulate nature of electromagnetic radiation.

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

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

(b) X-rays are produced by bombarding electrons, accelerated through a high potential difference, on a metal target. A typical X-ray spectrum is shown in Fig. 5.3.

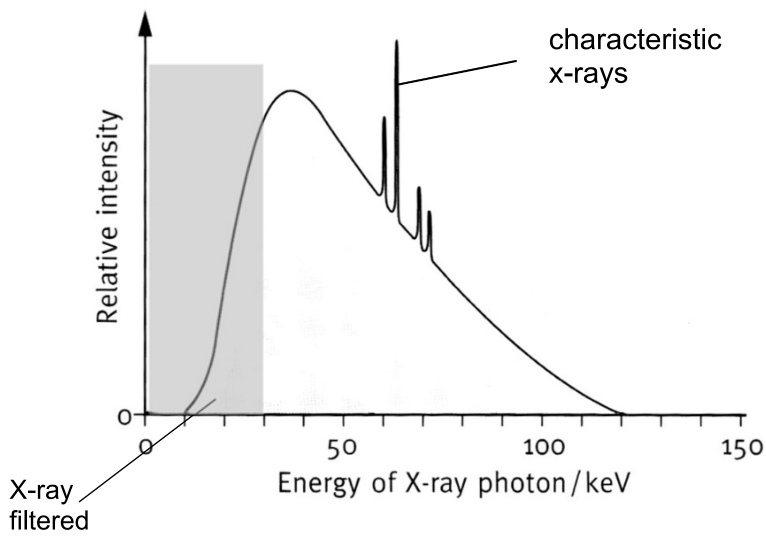


Fig. 5.3

(i) State the potential difference used to accelerate the electrons to produce the X-rays.

potential difference = ………………………. V [1]

For Examiner's Use

(ii) Explain the mechanism by which the characteristic X-rays are produced.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

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

(iii) Explain why characteristic X-rays produced are unique to the element used in the metal target.

……………………………………………………………………………………………

……………………………………………………………………………………………

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

(iv) X-rays can be used as a diagnostic tool. This is possible because different parts of our body absorb different amounts of X-ray. The lower energy X-rays are often filtered as shown in Fig. 5.3.

Suggest a reason why this is necessary.

……………………………………………………………………………………………

……………………………………………………………………………………………

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

For Examiner's Use

(c) An electron travelling at 1200 m s^{-1} passes through a slit of 24 μm as shown in Fig. 5.4.

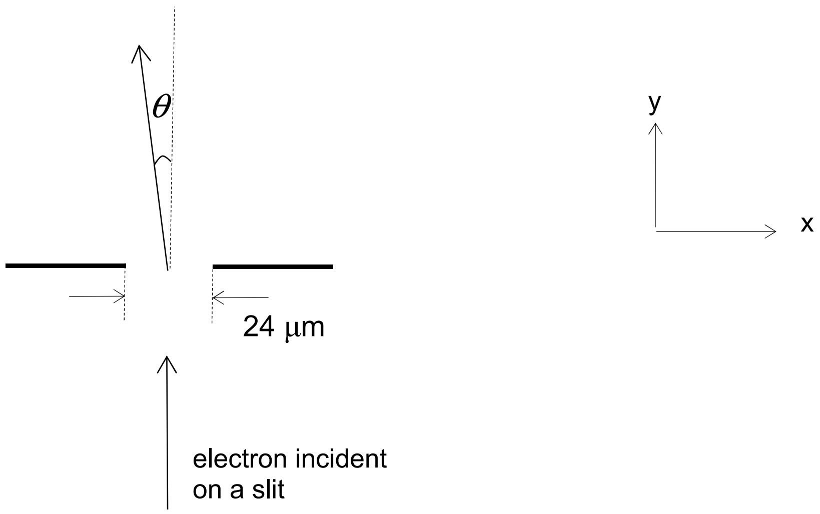


Fig. 5.4

(i) Calculate the minimum uncertainty of the momentum of the electron in the x-direction, Δp_x.

Δp_x= ……………………… kg m s^{-1} [2]

(ii) In an experiment where many electrons are put through the slit, it is observed that most electrons deviate from its original path within the angle θ as shown in Fig. 5.4 due to the uncertainty of the electrons' momentum.

Use your answer in **(c)(i)** or otherwise, calculate θ.

θ = ……………………… ° [3]

[Turn over

For Examiner's Use

Section B

Answer **one** question from this section.

6 (a) Define *electric field strength* at a point.

………………………………………………………………………………………………

………………………………………………………………………………………………

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

(b) (i) A long positively charged rod is placed at a distance from a stationary -2.0 μC point charge as shown in Fig. 6.1.

Sketch the electric field pattern between the rod and the point charge. [1]

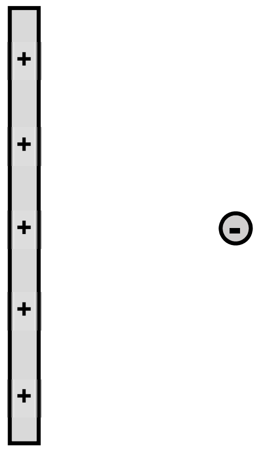


Fig. 6.1

(ii) A current I is passed through the rod and the charge moves at a speed of 1.5 cm s^{-1} as shown in Fig. 6.2. The charge experiences a magnetic field strength of 10 mT.

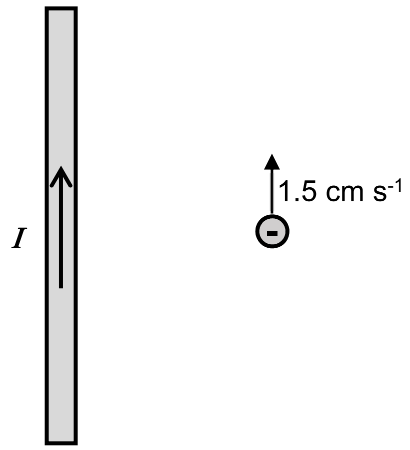


Fig. 6.2

For Examiner's Use

1. Calculate the magnitude of the force experienced by the charge due to the magnetic field of the rod.

force = ……………………… N [2]

2. The negative charge moves in a curved path to the right.

Explain this observation.

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

…………………………………………………………………………………… [2]

3. State and explain a modification that can be made to Fig. 6.2 such that the negative charge can be made to move parallel to the rod when the current I is still passing though the rod.

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

…………………………………………………………………………………… [2]

[Turn over

For Examiner's Use

(iii) In a second experiment, the rod carrying a current of 4.0 mA is placed next to a horizontal flat coil of wire which is fixed in its position. The centre of the coil, P, is at a perpendicular distance of 20 cm from the rod as shown in Fig. 6.3.

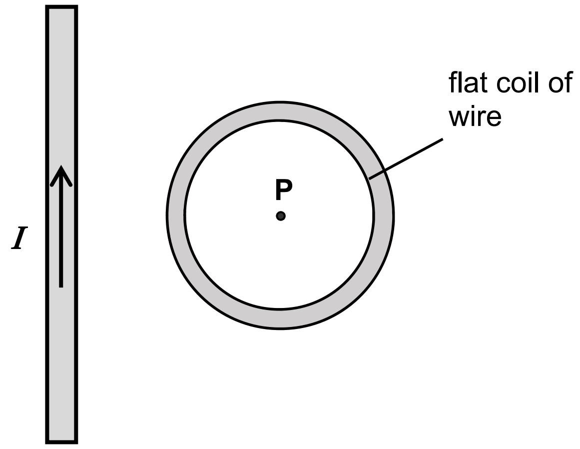


Fig. 6.3

1. Calculate the magnitude of the magnetic flux density at P.

magnetic flux density = ……………………… T [2]

2. A very small current now flows in the flat coil of wire in an anti-clockwise direction.

Without any further calculation, state and explain if the magnetic flux density at P will change compared to that obtained in **(b)(iii)1**.

……………………………………………………………………………

……………………………………………………………………………

……………………………………………………………………………

……………………………………………………………………………

…………………………………………………………………………… [2]

For Examiner's Use

3. State and explain the direction of the net force acting on the coil.

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

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

(c) A circular coil is placed with its axis vertical and a bar magnet aligned with the axis of the coil, is held above the coil as shown in Fig. 6.4. The bar magnet is then dropped. A datalogger is connected to the coil and records the e.m.f. induced in the coil.

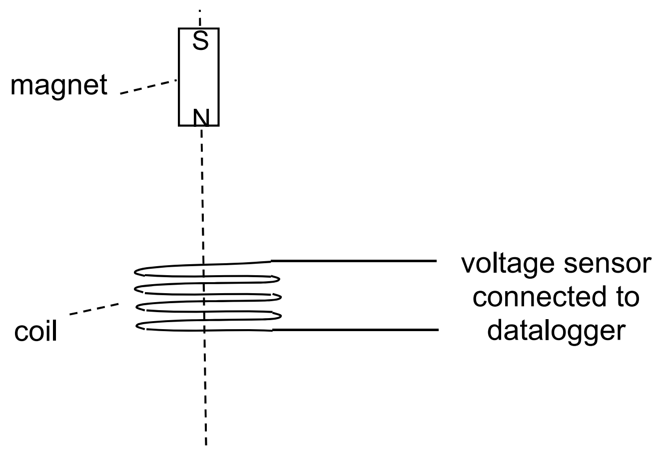


Fig. 6.4

Fig. 6.5 shows the variation with time of the e.m.f. induced as the magnet falls through the coil.

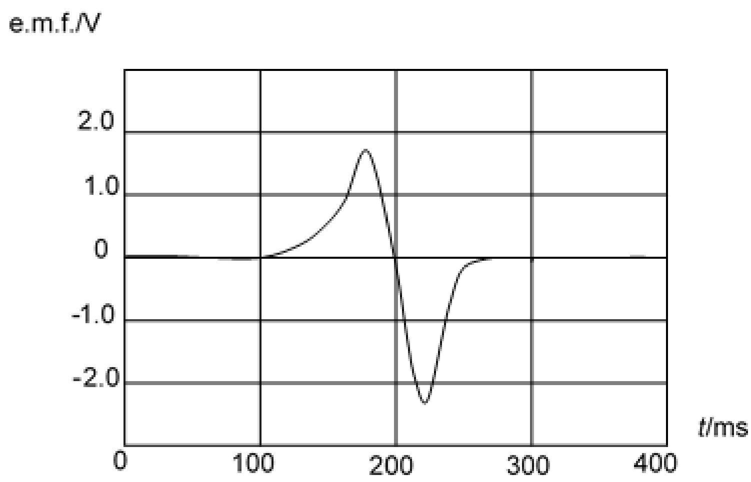


Fig. 6.5

[Turn over

For Examiner's Use

(i) State what the area under the graph between 200 ms and 270 ms represent.

……………………………………………………………………………………………

……………………………………………………………………………………………

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

(ii) Using the laws of electromagnetic induction, explain the shape of the graph obtained in Fig. 6.5.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

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

(iii) The experiment is repeated with the magnet now dropped from a higher height.

State and explain how the graph in Fig. 6.5 will change.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

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

For Examiner's Use

7 **(a)** Explain what is meant by the phase difference of two waves of the same frequency.

…………………………………………………………………………………………

…………………………………………………………………………………………

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

(b) An experiment to investigate two-source interference using light waves is set up as shown in Fig. 7.1. Three slits S_0, S_1 and S_2 of equal width are used with a lamp that is attached with a red filter.

Fig. 7.1 (not to scale)

(i) For observable interference, suggest why slit S_o is needed when the light source used is a lamp.

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

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

(ii) Draw on Fig. 7.1 lines to represent the rays of light from S_o to the point C on the screen which is equidistant to S_1 and S_2. [1]

(iii) State the path difference of the light reaching point C.

path difference = ……………………… [1]

[Turn over

For Examiner's Use

(iv) **1.** The amplitude of the light at point C on the screen in Fig. 7.1 is ***A***.

State and explain the new amplitude at point C on the screen when a piece of polariser is placed in front of S_2.

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

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

2. Describe the changes to the interference pattern on the screen if the red filter in Fig. 7.1 is replaced with a blue filter.

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

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

(c) **(i)** Explain the formation of a stationary wave.

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

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

For Examiner's Use

(ii) A stationary wave is setup in a one end open tube using a speaker which is connected to a signal generator as shown in Fig. 7.2.

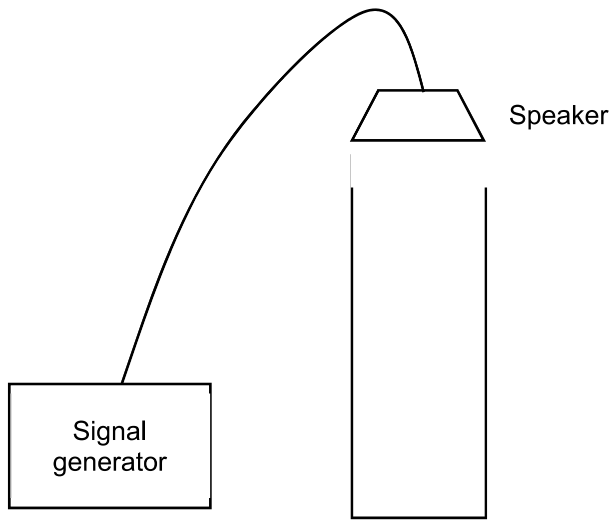


Fig. 7.2

The length of the tube is 90 cm long and the wavelength of the sound is 120 cm. A small microphone which senses pressure variation is placed in the tube to measure the frequency of the stationary wave formed.

The microphone is connected to a cathode-ray oscilloscope (c.r.o). When the microphone picks up the largest pressure variation, the waveform obtained on the c.r.o. is shown in Fig. 7.3.

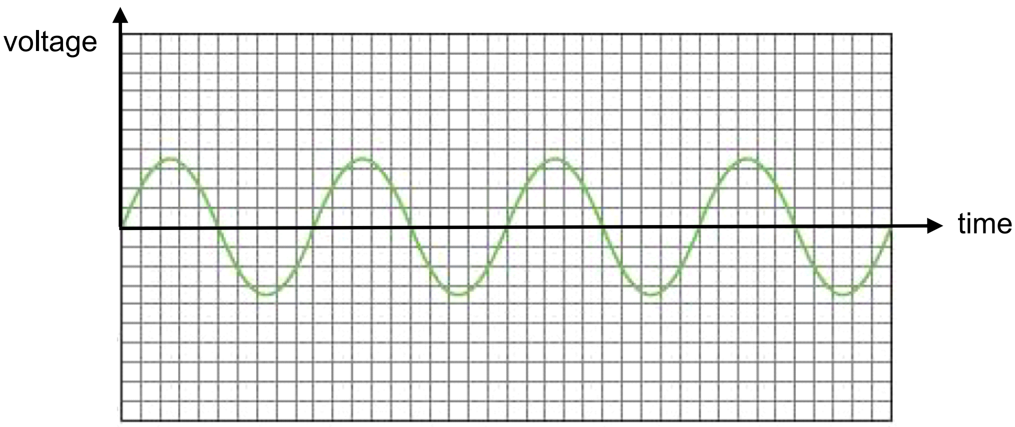


Fig. 7.3

For Examiner's Use

1. State and explain the distance in the tube from the open end for the microphone to be placed so that the waveform in Fig. 7.3 is obtained.

Include in your answer a diagram of the stationary wave setup in the air column of the tube. Label your diagram.

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

…………………………………………………………………………………… [3]

2. The wavelength of the sound from the speaker is increased to 330 cm. State and explain if a stationary wave can be formed.

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

…………………………………………………………………………………… [2]

For Examiner's Use

(d) A monochromatic laser is incident on a diffraction grating.

By drawing a suitable well-labelled diagram, describe how you would determine the wavelength of the laser light.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

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

[Turn over

1	
(a)(i)	By Conservation of linear momentum, $0 = m_{Rifle} v_{recoil} + m_{bullet} v_{bullet}$
	v_{recoil} = -2.3 m s^{-1} (2 sf)
(a)(ii)	Change in momentum of 1 bullet = 0.015 (700 – 0)
	By N2L, Average force by rifle on bullets = $\frac{m(v_f - v_i)}{\Delta t}$
	= 52.5 N By N3L, Average force by bullets on rifle is equal and opposite to average force by rifle on bullets = -52.5 N
	Alternative Change in momentum of rifle = 10(4.5)(-2.33333 – 0)
	By N2L, Average force by bullets on rifle = $\frac{m(v_f - v_i)}{\Delta t}$
	= -52.5 N
(b)(i)	Initial KE = 10 J Final KE = 5 J
	Since initial KE is greater than final KE, collision is inelastic.
	Alternative Relative speed of approach = 15 m s^{-1} Relative speed of separation = 10 m s^{-1}
	Since relative speed of approach is not equal to relative speed of separation, the collision is inelastic.
(b)(ii)	Impulse = change in momentum
	= -2.0 N s
(b)(iii)	If KE is fully converted to other forms of energy at the same time during the collision, total / sum of momentum is zero.
	By conservation of momentum, since total / sum of initial momentum is not zero, this is not possible.
(c)(i)	From point of release of block B to the point of contact with spring: Net loss of GPE of blocks is converted to gain in KE of blocks.
	From point of contact with spring to point where net force on block B is zero: Net loss of GPE of blocks is converted to gain in KE of blocks and EPE of spring.
	From point where net force on block B is zero to point of maximum compression: Net loss of GPE and KE of blocks is converted to gain in EPE of spring.
(c)(ii)	Net loss in GPE = Gain in EPE
	k = 460 N m^{-1} (2 sf)

2	
(a)	Work done per unit mass by an external agent in bringing a small point test mass from infinity to a point near Earth is negative.
	Gravitational potential at infinity is zero. It is negative because gravitational force is always attractive.
(b)	Negative gradient of gravitational potential - distance graph gives gravitational field strength.
	Tangent drawn with 2 points read off
	$\frac{(-0.075-(-0.190))\times 10^{8}}{(50-0)\times 10^{6}} = 0.23 \text{ N kg}^{-1}$ Gravitational force = 0.23 N kg^{-1} x 1200 kg = 276 N
(c)	Gravitational force provides centripetal force
	Centripetal force = $m\frac{v^2}{r}$ $\frac{1}{2}mv^2 = \frac{\text{force}\times r}{2}$
	= 5.7 x 10^9 J (2sf)
(d)	Increase in GPE required = *ΔΦ* x *m* (= 6.36 x 10^{10} J)
	Minimum energy required = Increase in GPE + KE at orbit
	= 6.93 x 10^{10} J (3 sf)
(e)	• Energy used to accelerate and decelerate the satellite to change direction of satellite • Energy to overcome resistive forces in Earth's atmosphere • Inefficiency in propulsion system • Energy required to launch satellite (due to rocket) • KE of satellite is not zero at Earth's surface due to Earth's rotation
3	
(a)	The internal energy of a body is the sum of the random distribution of all the potential and kinetic energies of the microscopic particles / atoms / molecules in the gas.
(b)(i)	Since B and C are at the same temperature, $P_C V_C = P_B V_B$
	$P_B = 6.36 \times 10^4$ Pa
	Alternative Using Ideal gas law, $P_B V_B = nRT_B$
	$P_B = 6.35 \times 10^4$ Pa

(b)(ii)

Applying Ideal gas equation,

$$\Delta U_{CD} = \frac{3}{2} nR\Delta T = \frac{3}{2}\Delta(PV) = \frac{3}{2}V(\Delta P)$$

$$\Delta U_{CD} = -11.2\times10^{-3}\ \text{J}$$

(b)(iii)

Isovolumetric process: W = 0 J

$$W_{CD} = W_{AB} = 0\ \text{J}$$

For a cyclic process,

$$\Delta U = 0$$

$$\Rightarrow \Delta U_{AB} = -\Delta U_{CD} = 11.2\times10^{-3}\ \text{J}$$

Apply first law of thermodynamics

$$Q_{AB} = 11.2\times10^{-3}\ \text{J};\ Q_{BC} = -27.5\times10^{-3}\ \text{J};$$

$$Q_{CD} = -11.2\times10^{-3}\ \text{J};\ Q_{DA} = 21.6\times10^{-3}\ \text{J}$$

	heat supplied / x 10^{-3} J	work done on the gas / x 10^{-3} J	change in internal energy / x 10^{-3} J
A $\rightarrow$ B	11.2	0	11.2
B $\rightarrow$ C	- 27.5	27.5	0
C $\rightarrow$ D	-11.2	0	-11.2
D $\rightarrow$ A	21.6	- 21.6	0

(b)(iv)1.

D $\rightarrow$ A

(b)(iv)2.

$$W_{net} = 27.5\times10^{-3} + \left(-21.6\times10^{-3}\right)$$

$$\text{COP} = \frac{21.6\times10^{-3}}{5.9\times10^{-3}} = 3.7\ \text{(2sf)}$$

4

(a)(i)

Maximum EPE stored in the 2 springs = $2\times\frac{1}{2}kx^2 = 0.050$ J

When this is all transferred to KE

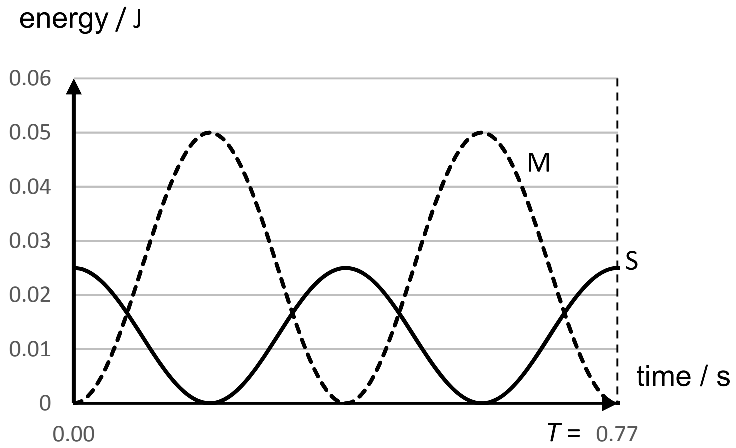
$$\frac{1}{2}mv_{max}^{\ 2} = 0.050\ \text{J}$$

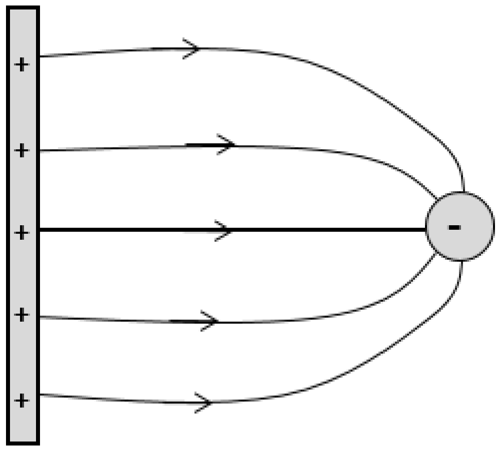
$$v_{max} = 0.41\ \text{m s}^{-1}\ \text{(2sf)}$$

(a)(ii)

$$v_{max} = \omega x_o$$

$$T = 0.77\ \text{s (2sf)}$$

(a)(iii)1. **(a)(iii)2.**	
	Correct M graph – $\sin^2$ and T or 0.77 shown
	Correct S graph – $\cos^2$ and ½ energy of M
(b)	During an earthquake, as the building sways, energy is transferred to the mass-spring system of the damper. Therefore, amplitude of oscillation of the building decreases, preventing structural damage.
5	
(a)(i)	Electrons are emitted from zinc when ultraviolet radiation is incident on it, discharging the gold leaf.
	Frequency of ultraviolet radiation, but not red light, exceeds threshold frequency of zinc.
(a)(ii)	Increasing intensity increases the number of photons incident per unit time.
	Energy of each photon doesn't change. Since electromagnetic radiation behave as particles which interact with electrons in a one-to-one manner, no electrons are emitted as energy of photon is still less than the work function of zinc.
(b)(i)	120 000 V
(b)(ii)	High energy electrons knock out the inner shell electrons from the metal target atoms. Electrons from higher energy level drops to lower energy level.
	The loss in energy of electrons is converted to X-ray photons of energy = energy difference between the two energy levels.
(b)(iii)	Different metal targets have their unique energy levels. Hence the differences are energy levels are unique.
(b)(iv)	Lower energy X-rays have insufficient energy to penetrate through the body. But they contribute to the overall dose in patients.
(c)(i)	Estimate uncertainty of position of x = 24 x 10^{-6} m
	$\Delta x \Delta p_x \geq h$ $\Delta p_x = \frac{6.63\times10^{-34}}{24\times10^{-6}}$ $= 2.8\times10^{-29}\ \text{kg m s}^{-1}$ (round up to 2sf)

(c)(ii)	$p_y = m_e v = 1.0932 \times 10^{-27}$ kg m s^{-1}
	$tan\,\theta = \dfrac{p_x}{p_y} = \dfrac{2.7625 \times 10^{-29}}{1.0932 \times 10^{-27}}$
	$\theta = 1.4°$ (1dp)
	Alternative Wavelength associated with the electrons $\lambda = \dfrac{h}{p_y} = 6.065 \times 10^{-7}$ m
	Using single slit diffraction formula, n = 1, b = 24 x 10^{-6} m $b \sin\theta = \lambda$
	$\theta = 1.448507° = 1.4°$ (1dp)
6	
(a)	Electric field strength at a point is the electric force experienced per unit charge on a small stationary positive point test charge placed at that point and is in direction of the electric force on a positive test charge at that point.
(b)(i)	
	Correct direction of E field E field stronger to the right Symmetrical field pattern At least 5 lines
(b)(ii)1.	$F = Bqv \sin 90°$
	= 3.0 x 10^{-10} N
(b)(ii)2.	Direction of magnetic field due to wire is into the page and current is downwards. Using FLHR, direction of magnetic force experienced by the charge is to the right.
	Force has a different direction from velocity of charge, hence path is curved.
(b)(ii)3.	Apply a uniform electric field to the right OR using parallel plates with positive plate at the left
	Net force on charge will be zero due to electric force which is opposite in direction but equal in magnitude to the magnetic force exerted by the rod.
	Alternative Apply a magnetic field out of page OR by placing another rod carrying current of the same magnitude and direction such that the charge lies exactly between the 2 rods
	Net force on charge will be zero due to magnetic force which is opposite in direction but equal in magnitude to the magnetic force exerted by the rod.

(b)(iii)1.	$B = \frac{\mu_o I}{2\pi r}$
	= 4.0 x 10^{-9} T
(b)(iii)2.	Using RHGR, magnetic field due to coil at P is out of the page while magnetic field due to rod at P is into the page.
	Hence resultant magnetic flux density at P is the vector sum of the magnetic field due to the coil and rod.
(b)(iii)3.	The part of the coil closer to the rod will experience a repulsive force / force to the right (current in opposite direction) while the opposite end of the coil will experience an attractive force / force to the left (current in the same direction)
	The repulsive force is stronger than the attractive force as the magnetic flux density decreases with distance from the rod, therefore the coil will experience a net force to the right.
(c)(i)	The area under the graph between 200 ms and 270 ms represents the loss in magnetic flux linkage experienced by the coil when the magnet is leaving the coil.
(c)(ii)	As the magnet approaches the coil, the coil experiences a change of magnetic flux linkage and emf is induced, reaching a maximum when the N-pole of the magnet reaches the coil.
	When the S-pole leaves the coil, rate of change of magnetic flux linkage is larger as speed increases due to acceleration, resulting in a higher induced emf.
	As the change in magnetic flux linkage is in the opposite direction when the magnet is entering and leaving the coil, with increasing flux when entering and decreasing flux when leaving, induced emf have opposite polarity.
(c)(iii)	Due to greater speed attained, there is a greater rate of change of magnetic flux linkage experienced by the coil.
	The two peaks will be higher as magnitude of induced emf increases.
	OR
	Due to greater speed attained and change in magnetic flux linkage remains unchanged.
	The time duration where there is an induced emf is shorter.
7	
(a)	Phase difference between two waves is the fraction of a cycle by which two waves are out of step with each other.
(b)(i)	Lamp is not a point source
	Single slit makes light from S_1 and S_2 coherent / light from lamp is not coherent
(b)(ii)	One line from S_0 to S_1 to C One line from S_0 to S_2 to C Arrows to indicate direction
(b)(iii)	Path difference = 0 m
(b)(iv)1.	Intensity at C due to S_2 is reduced
	Resultant amplitude at C is less than A since intensity is proportional to amplitude^2.
(b)(iv)2.	Fringe separation is smaller
	Contrast remains the same
(c)(i)	Two waves travelling in opposite directions meet/superpose
	Two waves have same speed and frequency/wavelength

(c)(ii)1.	Correct stationary wave pattern: two nodes and two antinodes
	Pressure variation is maximum at the displacement node
	Microphone is placed 30 cm from the open end or at the closed end
(c)(ii)2.	Fundamental mode requires wavelength of 360 cm
	No stationary wave pattern can be formed
(d)	Diagram shows: Laser Grating Screen showing zero and first order bright fringe or other order fringes (can be markings on screen) Angle θ between zero and first order bright fringe
	d is slit separation or example calculation like 1 mm / 600 lines
	D is screen distance and x is distance from n = 0 to n = 1
	$\tan\theta = x / D$ To find λ, use $\lambda = d \sin\theta$