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

30 August 2023

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	/ 12
2	/ 11
3	/ 11
4	/ 12
5	/ 14
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	$= -\dfrac{Gm}{r}$
temperature	T/K	$= T/^{\circ}\mathrm{C} + 273.15$
pressure of an ideal gas	p	$= \dfrac{1}{3}\dfrac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy 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	$= \dfrac{\ln 2}{t_{\frac{1}{2}}}$

[Turn over

For Examiner's Use

Section A

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

1 **(a)** Fig. 1.1 shows two identical balls on a smooth surface. Ball A moves with a speed of v m s^{-1} towards a stationary ball B.

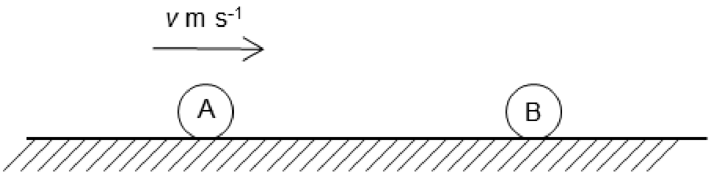

Fig. 1.1

Explain why it is not possible for ball A to move in the opposite direction after colliding with ball B.

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(b) Fig. 1.2 shows a 2.5 kg crate moving towards a stationary 2.0 kg crate on a smooth surface.

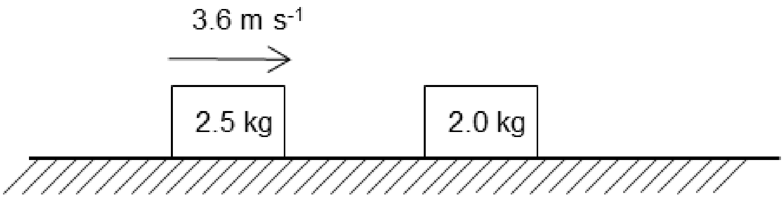

Fig. 1.2

The two crates collide elastically.

(i) Determine the speed of the 2.5 kg crate after collision.

speed = ……………………… m s^{-1} [3]

For Examiner's Use

(ii) The collision takes place over a period of 0.50 s.

Determine the average force that the 2.5 kg crate exerts on the 2.0 kg crate.

average force = ……………………… N [2]

(c) The crates are carrying tomatoes. A particular 3.0 kg crate has a speed of 1.5 m s^{-1} just before it slides down a 2.0 m high rough slope inclined an at an angle of 30° to the horizontal as shown in Fig. 1.3.

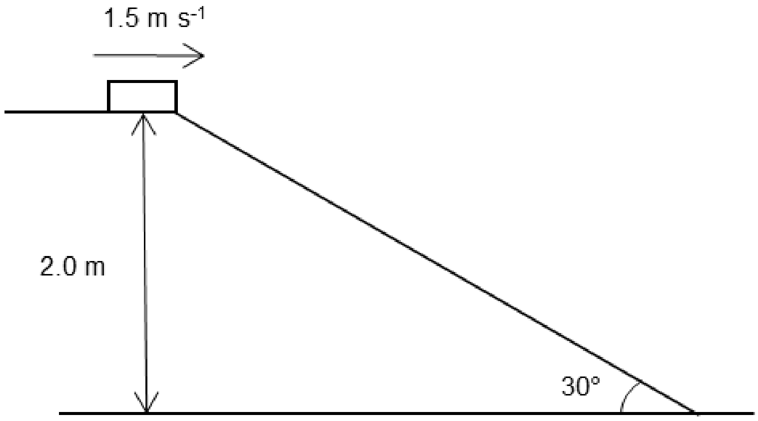

Fig. 1.3

An average frictional force of 15 N is exerted on the crate as it slides down the slope.

(i) Determine the speed of the crate when it reaches the bottom of the slope.

speed = ……………………… m s^{-1} [3]

[Turn over

For Examiner's Use

(ii) A co-worker suggested to replace the rough slope with a smooth one so that the crate can reach the bottom of the slope in a shorter time.

Suggest and explain a possible reason why this suggestion should not be implemented.

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.... [2]

[Total: 12]

For Examiner's Use

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

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(b) A positively charged conducting sphere P, isolated in space, has a radius R. The electric field strength at the surface of the sphere is E.

(i) P has a charge of 2.2×10^{-9} C and a diameter of 4.0 cm.

Determine the electric field strength at the surface of the sphere.

electric field strength = ……………………… N C^{-1} [2]

[Turn over

For Examiner's Use

(ii) On Fig. 2.1, sketch a graph to show the variation of the electric field strength of the sphere with distance from its centre until 8.0 cm.

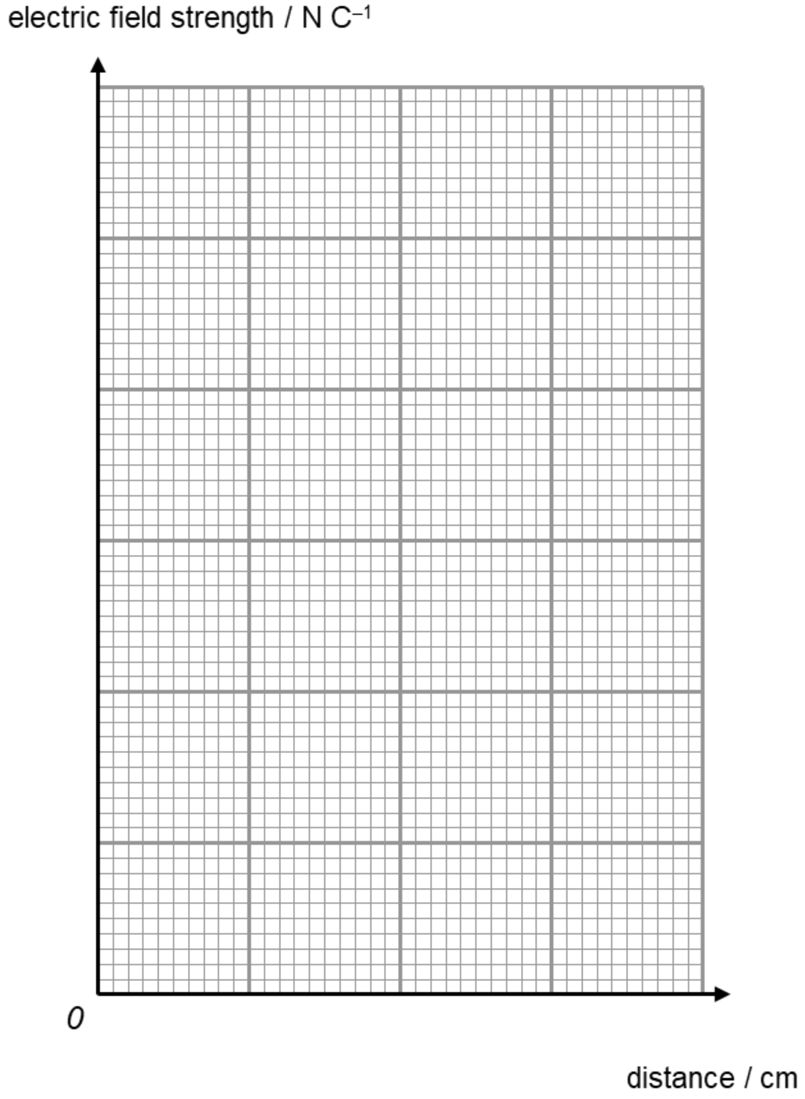

Fig. 2.1

[3]

For Examiner's Use

(c) Fig. 2.2 shows another positively conducting charged sphere Q, of the same magnitude of charge, placed at a close distance from P.

Fig. 2.2

(i) On Fig. 2.2, draw electric field lines to represent the electric field around the two spheres.

[2]

(ii) Explain why the equipotential lines are always perpendicular to the electric field lines.

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.... [2]

[Total: 11]

For Examiner's Use

3 **(a)** Explain what is meant by *magnetic flux linkage*.

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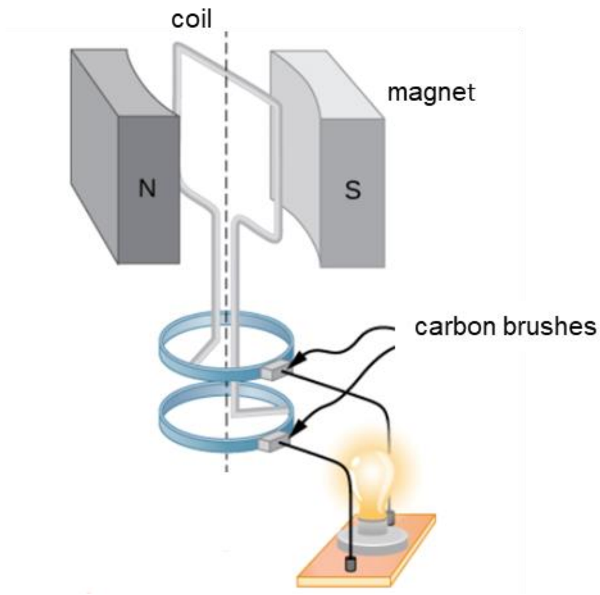
…………………………………………………………………………………………….... [1]

(b) Fig. 3.1 shows a simple generator that is used to generate electricity. A coil of wire of area 265 cm^2 is placed between two permanent magnets. The magnets provide a uniform magnetic flux density of 6.2 T and the coil rotates at a constant angular frequency of 30 revolutions per minute.



Source: https://openstax.org/

Fig. 3.1

(i) Explain how a sinusoidal current is generated in the coil.

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………………………………………………………………………………….… [3]

For Examiner's Use

(ii) Show that the maximum magnitude of the e.m.f. induced in the coil is 0.52 V.

[2]

(iii) On Fig. 3.2, sketch the variation with time *t* of the e.m.f. *E* generated in the coil. The orientation of the coil, seen from the top view of Fig. 3.1, is illustrated above the graph in Fig. 3.2.

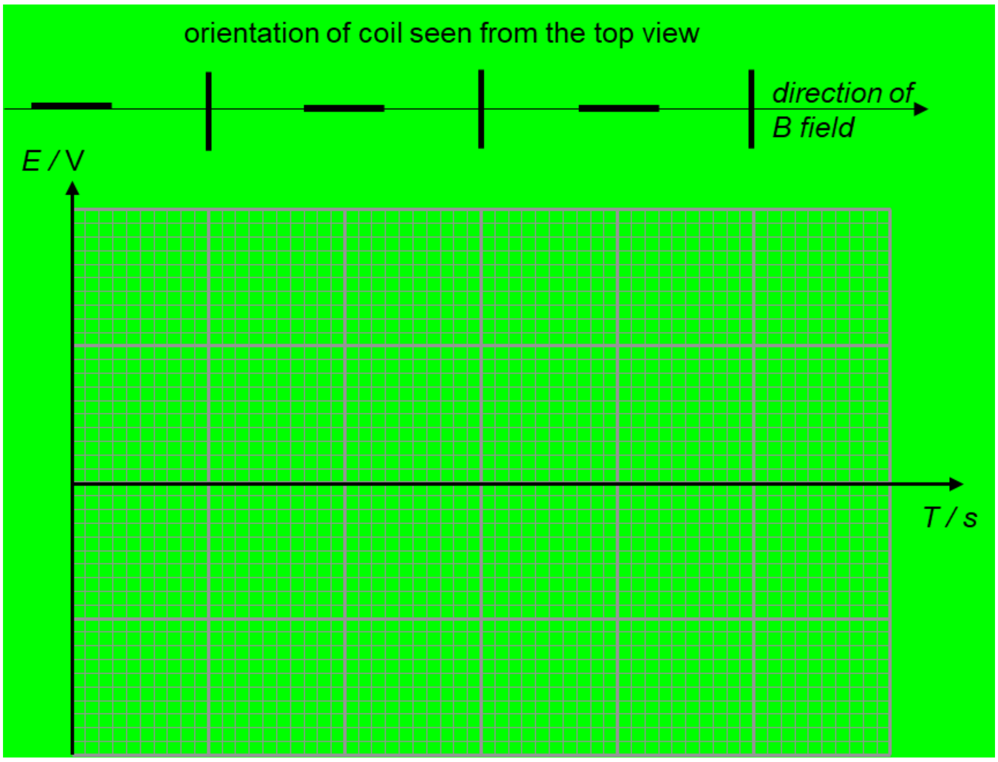

Fig. 3.2

[2]

[Turn over

For Examiner's Use

(c) The e.m.f. generated in **(b)** is now channelled to the input of a transformer as shown in Fig. 3.3.

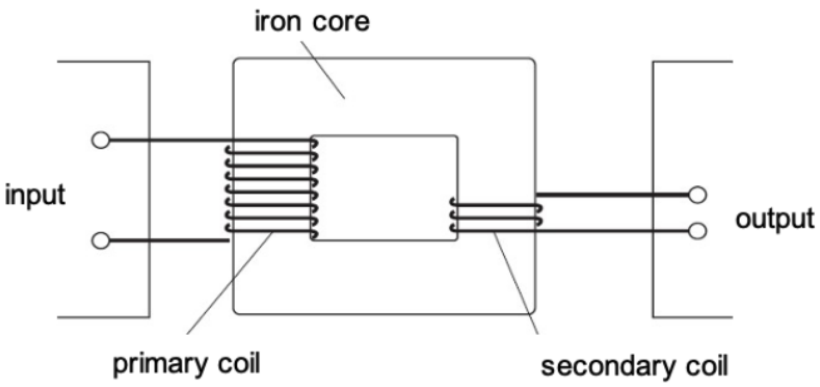

Fig. 3.3

(i) Determine the root-mean-square (r.m.s.) voltage, V_{rms}, in the primary coil.

V_{rms} = ………………………. V [1]

(ii) The output of the transformer is connected to a resistor of resistance 10 Ω. The turns ratio of the transformer $\frac{N_s}{N_p}$ is 0.25.

Determine the r.m.s. current, I_{rms}, across the resistor.

I_{rms} = ………………………. A [2]

[Total: 11]

For Examiner's Use

4 A 1.2 kg sphere resting on a smooth surface is connected to the side of the wall via a spring with spring constant of 65 N m^{-1} as shown in Fig. 4.1.

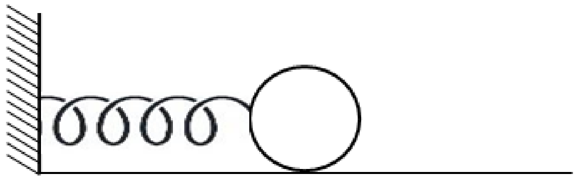

Fig. 4.1

A horizontal force of 8.0 N is exerted on the sphere and the spring is extended by x m.

(a) Determine x.

x = ……………………… m [2]

(b) The force is now removed and the sphere is observed to move in simple harmonic motion.

(i) Determine the maximum kinetic energy of the sphere.

maximum kinetic energy = ……………………… J [2]

(ii) Hence or otherwise, determine the period of the oscillation.

period = ……………………… s [2]

[Turn over

For Examiner's Use

(iii) On Fig 4.2, sketch the variation with time of the kinetic energy of the sphere.

Fig. 4.2

[2]

(iv) Sketch, on Fig 4.3, the variation with displacement of the kinetic energy of the sphere.

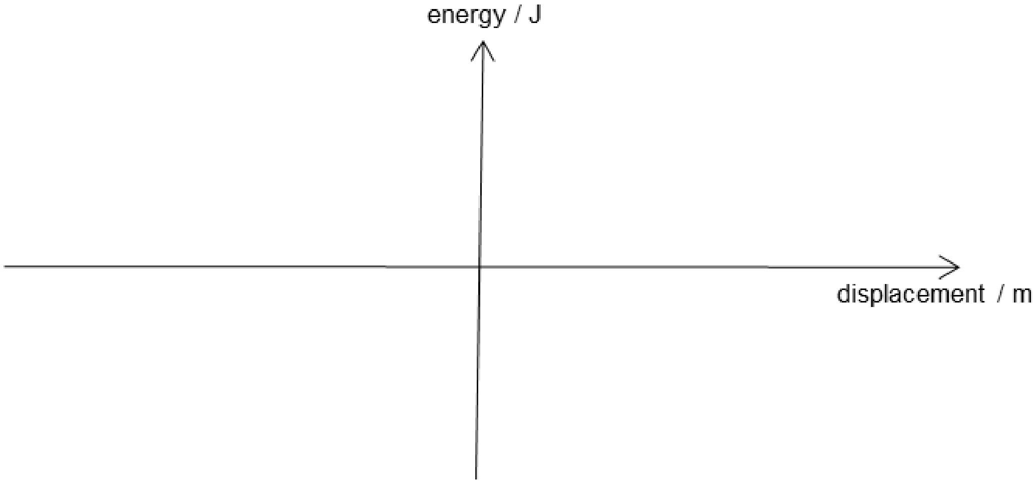

Fig. 4.3

[2]

(v) Sketch on Fig. 4.3, the variation with displacement of the kinetic energy of the sphere if the experiment is repeated on a rough surface. Label this graph as **A**.

[2]

[Total: 12]

For Examiner's Use

5 **(a)** Explain what is meant by a photon.

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

(b) A laser produces light of wavelength 656 nm in an ultrashort pulse with a duration of 9.00×10^{-15} s.

For a single photon in the pulse,

(i) calculate the momentum,

momentum = ……………………… kg m s^{-1} [1]

(ii) determine a value for the minimum uncertainty in momentum.

minimum uncertainty in momentum = ……………………… kg m s^{-1} [2]

(c) Explain how an emission line spectrum provides evidence for discrete energy levels in isolated atoms.

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[Turn over

For Examiner's Use

(d) When an electron transits from a higher energy level to the energy level –13.6 eV in a hydrogen atom, a photon of frequency 3.19×10^{15} Hz is emitted.

Determine the energy, in eV, of the higher energy level.

energy = ……………………… eV [2]

(e) The radiation emitted from transitions between electron energy levels of the hydrogen atom is incident on the surface of a sheet of metal of work function ϕ in a photoelectric effect experiment.

In order to investigate the relationship between the stopping potential V_s and the wavelength of incident light λ, a line of best fit was drawn from the data collected in the experiment.

Fig. 5.1 shows the variation with $\frac{1}{\lambda}$ of V_s.

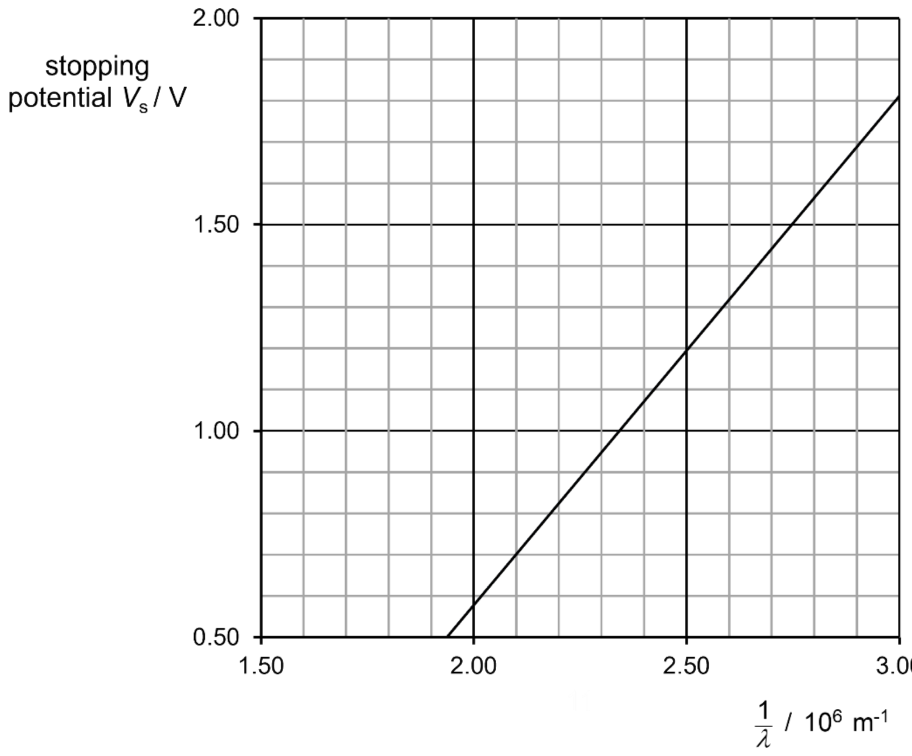

Fig. 5.1

For Examiner's Use

(i) State an equation that shows the relationship between V_s, λ and ϕ in a photoelectric effect experiment.

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

(ii) Using Fig. 5.1, determine a value for the Planck's constant.

Planck's constant = ……………………… J s [3]

[Total: 14]

For Examiner's Use

Section B

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

6 **(a)** The intensity of the light from a monochromatic laser is I_0 and is incident normally on a polarising filter. The polarising plane of the filter is currently vertical. The intensity of the light that emerges from the filter is equal to I_0.

(i) State what the observation suggests about the light from the laser.

....

.... [1]

(ii) Fig. 6.1 shows the polarising filter rotating slowly about a horizontal axis at right angles to its surface. As the angle θ through which the filter rotates increase from 0° to 360°, the intensity of the emerging light varies.

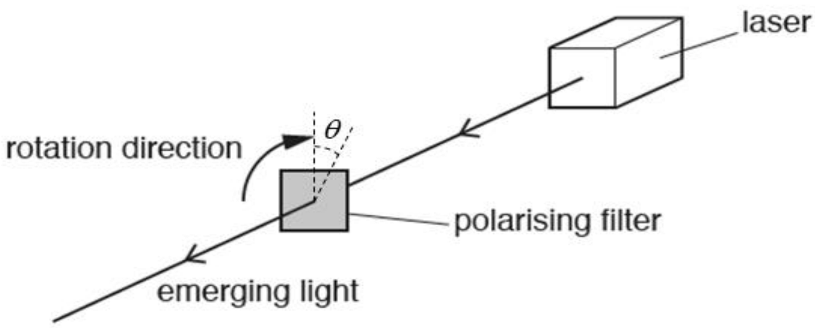

Fig. 6.1

On Fig. 6.2, sketch a graph to show how the intensity of the emergent light varies with the angle θ.

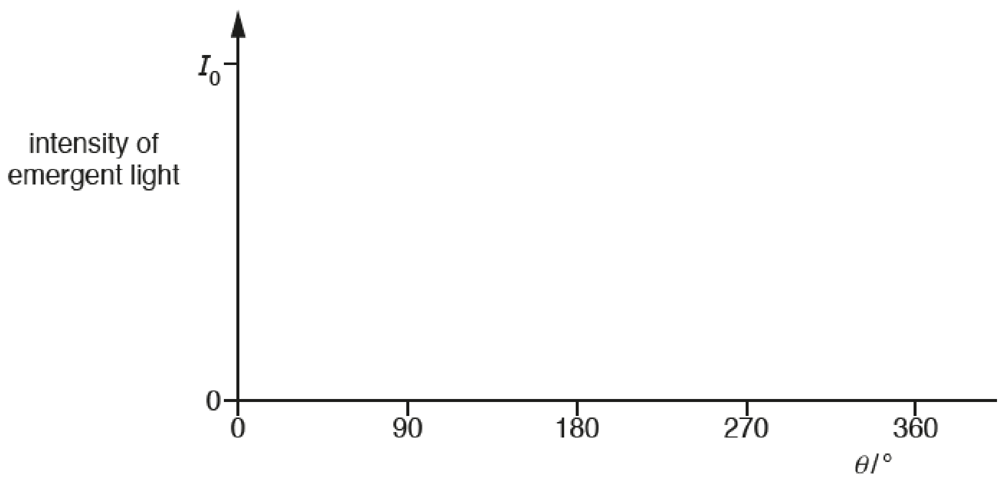

Fig. 6.2 [2]

For Examiner's Use

(iii) Fig. 6.3 shows light from the same laser reflecting off a surface before passing through the polarising filter. The intensity of the light incident on the polarising filter remains as I_o.

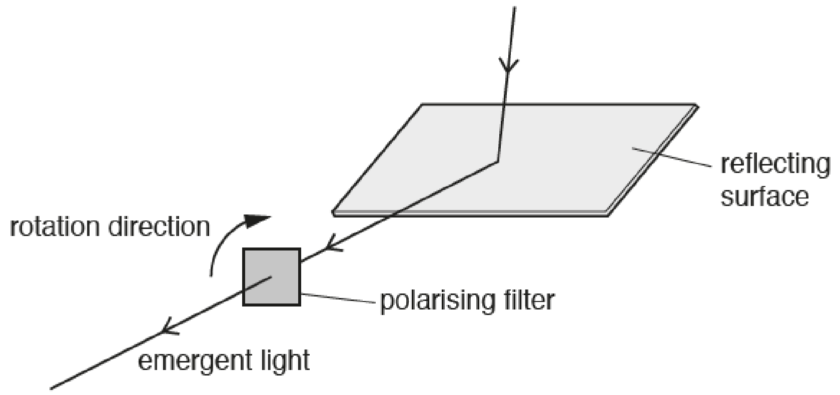

Fig. 6.3

When the polarising plane of the filter is vertical, the intensity of the emergent light is 0.179 I_o. When the polarising plane of the filter is horizontal, the intensity of the emergent light is 0.821 I_o.

Determine the intensity, in terms of I_o, of the emergent light when the polarising direction of the filter is 30° from the vertical.

intensity = ……………………… I_0 [2]

[Turn over

(b) Light from the laser in **(a)** is now incident on a double slit. The light emerging from the slits is detected by a light sensor attached to a toy train moving at a constant speed as shown in Fig. 6.4.

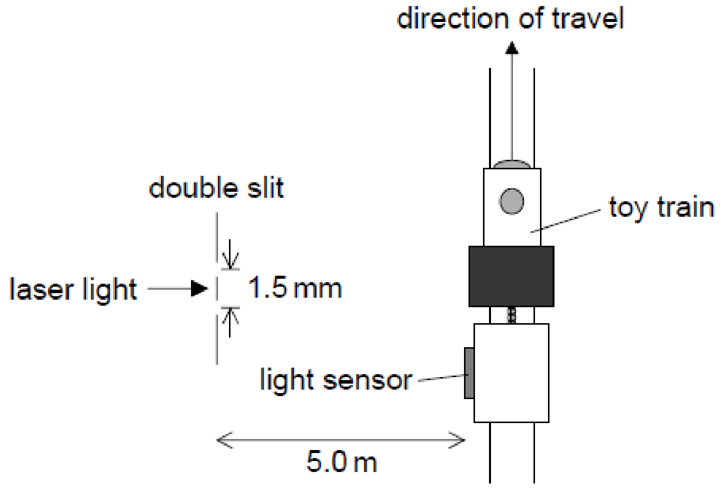

Fig. 6.4

Fig. 6.5 shows the variation with time of the output voltage from the light sensor as the train moves parallel to the slits at a constant speed. The output voltage is proportional to the intensity of light incident on the sensor.

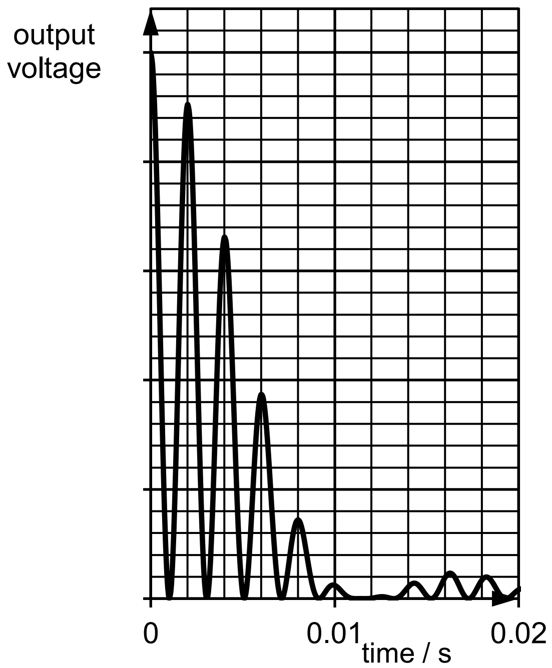

Fig. 6.5

(i) With reference to the light passing through the slits, explain the variation of the output voltage shown in Fig. 6.5.

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

(ii) The separation between the slits is 1.5 mm and the laser light has a wavelength of 630 nm. The distance between the track and the slits is 5.0 m.

1. Calculate the separation between two adjacent maxima detected by the train.

separation = ……………………… m [2]

2. Hence, determine the speed of the train.

speed = ……………………… m s^{-1} [2]

For Examiner's Use

(c) One of two the slits in Fig. 6.4 is now covered. When the train moves across the remaining slit, the first minima is detected when the light sensor is at 0.13 m from the centre of the fringe pattern.

(i) Determine the width of the slit.

width = ……………………… m [2]

(ii) The slit width is now widened.

State the changes that will be observed at the central bright fringe.

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…………………………………………………………………………………………

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

For Examiner's Use

(d) The light sensor on the train is replaced with a sound sensor. The train now travels away from a loudspeaker that is emitting unidirectional sound waves of constant amplitude and frequency towards a reflecting barrier as show in Fig. 6.6.

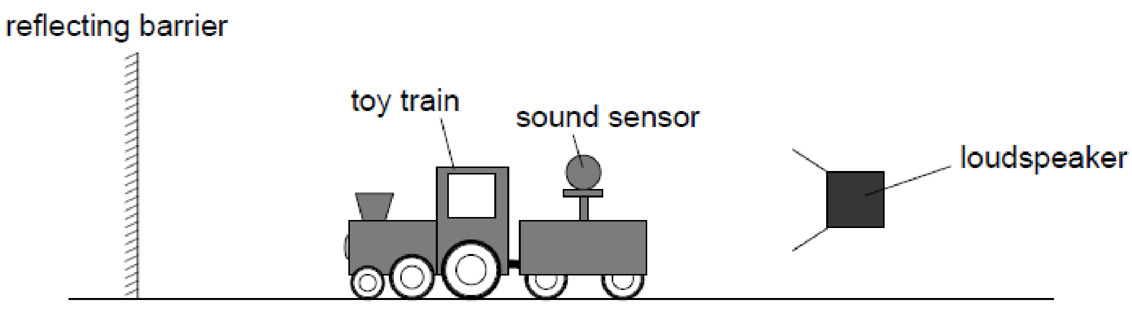

Fig. 6.6

On Fig. 6.7, sketch the variation with time of the output voltage from the sound sensor. Explain your answer.

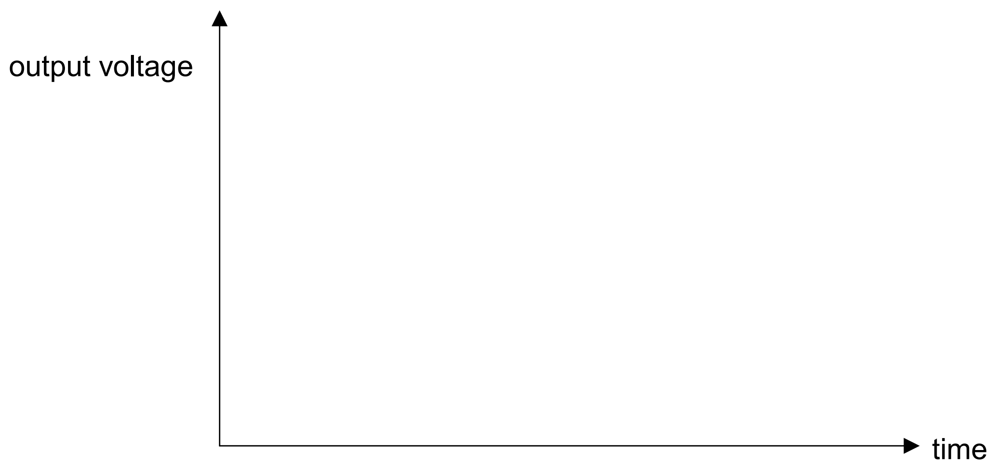

Fig. 6.7

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.... [3]

[Total: 20]

For Examiner's Use

7 **(a)** State what is meant by the *gravitational potential energy* stored between two point masses that are separated by a distance from each other.

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.... [2]

(b) The Moon orbits the Earth with a orbital radius of 3.84×10^8 m. The time it takes to complete one orbit is 27.3 days.

(i) Explain what is meant by a *geostationary* orbit.

....

.... [1]

(ii) Hence, explain why the moon is not in a geostationary orbit.

....

.... [1]

(iii) Calculate the angular velocity of the Moon.

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

(iv) Hence or otherwise, determine the mass of the Earth. Show your working clearly.

mass of Earth = ... kg [3]

For Examiner's Use

(v) The mass of the Earth is M_e.
The mass of the Moon is M_m.
The orbital radius of the Moon is x.

1. Show that the kinetic energy of the Moon is $\frac{GM_eM_m}{2x}$.

[1]

2. Derive an expression for the total energy of the Moon in terms of M_e, M_m and x.

[1]

3. Explain why the total energy of the moon must be less than zero.

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

(vi) The Moon is moving away from the Earth at about 3.8 cm per year and the Earth's days are getting longer at about 2 ms per century.

1. State and explain the effect on the total energy of the Moon.

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

For Examiner's Use

2. Explain how energy is conserved in the system.

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……………………………………………………………………………………..

…………………………………………………………………………..….. [1]

3. Suggest why this will cause a day on Earth to be longer.

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…………………………………………………………………………..….. [1]

(vii) Between the Earth and the Moon, the point where the resultant gravitational field strength is zero is 34.6×10^{7} m from the centre of the Earth.

A student is provided with the gravitational potential at two positions between the Earth and Moon as shown in the table.

Position	Distance from the centre of the Earth/ m	Gravitational potential/ J kg^{-1}
M	1.0×10^{7}	-40.2×10^{6}
N	37.4×10^{7}	-15.6×10^{6}

He states the following:

"An object at rest released at N will accelerate towards the Earth since the gravitational potential is lower at M."

Comment on his statement.

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

[Total: 20]

End of Paper