EUNOIA JUNIOR COLLEGE
JC2 Preliminary Examination 2021
General Certificate of Education Advanced Level
Higher 2

CANDIDATE NAME	

CIVICS GROUP	2	0	-			REGISTRATION NUMBER		

PHYSICS

9749/03

Paper 3 Longer Structured Questions

20 September 2021

2 hours

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

READ THESE INSTRUCTIONS FIRST

Write your name, civics group and registration number on all the work you hand in.
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 paper clips, highlighters, 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

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

For Examiner's Use	
1	
2	
3	
4	
5	
6	
7	
8	
Total	

This document consists of **25** printed pages and **1** blank page.

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,	$p = \rho gh$
gravitational potential,	$\phi = -\dfrac{Gm}{r}$
temperature,	$T/K = T/°C + 273.15$
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	$B = \dfrac{\mu_o NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_o nI$
radioactive decay,	$x = x_o \exp(-\lambda t)$
decay constant	$\lambda = \dfrac{\ln 2}{t_{\frac{1}{2}}}$

Section A

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

1 Fig 1.1 shows a displacement-distance graph for two sound waves A and B, of the same frequency and amplitude. Wave A is travelling to the right and wave B is travelling to the left.

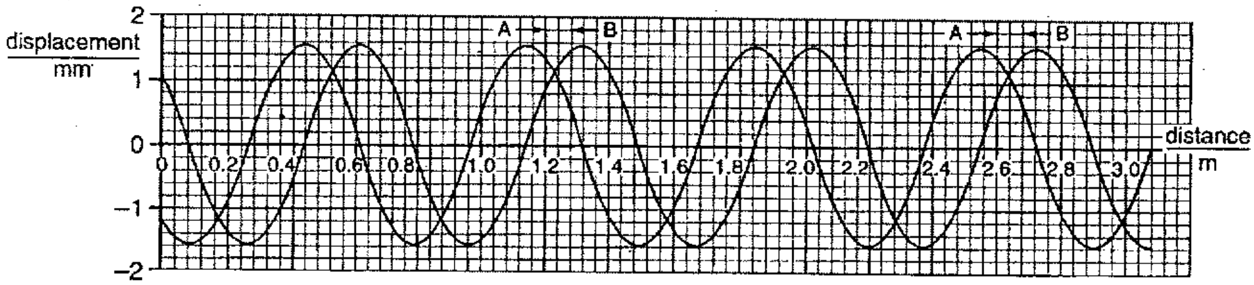

Fig 1.1

(a) **(i)** From the graph, deduce the phase difference between the two waves at the instant shown.

phase difference = ... rad [1]

(ii) The period of each wave is T.

Determine the maximum displacement of the resultant of the two waves

1. at the instant shown,

maximum displacement = ... mm [1]

2. at the instant shown + $\frac{T}{8}$,

maximum displacement = ... mm [1]

3. at the instant shown + $\frac{3T}{8}$.

maximum displacement = ... mm [1]

(b) Two microwaves sources S_1 and S_2 are located as shown in Fig 1.2. The sources are producing waves that are in phase and of wavelength λ. The distance between S_1 and S_2 is 3.5λ. Points lying on the line joining P and Q are equidistant from S_1 and S_2.

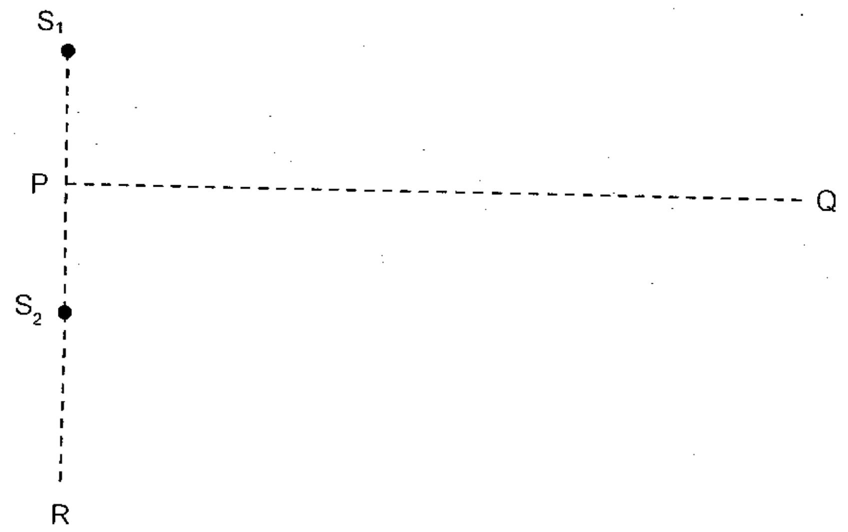

Fig 1.2

Assume that any drop in intensity of the wave, from each source, with distance is negligible.

State and explain whether a maximum or minimum is detected by a microwave sensor as it is moved along the line joining

(i) S_1 and S_2,

....

....

....

.... [2]

(ii) P and Q,

....

....

.... [2]

(iii) S_2 and R.

....

....

.... [2]

[Total: 10]

2 A roller coaster carriage of mass m enters a circular loop-the-loop at point A with speed v_A, reaches the top of the loop at B with speed v_B and exits the loop with the same speed v_A as shown in Fig. 2.1.

The radius of the loop is R. The magnitudes of the normal contact forces acting on the carriage at A and B are N_A and N_B respectively.

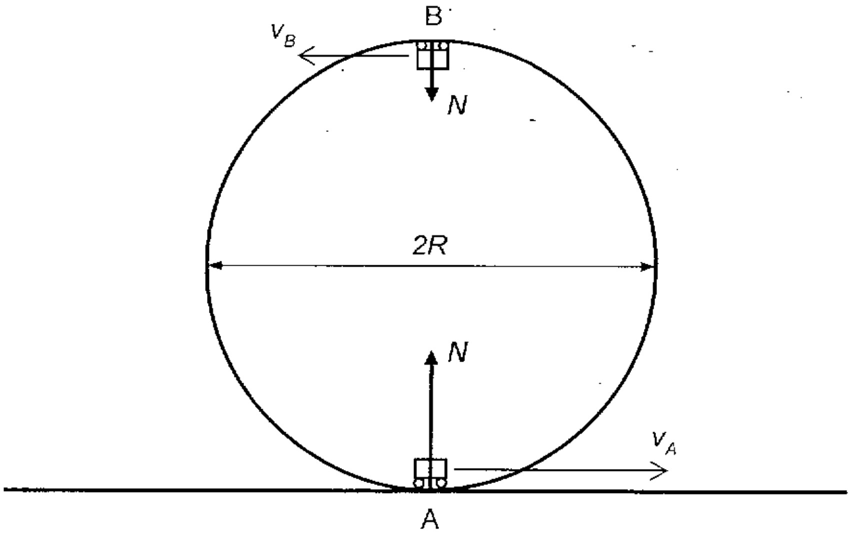

Fig. 2.1

(a) **(i)** State an expression for the loss in kinetic energy from A to B in terms of m, g and R, where g is the gravitational acceleration.

.... [1]

(ii) The track is smooth and there is no other resistive force present. Using your answer in **(a)(i)**, show that

$$N_A - N_B = 6mg.$$

[3]

(b) A rider may feel that he is heavier or lighter during a roller coaster ride depending on the normal contact force N from the seat that is acting on him. A quantity known as the g-force compares N with his weight as follows:

$$g\text{-force} = \frac{N}{\text{weight}}.$$

A g-force of 2.0 means that the rider feels twice as heavy as his normal weight.

As the carriage moves through the loop, the g-force varies with the angle θ with the vertical as shown in Fig. 2.2, according to the relation

$$g\text{-force} = \frac{v_A^{\,2}}{gR} + 3\cos\theta - 2$$

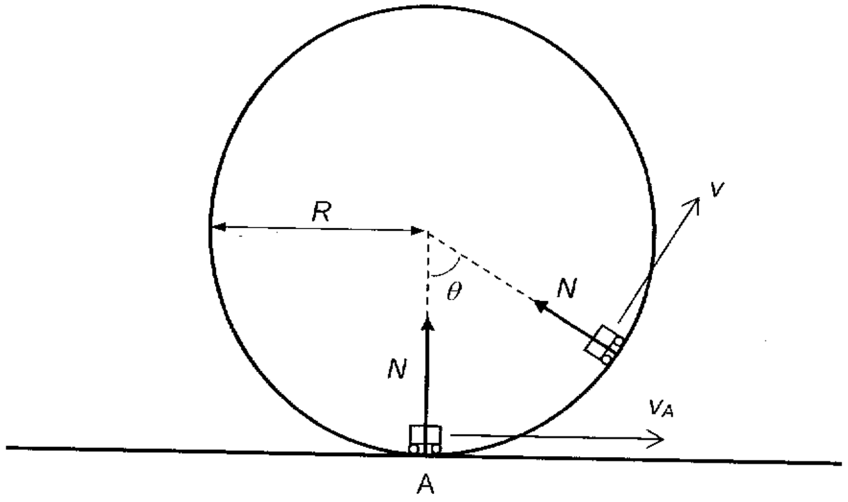

Fig. 2.2

(i) In order for the carriage to just reach the top of the loop (θ = 180°), the g-force at A (θ = 0°) would have to be 6.0, as shown in Fig. 2.3. The contact force at the top of the loop is then zero, and the rider would feel 'weightless'.

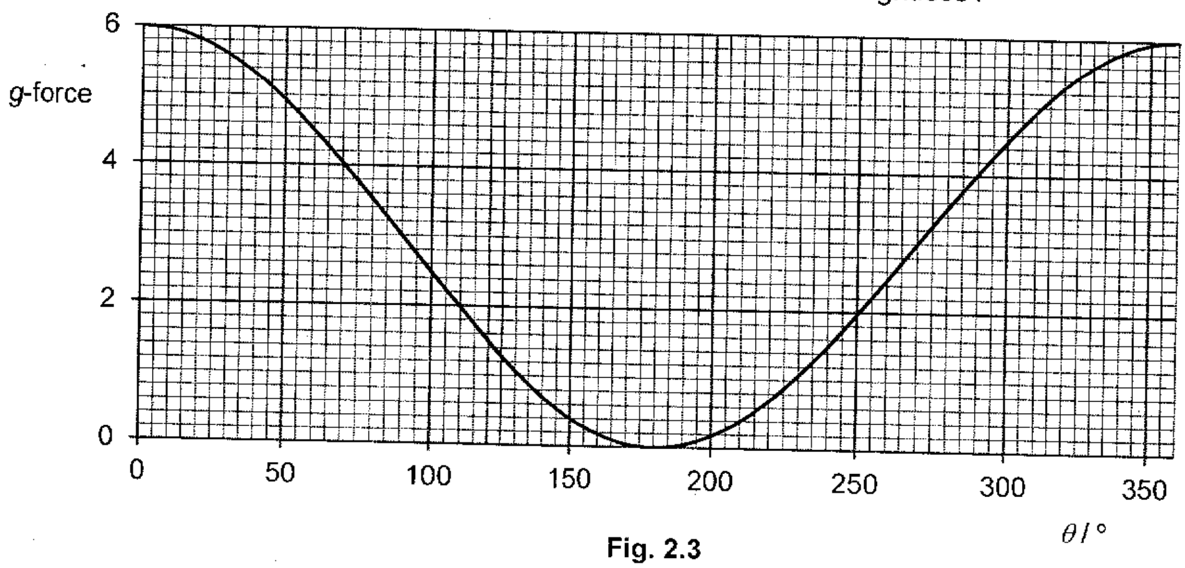

Fig. 2.3

1. Use information from Fig. 2.3 or otherwise to complete Fig. 2.4. Show your workings clearly. a_c refers to the centripetal acceleration.

θ / °	$\frac{a_c}{g}$
0	....
90	....
180	1.0

Fig. 2.4

[2]

2. Show that the speed of the carriage at A is equal to $\sqrt{5gR}$.

[1]

(ii) If the carriage enters the loop with a speed slower than $\sqrt{5gR}$ such that the g-force at A is 5.0, the carriage would lose contact with the track before it reaches the top of the loop.

Use Fig. 2.3 to deduce a value for θ at which the carriage first loses contact with the track.

θ = ... ° [1]

(c) A major disadvantage of circular loop-the-loop is that the circular track generates intense *g*-force, which makes it very uncomfortable for riders. A modern loop-the-loop is carefully designed with non-constant radius to overcome such limitations.

Fig. 2.5 shows two identical loop-the-loops at the Carolina Cyclone roller coaster located at Carowinds in North Carolina.

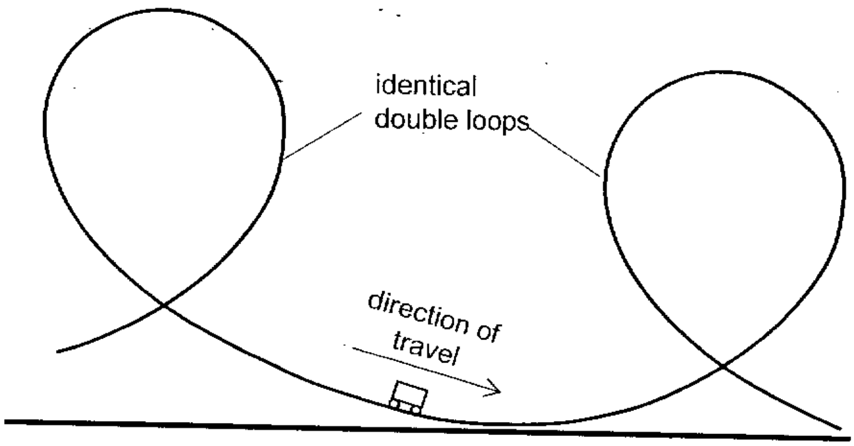

Fig. 2.5

(i) State and explain one advantage of the non-circular loop over the circular loop in **(a)** and **(b)**.

....

....

....

....[1]

(ii) Explain why the second loop in Fig. 2.5 is lower in height compared to the first loop.

....

....

....

....[1]

[Total: 10]

3 Fig. 3.1 shows the current-voltage (I-V) characteristics of two resistors R and X.

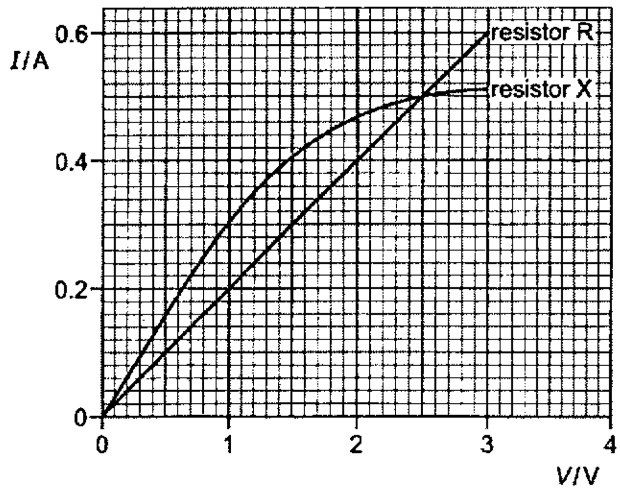

Fig. 3.1

The two resistors are connected in series with a cell of negligible internal resistance as shown in Fig. 3.2. The e.m.f. of the cell is 2.5 V.

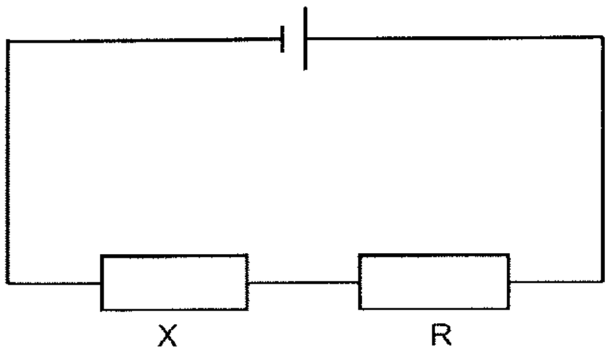

Fig. 3.2

(a) What is meant by the term *e.m.f.* of a cell?

....

....

....[2]

(b) Describe and explain how the resistance of resistor X varies with increasing potential difference with reference to the motion of the electrons.

....

....

....

....

....[3]

(c) **(i)** Using Fig. 3.1, determine the current passing through resistor X.
Show your working clearly.

current = ... A [3]

(ii) State

1. the resistance of X

resistance of X = ... Ω [1]

2. the resistance of R

resistance of R =.................................... Ω [1]

[Total: 10]

4 (a) A coil of wire is situated in a uniform magnetic field of flux density B.
The coil has diameter 3.6 cm and consists of 350 turns of wire, as illustrated in Fig. 4.1.

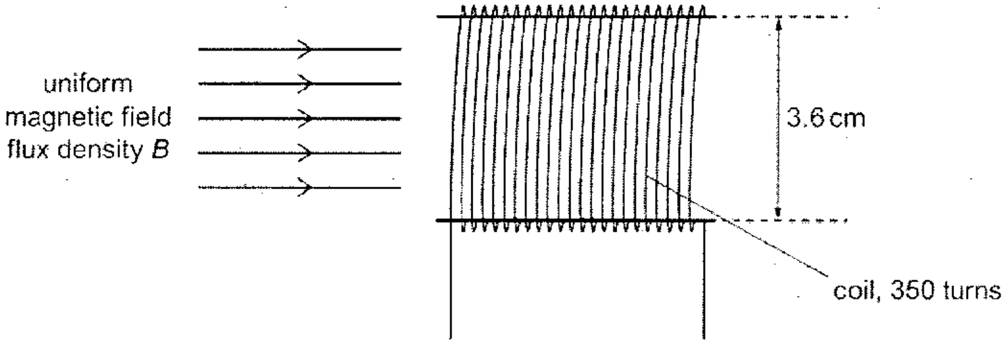

Fig. 4.1

The variation with time t of B is shown in Fig. 4.2.

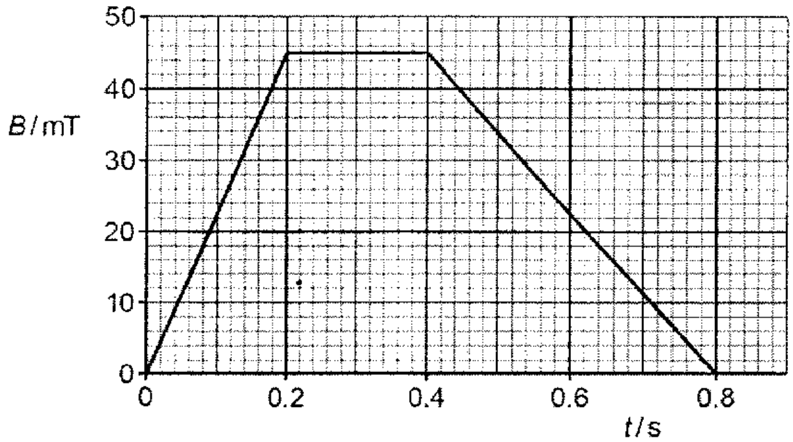

Fig. 4.2

(i) Show that, for the time t = 0 to time t = 0.20 s, the electromotive force (e.m.f.) induced in the coil is 0.080 V.

[2]

(ii) On the axes of Fig. 4.3, show the variation with time t of the induced e.m.f. E for time $t = 0$ to time $t = 0.80$ s.

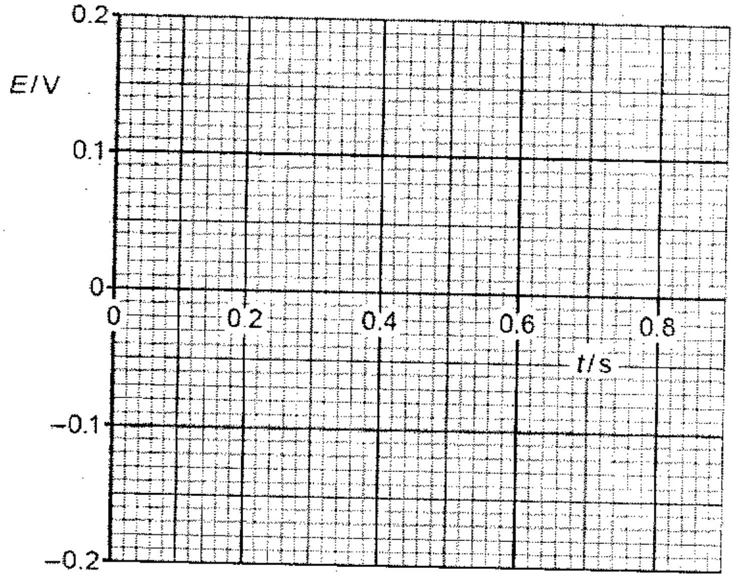

Fig. 4.3

[4]

(b) A bar magnet is held a small distance above the surface of an aluminium disc by means of a rod, as illustrated in Fig. 4.4.

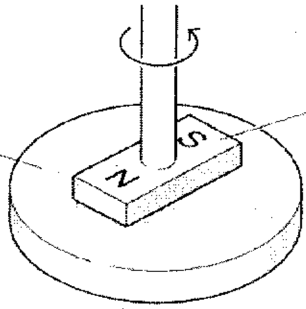

Fig. 4.4

The aluminium disc is supported horizontally and held stationary.
The magnet is rotated about a vertical axis at constant speed.

Use Faraday's law to explain why there is a force acting on the aluminium disc.

....

....

....

....

....

....

.... [4]

[Total: 10]

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5 A large container of volume 85 m^3 is filled with 110 kg of an ideal gas. The pressure of the gas is 1.0×10^5 Pa at temperature T.

The mass of 1.0 mol of the gas is 32 g.

(a) Show that the temperature T of the gas is approximately 300 K.

[3]

(b) The temperature of the gas is increased to 350 K at constant volume. The specific heat capacity of the gas for this change is 0.66 J kg^{-1} K^{-1}.

Calculate the energy supplied to the gas by heating.

energy = ... J [2]

(c) Explain how movement of the gas molecules causes pressure in the container.

....

....

....

....

....

....

.... [3]

(d) The temperature of a gas depends on the root-mean-square (r.m.s.) speed of its molecules.

Calculate the ratio:

$$\frac{\text{r.m.s. speed of gas molecules at 350 K}}{\text{r.m.s. speed of gas molecules at 300 K}}.$$

ratio = ... [2]

[Total: 10]

6 (a) Electromagnetic radiation is incident on a metal surface.

It is observed that there is a minimum frequency of electromagnetic radiation below which emission of electrons does not occur.

This observation provides evidence for a particulate nature of electromagnetic radiation.

State **two** other observations associated with photoelectric emission that provide evidence for a particulate nature of electromagnetic radiation.

1. ....

....

2. ....

....

[2]

(b) The maximum kinetic energy E_{MAX} of electrons emitted from a metal surface is determined for different wavelengths λ of the electromagnetic radiation incident on the surface.

The variation with $\frac{1}{\lambda}$ of E_{MAX} is shown in Fig. 6.1.

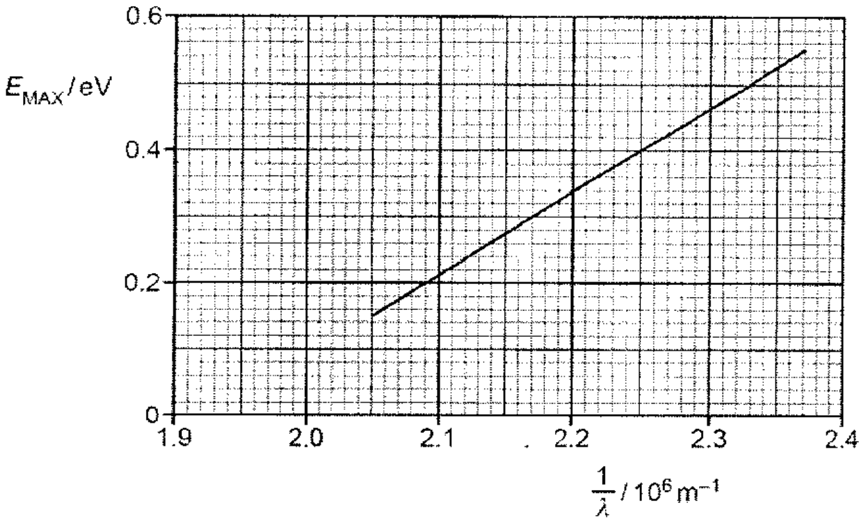


Fig. 6.1

(i) Use Fig. 6.1 to determine the threshold frequency f_0.

f_0 = ... Hz [2]

(ii) Use Fig. 6.1 to determine a value for the Planck constant h.

Explain your working.

h = ... J s [4]

(c) The electromagnetic radiation is now incident on a metal with a larger work function energy than the metal in **(b)**.

On Fig. 6.1, sketch the variation with $\frac{1}{\lambda}$ of E_{MAX}. [2]

[Total: 10]

Section B

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

7 **(a)** A dish is made from a section of a hollow glass sphere.

The dish, fixed to a horizontal table, contains a small solid ball of mass 45 g, as shown in Fig. 7.1.

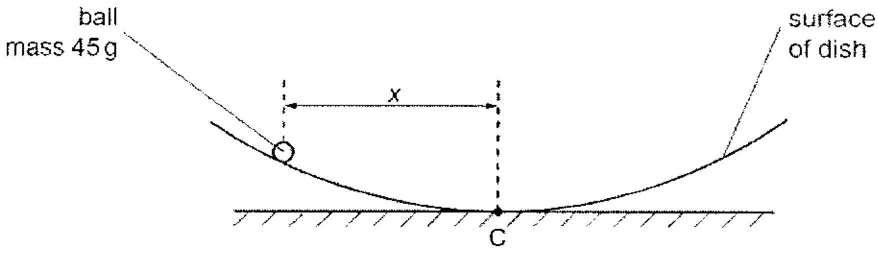


Fig. 7.1

The horizontal displacement of the ball from the centre C of the dish is x.

Initially, the ball is held at rest with distance x = 3.0 cm.

The ball is then released. The variation with time t of the horizontal displacement x of the ball from point C is shown in Fig. 7.2.

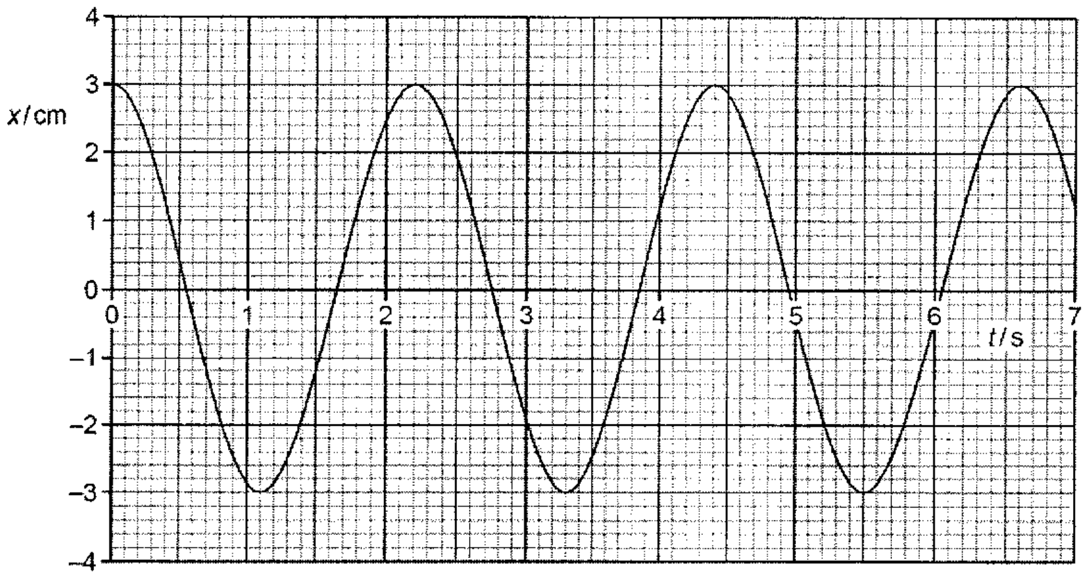


Fig. 7.2

The motion of the ball in the dish is simple harmonic with its acceleration a given by the expression

$$a = -\left(\frac{g}{R}\right)x$$

where g is the acceleration of free fall and R is a constant that depends on the dimensions of the dish and the ball.

(i) Explain how the expression $a = -\left(\frac{g}{R}\right)x$ suggests that the motion is simple harmonic?

....

....

....

....[2]

(ii) Use Fig. 7.2 to show that the angular frequency ω of the oscillation of the ball in the dish is 2.9 rad s^{-1}.

[1]

(iii) Determine R.

R = ... m [1]

(iv) Calculate the speed of the ball when x = 1.5 cm.

speed = ... m s^{-1} [2]

(v) Calculate the total energy of the oscillation.

total energy = ... J [3]

(vi) Determine the kinetic energy E_k of the ball in terms of time t.

E_k = ... J [2]

(vii) Some moisture collects on the surface of the dish so that the motion of the ball becomes damped.

On the axes of Fig. 7.3, draw a graph to show variation of x with E_k of the damped motion of the ball for the first 2.2 s after the release of the ball.

No numerical values are required.

[1]

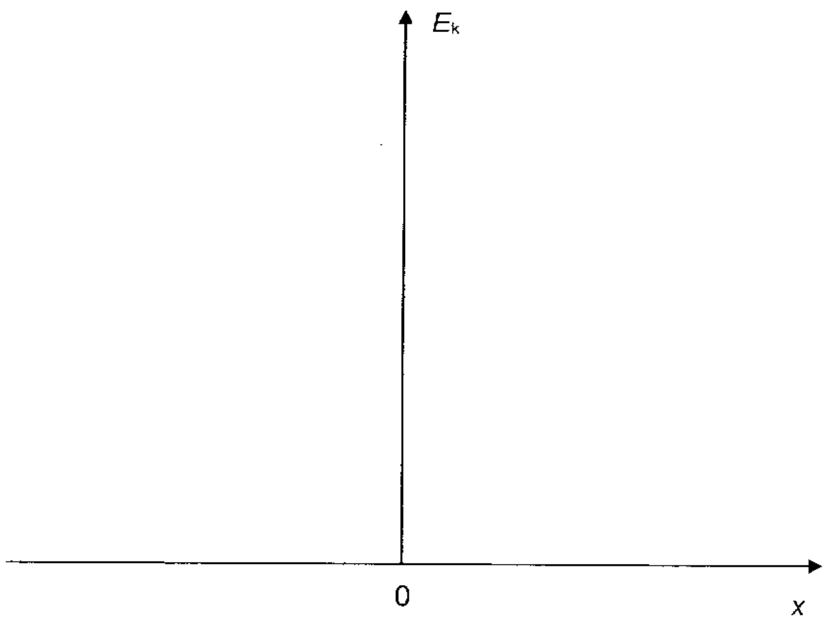


Fig. 7.3

(b) A block of wood of mass m floats in still water, as shown in Fig. 7.4 below.

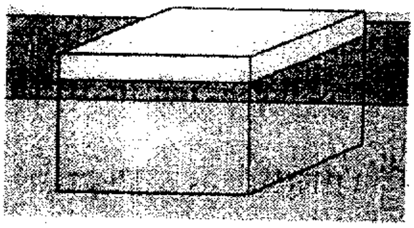


Fig. 7.4

When the block is pushed down into the water, without totally submerging it, and is then released, it bobs up and down in the water with a frequency f given by the expression

$$f = \frac{1}{2\pi}\sqrt{\frac{28}{m}}$$

where f is measured in Hz and m in kg.

Surface water waves of speed 0.90 m s^{-1} and wavelength 0.30 m are then incident on the block. These cause resonance in the up-and-down motion of the block.

(i) Calculate

1. the frequency of the water waves,

frequency = ... Hz [1]

2. the mass of the block.

mass = ... kg [1]

(ii) Describe and explain what happens to the amplitude of the vertical oscillations of the block after the following changes are made independently:

1. water waves of larger amplitude are incident on the block,

....

....

....[2]

2. the distance between the wave crests increases,

....

....

....[2]

3. the block has absorbed some water.

....

....

....[2]

[Total: 20]

8 (a) (i) Explain what is meant by *half-life*.

....

....[1]

(ii) Explain what is meant by *decay constant*.

....

....[2]

(iii) Write down the nuclear notation of a nuclide with particular reference to lithium (Li) nucleus containing 3 protons and 4 neutrons.

State the meaning of any number that you write down. [2]

(b) Naturally occurring radioactivity results in the emission of three types of ionising radiation - alpha, beta and gamma.

Distinguish between the three types in terms of their relative charges, masses and speeds.

....

....

....

....

....

....

.... [6]

(c) In the early years of this century Mdm Curie drew an illustration similar to the Fig. 8.1 below which indicated how the three radiations travelled in air in a uniform magnetic field.

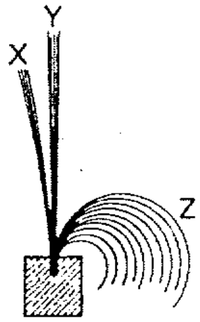


Fig. 8.1

(i) Identify the radiations X, Y and Z.

X: ....

Y: ....

Z: ....

[3]

(ii) Explain what is shown by the fact that the lines for X all have approximately the same length.

....

....[2]

(iii) Explain what is shown by the fact that the lines for Z have different curvatures?

....

....

....[2]

(iv) Give two reasons why it is difficult, if not impossible, to take a photograph which is like the figure.

1. ....

....

2. ....

....

[2]

[Total: 20]

EUNOIA JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATIONS 2021
General Certificate of Education Advanced Level
Higher 2

PHYSICS

MARK SCHEME

9749/03

September 2021

Question				Solution	Marks
1	(a)	(i)		Phase difference = ¼ cycle × 2π = π/2 or 1.57 rad	A1
		(ii)	1.	2.2 mm	A1
			2.	1.6 mm + 1.6 mm = 3.2 mm	A1
				1.6 mm – 1.6 mm = 0 mm	A1
	(b)	(i)		Path difference varies between nλ and (n + ½)λ (phase difference alternates between 0 and π) Series of alternating maxima and minima OR 2 waves of same amplitude and frequency travelling in opposite directions. A stationary wave is formed. Series of alternating maxima at the antinodes and minima at the nodes	M1 A1 (M1) (A1)
		(ii)		Path difference = 0 (waves meet in phase) Maximum throughout	M1 A1
				Path difference = 3.5λ (waves meet in antiphase) Minimum throughout	M1 A1

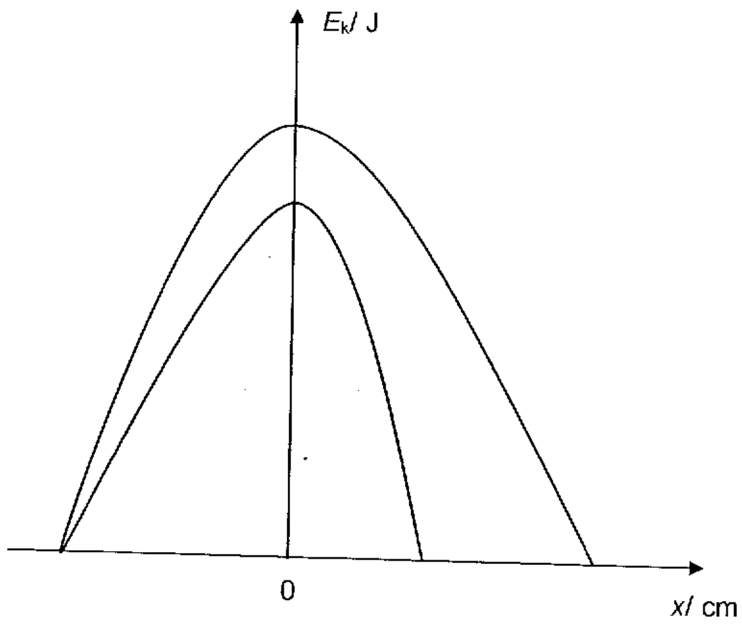
Question			Solution	Marks
2	(a)	(i)	$2mgR$	B1
		(ii)	Resultant force provides centripetal force $N_A - mg = \frac{mv_A^2}{R}$ ....(1) $N_B + mg = \frac{mv_B^2}{R}$ ....(2) From (a)(i): $\frac{1}{2}mv_A^2 - \frac{1}{2}mv_B^2 = mg(2R)$ ....(3) Correct workings leading to $N_A - N_B = 6mg$	B1 B1 M1
	(b)	(i)	1. When $\theta = 0°$, g-force = 6.0 $\Rightarrow N_A = 6.0\,mg$ $N_A - mg = ma \Rightarrow a = 5.0\,g \Rightarrow a/g = 5.0$ When $\theta = 90°$, g-force = 3.0 $\Rightarrow N_A = 3.0\,mg$ $N = ma \Rightarrow a = 3.0\,g \Rightarrow a/g = 3.0$	M1 A0 M1 A0
			2. Using g-force $= \frac{v_A^2}{gR} + 3\cos\theta - 2$ Either at $\theta = 0°$, $6 = \frac{v_A^2}{gR} + 3(1) - 2$ Or at $\theta = 180°$, $0 = \frac{v_A^2}{gR} + 3(-1) - 2$ Or any other points from the graph	M1 A0
		(ii)	Shift curve downwards, or shift x-axis upwards by 1 g-force. Read x-intercept value. Accept $130° \le \theta \le 135°$.	A1
	(c)	(i)	Either one of the following: • For non-circular loop, carriage enters loop not from a horizontal track, thus there is no sudden transition from g-force = 0 to 6. • Radius of non-circular loop decreases as θ increases, thus g-force does not decrease as much or as fast as the carriage travels to the top of the loop.	A1
		(ii)	Carriage loses KE due to resistive forces after going through the first loop, so it will exit the first loop with a lower speed. The second loop is lower so that the loss in GPE of the carriage as it moves from the first loop to the second loop compensates for the loss in KE.	A1

Question				Solution	Marks
3	(a)			The electromotive force of a source is the **<u>electrical energy, converted *from* other forms of energy per unit charge</u>**, transferred by the source in driving a charge round a complete circuit.	B1 B1
	(b)			The filament's **resistance to increase** with increasing p.d. When the temperature of resistor X increases, the <u>lattice ions gain more kinetic energy and vibrates more vigorously</u>. This results in the <u>more frequent collision between the conducting electrons and lattice ions</u> which reduces the mobility of the electrons (charge carriers).	A1 B1 B1
	(c)	(i)		Current passing through X and R must be the same. $V_X + V_R = 2.5$ V From graph: I = 0.20 A	C1 C1 A1
		(ii)		X = 3.3 Ω Y = 5.0 Ω	A1 A1

Question			Solution	Marks
4	(a)	(i)	e.m.f. = $(\Delta)B \times AN / t$	C1
			$= 45 \times 10^{-3} \times \pi \times (1.8 \times 10^{-2})^2 \times 350 / 0.20 = 0.080$ V	A1
		(ii)	0 to 0.2 s: straight horizontal line at 0.080 V or –0.080 V	B1
			0.2 s to 0.4 s: zero	B1
			0.4 s to 0.8 s: straight horizontal line at 0.040 V or –0.040 V	B1
			opposite polarity to 0 to 0.2 s line	B1
	(b)		either disc cuts flux lines (of the magnet) **or** there is a changing flux in the disc	B1
			(by Faraday's law) e.m.f. is induced in the disc	B1
			e.m.f. causes (eddy) currents in the disc	B1
			current in the disc causes force on disc (accepts FLHR)	B1

Question		Solution	Marks
5	(a)	n = 110 / 0.032 or 110000 / 32 or 3440 pV = nRT $T = (1.0 \times 10^5 \times 85) / (8.31 \times (110 / 0.032)) = 300$ K	C1 C1 A1
	(b)	$E = mc\Delta\theta$ = 110 × 0.66 × 50 = **3600** J	C1 A1
	(c)	Any 3 from: • molecule collides with **wall** • momentum of molecule changes during collision (with wall) • force on molecule so force on wall • many forces act over surface area of container exerting a pressure	B3
	(d)	$KE \propto T$ $v \propto \sqrt{T}$ *ratio* = $\sqrt{(350 / 300)}$ = ***1.1***	C1 A1

Question			Solution	Marks
6	(a)		any two points from: • (maximum) kinetic energy of electrons is independent of intensity • maximum kinetic energy of electrons depends on frequency • no time delay (between illumination and emission)	B2
	(b)	(i)	(for $E_{MAX} = 0$,) $1 / \lambda_0 = 1.93 \times 10^6$ (m^{-1}) $f_0 = 3.00 \times 10^8 \times 1.93 \times 10^6$ $= 5.8 \times 10^{14}$ Hz	C1 A1
			$hc / \lambda = \Phi + E_{MAX}$ hc = gradient gradient = e.g. $[(0.40 - 0.20) \times 1.60 \times 10^{-19}] / [(2.25 - 2.09) \times 10^6]$ (working needed) ($= 2.0 \times 10^{-25}$) $h = (2.0 \times 10^{-25}) / (3.00 \times 10^8) = 6.7 \times 10^{-34}$ J s (both working and answer needed)	C1 C1 M1 A1
			straight line with same gradient as the original straight line with x-axis intercept greater than 1.93×10^6 m^{-1}	B1 B1

Question				Solution	Marks
7	(a)	(i)		*g* and *R* are constants, hence a is proportional to x the negative sign indicates that a is in the opposite direction of x.	B1 B1
		(ii)		$\omega = 2\pi / T$ and $T = 2.2$ s $\omega = 2\pi / 2.2 = 2.9$ rad s^{-1}	A1
		(iii)		$\omega^2 = g / R$ $R = 9.81 / 2.86^2$ = 1.2 m	A1
		(iv)		$v = \omega\sqrt{x_o^2 - x^2}$ $v = (2.9)\sqrt{(0.030)^2 - (0.015)^2}$ = 0.075 m s^{-1}	C1 A1
		(v)		Total energy = maximum KE $= \frac{1}{2} m v_0^2$ $= \frac{1}{2} m(\omega x_0)^2$ $= \frac{1}{2}(0.045)(2.9 \times 3.0 \times 10^{-2})^2$ $= 1.7 \times 10^{-4}$ J	B1 M1 A1
		(vi)		$E_k = \frac{1}{2} m v_0^2 \sin^2 \omega t$ $E_k = 1.7 \times 10^{-4} \sin^2(2.9t)$	C1 A1
		(vii)		 *To show amplitude and kinetic energy decreasing clearly*	B1
	(b)	(i)	1.	$v = f\lambda$ $0.90 = f(0.30)$ $f = 3.0$ Hz	A1
			2.	$3.0 = \frac{1}{2\pi}\sqrt{\frac{28}{m}}$ $m = 0.079$ kg	A1
		(ii)	1.	(Since energy is proportional to amplitude squared) more energy is being transferred,	M1 A1

				Amplitude increases	
			2.	Frequency of wave decreases. Does not match natural frequency Amplitude decreases	M1 A1
			3.	Mass of system increases. Natural frequency drops. Does not match driver frequency of the waves. Amplitude decreases.	M1 A1