HWA CHONG INSTITUTION
JC2 Preliminary Examination
Higher 2

CANDIDATE NAME		**CT GROUP**	21S
CENTRE NUMBER		**INDEX NUMBER**	

PHYSICS — 9749/03

Paper 3 Longer Structured Questions — **15 September 2022**

SECTION A BOOKLET — **2 hours**

Candidates answer on the Question Paper.

No Additional Materials are required.

INSTRUCTIONS TO CANDIDATES

Write your **Centre number**, **index number, name** and **CT class** clearly on all 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 staples, paperclips, 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. **Circle** the question number on the cover page.

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.

You are reminded of the need for good English and clear presentation in your answers.

For Examiner's Use		
Section A		
1		**8**
2		**8**
3		**9**
4		**8**
5		**10**
6		**7**
7		**10**
Section B		
8		**20**
9		**20**
Deductions		
P3		**80**

Data

speed of light in free space,
$c = 3.00 \times 10^{8}\ \text{m s}^{-1}$

permeability of free space,
$\mu_o = 4\pi \times 10^{-7}\ \text{H m}^{-1}$

permittivity of free space,
$\varepsilon_o = 8.85 \times 10^{-12}\ \text{F m}^{-1}$
$\approx (1/(36\pi)) \times 10^{-9}\ \text{F m}^{-1}$

elementary charge,
$e = 1.60 \times 10^{-19}\ \text{C}$

the Planck constant,
$h = 6.63 \times 10^{-34}\ \text{J s}$

unified atomic mass constant,
$u = 1.66 \times 10^{-27}\ \text{kg}$

rest mass of electron,
$m_e = 9.11 \times 10^{-31}\ \text{kg}$

rest mass of proton,
$m_p = 1.67 \times 10^{-27}\ \text{kg}$

molar gas constant,
$R = 8.31\ \text{J K}^{-1}\ \text{mol}^{-1}$

the Avogadro constant,
$N_A = 6.02 \times 10^{23}\ \text{mol}^{-1}$

the Boltzmann constant,
$k = 1.38 \times 10^{-23}\ \text{J K}^{-1}$

gravitational constant,
$G = 6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2}$

acceleration of free fall,
$g = 9.81\ \text{m s}^{-2}$

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on / by a gas	$W = p\,\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -\frac{Gm}{r}$
temperature	$T/\text{K} = T/\,^\circ\text{C} + 273.15$
pressure of an ideal gas	$P = \frac{1}{3}\frac{Nm}{V} \langle c^2 \rangle$
mean kinetic energy of a molecule of an ideal gas	$E = \frac{3}{2}kT$
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	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential	$V = \frac{Q}{4\pi\varepsilon_o r}$
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	$B = \frac{\mu_o NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_o nI$
radioactive decay	$x = x_o \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

1 (a) (i) Define gravitational potential at a point.

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

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

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

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

(ii) Explain why gravitational potential is negative.

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

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

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

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

(b) A meteorite was observed to be traveling fast on a straight-line path inside a gravitational field. AB is a segment of this path, which occurs over a short period of time. The variation in the gravitational potential ϕ along AB is shown in Fig 1.1 where x is the displacement of the meteorite from A. The gravitational potential reaches a maximum value when $x = x_0$ at the point C.

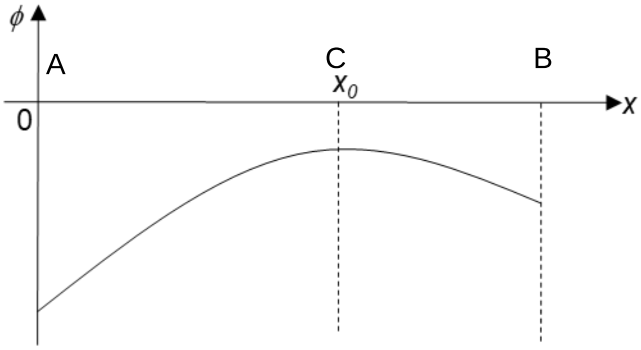

Fig 1.1

(i) Describe the variation in the gravitational force acting on the meteorite along the path AC.

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

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

(ii) On Fig 1.2, sketch the graph of the variation in the kinetic energy of the meteorite.

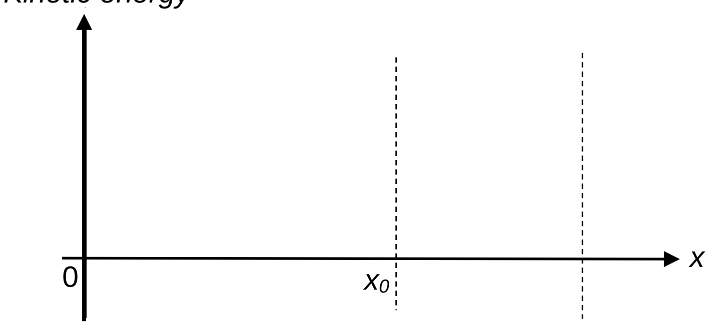

Fig 1.2 [2]

[Total: 8]

2 Fig. 2.1 shows a cylinder containing an ideal gas of pressure *P* and volume *V* enclosed by a movable piston. The cylinder is kept submerged in a large ice-water bath maintained at 0 °C.
The specific latent heat of fusion of the ice = 334 J g^{-1}.

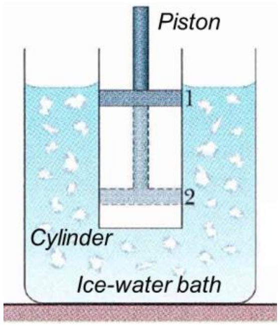

Fig. 2.1

The gas undergoes three processes in the following sequence:

Process A: Gas compressed quickly from position 1 to 2 (such that there is no heat transfer to and from gas).

Process B: Piston held at position 2 until the gas reaches the temperature of the ice-water bath.

Process C: Piston slowly raised back to position 1.

(a) The volume of gas when the piston is at position 1 and 2 are indicated as V_1 and V_2 respectively. The dot represents the state of gas in cylinder at the start of process A.
Sketch the 3 processes on the *P-V* diagram in Fig. 2.2. Label the processes clearly using A, B & C.

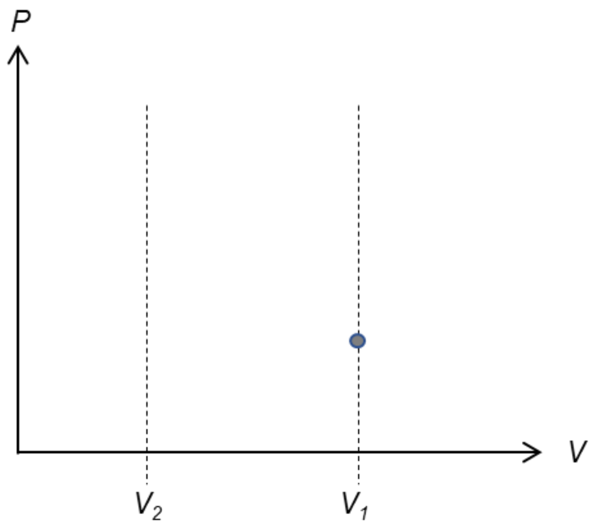

Fig. 2.2

[3]

(b) Identify process B.

.... [1]

(c) At the end of process C, 100 g of ice has melted. There is no heat transfer between the ice and environment.

State whether net heat is transferred into or out of the gas cylinder.

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

(d) Determine the net temperature change for the gas for one complete cycle.

net temperature change = ………………….. K [1]

(e) Calculate the net work done on the gas.

net work done on the gas = ……………………….. J [2]

[Total: 8]

3 One end of a spring is fixed to a support. A block is attached to the other end of the spring and gently lowered to its equilibrium position, as shown in Fig. 3.1.

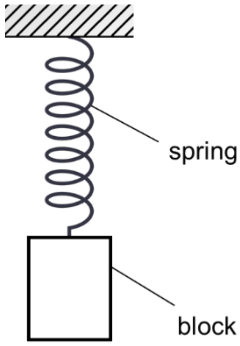

Fig. 3.1

Using two fingers, a student pushes down sharply on the block.
This immediately imparts some downward momentum to the block, causing it to oscillate.

(a) Theory suggests that the vertical acceleration a of the block is related to its vertical displacement y by the expression

$$a = -\frac{k}{m}y$$

where k is the spring constant and m is the mass of the block.

Explain why this expression leads to the conclusion that the block is performing simple harmonic motion.

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

(b) Fig. 3.2. shows some measurements obtained by the student.

Spring constant k / N m^{-1}	25
Mass of block / kg	0.15

Fig. 3.2

(i) Determine the angular frequency ω of the oscillation.

ω = ………………………….. rad s^{-1} [1]

(ii) The block has a maximum speed of 0.31 m s^{-1}. Damping effects can be neglected. **Using your result in (b)(i)**, calculate the amplitude y_0 of the oscillation.

y_0 = ………………………….. m [1]

(iii) Using your answers in **(b)(i)** and **(b)(ii)**, sketch on Fig. 3.3 the variation of velocity v of the oscillating system with the displacement y.

Indicate on your graph when the mass is at the start of its motion and when it first comes to rest. Label these points A and B respectively.

Take downwards as positive displacement.

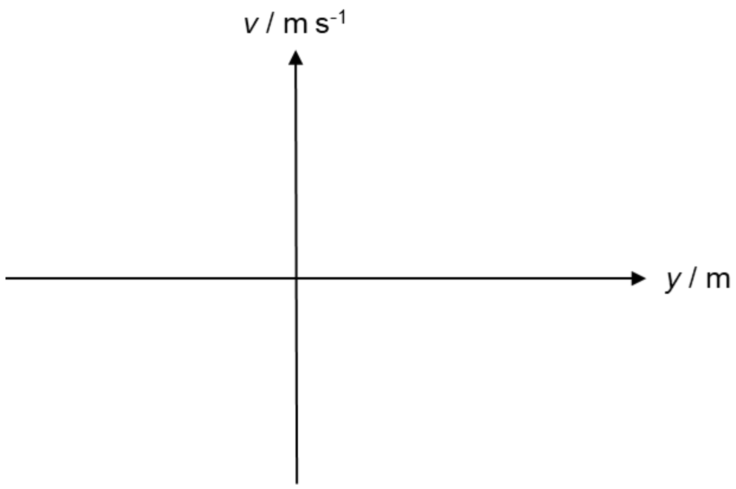

Fig. 3.3 [3]

(iv) Sketch two graphs on Fig. 3.4 to show the variation of kinetic energy (KE) and elastic potential energy (EPE) of the oscillating system as the block moves between the equilibrium position and the lowest position. Label each graph clearly.

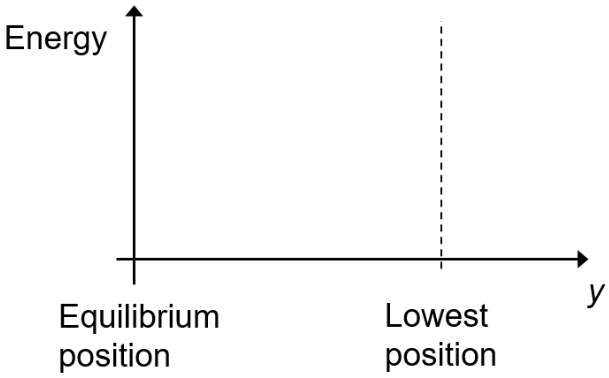

Fig. 3.4 [2]

[Total: 9]

4 A circuit is set up to determine the e.m.f. E and internal resistance r of an unknown cell as shown in Fig. 4.1. Initially, both switch S_1 and switch S_2 are opened.

An accumulator with a negligible internal resistance is connected in series to a resistor R_1 and a resistance wire. The resistance wire AB is 120.0 cm long. Both resistance wire and the external resistor R_1 has the same resistance. When the jockey J is placed at end point B, the potential difference across the resistor R_1 is 4.00 V. The resistance of the fixed resistor R_2 is 12.0 Ω.

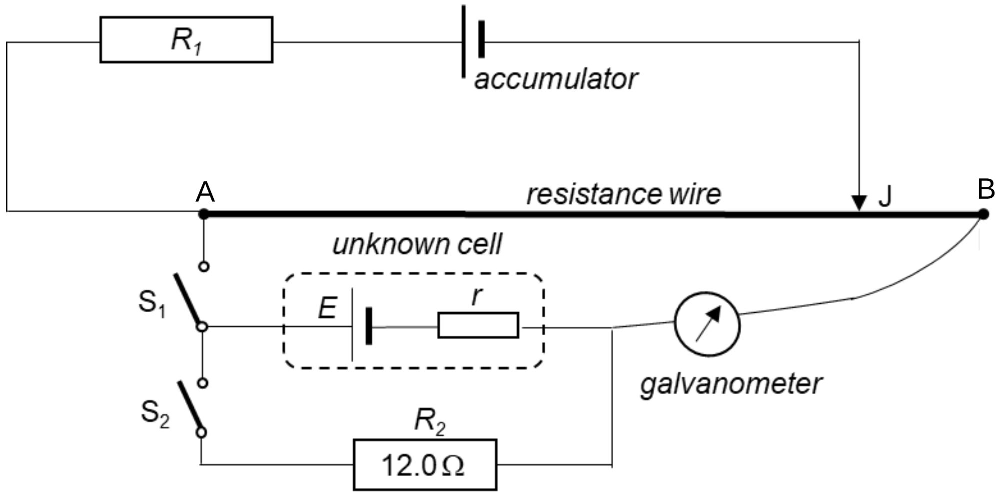

Fig. 4.1

(a) Determine the e.m.f. of the accumulator.

e.m.f. = ………………. V [1]

(b) The switch S_1 is closed. When the jockey J touches the point B on the resistance wire, the galvanometer shows null deflection. Determine the e.m.f. E and terminal potential difference of the unknown cell.

terminal potential difference = ………………. V

E = ………………. V [2]

(c) Both switches S_1 and S_2 are closed. When the jockey J is moved to a new point C on the resistance wire where it is at a distance of 72.0 cm from the point A, the galvanometer shows null deflection. Determine

(i) the potential difference between point A and point C.

potential difference = ………………. V [2]

(ii) the potential difference across the fixed resistance R_2.

potential difference = ………………. V [1]

(iii) the internal resistance r of the unknown cell.

r = ………………. Ω [2]

[Total: 8]

5 **(a)** The square loop ***abcd*** is placed in a region of uniform magnetic field of flux density B as shown in Fig. 5.1. The loop carries a steady current I in the direction as shown. Dotted lines CD, EF, GH and JK are axes of symmetry through the centre of the square loop.

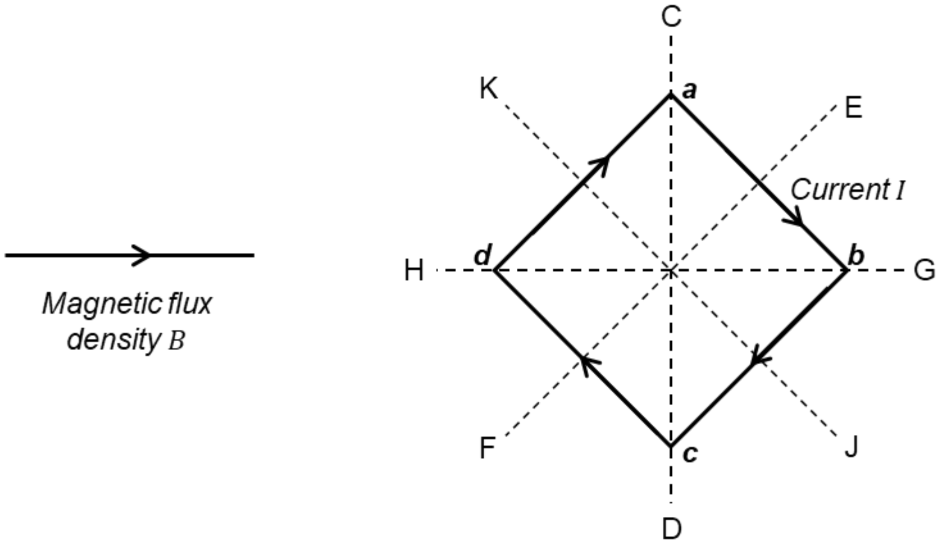

Fig. 5.1

(i) State the axis (CD, EF, GH or JK) about which the square loop will rotate.

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

(ii) State and explain the direction of rotation of the square loop about the axis you have identified in **(a)(i)**.

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

(b) The square loop in Fig. 5.2 is made of wires with total series resistance of 10.0 Ω. It is placed in a uniform magnetic field of magnetic flux density 0.100 T directed perpendicularly into the plane of the diagram.

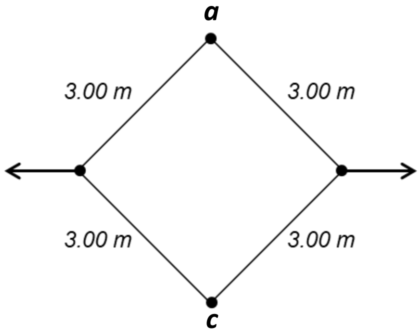

Fig. 5.2

The loop which is made of inextensible wires is hinged at each corner. In a time of 0.100 s, it is pulled in the directions as shown by the arrows until the separation between points ***a*** and ***c*** is 2.00 m.

(i) Determine the average induced e.m.f. in the loop.

average induced e.m.f. = …………………… V [4]

(ii) Hence, or otherwise, find the induced current in the loop.

induced current = ………………… A [1]

[Total: 10]

6 **(a)** The equation $V = 340 \sin(100\pi t)$ represents a sinusoidal alternating voltage for a household power supply, where V is in volts and t is in seconds. State the frequency, peak voltage and root-mean-square voltage for this alternating voltage.

(i)

frequency = ……………… Hz [1]

(ii)

peak voltage = ………………. V [1]

(iii)

root-mean-square voltage = ………………. V [1]

(b) Fig. 6 shows an ideal iron-cored transformer. The ratio of the secondary turns to the primary turns is 1:20.

A 240 V a.c. supply is connected to the primary coil and a 6.0 Ω resistor is connected to the secondary coil.

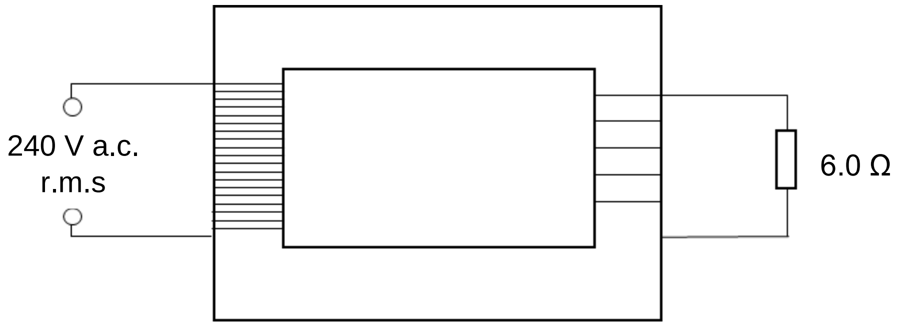

Fig. 6

(i) Determine the voltage across the 6.0 Ω resistor.

voltage = …………………… V [1]

(ii) Calculate the current in the primary coil.

current = ………………… A [3]

[Total: 7]

7 In an experiment, incident photons that enter a tube strike a metal surface, resulting in electrons being ejected. By counting the number of collected electrons, the number of incident photons can be determined.

(a) State the phenomenon where electrons are ejected from a metal irradiated with light.

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

(b) Determine the maximum kinetic energy of the ejected electrons if monochromatic light of wavelength 500 nm is incident on a metal of work function of 1.0 eV.

maximum kinetic energy = ………………. eV [2]

(c) Hence, calculate the maximum momentum of the ejected electrons.

maximum momentum = ……………..……. N s [2]

(d) A laser light of wavelength 500 nm and power 25 x 10^{-6} W is incident onto the metal. The probability of a photon ejecting an electron from the metal is 20%. Calculate the electron current produced, assuming all electrons are collected.

electron current = ……………..……. A [3]

(e) The metal chosen for this experiment is required to eject electrons when irradiated with light of all incident wavelengths throughout the visible light range (400 nm to 700 nm). Determine the maximum value for the work function of this metal.

maximum work function of metal = ……………..……. eV [2]

[Total: 10]

End of Paper 3 Section A