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 B 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 B (circle 1 question)		
8		**20**
9		**20**
Deductions		

Data

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

permeability of free space,
$\mu_0 = 4\pi \times 10^{-7}\ \mathrm{H\,m^{-1}}$

permittivity of free space,
$\varepsilon_0 = 8.85 \times 10^{-12}\ \mathrm{F\,m^{-1}}$
$\approx (1/(36\pi)) \times 10^{-9}\ \mathrm{F\,m^{-1}}$

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

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

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

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

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

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

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

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

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

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

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	$\phi = -\frac{Gm}{r}$
temperature	$T/\mathrm{K} = T/^{\circ}\mathrm{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $= \pm\omega\sqrt{(x_0^2 - x^2)}$
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	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current / voltage	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 N I}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 n I$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

Section B

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

8 **(a)** **(i)** State the *principle of superposition*.

....

....

....

....

.... [2]

(ii) When two waves superpose, state three conditions necessary for a stable and observable interference pattern.

1. ....

....

....

2. ....

....

....

3. ....

....

....

[3]

(b) Two coherent transverse wave sources produce wavefronts as shown in Fig. 8.1. The sources S_1 and S_2 are 3.0 mm apart. The line CC is parallel to the line joining S_1 and S_2 and it is 1.00 m away from the sources. Fig. 8.1 is not drawn to scale.

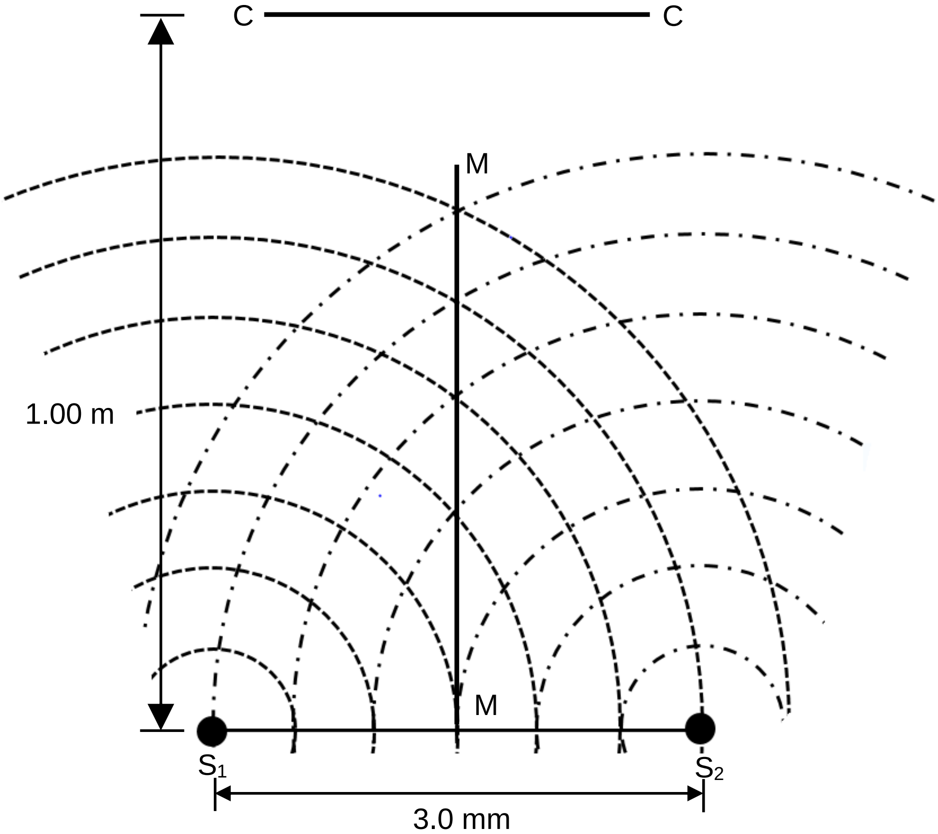

Fig. 8.1 (not to scale)

Lines where the amplitude of the resultant wave is minimum is known as a nodal line. Lines where the amplitude of the resultant wave is a maximum is known as an antinodal line.

(i) Line MM is a nodal line.

Hence, deduce the phase difference (in degrees) between the sources S_1 and S_2.

phase difference = …………………… ° [1]

(ii) On Fig. 8.1, draw a line where the path difference in terms of wavelength λ of the waves from the two sources is

1. 2 λ. Label this line EE. [1]
2. 0.5 λ. Label this line FF. [1]

(iii) State whether the line FF is a nodal or antinodal line.

Line FF: ……………………………………………………………..………… [1]

(iv) Identify the particular interference pattern detected along line S_1S_2.

.... [1]

(v) Show that the wavelength of the waves generated by the two sources is 0.5 mm.

[1]

(vi) Along line S_1S_2 , determine the number of minimas (locations where the resultant wave has the smallest amplitude) detected between the two sources. Ignore what is detected at the sources.

number of minimas = …………………….. [3]

(vii) Determine the distance between each maxima that can be detected along line CC.

distance between each maxima = …………………….. m [2]

(viii) Describe how the new interference pattern detected along lines CC and S_1S_2 compares with the old pattern when the following changes are made separately.

1. The distance between S_1 and S_2 is increased.

CC: …………………………………………………………………………………………..

…………………………………………………………………………………………………

…………………………………………………………………………………………………

S_1S_2: ……………………………………………………………………………………….

…………………………………………………………………………………………………

…………………………………………………………………………………………………

[2]

2. The amplitude of waves from S_1 is smaller than the waves from S_2.

CC: …………………………………………………………………………………………...

…………………………………………………………………………………………………

…………………………………………………………………………………………………

S_1S_2: ……………………………………………………………………………………….

…………………………………………………………………………………………………

…………………………………………………………………………………………………

[2]

[Total: 20]

9 **(a)** State *Coulomb's Law.*

…….

…….

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

(b) In a simple model of the structure of an atom, a hydrogen atom can be thought of as consisting of an electron in circular orbit around a proton, as shown in Fig. 9.1.

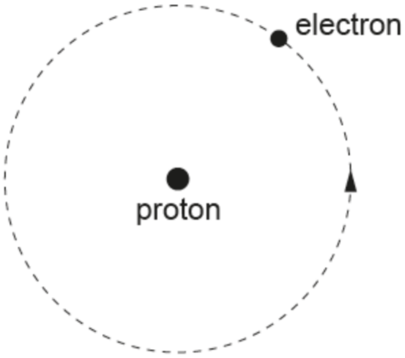

Fig. 9.1

(i) Show that the speed v of the electron is given by

$$v = \frac{e}{\sqrt{4\pi\varepsilon_0 mr}}$$

where e is the elementary charge, r is the radius of the orbit and m is the mass of the electron.

[2]

(ii) Hence, show that the total energy E_T of this system is given by

$$E_T = -\frac{e^2}{8\pi\varepsilon_0 r}$$

[2]

(iii) The ground state energy of an electron in a hydrogen atom is -13.6 eV.

Use the expression in **(b)(ii)** to show that the radius of orbit of an electron in its ground state in a hydrogen atom is approximately 5×10^{-11} m.

[2]

(c) Gravitational fields and electric fields are similar in that they can both be described as regions in which force is applied to an object. However, there are some differences between the two fields as well.

State, in words, a further *similarity* and a *difference* between gravitational and electric fields.

Similarity: ……………………………………………………………………………………………….

……

……

Difference: ………………………………………………………………………………………………..

……

……

[2]

(d) The table shows data relating to the Moon orbiting the Earth and an electron orbiting the nucleus of a hydrogen atom.

	Moon orbiting Earth	electron orbiting nucleus
mass / kg	7×10^{22}	9×10^{-31}
speed / m s^{-1}	1×10^{3}	2×10^{7}
orbital radius / m	4×10^{8}	5×10^{-11}

(i) Use the data in the table to determine

1. the de Broglie wavelength of the Moon orbiting the Earth,

wavelength = ………………………… m [1]

2. the de Broglie wavelength of the electron orbiting the nucleus.

wavelength = ………………………… m [1]

(ii) Use your answers to **(d)(i)** to explain why it is more reasonable to consider an electron in orbit around the nucleus as a wave while the Moon in orbit around the Earth as a particle.

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

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

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

(e) A mixture of 2 different powdered minerals can sometimes be separated in the laboratory by using an electric field.

The mixture to be separated is first placed in a vibrating tray in which the two types of powdered minerals become oppositely charged by friction. The tray has a small opening through which the minerals fall vertically from rest through a constant horizontal electric field set up between a pair of charged parallel plates. Fig. 9.2 shows a possible setup.

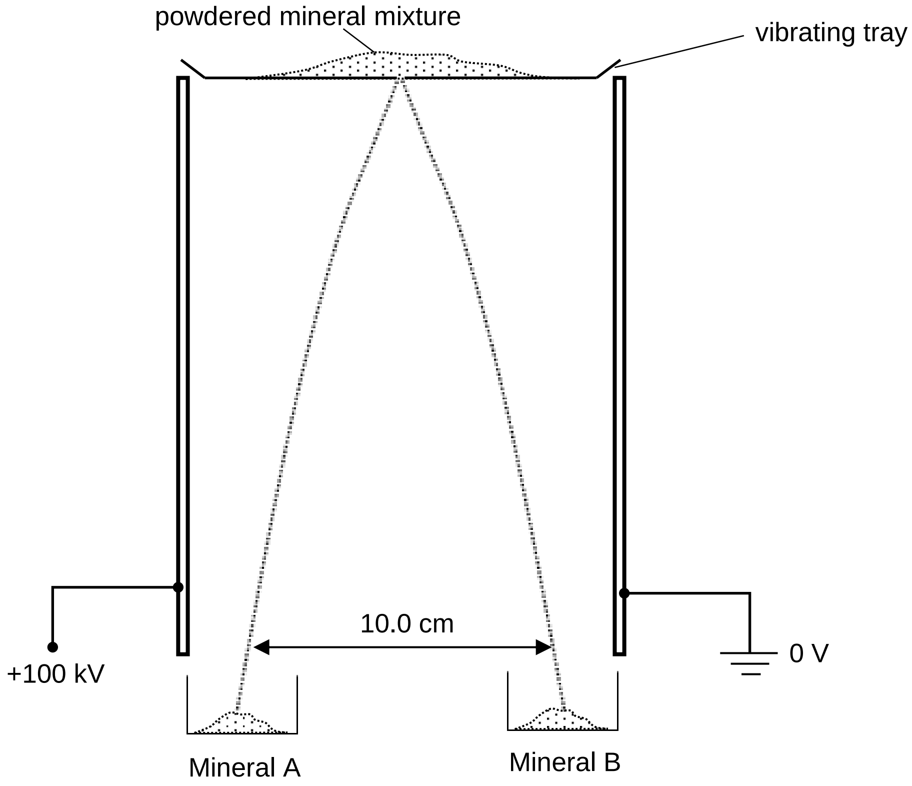

Fig. 9.2

In the above setup, a potential difference of 100 kV is maintained between the two large parallel plates which are separated horizontally by a distance of 15.0 cm. After falling through the plates, the minerals are separated by a horizontal distance of 10.0 cm.

The individual grains of the powdered minerals can be modelled as spheres of diameter 100 μm, each carrying a charge of magnitude 1.60 x 10^{-17} C.

(You may assume that air resistance and upthrust is negligible.)

(i) Determine the magnitude of the force on a grain due to the electric field produced by the two large parallel plates.

force = …………………………… N [2]

(ii) With the support of an appropriate calculation, explain why the electrical force between two charged mineral grains that are adjacent to each other can be ignored when considering the motion of the grains in the electric field.

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

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

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

(iii) Given that the magnitude of charge per unit mass of the minerals is 2.00×10^{-6} C kg^{-1}, show that the horizontal acceleration of each mineral grain is 1.33 m s^{-2}.

[1]

(iv) Hence, determine the time taken for the minerals to pass out of the parallel plates.

time taken = …………………… s [2]

[Total: 20]

End of Paper 3 Section B