Name: ______________________________ (   )   Class: 21 / ______

ANDERSON SERANGOON JUNIOR COLLEGE

2021 JC2 Preliminary Examination

PHYSICS Higher 2 — 9749/02

Paper 2 Structured Questions — **Wednesday 1 September 2021**

2 hours

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

READ THESE INSTRUCTIONS FIRST

Write your name, class index number and class 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 or graphs.

The use of an approved scientific calculator is expected, where appropriate.
Answer **all** questions.

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 Examiner's Use	
Paper 2 (80 marks)	
1	
2	
3	
4	
5	
6	
7	
Deduction	
Total	

Data

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_0	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_0	=	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	$\varphi = -\frac{Gm}{r}$
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 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.	$v = v_0 \cos \omega t$
	$= \pm\omega\sqrt{x_o^2 - x^2}$
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	$x = x_0 \sin \omega t$
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	$B = \mu_0 \ni \frac{¿}{2r} ¿$
magnetic flux density due to a long solenoid	$B = \mu_0 \ni ¿¿$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

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

1 **(a)** State one similarity and one difference between the electric field lines and the gravitational
field lines around an isolated positively charged metal sphere.

similarity: ....

....

difference: ....

.... [2]

(b) **(i)** Define *gravitational potential* at a point.

....

....

.... [2]

(ii) Use your answer in **(b)(i)** to explain why the gravitational potential near an isolated mass is always negative.

....

....

....

....

....

.... [3]

(c) A spherical planet has mass 6.00×10^{24} kg and radius 6.40×10^{6} m. The planet may be assumed to be isolated in space with its mass concentrated at its centre.

A satellite of mass 340 kg is to be raised from the planet to a height of 9.00×10^{5} m above the surface of the planet.

(i) Calculate the increase in potential energy of the satellite.

increase in potential energy = ………………….. J [2]

(ii) On the axes of Fig. 1.1, sketch a graph to show the variation of the gravitational force on the satellite with distance between the planet and the satellite, as the satellite is raised from the planet to its final position.

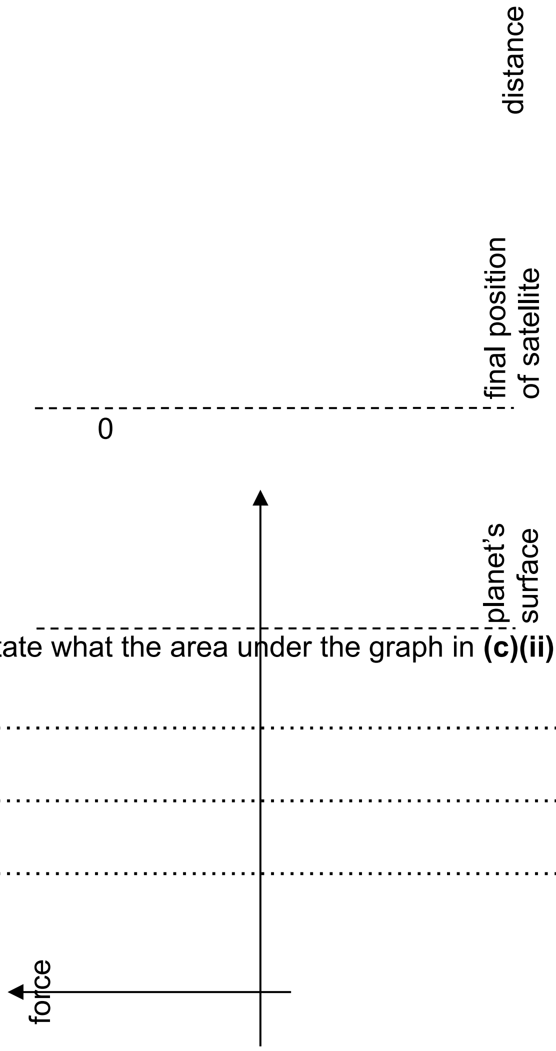

Fig. 1.1

[2]

(iii) State what the area under the graph in **(c)(ii)** represents.

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

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

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

[Total: 12]

2 **(a)** The kinetic theory of gases is based on a number of assumptions about the molecules of a gas.

State the assumption that is related to the volume of the molecules of the gas.

………

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

(b) An ideal gas occupies a volume of 2.40×10^{-2} m^3 at a pressure of 4.60×10^{5} Pa and a temperature of 23 °C. Each molecule has a diameter of approximately 3×10^{-10} m.

Estimate the total volume of the gas molecules.

volume = ……………………………m^3

[3]

(c) By reference to your answer in **(b)**, suggest why the assumption in **(a)** is justified.

………

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

(d) The ideal gas undergoes the cycle of changes PQRP as shown in Fig. 2.1.

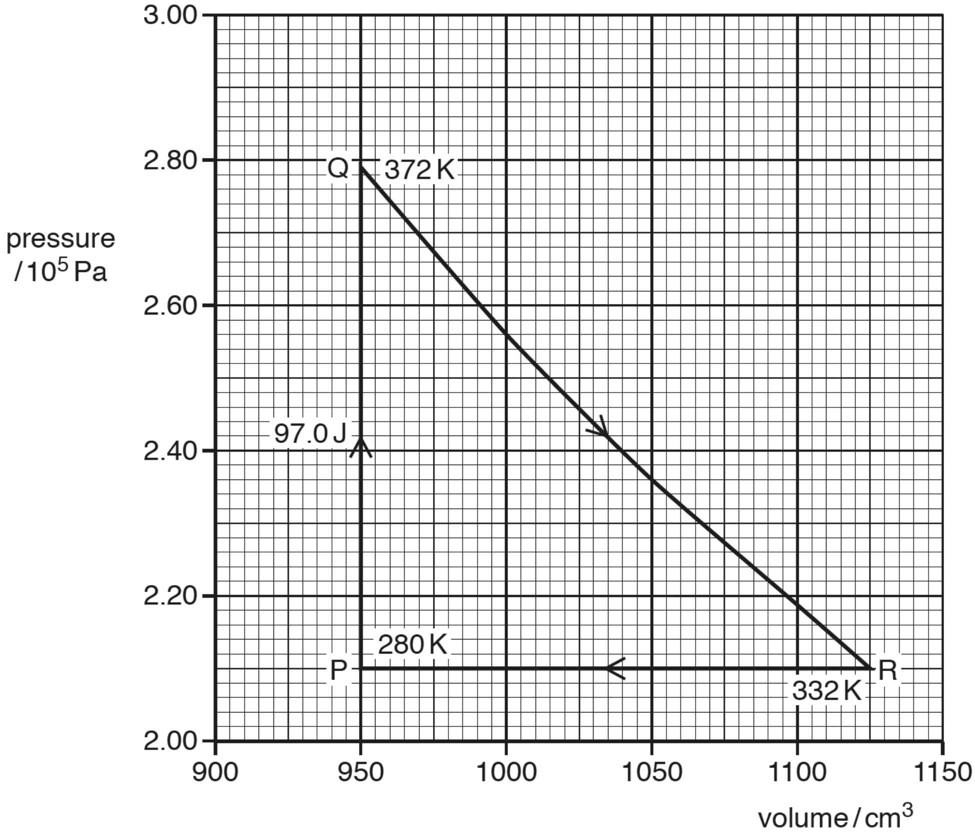

Fig. 2.1

Some energy changes during one cycle PQRP are shown in Fig. 2.2.

	change P → Q	change Q → R	change R → P
thermal energy transferred to gas / J	+97.0	0	....
work done on gas / J	....	–42.5	....
increase in internal energy of gas / J	....	....	....

Fig. 2.2

On Fig. 2.2, complete the energy changes for the gas. [5]

[Total: 10]

3 A hollow tube, sealed at one end, has a cross-sectional area A of 24 cm^2.
The tube contains sand so that the total mass M of the tube and sand is 0.23 kg.

The tube floats upright in a liquid of density ρ, as illustrated in Fig. 3.1.

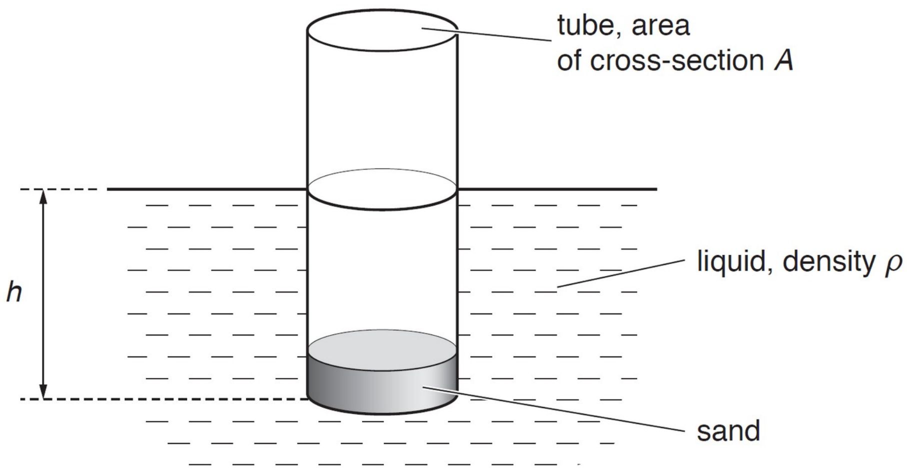

Fig. 3.1

The depth of the bottom of the tube below the liquid surface is h.

The tube is displaced vertically and then released. The variation with time t of the depth h is shown in Fig. 3.2.

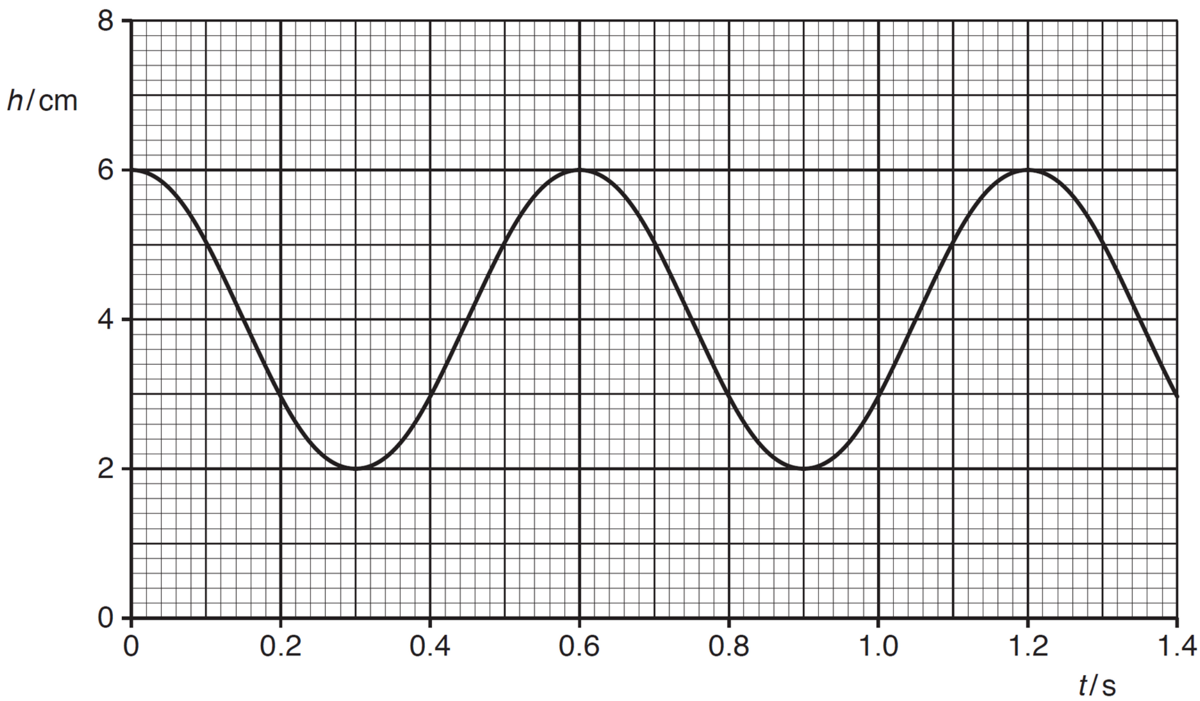

Fig. 3.2

(a) Determine the acceleration of the tube when *h* is a maximum.

acceleration = …………………………… m s^{-2} [3]

(b) Describe the restoring force that gives rise to the oscillations of the tube.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

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

(c) The oscillations illustrated in Fig. 3.2 are undamped. In practice, the liquid does cause light damping.

On Fig. 3.2, draw a line to show light damping of the oscillations for time t = 0 to time t = 1.4 s. [3]

[Total: 8]

4 **(a)** State what is meant by the term *polarisation* when applied to a wave.

....

.... [1]

(b) Explain why only transverse waves can be polarised.

....

....

....

.... [2]

(c) Some films released have enabled viewing in three dimensions (3D). This can be done using two superimposed polarised images on the screen. One of the images is the scene as viewed by a left eye and the other the scene as viewed by a right eye.

Explain how the images on the screen need to be polarised and how the spectacles of the cinema-goer also need to be polarised.

....

....

....

.... [3]

(d) Suggest why superposition has no meaning for the two superimposed images in part **(c)**.

....

....

.... [1]

[Total: 7]

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5 **(a)** A vertical tube of length 0.60 m is open at both ends, as shown in Fig. 5.1.

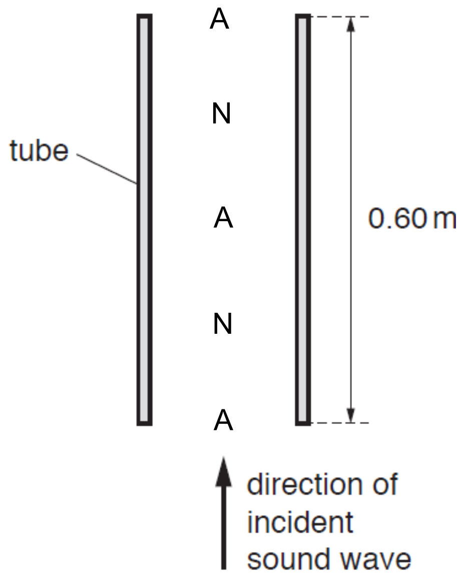

Fig. 5.1

An incident sinusoidal sound wave of a single frequency travels up the tube. A stationary wave is then formed in the air column in the tube with antinodes A and nodes N.

(i) Explain how the stationary wave is formed from the incident sound wave.

....

....

....

.... [2]

(ii) On Fig. 5.2, sketch a graph to show the variation of the amplitude of the stationary wave with height h above the bottom of the tube.

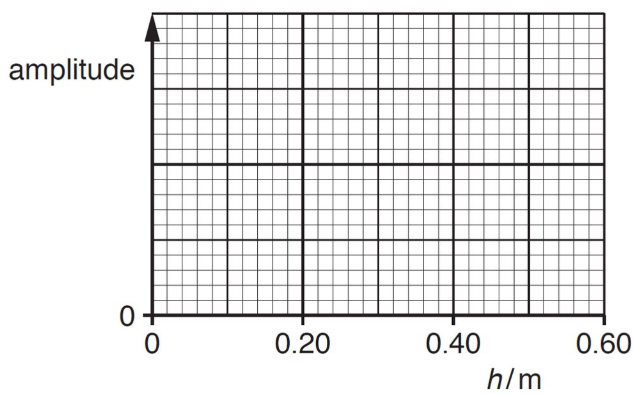

Fig. 5.2

[2]

(iii) For the stationary wave, state

1. the direction of the oscillations of an air particle at a height of 0.30 m above the bottom of the tube,

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

2. the phase difference between the oscillations of a particle at a height of 0.10 m and a particle at a height of 0.20 m above the bottom of the tube.

phase difference = …………………………….° [1]

(iv) The speed of the sound wave is 340 m s^{-1}. The frequency of the sound wave is gradually increased.

Determine the frequency of the wave when a stationary wave is next formed.

frequency = …………………………….Hz [2]

(b) **(i)** Monochromatic light is incident on a diffraction grating. Describe the diffraction of the light waves as they pass through the grating.

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

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

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

(ii) A parallel beam of light consists of two wavelengths 540 nm and 630 nm. The light is incident normally on a diffraction grating. Third-order diffraction maxima are produced for each of the two wavelengths. No higher orders are produced for either wavelength.

Determine the smallest possible line spacing *d* of the diffraction grating.

d = …………………………….m [2]

(iii) The beam of light in **(b)(ii)** is replaced by a beam of blue light incident on the same diffraction grating.

State and explain whether a third-order diffraction maximum is produced for this blue light.

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

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

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

[Total: 12]

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6 **(a)** Some electron energy levels in atomic hydrogen are illustrated in Fig. 6.1.

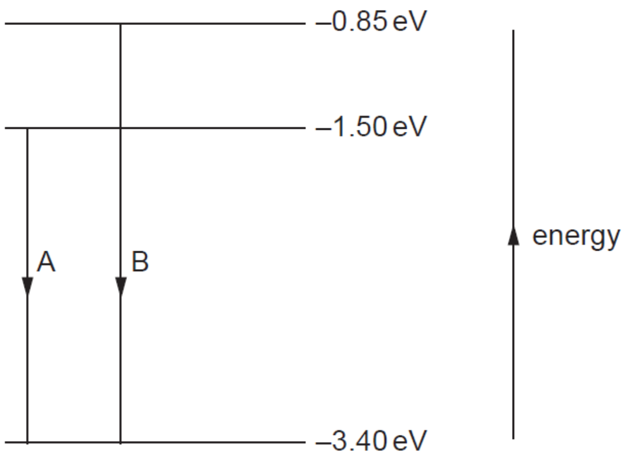

Fig. 6.1

Two possible electron transitions A and B giving rise to an emission spectrum are shown.
These electron transitions cause light of wavelengths 654 nm and 488 nm to be emitted.

(i) On Fig. 6.1, draw an arrow to show a third possible transition. [1]

(ii) Calculate the wavelength of the emitted light for the transition in **(i)**.

wavelength = ... m [2]

(b) Some hydrogen gas is heated so that electrons are excited to the highest energy level shown in Fig. 6.1.

Using the values of wavelength in **(a)**, state and explain the appearance of the spectrum of the emergent light from the hydrogen gas.

....

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....

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....

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

(c) High-speed electrons are incident on a metal target. The spectrum of the emitted X-ray radiation is shown in Fig. 6.2.

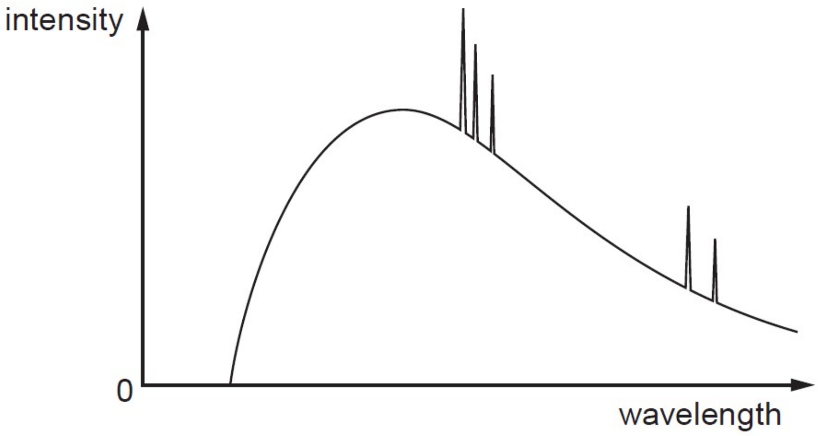


Fig. 6.2

Explain why

(i) there is a continuous distribution of wavelengths,

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

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

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

(ii) there is a sharp cut-off at short wavelength.

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

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

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

[Total: 10]

7 Read the following article and then answer the questions that follow.

Physics of Microwave Oven

Microwaves are electromagnetic (e.m.) waves that have frequencies ranging from 300 MHz up to 300 GHz. Following international conventions, microwave ovens operate at frequencies at around 2.45 GHz.

Fig. 7.1. depicts a typical microwave oven. Microwaves are generated in magnetron which feeds via a waveguide into the cooking chamber. The cooking chamber has metallic walls which are able to perfectly reflect the microwaves fed into the cooking chamber, whilst the front door of the microwave oven is made of glass and is covered by metal grids. The holes in the metal grids are usually 100 times smaller than the wavelength of the microwaves, hence the walls and the grids act like a Faraday's cage, which is a safety feature.

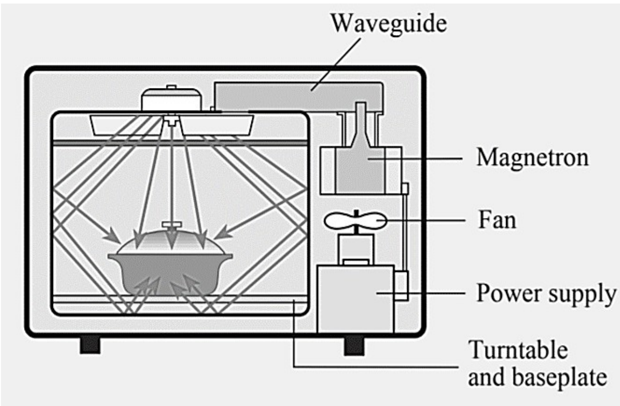


Fig. 7.1. Schematic diagram of a typical microwave oven

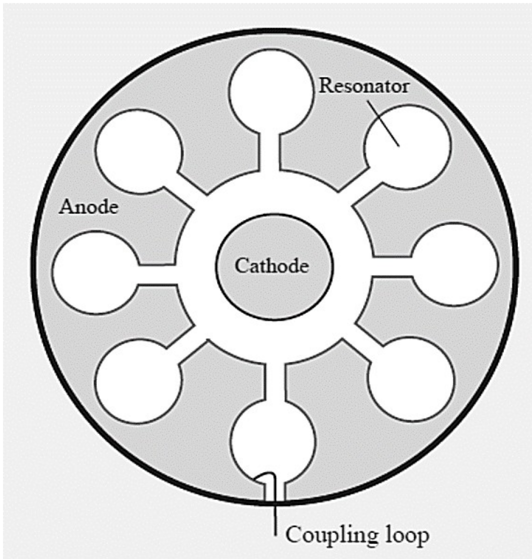


Fig. 7.2. Schematic diagram of a magnetron

Fig. 7.2 shows the schematic diagram of a magnetron. A cylindrical cathode is at the central axis, several millimetres from a hollow circular anode. Inside the anode there are a number of cavities known as resonators which allow for resonance at 2.45 GHz. A voltage of 5.00 kV is applied between the electrodes and a magnetic field is applied parallel to the axis such that the electric and magnetic fields are perpendicular to each other. In the magnetron, the combined effect of electric and magnetic fields causes the electrons emitted from the hot cathode to travel in curved paths.

So how does the interaction of the molecules in food with the microwaves produce a heating effect to cook food? The water molecules in food oscillate in the alternating electric field of the microwaves. As the individual molecules oscillate, the work done against the forces between neighbouring molecules increases their kinetic energy in a random manner, raising the temperature of the food. Fat, sugar and salt in food are able to heat up through a similar mechanism though they often play a smaller role as they are less abundant than water.

The absorption of microwaves by water molecules in the food, is often described as resonance, but this is not true: free water molecules resonate at 22 GHz and 183 GHz. Microwaves with a frequency of 22 GHz would be totally absorbed in the surface of the food without penetrating. If waves with a frequency as low as 100 MHz were used, they would pass straight through the food, and it would not heat up. The choice of 2.45 GHz is a compromise.

Upon entering foods, the intensity of microwaves is gradually reduced along its path according to the relationship:

$$I = I_0 e^{-\mu z}$$

where I_o is the intensity of the microwaves incident on the surface of the food, I is the microwave intensity in the food at a distance *z* below the surface and μ is a constant known as the attenuation coefficient.

Another method to characterise the penetration of microwaves in food is using a quantity known as *penetration depth* δ_p. It is a quantity that is dependent on the frequency of microwaves incident on the food and is defined as the distance at which the microwave intensity is reduced to 1/e (*e* = 2.718) from the intensity at the point of entry.

Passage extracted and adapted from "Physics of Microwave Oven" by Michael Volmer and OCR Jan 2004 Paper 2865.

(a) **(i)** Suggest what is the function of a 'Faraday's cage'.

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

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

(ii) Estimate a suitable spacing for the holes in the metal grids used in the front door of a microwave oven.

spacing = …………………………….m [2]

(b) Fig. 7.3 shows a simplified model of part of the magnetron. The electric field between the cathode and anode is illustrated.

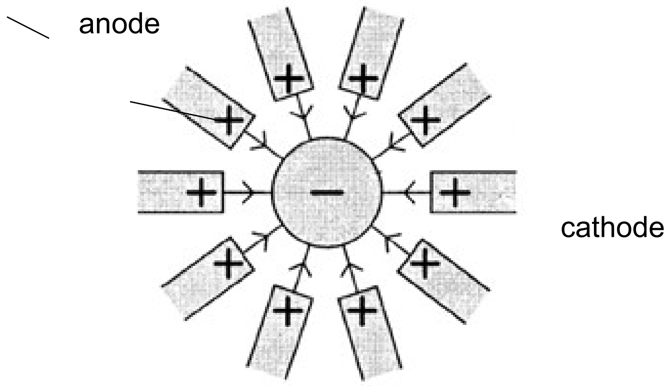


Fig. 7.3

(i) Show that the maximum kinetic energy that an electron can gain when moving to the anode is 8.0×10^{-16} J.

[1]

(ii) Hence, if the microwave power output of the magnetron is about 1000 W, determine the least number of electrons that must be emitted by the cathode each second.

least number of electrons per second = ……………………………s^{-1} [1]

(iii) Suggest one reason why the actual number of electrons emitted is likely to be larger than your answer to **(b)(ii)**.

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

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

(iv) Fig. 7.4 shows the trajectory of an electron of mass m and charge q moving at a speed v in the magnetic field of flux density B inside a magnetron.

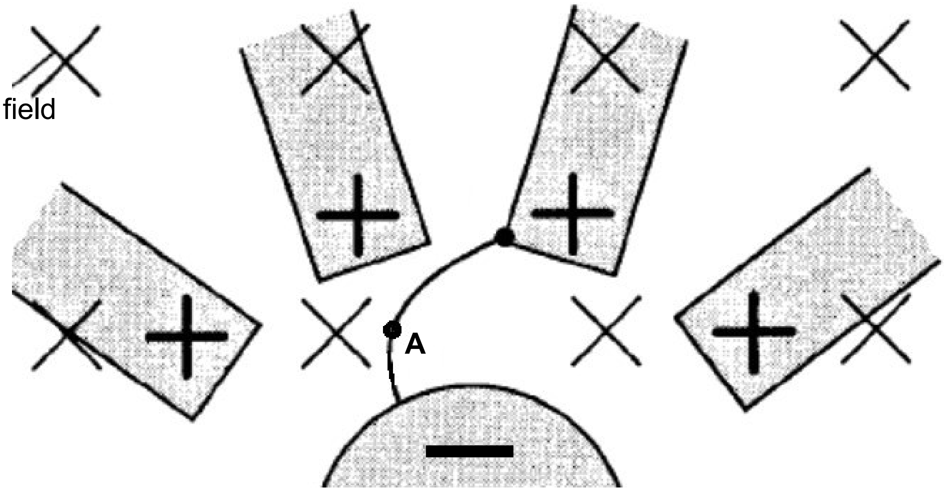


Fig. 7.4

1. On Fig. 7.4, draw and label the forces acting on the electron at A. [2]

2. State and explain how the introduction of the magnetic field will affect the maximum kinetic energy gained by an electron when moving to the anode calculated in **(b)(i).**

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

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

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

(c) An experiment is conducted to investigate the penetration of microwaves of frequency 2.45 GHz for a sample of potato mash.

Fig. 7.5 shows the readings obtained for the experiment.

depth into food z / mm	intensity of microwaves at depth z I / A.U.	ln (I / A.U.)
0	24	3.18
4	19	2.94
8	15	
12		2.49
16	10	2.30

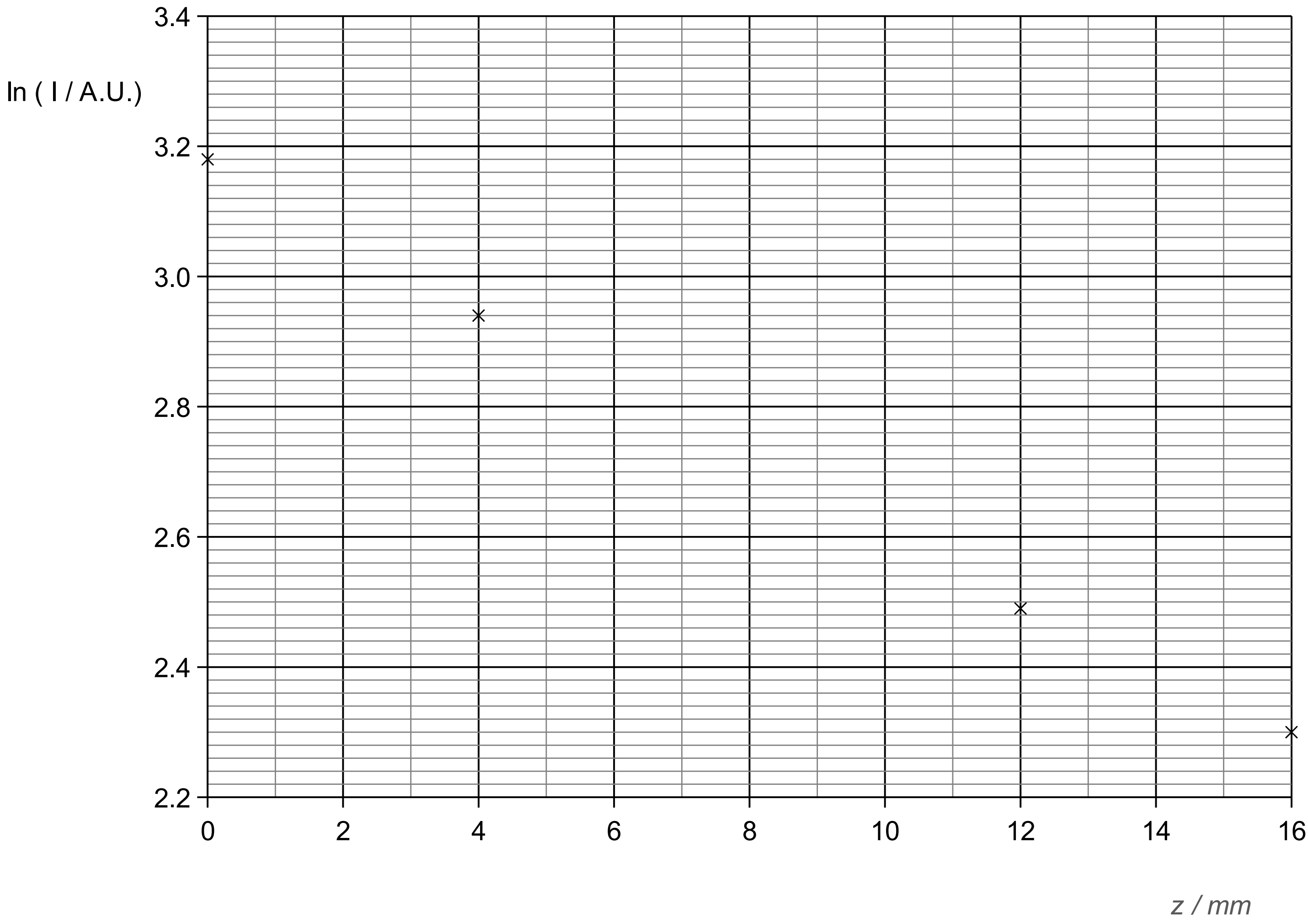
Note that intensity I is measured in arbitrary units (A.U.)

Fig. 7.5

(i) Complete Fig. 7.5 for z = 8 mm and z = 12 mm.

[2]

(ii) A graph of ln (I / A.U.) with (z / mm) is shown in Fig. 7.6.



1. On Fig. 7.6, plot the point corresponding to z = 8 mm. [1]

2. Draw the best fit line for all the points. [1]

(iii) Determine the gradient of the line you have drawn.

gradient = …………………………….. [2]

(iv) Hence, determine the penetration depth δ_p for the potato mash.

δ_p = ……………………………mm [2]

(v) The experiment is then repeated with a potato mash of higher water content.

1. Suggest and explain how the penetration depth will differ from that found in **(c)(iv).**

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

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

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

2. Sketch on Fig. 7.6, the new graph of ln(I / A.U.) with (z / mm) for this experiment. Label this graph **N**. [1]

[Total: 21]

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