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.

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**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** | |

This document consists of **21** printed pages and **3** blank pages.

**Data**

| | |
|---|---|
| speed of light in free space | $c = 3.00 \times 10^{8}\ \text{m s}^{-1}$ |
| permeability of free space | $\mu_0 = 4\pi \times 10^{-7}\ \text{H m}^{-1}$ |
| permittivity of free space | $\varepsilon_0 = 8.85 \times 10^{-12}\ \text{F m}^{-1}$<br>$(1/(36\pi)) \times 10^{-9}\ \text{F m}^{-1}$ |
| 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 | $s = ut + \frac{1}{2}at^2$<br>$v^2 = u^2 + 2as$ |
| 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 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. | $v = v_0 \cos \omega t$<br>$= \pm \omega\sqrt{x_o{}^2 - x^2}$ |
| 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 | $B = \frac{\mu_o NI}{2r}$ |
| magnetic flux density due to a long solenoid | $B = \mu_o nI$ |
| 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: ..........................................................................................................

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difference: ..........................................................................................................

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

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

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**(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.

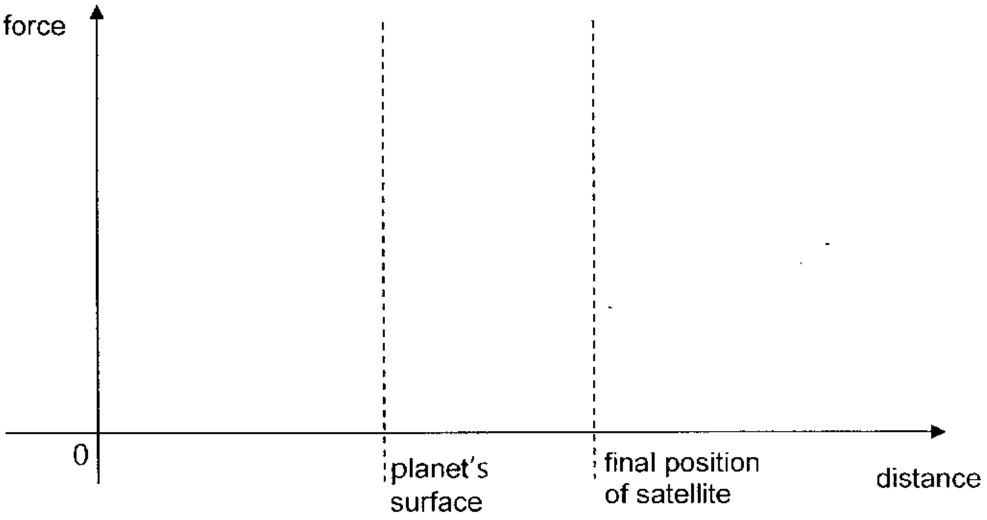

**Fig. 1.1**

[2]

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

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

[Total: 12]

**[Turn Over**

**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 $2.40 \times 10^{-2}$ m$^3$ at a pressure of $4.60 \times 10^5$ Pa and a temperature of 23 °C. Each molecule has a diameter of approximately $3 \times 10^{-10}$ 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.

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

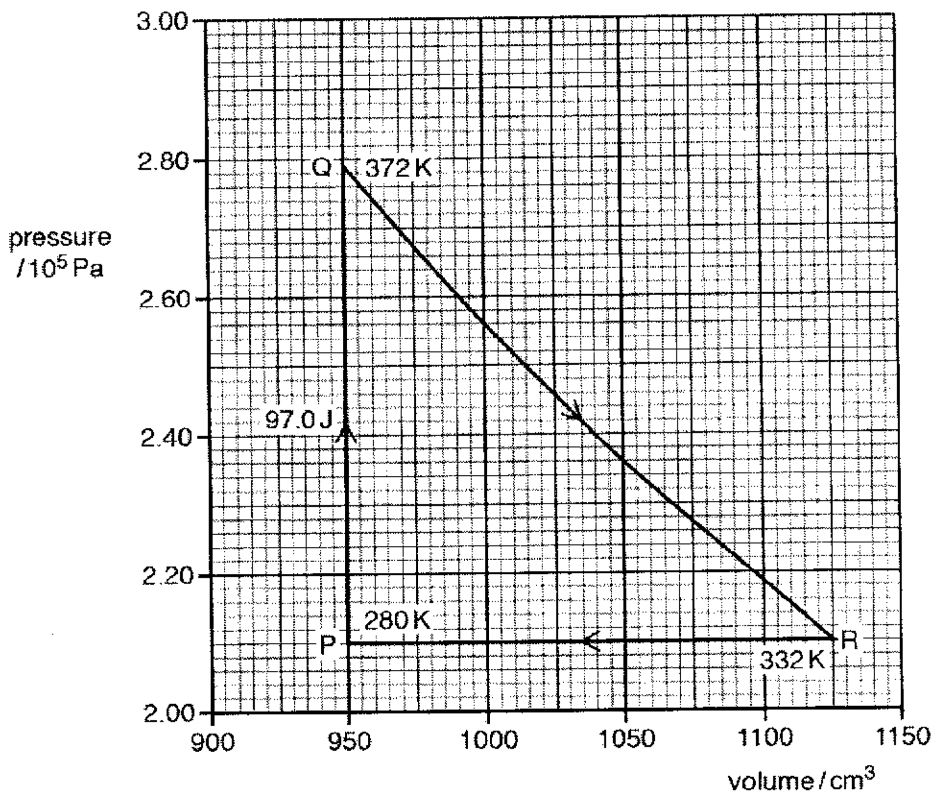

**Fig. 2.1**

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 $\rho$, as illustrated in Fig. 3.1.

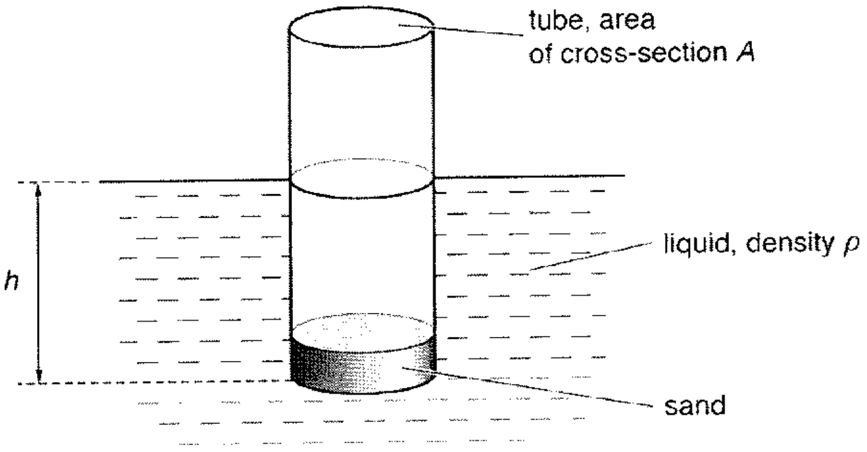

**Fig. 3.1**

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.

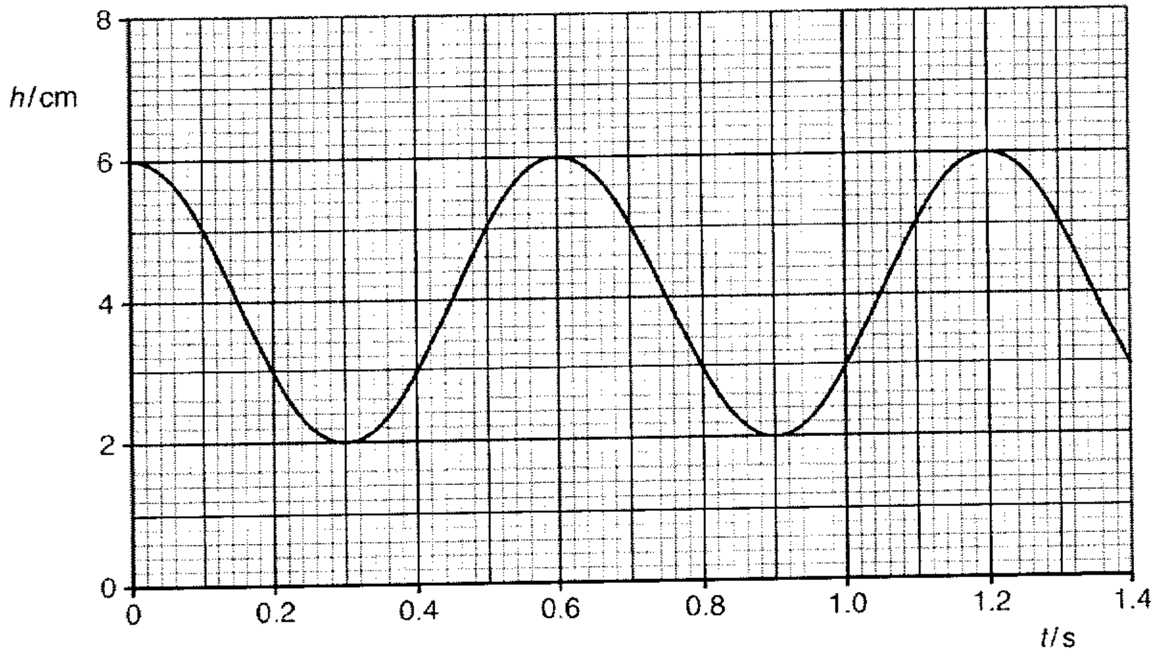

**Fig. 3.2**

**(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.

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.................................................................................................................... [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.

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

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**(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.

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

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[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.

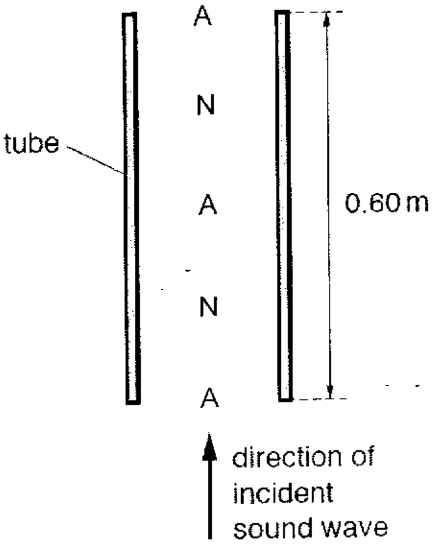

**Fig. 5.1**

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.

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**(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.

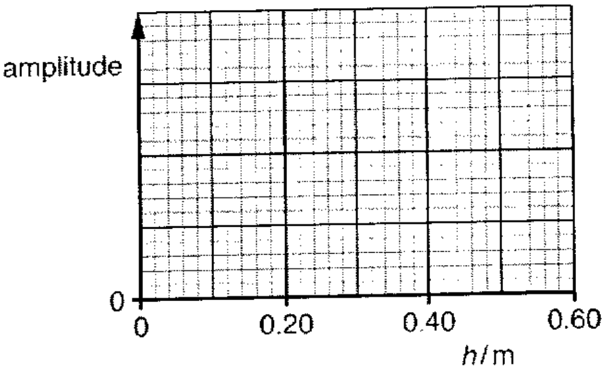

**Fig. 5.2**

[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.

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.......................................................................................................... [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]

**[Turn Over**

**(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.

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[Total: 12]

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

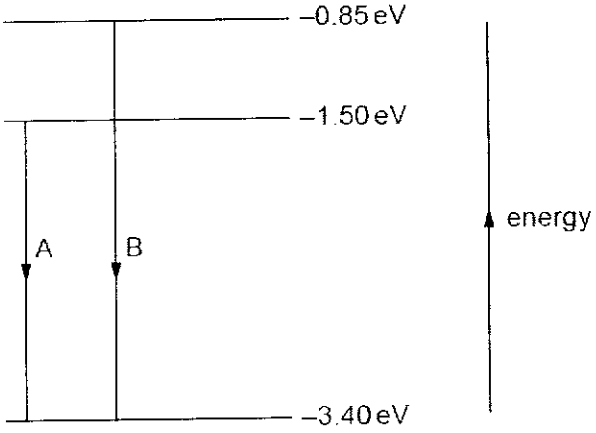

**Fig. 6.1**

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

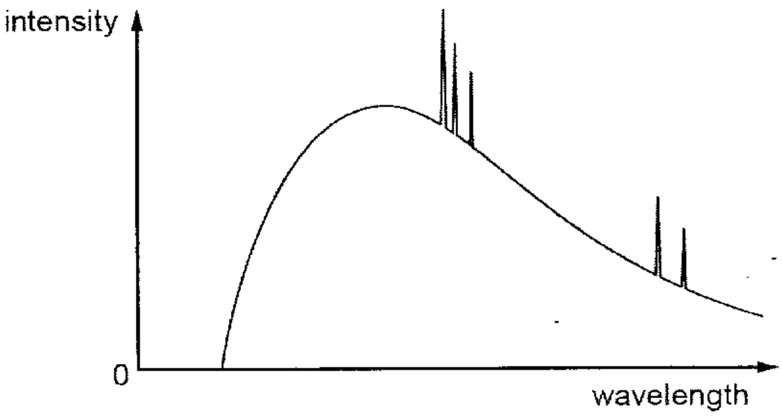

**Fig. 6.2**

Explain why

**(i)** there is a continuous distribution of wavelengths,

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

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

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[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.

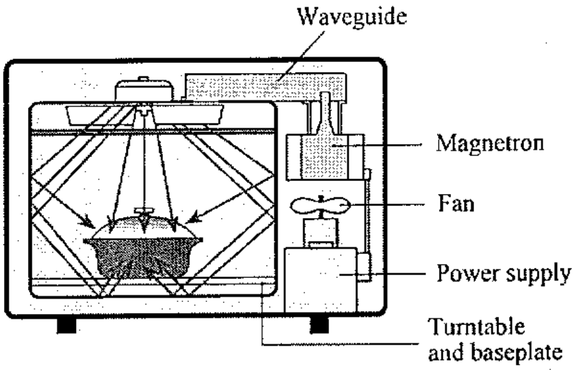

**Fig. 7.1.** Schematic diagram of a typical microwave oven

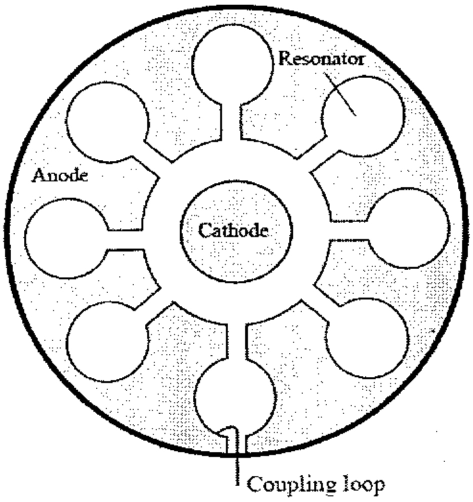

**Fig. 7.2.** Schematic diagram of a magnetron

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 $I_0$ 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 $\mu$ 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* $\delta_p$. 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.

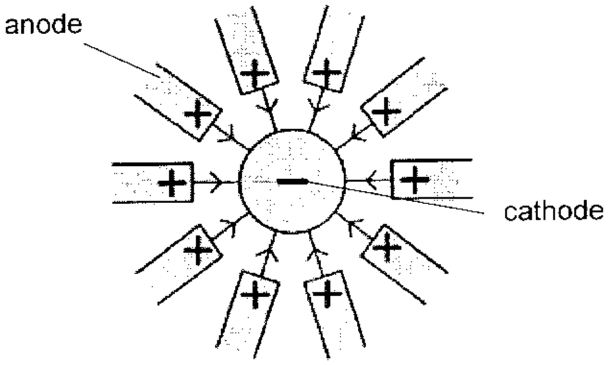

**Fig. 7.3**

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

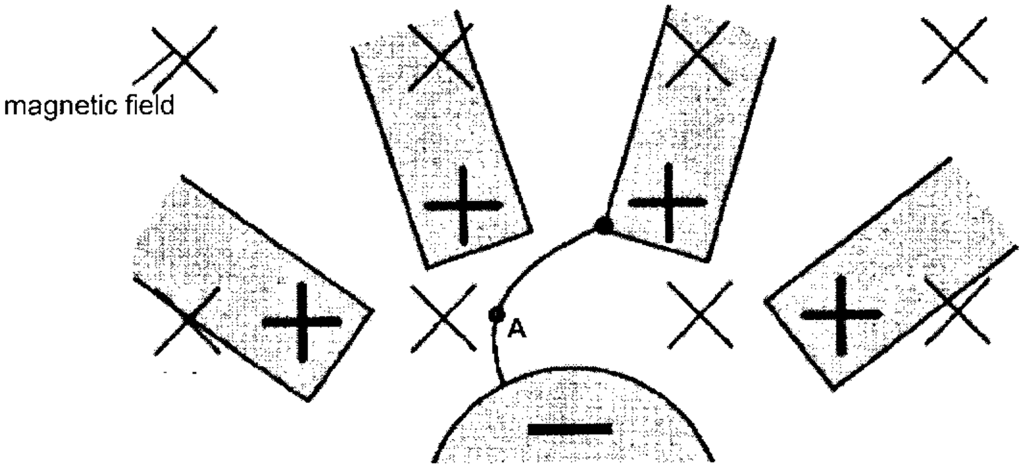

**Fig. 7.4**

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).**

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........................................................................................................................ [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]

**[Turn Over**

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

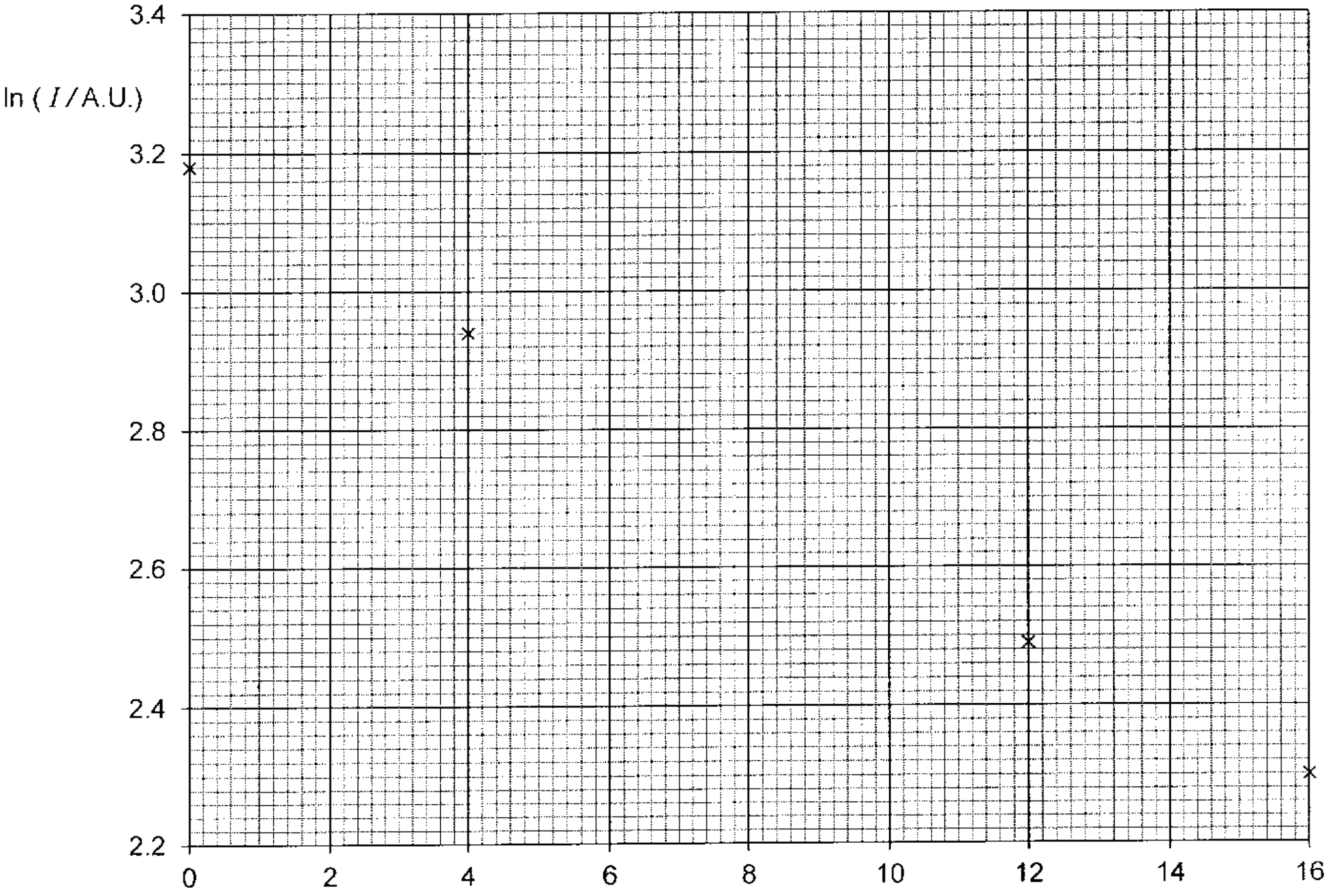

**Fig. 7.6**

**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 $\delta_p$ for the potato mash.

$\delta_p$ = ..................................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).**

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.......................................................................................................................... [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]

**[Turn Over**

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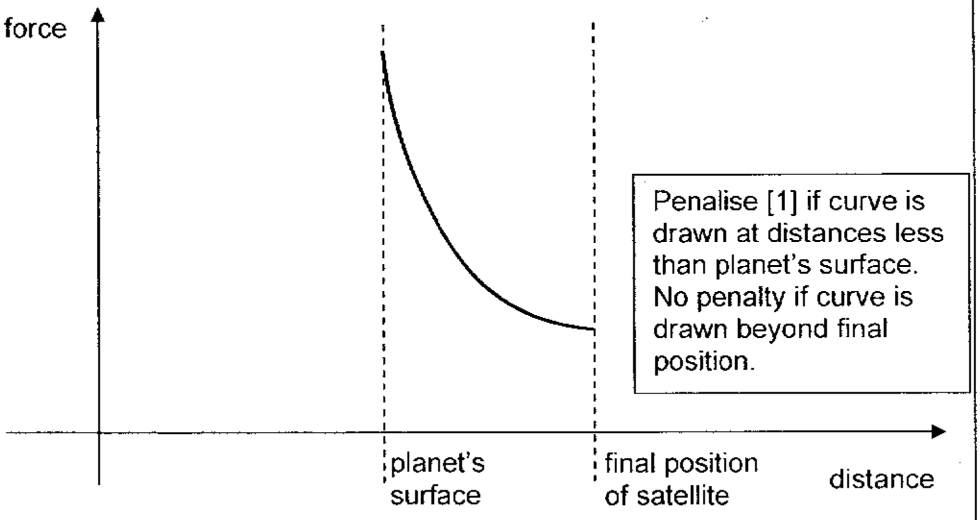
## Anderson Serangoon Junior College 2021 H2 Physics Prelim Mark Scheme

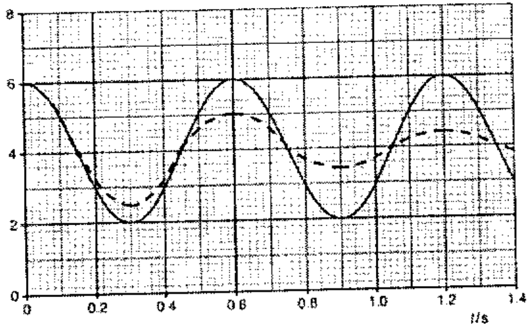
**Paper 2 (80 marks)**

| | | |
|---|---|---|
| **1a** | similarity: lines are radial / greater separation of lines with increased distance from the sphere / lines are perpendicular to the surface of sphere<br>difference: gravitational field lines directed towards sphere and electric field lines directed away from sphere | B1<br>B1 |
| **1bi** | The gravitational potential at a point is the work done per unit mass<br>in bringing a small test mass from infinity to that point. | B1<br>B1 |
| **1bii** | (gravitational) potential is taken to be zero at infinity<br>(gravitational) force is attractive<br>work done by the external agent on the point mass moving it from infinity is negative | B1<br>B1<br>B1 |
| **1ci** | $\text{GPE} = -\frac{\text{GMm}}{\text{r}}$<br>increase in GPE $= -\frac{\text{GMm}}{(6.40+0.900)\times10^{6}} - \left(-\frac{\text{GMm}}{6.40\times10^{6}}\right)$<br>$= (6.67\times10^{-11})(6.00\times10^{24})(340)\left(\frac{1}{6.40\times10^{6}} - \frac{1}{(6.40+0.900)\times10^{6}}\right)$<br>$= 2.62\times10^{9}\text{ J}$ | M1<br>A1 |
| **1cii** |  <br>Penalise [1] if curve is drawn at distances less than planet's surface. No penalty if curve is drawn beyond final position.<br>• magnitude of force decreases non-linearly with distance<br>• decreasing gradient, never infinite nor zero | B1<br>B1 |
| **1ciii** | It represents the increase in potential energy of the satellite. | B1 |

| | | |
|---|---|---|
| **2a** | total volume of molecules is negligible compared with volume occupied by the gas | B1 |
| **2b** | $pV = NkT$<br>$4.60\times10^{5}\times2.40\times10^{-2} = N\times1.38\times10^{-23}\times(273+23)$ | C1 |

| | | |
|---|---|---|
| | $N = 2.7 \times 10^{24}$<br>volume of one molecule = $(4/3)\pi r^3$ (= $1.41 \times 10^{-29}$ m$^3$)<br>volume of all molecules = $2.7 \times 10^{24} \times 1.41 \times 10^{-29}$<br>= $4 \times 10^{-5}$ m$^3$ (1 s.f.; as this is an estimation question the uncertainty of final answer cannot be more precise than that of the given data.)<br>**or**<br>volume of one molecule = $d^3$ (= $2.7 \times 10^{-29}$ m$^3$)<br>volume of all molecules = $2.7 \times 10^{-29} \times 2.7 \times 10^{24}$<br>= $7 \times 10^{-5}$ m$^3$ (1 s.f.; as this is an estimation question the uncertainty of final answer cannot be more precise than that of the given data.) | C1<br>A1 |

| | | |
|---|---|---|
| **2c** | Since volume of all atoms ($4 \times 10^{-5}$ m$^3$ or $7 \times 10^{-5}$ m$^3$) is *3 orders of magnitude less* than volume occupied by the gas ($2.4 \times 10^{-2}$ m$^3$), so assumption in (a) is justified. | B1 |
| **2d** | work done on gas (P → Q): 0<br>increase in internal energy (P → Q): (+)97.0 J<br>increase in internal energy (Q → R): –42.5 J<br>work done on gas (R→P)<br>$W = p\,\Delta V = 2.10 \times 10^5 \times (1125 - 950) \times 10^{-6} = 36.8$ J<br>increase in internal energy (R→P)<br>since total change in internal energy is zero, $97 + (-42.5) + \Delta U = 0 \rightarrow \Delta U = -54.5$ J<br>thermal energy supplied (R→P)<br>$Q = \Delta U - W = -54.5 - 36.8 = -91.3$ J | A1<br>A1<br>A1<br>A1<br>A1 |

| | | | |
|---|---|---|---|
| **3a** | amplitude = 0.020 m<br>$f = 1/T = 1/0.60 = 1.7$ Hz<br>$a = (-)\omega^2 x$ **and** [$\omega = 2\pi f$ **or** $\omega = 2\pi/T$]<br>$= (2\pi/0.60)^2 \times 2.0 \times 10^{-2}$<br>$= 2.2$ m s$^{-2}$ [accept –ve a] | **E** | C1<br>C1<br>A1 |
| **3b** | Resultant between upthrust and weight<br>Upthrust increases with depth of immersion | **A** | B1<br>B1 |
| **3c** | wave starting with a peak at (0,6), and same period<br>peak height decreasing successively<br>exponentially wrt time.  | **A** | B1<br>B1<br>B1 |

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| **4a** | *Polarisation* is where the oscillations in a wave are confined to one direction only in a plane normal to the direction of transfer of energy of the wave.<br>*OR*<br>*Oscillations occur only in one plane, parallel to the direction of energy transfer.* | **E** | B1 |
| **4b** | (A polarised wave vibrates in a single plane in space.) Since longitudinal waves vibrate along their axis of propagation, it is not possible to polarise a longitudinal wave.<br>Hence, only transverse waves can be polarised as it vibrates perpendicular to its axis of propagation. | **A** | B1<br>B1 |
| **4c** | Angle between axis of polarisation between images is 90°.<br>Angle between axis of polarisation between left and right lenses is 90°.<br>Angle of polarisation of each image needs to match angle of polarising axis of the lens for the appropriate eye. | **D** | B1<br>B1<br>B1 |
| **4d** | (Since the plane of the images are perpendicular to each other), the two images are never added together in either eye. | **D** | B1 |

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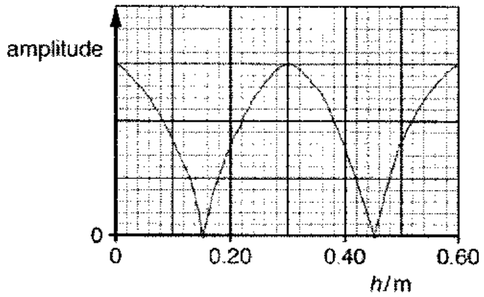
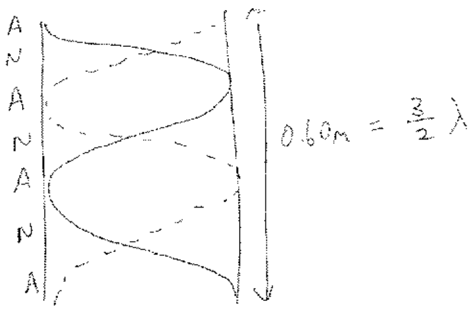
| **5ai** | The incident wave reflects at the top of the tube.<br>The incident and reflected wave interfere / superpose to form the stationary wave. | **A** | B1<br>B1 |
| **5aii** |  <br>Maximum value at $h$ = 0, 0.30 m, 0.60 m, and 0 amplitude at $h$ = 0.15 m, 0.45m.<br>The line should be a modulus of a sinusoidal function. | **D** | B1<br>B1 |
| **5aiii1** | vertical/along length of tube/along axis of tube | **E** | B1 |
| **5aiii2** | phase difference = 180° | **E** | B1 |
| **5aiv** | When next stationary wave is formed:<br>0.60 m = 1.5 λ<br>v = f λ,<br>so f = v/λ = 340 / [0.60/1.5]<br>= 850 Hz<br> | **A** | C1<br>A1 |
| **5bi** | The waves spread as they pass through the slits. | **A** | B1 |

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| **5bii** | d sin θ = nλ<br>sin θ = nλ/d<br>since sin θ ≤ 1, nλ/d ≤ 1<br><br>when n=3 and $\lambda = 540 \times 10^{-9}$ m<br>$3(540 \times 10^{-9})/d \leq 1$<br>$d \geq 1.62 \times 10^{-6}$ m<br><br>when n=3 and $\lambda = 630 \times 10^{-9}$ m<br>$3(630 \times 10^{-9})/d \leq 1$<br>$d \geq 1.89 \times 10^{-6}$ m<br><br>to satisfy both conditions above, minimum d is $1.89 \times 10^{-6}$ m | **D** | C1<br>A1 |
| **5biii** | wavelength of blue light is shorter (than both given lights) so the third order diffraction maximum is produced. | **A** | B1 |

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| **6ai** | arrow from –0.85 eV level to –1.50 eV level | **E** | B1 |
| **6aii** | $\Delta E = (1.50 - 0.85) \times 1.60 \times 10^{-19}$<br>$= 1.04 \times 10^{-19}$ J<br><br>Since $\Delta E = hc/\lambda$<br>$\lambda = (6.63 \times 10^{-34} \times 3.00 \times 10^{8})/(1.04 \times 10^{-19})$<br>$= 1.91 \times 10^{-6}$ m | **A** | C1<br>A1 |
| **6b** | Spectrum appears as dark background crossed by two bright lines.<br><br>Electrons in gas de-excite, emitting photons with specific energies equal to the energy difference of two levels.<br><br>These photons have specific frequencies (or wavelengths) which correspond to the lines. | **D** | B1<br>B1<br>B1 |

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| **6ci** | e.m. radiation produced whenever charged particle is accelerated<br><br>electrons hitting target have distribution of accelerations | **A** | M1<br>A1 |
| **6cii** | all electron energy given up in one collision/converted to a single photon<br><br>(since $\lambda_{min} = hc/E_{max}$,) maximum photon energy corresponds to minimum wavelength | **A** | B1<br>B1 |

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| **7ai**<br>*para 2* | To prevent microwave/(em) radiation from leaking/escaping **out**/exiting of the cage/microwave oven. | **E** | A1 |
| **7aii** | From the passage, by international convention, microwave ovens operate at frequencies at around 2.45 GHz.<br>Wavelength of the microwaves = $3.00 \times 10^{8}$/ $2.45 \times 10^{9}$Hz = 0.122 m | **A** | C1 |

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| *para*<br>*1, 2*<br>*& 5* | 100 times smaller than 0.122 m or 12.2 cm = $1.22 \times 10^{-3}$ m or 0.00122 m.<br>Hence, estimated spacing of holes is $1 \times 10^{-3}$ m or $1.2 \times 10^{-3}$ m.<br>[-1] Powers of Ten error for conversion of GHz | | A1 |
| **7bi**<br>*para*<br>*3* | Potential difference across the electrodes = 5000.00 V<br>By conservation of energy,<br>Kinetic energy gained by an electron = electrical potential energy loss by the electron<br>$= (5000.00)(1.60 \times 10^{-19}) = 8.00 \times 10^{-16}$ J<br>$= 8.0 \times 10^{-16}$ J | **E** | M1<br>A0 |
| **7bii**<br>*para*<br>*3* | Power output, P = (energy of an electron) × (n/t)<br>Each electron has available max. 8.0 x $10^{-16}$ J of energy (assuming that the electrons start off from cathode with negligible kinetic energy) to be converted to microwaves.<br>Least number of electrons per second $= \dfrac{1000}{8.0 \times 10^{-16}} = 1.25 \times 10^{18}\ \text{s}^{-1}$ | **A** | A1 |

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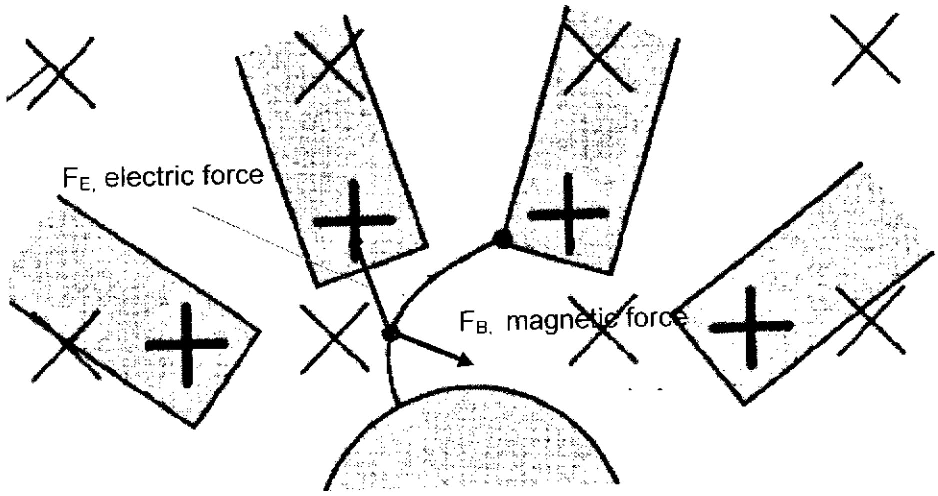
| **7biii**<br>*para*<br>*3* | Not all the (kinetic) energy of the electrons is converted into **microwave energy** as:<br>• electrons give off e.m. radiation of varying wavelengths as it accelerates towards the anode and hence actual energy possessed by electrons are lower when reaching the anode<br>• some electrons hit the anode, some of its kinetic energy is also converted to thermal energy / passed to the molecules (or atoms) in the anode causing thermal agitation so less energy is available for conversion to microwave energy<br>Not all the microwaves generated from the energy is fed into the cavity resulting in energy losses due to:<br>• the walls in the cavity of the food chamber absorbing some of the microwaves<br>• microwaves may be fed back / coupled back to the magnetron<br>(resulting in actual useful power of microwaves less than the actual energy that can be supplied by the electrons)<br>*Answer must be related back to the efficiency of* ***conversion of energy of the electrons to the power output of the microwaves;*** ***or loss in microwaves produced fed into cavity.*** | **D** | A1 |

<table>
<tr><td><b>7biv<br>1</b><br><br><i>para<br>3</i></td><td>
<br>Correct direction of $F_E$ drawn and labelled. (// to electric field line towards anode, see Fig. 7.3 for the electric field between the anode and cathode.)<br>Correct direction of $F_B$ drawn and labelled. (The velocity of the electron should be tangential to the trajectory. Apply Fleming's left hand rule to get direction, towards centre of "circular motion" and perpendicular to trajectory)<br><i>[-1] if $F_E$ and $F_B$ are not defined.</i><br><i>Ignore weight if labelled. (Weight is insignificant to electric and magnetic forces)</i></td><td><b>A</b></td><td>A1<br>A1</td></tr>
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<tr><td><b>7biv<br>2</b><br><br><i>para<br>3</i></td><td>As the magnetic force on the electron is acting perpendicular to its motion, (no work is done by the magnetic force on the electron), hence it does not affect the speed of motion as it moves towards the anode.<br>Hence the maximum kinetic energy gained remains <b>unchanged</b>.</td><td><b>D</b></td><td>B1<br>A1</td></tr>
<tr><td><b>7ci</b><br><br><i>para<br>6</i></td><td><table>
<tr><th>depth into food<br>$z$ / mm</th><th>intensity of microwaves at depth $z$<br>$I$ / A.U.</th><th>ln ($I$ / A.U.)</th></tr>
<tr><td>0</td><td>24</td><td>3.18</td></tr>
<tr><td>4</td><td>19</td><td>2.94</td></tr>
<tr><td>8</td><td>15</td><td>2.71</td></tr>
<tr><td>12</td><td>12</td><td>2.49</td></tr>
<tr><td>16</td><td>10</td><td>2.30</td></tr>
</table></td><td><b>E</b></td><td>A1<br>A1</td></tr>
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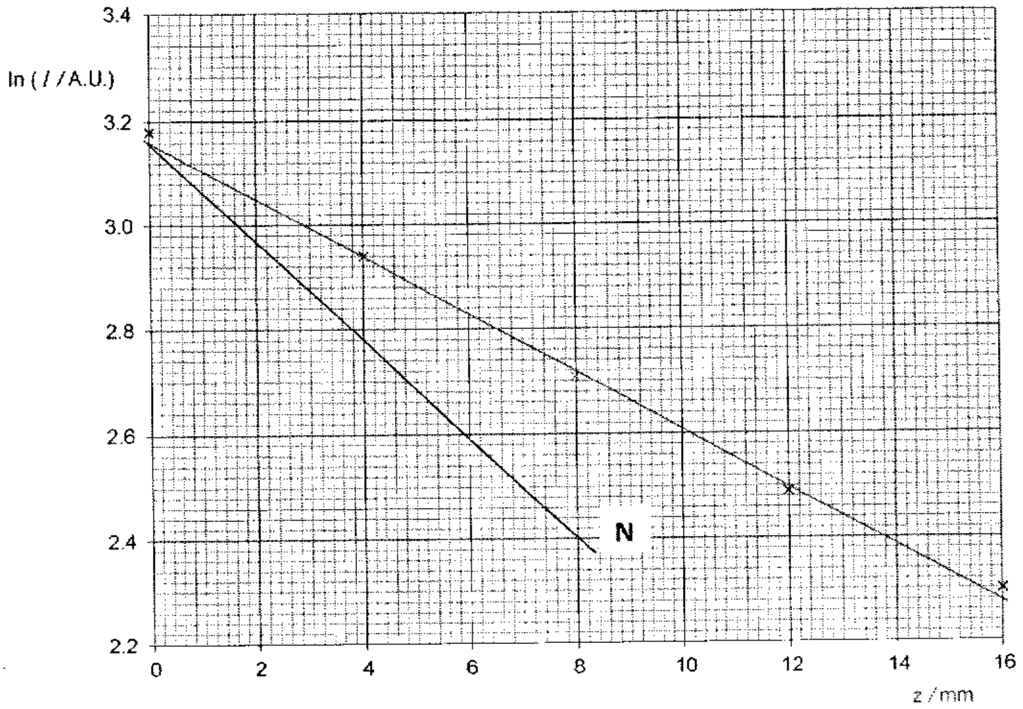
| **7cii**<br>**1.**<br>**2.**<br>*para 6* |  <br>1. Plot the point accurately to ½ smallest square.<br>2. Appropriate best fit line drawn. | **E** | A1<br>A1 |

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| **7ciii**<br>*para 6* | Using (0, 3.16) and (15.2, 2.32),<br>Gradient $= \frac{3.16-2.32}{0-15.2} = -\frac{0.84}{15.2} = -0.055$<br>*Correct computation of the gradient with two points on the best fit line.*<br>*[-1] if the points are not read to ½ smallest square precision, ½ square off. If more than one square off [0] for whole part.*<br>*[-1] if the two points chosen are less than half the line drawn*<br>*No units are required. However, if units are incorrect [-1]* | **E** | C1<br>A1 |
| **7civ**<br>*para 6 & 7* | $I = I_o e^{-\mu z} \Rightarrow \ln I = \ln I_o - \mu z$ Hence, gradient of the graph = $-\mu$<br>When $z = \delta_p$ , $I = I_o/e$<br>$\Rightarrow \frac{I_o}{e} = I_o e^{-\mu\delta_p} \Rightarrow \delta_P = 1/\mu$ = 1/0.055 = 18 mm | **D** | C1<br>A1 |
| **7cv1**<br>*para 5* | The potato mash with a higher water content would have more of the microwave (energy) **absorbed at the surface/** more microwaves absorbed per unit length/per unit volume by the water molecules as the microwaves move through the food, (the intensity of the microwaves will then fall to 1/e of its intensity at the surface in a shorter depth),<br>causing the penetration depth to be smaller. | **D** | M1<br>A1 |
| **7cv2** | **N** – straight line graph with y-intercept unchanged, gradient is steeper.<br>*Graph must be coherent with conclusion of penetration depth obtained earlier.* | **E** | A1 |

**[Turn Over**

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| *para 6* | | | |