OCR
RECOGNISING ACHIEVEMENT

Friday 25 May 2012 – Afternoon

AS GCE PHYSICS A

G482 Electrons, Waves and Photons

Candidates answer on the Question Paper.

OCR supplied materials:
- Data, Formulae and Relationships Booklet (sent with general stationery)

Other materials required:
- Electronic calculator

Duration: 1 hour 45 minutes

Candidate forename	Cowen	Candidate surname	Physics

Centre number						Candidate number				

INSTRUCTIONS TO CANDIDATES

- Write your name, centre number and candidate number in the boxes above. Please write clearly and in capital letters.
- Use black ink. HB pencil may be used for graphs and diagrams only.
- Answer **all** the questions.
- Read each question carefully. Make sure you know what you have to do before starting your answer.
- Write your answer to each question in the space provided. If additional space is required, you should use the lined pages at the end of this booklet. The question number(s) must be clearly shown.
- Do **not** write in the bar codes.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets [ ] at the end of each question or part question.
- The total number of marks for this paper is **100**.
- You may use an electronic calculator.
- Where you see this icon you will be awarded marks for the quality of written communication in your answer.
  This means for example your should:
  - ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear;
  - organise information clearly and coherently, using specialist vocabulary when appropriate.
- This document consists of **20** pages. Any blank pages are indicated.

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Answer **all** the questions.

1 The power of a 230V mains filament lamp is 40W.

(a) Define *power*.

$$\text{Power} = \frac{\text{work done}}{\text{time}}$$ **[1]**

(b) The lamp is connected to the 230V supply. Calculate

(i) the current I in the filament

$$P = IV$$

$$I = \frac{P}{V} = \frac{40}{230} =$$

I = 0.17 A **[2]**

(ii) the resistance R of the filament.

$$V = IR$$

$$R = \frac{V}{I} = \frac{230}{0.17} = 1323$$

R = 1320 Ω **[1]**

(c) The cross-sectional area of the wire of the filament is $3.0 \times 10^{-8}\,m^2$. The resistivity of the filament when the lamp is lit is $7.0 \times 10^{-5}\,\Omega m$. Use your answer to **(b)(ii)** to calculate the length L of the filament wire.

$$R = \frac{\rho L}{A}$$

$$l = \frac{RA}{\rho} = \frac{1323 \times 3.0 \times 10^{-8}}{7.0 \times 10^{-5}}$$

$$= 0.567\,m$$

L = 0.567 m **[3]**

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(d) Explain whether the filament of a 60W, 230V lamp is thicker or thinner than that of the 40W, 230V lamp. The length and material of the filament are the same in both lamps.

$P = \frac{V^2}{R}$

$P \propto \frac{1}{R}$

Larger power will require a higher current, so the resistance will be lower in the 60W bulb.

Therefore a larger cross-sectional area (thickness) will be needed.

[3]

(e) The 40W filament lamp is left on for 8 hours.

(i) Calculate the charge Q passing through the lamp in this time.

$Q = It = 0.17 \times 8 \times 60 \times 60$

$= 4896$

$Q =$ 4900 C **[2]**

(ii) **1** Define the *kilowatt-hour*.

The energy transferred by a 1 kW device in a time of one hour. **[1]**

2 Calculate the cost of leaving the lamp switched on. The cost of 1 kWh is 22p.

$40W = 0.040\ kW$

$0.040 \times 8 = 0.32\ kWh$

$0.32 \times 22 = 7.04p$

cost = 7.04 p **[2]**

[Total: 15]

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2 Fig. 2.1 shows the *I–V* characteristic of a light-emitting diode (LED).

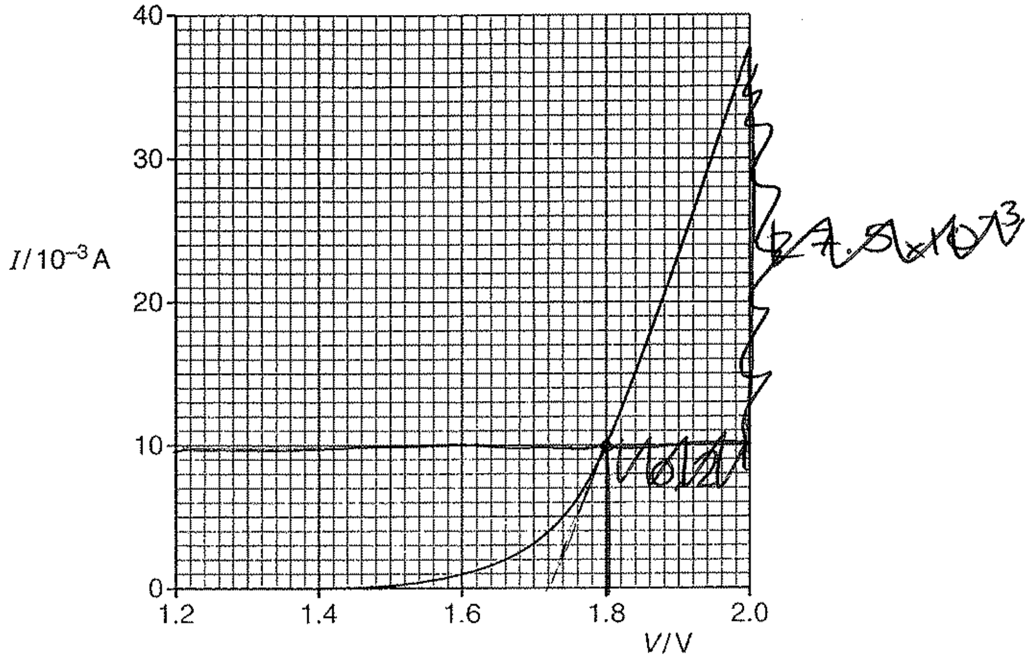

Fig. 2.1

(a) **(i)** Use Fig. 2.1 to

1 state the value of the resistance *R* below 1.4 V.

R = ...Infinite...... Ω **[1]**

2 determine the resistance *R* of the LED at *V* = 1.8 V.

~~0.12 / 47.5×10⁻³ 2.527Ω~~ $\frac{1.8}{10 \times 10^{-3}} = 180$

R = ...180...... Ω **[2]**

(ii) At voltages *V* above 1.8 V, state whether the resistance of the LED increases, remains the same or decreases as *V* increases. Justify your answer.

In your answer you should link features of the graph into your justification.

e.g. At 2V, $I = 37.5 \times 10^{-3}$ ∴ $R = 53.3\,\Omega$

At 1.9V, $I = 23 \times 10^{-3}$ ∴ $R = 82.6\,\Omega$

R decreases as V increases.

.... **[3]**

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(b) A circuit is set up to obtain the I–V characteristic shown in Fig. 2.1. It consists of a variable 0–6.0 V d.c. power supply connected in **series** to a 100 Ω resistor and the LED. Fig. 2.2 shows the variable supply. Draw the resistor, LED and suitable meters on the diagram between terminals **X** and **Y** to complete the circuit required for the experiment. **[4]**

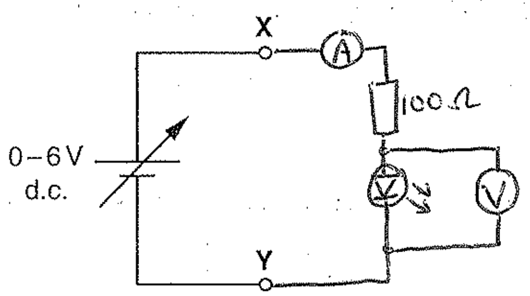

Fig. 2.2

(c) One or more LEDs are often used in places where, in the past, a filament lamp would have been used.
Give **one** example of such a situation.
Explain **one** advantage of using LEDs in place of a filament lamp in the situation you have chosen.

Traffic lights, because LEDs consume less power than a conventional light bulb due to less energy being wasted as heat.

[2]

[Total: 12]

3 Fig. 3.1 shows how the resistance of a thermistor varies with temperature.

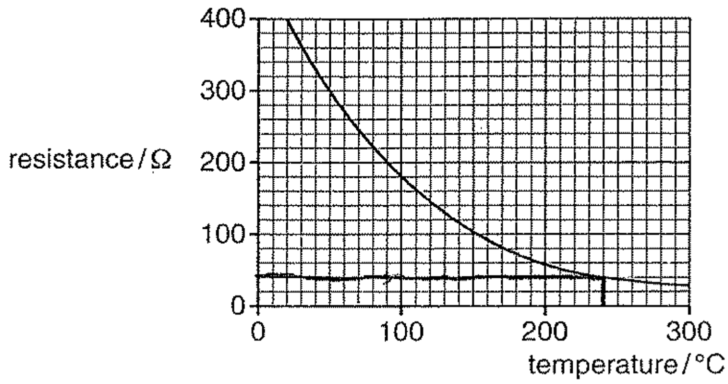

Fig. 3.1

The thermistor is used in the potential divider circuit of Fig. 3.2 to monitor the temperature of an oven. The 6.0 V d.c. supply has zero internal resistance and the voltmeter has infinite resistance.

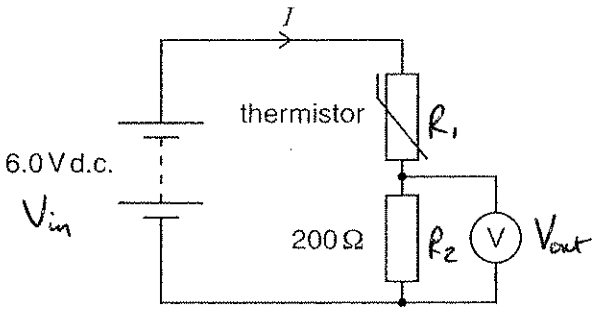

Fig. 3.2

(a) State and explain how the current I in the circuit changes as the thermistor is heated.

As temperature increases, resistance of the thermistor decreases

~~As~~ $\cancel{V_{out} = \frac{R_2}{R_1 + R_2} \times V_{in}}$ ~~(potential divider)~~

Combined resistance of thermistor and 200 Ω resistor is lower. $V = IR$ $I = \frac{V}{R}$, therefore current increases.

[3]

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(b) Use Fig. 3.1 to calculate the voltmeter reading when the temperature of the oven is 240 °C.

At 240°C, $R_1 = 40\,\Omega$

$$V_{out} = \frac{R_2}{R_1 + R_2} V_{in} = \frac{200}{240} \times 6.0 = 5.0\,\text{V}$$

voltmeter reading = 5.0 V **[4]**

(c) A light-dependent resistor (LDR) is another component used in sensing circuits.

(i) Complete Fig. 3.3 with an LDR between **X** and **Y**.

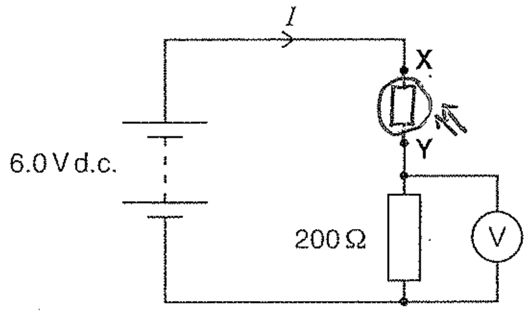

Fig. 3.3

[1]

(ii) State with a reason how the voltmeter reading varies as the intensity of the light incident on the LDR increases.

Resistance of LDR decreases as light intensity increases.

Potential divider, so p.d. across 200 Ω resistor will increase.

[2]

[Total: 10]

4 Fig. 4.1 shows part of a circuit where three resistors are connected together.

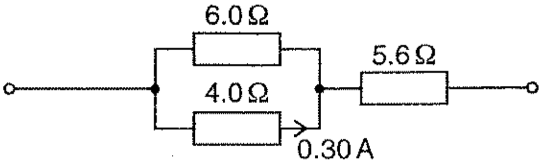

Fig. 4.1

The current in the 4.0 Ω resistor is 0.30 A.

(a) Explain why the current in the 6.0 Ω resistor is 0.20 A.

Resistors in parallel have the same p.d. across them.

$V = IR$ ~~$\div$~~ $V = 0.3 \times 4.0 = 1.2V$

$I = \frac{V}{R} = \frac{1.2}{6.0} = 0.2A$

[2]

(b) (i) State the law which enables you to calculate the current in the 5.6 Ω resistor.

Kirchhoff's first law (sum of currents into a junction = sum of currents out of the junction). [1]

(ii) Calculate the current in the 5.6 Ω resistor.

$0.30 + 0.20 = 0.50$

current = 0.50 A [1]

(c) Calculate the total resistance R of the combination of resistors.

$$R_{TOT} = \left(\frac{1}{6.0} + \frac{1}{4.0}\right)^{-1} + 5.6$$

$$= 2.4 + 5.6$$

$$= 8.0$$

$R =$ 8.0 Ω [3]

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(d) To cause the current of 0.30 A in the 4.0 Ω resistor, the resistor combination is connected to a d.c. supply of electromotive force (e.m.f.) 5.0 V.

(i) Explain the term *e.m.f.*

Energy per unit charged transferred into electrical energy from another form (eg chemical). **[2]**

(ii) Show that the terminal potential difference across the supply is 4.0 V.

$V = IR = 0.5 \times 8.0 = 4.0\ V$

[1]

(iii) Calculate the internal resistance of the supply.

$E = V + Ir$

~~E 4.0A~~

$r = \frac{E - V}{I} = \frac{5 - 4}{0.5}$

$= 2\ \Omega$

internal resistance = 2.0 Ω **[2]**

[Total: 12]

5 This question is about electrons and photons.

(a) Both electrons and photons can be considered as particles. State **two** differences between their properties.

Electrons have mass and charge, photons have neither.
Photons travel at speed of light [2]

(b) An electron is accelerated from rest through a p.d. of 5000 V.

(i) Show that the energy gained by the electron is 8.0×10^{-16} J.

$E_k = eV = 1.6 \times 10^{-19} \times 5000 = 8.0 \times 10^{-16}$

[2]

(ii) Show that the speed of the electron is about $4 \times 10^7\,\text{m s}^{-1}$.

$E_k = \frac{1}{2}mv^2$

$v = \sqrt{\frac{2E_k}{m}} = \sqrt{\frac{2 \times 8.0 \times 10^{-16}}{9.11 \times 10^{-31}}} = 4.2 \times 10^7$

[3]

(c) (i) Explain what is meant by the de Broglie wavelength of an electron.

Wavelength of an electron is inversely proportional to its momentum.
[1]

(ii) Calculate the de Broglie wavelength of the electron in **(b)**.

$\lambda = \frac{h}{mv} = \frac{6.63 \times 10^{-34}}{9.11 \times 10^{-31} \times 4.2 \times 10^7} = 1.7 \times 10^{-11}$

wavelength = 1.7×10^{-11} m [3]

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(d) Calculate the wavelength of a photon of energy 8.0×10^{-16} J.

$$E = \frac{hc}{\lambda} \qquad \lambda = \frac{hc}{E} = \frac{6.63 \times 10^{-34} \times 3.0 \times 10^{8}}{8.0 \times 10^{-16}}$$
$$= 2.5 \times 10^{-10}\,m$$

wavelength = 2.5×10^{-10} m **[3]**

(e) Photons of energy 9.0×10^{-19} J are incident on a clean tungsten surface causing electrons to be emitted.

(i) State the name of this process.

Photoelectric effect **[1]**

(ii) Calculate the maximum kinetic energy of the emitted electrons. Tungsten has a work function of 7.2×10^{-19} J.

$$hf = \phi + E_{k\,max}$$
$$E_{k\,max} = hf - \phi = \cancel{6.63 \times 10^{-34}} \; 9.0 \times 10^{-19} - 7.2 \times 10^{-19}$$
$$= 1.8 \times 10^{-19}$$

maximum kinetic energy = 1.8×10^{-19} J **[2]**

(iii) Explain why your answer to **(ii)** is a maximum value.

Work function is the minimum energy required to escape metal surface. Most electrons require more than this, thus leaving them with less than KEmax.

[2]

[Total: 19]

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6 **(a)** Define the following terms as applied to wave motion

(i) *displacement* and *amplitude*

Displacement: Distance moved by a particle from its equilibrium position

Amplitude: Maximum displacement

[2]

(ii) *frequency* and *phase difference*.

Frequency: Number of waves passing a point per unit time

Phase difference: Difference (in degrees) between two points on the same wave.

[2]

(b) Fig. 6.1 shows a transverse pulse on a *slinky*, an open wound spring, at time $t = 0$. The pulse is travelling at a speed of $0.50\,\text{m}\,\text{s}^{-1}$ from left to right. The front of the pulse is at point **X**, 0.25 m from the point **P**.

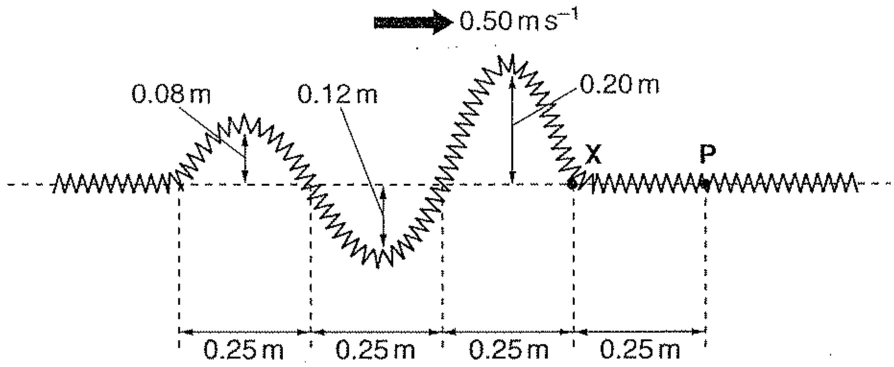

Fig. 6.1

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On Fig. 6.2 draw a displacement y against time t graph of the motion of point **P** on the slinky from $t = 0$ to $t = 2.5$ s.

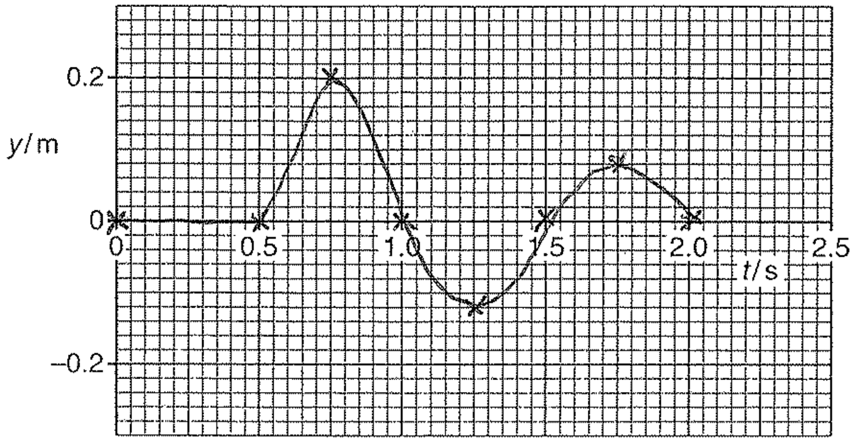

Fig. 6.2

[4]

[Total: 8]

7 Fig. 7.1 shows the three lowest energy levels of the hydrogen atom, labelled $n = 1$, 2 and 3.

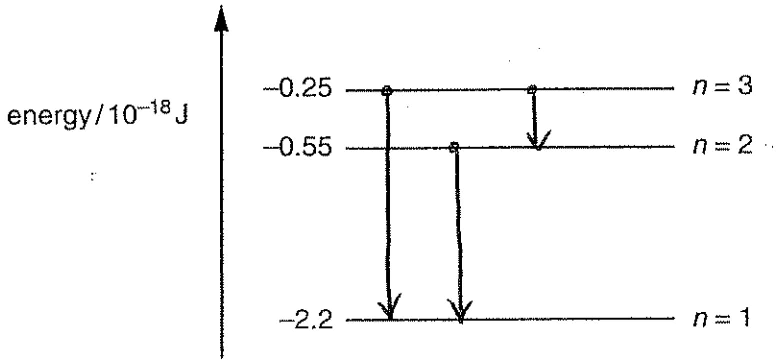

Fig. 7.1

(a) (i) Explain why electron transitions between the energy levels can produce three different wavelengths of radiation. You may draw lines on Fig. 7.1 to illustrate your explanation.

Energy is released as a photon when an electron moves from a high energy level to a low energy level.

There are three possible transitions (shown on diagram)

[3]

(ii) The strong red line in the hydrogen spectrum has a wavelength of 6.56×10^{-7} m.

1 Calculate the energy of the photon at this wavelength.

$$E = \frac{hc}{\lambda} = \frac{6.63 \times 10^{-34} \times 3.0 \times 10^{8}}{6.56 \times 10^{-7}}$$

$$= 3.03 \times 10^{-19}$$

energy = 3.0×10^{-19} J **[2]**

2 Use Fig. 7.1 to identify the electron transition responsible for the spectral line of this wavelength.

n_3 to n_2 $(-0.25 - -0.55 = 0.3)$

[1]

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(b) A parallel beam of light from a hydrogen lamp is incident on a diffraction grating. The first order red spectral line at 6.56×10^{-7} m is seen at an angle of 11.4° as shown in Fig. 7.2.

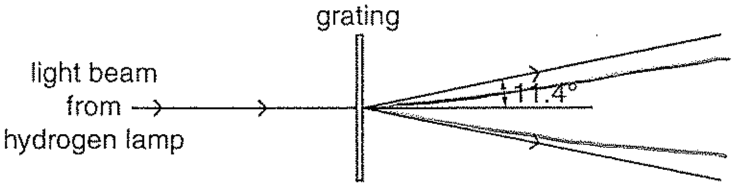

Fig. 7.2

(i) Calculate

1 the separation d of the lines on the grating

$$d \sin\theta = n\lambda$$

$$d = \frac{n\lambda}{\sin\theta} = \frac{1 \times 6.56\times10^{-7}}{\sin 11.4} = 3.3\times10^{-6}\ m$$

d = 3.3×10^{-6} m **[3]**

2 the number of lines per millimetre on the grating.

$$\frac{1}{d} = 301306 \text{ lines per m}$$

$$\frac{301306}{1000} = 301$$

number = 301 lines mm^{-1} **[1]**

(ii) The hydrogen lamp also emits blue light at a wavelength of 4.86×10^{-7} m.

Draw rays on Fig. 7.2 to indicate roughly, that is without calculation, the direction of the **first** order blue spectral line as the rays leave the grating. **[1]**

$\lambda \propto \sin\theta$

Smaller $\lambda \Rightarrow$ smaller $\sin\theta$

$\Downarrow$

smaller θ

[Total: 11]

8 **(a)** State **two** properties shared by all electromagnetic waves which distinguish them from all other waves.

Travel in a vacuum

Travel at the speed of light

....

.... [2]

(b) The two columns below list four regions of the electromagnetic spectrum and four orders of magnitude of wavelength in m.

	region	**wavelength / m**
longest	microwaves	10^{-12}
	ultra violet light	10^{-8}
shortest	gamma rays	10^{-6}
	infra red light	10^{-4}

Draw a straight line from each **region** box to the corresponding **wavelength** box. [2]

(c) Fig. 8.1 shows a microwave receiver **R** placed between a microwave transmitter **T** and a flat metal sheet.

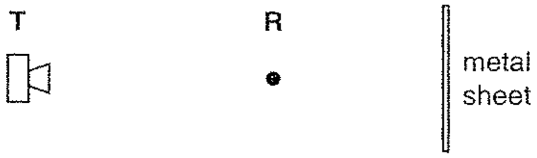

Fig. 8.1

(i) Explain why **R** receives two signals of different amplitude but of the same frequency.

Incident wave from T is reflected by metal sheet, producing a wave of the same frequency.
Reflected wave is weaker because some of its energy is absorbed by sheet/air, resulting in lower amplitude. [2]

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(ii) Explain why the strength of the detected signal varies between maximum and minimum values as **R** is moved towards or away from the metal sheet.

In your answer you should make clear how the maxima and minima occur.

Reflected wave superposes with incident wave
Constructive interference produces maxima and destructive interference produces minima.
Constructive interference occurs when waves are in phase, destructive when out of phase. **[3]**

(iii) Determine the wavelength of the microwaves given that the distance between adjacent positions of maximum and minimum signal strength is 7.5 mm.

Separation of adjacent maximum and minimum $= \frac{\lambda}{4}$

$\frac{\lambda}{4} = 7.5\,mm$

$\lambda = 30\,mm$

wavelength = 30 mm **[1]**

(iv) The amplitude of the signal from the transmitter is *a*. The amplitude of the two signals detected at **R** are 0.8*a* and 0.6*a*. The changes in amplitude of the detected signals are negligible as **R** moves 7.5 mm. Show that the ratio

$$\frac{\text{maximum intensity of detected signal}}{\text{minimum intensity of detected signal}}$$

is about 50.

$I \propto A^2$

constructive

$$\frac{(0.8+0.6)^2}{(0.8-0.6)^2} = 49$$

destructive

[3]

[Total: 13]

END OF QUESTION PAPER

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ADDITIONAL PAGE

If additional space is required, you should use the lined pages below. The question number(s) must be clearly shown.

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