YISHUN INNOVA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME

CG   INDEX NO

PHYSICS 9749/02

Paper 2 Structured Questions

1 September 2021

2 hours

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

READ THESE INSTRUCTIONS FIRST

Write your name 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.
Do not use staples, paper clips, highlighters, glue or correction fluid/tape.

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	
1	**/8**
2	**/8**
3	**/5**
4	**/6**
5	**/11**
6	**/8**
7	**/11**
8	**/23**
Penalty	
Paper 2 Total	
	/80

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

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Data

speed of light in free space,	c	=	3.00×10^{8} m s^{-1}
permeability of free space,	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_o	=	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	=	$\rho g h$
gravitational potential,	ϕ	=	$-\frac{Gm}{r}$
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	=	$x_o \sin \omega t$
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	=	$R_1 + R_2 + \ldots\ldots\ldots$
resistors in parallel,	$\frac{1}{R}$	=	$\frac{1}{R_1} + \frac{1}{R_2} + \ldots\ldots$
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,	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

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

1 **(a)** State the principle of conservation of linear momentum.

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

(b) Two microscopic particles are travelling along the same straight line in the same direction, as shown in Fig. 1.1.

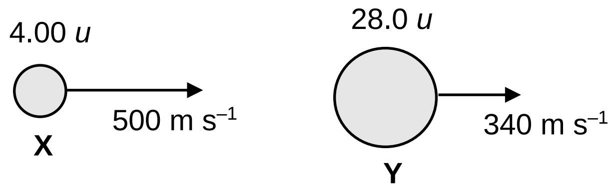

Fig. 1.1

Particle **X** has mass 4.00 *u* and horizontal velocity 500 m s^{-1} whereas particle **Y** has mass 28.0 *u* and horizontal velocity 340 m s^{-1}.

After the two particles collide, **X** has a horizontal velocity of 220 m s^{-1} in the same direction as before and **Y** has horizontal velocity *v*.

(i) Determine the magnitude of velocity *v*.

v = ……………….. m s^{-1} [2]

(ii) Deduce whether the above collision is elastic or not. Show your workings clearly.

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

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

(iii) Use Newton's third law to explain why, during the collision, the change in momentum of **X** is equal and opposite to the change in momentum of **Y**.

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

[Total: 8]

2 Fig. 2.1 shows a cross-sectional view of a Formula 1 racing car travelling on a rough track that is banked such that it makes an angle of 30° with the horizontal. At a certain bend along the track, the radius of curvature is 50.0 m. The mass of the car is 1000 kg.

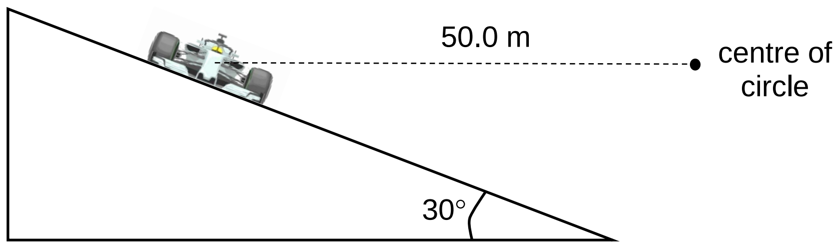

Fig. 2.1

(a) Explain briefly how the banked track assists the car in travelling round the bend.

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

(b) The driver tries to negotiate the bend **at its maximum speed** without slipping.

(i) In Fig. 2.1, draw a free-body diagram of the forces acting on the car. [3]

(ii) Given that the maximum frictional force between the wheels of the car and the track is 6000 N, calculate this maximum speed.

maximum speed = ………………….. m s^{-1} [3]

[Total: 8]

3 **(a)** Explain why the internal energy of a fixed amount of real gas is NOT solely dependent on its thermodynamic temperature.

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

(b) The pressure of an ideal gas, p, is related to its density, ρ, by the equation $p = \frac{1}{3}\rho\langle c^2 \rangle$ where $\langle c^2 \rangle$ is the mean square speed of the gas molecules.

Using the above equation, show that the internal energy of a fixed amount of ideal gas is directly proportional to its thermodynamic temperature.

[3]

[Total: 5]

4 A cylinder of constant volume 3.8×10^4 cm^3 contains an ideal gas at pressure 2.5×10^5 Pa and temperature 181 °C. The gas is heated with 2700 J of the thermal energy. The final temperature and pressure of the gas are T and p.

(a) Calculate

(i) the number of molecules N in the cylinder,

N = ………………….. [2]

(ii) the change in internal energy of the ideal gas.

Explain your working.

change in internal energy = ………………….. J [2]

(b) Use your answer in **(a)** to determine the final temperature T, in Kelvin, of the gas in the cylinder.

T = ………………….. K [2]

[Total: 6]

5 **(a)** A metal wire in a circuit has a damaged part. The resistivity of the metal is unchanged but the cross-sectional area of the wire is reduced over a 4.0 mm length, as shown in Fig. 5.1.

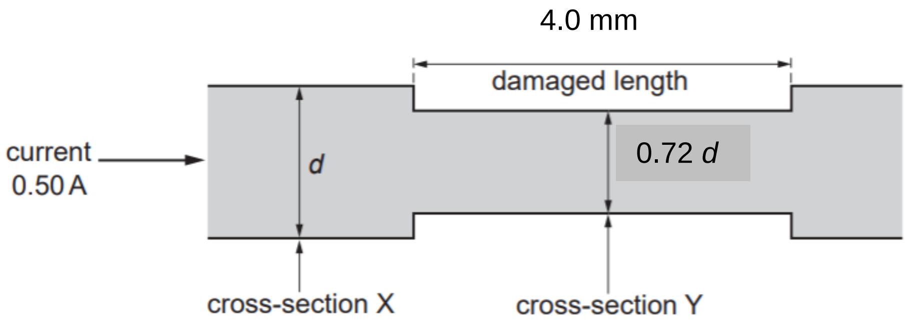

Fig. 5.1

The wire has diameter d at cross-section X and diameter 0.72 d at cross-section Y. The current in the wire is 0.50 A.

(i) Determine the ratio of $\dfrac{\text{average drift speed of electrons at cross-section Y}}{\text{average drift speed of electrons at cross-section X}}$.

ratio = …………………….. [2]

(ii) If the resistivity of the material of the wire is 1.12×10^{-6} Ω m and d = 0.21 mm, determine the resistance of the damaged length.

resistance = …………………….. Ω [2]

(iii) When current flows through the wire, explain why the damaged part of the wire has a higher voltage per unit length as compared to the rest of the wire.

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(b) Fig. 5.2 shows a cell of e.m.f. E_1 and internal resistance r_1 connected in series with a resistor of resistance R_1 and a uniform metal wire of resistance R_2 with length 1.000 m placed between points B and F.

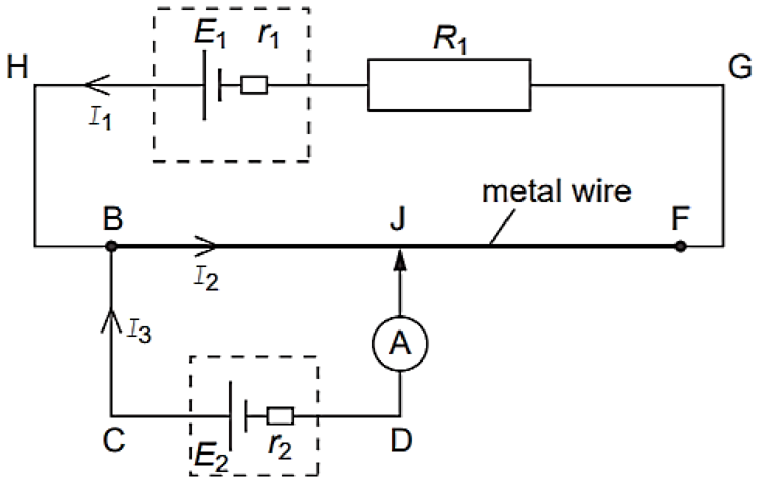

Fig. 5.2

A second cell of e.m.f. E_2 and internal resistance r_2 is connected in series with a sensitive ammeter and is then connected across the wire at points B and J. The current directions are shown on Fig. 5.2.

(i) Write down the relationship between the three currents at B.

[1]

(ii) The connection at J is moved along the wire. Explain why the reading on the ammeter changes.

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…………………………………………………………………………………… [2]

(iii) The values of the e.m.f.s and resistances are as follows.

$E_1 = 4.5$ V

$E_2 = 1.2$ V

$r_1 = 1.5\ \Omega$

$r_2 = 0.8\ \Omega$

$R_1 = 3.0\ \Omega$

$R_2 = 3.5\ \Omega$

Determine the length of BJ for which the ammeter reads zero.

length = ………………….. m [3]

[Total: 11]

6 **(a)** State Faraday's law of electromagnetic induction.

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

(b) Two parallel rails of negligible resistance are placed 15.0 cm apart as shown in Fig. 6.1. Two metal rods, AB and CD, which can slide smoothly along the rails, are being pulled by external forces. Rod AB is being pulled at a constant speed of 3.0 m s^{-1} while rod CD is being pulled at a constant speed of 5.0 m s^{-1} in the opposite direction. There is a uniform magnetic flux density of 0.20 T applied perpendicular to the plane of the rails into the paper.

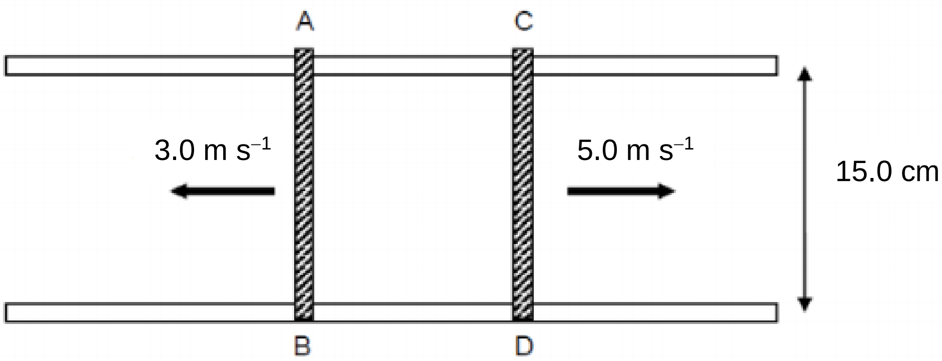

Fig. 6.1

(i) Calculate the e.m.f. induced in the loop ABDCA.

induced e.m.f. = ………………….. V [3]

(ii) Describe and explain, using Lenz's law, the direction of the induced current in the loop ABDCA.

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

(iii) Explain why there is a need for external forces to be applied to allow the rods to move at constant speed.

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[Total: 8]

7 **(a)** State three pieces of evidence provided by the photoelectric effect for the particulate nature of electromagnetic radiation.

1. ……………………………………………………………………………………………………

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2. ……………………………………………………………………………………………………

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3. ……………………………………………………………………………………………………

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

(b) The work function energies of some metals are shown in Fig. 7.1.

	work function energy / eV
sodium	2.4
calcium	2.9
zinc	3.6
silver	4.3

Fig. 7.1

Each metal is irradiated with electromagnetic radiation of wavelength 380 nm.

(i) Explain what is meant by *work function energy*.

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

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

(ii) Calculate the energy, in eV, of a photon of electromagnetic radiation of wavelength 380 nm.

energy = ...eV [2]

(iii) Determine which metal or metals will give rise to the emission of photoelectrons. Explain your answer.

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

(c) Photons of wavelength 380 nm are incident normally on a metal surface at a rate of 7.6×10^{14} s^{-1}. All the photons are absorbed in the surface and no photoelectrons are emitted.

Calculate the force exerted on the metal surface by the incident photons.

force = ... N [3]

[Total: 11]

8 Microwaves are a form of electromagnetic waves which has wavelengths ranging from one meter to one millimetre with frequencies between 300 MHz and 300 GHz. Microwaves are very widely used in today's world. They are used for point-to-point communication links, wireless networks, satellite and spacecraft communication, cancer treatment, collision avoidance systems, garage door openers and keyless entry systems, and for cooking food in microwave ovens.

Microwaves are divided into sub-bands based on their wavelengths. Some bands of microwaves and their applications are shown in Fig. 8.1.

Band	Wavelength range	Applications
L	15 cm to 30 cm	Used in navigations, GSM mobile phones, and in military applications
S	7.5 cm to 15 cm	Used in navigation beacons, optical communications, microwave ovens and wireless networks
C	2.0 cm to 7.5 cm	Used in long-distance radio telecommunications as they can penetrate clouds, dust, smoke, snow, and rain
X	25 mm to 6.0 mm	Used in satellite communications, broadband communications, radars, space communications, and amateur radio signals
Ku		
K		
Ka		

Fig. 8.1

Some properties of microwaves are listed below.

- Microwave transmission is affected by wave effects such as reflection, refraction, diffraction and interference.
- When microwaves interact with materials, some of the energy can be absorbed or transmitted while a portion of it can be reflected. The microwave energy absorbed by the material is converted to heat.
- Metal surfaces are considered reflectors of microwaves while most of the microwave energy can pass through glass and plastics. Rubber-based materials are considered good absorbers of microwaves.
- Microwaves follow the law of reflection, which states that the angle of incidence equals to the angle of reflection, where both angles are measured between the beam and the normal of the surface.

There are many different types of experiments which can be used to determine the wavelength of microwaves. One of the ways is described below.

A monochromatic microwave transmitter T and a receiver R are arranged on a straight line marked on the bench. A thin metal sheet M is placed on the marked line perpendicular to the bench, at the mid-point between the R and T.

Fig. 8.2 shows the side and plan views of the arrangement. The circuit connected to T and the ammeter connected to R are only shown in the plan view.

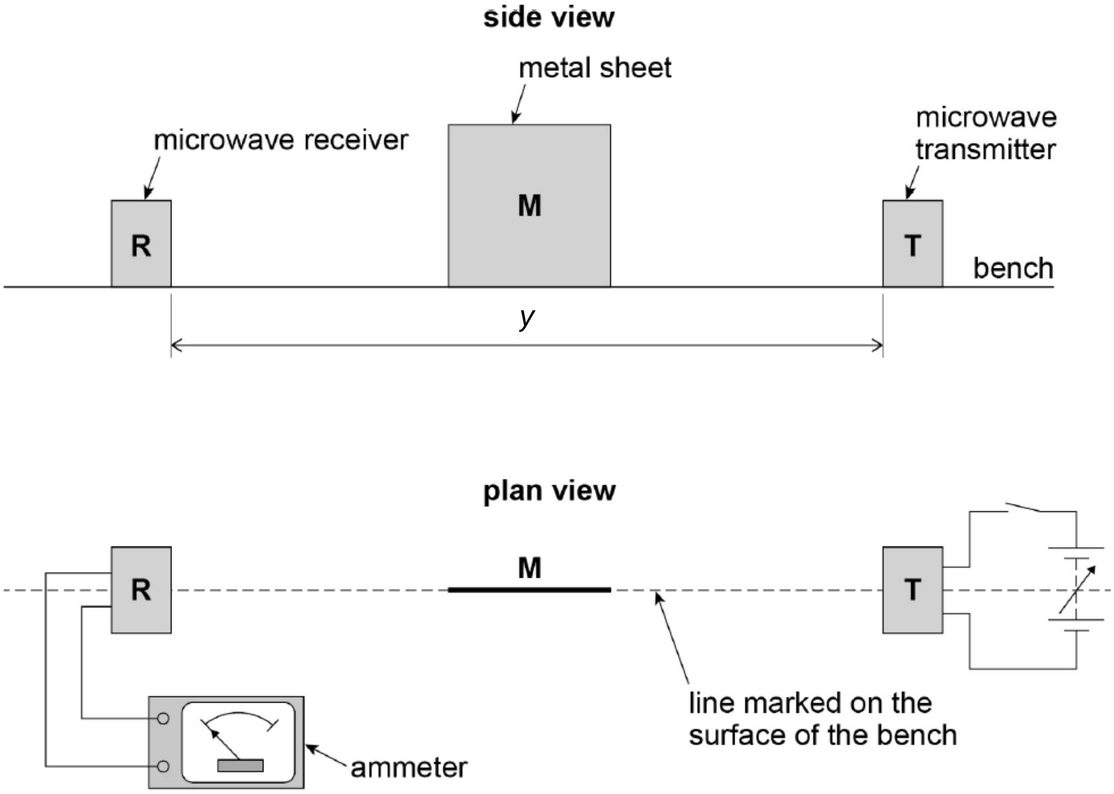

Fig. 8.2

The distance *y* between T and R is recorded.

T is switched on and the output from T is adjusted so a reading is produced on the ammeter as shown in Fig. 8.3.

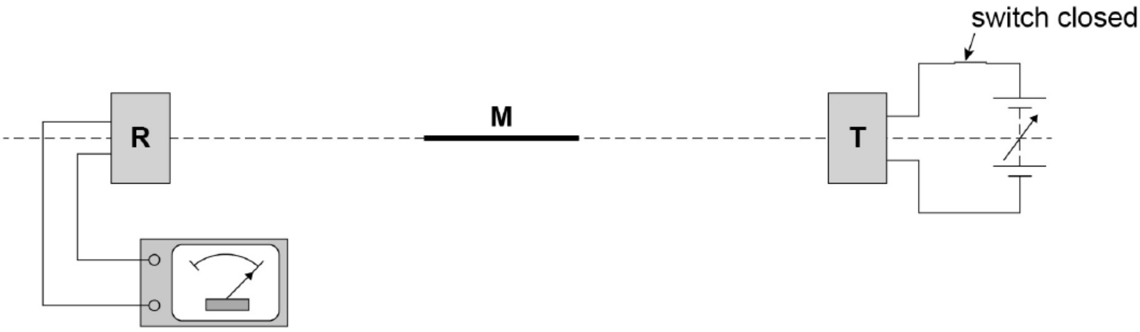

Fig. 8.3

M is kept parallel to the marked line and moved slowly away as shown in Fig. 8.4.

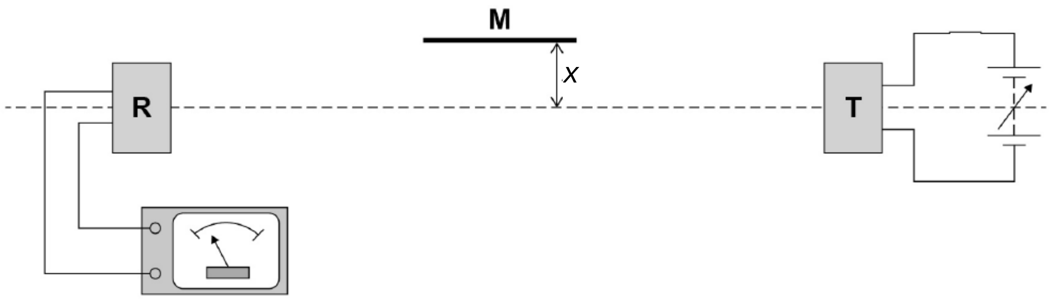

Fig. 8.4

The ammeter reading decreases to a minimum reading **which is not zero**. The ammeter reading depends on the superposition of waves travelling directly to R and other waves that reach R after reflection from M.

The perpendicular distance x between the marked line and M is recorded.

(a) State the phase difference between the sets of waves superposing at R when the ammeter reading is a minimum.

phase difference = ………………….. rad [1]

(b) **(i)** In Fig. 8.4, draw the two paths of the microwaves which results in the ammeter reading due to superposition at the receiver.

[2]

(ii) By considering the principle of superposition, explain why the minimum reading of ammeter is **not zero**.

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……………………………………………………………………………………… [3]

(c) When M is moved further away, the reading increases to a maximum then decreases to a minimum.

At the first minimum position, a student labels the minimum *n* = 1 and records the value of *x*.

The next minimum position is labelled *n* = 2 and the new value of *x* is recorded. Several positions of maxima and minima are produced.

(i) Describe a procedure that the student could use to make sure that M is parallel to the marked line before measuring each value of *x*.

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……………………………………………………………………………………… [2]

(ii) There is a phase change of π radians upon reflection at the surface M. By considering the path difference of the waves arriving at R, show that the equation

$$n\lambda = \sqrt{4x^2 + y^2} - y$$

holds when the ammeter reading is a minimum, where λ is the wavelength of the microwaves and y is the distance defined in Fig. 8.2.

[3]

(d) The variation of $\sqrt{4x^2 + y^2}$ with n is shown in Fig. 8.5.

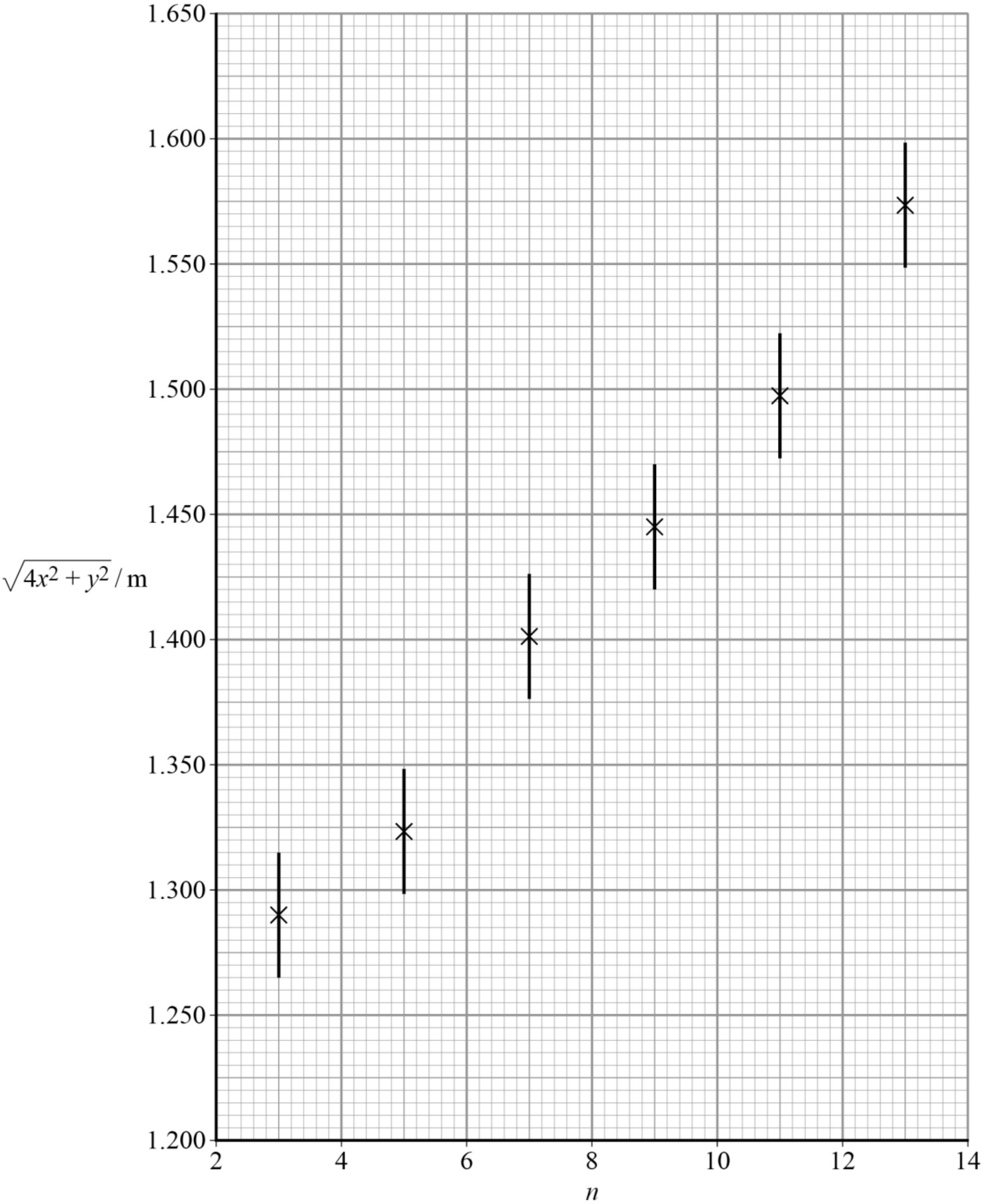

Fig. 8.5

The student estimates the uncertainty in each value of $\sqrt{4x^2 + y^2}$ to be 0.025 m and adds error bars (as indicated by the vertical lines at each point) to the graph.

Determine

(i) the maximum gradient G_{max} of a line that passes through all the error bars,

G_{max} = ………………….. m [2]

(ii) the minimum gradient G_{min} of a line that passes through all the error bars,

G_{min} = ………………….. m [2]

(iii) the average value of λ,

λ = ………………….. m [1]

(iv) the band of the microwave that is used in the experiment,

……………………………………………………………………………………… [1]

(v) the percentage uncertainty in value of λ found.

percentage uncertainty = ………………….. % [2]

(e) Another student performed a separate set of experiments by varying the values of y to obtain the different values of x for which the first minimum reading is obtained by the ammeter.

The set of readings obtained is shown in Fig. 8.6.

y / cm	4.5	22.3	55.5	99.5
x / cm	2.9	5.8	9.0	12.0

Fig. 8.6

The student proposed that x and y are proportional to each other.

Use the values in Fig. 8.6 to conclude whether this student's proposal is valid.

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

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

(f) The experiment is repeated by a third student who has initially placed the thin plate M very close to the transmitter T instead, as shown in Fig. 8.7.

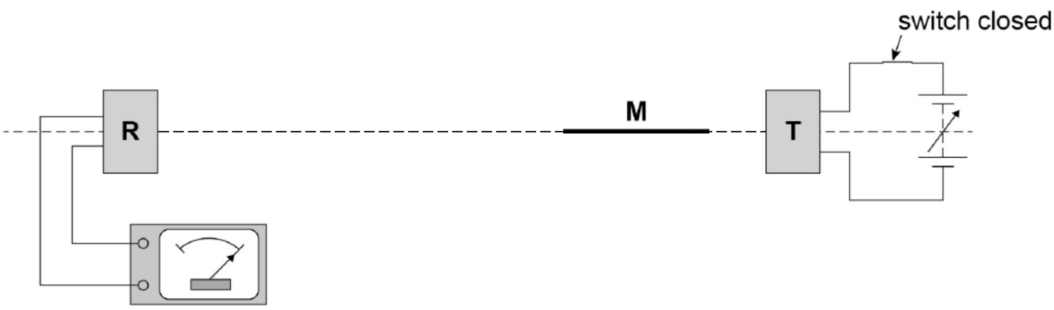

Fig. 8.7

Plate M is again moved away parallel to the marked line over a small distance. Explain why the ammeter reading does not vary.

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

[Total: 23]

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