Catholic Junior College

JC2 Block Test

Higher 2

Topics: Gravitational Field, Oscillations, Wave Motion, Superposition, Thermal Physics, Electric Fields, Current of Electricity and D.C. circuits

CANDIDATE NAME	
CLASS	**2T**

PHYSICS **9749**

Section A: Multiple Choice Questions **5 March 2024**

Section B: Structured Questions **2 hours**

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write your name and tutorial group on this cover page.

FOR SECTION A

Write and shade your name, NRIC/FIN number and HT group on the Answer Sheet (OMR sheet).
Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.

There are a total of **15 Multiple Choice Questions (MCQs)** in this paper. Answer **all** questions.
For each question, there are four possible answers, **A, B, C** and **D**. Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet (OMR sheet).

FOR SECTION B

Write in dark blue or black pen in the spaces provided.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, glue or correction fluid.
Answer **all** questions.
The number of marks is given in brackets [ ] at the end of each question or part question.

Answer all questions.
You are advised not to spend more than 30 minutes on Section A.

FOR EXAMINER'S USE		
SECTION A		/ 15
SECTION B		
Q1		/ 12
Q2		/ 8
Q3		/ 17
Q4		/ 9
Q5		/ 14
GRAND TOTAL		/ 75

PHYSICS 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}
			$\approx (1/(36\pi)) \times 10^{-9}$ 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} mol^{-1}
gravitational constant	G	=	6.67×10^{-11} N m^{2} kg^{-2}
acceleration of free fall	g	=	9.81 m s^{-2}

PHYSICS 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	=	$-\dfrac{Gm}{r}$
temperature	T/K	=	$T/{}^\circ C + 273.15$
pressure of an ideal gas	p	=	$\dfrac{1}{3}\dfrac{Nm}{V}\langle c^2\rangle$
mean translational kinetic energy of an ideal gas molecule	E	=	$\dfrac{3}{2}kT$
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	=	$\dfrac{Q}{4\pi\varepsilon_o r}$
alternating current / voltage	x	=	$x_0 \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\dfrac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\dfrac{\mu_o N I}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_o n I$
radioactive decay	x	=	$x_0 \exp(-\lambda t)$
decay constant	λ	=	$\dfrac{\ln 2}{t_{\frac{1}{2}}}$

Section A

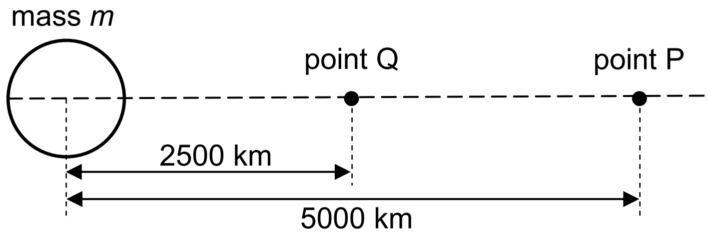
Shade your answers on the OMR sheet.

1 A satellite is in orbit above a planet at a height of 42000 km. The radius of the planet is 4600 km. The orbital period of the satellite is 24 hours.

What is the mass of this planet?

A 1.3×10^{24} kg **B** 3.7×10^{24} kg **C** 5.9×10^{24} kg **D** 8.0×10^{24} kg

2 A mass *m* is isolated in space. Point P is 5000 km from the centre of mass *m* and has a gravitational potential of −1000 J kg^{-1}. Point Q is 2500 km from the centre of mass *m*.



When a small test mass is moved from point P to point Q, what is the increase in gravitational potential experienced by the test mass?

A +1000 J kg^{-1} **B** −1000 J kg^{-1} **C** +3000 J kg^{-1} **D** −3000 J kg^{-1}

3 The displacement *x* of a body of mass 0.020 kg in simple harmonic motion varies with time *t* according to the equation

$$x = 5.0 \times 10^{-3} \sin (6\pi t)$$

where *x* is in metres and *t* in seconds.

What is the maximum restoring force on the body?

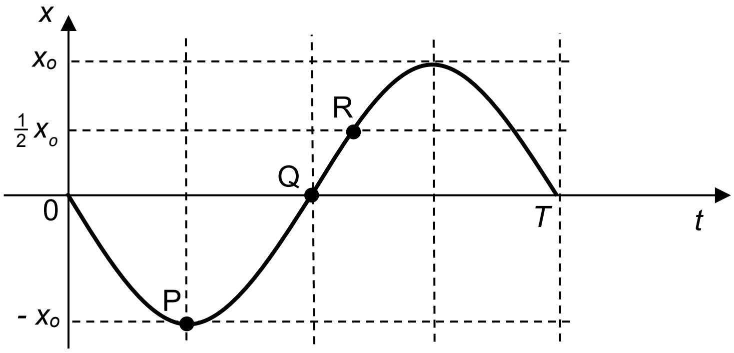
A 0.00189 N **B** 0.0355 N **C** 0.0942 N **D** 1.78 N

4 While travelling on a level road, a small car passes over a speed bump and experiences rapid vertical oscillations. The amplitude of the oscillations is 0.100 m, and its angular frequency is 8.72 rad s^{-1}.

What is the shortest time taken for the car to move from its lowest point to a point 0.0250 m below its equilibrium position during its oscillations?

A 0.0290 s **B** 0.151 s **C** 1.66 s **D** 8.66 s

5 The graph below shows how the displacement x of a body varies with time t when it is oscillating with simple harmonic motion.



Which statement about the body is false?

A The kinetic energy of the body is a minimum at P.

B The kinetic energy of the body is a maximum at Q.

C The kinetic energy of the body at R is half the maximum kinetic energy.

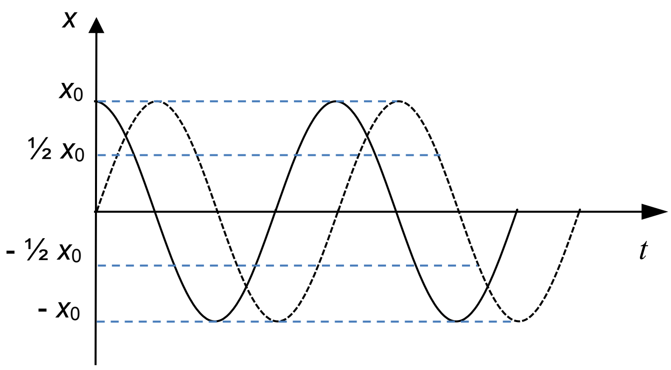
D The kinetic energy of the body at R is 0.75 times the kinetic energy at Q.

6 A point source emits 60 W of sound uniformly in all directions. A small microphone of area 7.5×10^{-5} m^2 detects the sound at 5.0 m from the source.

What is the power received by the microphone?

A 1.4×10^{-5} W **B** 1.4×10^{-4} W **C** 9.0×10^{-4} W **D** 1.4×10^{-1} W

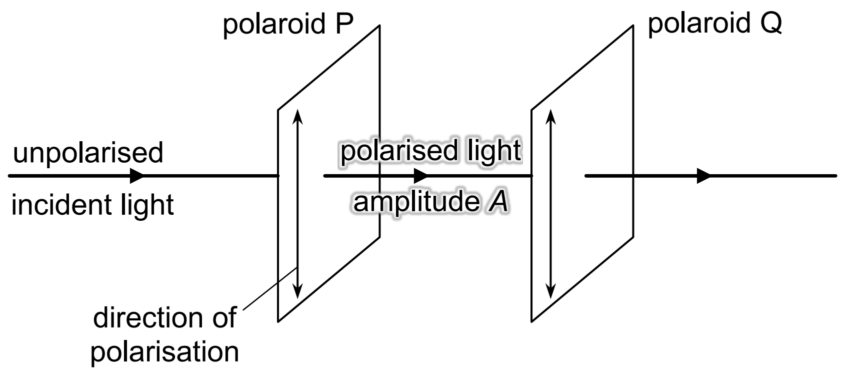
7 Two identical vertical spring-mass systems execute simple harmonic motion of the same amplitude and frequency. The graph below shows the variation of the displacement x of the masses with time t.



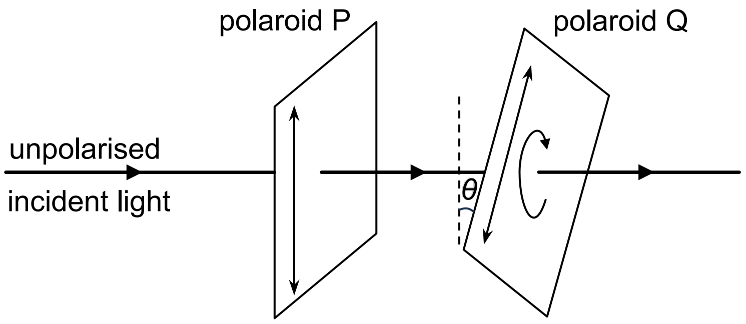
What is the phase difference between them?

A 90° **B** 120° **C** 135° **D** 150°

8 Two sheets of polaroid, P and Q, are placed so that their polarising directions are parallel and vertical, as shown below. A parallel beam of light passes through polaroid P. The beam after passing through polaroid P has amplitude *A*. The beam then passes through polaroid Q.



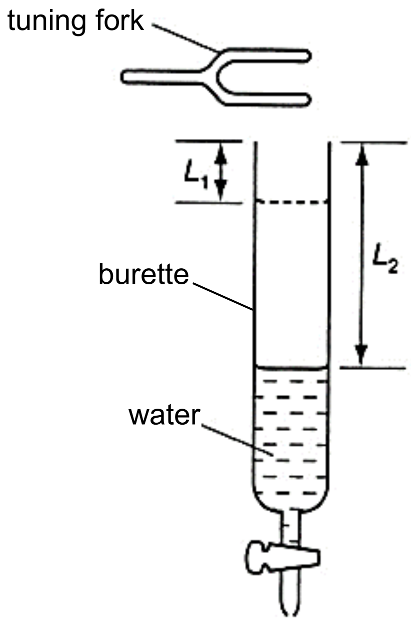
Polaroid Q is now rotated about the axis of the light beam, as shown below.



What is the smallest angle θ through which Q must be rotated for the amplitude of the emergent beam from Q to be reduced to ½ *A*?

A 30° **B** 45° **C** 60° **D** 90°

9 A tuning fork is made to vibrate above a burette filled with water. The water is allowed to run out of the tube. A loud sound is heard when the length of the air column is L_1 = 18 cm and again when the length is L_2 = 45 cm.



What is the wavelength of the sound in the air column?

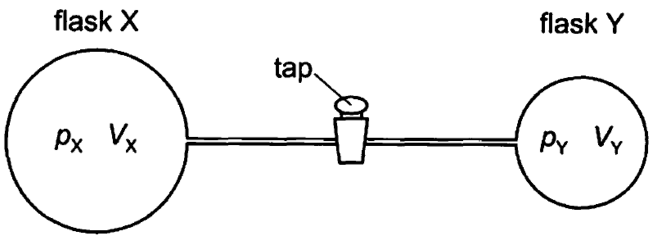
A 27 cm **B** 54 cm **C** 60 cm **D** 72 cm

10 A beam of white light was projected onto a diffraction grating with 400 lines per mm.

How many orders of the entire visible spectrum (400 nm to 700 nm) can be produced using this grating? (Do not count the zeroth order.)

A 3 **B** 4 **C** 6 **D** 7

11 Some ideal gas is contained in two flasks X and Y. The flasks are connected by a tube of negligible volume that is fitted with a tap, as shown.



With the tap closed, the pressure and volume of the gas in flask X are p_X and V_X respectively. In flask Y, the gas has pressure p_Y and volume V_Y. The temperature of the gas in both flasks is T.

The tap is opened. After some time, the temperature of the gas returns to T.

Which expression gives the final pressure of the gas in the flasks after opening the tap once the temperature has returned to T?

A $\dfrac{p_X V_X + p_Y V_Y}{V_X + V_Y}$

B $\dfrac{1}{2}\dfrac{p_X V_X + p_Y V_Y}{V_X + V_Y}$

C $\dfrac{(p_X + p_Y) V_X V_Y}{V_X + V_Y}$

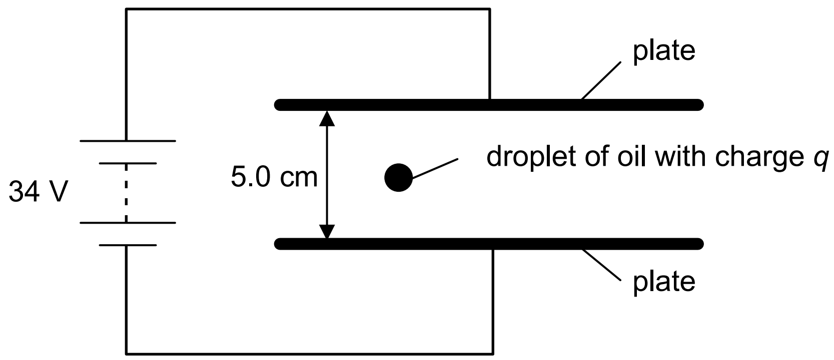
D $\dfrac{(p_X - p_Y)(V_X - V_Y)}{V_X + V_Y}$

12 A school laboratory has dimensions 12 m by 10 m by 3 m. The laboratory contains air of molar mass 0.029 kg, at an atmospheric pressure of 1.0×10^5 N m^{-2}. The air has a density of 1.2 kg m^{-3}.

What is the root-mean-square speed of the gas molecules in the air?

A 410 m s^{-1} **B** 500 m s^{-1} **C** 50000 m s^{-1} **D** 61000 m s^{-1}

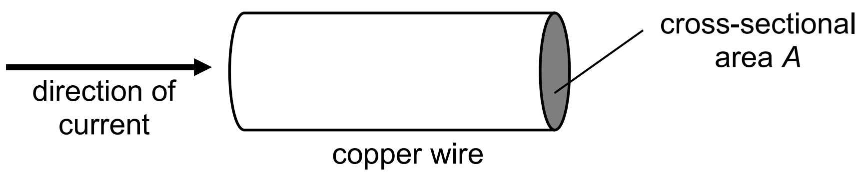
13 A droplet of oil of mass 0.21 g is held in equilibrium between two horizontal parallel charged plates as shown. The droplet of oil has a charge q. The parallel plates are fixed with a separation of 5.0 cm and a potential difference of 34 V is applied across the plates.



What is the electric field strength experienced by the droplet of oil?

A 0.070 N C^{-1} **B** 34 N C^{-1} **C** 680 N C^{-1} **D** 1.6×10^4 N C^{-1}

14 An electric current $I = 4.0$ A flows through a cylindrical shaped copper wire as shown. The wire has a cross-sectional area $A = 4.0 \times 10^{-6}$ m^2.

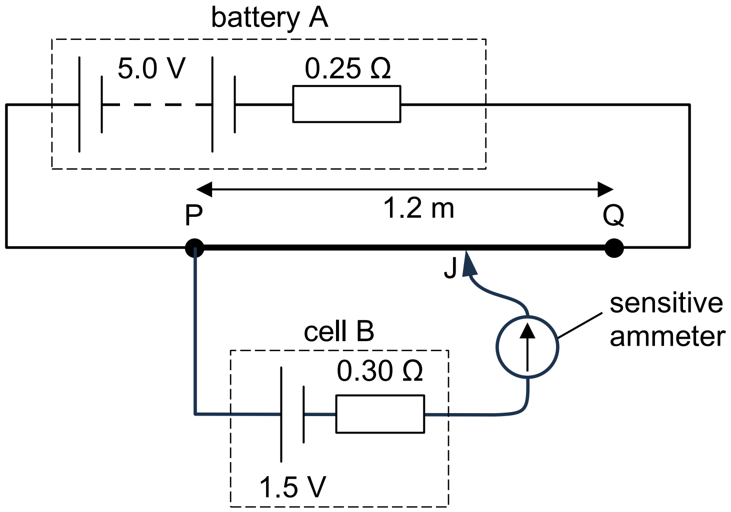


Given that the number of free electrons per cubic metre for copper is 8.6×10^{28}, what is the drift velocity of electrons through the copper wire?

A 1.2×10^{-23} m s^{-1} **B** 7.3×10^{-5} m s^{-1}

C 8.5×10^{-3} m s^{-1} **D** 2.2×10^{5} m s^{-1}

15 A battery A with internal resistance 0.25 Ω is connected in series with a uniform resistance wire PQ as shown. Resistance wire PQ has a length of 1.2 m and a resistance of 3.0 Ω. A cell B and a sensitive ammeter is connected to points P and J on the resistance wire.



The ammeter reads zero.

What is the length PJ?

A 0.32 m **B** 0.35 m **C** 0.36 m **D** 0.39 m

Proceed to Section B

Section B

Answer all questions in the answer spaces provided in this paper.

1 Coherent light of wavelength 590 nm is incident normally on a double slit, as illustrated in Fig. 1.1.

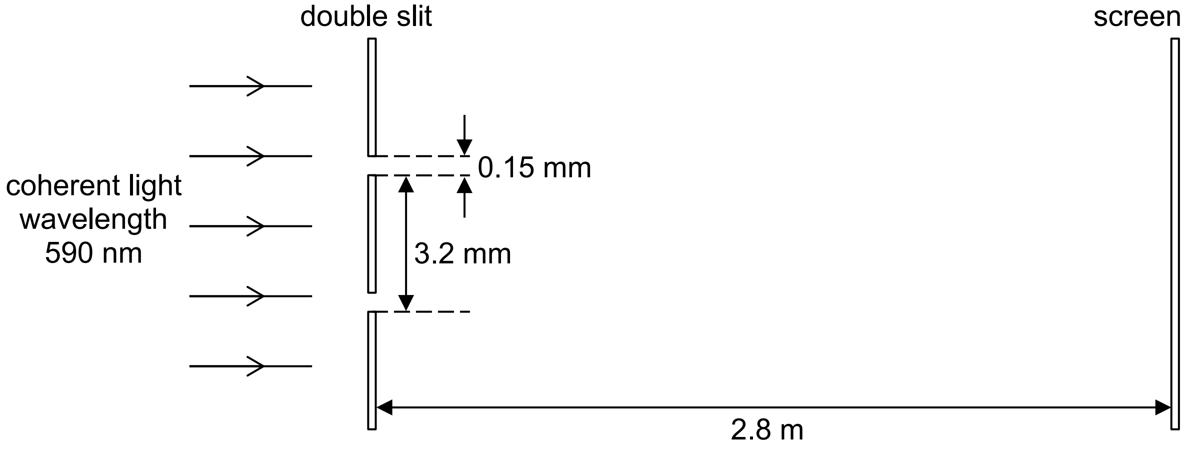


Fig. 1.1 (not to scale)

Both slits in the double-slit arrangement are rectangular with a width of 0.15 mm. The separation of the two slits is 3.2 mm.

A screen is placed parallel to the plane of the double slit at a distance of 2.8 m from the double slit.

(a) Initially, one of the two slits is covered.

Calculate the width of the central bright maximum formed on the screen by diffraction through the uncovered slit.

width = …………………..…………….. m [4]

(b) State the *Rayleigh criterion* for the resolution of two images.

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(c) Both slits in the double slit are now uncovered.

Use the Rayleigh criterion to explain whether the diffraction patterns produced by the two slits are seen on the screen as being separate.

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(d) Calculate the width of a fringe produced by the interference of light passing through the uncovered double slit.

fringe width = ………………….……………….. m [2]

(e) Use your answers to **(a)** and **(d)** to estimate, to one significant figure, the number of double-slit fringes observed in the central bright maximum produced by diffraction at one of the slits.

number = ………………….……………….. [1]

[Total: 12]

2 A receiver aerial is placed between a transmitter emitting radio waves at a single fixed frequency and a metal sheet, as shown in Fig. 2.1. The radio waves undergo π radians phase change upon reflection at the metal sheet.

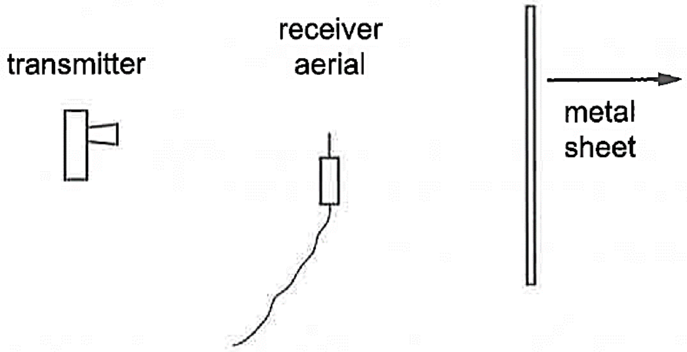

Fig. 2.1

The metal sheet is moved away from the receiver aerial by distance *h*. The variation of the intensity detected by the receiver aerial with *h* is shown in Fig. 2.2.

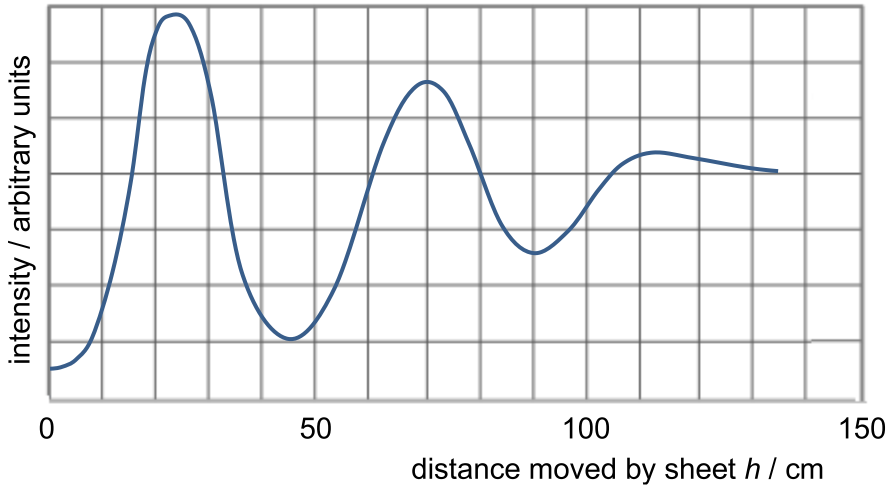

Fig. 2.2

(a) A minimum intensity is detected when $h = 0$.

State the phase difference, in radians, between the direct wave from the transmitter and the reflected wave at the receiver aerial when $h = 0$.

phase difference = ... rad [1]

(b) Explain why as *h* increases, the intensity detected by the antenna alternates between maximum and minimum.

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(c) Explain why as *h* increases, the intensity of the minimum increases.

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(d) Use Fig. 2.2 to estimate, to one significant figure in cm, the wavelength of the radio wave.

wavelength = ………………………………. cm [2]

[Total: 8]

3 **(a)** Define *electric field strength*.

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(b) A charged solid metal sphere A is isolated in vacuum. The variation with distance x from the centre of sphere A of the electric field strength E is shown in Fig. 3.1.

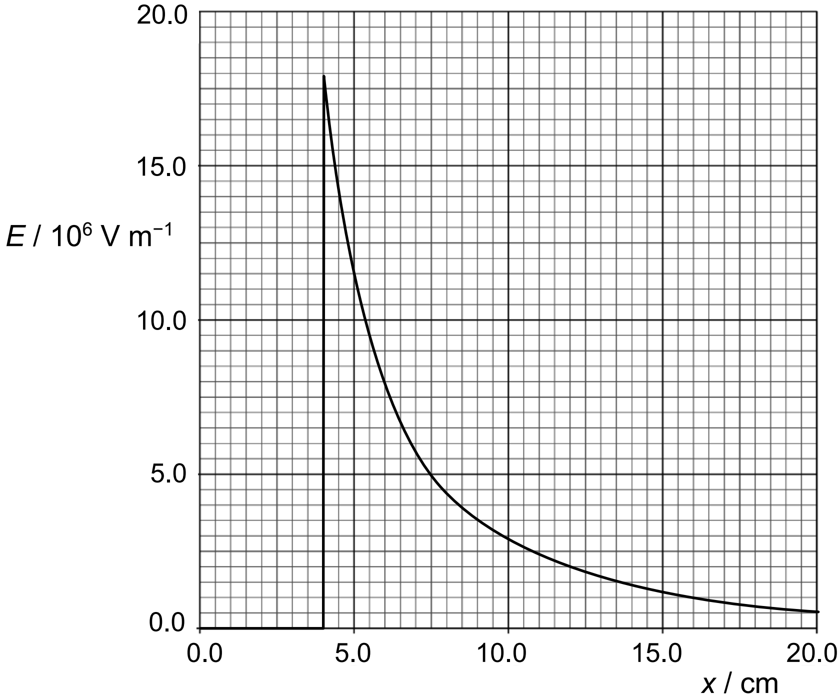

Fig. 3.1

(i) Explain why the electric field strength is zero for certain values of x.

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

(ii) Using Fig. 3.1, state the radius of the sphere A.

radius = ………………………… cm [1]

(iii) Using Fig. 3.1, determine the magnitude of the charge of sphere A.

charge = ………………………… C [2]

(c) Another charged solid metal sphere B is placed with a centre-to-centre separation of 25 cm from sphere A as shown in Fig. 3.2. Both metal spheres are isolated in vacuum.

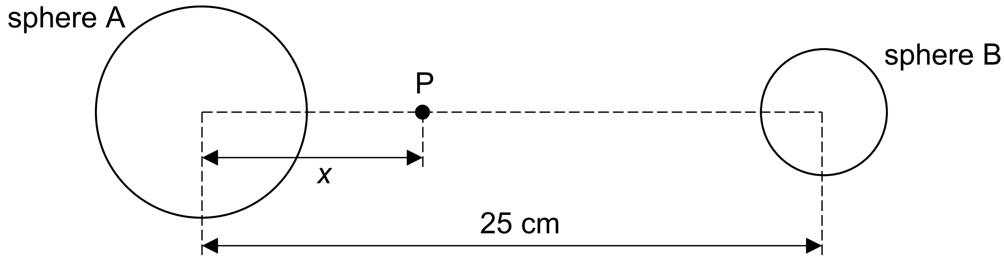

Fig. 3.2 (not to scale)

Point P is a point on the line joining the centres of the two spheres. Point P is a distance x from the centre of sphere A.

The variation with distance x from the centre of sphere A of the electric potential V due to both spheres is shown in Fig. 3.3.

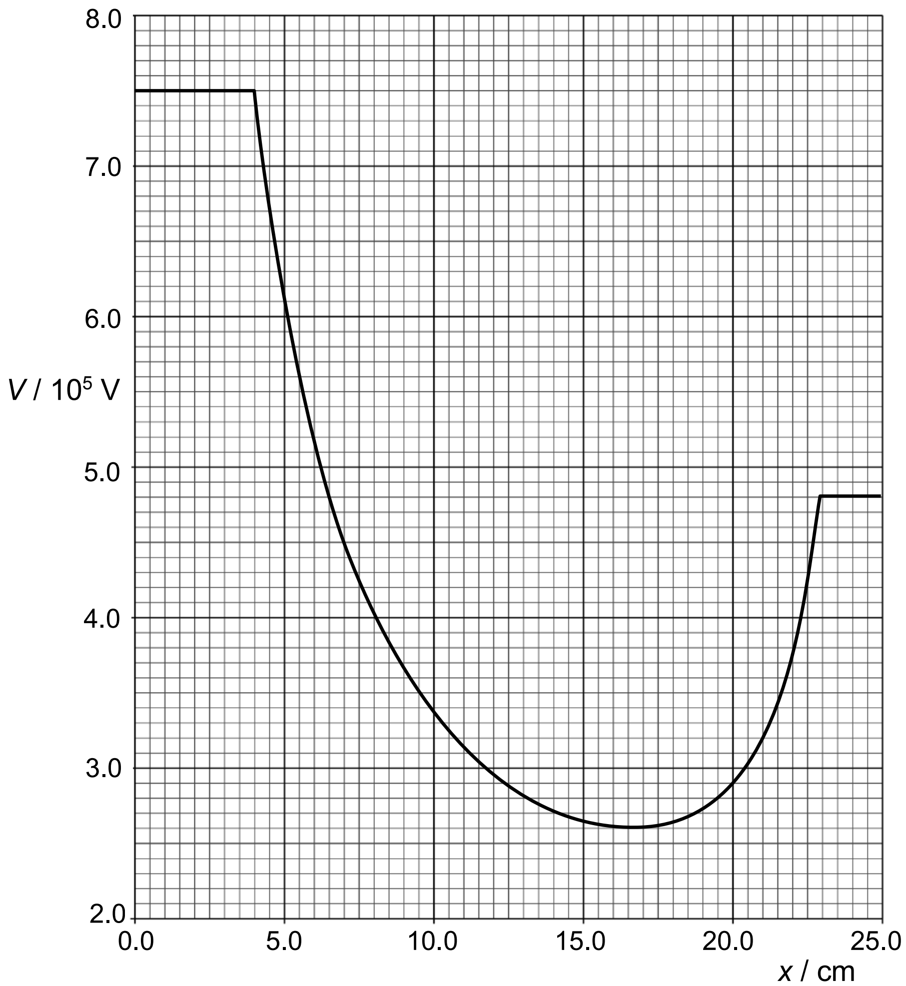

Fig. 3.3

(i) State and explain whether the spheres have charges of the same, or opposite, sign.

....

.... [1]

[Turn over

(ii) Using the charge of sphere A found in **(b)(iii)**, determine the charge of sphere B.

charge = ………………………… C [2]

(iii) State and explain the direction of the electric field at point P, where x = 10.0 cm.

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(iv) Use Fig. 3.3 to determine the magnitude of the electric force on an electron placed at point P, where x = 10.0 cm.

magnitude of electric force = ………………………… N [3]

(v) An electron is initially at rest a long distance from spheres A and B. The electron approaches the spheres and passes between the two spheres.

Calculate the minimum speed of the electron as it crosses the line joining the centres of the two spheres.

speed = ………………………… m s^{-1} [2]

(vi) Suggest why the answer in **(c)(v)** is not possible.

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[Total: 17]

4 The *I*-*V* characteristic graph for a thermistor shown in Fig. 4.1.

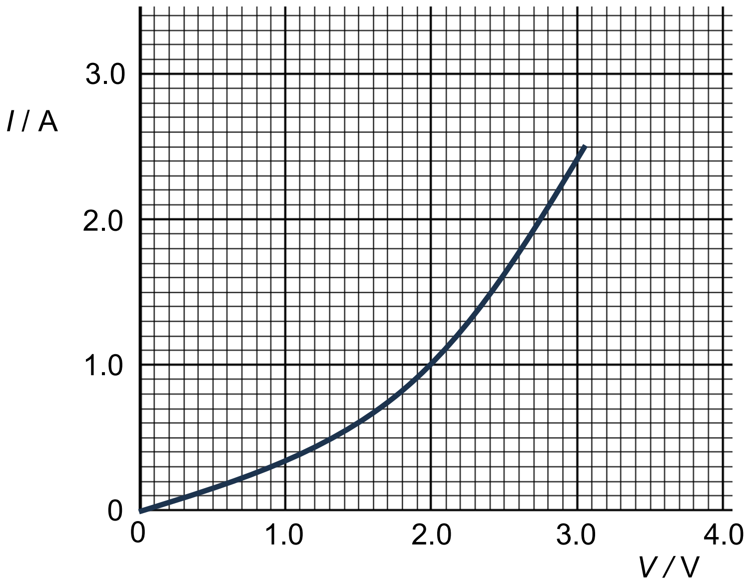

Fig. 4.1

(a) Explain why the resistance of the thermistor decreases when the temperature of the thermistor increases.

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(b) In an attempt to obtain the graph in Fig. 4.1 for the thermistor, a student set up a circuit as shown in Fig. 4.2.

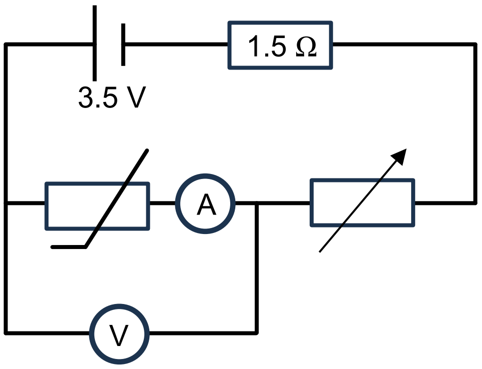

Fig. 4.2

A cell of e.m.f. 3.5 V with negligible internal resistance is connected to the thermistor, a 1.5 Ω fixed resistor and a variable resistor.

When the variable resistor has a resistance value of 2*R*, the thermistor has a resistance value of *R*. The potential difference across the variable resistor is 2.0 V.

(i) Determine the value of *R*.

R = ………………………….. Ω [2]

(ii) Use Fig. 4.1 to determine the current passing through the thermistor.

current = ………………………….. A [2]

(iii) The variable resistor has a resistance between zero to 10 Ω.

Explain, using appropriate calculations, why the circuit shown in Fig. 4.2 is inappropriate for determining the graph of Fig. 4.1.

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.... [2]

[Total: 9]

5 **(a)** A battery of e.m.f. E and internal resistance r is connected to a load of variable resistance R as shown in Fig. 5.1.

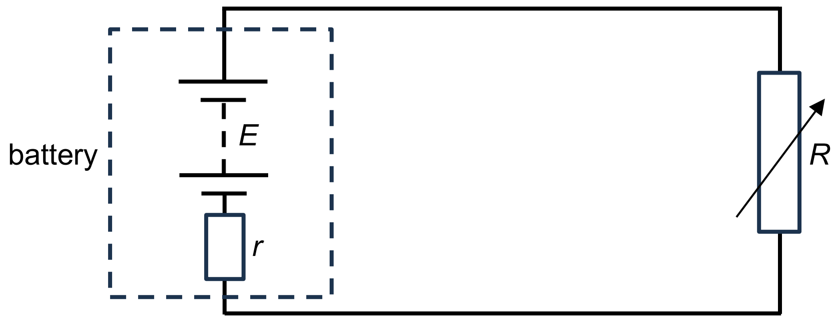

Fig. 5.1

(i) Derive an expression for the power P dissipated in the load resistor in terms of E, r and R.

[2]

(ii) On Fig. 5.2, sketch the variation of the power P dissipated in the load with resistance R of the load resistor. At the maximum point of the curve, label the axes with appropriate expressions.

Fig. 5.2 [3]

(b) A battery has an e.m.f. 12.0 V and internal resistance 0.500 Ω. It is connected to a parallel arrangement of four lamps, as shown in Fig. 5.3.

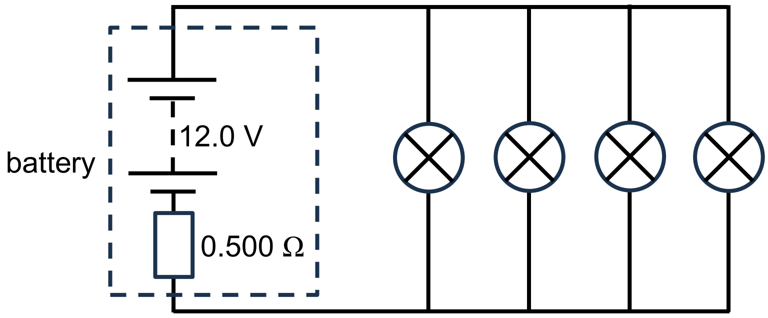

Fig. 5.3

Each lamp has a constant resistance of 30.0 Ω.

For the circuit as shown in Fig. 5.3, calculate

(i) the terminal potential difference of the battery,

terminal potential difference = …………………………..V [2]

(ii) the total power dissipated in the four lamps,

power = …………………………..W [2]

(iii) the efficiency, assuming that the total power dissipated in the lamps are useful power.

efficiency = ………………………….. % [2]

(c) A student thinks that the brightness of the lamps in **(b)** would be increased by connecting an additional resistor in the circuit, placed so as to extract the maximum power from the battery.

The additional resistor may be placed as shown in Fig. 5.4(a) or in Fig. 5.4(b).

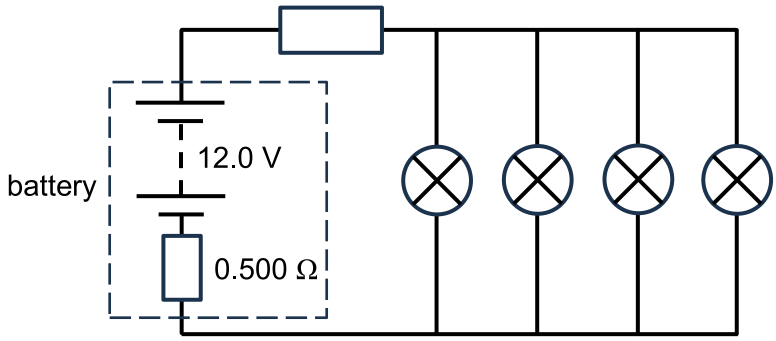

Fig. 5.4(a)

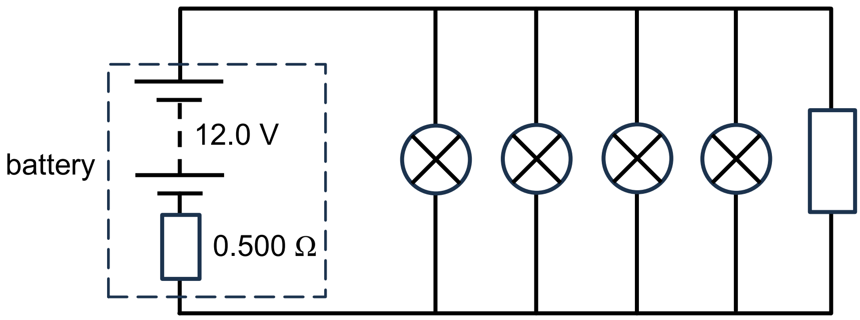

Fig. 5.4(b)

State and explain in which of the two circuits, shown in Fig. 5.4(a) or Fig. 5.4(b), should the additional resistor be connected so as to extract the maximum power from the battery.

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[Total: 14]

End of Paper