Catholic Junior College
JC2 Mid-Year Examinations
Higher 2

CANDIDATE NAME	MARK SCHEME
CLASS	2T

PHYSICS **9749/02**

Paper 2 Structured Questions

25 June 2024

2 hours

Candidates answer on the Question Paper.

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, glue or correction fluid.

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

The number of marks is given in brackets [ ] at the end of each question or part question.

FOR EXAMINER'S USE			DIFFICULTY		
			L1	L2	L3
Q1		/ 7			
Q2		/ 5			
Q3		/ 6			
Q4		/ 7			
Q5		/ 8			
Q6		/ 6			
Q7		/ 7			
Q8		/ 9			
Q9		/ 12			
Q10		/ 13			
PAPER 2		/ 80			
PAPER 1		/ 30			
PAPER 4		/ 55			
TOTAL (WEIGHTED)		%			

This document consists of **31** printed pages and **one** blank page.

DATA

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_0	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_0	=	8.85×10^{-12} F m^{-1}
			$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	e	=	1.60×10^{-19} C
the Planck constant	h	=	6.63×10^{-34} J s
unified atomic mass constant	u	=	1.66×10^{-27} kg
rest mass of electron	m_e	=	9.11×10^{-31} kg
rest mass of proton	m_P	=	1.67×10^{-27} kg
molar gas constant	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant	k	=	1.38×10^{-23} mol^{-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	$\phi = -\dfrac{Gm}{r}$
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	$\lambda = \dfrac{\ln 2}{t_{\frac{1}{2}}}$

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

1 **(a)** Define impulse.

………

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

L1 Impulse is the **product** of the **average force acting** on an object and the **duration of time for which the force acts**. **B1**

Examiners' comments:

- **A significant number of candidates were unable to produce a complete definition of impulse.**
- **Many candidates wrongly assumed impulse as momentum instead.**
- **Some candidates attempted to provide unnecessary mathematical formulas for impulse.**
- **Some candidates left this question un-attempted.**

(b) An object accelerates from rest in a straight line. Fig. 1.1 shows the variation with time of the resultant force acting on the object for a period of 52.0 s.

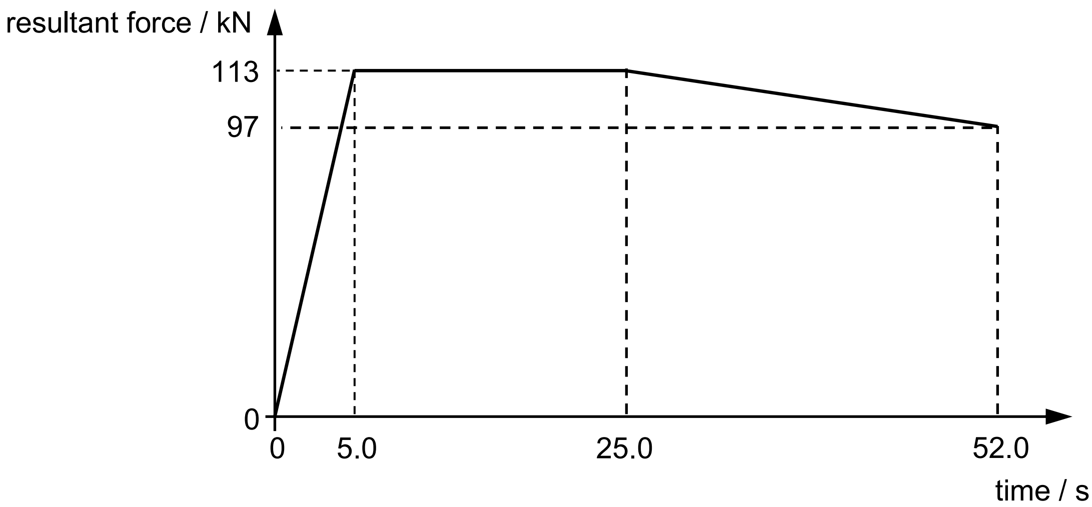


Fig. 1.1

(i) Calculate the momentum of the object at t = 52.0 s.

momentum = ………………………….…….. N s [2]

L2 By Newton's 2nd law of motion,
Change in momentum of the object
= area under the resultant force - time graph
= final momentum - initial momentum
= final momentum - 0

Final momentum of object at 52.0 s
= 0 + change in momentum
= 0 +

$$\left(\frac{1}{2}\times 5.0\times 1.13\times 10^{5}\right)+\left(20.0\times 1.13\times 10^{5}\right)+\left[\frac{1}{2}(1.13+0.97)\times 10^{5}\times 27.0\right]$$ **M1**

$= 5.38\times 10^{6}$ N s **A1**

Examiners' comments:

- **Many candidates were able to obtain some credit for this question.**
- **Some candidates attempted to find the gradient of the graph and equated it to the momentum of the object.**
- **In addition, some candidates substituted the value of momentum and velocity of the object at *t* = 52.0 s to find the value of momentum.**
- **Some candidates did not convert the units for the resultant force correctly.**

(ii) Describe the change in the magnitude of velocity of the object from 25.0 s to 52.0 s.

....

....

.... [1]

L2 It **increases at a decreasing rate**. **B1**

Examiners' comments:

- **Similar skills tested in <u>Alevel 2013/P2/Q2.</u>**
- **A significant number of candidates were unable to deduce the correct relationship between the change in momentum of an object and the area under force-time graph.**
- **Some candidates did not provide clear and detailed description of the change in velocity of the object.**
- **A few candidates described the change in velocity of the object in different intervals of time instead.**

(iii) On Fig. 1.2, sketch a graph to show the variation with time of the momentum of the object. (Numerical values for the momentum are not required.)

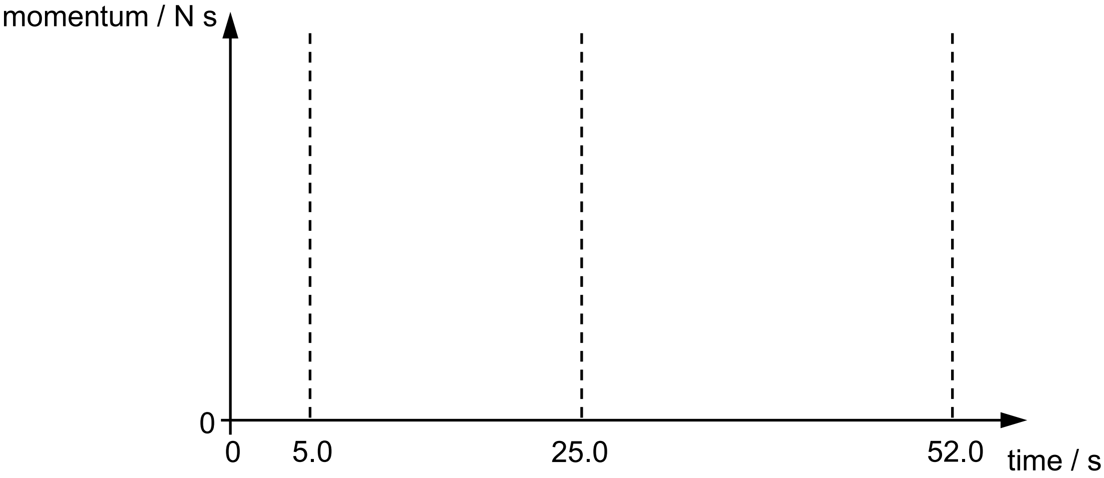
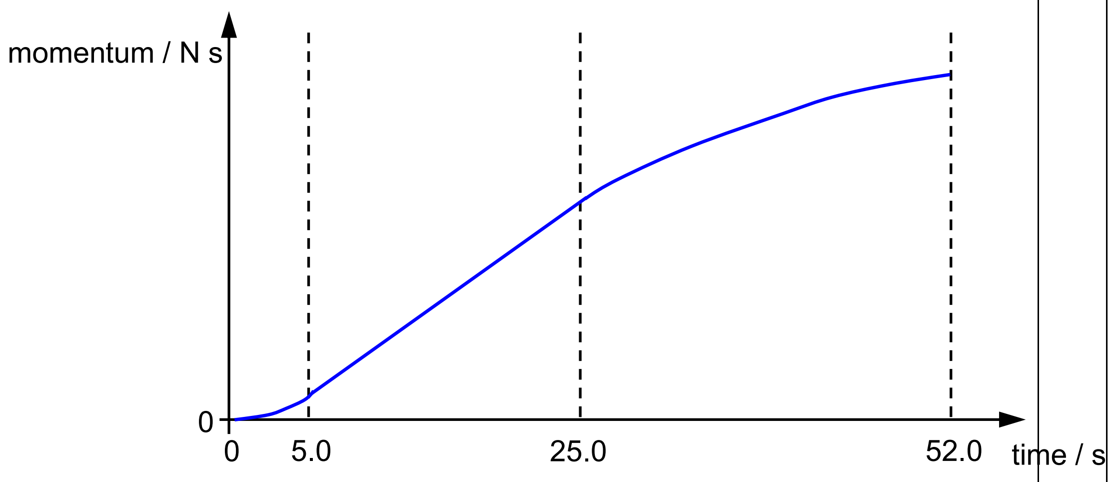


Fig. 1.2 [3]

L2



- Line of increasing positive gradient from origin between 0 s and 5.0 s, with gradient = 0 at 0 s. **B1**
- Line of constant positive gradient between 5.0 s and 25.0 s. **B1**
- Line of decreasing positive gradient between 25.0 s and 52.0 s. (Note: gradient is NON-zero positive at 52.0 s.) **B1**

Examiners' comments:

- **Similar skills tested in Alevel 2016/P2/Q2.**
- **A significant number of candidates did not obtain much credit for this question.**
- **Many candidates did not realize that the gradient of the graph should be 0 at *t* = 0 s and non-zero at *t* = 52.0 s as the gradient was related to the force.**
- **Candidates are reminded to draw smooth and continuous curves.**

[Total: 7]

2 An isolated spherical planet has radius *R*. From any point above the planet, its mass *M* appears to be concentrated at its centre.

A rock, initially at rest at an infinite distance away, approaches the planet, as shown in Fig. 2.1.

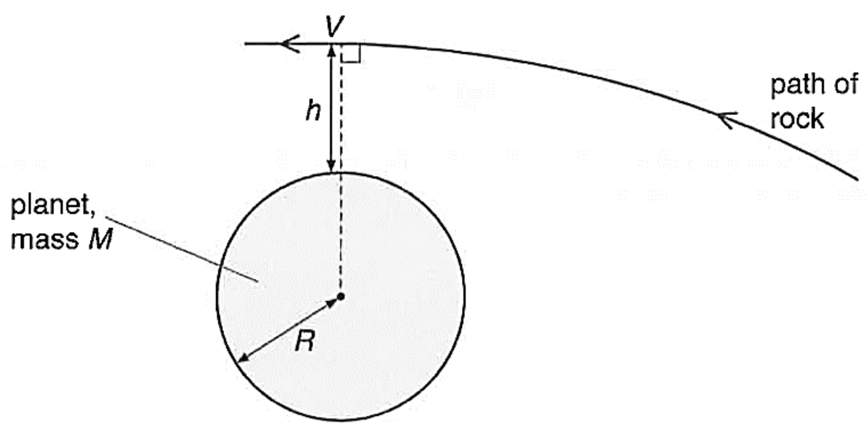


Fig. 2.1

At the height *h* above the surface of the planet, the rock is travelling at speed *V* in a direction parallel to a tangent to the planet's surface.

(a)	Show that the speed *V* of the rock is given by the expression $$V = \sqrt{\frac{2GM}{(R+h)}}$$ where *G* is the gravitational constant. Explain your working.		
			[3]
L2	By the law of conservation of energy, Total initial energy = Total final energy (OR: Loss in GPE = Gain in KE) $GPE_{initial} + KE_{initial} = GPE_{final} + KE_{final}$ As the rock starts from rest at an infinite distance away, $GPE_{initial} = 0$ and $KE_{initial} = 0$ Therefore, $0 + 0 = GPE_{final} + KE_{final}$ $0 = -\frac{GMm}{(R+h)} + \frac{1}{2}mV^2$ (where *m* is the mass of the rock) $\frac{1}{2}mV^2 = \frac{GMm}{(R+h)}$ $V = \sqrt{\frac{2GM}{(R+h)}}$ ***A-level Examiners' Report:*** ***Candidates should explain clearly the energy changes.***	B1 B1 M1 A0	
	Examiners' comments: • **Similar skills tested in Alevel 2019/P3/Q2.** • **Candidates must clearly state the physics concepts and apply them into the question, instead of showing only mathematical equations. The command word(s) are "Explain your working"** • **Candidates will need to take note of the scenario and not apply something that looks like previous questions. E.g. Equating**		

		gravitational force equal to centripetal force. The final v is not the same as what is required to show. • Candidates must pay attention to the use of conservation of energy. State clearly the change in gravitational potential energy and kinetic energy. In addition, gravitational potential energy is negative. Pay attention to the initial and final positions of the rock that is travelling to assist in the use of conservation of energy.	
	(b)	State and explain whether the rock will fall to the planet's surface, or, go into circular orbit around the planet, or, travel off into space.	
		…………………………………………………………………………………………	
		…………………………………………………………………………………………	
		…………………………………………………………………………………………	
		…………………………………………………………………………………………	
		…………………………………………………………………………………………	[2]
	L3	<u>Method 1: comparing forces</u> For the rock to go into orbit around the planet with speed $V=\sqrt{\dfrac{2GM}{(R+h)}}$, the centripetal force required is $\dfrac{mV^2}{(R+h)}=\dfrac{2GMm}{(R+h)^2}$, where m is the rock's mass. However, the gravitational force available at the location of the rock is only of magnitude $\dfrac{GMm}{(R+h)^2}$ which is insufficient to provide the centripetal force required for the rock to be in orbit. Therefore the rock will travel off into space. <u>Method 2: comparing speeds</u> For the rock to be in orbit around the planet, the gravitational force at that location must just sufficiently provide for the centripetal force required. This implies the orbital speed has to be equal to $\sqrt{\dfrac{GM}{(R+h)}}$. However, the speed of the rock when it arrives at the planet is $\sqrt{\dfrac{2GM}{(R+h)}}$. Since the speed of the rock is higher than that required to be in orbit it, it implies that the gravitational force is insufficient to provide the centripetal force required for the rock to be in orbit. Therefore the rock will travel off into space. *Additional note: Coincidentally, the speed that the rock arrives at the planet is the escape speed so the rock has enough kinetic energy to travel and reach infinity again.* ***A1 mark is awarded only if M1 mark is scored.***	**M1** **A1**
		Examiners' comments: • **Similar skills tested in <u>Alevel 2019/P3/Q2.</u>**	

		• **Candidates must take note of the conditions for the rock to go into orbit or otherwise. Do not just state that there is a gravitational force and therefore it provides for the centripetal force and conclude the rock will orbit.** • **Candidates must take note of the significance of escape velocity and centripetal force.**	

[Total: 5]

3 Fig. 3.1 shows the variation with applied potential difference V of the current I in an electrical component C.

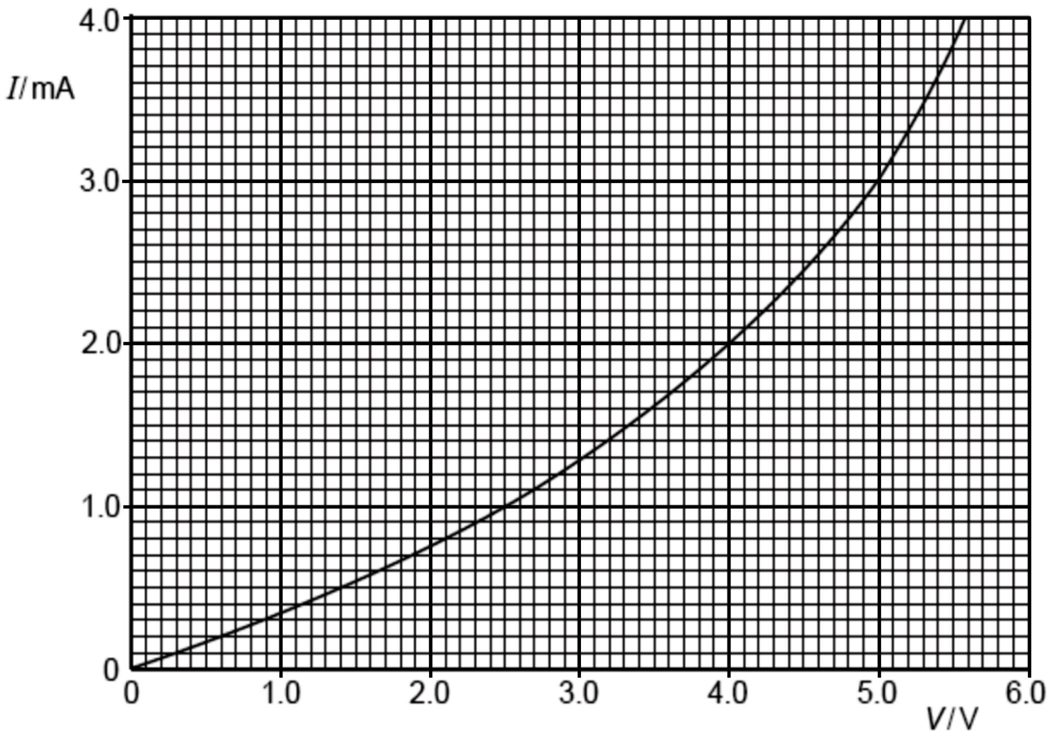
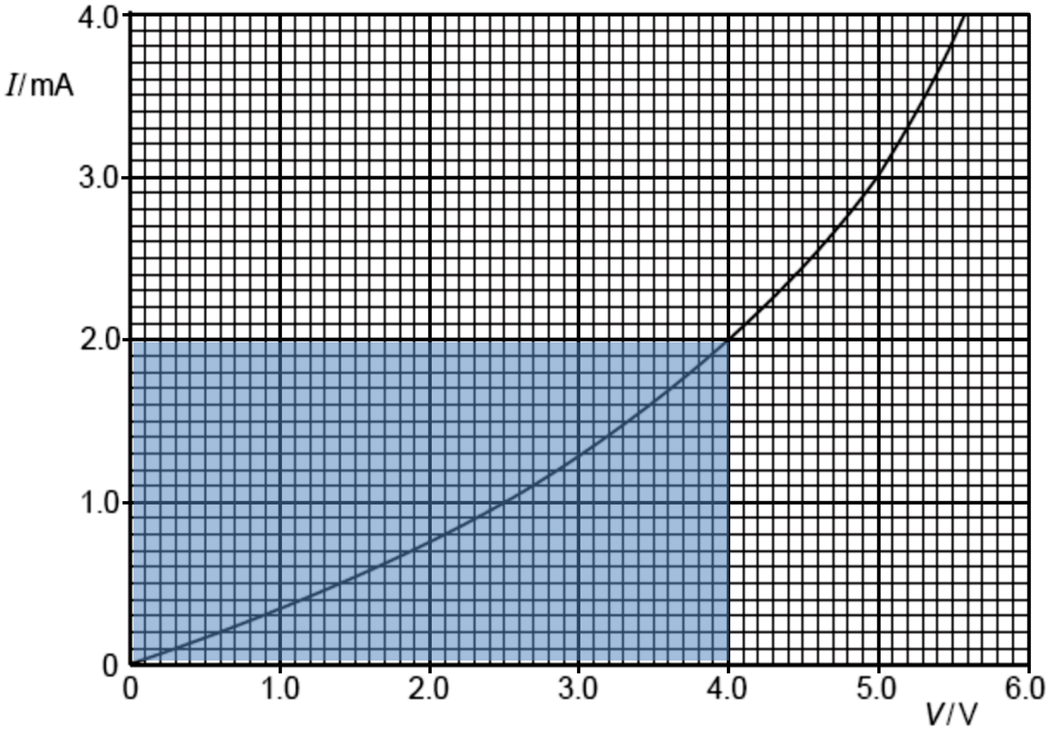


Fig. 3.1

(a) On Fig. 3.1, shade the area that represents the power dissipated in component C when the potential difference across it is 4.0 V. [1]

L2 The corresponding current is 2.0 mA when the potential difference across the component C is 4.0 V.
Since ***P* = *IV*, the product of *I*-coordinate and *V*-coordinate is equal to the blue rectangular shaded area**. **A1**

Solution:



Examiners' comments:

- **Similar skills tested in <u>Alevel 2021/P3/Q6.</u>**
- **Many candidates did not realize that the product of the *I* and *V* coordinates was equal to the power dissipated.**
- **Some candidates provided random shaded areas in their answers.**
- **Some candidates left this question un-attempted.**

(b) Component C is connected in parallel with a resistor R of resistance 1560 Ω and a battery of e.m.f. *E* with an internal resistance *r* of 12.0 Ω, as shown in Fig. 3.2.

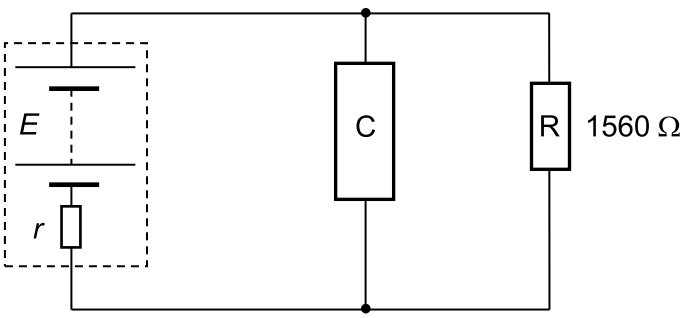
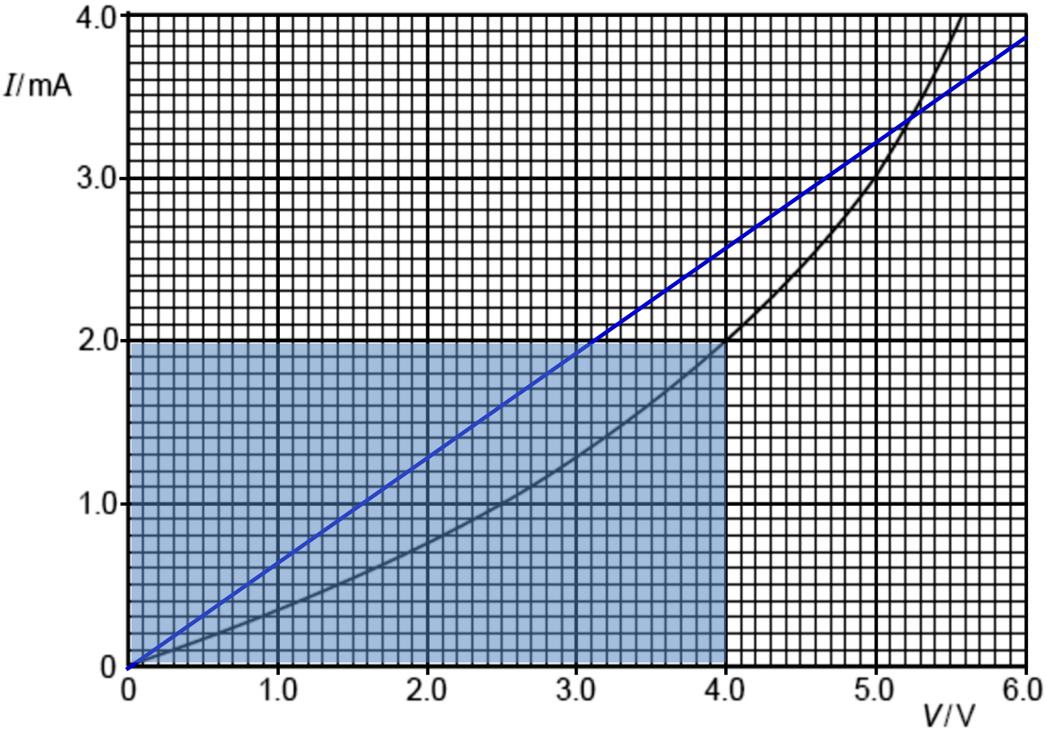


Fig. 3.2

On Fig. 3.1, draw a line to show the variation of *I* with *V* in R. [1]

L2 The line should be a **straight line passing through the origin and (6.0, 3.85).** **A1**

When potential difference is 6.0 V, the current passing through R is 6.0 / 1560 = 3.85 mA (3 s.f.) *(Allow ± 2 to 3 small squares deviation for I at V = 6.0.)*

		Solution: 	
		Examiners' comments: • **Many candidates were able to deduce the correct gradient of the line drawn.** • **Some candidates calculated the value of resistance wrongly and thus drew lines of wrong gradient.** • **Some candidates did not convert the units for the current correctly.** • **A few candidates wrongly assumed the line to be the same as the given curve in Fig. 3.1.**	
	(c)	Hence, use Fig. 3.1 to determine the current from the battery for a terminal potential difference (p.d.) of 3.90 V.	
		current = …………………………………… mA	[2]
	L3	For a terminal p.d. of 3.90 V, **p.d. across component C = p.d. across *R* = 3.90 V** **On Fig. 3.1, draw a vertical line corresponding to 3.90 V to determine the current through the component C and *R*.** **I_C = 1.90 mA and I_R = 2.50 mA** **$I = I_C + I_R$ = 4.40 mA** **OR**	 **B1** **A1**

		For a terminal p.d. of 3.90 V, p.d. across component C = p.d. across R = 3.90 V From Fig. 3.1, draw a vertical line corresponding to 3.90 V to determine the current through the component C. I_C = 1.90 mA Using $E = Ir + IR$, we will need to determine R, which is the effective resistance of component C and R. Resistance of component C = 3.90 / 0.00190 = 2052.63 Ω $R = (1/2052.63 + 1/1560)^{-1}$ = 886.364 Ω Current from battery = terminal p.d. / total external resistance = 3.90 / 886.364 = 4.40 mA	
		Examiners' comments: • **A significant number of candidates obtained some credit for this question.** • **It was evident that some candidates did not fully understand the terminology 'terminal potential difference' correctly and thus deduced various wrong values of current.** • **Some candidates did not realize that the current from the battery was a summation of the current flowing through component C and resistor R.** • **A few candidates were unable to calculate the total effective resistance of the circuit.**	
	(d)	Determine the e.m.f. E of the battery.	
		E = ……………………………...……. V	[2]
	L1	E = terminal p.d. + Ir = 3.90 + 4.40 x 10^{-3} x 12.0 = 3.95 V	 **M1** **A1**
		Examiners' comments: • **Many candidates were able to obtain full credit for this question.** • **Some candidates substituted the wrong value of current into the equation.** • **Some candidates omitted the units of the current in their answers.** • **A few candidates assumed the terminal potential difference as the e.m.f. of the battery.**	

[Total: 6]

4	(a)	An alternating power supply is connected to a resistor of resistance 45.0 Ω, as shown in Fig. 4.1.  **Fig. 4.1** The variation with time t of the potential difference V across the supply is given by the expression $$V = 240 \sin 100\pi t \ ,$$ where V is in volts and t is in seconds.		
		(i)	Determine the root-mean-square (r.m.s.) potential difference V_{rms} of the supply.	
			V_{rms} = ...V	[1]
L1			$V_{rms} = \frac{V_0}{\sqrt{2}} = \frac{240}{\sqrt{2}} = 169.71 \approx 170\,\text{V}$	A1
			Examiners' comments: • **Many candidates obtained the full credit for this question.** • **Some candidates applied wrong formulas in their workings.** • **Some candidates assumed the V_{rms} as 240 V instead.** • **A few candidates were careless in their workings and obtained wrong values of V_{rms}.**	
		(ii)	Determine the period T of the supply.	
			T = ...s	[1]
L1			$T = \frac{2\pi}{\omega} = \frac{2\pi}{100\pi} = 0.0200\,\text{s}$	A1
			Examiners' comments: • **Many candidates obtained full credit for this question.** • **Some candidates were unable to deduce the angular velocity of the potential difference correctly.** • **A few candidates provided wrong formulas for calculation of period of the supply.**	

- **A few candidates stated random answers, without providing any workings.**

(iii) Calculate the mean power P dissipated in the resistor.

P = ………………………….…………W [2]

L1

$$\langle P\rangle = \frac{V_{rms}^{\ 2}}{R} = \frac{169.71^2}{45.0}$$ **M1**

$$\langle P\rangle = 640\ \text{W}$$ **A1**

Examiners' comments:

- **Many candidates were able to obtain some credit for this question.**
- **Some candidates were confused with the values of V_{rms} and V_0 of the supply.**
- **Some candidates provided wrong formulas for peak and mean power.**
- **A few candidates attempted to calculate I_0 of the supply instead.**

(b) Use your answers in **(a)** to sketch, on Fig. 4.2, the variation with time t of the power P dissipated in the resistor. Include on your graph a time equal to two periods of the alternating potential difference.

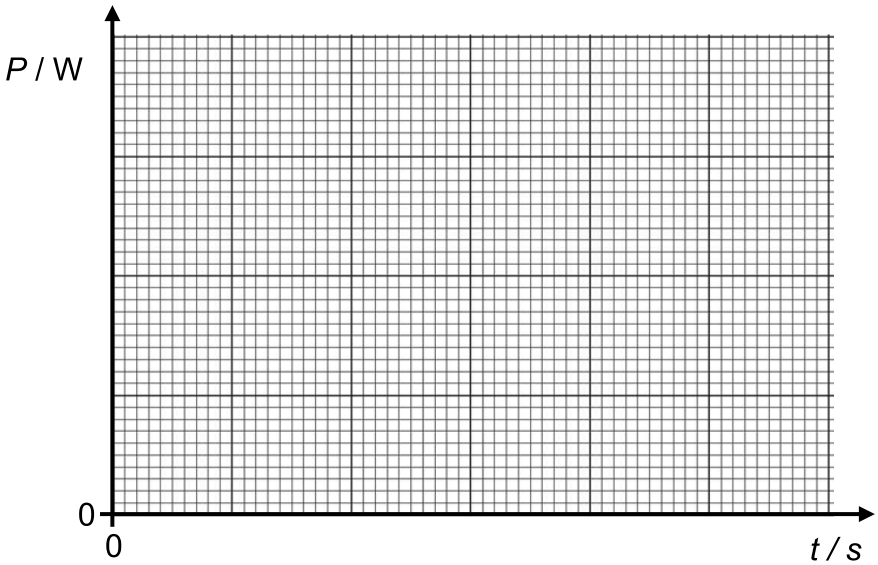
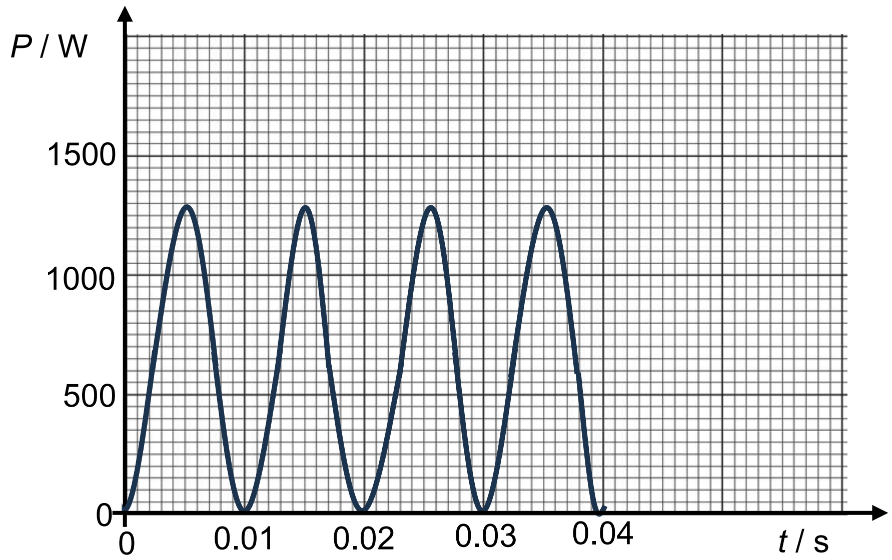


Fig. 4.2 [3]

L2 Solution:



B1

B1

B1

Marks scheme:
1 mark – Correct shape (sine square graph, at t = 0, P = 0 following the initial condition implicit in the given equation); Good scale in both horizontal and vertical directions.
1 mark – Correct peak and mean power values ($\langle P \rangle$ = 640 W; $P_0 = 2 \langle P \rangle$ = 1280 W). Allow ECF from (a).
1 mark – At least two T, and labelled correctly. Allow ECF from (a).

Examiners' comments:

- **Similar skills tested in Alevel 2018/P3/Q5, 2019/P3/Q7.**
- **A significant number of candidates obtained some credit for this question.**
- **Some candidates were unable to draw the shape of a sine square graph correctly.**
- **Some candidates did not indicate any appropriate values on the axes.**

[Total: 7]

5	**(a)**	An electron is accelerated from rest in a vacuum through a potential difference of 300 V. It then travels at right-angles to a uniform magnetic field of flux density 1.50×10^{-3} T. Calculate		
		(i)	the magnitude of its velocity,	
			velocity = ……………………….………..m s^{-1}	[2]
	L2		The electric potential energy is converted to kinetic energy of the electron.	

			$q\Delta V = \frac{1}{2}mv^2 - 0$ $v = \sqrt{\frac{2q\Delta V}{m}} = \sqrt{\frac{2\ 1.60\times10^{-19}\ \ 300}{9.11\times10^{-31}}}$ $v = 10.265\times10^6 \approx 10.3\times10^6$ m s^{-1}	**M1** **A1**
			Examiners' comments: • **Similar skills tested in Alevel 2014/P3/Q7d.** • **Note the question phrasing. Step 1: accelerate due to potential difference. Step 2: "Then" travels into magnetic field. Most students wrongly assume situation as electric and magnetic cross-field.** • **Some students quote wrong equations showing unfamiliarity with electric field quantities. Eg. Wrong equation for electric potential energy, wrongly find *F* (and *a*) to use kinematics method but there isn't enough info to find *F*.** • **Some students obtain a speed more than speed of light! This should be a red flag that your working is not correct!**	
		(ii)	the radius of its circular motion in the magnetic field.	
			radius = ……………………………………m	[2]
		L2	The magnetic force on the electron provides for the centripetal force. $Bqv\sin90° = \frac{mv^2}{r}$ $r = \frac{mv}{Bq} = \frac{9.11\times10^{-31}\ \ 10.265\times10^6}{1.50\times10^{-3}\ \ 1.60\times10^{-19}}$ $r = 0.038966 \approx 0.0390$ m	**M1** **A1**
			Examiners' comments: • **Similar skills tested in Alevel 2014/P3/Q7d.** • **Many students wrongly think that the "*v*" in magnetic force *Bqv* is referring to potential difference. Need more practice to be familiar with the symbols.** • **Most students obtain full marks due to error carried forward from previous part.**	
	(b)	The magnetic field in **(a)** is rotated. The initial direction of the electron is now at an angle to the direction of the uniform magnetic field, as shown in Fig. 5.1.		

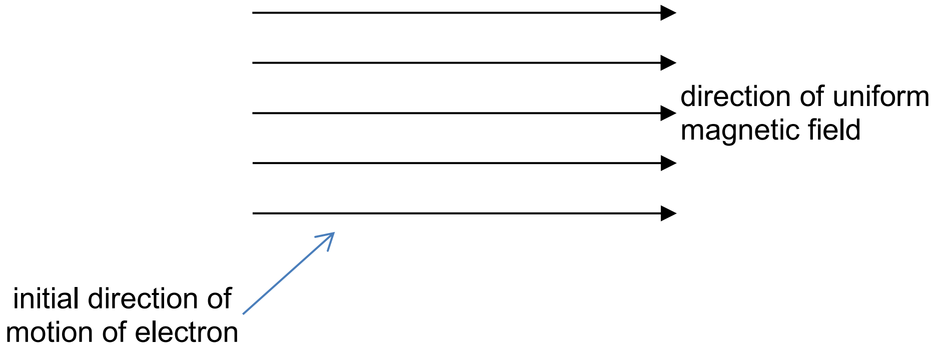


Fig. 5.1

By considering the components of the velocity parallel to the magnetic field and at right-angles to the magnetic field, describe and explain qualitatively the motion of the electron in the field.

…………………………………………………………………………………………………

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……………………………………………………………………………………………… [4]

L2	Let the component of the velocity parallel to the magnetic field be v_x and the component of the velocity at right-angles to the magnetic field be v_y.	**B1**
	For the electron moving with v_y, there is an electron current perpendicular to the magnetic field, resulting in the electron experiencing a magnetic force which is at right-angles to both v_y and the magnetic field.	**B1**
	This magnetic force provides for the centripetal force to keep the electron in circular motion, with constant radius.	**B1**
	For the electron moving with v_x, there is no magnetic force due to v_x. As the electron moves in a circular motion, it also moves with constant velocity along the direction of the field, resulting in a helical path.	**B1**
	Suggested marking: 1 mark – centripetal force due to component of the velocity at right-angles to the magnetic field, 1 mark – resulting in a circular motion with constant radius, 1 mark – no force due to component of the velocity parallel to the magnetic field, 1 mark – move along the field direction with constant velocity.	

		If "helical path" is mentioned only without constant radius and constant velocity along the direction of the magnetic field, award at most 1 mark. Also can award 4 marks if answer has the first 4 paragraphs but no mention of helical path.	
		Examiners' comments: • **Similar skills tested in Alevel 2014/P3/Q7e.** • **Some students did not see that the velocity has two perpendicular components and wrongly describe as 2 different situations where *v* is perpendicular or when *v* is parallel to magnetic field.** • **Many students did not clearly state what the magnetic force does.**	

[Total: 8]

6 A straight solenoid of length 55.0 cm is wound evenly with 850 turns of insulated wire. The solenoid has a circular cross section of diameter 2.4 cm.

A flat coil having 75 turns of wire is wound tightly around the centre of the solenoid, as illustrated in Fig. 6.1.

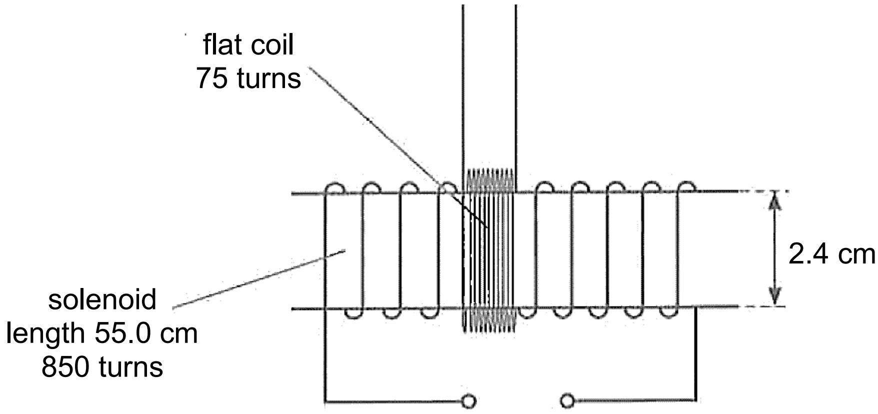


Fig. 6.1

The direct current in the solenoid is 2.0 A.

	(a)	Calculate the magnetic flux density B at the centre of the solenoid.	
		B = ...T	[2]
	L2	$B = n\mu_0 I = \frac{N}{L}\mu_0 I = \frac{850}{0.550}\ 4\pi\times10^{-7}\ \ 2.0$ $B = 3.8842\times10^{-3} \approx 3.88\times10^{-3}\,\text{T}$	**M1** **A1**
		Examiners' comments: • **Candidates must pay attention and take note of what is happening in this scenario. The current is flowing through the solenoid only. Do not add in the flux density of the flat coil.** • **Candidates must take note of the 3 different formulae for the 3 different set-ups for magnetic flux density. There are responses using the formula**	

		for flat circular coil instead of the solenoid. Pay attention to where the current is flowing.		
	(b)	The current I in the solenoid is now made to vary the time t from time t = 0 to time t = 4.0 ms as shown in Fig. 6.2.		

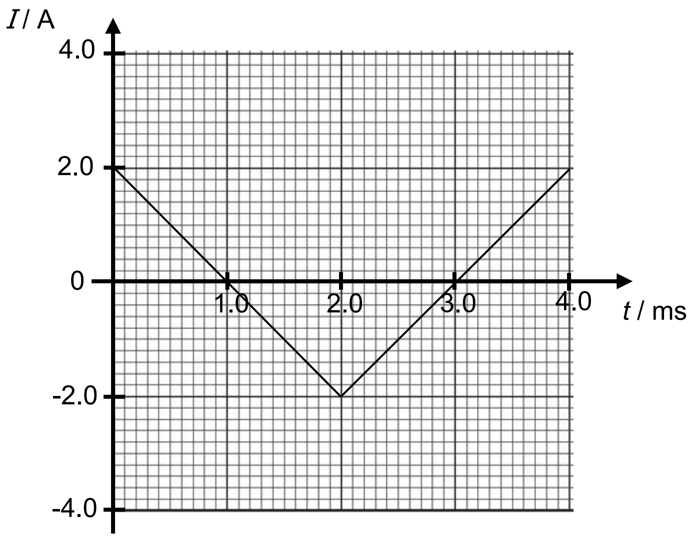


Fig. 6.2

(i) Calculate the electromotive force (e.m.f.) induced in the flat coil during the time t = 0 to time t = 2.0 ms.

e.m.f. = ……………………………….…….V [2]

L3 By Faraday's law of electromagnetic induction,

$$|E| = \left|\frac{d\Phi}{dt}\right| = \left|\frac{d\ NBA}{dt}\right| = \left|\frac{d\ N\mu_o nIA}{dt}\right| = \left|NAn\mu_0 \frac{d\ I}{dt}\right|$$

where $\frac{d\ I}{dt}$ is the gradient of Fig. 6.2.

Therefore,

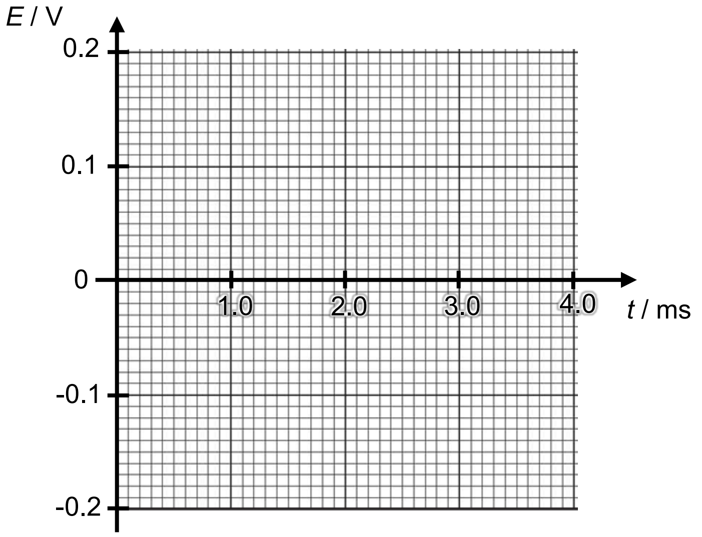
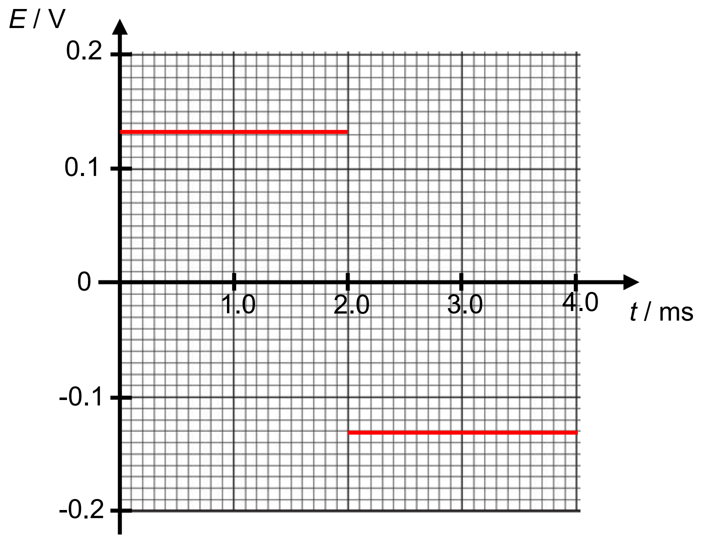
$$|E| = \left|\ 75\ \left(\pi\left(\frac{2.4\times10^{-2}}{2}\right)^2\right)\left(\frac{850}{0.550}\right)\ 4\pi\times10^{-7}\ \left(\frac{-2.0-2.0}{2.0\times10^{-3}-0}\right)\right|$$ **M1**

$$|E| = 0.13179 \approx 0.132\,\text{V}$$ **A1**

Examiners' comments:

- **Similar skills tested in Alevel 2019/P3/Q6.**

[Turn over

			• **Candidates must focus on what exactly is going on with this scenario and the relevant physics concepts that are tested.** • **Candidates to note that as the current flow through the solenoid, magnetic field is produced and passes through the flat coil. Therefore, based on the laws of electromagnetic induction, there will be an e.m.f. induced in the flat coil.**	
		(ii)	On Fig. 6.3, show the variation of the induced e.m.f. E with time t during the time t = 0 to time t = 4.0 ms. 	
			Fig. 6.3	[2]
		L3	Solution:  Marks scheme: 1 mark – Correct Shape (Horizontal Lines) and correct magnitude 1 mark – Evidence of Lenz's Law; signs to be different between t = 0 to time t = 2.0 ms and that of between t = 2.0 to time t = 4.0 ms (opposite sign to sign of gradient of I-t graph since $E = -NAn\mu_0 \frac{dI}{dt}$)	**B1** **B1**
			Examiners' comments: • **Similar skills tested in Alevel 2019/P3/Q6.** • **Candidates to note how does the current against time graph relate to the e.m.f. against time graph. Start from the formula that relates e.m.f. to the rate of change of magnetic flux linkage (faraday's law).**	

			From there, the understanding of each term within the magnetic flux linkage formula is important. Note that the N represents the number of turns of the flat coil, not the solenoid. The B represents the flux density due to the solenoid.	

[Total: 6]

7 Coherent light is incident normally on a double slit, as shown in Fig. 7.1.

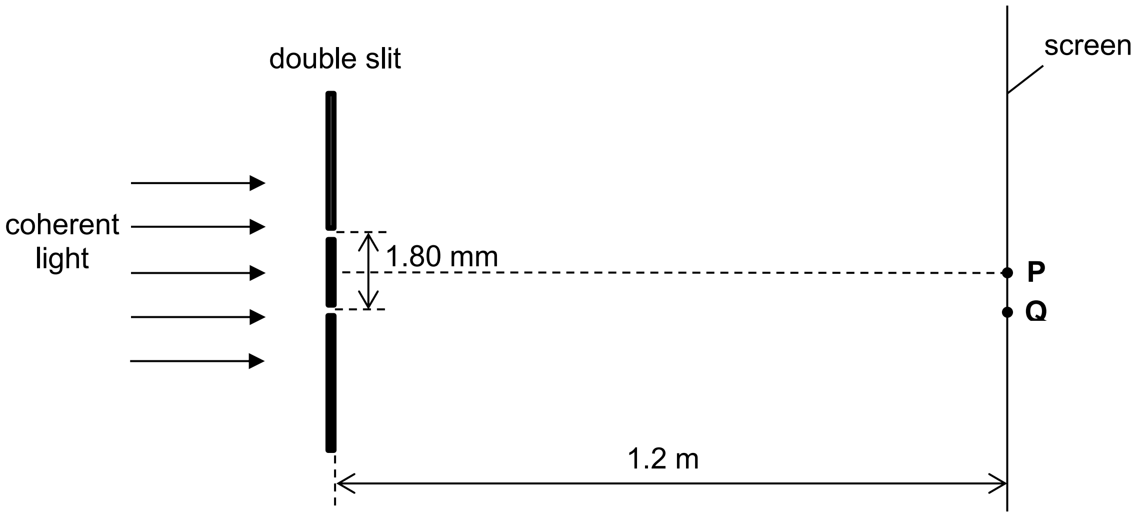


Fig. 7.1 (not to scale)

The separation of the slits in the double slit arrangement is 1.80 mm. A screen is placed parallel to, and at a distance of 1.2 m from, the double slit. P is a point on the screen that is equidistant from the two slits.

Fig. 7.2 shows the variation with distance from P of the intensity I of the light on the screen.

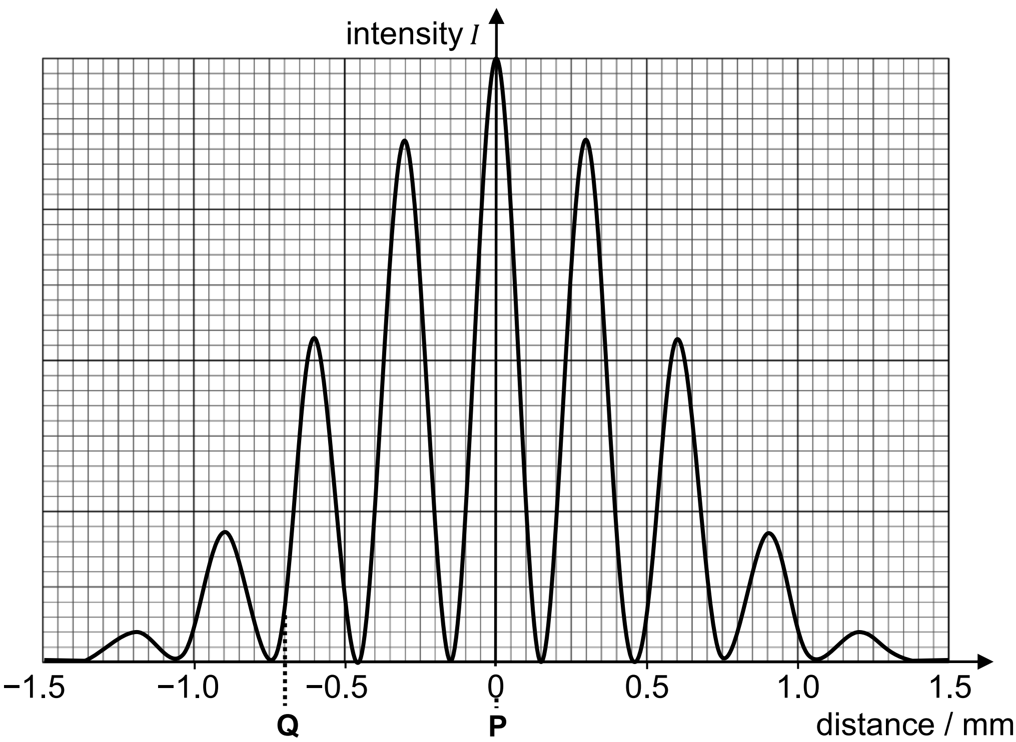


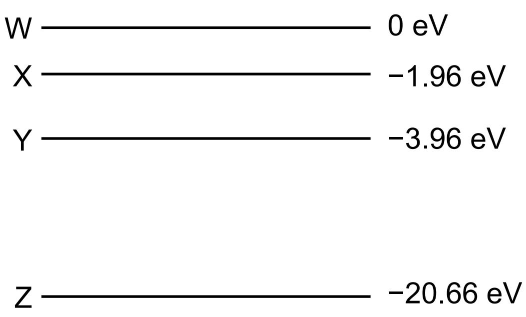
Fig. 7.2

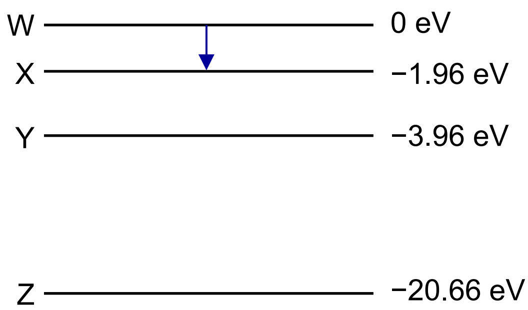
(a)	Calculate the wavelength of the coherent light.		
		wavelength = ………………………………….. m	[3]
L2	From Fig. 7.2, fringe separation **x = 0.30 mm** Using Young's equation, $x = \frac{\lambda D}{a}$ $\mathbf{0.30 \times 10^{-3}} = \frac{\boldsymbol{\lambda}\,\mathbf{(1.2)}}{\mathbf{1.80 \times 10^{-3}}}$ ***λ*** **=** <u>**4.5 x 10^{-7} m**</u>		**C1** **C1** **A1**
	Examiners' comments: • Many candidates completed this question successfully. • A significant minority used the wrong formula e.g. used equations for diffraction grating, or v = fλ, or mistook the fringe separation of 0.30mm from the graph as the wavelength λ. • Some candidates read off the graph scale wrongly and took x as 0.60mm instead of 0.30mm.		
(b)	Q is a point on the screen some distance away from point P. Its position is indicated on Fig. 7.2. Determine the phase angle, in radians, between the waves from the double slit when the waves meet at point Q.		
		phase angle = ………………………………….. rad	[2]
L2	***Note that the horizontal axis of Fig. 7.2 represents the distance measured along the screen, NOT distance along the wave! Hence the wavelength CANNOT be read off directly from Fig. 7.2!*** The **slits-to-screen distance *D* is much greater than the slits separation *a***, hence it may be assumed that **distances measured along the screen is**		

		approximately <u>directly proportional</u> to the phase angle between the waves arriving at the screen. Distance of Q from zeroth order maximum = 0.70 mm. Distance of the 4th order minima from the zeroth order maximum = 1.05 mm. Phase angle between the two waves arriving at the 4th order minima = 7π rad By proportionality, $\frac{\Delta\varphi_Q}{7\pi} = \frac{0.70}{1.05}$ $\Delta\varphi_Q = \frac{0.70}{1.05} \times 7\pi$ $\Delta\varphi_Q = 4.6667\pi = 14.661 = \underline{15\ \text{rad}}$ **OR** $\Delta\varphi_Q = 0.6667\pi$ **in the principal range = 2.0945 = <u>2.1 rad</u>** **OR (other equivalent working) e.g.** $\frac{\Delta\varphi_Q}{2\pi} = \frac{0.70}{0.30}$ $\Delta\varphi_Q = \frac{0.70}{0.30} \times 2\pi$ $\Delta\varphi_Q = 4.6667\pi = 14.661 = \underline{15\ \text{rad}}$ **OR** $\Delta\varphi_Q = 0.6667\pi$ **in the principal range = 2.0945 = <u>2.1 rad</u>** ***Accept either 15 rad or 2.1 rad in the principal range.***	**C1** **A1**
		Examiners' comments: • This was a **<u>Tutorial question and past A-level [2006/P2/Q6] question,</u>** but many candidates could not answer this question. • Many candidates thought the horizontal axis of Fig. 7.2 represents the distance measured along a wave and used the expression $\frac{\Delta\phi}{2\pi} = \frac{\Delta x}{\lambda}$ and substituted the horizontal coordinates from Fig. 7.2 as Δx and λ form part (a). Candidates should note that the horizontal axis of Fig. 7.2 represents the distance measured along the screen, NOT along the wave! • Students should also remember to evaluate the final answer and not leave it as $\frac{2}{3}\pi$ rad for example.	
	(c)	Explain why the maxima on Fig. 7.2 are not all of the same intensity.	
		....	
		....	
		....	[2]
	L2	**<u>Diffraction</u> through <u>non-infinitely small</u> double slits** **causes the light intensity to decrease as the angle of diffraction of light at the slits increases.**	**B1** **B1**

		A-level Examiners' Report 2006/P2/Q6: ***Answers that only indicate the decrease of intensity with distance from the slits are NOT acceptable since the change of distance is negligible.***	
		Examiners' comments: • This was a **Tutorial question and past [A-level 2006/P2/Q6] question,** but many candidates could not answer this question. Many cited Intensity inversely proportional to distance-squared as the reason. • Among those who mentioned 'diffraction envelope', these candidates didn't mention it was for non-infinitely small slits.	

[Total: 7]

8	**(a)**	Four electron energy levels (W, X, Y and Z) for a gas atom are shown in Fig. 8.1. The energy values for the respective energy levels are indicated in Fig. 8.1.  **Fig. 8.1**		
		(i)	Explain why an excited atom emits photons.	
			....	
			....	[1]
		L1	When an excited **electron** in the atom de-excites/transits from a higher energy level to a lower energy level, a photon is emitted with energy equivalent to the energy difference between these 2 levels.	**B1**
			Examiners' comments: • **Candidates must reference to the point that an excited electron de-excites and moves to a lower energy level and in the process, a photon is emitted.**	
		(ii)	Use Fig. 8.1 to determine, for the electron energy levels shown, the number of lines that are produced in the emission spectrum.	
			number of lines = ...	[1]
		L1	Since there are 4 distinct energy levels, there are ${}^{4}C_{2}=6$ different transitions from higher to lower energy levels. Hence, <u>**6**</u> different distinct energies of photons can be produced.	**A1**
			Examiners' comments: • **Candidates need to take note of the concept here. An electron moving down from a higher energy level to a lower energy level will**	

			result in the emission of a photon. Deduce from the Fig. how many of such transitions are possible.	
		(iii)	On Fig. 8.1, draw an arrow for the transition that will emit photons with the longest wavelength.	
				[1]
		L2	Solution:  Lowest energy difference gives rise to lowest energy photon produced. Energy of photon is inversely proportional to wavelength. Hence the lowest energy photon has the longest wavelength.	**A1**
			Examiners' comments: • **Emission of a photon is represented with an electron moving down to a lower energy level.** • **Longest wavelength correspond to the lowest energy the photon has.**	
		(iv)	Calculate the frequency for the photon emitted in the transition marked in **(a)(iii)**.	
			frequency = ...Hz	[2]
		L1	$\Delta E = hf$ $[0-(-1.96)](1.60\times10^{-19}) = (6.63\times10^{-34})f$ $f = 4.73\times10^{14}$ Hz ***Allow ECF from (a)(iii). Mark according to arrow drawn by student in (a)(iii).***	**M1** **A1**
			Examiners' comments: • **Candidates need to take note of the conversion of eV into J, the SI units for calculation.**	
	(b)	Fig. 8.2 below shows two X-ray spectra produced by X-ray tubes.		

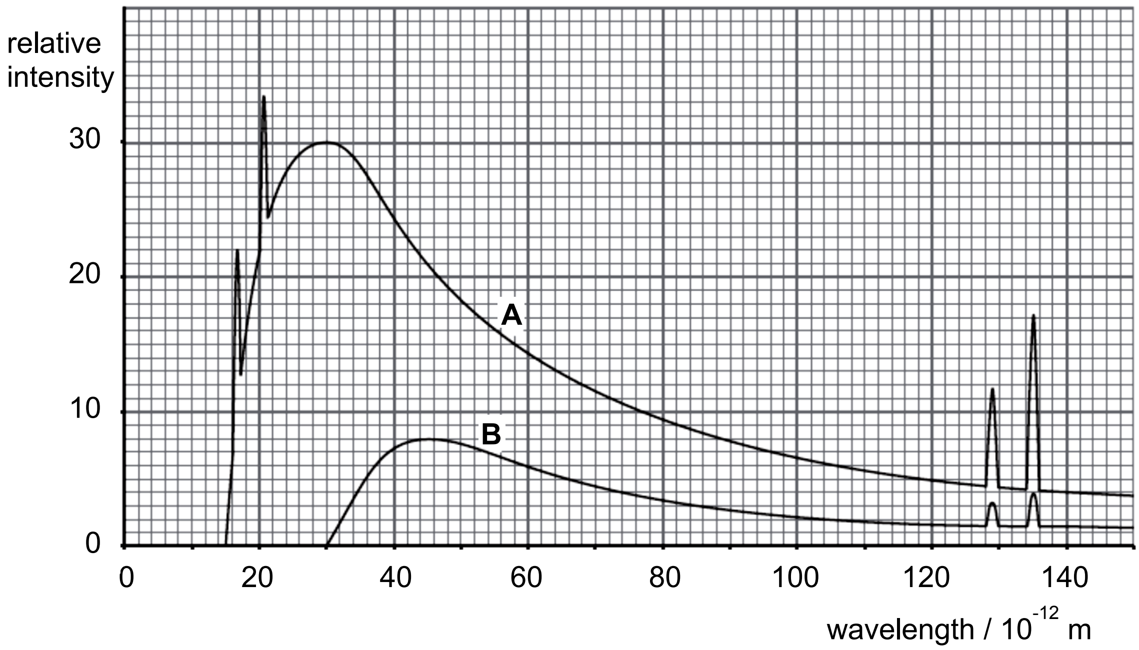


Fig. 8.2

		(i)	Using Fig. 8.2, state and explain if both spectra A and B are produced by the same target material.	
			………………………………………………………………………………………………	
			………………………………………………………………………………………………	
			………………………………………………………………………………………………	
			………………………………………………………………………………………………	
			………………………………………………………………………………………………	
			………………………………………………………………………………………………	[2]
		L2	Fig. 8.2 shows that both A and B have the same characteristic X-ray wavelengths (peaks). The characteristic wavelength depends on the **difference** between 2 electron energy levels in the atom.	**B1**
			Each material/element has its own unique set of electron energy levels. Hence, having the same characteristic wavelengths would imply that the energy levels were the same, resulting from the same target material.	**B1**
			Examiners' comments: • **Candidates need to take note of the physics concept tested here. Do not mix up different scenarios.** • **Candidates need to take note how X-rays are formed and the relevant experimental observations in understanding an X-ray spectrum.**	
		(ii)	Spectrum A was produced using an accelerating voltage of 80 kV. Calculate the accelerating voltage used to produce spectrum B.	

			accelerating voltage = ... kV	[2]
		L2	Photon of minimum wavelength (maximum photon energy = $\frac{hc}{\lambda_{\min}}$) has energy equal to the maximum electric potential energy supplied to the incident electrons by the accelerating voltage V (= eV). Hence, $\frac{hc}{\lambda_{\min}} = eV$ Since h, c and e are constants, $V \propto \frac{1}{\lambda_{\min}}$ $\frac{V_A}{V_B} = \frac{\lambda_{\min B}}{\lambda_{\min A}}$ $V_B = \frac{\lambda_{\min A}}{\lambda_{\min B}}(V_A)$ $= \frac{15}{30}(80\text{ kV})$ $= 40\text{ kV}$	M1 A1
			Examiners' comments: • **Candidates must take note of how an x-ray photon is formed with the highest energy and hence lowest wavelength.**	

[Total: 9]

9	**(a)**	**(i)**	Explain what is meant by *nuclear binding energy.*	
			....	
			....	[1]
		L1	**Nuclear binding energy** is the work that would have to be done to separate a nucleus into its constituent protons and neutrons. OR **Nuclear binding energy** is the energy released if a nucleus is formed from its constituent separate protons and neutrons.	B1

Examiners' comments:

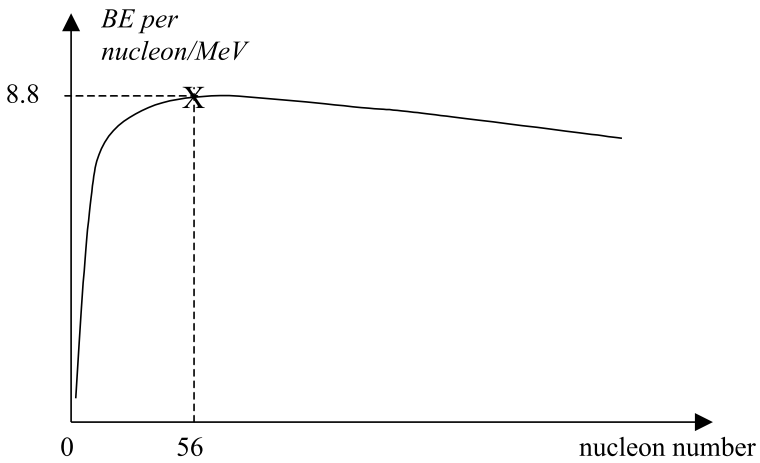
- **Many students do not know the definition and randomly describe what they understand.**

(ii) Sketch a graph in Fig. 9.1 to show the variation of the binding energy per nucleon with nucleon number. Label the coordinates for the most stable nuclide on your graph.

Fig. 9.1 [1]

L1

Solution:



Marking points:

- **correct shape**
- correct nucleon number A and BE per nucleon for the most stable nuclide (Fe-56): **A = 56, BE per nucleon = 8.8 MeV or 9 MeV**

B1

Examiners' comments:

- **Note that the graph shouldn't start from origin (0,0).**
- **Some students did not realise that the drop in BE/nucleon at higher nucleon number is gentler than the increase at small nucleon number. Hence, the portion of curve after nucleon number 56 is drawn too steep (reaches too low).**
- **Many students did not label the values on the axes.**

(iii) With reference to binding energy per nucleon, explain how nuclear fission can be a source of energy.

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

			....	
			....	
			....	
			....	[2]
		L2	A nucleus with high mass number/nucleon number can undergo nuclear fission to give two daughter nuclei of greater binding energy per nucleon. The difference in the total binding energy between the products and reactants results in a large amount energy release during the process. This is a source of energy.	B1 B1
			Examiners' comments: • **Similar skills tested in Alevel 2011/P3/Q5.** • **Must learn to read the expectations of the question! "with reference to binding energy per nucleon" means that the answer must use BE per nucleon to explain how there is energy released.** • **Many students do not understand BE per nucleon.**	
	(b)	When a caesium-137 nucleus undergoes decay to barium-137, a β-particle is produced with the release of energy as shown in the equation below. $^{137}_{55}\text{Cs} \rightarrow {}^{137}_{A}\text{Ba} + \beta$ The masses of the nuclei and of the β-particle are given in the table. **nuclide** — **mass / u** caesium-137 — 136.90709 barium-137 — 136.90583 β-particle — 5.49×10^{-4}		
		(i)	State the value of A, the proton number of barium-137.	
			A = ...	[1]
		L1	**56.** One neutron in Cs decays into a proton and an electron. The electron leaves the nucleus as a β particle and the daughter nucleus gains a proton, increasing the proton number by 1.	A1
			Examiners' comments: • **Many students gave 54. Good chance to learn that electron (β particle has an atomic (proton number) of −1.**	
		(ii)	Determine the energy released in one reaction.	

			energy released = ... J	[2]
		L2	Energy released in one reaction $=\left(m_{\text{Cs}}-\left(m_{\text{Ba}}+m_{\beta}\right)\right)uc^2$ $=\left(136.90709-\left(136.90583+5.49\times10^{-4}\right)\right)$ $\times\left(1.66\times10^{-27}\right)\left(3.00\times10^{8}\right)^2$ $=1.0622\times10^{-13}$ J $=1.06\times10^{-13}$ J	**M1** **A1**
			Examiners' comments: • **Some students left out "*u*" in the equation. Some left out "*c*²".** • **Some students confused mass with BE per nucleon and hence wrongly multiplied the mass with number of nucleons.**	
		(iii)	A caesium-137 nucleus is stationary when it decays. Determine the magnitude of momentum of barium-137 nucleus immediately after the decay.	
			momentum = ... Ns	[2]
		L2	By conservation of momentum, given that the initial momentum is zero, the final momenta of barium nucleus and β-particle must be equal in magnitude but opposite in direction. Hence, by conservation of energy, the energy released must comprise of the kinetic energies of barium nucleus and β-particle.	

			$E_{K,\,Ba\text{-}137}+E_{K,\,\beta^-}=\dfrac{p^2}{2m_{Ba}}+\dfrac{p^2}{2m_\beta}=1.06\times10^{-13}$	**M1**
			$p=\sqrt{\dfrac{1.06\times10^{-13}}{\left(\dfrac{1}{2\times1.66\times10^{-27}}\right)\left(\dfrac{1}{136.90583}+\dfrac{1}{5.49\times10^{-4}}\right)}}$ $=4.3955\times10^{-22}$ Ns $=4.40\times10^{-22}$ Ns	**A1**
			Examiners' comments: • **Similar skills tested in Alevel 2019/P3/Q9.** • **Very badly done as many students did not include kinetic energy of both particles (they only consider one of the particle).** • **Some students wrongly use *p = h/λ* but there's no wave involved.**	
	(c)	Plutonium-238, which has a decay constant of 7.88 × 10^{-3} year^{-1}, also undergoes radioactive decay by α-particle emission. Calculate the initial activity of a 5.0 g sample of plutonium-238.		
		initial activity = ... Bq		[3]
	L2 [2m] **L3** [1m]	initial no. of undecayed nuclei $N_0=\dfrac{5}{238}\times6.02\times10^{23}=1.26\times10^{22}$ Initial activity $A_0=\lambda N_0$ $=(7.88\times10^{-3})(1.26\times10^{22})$ $=9.9288\times10^{19}$ yr^{-1} $=(9.9288\times10^{19})\div(365\times24\times60\times60)$ s^{-1} $=3.15\times10^{12}$ Bq		**M1** **M1** **A1**
		Examiners' comments: • **Similar skills tested in Alevel 2014/P3/Q8.** • **Most students are clearly not familiar with equations for nuclear physics. They couldn't quote the correct equation A=λN.**		

- **Many students were not sure of what *N* in the equation represents and wrongly let it be number of moles.**
- **Many students did not convert activity in year^{-1} to s^{-1} correctly.**

[Total: 12]

10 The range of frequencies which can be heard by different people varies, but most can hear sounds in the range 20 Hz to 20 kHz.

Loudness is the human mental response to the intensity of sound. For a sound frequency of 1 kHz, the lowest sound intensity which can be heard by normal healthy adult is 1.0×10^{-12} W m^{-2}. This intensity is known as the *threshold intensity* I_o and any increase from this intensity will be perceived as an increase in the loudness of the sound.

The *intensity level* of a sound is a comparison of its intensity and the threshold intensity, and is given by

$$\text{Intensity Level} = 10 \lg \frac{I}{I_o}$$

where I is the intensity of the sound incident on the eardrums. The unit of intensity level is the decibel (dB).

Fig. 10.1 below shows the typical values of intensity levels for a sound frequency of 1 kHz from a variety of sources measured at various distances.

Source	distance from source / m	Intensity Level / dB
Jet engine at takeoff	30.0	140
Speakers at a rock concert	10.0	120
Diesel generator	3.0	100
Vacuum Cleaner	1.0	80
Normal conversation	1.0	60
Whispered conversation	1.0	30
Healthy hearing threshold	-	0

Fig. 10.1

For a sound frequency of 1 kHz, long term exposure to intensity levels above 90 dB may result in noise-induced deafness. The onset of pain in eardrums typically occurs at an intensity level of 120 dB while an intensity level of 160 dB will cause eardrums to rupture.

The loudness of a sound not only depends on the intensity level of the sound but also on its frequency. The *phon* is the unit of measurement of *loudness level*. In order to define this unit of measurement, sound frequency of 1 kHz is chosen as the standard for comparison. Hence, a source is said to have a loudness of 40 phon if a 1 kHz standard source has an intensity level of 40 dB.

Sounds of different frequencies having the same loudness fall on the same equal-perceived-loudness contour. Fig. 10.2 shows different equal-perceived-loudness contours for a healthy 18-year-old man, as a function of frequency of the sound.

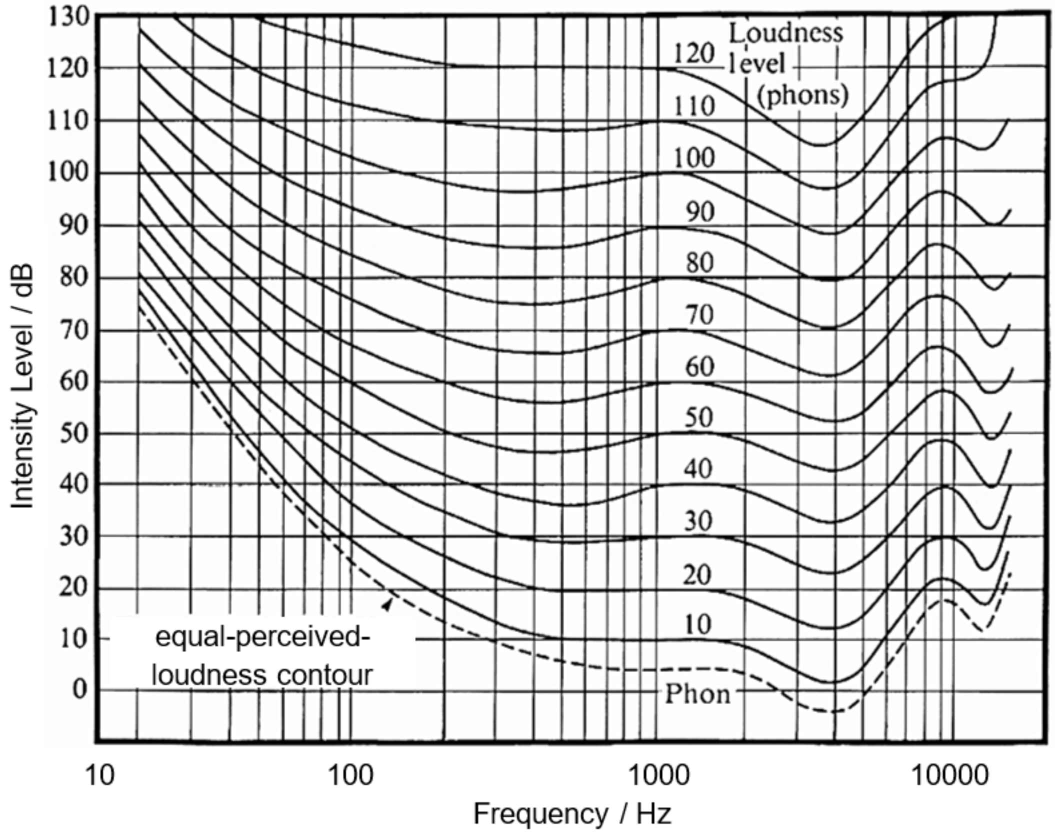


Fig. 10.2

(a) The earphones attached to a portable music player can produce up to 0.30 μW of power. When the earphones are fitted to the ears, all the sound energy propagates through the auditory canal and is collected by the eardrums with an effective area 1.8×10^{-5} m^2.

For a sound produced by the earphones attached to a portable music player at frequency 1 kHz,

(i) Calculate the maximum intensity of the sound incident on the eardrums.

intensity = ... W m^{-2} [1]

L1

$$\text{Intensity} = \frac{\text{power}}{\text{area}}$$

$$= \frac{0.30 \times 10^{-6}}{1.8 \times 10^{-5}}$$

$$= 0.016667 = 0.0167 \text{ W m}^{-2}$$

A1

Examiners' comments:

- A significant majority of candidates answered this correctly.
- Some made powers of ten error when converting μW to W.

(ii) Show that the intensity level of the sound incident on the eardrums is 102 dB.

			intensity level = ………………………………… dB	[1]
		L1	$\text{Intensity Level} = 10\lg\dfrac{0.016667}{1.0\times10^{-12}}$ $= 102.22 = 102 \text{ dB}$	M1 A0
			Examiners' comments: • Many candidates obtained credit from ECF from previous part.	
		(iii)	Suggest, with a reason, the impact of using the earphones at maximum power.	
			…………………………………………………………………………………………	
			…………………………………………………………………………………………	[1]
		L2	As the intensity level is **greater than 90 dB**, **prolonged use** of earphones at maximum power **will induce deafness**.	B1
			Examiners' comments: • Many students mentioned deafness without mentioning that it is a consequence of **prolonged usage**.	
	(b)	(i)	Using data in Fig. 10.1, determine the sound power of the diesel generator. Assume that the sound is emitted uniformly in all directions.	
			sound power = ………………………………… W	[3]
		L2	From Fig. 10.1, for diesel generator, $100 \text{ dB} = 10\lg\dfrac{I}{I_o}$ Intensity of sound, $I = 10^{10} I_0 = 10^{10}\left(1.0\times10^{-12}\right) = 1.0\times10^{-2} \text{ W m}^{-2}$	C1

			Since sound is assumed to be emitted uniformly in all directions, the wavefront is spherical. Thus, Sound power $= \left(1.0\times10^{-2}\right)\ 4\pi\left(3.0\right)^2$ $= 1.1310 = 1.13\text{W}$	**M1** **A1**
			Examiners' comments: There were several candidates who completed this question successfully. However there were candidates making the following common mistakes as well: • **Not converting the Intensity Level of 100 dB to Intensity I** before using in the equation "Intensity = Power / Area". • In applying "Intensity = Power / Area", **several candidates used "πr^2" to calculate the Area normal to the direction of energy transfer instead of "$4\pi r^2$".** • **Some candidates wrongly used the effective area of the eardrums in part (a).**	
		(ii)	For occupational health and safety reasons, all personnel are required to wear ear protection if the intensity level at the ear exceeds 85 dB. Determine the minimum distance from the diesel generator such that no ear protection is required.	
			minimum distance = ……………..……………………… m	[2]
		L2	$85\text{ dB} = 10\lg\dfrac{I}{I_o}$ Intensity of sound, $I = 10^{8.5}I_o = 10^{8.5}\left(1.0\times10^{-12}\right) = 3.1623\times10^{-4}\ \text{W m}^{-2}$ Using $I = \dfrac{Power\ of\ source}{4\pi r^2}$ and assuming constant power source (i.e. value in (**b**)(**i**)), Minimum distance $r = \sqrt{\dfrac{1.1310}{(4\pi)3.1623\times10^{-4}}}$ $= 16.870 = 16.9$ m	**M1** **A1**
			Examiners' comments: • Many candidates were credited ECF marks from errors carried over from previous part.	
	(c)	**(i)**	Suggest why the frequency axis on Fig. 10.2 is plotted on a *logarithmic* scale.	
			…………………………………………………………………………………………..	
			………………………………………………………………………………………..	[1]

		L3	This is to **allow a <u>large range</u>** (3 orders of magnitude) **of frequencies to be compressed within the graph**.		B1
			Examiners' comments: • A minority answered this question successfully. • Many candidates gave the reason that Intensity levels were measured using logarithms (referring to the given formula in the question). No reference was made at all to 'frequency' which the question asked for.		
		(ii)	Using Fig. 10.2,		
			1.	state the intensity level for a sound wave of 100 Hz for it to have the same perceived loudness as a sound wave of 1000 Hz at 50 dB;	
				intensity level = ……………………………… dB	[1]
			L2	Perceived loudness as a sound wave of 1000 Hz at 50 dB = 50 *phons* Reading off the *50 phons* equal-perceived-loudness contour, At 100 Hz, Intensity level = **<u>60 dB</u>**	
				Examiners' comments: • About 50% of the candidates were able to answer this correctly.	
			2.	state and explain which of the following sounds will be perceived to be louder: a sound wave of 50 Hz at 60 dB, or a sound wave of 2000 Hz at 45 dB.	
				…………………………………………………………………………………………	
				…………………………………………………………………………………………	
				…………………………………………………………………………………………	
				…………………………………………………………………………………………	[2]
			L3	**A sound wave of 50 Hz at 60 dB is <u>less than 40 phons</u> (or <u>about 30 phons</u>) while** **a sound wave of 2000 Hz at 45 dB is <u>more than 40 phons</u> (or <u>about 45 phons</u>).** **Hence the <u>sound wave of 2000 Hz at 40 dB sounds louder</u>.** ***Mark scheme: A1 mark not awarded if M1 mark not attained.***	M1 A1
				Examiners' comments: • A minority answered this question successfully. However not all were able to **refer to specific read-offs from Fig.10.2** and gave vague reasons like "the sound wave at 2000 Hz at 45 dB falls on a higher contour compared to the other sound wave".	
		(iii)	Suggest any changes in the equal-perceived-loudness contours for an 80-year-old man when compared to that for a healthy 18-year-old man.		
			…………………………………………………………………………………………		
			…………………………………………………………………………………………		[1]

		L3	A 80-year-old man will experience hearing loss and thus will require a higher intensity level for the same perceived loudness. Thus, **the equal-perceived-loudness contours will be higher /shifted up**. ***Mark scheme: Reason not marked for. Mark for correct changes to the contours.***	**B1**
			Examiners' comments: • Many candidates did not refer to the 'contours' at all and simply stated that the 80 year old man will have poorer hearing. • Some candidates thought that the contours would shift lower since the 80 year old man has poorer hearing. • Some candidates gave vague descriptions e.g. "It will be greater/increase/larger." / "Values will increase." Such descriptions do not specify clearly in which direction the contours would shift, i.e. shift upwards.	

[Total: 13]

END OF PAPER 2

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