Catholic Junior College
JC2 Preliminary Examinations
Higher 2

CANDIDATE NAME	
CLASS	**2T**

PHYSICS — 9749/3

Paper 3: Longer Structured Questions

September 2023
2 hours

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, graphs or rough working.
Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Section A
Answer **all** questions.

Section B
Answer one question only.
Circle on the cover page the question number attempted in Section B.

You are advised to spend one and a half hours on Section A and half an hour on Section B.

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

Suggested Solutions

FOR EXAMINER'S USE	
SECTION A	
Q1	/ 8
Q2	/ 8
Q3	/ 8
Q4	/ 14
Q5	/ 8
Q6	/ 11
Q7	/ 3
SECTION B	
Q8	/ 20
Q9	/ 20
TOTAL	/80

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	$\phi = -\frac{Gm}{r}$
temperature	$T/K = T/^{\circ}C + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $= \pm\,\omega\sqrt{x_0^{\,2} - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + ...$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + ...$
electric potential	$V = \frac{Q}{4\pi\varepsilon_o r}$
alternating current / voltage	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_o N I}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_o n I$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

[Turn over

Section A

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

1 A ball of mass 10 g is dropped from a height and falls through air. The variation with time t of the speed of the ball v is shown in Fig. 1.1

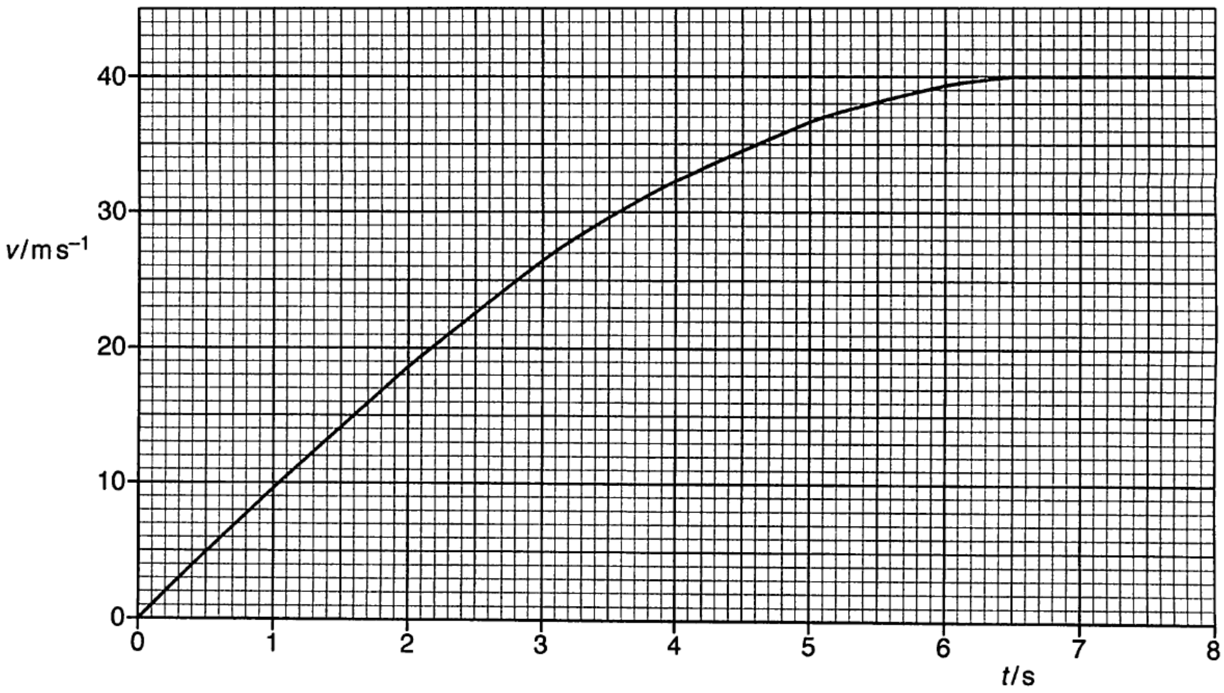
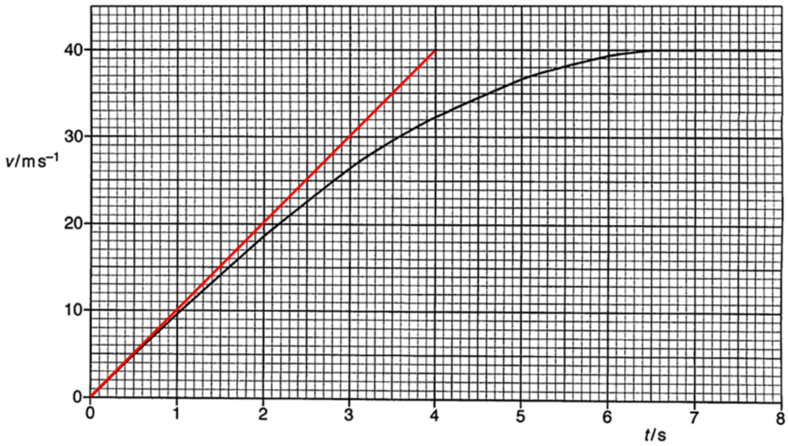


Fig 1.1

(a) (i) Use Fig 1.1. to determine the acceleration of the ball at time t = 0. Show your construction on Fig 1.1.

acceleration = …………………….. m s^{-2} [3]

Solution:



1

1

1

acceleration
= gradient of the v – t graph at t = 0
= $\frac{40-0}{4-0}$
= 10 m s^{-2}

(ii) By reference to your answer in **(a)(i)**, suggest the difference, if any, between your answer and the acceleration of free fall.

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

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

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

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

Solution:

The value obtained in **(a)(i)** is close to the value of the acceleration of the free fall. 1

At time t = 0, the velocity of the ball is (close to) 0, so no (or very little) drag force acting on it. The net force = weight, acceleration = g 1

(b) Calculate the maximum resistive force acting on the ball.

force = ………………………… N [1]

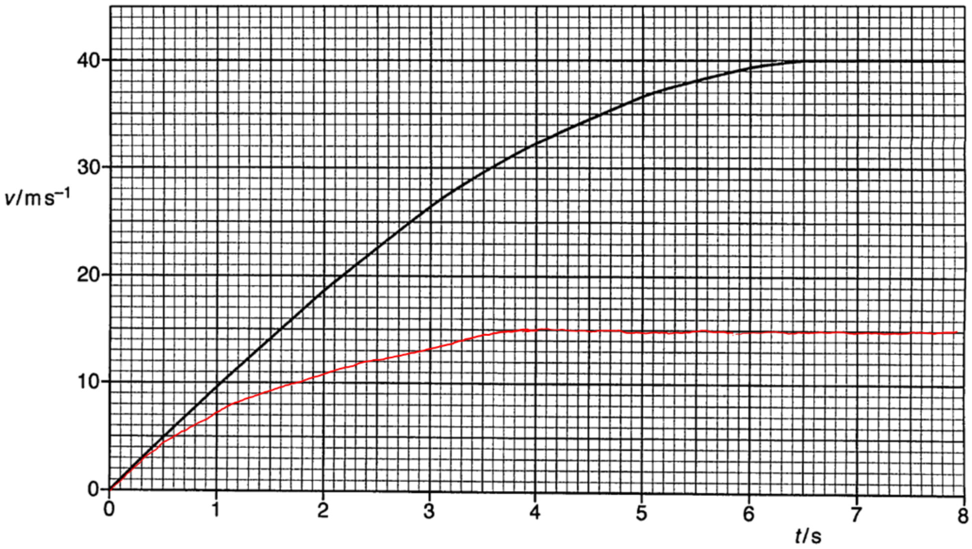
Solution:

Maximum resistive force acts when the ball is at terminal velocity (a = 0)

At this point,
$F_{net} = mg - F_{resistive} = 0$
$F_{resistive} = mg$ = 0.01 x 9.81 = 0.0981 N 1

	(c)	On Fig 1.1, draw another curve to show the variation with time *t* of the speed of the ball *v* if the ball was dropped in a more viscous medium. [2] [Total: 8]

Solution:



1 mark – rate of increase of v is lower than the original graph.
Note: mg – kv = ma, k is larger and hence acc is smaller

1 mark – object reaches terminal velocity at a lower velocity and at an earlier time.
Note: When mg = kv, terminal vel is reached or when a = 0, Hence acc = 0 is reached earlier when k is larger.

2 A binary star consists of two stars A and B. The two stars may be considered to be isolated in space. The centres of the two stars are separated by a constant distance, as illustrated in Fig. 2.1.

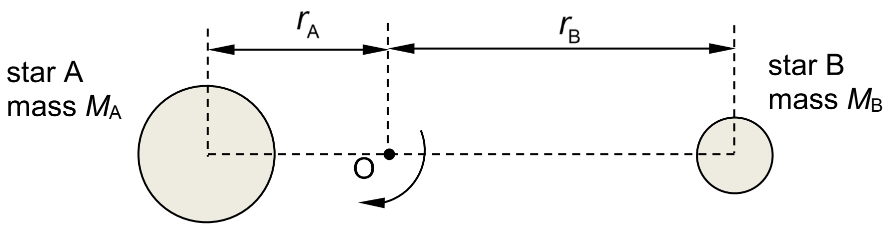


Fig. 2.1

Star A of mass M_A has a larger mass than star B of mass M_B such that $M_A = 4M_B$.

The stars are in circular orbits about each other such that the centre of their orbits is at a fixed point O. The radius of orbit of star A and star B are r_A and r_B respectively.

The period of each orbit is *T*.

	(a)	Explain why the two stars must always be directly opposite as they move in the circular orbit.	
		.... [2]	
		Solution: The centripetal force acting on each star is provided by the gravitational force between the two stars. The direction of the gravitational force acts along the line joining their centres of mass (which is the diameter of the circular orbit).	1 1
	(b)	Show that $\frac{r_B}{r_A} = 4$. Explain your working.	
			[2]
		Solution: The gravitational force on each star provides the centripetal force required for its respective circular motion about O. Since the stars have the same period, they have the same angular velocity ω. For star A, $\frac{GM_AM_B}{(r_A+r_B)^2} = M_A r_A \omega^2$ .... (1) For star B, $\frac{GM_AM_B}{(r_A+r_B)^2} = M_B r_B \omega^2$ .... (2) ----------------------------- Equating (1) and (2) OR Since the stars have the same period, they have the same angular velocity. Therefore the magnitude of centripetal force acting on each star is equal. $M_A r_A \omega^2 = M_B r_B \omega^2$ .... (3)	1 1

		-------------------------------- $$\frac{r_B}{r_A}=\frac{M_A}{M_B}=\frac{4M_B}{M_B}$$ $$\frac{r_B}{r_A}=4\ \ \text{(shown)}$$		
	(c)	If the period T is 104 days and the separation of the centres of the stars is 1.1×10^{11} m,		
		(i)	calculate the angular velocity of star A, and	
			angular velocity = ... rad s^{-1}	[1]
		L1	**Solution:** angular velocity $\omega=\frac{2\pi}{T}=\frac{2\pi}{104\times24\times60\times60}=7.0\times10^{-7}$ rad s^{-1}	1
		(ii)	determine the mass of each star.	
			mass M_A of star A = ... kg mass M_B of star B = ... kg	[3]
		L2	**Solution:** $r_A+r_B=1.1\times10^{11}$ $r_A+4r_A=1.1\times10^{11}$ $r_A=2.2\times10^{10}$ m and $r_B=8.8\times10^{10}$ m	1

			The gravitational force on star A provides the centripetal force for its circular motion about O. $\dfrac{GM_A M_B}{(r_A + r_B)^2} = M_A r_A \omega^2$ $\dfrac{GM_B}{(r_A + r_B)^2} = r_A \omega^2 \Rightarrow M_B = \dfrac{\omega^2 r_A (r_A + r_B)^2}{G}$ $M_B = \dfrac{(7.0\times10^{-7})^2 (2.2\times10^{10})(1.1\times10^{11})^2}{(6.67\times10^{-11})}$ $M_B = 1.96\times10^{30} = 2.0\times10^{30}$ kg $M_A = 7.8$ or 8.0×10^{30} kg	1 1

3	Ice is less dense than liquid water due to the structure of the bonds between the molecules when it is in a solid state. Hence, when ice melts into water at 0°C, the density of water increases. As the liquid water increases in temperature, its density further increases to a maximum value at 4.0°C.			
	(a)	Consider a 5.0 kg block of ice at 0°C that is melted into liquid water at the same temperature using a heat source supplying a constant power of 4180 W.		
		(i)	The specific latent heat of fusion of ice is 3.34×10^5 J kg^{-1}. Determine the time taken to completely melt the block of ice into liquid water at 0°C. time = ……………….. s [3]	
			Solution: The heat required to melt the 5.0 kg block of ice, Q: = mass × latent heat of fusion	

			= 5.0 kg × 3.34 x 10^5 J kg^{-1} = 1.67 x 10^6 J Time to melt the ice: = Q / P = 1.67 x 10^6 / 4180 = 400 s	
		(ii)	The density of ice at 0°C is 0.915 kg m^{-3} while the density of liquid water at 0°C is 0.999 kg m^{-3}. Calculate the work done on the ice by a constant atmospheric pressure of 1.01 x 10^5 Pa as the ice melts completely into water at 0°C. work done on the ice = ………………. J [3]	
			Solution: Volume of the ice, V_{ice} = mass of ice / density of ice = 5.0 / 0.915 = 5.46 m^3 Volume of the liquid water, V_{water} = mass of water / density of water = 5.0 / 0.999 = 5.01 m^3 Change in volume, ΔV = 5.01 m^3 - 5.46 m^3 = -0.45 m^3 Work done ON ice, w = - P x ΔV = - [1.01 x 10^5 * (-0.45)] = 4.55 x 10^4 J or 4.6 x 10^4 J	 1 1 1
	(b)	The first law of thermodynamics for a system can be expressed as $$\Delta U = q + w$$ where *ΔU* is the increase in internal energy of the system, *q* is the heat supplied to the system and *w* is the work done on the system.		

Use the words **positive**, **negative** and **zero** to complete Table 3.1 for the three terms in the equation for each of the processes shown. You may use each word once, more than once, or not at all.

Table 3.1

Process	*ΔU*	*q*	*w*
Ice melting into liquid water at 0°C			
Liquid water warming up from 0°C to 4°C			

[2]

[Total: 8]

Solution:

As the ice melts, its internal energy increases due to the energy used to increase the intermolecular separation. The source of this energy is the heat supplied to the ice and the work done on the ice by the atmospheric pressure (since the ice contracts as it melts)

As the liquid water increases in temperature, its internal energy increases. The source of this energy is the heat supplied to the water from the surroundings and the further contraction of the volume of the water (as its density continues to increase) means that the atmospheric pressure does further work on the water.

Process	*ΔU*	*q*	*w*
Ice melting into liquid water at 0°C	**positive**	**positive**	**positive**
Liquid water warming up from 0°C to 4°C	**positive**	**positive**	**positive**

4 **(a)** State what is meant by *radioactive decay*.

....

....

....

.... [2]

		Solution: Radioactivity (or radioactive decay) is the spontaneous and random disintegration (or decay) of an unstable nucleus into a more stable one (either unstable or become more stable) with the emission of particles (and photons i.e. alpha-particle beta-particle, gamma ray photon). (particles/ radiation – can give marks if mention partial)	1 1
	(b)	A radiation detector is placed close to a radioactive source. The detector does not surround the source. Radiation is emitted in all directions and, as a result, the activity of the source and the measured count rate are different. Suggest two other reasons why the activity and the measured count rate may be different. 1. .... 2. .... [2]	
		Solution: • emission from radioactive daughter products • self-absorption in source • absorption in air before reaching detector • detector not sensitive to all radiations • window of detector may absorb some radiation • background radiation **(not accepting a repeat mention of part of radiation is detected)** **Any of the above 2 points**	2
	(c)	The variation with time *t* of the measured count rate in **(b)** is shown in Fig. 4.1.	

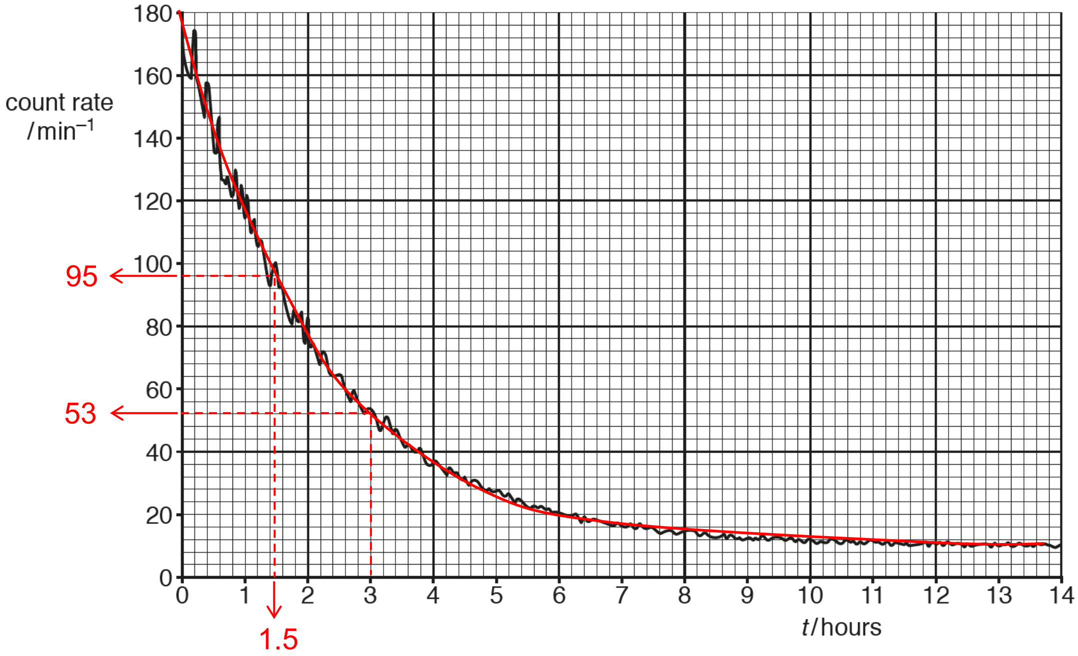


Fig. 4.1

(i) State the feature of Fig. 4.1 that indicates the random nature of radioactive decay.

....

.... [1]

Solution:
Curve is not smooth or curve fluctuates or curve is jagged. — 1

(ii) Use Fig. 4.1 to determine

1. the background count rate and,

background radiation = ... min^{-1} [1]

Solution:
The curve is almost flat between 10 hours and 14 hours.
background radiation = 10 min^{-1} — 1

2. the half-life of the radioactive isotope in the source.

half-life = ... hours [4]

Solution:

half-life determined at least twice | 1

Draw a curve of best fit to read off the values from the graph

First half-life

C_0 = 180 – 10 = 170 min^{-1}

$C_1 = \frac{C_0}{2} = \frac{170}{2} = 85 \text{ min}^{-1}$

C_1 (measured) = 85 + 10 = 95 min^{-1}, from the graph, $t_{½} = 1.5$ hour

(correct method of determining half life from graph) | 1

Second half-life

$C_2 = \frac{C_1}{2} = \frac{85}{2} = 43 \text{ min}^{-1}$

C_2 (measured) = 43 + 10 = 53 min^{-1}, from the graph,

$t_{½} = 3 - 1.5$ =1.5 hour

half-life = 1.5 hours – (mark for background considerations here) | 2

(d) The readings in **(c)** were obtained at room temperature.

A second sample of this isotope is heated to a temperature of 500 °C.
The initial count rate at time t = 0 is the same as that in **(c)**.
The variation with time t of the measured count rate from the heated source is determined.

State, with a reason, whether the heating will cause a difference, if any, in

1. the half-life,

....

		.... **2.** the measured count rate for any specific time. .... [4] [Total: 14]
		Solution: **1.** half life : no change — 1 because decay is spontaneous / independent of environment — 1 **2.** count rate: likely to be <u>different</u> — 1 because radioactive decay is random or cannot be predicted — 1

5	**(a)**	Explain what is meant by *coherent* light waves.	
		.... [1]	
		Solution: The light waves have a constant phase difference which does not vary with time.	1
	(b)	Coherent light of wavelength 550 nm is incident normally on a double slit of slit separation 2.1 mm, as shown in Fig. 5.1. Both slits in the double slit arrangement have a width of 0.1 mm. A series of bright and dark fringes forms on a screen placed a distance of 2.4 m from the double slit. The screen is parallel to the double slit.	

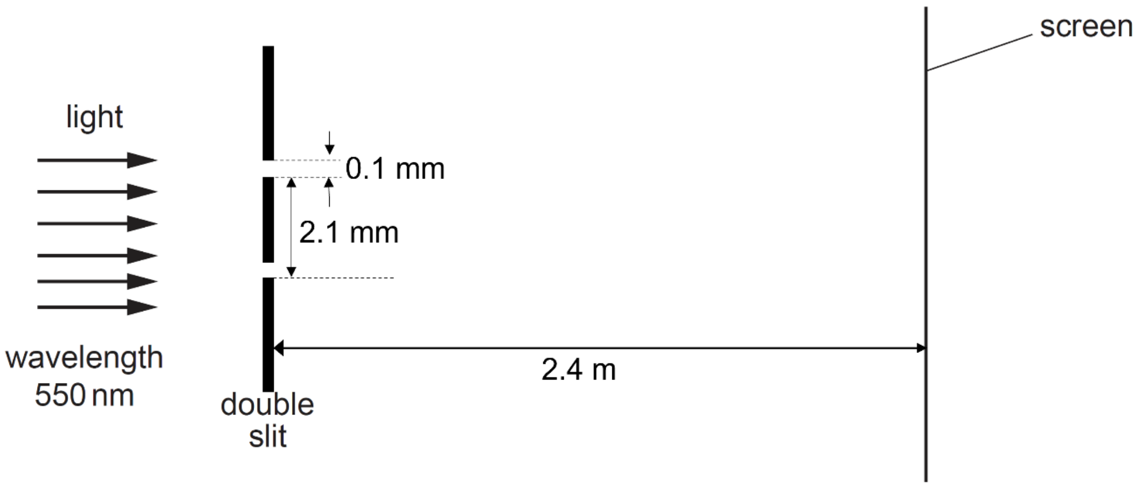


Fig. 5.1 (not to scale)

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

Calculate the width of the central fringe of the single-slit diffraction pattern seen on the screen.

Give your answer to three significant figures.

fringe width = ... m [3]

Solution:
For minima of a single slit,

$$\sin\theta_{min} = m\frac{\lambda}{b}$$

For first minima, m = 1

$\sin\theta_{min} = \frac{\lambda}{b} = \frac{550\text{x}10^{-9}}{0.1\text{x}10^{-3}}$ = 0.0055 1

$\tan\theta_{min} = \frac{y}{L}$
where y is half the width of the central fringe and L is the distance between the slits and the screen

Since θ_{min} is very small, we can use the approximation $\sin\theta \approx \tan\theta$ and then solve for y:

$$\sin\theta_{min} \approx \frac{y}{L}$$

$$0.0055 \approx \frac{y}{2.4}$$

y = 0.0132 m 1

Fringe width = 0.0132 x 2 = 0.0264 m (3sf) 1

		(ii)	Both slits are now uncovered. Estimate, to one significant figure, the number of fringes resulting from double-slit interference that are seen within the central maximum produced by single-slit diffraction.	
			number = ...	[3]
			Solution: Using the double slit equation to find interference fringe separation, *x* $x = \frac{\lambda D}{d} = \frac{550 \times 10^{-9} \times 2.4}{2.1 \times 10^{-3}}$ $x = 6.29 \times 10^{-4}\ m$ Since these double-slit fringes sit within the width of the central single-slit diffraction fringe, number of fringes = $\frac{\text{width of central diffraction fringe}}{\text{interference fringe separation}}$ = 40 (1sf)	1 1 1
		(iii)	The light of wavelength 550 nm is replaced with monochromatic red light. State and explain the change, if any, in the distance between the centres of adjacent double slit bright fringes.	
			.... [1] [Total: 8]	

			Solution: red light has longer wavelength (than 550 nm) so distance (between fringes) increases	1

6	**(a)**	Use the theory of the particulate nature of electromagnetic radiation to explain why there is a threshold frequency for the photoelectric effect.	
		…………………………………………………………………………………………… …………………………………………………………………………………………… …………………………………………………………………………………………… …………………………………………………………………………………………… …………………………………………………………………………………………… ……………………………………………………………………………………………[3]	
		Solution: In the particulate theory of light, electromagnetic radiation comprises of discrete quanta of energy, called photons. The energy *E* of each *photon* is determined by the frequency *f* of the radiation, *E=hf*, where *h* is the Planck's constant. When these photons are incident on the metal surface, they interact with the electrons in the metal on a one-to-one basis, meaning that a photon is either completely absorbed or rejected. (i.e. the energy of different photons cannot be cumulated). For an electron to be ejected from the metal surface, the electron must gain enough energy to be completely freed from the electrostatic forces of attraction of the metal cations. The minimum amount of energy required is called the *work function energy Φ* that is unique to the type of metal. The value hf must be at equal or larger than Φ. Thus there is a *minimum frequency f=Φ/h* the incoming electromagnetic radiation must be at for photoelectric emission to occur.	1 1 1
	(b)	An experimental setup to investigate the photoelectric effect is shown in Fig. 6.1. Electromagnetic radiation is incident on the emitter E of the photocell and the photoelectrons move towards the collector C.	

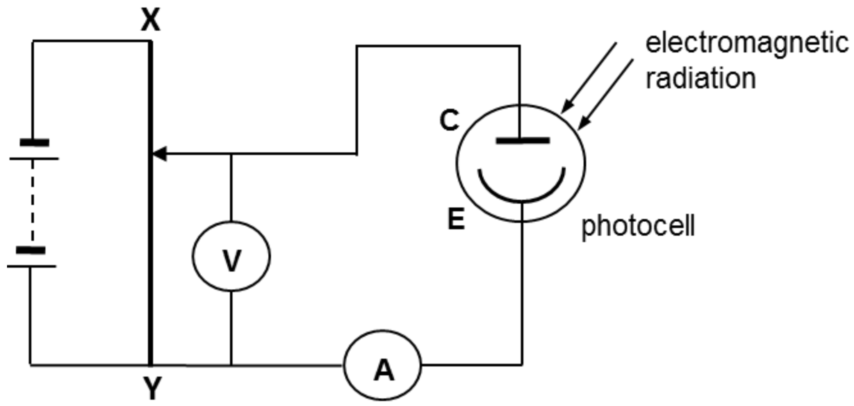


Fig. 6.1

The wavelength of the electromagnetic radiation incident on the photocell was varied. For two values of wavelength λ, the stopping potential V_S required for the ammeter reading to become zero was measured. The results are shown in Fig. 6.2.

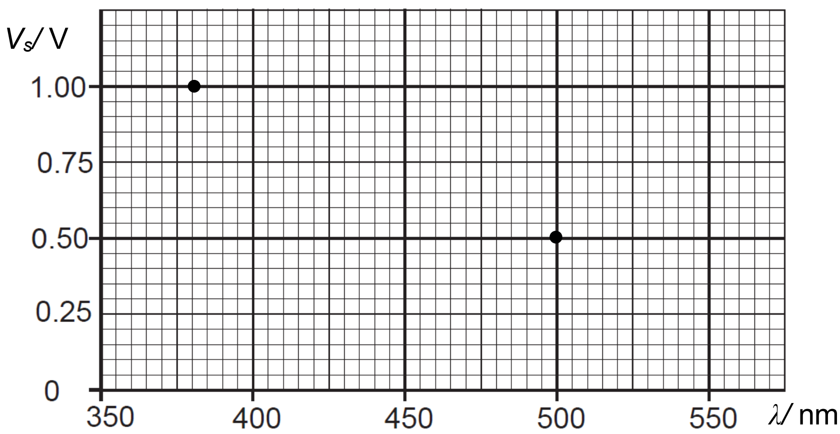


Fig. 6.2

(i) Calculate the maximum kinetic energy of a photoelectron emitted from the metal surface by radiation of wavelength 500 nm.

maximum kinetic energy = ………………………………… J [2]

Solution:

Max KE = eV_s = 1.6 x 10^{-19} x 0.5 1

= 8.0 x 10^{-20} J 1

		(ii)	Calculate the energy of a photon of wavelength 500 nm. energy = ………………………………… J		[2]
			Solution: $E = \frac{hc}{\lambda} = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{500 \times 10^{-9}}$ $= 3.98 \times 10^{-19}$ J		1 1
		(iii)	Hence, determine		
		1.	the work function energy of the metal surface, and work function energy = ……………………………… J		[1]
			Solution: Work function energy = $E_{photon} - KE_{max}$ $= 3.98 \times 10^{-19} - 8 \times 10^{-20}$ $= 3.18 \times 10^{-19}$ J		1
		2.	the maximum photon wavelength that can liberate a photoelectron. maximum wavelength = ………………………….. nm		[2]
			Solution: Work function energy = $\frac{hc}{\lambda_o}$ $\lambda_o = \frac{hc}{\phi} = \frac{6.63 \times 10^{-34} \times (3 \times 10^{8})}{3.18 \times 10^{-19}}$ = 625 nm		1 1

		(iv)	Suggest why it is not possible to deduce the maximum photon wavelength that can liberate a photoelectron from this metal plate directly from the data in Fig. 6.2. ………………………………………………………………………………………… ………………………………………………………………………………………… ……………………………………………………………………………………[1] [Total: 11]	
			Solution: The graph of V_s against λ should give a curve. Since only two points are plotted on Fig 6.2, a curve cannot be drawn to find the value of λ when V_s approaches zero.	1

7 Fig. 7.1 shows an x-ray spectrum.

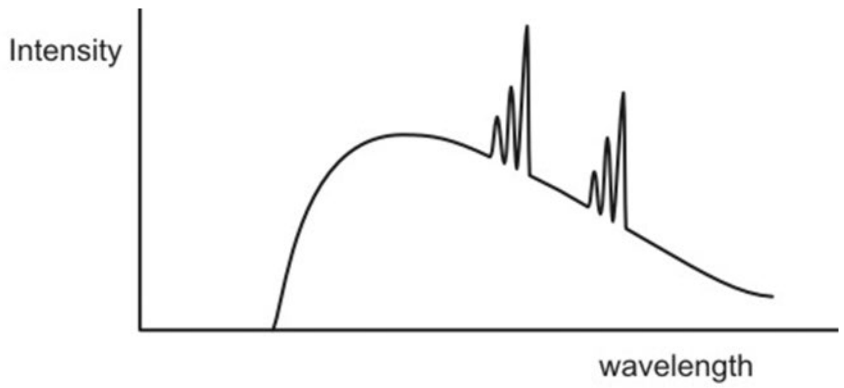


Fig. 7.1

Describe how the continuous spectrum is produced.

…………………………………………………………………………………………

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…………………………………………………………………………………………

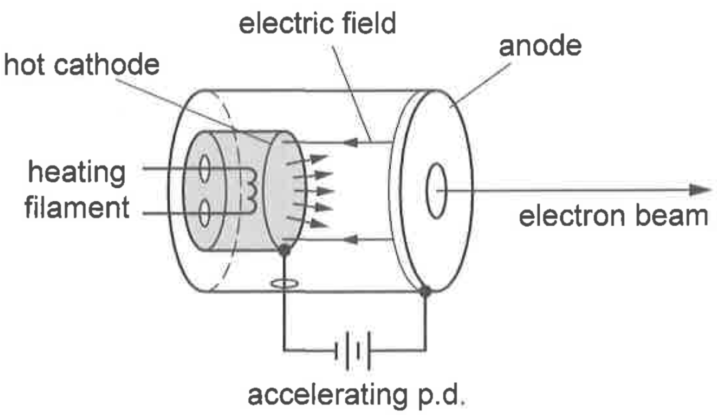
……………………………………………………………………………………[3]

[Total: 3]

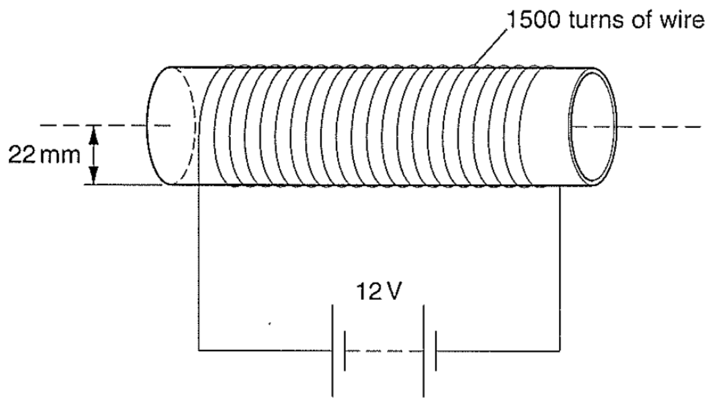
		Solution: An electron with high speed/ KE interacts with the nucleus of a target metal and accelerates/decelerates. As electron is a charged particle, when it undergoes a rapid deceleration, it produces an x-ray photon of energy equal to the kinetic energy lost by the incident electron via Bremsstrahlung process. If an electron has excess kinetic energy after the deceleration it goes through a series of decelerations and produces photons of a (continuous) range of wavelengths.	1 1 1

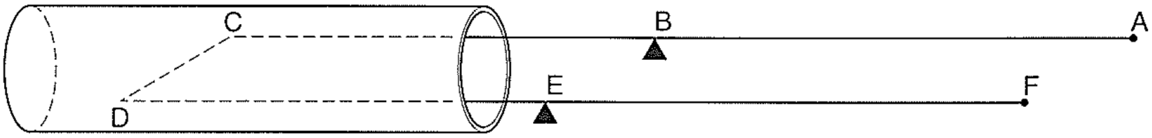
Section B

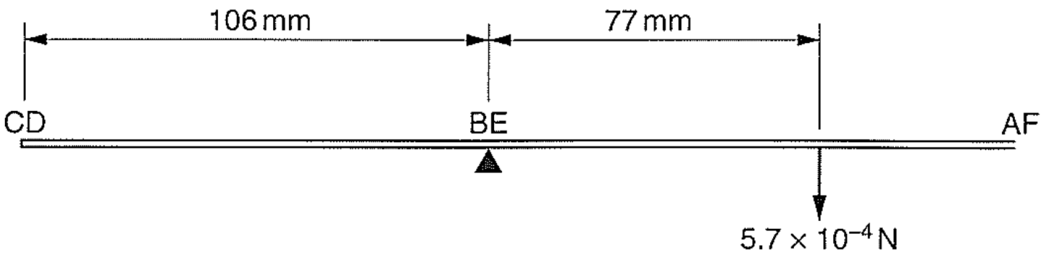
Answer **one** question from this section.

8	**(a)**	Fig. 8.1 shows a diagram of an electron gun. Electrons are emitted from a hot cathode. The electric field between the cathode and the anode accelerates the electrons through an accelerating potential difference (p.d.).  **Fig. 8.1**		
		(i)	Explain what is meant by an electric field.	
			....[1]	
			Solution: Region of space where a charged body experiences an electric force	1
		(ii)	Explain why the electron gun in Fig. 8.1 must be in a vacuum.	
			....	

			…………………………………………………………………………………… …………………………………………………………………………………… …………………………………………………………………………………… [2]	
			Solution: Electrons have a small mass easily deflected/ weakly ionizing/ collide with air molecules and scatter In vacuum, they can travel in a straight line and reach the anode (if not they will be deflected from their path)	1 1
		(iii)	The kinetic energy of the electrons increases by 5.68×10^{-16} J between leaving the cathode and reaching the anode. Calculate the accelerating p.d..	
			accelerating p.d. = …………………… V [2]	
			Solution: W = qV $5.68 \times 10^{-16} = 1.6 \times 10^{-19} \times V$ V = 3.55 kV	 1 1
		(iv)	Suggest why the electrons reaching the anode have a range of speeds.	
			…………………………………………………………………………………… …………………………………………………………………………………… …………………………………………………………………………………… …………………………………………………………………………………… [2]	
			Solution: Thermionic emission of electrons from the filament is a random process and electrons are emitted with a range of KE from the filament.	1

			When accelerated by the p.d., the increase in KE is the same, but since they had a range of KE when they were produced, the final KE when reaching the anode will have a range of values, hence a range of speeds.	1
	(b)	A uniform magnetic field is produced using a coil of 1500 turns of insulated wire, tightly wound on a non-magnetic tube to make a solenoid of mean radius 22 mm, as shown in Fig. 8.2. The wire itself has radius 0.86 mm and is made of a material of resistivity 1.7×10^{-8} Ω m. The coil is connected to a supply of e.m.f. 12 V and negligible internal resistance.  **Fig. 8.2** Calculate		
		(i)	the total length of the 1500 turns of wire in the coil, length = ... m [1]	
			Solution: total length of wire in the coil = $2\pi(22\text{x}10^{-3})$ (1500) = 207.3 m	1
		(ii)	the total resistance of the coil, resistance = ... Ω [2]	
			Solution: $R = \frac{\rho l}{A} = \frac{1.7\times10^{-8}\times207.3}{\pi(0.86\times10^{-3})^2}$ $= 1.52$ Ω	1 1

		(iii)	the current in the coil. current = ………………………… A [2]
			Solution: I = 12 / 1.52 1 = 7.91 A 1
	(c)	The magnetic flux density in the solenoid is measured using a current balance. The current balance is a U-shaped piece of stiff wire ABCDEF pivoted at BE, as shown in Fig. 8.3.  **Fig. 8.3** When in use, there is a turning force on the stiff wire caused by a current in CD.	
		(i)	Explain why the current in CD causes a turning effect. …………………………………………………………………………………… …………………………………………………………………………………… …………………………………………………………………………………… [2]
			Solution: When there is a current in CD, it produces a magnetic field around the wire which interacts with the magnetic field of the solenoid. This results in a force perpendicular to both the current and the magnetic field of the solenoid. 1 This force x the perpendicular distance of wire CD from the pivot produces a moment and causes a turning effect. 1
		(ii)	Explain why currents in CB and DE do not contribute to the turning force. …………………………………………………………………………………… …………………………………………………………………………………… [1]

			Solution: Currents in CB and DE are parallel to the magnetic field of the solenoid and hence no force. 1
		(iii)	CD has length 25 mm, CB and DE each have length 106 mm. The stiff wire is first balanced when there is no current in it. A current of 4.9 A is then passed through CD and, in order to rebalance the stiff wire, a force of 5.7×10^{-4} N is applied at a distance of 77 mm from the pivot, as shown in Fig. 8.4. which is the side view of the balance.  **Fig. 8.4 (side view)**
			1. State the direction of the current in CD direction = …………………. [1]
			Solution: C to D 1
			2. Calculate the magnetic flux density in the solenoid. Give the full name of the unit for magnetic flux density. magnetic flux density = ………………………… full name of unit = ……………………. [4] [Total: 20]
			Solution: By POM, F x 0.106 = 5.7x10^{-4} x 0.077 1 And F = BIL = B(4.9)(0.025) 1 B = 3.38 x 10^{-3} T 1 Tesla 1

9 **(a)** State what is meant by *simple harmonic motion.*

....

....

....

....[2]

Solution:

A periodic motion in which the body's acceleration is directly proportional to its displacement from its equilibrium position 1

its acceleration is always in opposite direction to its displacement 1

A long strip of springy steel is clamped at one end so that the strip is vertical. A mass *m* of 65 g is attached to the free end of the strip, as shown in Fig. 9.1.

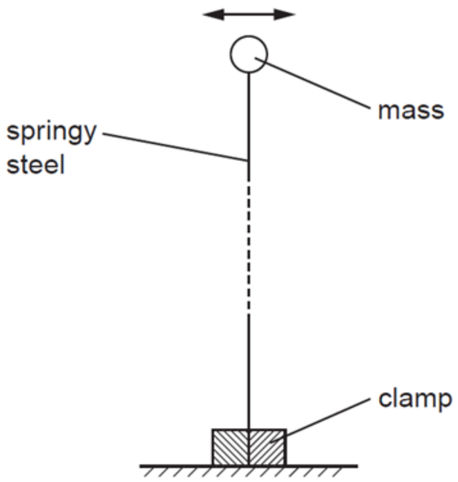


Fig. 9.1

The mass is pulled to one side and then released. The variation with time *t* of the horizontal displacement of the mass is shown in Fig. 9.2.

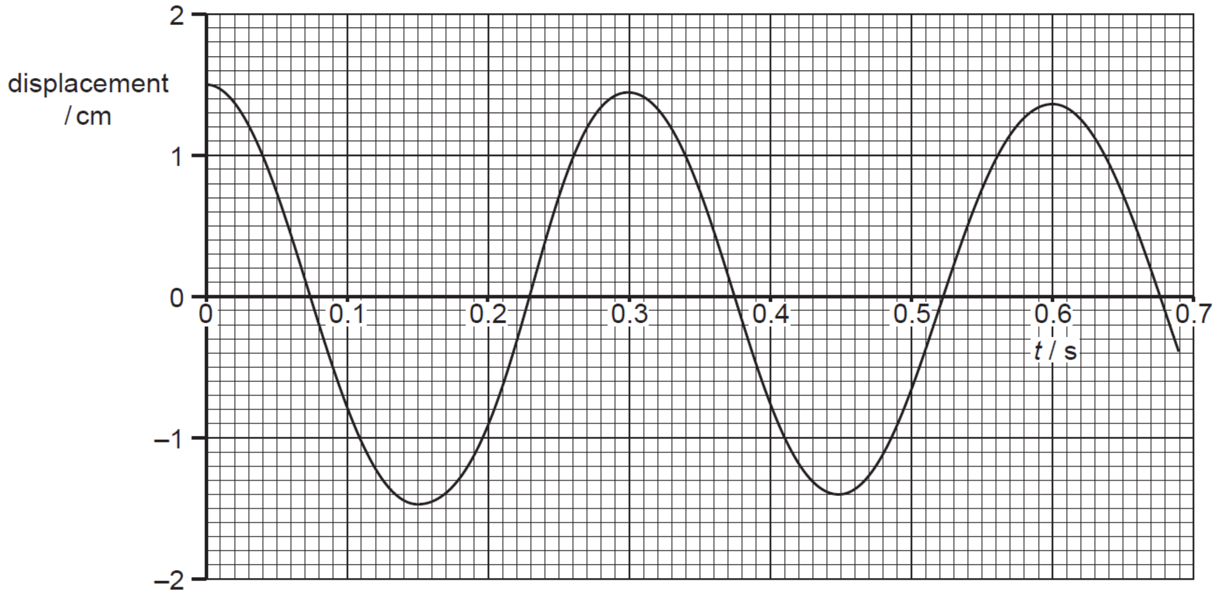


Fig. 9.2

The mass undergoes damped oscillation.

(b) **(i)** Suggest, with a reason, whether the damping is light, critical or heavy.

....

....

.... [2]

Solution:

The amplitude of the oscillation is decreasing gradually / oscillations continue for a long time — 1

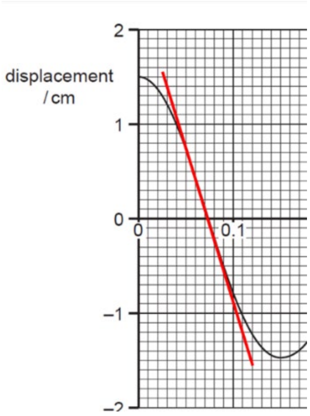
Light damping — 1

(ii) **1.** Using the data from Fig. 9.2, determine the maximum speed of the oscillation. State one time at which it is moving at maximum speed.

maximum speed =..............................m s^{-1}

time = ... s [2]

Solution:



speed
= gradient of the tangent
$= \left| \frac{(-1.2 - 1.4)}{(0.11 - 0.03)} \right|$
= 32.5 cm s^{-1} = 0.325 m s^{-1}

1

Time = 0.075 s, 0.23 s, 0.375 s, 0.52 s, 0.675 s

1

2. Sketch a graph showing the variation of the velocity of the mass *v* with its displacement from the equilibrium position in Fig. 9.3 for the first complete period of the oscillation.

Label the axes with an appropriate scale.

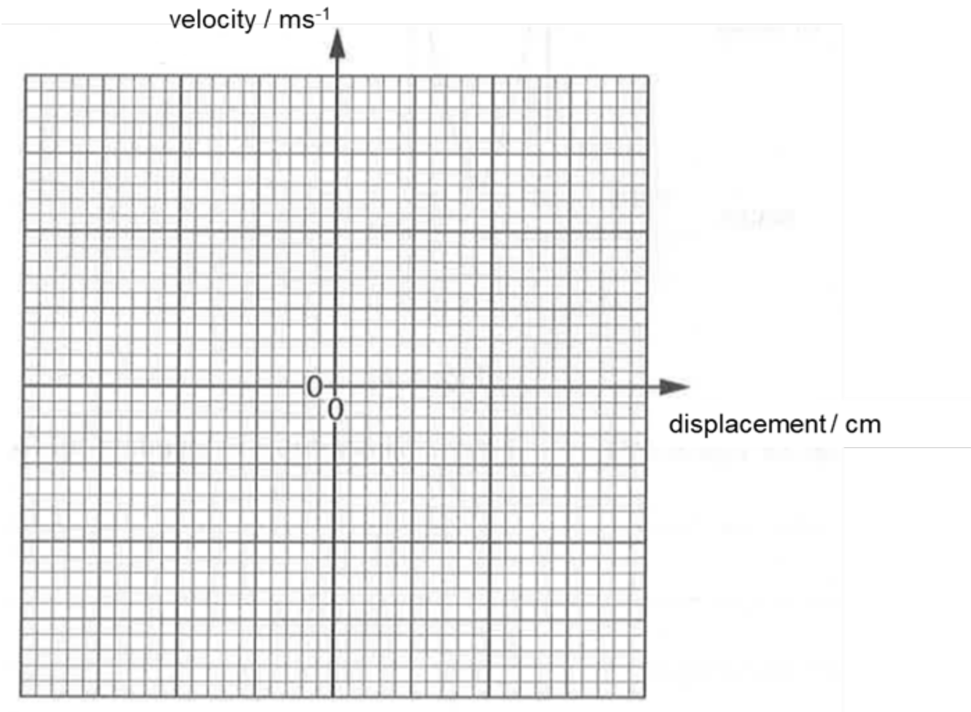
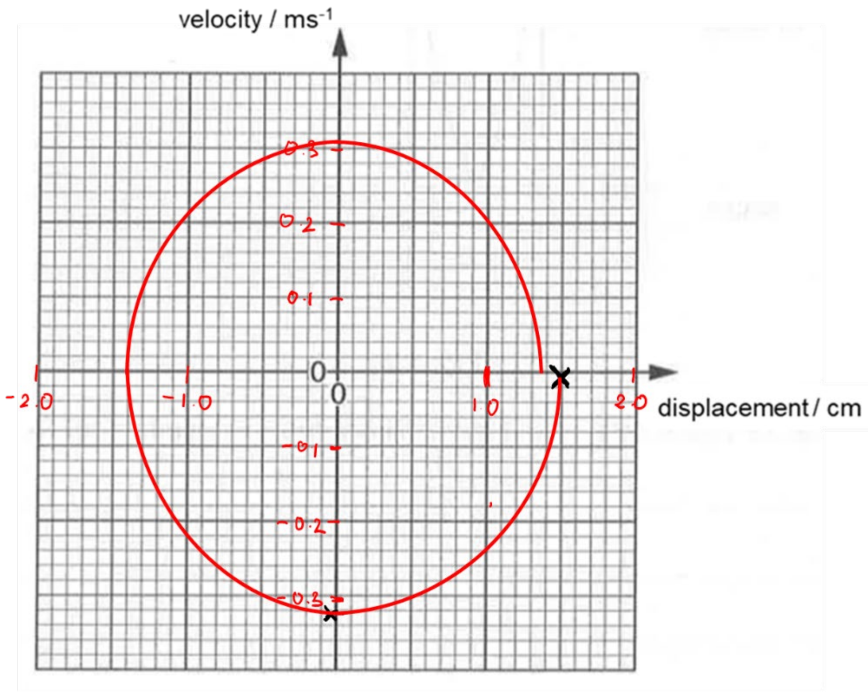


Fig. 9.3

[3]

		L3		**Solution:**  1 mark – graph begins at (1.5 cm, 0) 1 mark - graph shape (clockwise, ellipse, not "closed") 1 mark – correct intercepts of axes (v and x values smaller than the previous intercept)
		(iii)	After eight complete oscillations of the mass, the amplitude of vibration is reduced from 1.5 cm to 1.1 cm.	
			1.	Show that the total energy of a body oscillating in simple harmonic motion is given by $$E_T = \frac{1}{2} m\omega^2 x_0^2$$ where ω is the angular frequency of the oscillation and x_0 is its amplitude [3]

				Solution: $v = \pm\omega\sqrt{x_0^2 - x^2}$ speed is maximum when $x = 0$ $v_0 = \pm\omega\sqrt{x_0^2} = \omega x_0$ The total energy of the oscillation = maximum kinetic energy $= \frac{1}{2}mv_0^2$ $= \frac{1}{2}m\omega^2 x_0^2$	1 1 1
			2.	Calculate the angular frequency of the oscillations. angular frequency = ……………………………rad s^{-1} [2]	
				Solution: $\omega = 2\pi/T$ $= 2\pi/0.3$ $= 20.9$ rad s^{-1}	1 1
			3.	Calculate the loss of energy after eight complete oscillations. loss of energy = ……………………………J [2]	
				Solution: Loss of Energy = total initial energy of oscillation – total final energy of oscillation $= \frac{1}{2} m\omega^2 x_{o,initial}^2 - \frac{1}{2} m\omega^2 x_{o,final}^2$ $= \frac{1}{2} \times 0.065 \times 20.9^2 \times (0.015^2 - 0.011^2)$ = 0.00147 = 0.0015 J	1 1
			4.	Suggest with a reason, whether after another eight complete oscillations, the amplitude will be 0.7 cm.	

....

....

.... [2]

Solution:

amplitude reduces exponentially / does not decrease linearly 1
so will be not be 0.7 cm 1

(c) The variation of kinetic energy E_k of the mass with displacement x from its equilibrium position for the first period of oscillation is shown in Fig. 9.4.

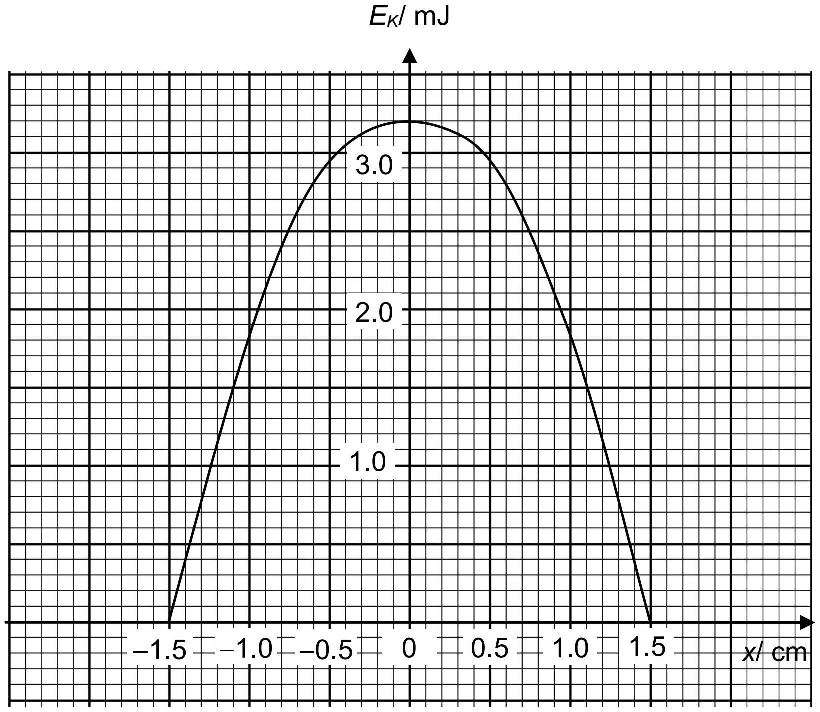


Fig. 9.4

The mass loses energy such that, after some time, its maximum kinetic energy is reduced by 1.5 mJ.

Use Fig. 9.4, without further calculation, to determine the amplitude of the oscillations. Show your construction on Fig. 9.4.

		amplitude = ... cm [2] [Total: 20]	
		Solution: When the objects loses KE, the entire graph will be translated downwards by 1.5 mJ. The point that will now have 0 KE, or the amplitude will be the displacement at which the E was originally 1.5 mJ Construction of horizontal line at 1.5 mJ or correctly translated KE graph amplitude = 1.1 cm If shifted curve is shown with the correct 3 key points (i.e. max and the two amplitude points, 2 marks). If shifted curve is shown with only the correct max point (wrong amplitude values), 1 mark	 1 1