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.
Write 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.

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

This document consists of **26** printed pages and **0** blank page.

[Turn over

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	$p = \rho gh$
gravitational potential	$\phi = -\frac{Gm}{r}$
temperature	$T/\text{K} = T/^{\circ}\text{C} + 273.15$
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	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
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	$B = \frac{\mu_o NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_o nI$
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

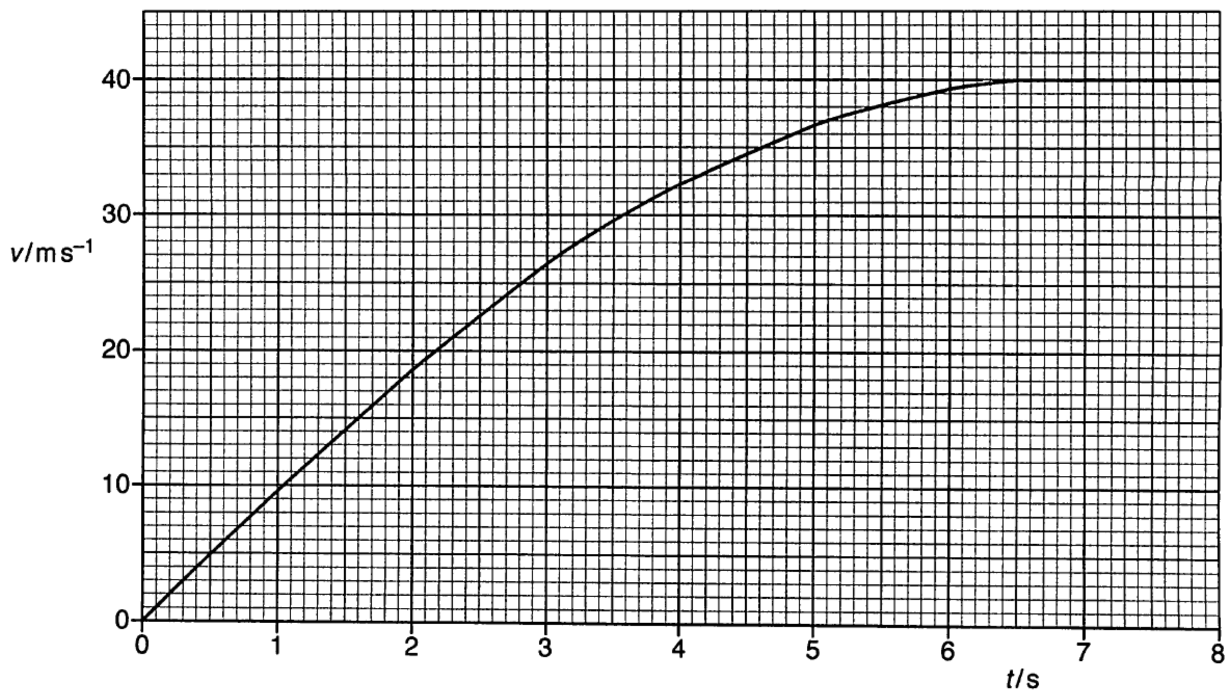

Fig 1.1

(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]

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

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

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

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

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

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

force = …..…………………… 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]

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.

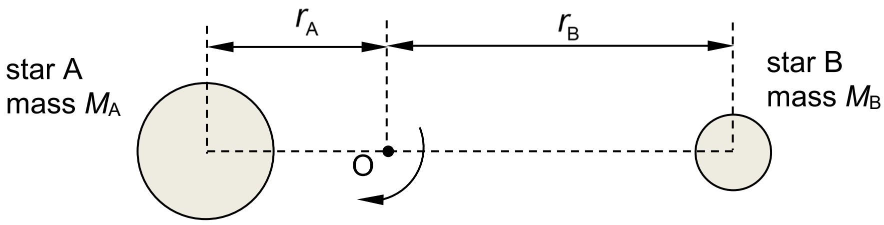

Fig. 2.1

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]

(b) Show that $\frac{r_B}{r_A} = 4$. Explain your working.

[2]

(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]

(ii) determine the mass of each star.

mass M_A of star A = ………………………………… kg

mass M_B of star B = ………………………………… kg [3]

[Total:8]

[Turn over

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]

(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 1.01×10^5 Pa as the ice melts completely into water at 0°C.

work done on the ice = ………………. J [3]

(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]

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

....

....

....

.... [2]

(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]

(c) The variation with time *t* of the measured count rate in **(b)** is shown in Fig. 4.1.

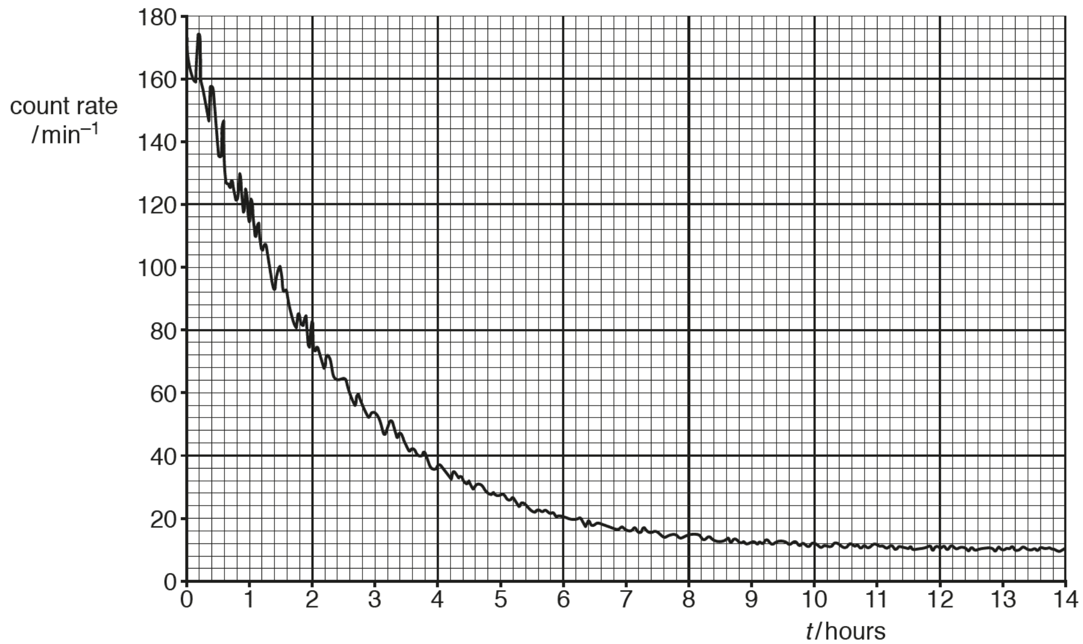

Fig. 4.1

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

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

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

(ii) Use Fig. 4.1 to determine

1. the background count rate and,

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

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

half-life = ……………………………………… hours [4]

[Turn over

(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]

5 (a) Explain what is meant by *coherent* light waves.

....

.... [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.

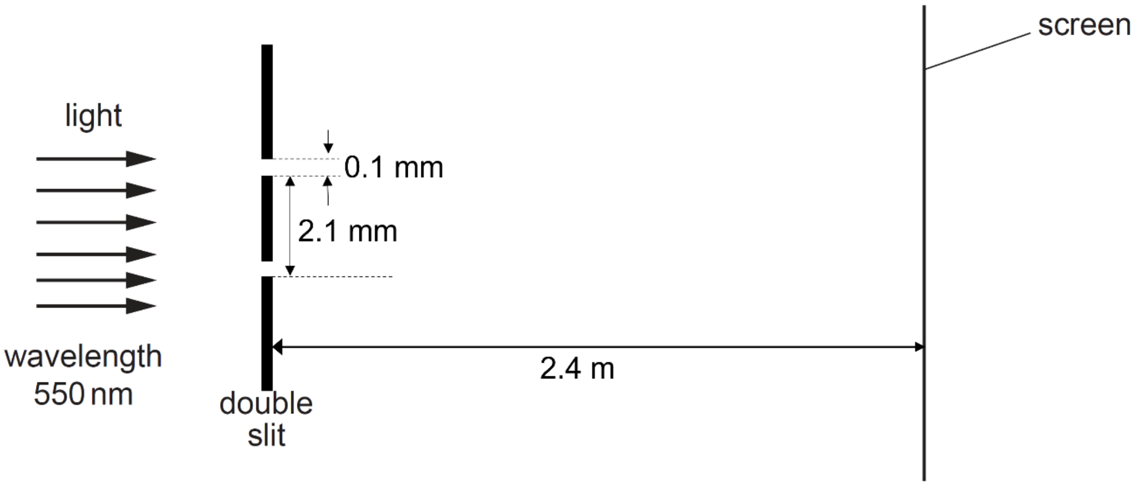

Fig. 5.1 (not to scale)

(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]

[Turn over

(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]

(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]

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]

(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.

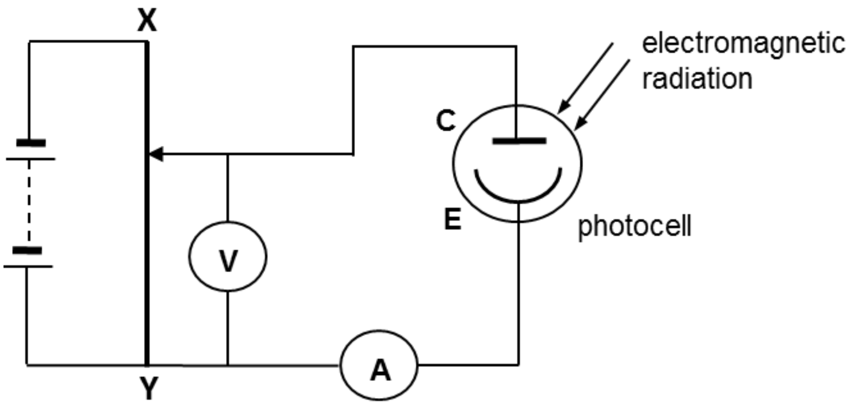

Fig. 6.1

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.

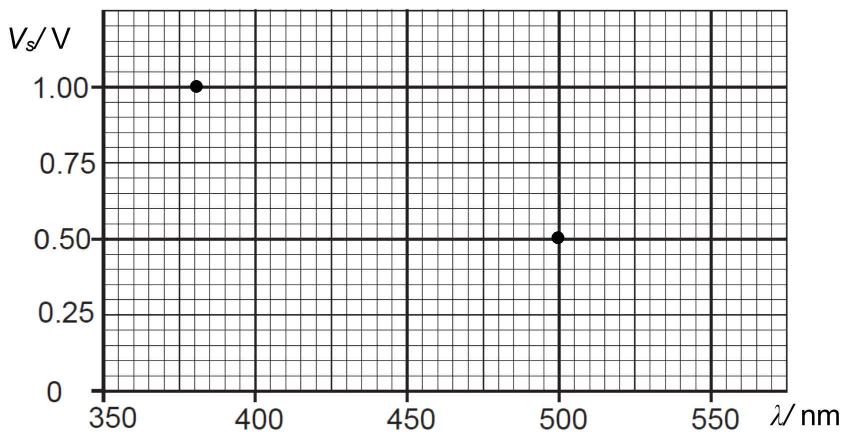

Fig. 6.2

[Turn over

(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]

(ii) Calculate the energy of a photon of wavelength 500 nm.

energy = …………………………………. J [2]

(iii) Hence, determine

1. the work function energy of the metal surface, and

work function energy = ……………………………… J [1]

2. the maximum photon wavelength that can liberate a photoelectron.

maximum wavelength = …………………….…….. nm [2]

(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]

7 Fig. 7.1 shows an x-ray spectrum.

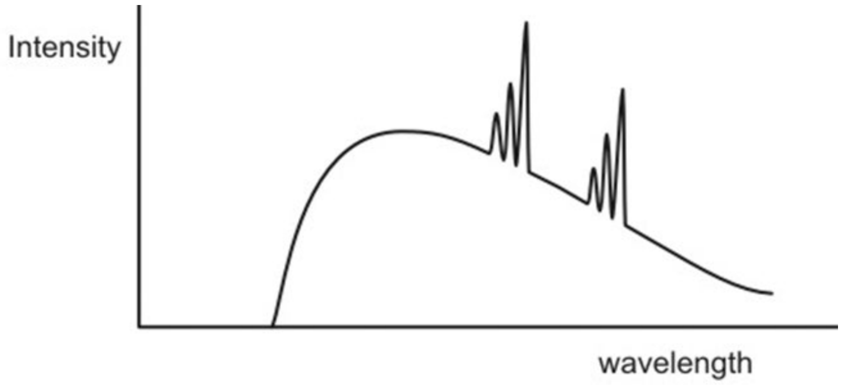

Fig. 7.1

Describe how the continuous spectrum is produced.

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....

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....

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....[3]

[Total: 3]

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.).

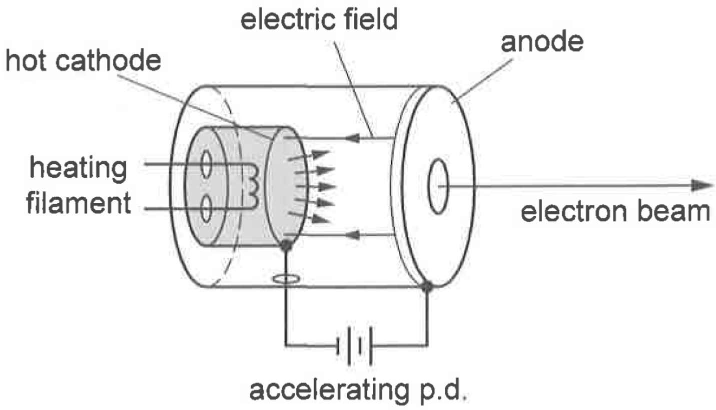

Fig. 8.1

(i) Explain what is meant by an electric field.

…………………………………………………………………………………………...

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

(ii) Explain why the electron gun in Fig. 8.1 must be in a vacuum.

…………………………………………………………………………………………..…

…………………………………………………………………………………………..

…………………………………………………………………………………………..

…………………………………………………………………………..……… [2]

(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]

(iv) Suggest why the electrons reaching the anode have a range of speeds.

……………………………………………………………………………………..

……………………………………………………………………………………..

……………………………………………………………………………………..

…………………………………………………………………………………… [2]

(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.

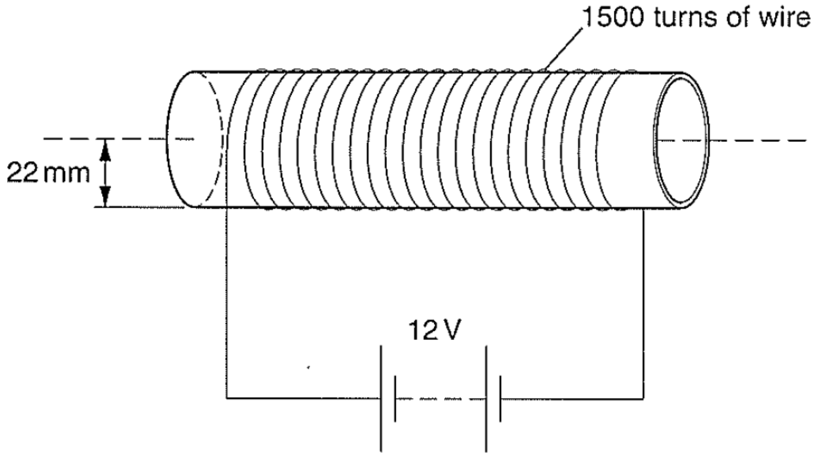

Fig. 8.2

Calculate

(i) the total length of the 1500 turns of wire in the coil,

length = ………………………… m [1]

(ii) the total resistance of the coil,

resistance = ………………………… Ω [2]

(iii) the current in the coil.

current = ………………………… A [2]

(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.

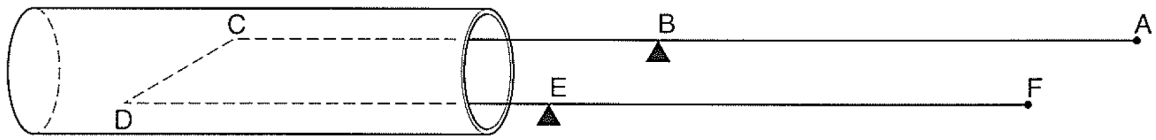

Fig. 8.3

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]

[Turn over

(ii) Explain why currents in CB and DE do not contribute to the turning 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.

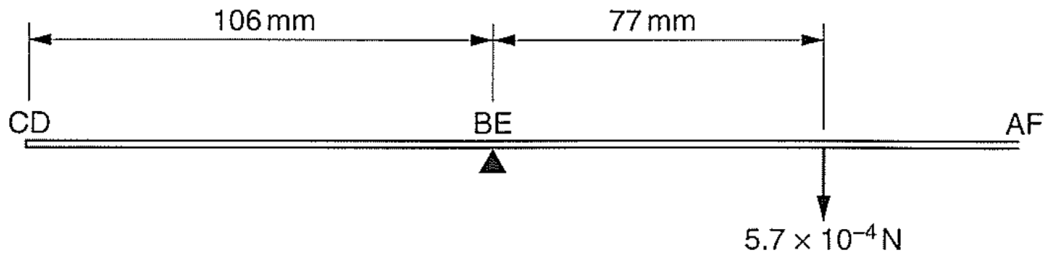

Fig. 8.4 (side view)

1. State the direction of the current in CD

direction = ………………….. [1]

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]

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

....

....

....

....[2]

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.

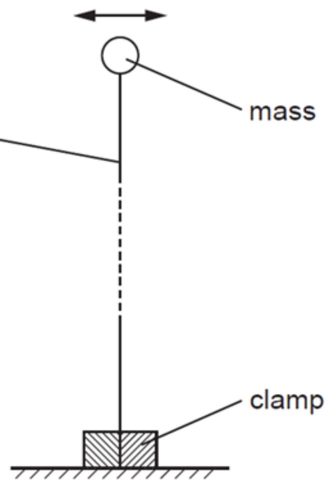

Fig. 9.1

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

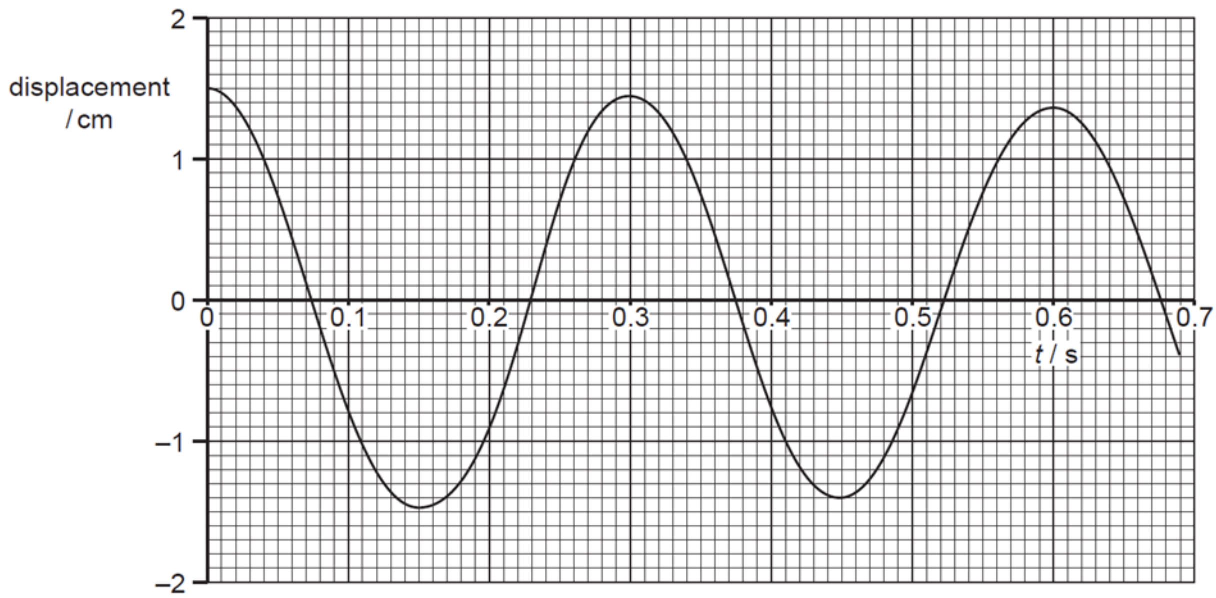

Fig. 9.2

The mass undergoes damped oscillation.

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

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

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

……………………………………………………………………………………. [2]

(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]

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.

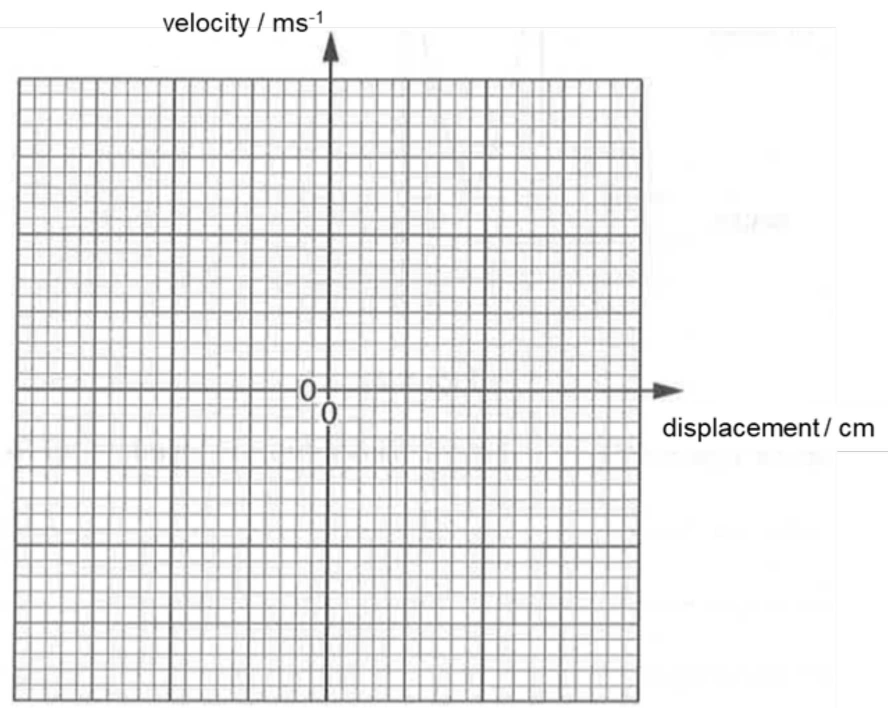

Fig. 9.3

[3]

(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]

2. Calculate the angular frequency of the oscillations.

angular frequency = ……………………………rad s^{-1} [2]

3. Calculate the loss of energy after eight complete oscillations.

loss of energy = …………………………….J [2]

[Turn over

4. Suggest with a reason, whether after another eight complete oscillations, the amplitude will be 0.7 cm.

……………………………………………………………………………………

……………………………………………………………………………………

…………………………………………………………………………………… [2]

(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.

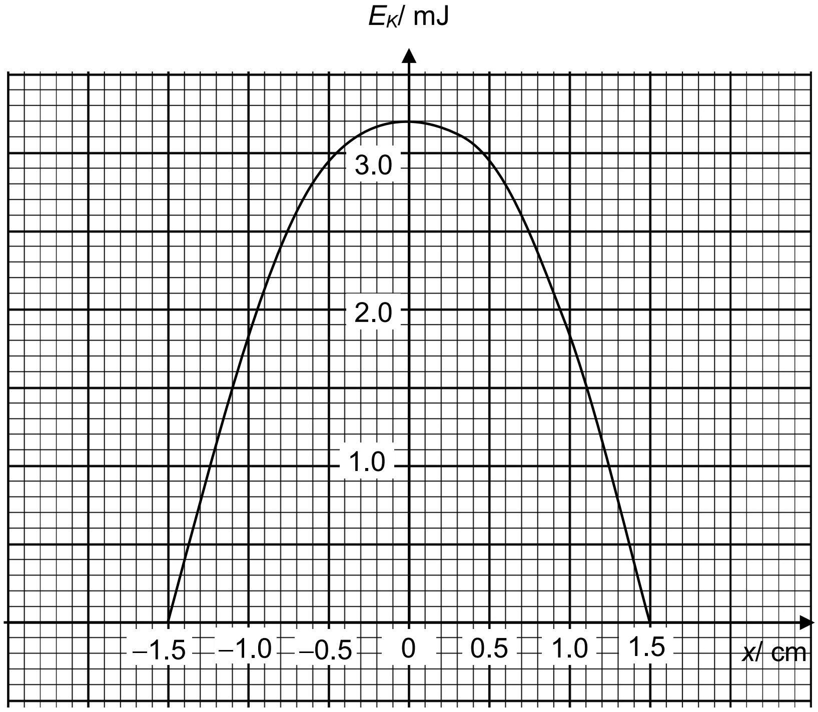

Fig. 9.4

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]

-- END OF PAPER 3 -