Name: ______________________________ (   )   Class: 25 / ______

ANDERSON SERANGOON JUNIOR COLLEGE

2025 JC2 Preliminary Examination

PHYSICS Higher 2 — 9749/02

Paper 2 Structured Questions — **Friday 22 August 2025**

2 hours

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

READ THESE INSTRUCTIONS FIRST

Write your name, class index number 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	
Paper 2 (80 marks)	
1	
2	
3	
4	
5	
6	
7	
Deductions	
Total	

This document consists of **23** printed pages and **1** blank page.

Data

speed of light in free space	$c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1}
	$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	$e = 1.60 \times 10^{-19}$ C
the Planck constant	$h = 6.63 \times 10^{-34}$ J s
unified atomic mass constant	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron	$m_e = 9.11 \times 10^{-31}$ kg
rest mass of proton	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant	$R = 8.31$ J K^{-1} mol^{-1}
the Avogadro constant	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant	$k = 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant	$G = 6.67 \times 10^{-11}$ 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	$T/\text{K} = T/°\text{C} + 273.15$
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.	$v = v_0 \cos \omega t$
	$= \pm \omega\sqrt{x_o{}^2 - x^2}$
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	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

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

1 **(a)** The acceleration of free fall g may be determined from an oscillating pendulum using the equation

$$g = \frac{4\pi^2 l}{T^2}$$

where l is the length of the pendulum and T is the period of oscillation.

In an experiment, the measured values for an oscillating pendulum are

l = 1.50 m ± 2%
and T = 2.48 s ± 3%.

(i) Calculate the acceleration of free fall g.

g = ... m s^{-2} [1]

(ii) Determine the actual uncertainty of the calculated value of g.

actual uncertainty = ………………………….. m s^{-2} [2]

(b) A trolley on a track is attached by springs to fixed blocks X and Y, as shown in Fig. 1.1. The track contains many small holes through which air is blown vertically upwards. This results in the trolley resting on a cushion of air rather than being in direct contact with the track.

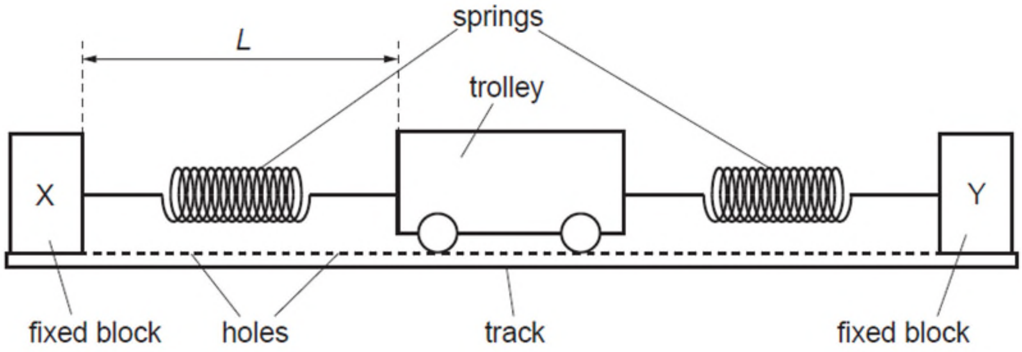

Fig. 1.1

The trolley is pulled to one side of its equilibrium position and then released so that it oscillates initially with simple harmonic motion. After a short time, the air blower is switched off. The variation with time t of the distance L of the trolley from block X is shown in Fig. 1.2.

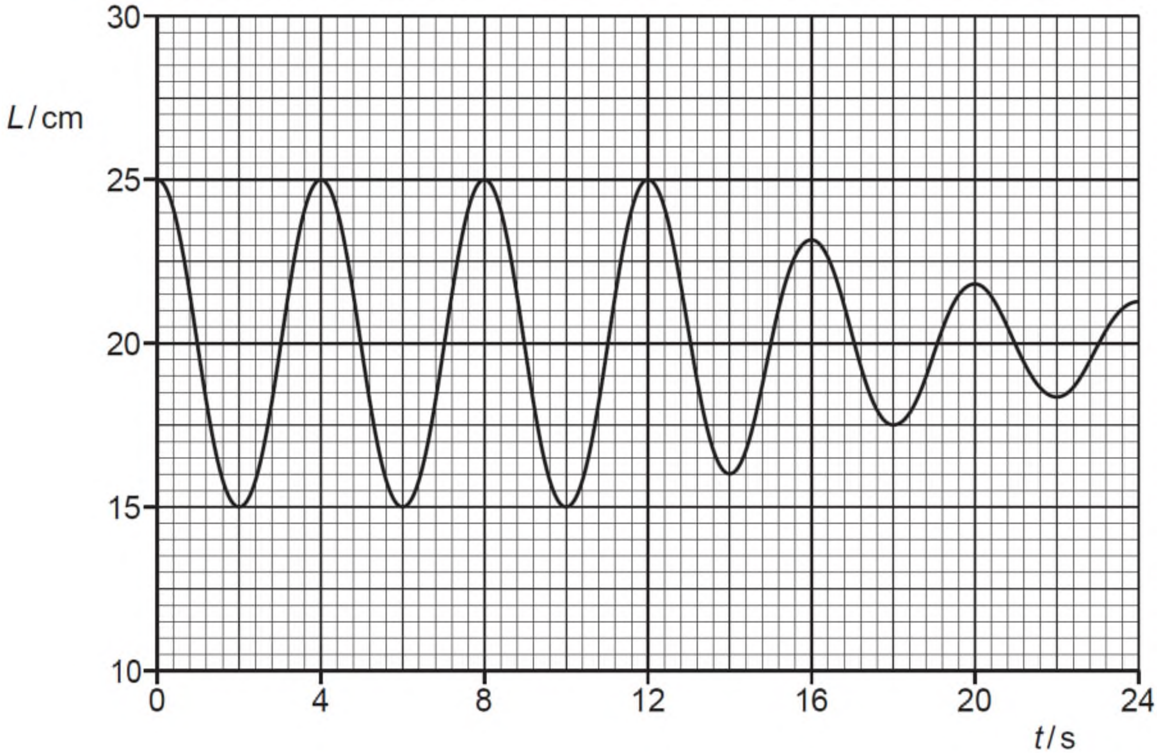

Fig. 1.2

(i) Use Fig. 1.2 to determine the maximum speed v_0, of the oscillating trolley.

v_0 = ... cm s^{-1} [2]

(ii) Apart from the quantities determined in **(b)(i)**, describe what may be deduced from Fig. 1.2 about the motion of the trolley between time t = 0 and time t = 24 s. No calculations are required.

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

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

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

(iii) On Fig. 1.3, sketch the variation with L of the velocity v of the trolley for its first complete oscillation.

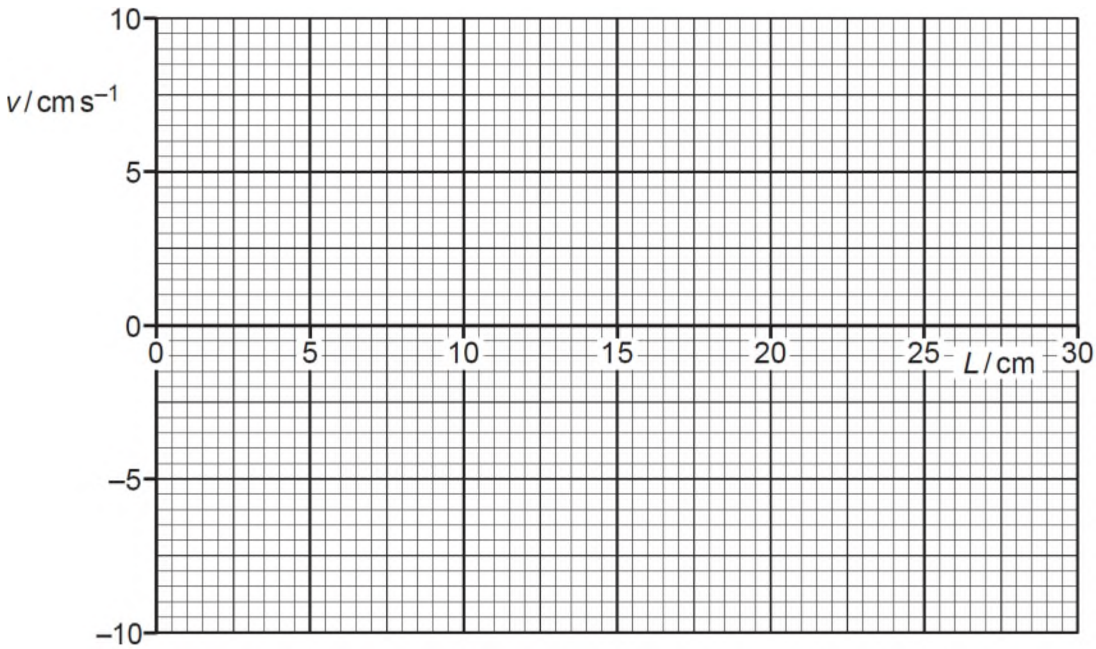

Fig. 1.3

[2]

[Total: 9]

2 **(a)** A block is pulled by a force *X* along a rough surface inclined at 30° to the horizontal, as shown in Fig. 2.1. The weight of the block is 0.80 N.

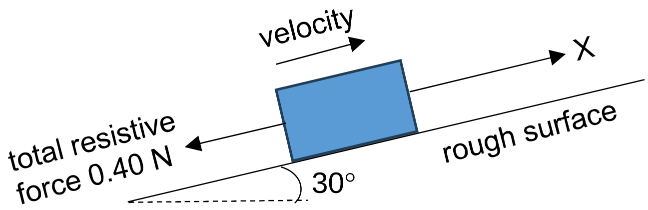

Fig. 2.1 (not to scale)

Assume that the total resistive force opposing the motion of the block is 0.40 N at all speeds of the block.

The variation with time *t* of the magnitude of the force *X* is shown in Fig. 2.2.

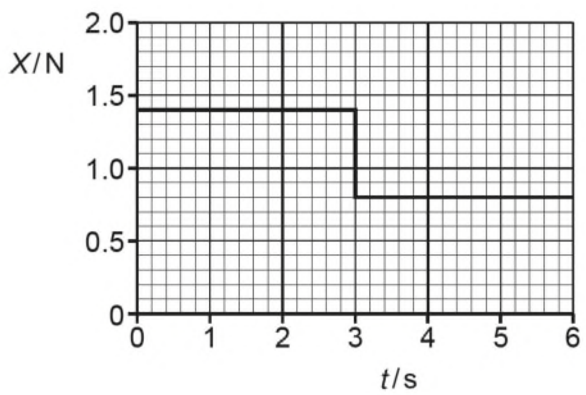

Fig. 2.2

(i) Show that the change in momentum of the block from time $t = 0$ to time $t = 3.0$ s is 1.8 kg m s^{-1}.

[2]

(ii) Describe and explain the motion of the block between time $t = 3.0$ s and time $t = 6.0$ s.

……………………………………………………………………………………………

……………………………………………………………………………………………

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

(iii) The block is at rest at time t = 0.

On Fig. 2.3, sketch a graph to show the variation of the momentum of the block with time t from t = 0 to t = 6.0 s.
Numerical values of momentum are not required.

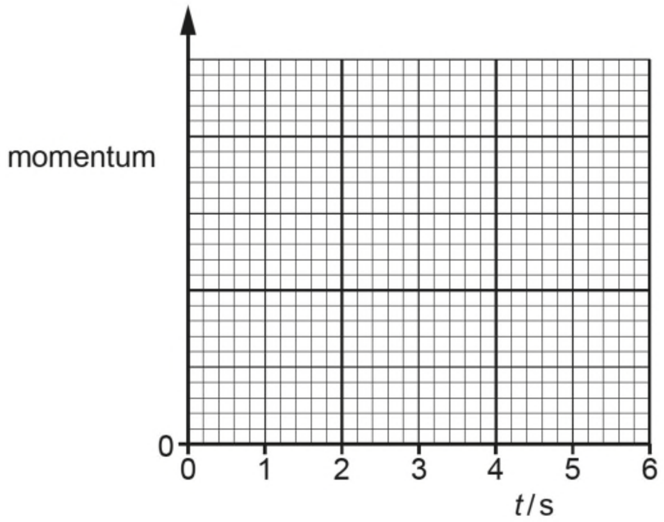

Fig. 2.3

[2]

(b) A nucleus P and a nucleus Q are moving towards each other at the same speed v as shown in Fig. 2.4. The mass of nucleus Q is smaller than that of nucleus P. The interaction between the nuclei is elastic.

Fig. 2.4

The variation with time t of the velocity of each nucleus is shown in Fig. 2.5.

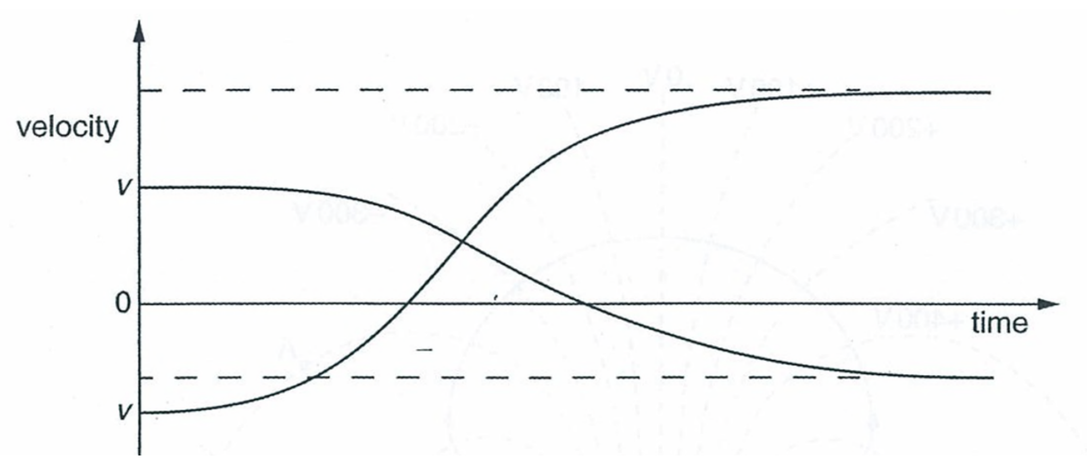

Fig. 2.5 (not to scale)

(i) Explain why it is not possible for the nuclei to stop at the same instant.

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

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

(ii) On Fig. 2.5, label the curve for nucleus Q.

Explain your reasoning.

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

[Total: 11]

3 **(a)** State what is meant by a line of force in

(i) a gravitational field,

....

.... [1]

(ii) an electric field.

....

.... [1]

(b) State **one** similarity and **one** difference between the electric field lines and the gravitational field lines around an isolated positively charged metal sphere.

similarity ....

....

difference ....

....

....
[2]

(c) A positive point charge +*Q* is positioned at a fixed point X and an identical positive point charge is positioned at a fixed point Y, as shown in Fig. 3.1.

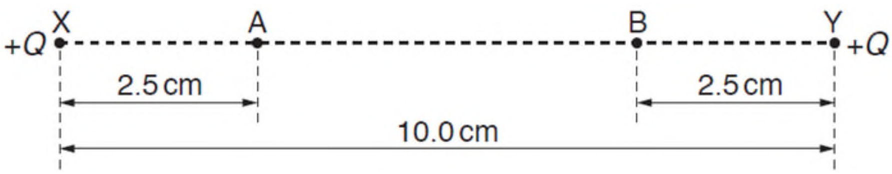

Fig. 3.1

The charges are separated in a vacuum by a distance of 10.0 cm.

Points A and B are on the line XY. Point A is a distance of 2.5 cm from X and point B is a distance of 2.5 cm from Y. The electric field strength at point A is 4.1×10^{-5} V m^{-1}.

(i) Calculate charge +*Q*.

+*Q* = ... C [3]

(ii) On Fig. 3.2, sketch the variation of the electric field strength *E* with distance *d* from A to B, along the line AB.

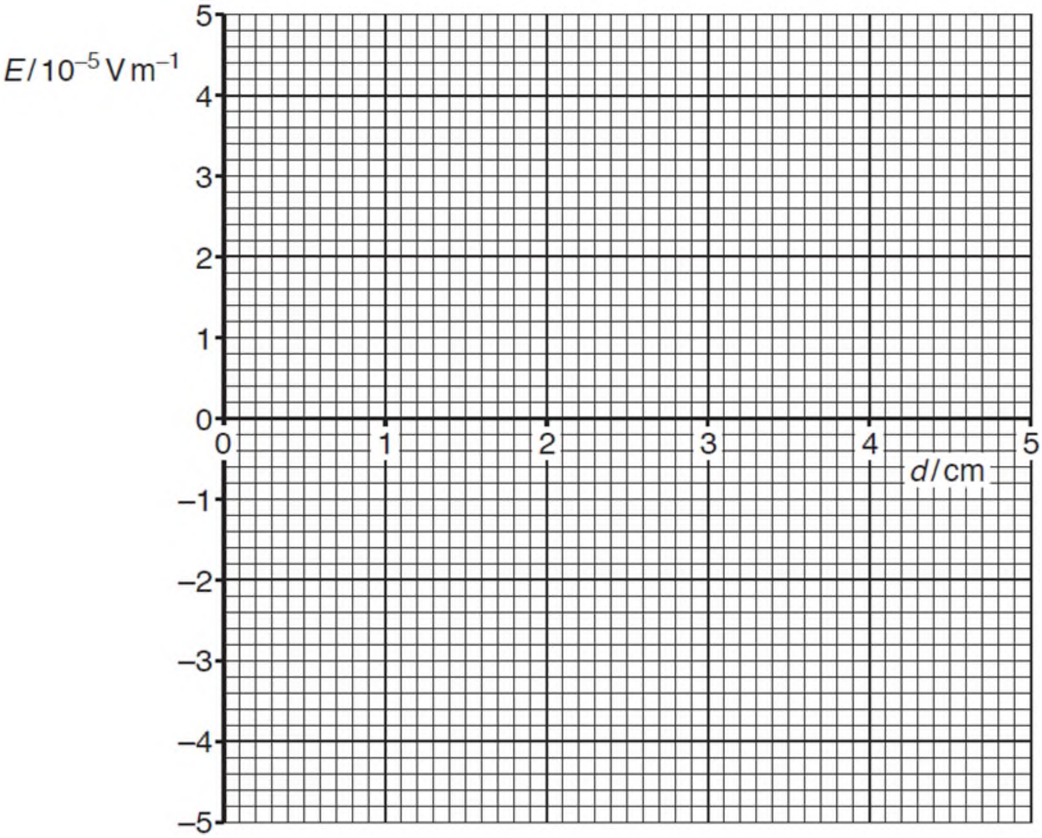

Fig. 3.2

[2]

(iii) A small positive charge is placed at A. The electric field causes this charge to move from rest along the line AB.

Describe the acceleration of the charge as it moves from A to B.

....

....

....

.... [2]

[Total: 11]

4 **(a)** **(i)** An ideal gas is said to consist of molecules that are hard elastic identical spheres and there are no intermolecular forces of attraction or repulsion between the molecules.

State two further assumptions of the kinetic theory of gases.

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

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

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

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

(ii) Explain why an increase in internal energy of an ideal gas is directly related to a rise in temperature of the gas.

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

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

(iii) A fixed mass of oxygen gas at initial pressure *P* is sealed in a cylindrical container by a movable piston at one end, as shown in Fig. 4.1. Assume that oxygen behaves as an ideal gas.

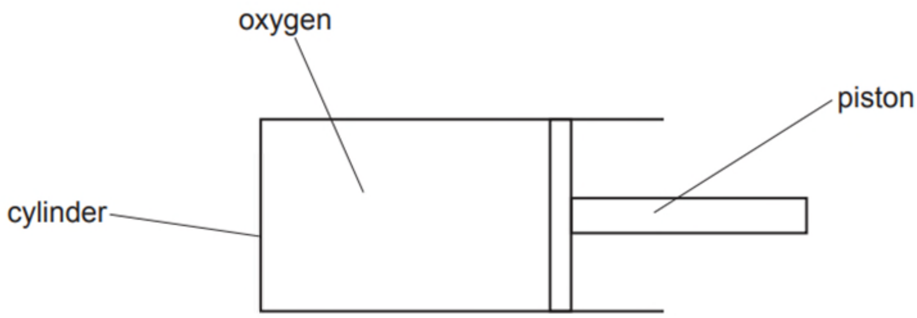

Fig. 4.1

The temperature of gas is *T* and the root-mean-square (r.m.s.) speed of an oxygen molecule at *T* is *u*.

The piston is slowly moved into the cylinder so that the oxygen gas is compressed. At all times, the gas and the container remain in thermal equilibrium with the surroundings.

On Fig. 4.2, sketch the variation with pressure of the root-mean-square (r.m.s.) speed of the oxygen molecules as the pressure increases.

Fig. 4.2 [1]

(b) State and explain using the first law of thermodynamics the change, if any, in the internal energy of the gas in a tyre when the tyre bursts so that the gas suddenly increases in volume. Assume that the gas is ideal.

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

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

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

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

[Total: 8]

5 **(a)** State **two** features of a stationary wave that distinguish it from a progressive wave.

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

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

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

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

(b) A loudspeaker, microphone A, cathode-ray oscilloscope (CRO) and a metal sheet are arranged as shown in Fig. 5.1.

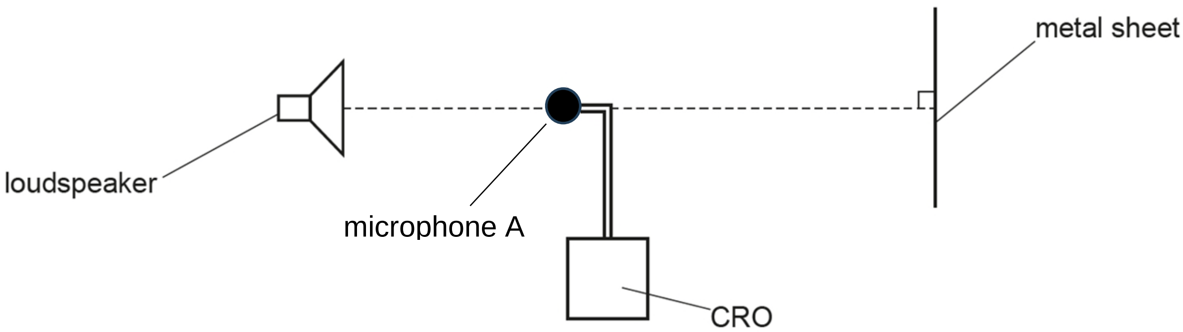

Fig. 5.1

A stationary wave is formed between the loudspeaker and the metal sheet.

(i) Explain how this stationary wave is formed.

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

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

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

(ii) The initial position of the microphone is such that the trace on the CRO has an amplitude minimum. It is now moved a distance of 1.05 m away from the loudspeaker along the line joining the loudspeaker and metal sheet.

As the microphone moves, it passes through three positions where the trace has an amplitude maximum before ending at a position where the trace has an amplitude minimum.

Determine the wavelength of the sound wave.

wavelength = …………………………….m [2]

(c) The metal sheet is removed and microphone B is added to the setup. Microphones A and B are placed at distances 1.05 m and 1.40 m from the loudspeaker as shown in Fig. 5.2.

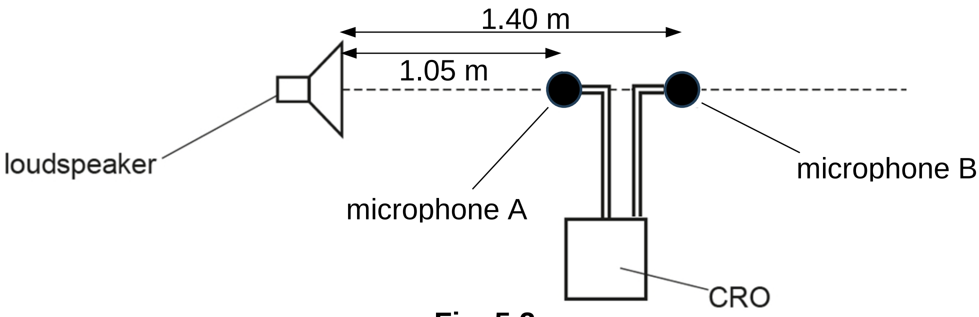

Fig. 5.2

The loudspeaker is assumed to emit sound waves uniformly in all directions.
Fig. 5.3 shows the trace on the screen of the CRO due to input from microphone A.

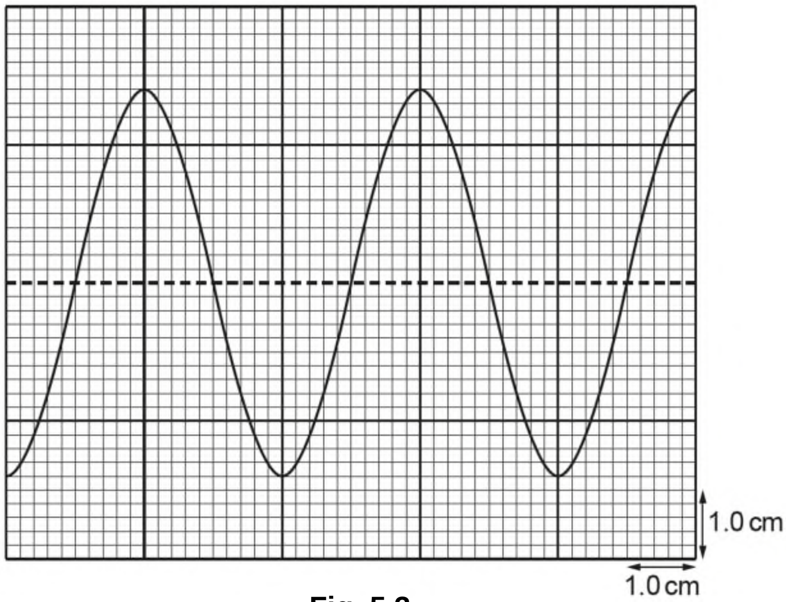

Fig. 5.3

Assume that the amplitude of the signal received by the CRO is proportional to the amplitude of the sound wave.

(i) Determine the amplitude (in cm) of the trace on the screen of the CRO due to input from microphone B. Show your working.

amplitude = …………………………… cm [2]

(ii) On Fig. 5.3, sketch the trace seen on the screen of the CRO due to input from microphone B. [2]

[Total: 10]

[Turn Over

6 **(a)(i)** Define nuclear *binding energy*.

....

....

.... [1]

(ii) A student suggests that one possible nuclear reaction is

$$^{56}_{26}\text{Fe} + ^{1}_{0}\text{n} \rightarrow ^{20}_{9}\text{F} + ^{37}_{17}\text{Cl}$$

The binding energy per nucleon of a nucleus varies with the nucleon number.
Use this variation to explain why the reaction would **not** result in an overall release of energy.

....

....

....

....

.... [3]

(b) One possible nuclear reaction that takes place is

$$^{235}_{92}\text{U} + ^{1}_{0}\text{n} \rightarrow ^{95}_{42}\text{Mo} + ^{139}_{57}\text{La} + 2^{1}_{0}\text{n} + 7^{0}_{-1}\text{e}$$

Data for nuclei in this reaction are given in Fig. 6.1.

nucleus	mass / u	total mass of separate nucleons / u	mass defect / u	binding energy per nucleon / MeV
$^{95}_{42}\text{Mo}$	94.906	95.765	0.859	8.443
$^{139}_{57}\text{La}$	138.906	140.125	1.219	8.189
$^{235}_{92}\text{U}$	235.044	236.909	....	....

Fig. 6.1

The energy equivalent to a mass of 1.00 u is 934 MeV.

(i) Use data from Fig. 6.1 to calculate the mass defect and binding energy per nucleon of a nucleus of uranium-235 ($^{235}_{92}U$). Complete Fig. 6.1.

[3]

(ii) Calculate the total energy, in MeV, released in this nuclear reaction.

energy = ... MeV [2]

(iii) The nuclei in 1.2×10^{-7} mol of uranium-235 all undergo this reaction in a time of 25 ms.

Calculate the average power release during the time of 25 ms.

power = ... W [3]

[Total: 12]

7 The article below is based on articles on the Internet.

Read the article and then answer the questions that follow.

Use of ultrasonic sound waves on biological cells

Ultrasonic sound waves (ultrasound) are produced and detected using an ultrasound transducer. Ultrasound transducers are capable of sending an ultrasound and then the same transducer can detect the sound and convert it to an electrical signal to be diagnosed.

To produce an ultrasound, a piezoelectric crystal has an alternating current running through it. The piezoelectric crystal grows and shrinks depending on the voltage applied across it. Running an alternating current through it causes it to vibrate at a high speed and to produce an ultrasound.

Ultrasound have frequencies outside the audible range of the human ear, that is, greater than about 20 kHz.

When an ultrasound passes through a medium, its wave energy is absorbed. The rate at which energy is absorbed by unit mass of the medium is known as the dose-rate. The dose-rate is measured in W kg^{-1}. The total energy absorbed by unit mass of the medium is known as absorbed dose. This is measured in J kg^{-1} or, as in this question, kJ kg^{-1}.

Under certain circumstances, biological cells may be destroyed by ultrasound. The effect on a group of cells is measured in terms of the survival fraction (*SF*).

$$SF = \frac{\text{number of cells surviving after exposure}}{\text{number of cells before exposure}}$$

For any particular absorbed dose, it is found that the survival fraction changes as the dose-rate increases. Fig. 7.1 shows the variation with dose-rate of the survival fraction for samples of cells in a liquid. The absorbed dose for each sample of cells was 240 kJ kg^{-1}.

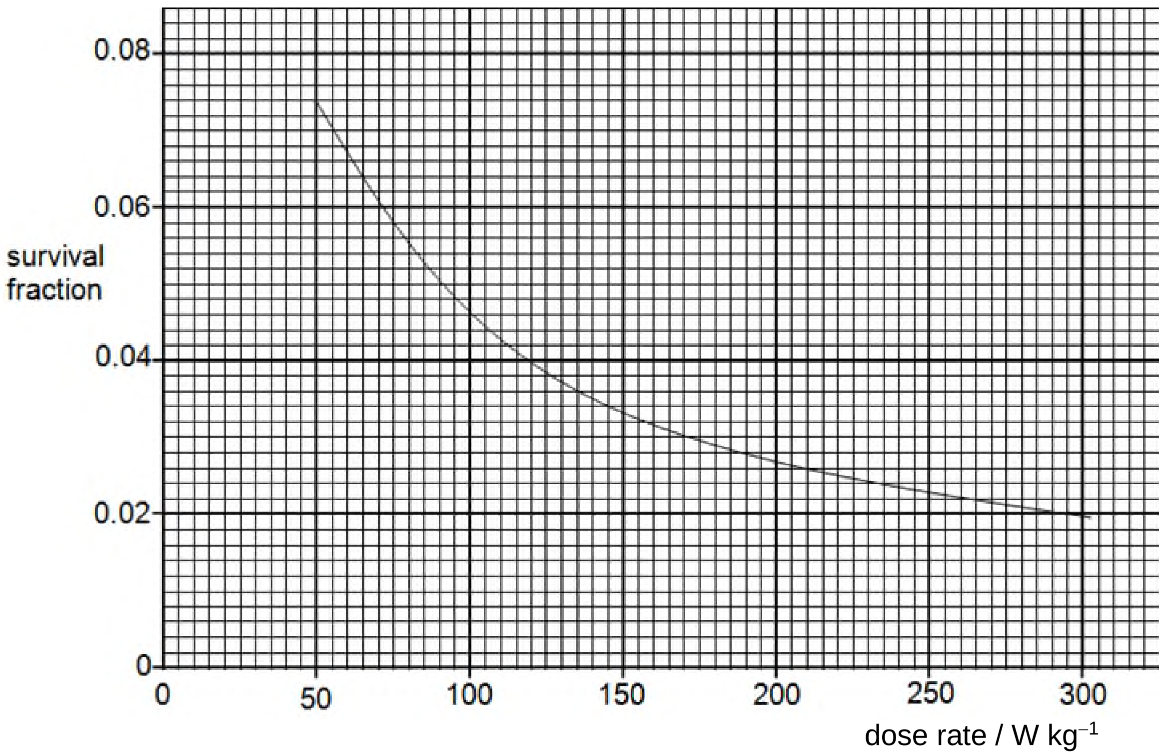

Fig. 7.1

(a) **(i)** State the transformation of energy that occurs in an ultrasound transducer.

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

(ii) State two differences between ultrasound and light.

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

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

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

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

(iii) A medical ultrasound device emits a pulse of frequency 5.0 MHz and wavelength 3.1×10^{-4} m into a patient's body. The pulse travels through soft tissue, reflects off and returns to the transducer as an echo after a total time of 52.0 µs.

Assuming that the speed of pulse remains constant in the tissue, calculate the one-way distance from the transducer to the reflecting surface inside the body.

distance = ………………….... m [3]

(b) Calculate the exposure time for an absorbed dose of 240 kJ kg^{-1} and at a dose-rate of 200 W kg^{-1}.

exposure time = ………………….... s [2]

[Turn Over

(c) Survival fraction depends not only on dose-rate but also on absorbed dose. Fig. 7.2 shows the variation with dose-rate of $\log_{10}(SF)$ for different values of absorbed dose.

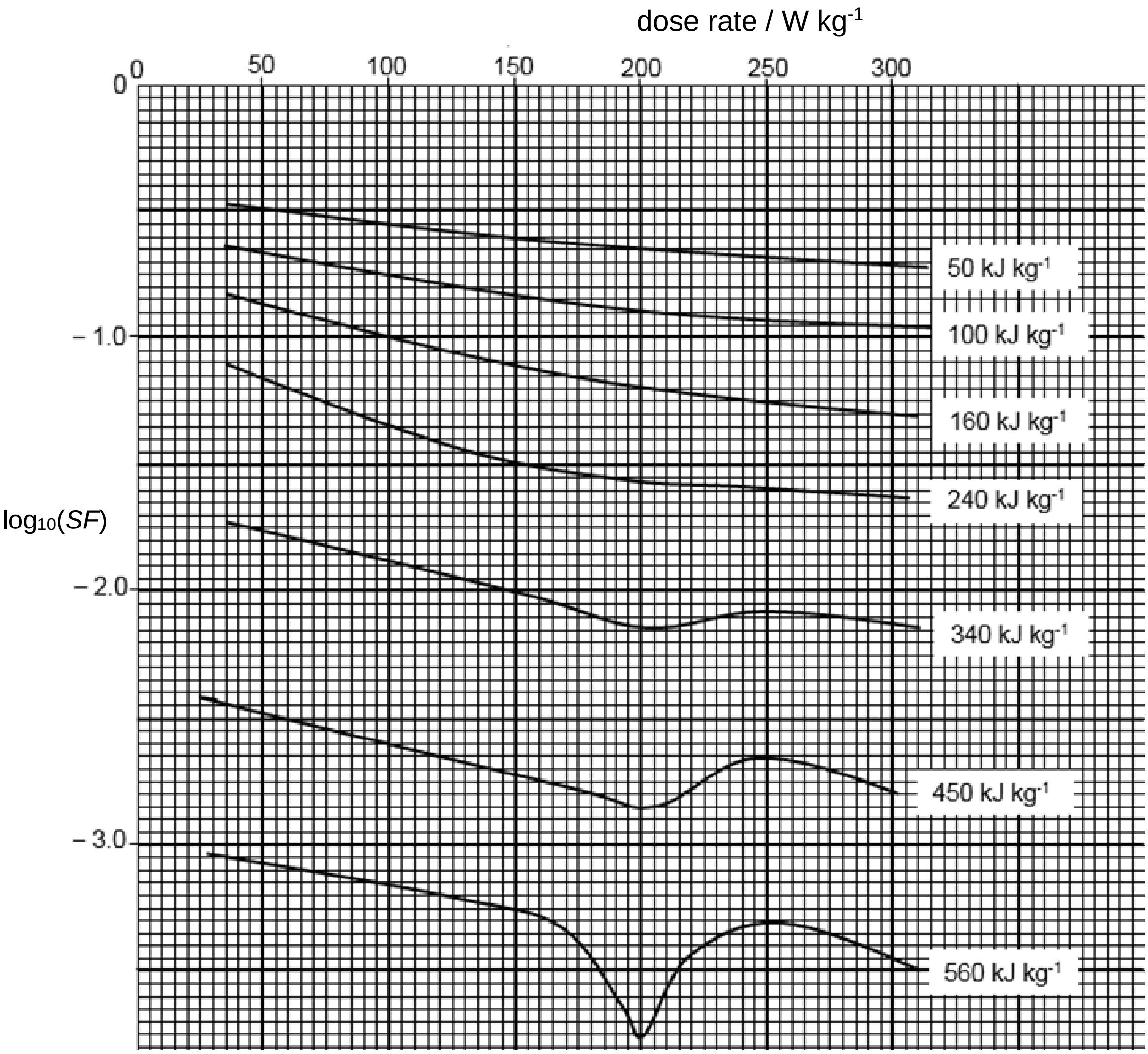

Fig. 7.2

The line with absorbed dose of 240 kJ kg^{-1} represents the data given in Fig. 7.1, but with survival fraction plotted on a logarithmic scale.

(i) Suggest why the survival fraction is plotted on a logarithmic scale.

……………………………………………………………………………………………

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

(ii) Suggest why, for the same absorbed dose, a lower dose rate generally results in higher cell survival fraction.

……………………………………………………………………………………………

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

(iii) Use Fig. 7.2 to complete the table of Fig. 7.3 for a dose-rate of 200 W kg^{-1}.

absorbed dose / kJ kg^{-1}	$\log_{10}(SF)$
50	– 0.65
100	–0.90
160	–1.18
240	–1.58
340	–2.15
450	–2.85
560	

Fig. 7.3

[1]

(d) Fig. 7.4 is a graph of some of the data of Fig. 7.3.

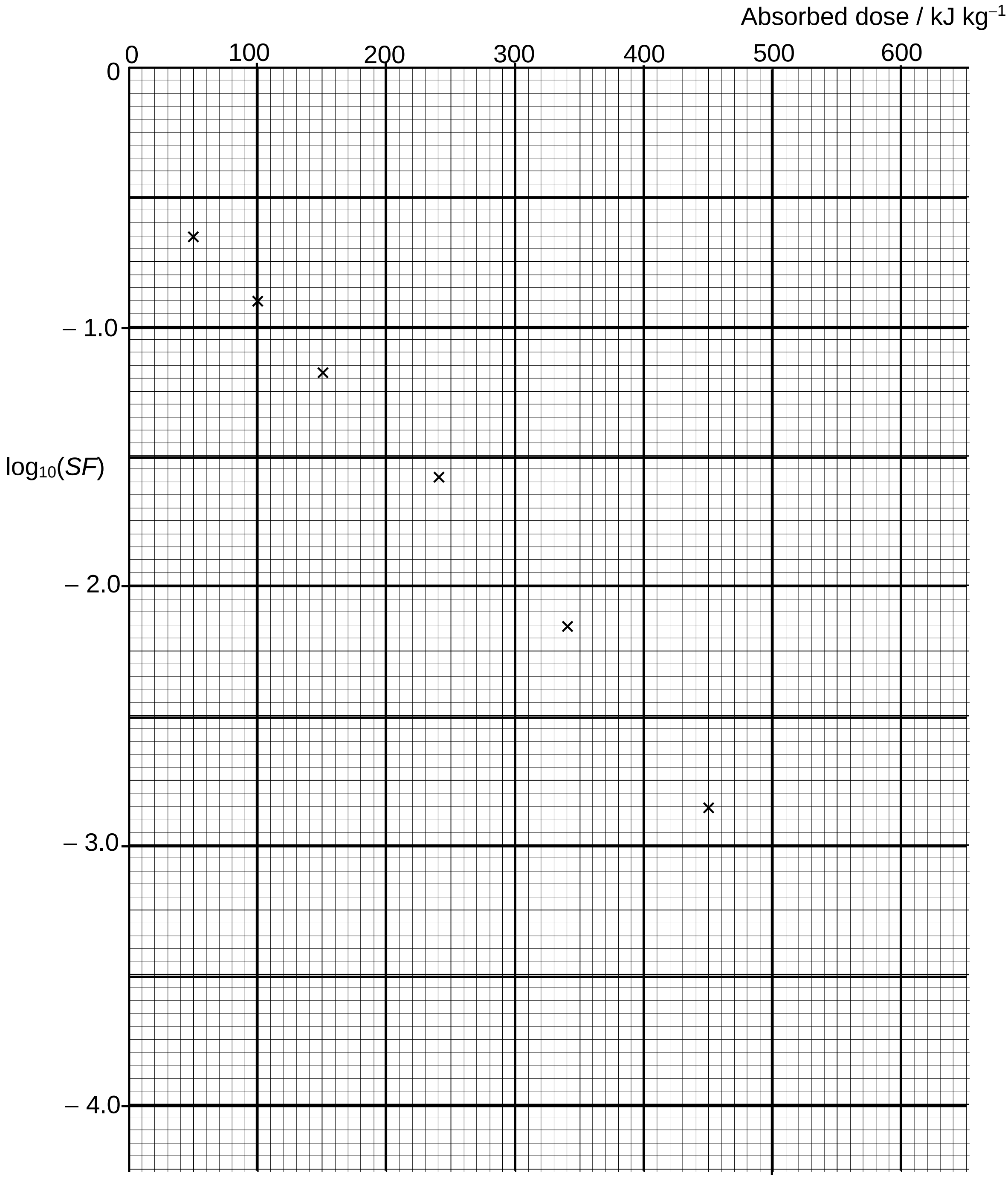

Fig. 7.4

On Fig. 7.4,

(i) plot the point corresponding to absorbed dose = 560 kJ kg^{-1},

(ii) draw the best-fit line.

[2]

(e) Theory suggests that at a dose-rate of 200 W kg^{-1}, two separate effects may give rise to cell destruction. According to this theory, one of the effects becomes apparent only at higher absorbed doses. State the evidence provided for this theory by

(i) Fig. 7.2,

....

....[1]

(ii) Fig 7.4.

....

.... [2]

(f) Ultrasound can be employed both for diagnostic imaging, where it's important not to damage tissues, and for therapeutic ablation, where the goal is to destroy unwanted cells.

With reference to Fig. 7.2, suggest and explain an appropriate dose-rate for each for the application of ultrasound.

diagnostic imaging: ....

....

therapeutic ablation: ....

....[3]

[Total: 19]

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