



Catholic Junior College

JC2 Preliminary Examinations

Higher 2

CANDIDATE
NAME

CLASS

PHYSICS

Paper 2 Structured Questions

9749/02

August 2025

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		
Q1		/ 10
Q2		/ 8
Q3		/ 12
Q4		/ 8
Q5		/ 9
Q6		/ 11
Q7		/ 22
PAPER 2		/ 80

DATA

speed of light in free space	$c = 3.00 \times 10^8 \text{ m s}^{-1}$
permeability of free space	$\mu_0 = 4\pi \times 10^{-7} \text{ H m}^{-1}$
permittivity of free space	$\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$ $(1/(36\pi)) \times 10^{-9} \text{ F m}^{-1}$
elementary charge	$e = 1.60 \times 10^{-19} \text{ C}$
the Planck constant	$h = 6.63 \times 10^{-34} \text{ J s}$
unified atomic mass constant	$u = 1.66 \times 10^{-27} \text{ kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31} \text{ kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27} \text{ kg}$
molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
the Avogadro constant	$N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$
the Boltzmann constant	$k = 1.38 \times 10^{-23} \text{ J K}^{-1}$
gravitational constant	$G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
acceleration of free fall	$g = 9.81 \text{ m s}^{-2}$

FORMULAE

uniformly accelerated motion

$$s = ut + \frac{1}{2}at^2$$

work done on / by a gas

$$v^2 = u^2 + 2as$$

hydrostatic pressure

$$W = p \Delta V$$

$$p = \rho gh$$

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

$$R = R_1 + R_2 + \dots$$

resistors in parallel

$$1/R = 1/R_1 + 1/R_2 + \dots$$

electric potential

$$V = \frac{Q}{4\pi\epsilon_0 r}$$

alternating current / voltage

$$x = x_0 \sin \omega t$$

magnetic flux density due to a long straight wire

$$B = \frac{\mu_0 I}{2\pi d}$$

magnetic flux density due to a flat circular coil

$$B = \frac{\mu_0 NI}{2r}$$

magnetic flux density due to a long solenoid

$$B = \mu_0 nI$$

radioactive decay

$$x = x_0 \exp(-\lambda t)$$

decay constant

$$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$$

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

- 1 A toy car of mass 0.42 kg is released from rest and accelerates along a straight track towards a wall. It hits the wall and rebounds in the opposite direction. The variation with time t of the momentum p of the toy car when not in contact with the wall is shown in Fig. 1.1

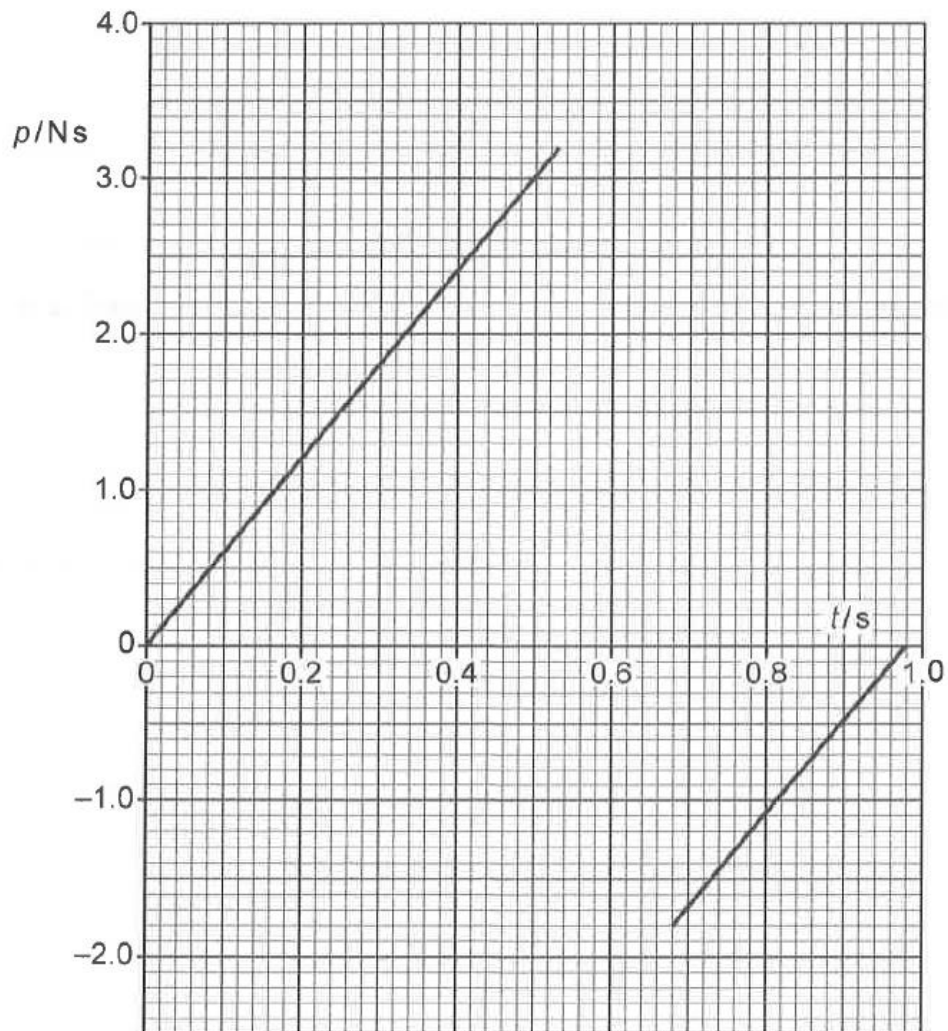


Fig 1.1

- (a) Using Fig 1.1, calculate the impulse acting on the toy car during the collision.

impulse = N s [2]

- (b) Calculate the magnitude of the average acceleration of the car during the collision and state the direction of this acceleration relative to the initial motion of the car.

average acceleration =m s⁻²

direction = [3]

- (c) Explain why the collision was inelastic.

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..... [2]

- (d) Calculate the percentage change in the kinetic energy of the car as a result of the collision.

percentage change = % [3]

[Total: 10]

[Turn over

- 2 (a) State what is meant by the centre of gravity of an object.

.....
 [1]

- (b) A hollow plastic sphere is attached at one end of a bar. The sphere is partially submerged in water and the bar is attached to a fixed vertical support by a pivot P, as shown in Fig. 2.1.

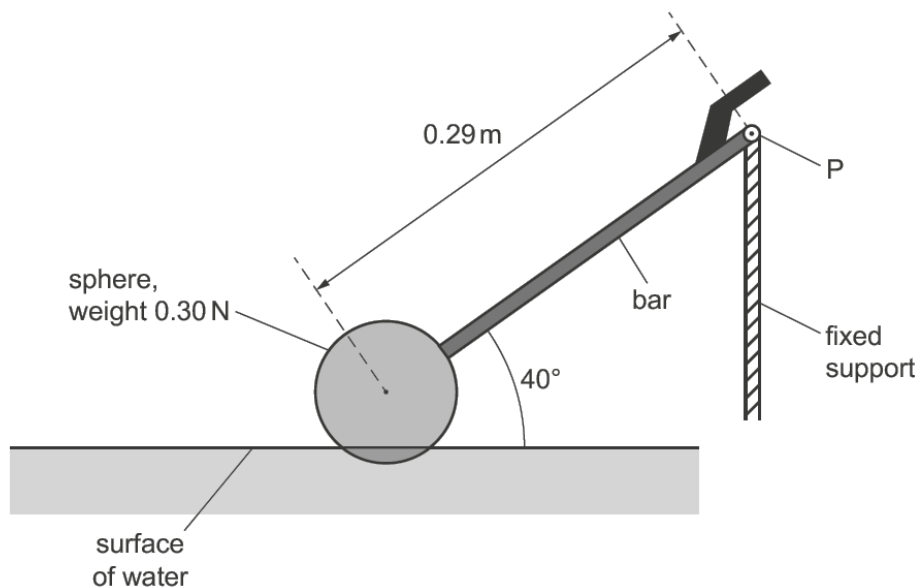


Fig. 2.1 (not to scale)

The sphere has weight 0.30 N. The distance from P to the centre of gravity of the sphere is 0.29 m. The weight of the bar is negligible.

The system shown in Fig. 2.1 is part of a mechanism that controls the amount of water in a tank. Water enters the tank and causes the sphere to rise. This results in the bar becoming horizontal as shown in Fig. 2.2.

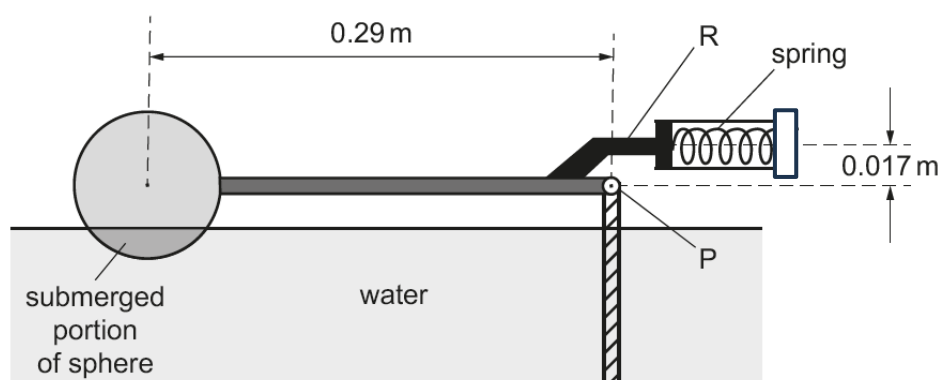


Fig. 2.2 (not to scale)

At the position shown in Fig. 2.2, the system is stationary and in equilibrium. The rod R exerts a force to compress a horizontal spring that controls the water supply to the tank. The spring has a spring constant of 2100 N m^{-1} . R is positioned at a perpendicular distance of 0.017 m above P.

- (i) The radius of the sphere is 0.0480 m and 26.0% of the volume of the sphere is submerged.

The density of water is $1.00 \times 10^3 \text{ kg m}^{-3}$.

Show that the upthrust on the sphere is 1.18 N.

[2]

- (ii) For the position shown in Fig. 2.2, by taking moments about P, determine the force exerted on the spring by the rod R.

force = N [2]

- (iii) Calculate the elastic potential energy E_P of the compressed spring.

E_P = J [2]

- (c) When the sphere moves from the position shown in Fig. 2.1 to the position shown in Fig. 2.2, the upthrust on the sphere does work. Assume that resistive forces are negligible.

Explain why the work done by the upthrust is not equal to the gain in elastic potential energy of the spring.

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..... [1]

[Total: 8]

- 3 (a) Fig. 3.1 shows a string stretched between two fixed points P and Q.

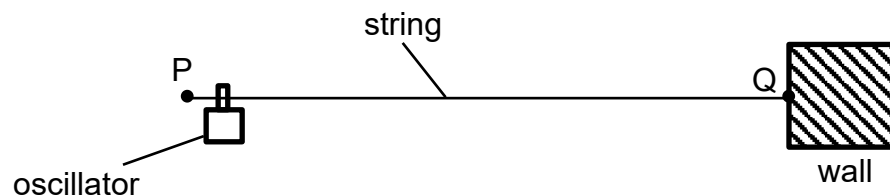


Fig. 3.1

An oscillator is attached near end P of the string. End Q is fixed to a wall. The oscillator has a frequency of 480.0 Hz.

The stationary wave produced on PQ at an instant time t is shown in Fig. 3.2. Each point on the string is at its maximum displacement.

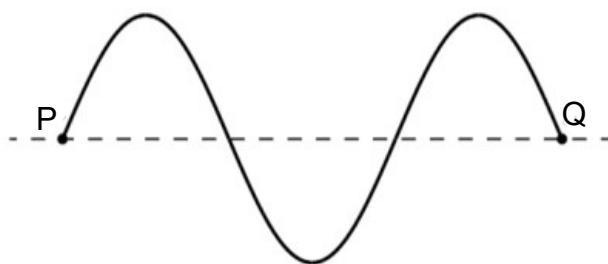


Fig. 3.2

- (i) On Fig. 3.2, label all the nodes with the letter **N** and the antinodes with the letter **A** along the dotted line PQ. [2]
- (ii) Calculate the lowest possible frequency of the wave that can be formed between end P and Q of the string.

frequency = Hz [3]

- (b) A loudspeaker is connected to a signal generator. It is then oriented to face a wall as shown in Fig. 3.3. Sound waves are produced between the speaker and the wall to form a stationary wave.

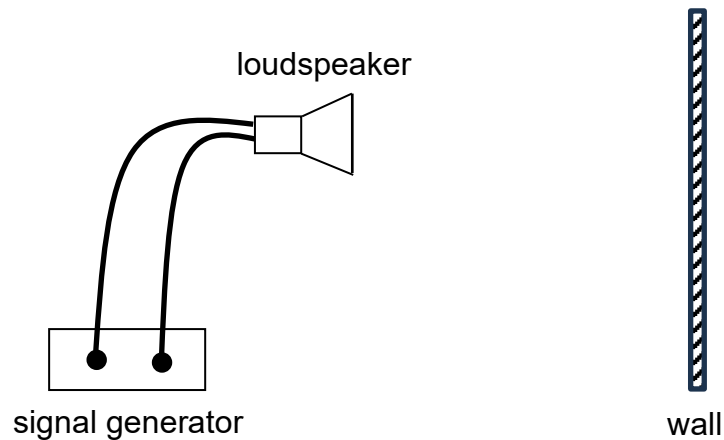


Fig. 3.3

- (i) Explain why there are alternate regions of high and low intensity detected between the loudspeaker and the wall.

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..... [3]

- (ii) Outline how you would use this setup to obtain the speed of sound waves in air.

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..... [4]

- 4 A battery B, a variable resistor R and a uniform resistance wire PQ are connected in series, as shown in Fig. 4.1

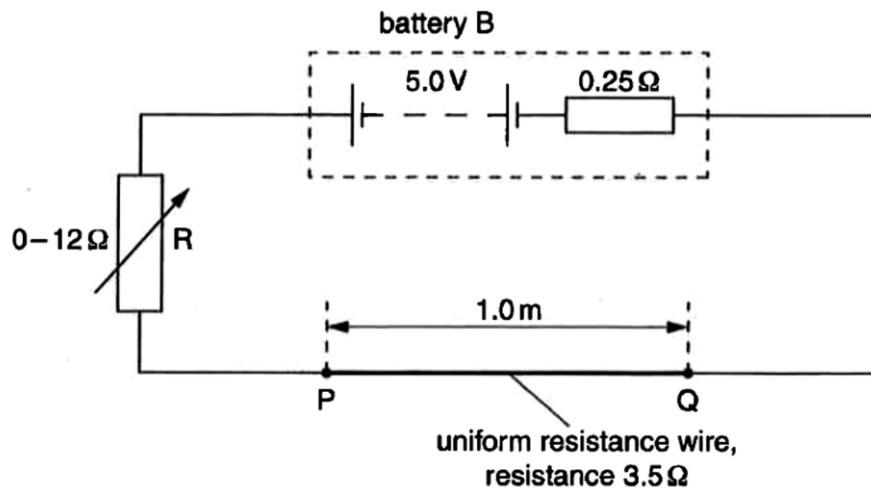


Fig. 4.1

Battery B has electromotive force (e.m.f.) 5.0 V and internal resistance 0.25 Ω.

Wire PQ has length 1.0 m and resistance 3.5 Ω at room temperature.

- (a) The resistance of R is set to 4.0 Ω.

Calculate, when the circuit is just turned on,

- (i) the potential difference across wire PQ,

p.d. =V [2]

- (ii) the percentage of total power transferred to wire PQ.

percentage =% [2]

(b) The temperature of the wire is gradually increased from room temperature to a maximum steady temperature.

(i) Describe and explain the variation in the terminal potential difference (p.d.) across B. Numerical values are not required.

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..... [2]

(ii) Suggest why the temperature of the wire will reach a steady maximum value.

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..... [2]

[Total: 8]

- 5 (a) An ideal gas is said to consist of molecules that are hard elastic identical spheres.

State two further assumptions of the kinetic theory of gases.

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..... [2]

- (b) The number of molecules per unit volume in an ideal gas is n .

If it is assumed that all the molecules are moving with speed v_x in the x-direction, the pressure p exerted by the gas on the walls of the vessel is given by

$$p = nmv_x^2$$

where m is the mass of one molecule.

Explain the reasoning by which this expression is modified to give the formula

$$p = \frac{1}{3}nm\langle c^2 \rangle$$

where $\langle c^2 \rangle$ is the mean square speed of the molecules.

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..... [2]

- (c) The density of an ideal gas is 1.2 kg m^{-3} at a pressure of $1.0 \times 10^5 \text{ Pa}$ and a temperature of 27°C .

- (i) Calculate the root-mean-square (r.m.s.) speed of the molecules of the gas at 27°C .

root-mean-square speed = m s^{-1} [3]

- (ii) Calculate the mean-square speed of the molecules at 207 °C.

mean-square speed = $\text{m}^2 \text{s}^{-2}$ [2]

[Total: 9]

- 6 (a) When ultraviolet radiation of a specific frequency is incident on a metal surface, electrons are emitted with a range of kinetic energies up to a maximum value.

Explain why the emitted electrons have a range of kinetic energies up to a maximum value.

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..... [3]

- (b) The maximum kinetic energy E_{MAX} of electrons emitted from a metal surface is measured for different wavelengths λ of the electromagnetic radiation. The variation of E_{MAX} with $\frac{1}{\lambda}$ is shown in the Fig. 6.1.

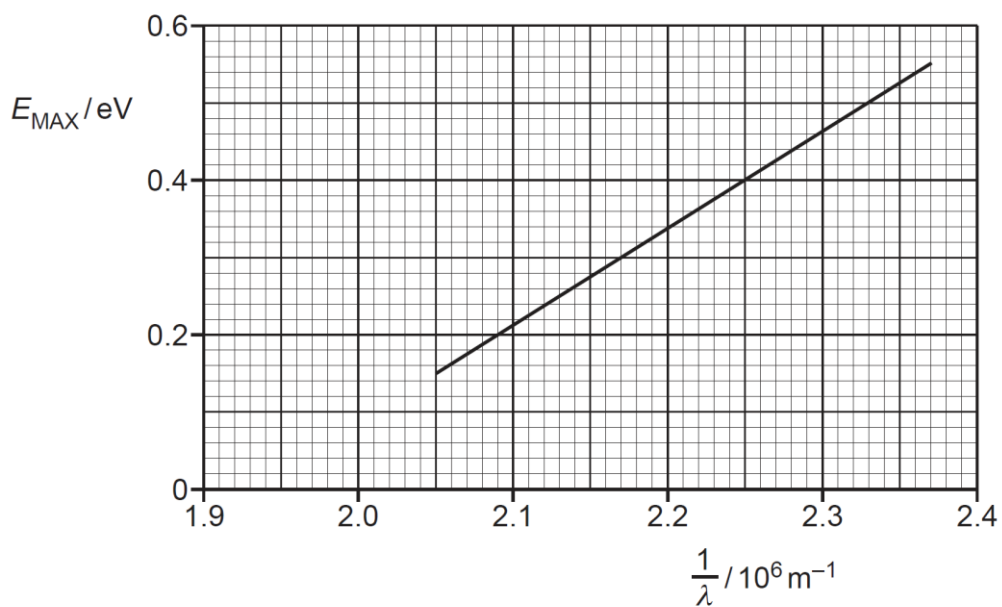


Fig. 6.1

Use the graph to:

- (i) determine the threshold frequency f_0 of the metal.

$f_0 = \dots\dots\dots$ Hz [2]

[Turn over

- (ii) determine a value for the Planck constant h . Explain your working clearly.

$$h = \dots\dots\dots \text{J s} \quad [3]$$

- (c) The electromagnetic radiation is now incident on a metal with a larger work function energy than the metal in (b).

On Fig 6.1, sketch the variation with $\frac{1}{\lambda}$ of E_{MAX} . [1]

- (d) Infrared radiation of the same intensity is now incident on the same metal surface used in (b).

Explain why no electrons are emitted from the metal surface.

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 [2]

[Total: 11]

7 Read the passage and answer the questions that follow.

Zircon (ZrSiO_4) crystals found in rocks serve as reliable timekeepers for determining the age of geological formations. These crystals readily incorporate uranium atoms into their crystal lattice during formation but strongly exclude lead. As a result, any lead found in a zircon crystal can be assumed to be the product of radioactive decay, making the crystal an effective record of the time that has passed since it solidified.

Two uranium decay chains are used in zircon dating: uranium-238 (U-238) decaying to lead-206 (Pb-206), and uranium-235 (U-235) decaying to lead-207 (Pb-207). These decay processes follow predictable rates, governed by their half-lives: 4.47 billion years for U-238 and 704 million years for U-235. By measuring the ratio of lead to uranium isotopes in a zircon, geologists can determine its age, and thus the age of the rock in which it was found.

The age of a sample of zircon can be derived from the radioactive decay equation and the measured ratio of the lead to uranium isotopes $\frac{D}{N}$. For each parent isotope, the number of daughter atoms D accumulated over time is given by:

$$D = N_0 - N$$

where N_0 is the initial number of the parent atom and N is the number of remaining parent atoms.

When both decay systems (U-238 to Pb-206 and U-235 to Pb-207) are measured in a single zircon sample, the results can be plotted on a Concordia diagram—a graph of the isotopic ratios $\frac{\text{Pb-206}}{\text{U-238}}$ against $\frac{\text{Pb-207}}{\text{U-235}}$. The curve on this graph, known as the Concordia curve, represents points where both decay systems yield the same age, as shown in Fig. 7.1.

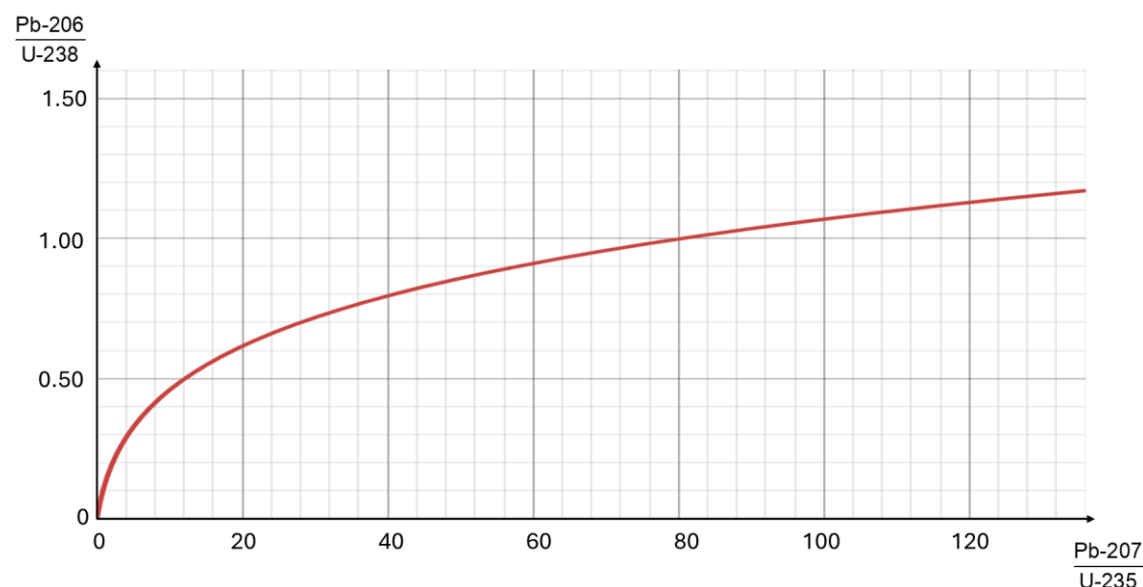


Fig. 7.1

A zircon that has remained isolated from chemical changes since its formation will have ratios of isotopes that lie on this curve, and its age can be confidently determined. If the sample has been altered by natural processes, the resulting isotopic ratios will not be on the curve, indicating that further analysis is required.

To determine these isotopic ratios, geologists use a technique called Secondary Ion Mass Spectrometry (SIMS). In SIMS, a focused primary ion beam (typically O^- or Cs^+) bombards the zircon crystal, releasing atoms from its surface. Some of these atoms are ionised, forming secondary ions that include the uranium and lead isotopes of interest. These ions are then accelerated through a potential difference of 10 kV, gaining kinetic energy as they do so.

After acceleration, the ions enter a uniform magnetic field of 0.75 T that is perpendicular to their velocity. The magnetic force causes the ions to move in circular arcs, with their radius determined by their mass-to-charge ratio. The mass spectrometer thus separates the ions by isotope, as ions like $^{206}Pb^+$ and $^{238}U^+$ follow different trajectories and strike the detector at different positions. The relative intensities of the ion signals are used to calculate the isotopic ratios. Fig. 7.2 below shows the path of the ions in a mass spectrometer.

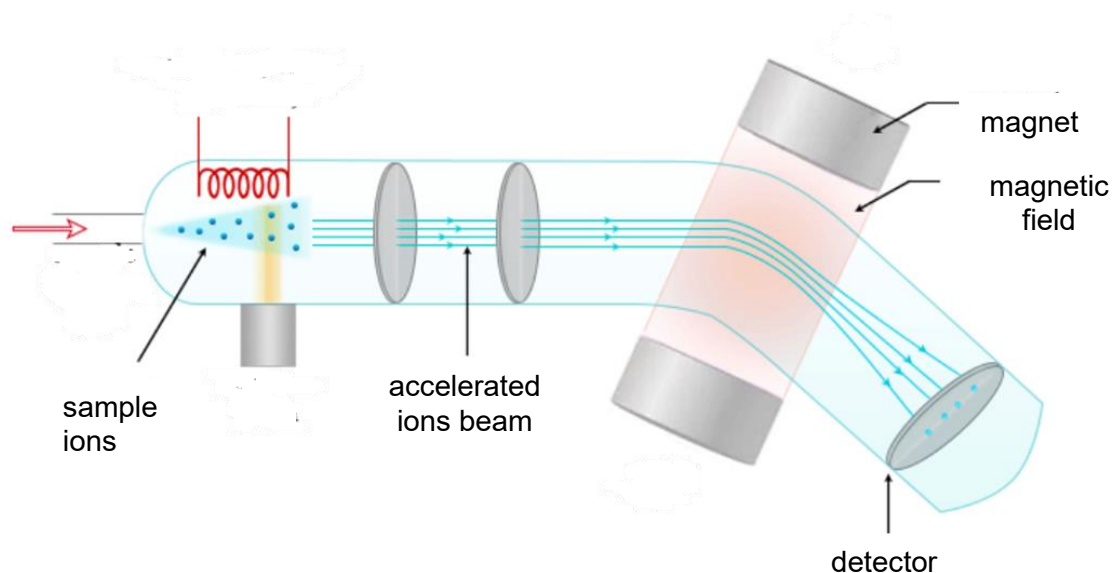


Fig. 7.2

SIMS allows highly precise measurement of isotope ratios in microscopic regions within a single zircon grain. By comparing these measured ratios with those expected from known decay rates and plotting the results on the Concordia diagram, geologists can derive robust and accurate age estimates—often within a few million years—even for samples that are over 4 billion years old.

- (a) Explain, using the ratio of daughter to parent nuclei, why isotopes with long half-lives are more suitable than those with short half-lives for dating very old geological samples.

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.....

..... [1]

(b) Uranium-238 decays into stable lead-206 via a series of alpha and beta decays.

- (i) In the first step of the uranium-238 decay chain, a uranium-238 nucleus undergoes alpha decay to form a thorium-234 nucleus and an alpha particle.

The atomic masses of the nuclei involved are:

Mass of uranium-238 nucleus = 238.0508 u

Mass of thorium-234 nucleus = 234.0436 u

Mass of helium-4 nucleus = 4.0026 u

Calculate the energy released in this decay in MeV.

energy released = MeV [4]

- (ii) Calculate the total number of alpha and beta decays in the decay chain of uranium-238 (${}^{238}_{92}\text{U}$) to lead-206 (${}^{206}_{82}\text{Pb}$).

number of alpha decays =

number of beta decays = [3]

- (c) (i) Using the radioactive decay equation and the information in the passage, show that the age of a sample of zircon t with a ratio of daughter to parent isotopes $\frac{D}{N}$ is given by

$$t = \frac{1}{\lambda} \ln\left(\frac{D}{N} + 1\right)$$

where λ is the decay constant of the parent isotope.

[2]

- (ii) In a particular sample of zircon found in Western Australia, the ratio of lead-206 to uranium-238 isotope was found to be 0.978.

Determine the age of the zircon sample t in years.

$t = \dots\dots\dots$ years [2]

- (iii) The ratio of lead-207 to uranium-235 ratio for the same sample was measured to be 76.0. Using the Concordia diagram (Fig 7.1), determine whether the two ratios agree on the age of this zircon sample.

.....

 [2]

- (iv) Natural processes may change the number of lead or uranium nuclei in a sample. Suggest what changes may have occurred to the number of nuclei in a certain sample for it to have a data point that lies below the Concordia curve.

.....
 [1]

- (d) (i) The ions from a zircon crystal in a SIMS device are accelerated through a potential difference of V before entering a uniform magnetic field of magnetic flux density B where they move in a circular arc of radius r .

Show that the mass to charge ratio of the ions $\frac{m}{q}$ is given by

$$\frac{m}{q} = \frac{B^2 r^2}{2V}$$

[3]

- (ii) For the SIMS described in the passage, determine the expected arc radius r for a singly charged $^{206}\text{Pb}^+$ ion.

The mass of a $^{206}\text{Pb}^+$ ion is 205.974 u.

$r = \dots\dots\dots$ m [2]

- (iii) State and explain whether the arc radius of the singly charged $^{238}\text{U}^+$ ion will be larger or smaller than that of the lead ion from (d)(ii).

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..... [2]

[Total: 22]

END OF PAPER