EUNOIA JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATIONS 2025
General Certificate of Education Advanced Level
Higher 2

CANDIDATE NAME	

CIVICS GROUP	2	4	-			REGISTRATION NUMBER		

PHYSICS
Structured Questions

9749/02

September 2025

2 hours

READ THESE INSTRUCTIONS FIRST

Write your name, civics group and registration number on all the work you hand in.
The use of an approved scientific calculator is expected where appropriate.
Answer **all** questions.

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 paper clips, highlighters, glue or correction fluid.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Q1	6
Q2	11
Q3	5
Q4	7
Q5	9
Q6	8
Q7	6
Q8	8
Q9	20
s.f.	
P2 Total	80

This document consists of **24** printed pages.

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,	$T / \text{K} = T / {}^\circ\text{C} + 273.15$
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.	$v = v_0 \cos \omega t$ $= \pm \omega \sqrt{\left(x_0^2 - x^2\right)}$
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,	$V = \frac{Q}{4\pi\varepsilon_0 r}$
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	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

1 A student proposes that the speed v of a sound wave through a gas of pressure P and density ρ is given by the equation

$$v = \sqrt{\frac{kP}{3\rho}}$$

where k is a constant with no unit.

An experiment is performed to determine the value of k. The data from the experiment are shown in Table 1.1.

Table 1.1

quantity	value	
v	3.3×10^2 m s^{-1}	percentage uncertainty = $\pm$ 8%
P	9.9×10^4 Pa	fractional uncertainty = $\pm$ 0.07
ρ	1.29 kg m^{-3}	absolute uncertainty = 0.09 kg m^{-3}

(a) Use data from Table 1.1 to calculate k.

k = ... [1]

(b) Use your answer in **(a)** and data from Table 1.1 to determine the value of k, with its absolute uncertainty, to an appropriate number of significant figures.

k = ... ± .... [3]

(c) It is proposed in that in the presence of wind, the actual speed u of the sound wave of frequency f is

$$u = v + fA$$

Derive the unit for A.

unit = ………………………… [2]

[Total: 6]

2 (a) An Olympic diver stands on a platform above a pool of water, as shown in Fig. 2.1.

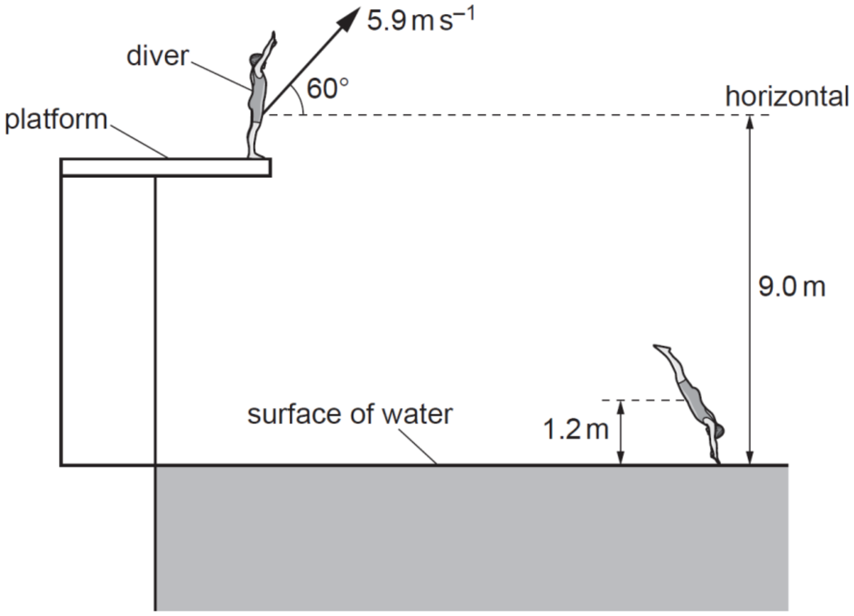

Fig. 2.1 (not to scale)

When the diver is on the platform his centre of gravity is a vertical height of 9.0 m above the surface of the water. The diver jumps from the platform with a velocity of 5.9 m s^{-1} at an angle of 60° to the horizontal.

Air resistance is negligible.

When the diver hits the surface of the water, his centre of gravity is a vertical height of 1.2 m above the surface of the water.

(i) Calculate the time it takes him to hit the surface of the water.

time = ... s [2]

(ii) Calculate the angle from the water surface when he hits the surface of the water.

angle = …………………………… ° [3]

(b) The diver in **(a)** enters the water.

(i) Explain the why the resultant force acting on the diver in decreases in the water as he moves downwards.

…………………………………………………………………………………………...

…………………………………………………………………………………………...

…………………………………………………………………………………………...

…………………………………………………………………………………………...

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

(ii) The diver has a volume of 7.5×10^{-2} m^3. The density of the water is 1.0×10^3 kg m^{-3}.

Show that the upthrust acting on the diver when he is entirely underwater is 740 N.

[1]

(iii) At a particular instant when the diver is entirely underwater his horizontal velocity is zero. The viscous drag force acting on him at this instant is 950 N vertically upwards. The diver has a mass of 78 kg.

Determine the magnitude and direction of the acceleration of the diver.

acceleration = ... m s^{-2}

direction ....

[3]

[Total: 11]

3 **(a)** State the principle of moments.

………

………

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

(b) A uniform rod of weight 1000 N rests at angle of 30° to the ground. It is in equilibrium when supported by tension *T* which acts 47° from the horizontal, as shown in Fig. 3.1.

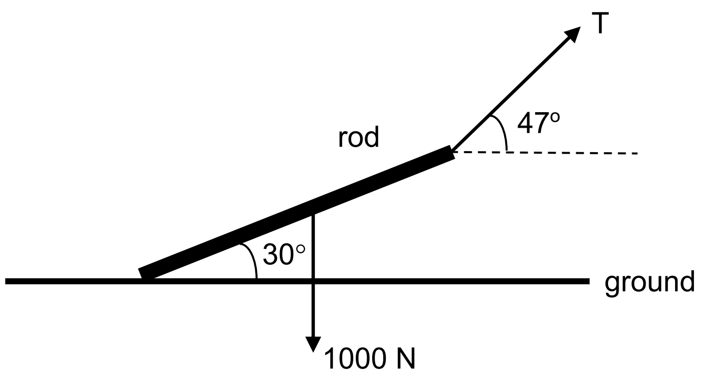

Fig. 3.1

Calculate the tension *T*.

T = ... N [3]

[Total: 5]

4 In Fig. 4.1 below, a trolley of mass 0.50 kg moves with a velocity 2.0 m s^{-1} towards a stationary pendulum bob of mass 0.20 kg, which is hung on a light string at a distance of 1.5 m from the ceiling. The trolley collides elastically with the pendulum bob and the pendulum bob then swings upwards.

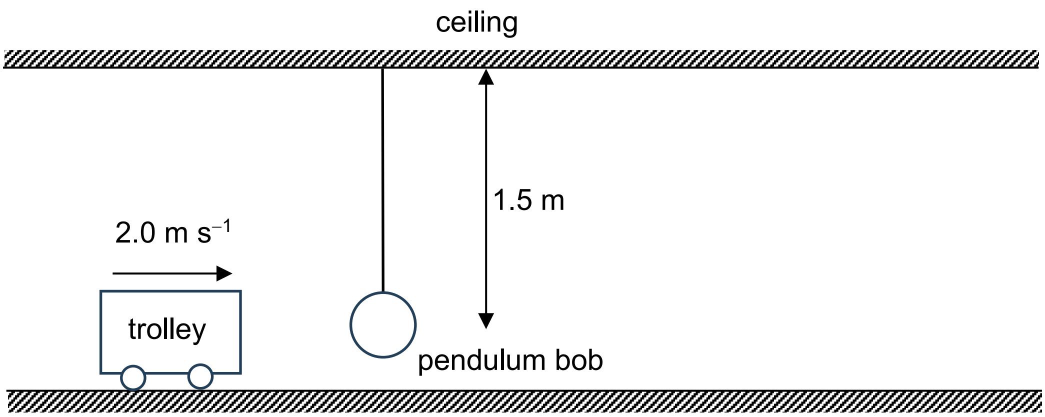

Fig. 4.1

(a) Calculate the speed of the pendulum bob immediately after the collision.

speed = ... m s^{-1} [3]

(b) Calculate the maximum angle, measured from the vertical, through which the pendulum bob swings.

maximum angle = ... ° [3]

(c) Use the principle of conservation of linear momentum to explain why the momentum of the bob is not conserved as it swings upwards after the collision.

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

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

[Total: 7]

5 **(a)** State what is meant by *angular velocity*.

....

.... [1]

(b) A spring is used to project a toy car along a track from point X, round a vertical loop, to point Y, as illustrated in Fig. 5.1.

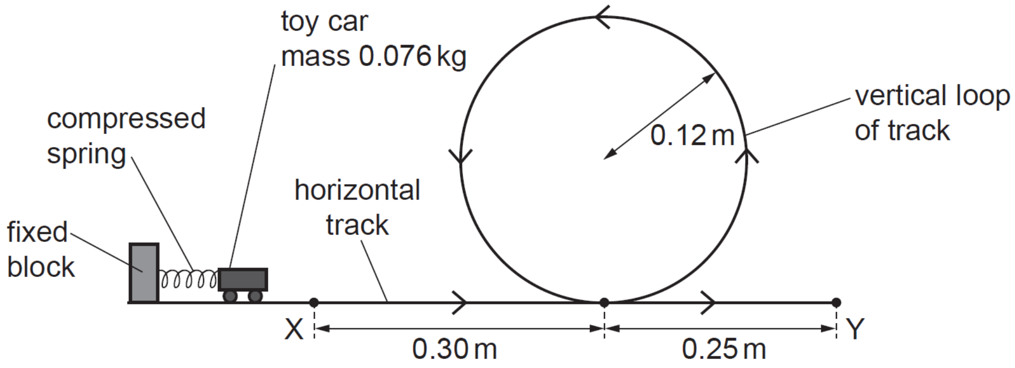

Fig. 5.1

The spring is initially given a compression of 16 cm. The car of mass 0.076 kg is held against one end of the compressed spring. When the spring is released, it projects the car forward. The car leaves the spring at point X with kinetic energy that is equal to the initial elastic potential energy of the compressed spring.

Assume that friction and air resistance are negligible.

(i) Calculate the minimum speed needed at the top of the circular path so that the toy car does not fall off the track.

minimum speed = ... m s^{-1} [3]

(ii) Calculate the value of the spring constant needed for the toy car to have the speed found in **(b)(i)** when it is at the top of the path.

spring constant = ………………………… N m^{-1} [3]

(c) In practice, a resistive force due to friction and air resistance acts on the car so that its kinetic energy at Y is 0.23 J less than its kinetic energy at X.

Determine the average resistive force acting on the car for its movement from X to Y.

average resistive force = ... N [2]

[Total: 9]

6 A sphere of mass 1.6×10^{-10} kg has a charge of +0.27 nC. The sphere is in a uniform electric field that acts vertically upwards, as shown in the side view in Fig. 6.1.

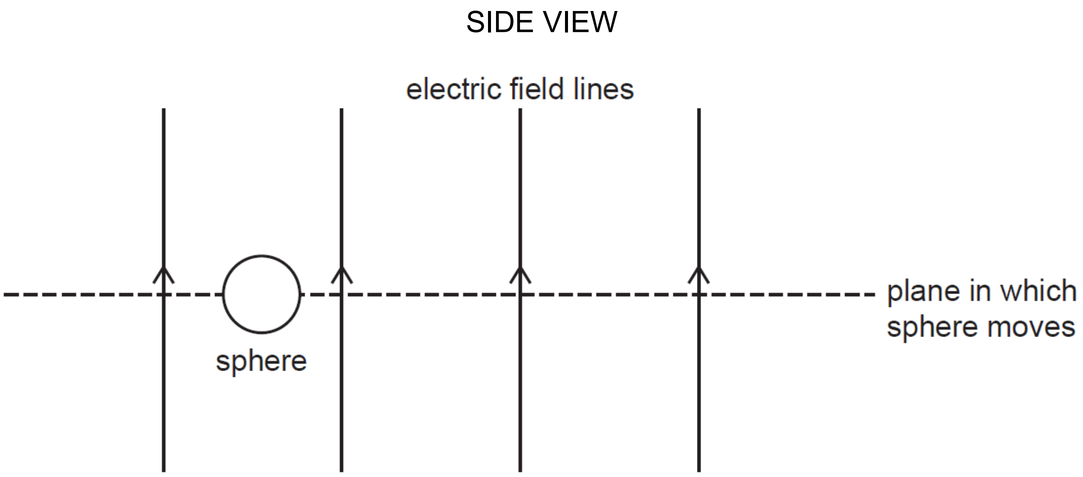

Fig. 6.1

The force exerted on the sphere by the electric field causes the sphere to remain at a fixed vertical height in a horizontal plane.

There is a uniform magnetic field in the region of the electric field. The sphere moves at a speed of 0.78 m s^{-1} in the horizontal plane. The magnetic field causes the sphere to move in a circular path of radius 3.4 m, as shown in the view from above in Fig. 6.2.

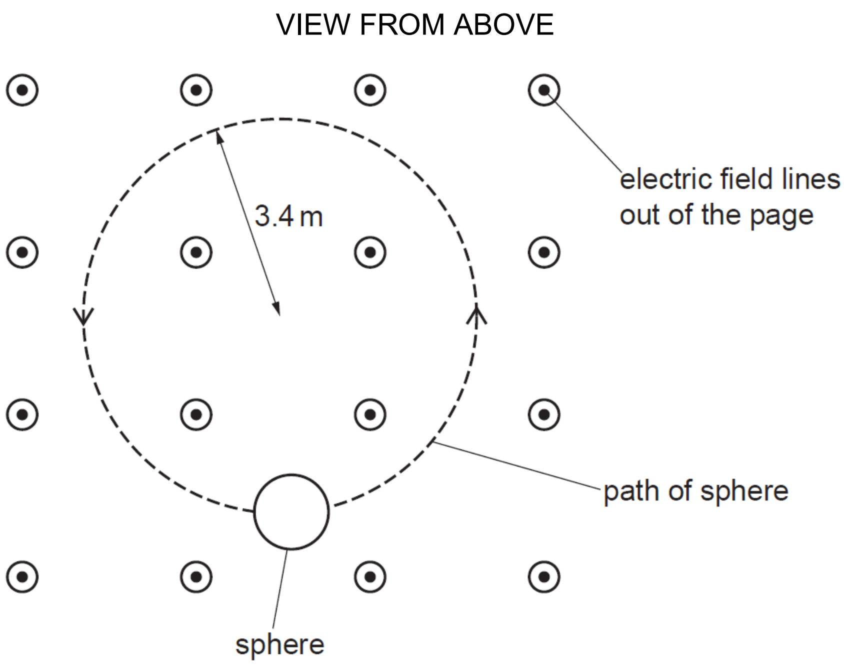

Fig. 6.2

(a) **(i)** State the direction of the uniform magnetic field from the SIDE VIEW in Fig. 6.1.

.... [1]

(ii) Explain why the sphere moves at constant speed in the circular path.

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

…………………………………………………………………………………………

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

(b) Calculate the strength of the uniform electric field.

electric field strength = ... N C^{-1} [2]

(c) By considering the magnetic force on the sphere, show that the flux density of the uniform magnetic field is 0.14 T.

[3]

[Total: 8]

7 Fig. 7.1 shows the lowest four energy levels of an electron in an isolated atom.

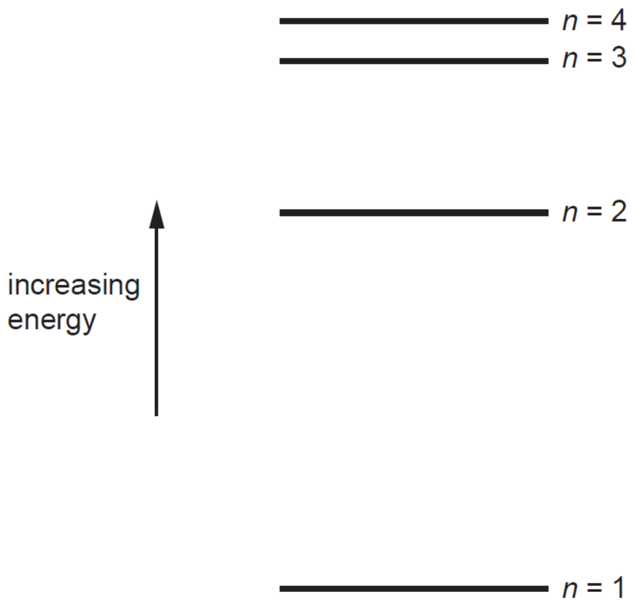

Fig. 7.1 (drawn to scale)

Fig. 7.2 shows the lines in the emission spectrum of the atom that correspond to the transitions of the electron from n = 3 to n = 1 and from n = 4 to n = 1.

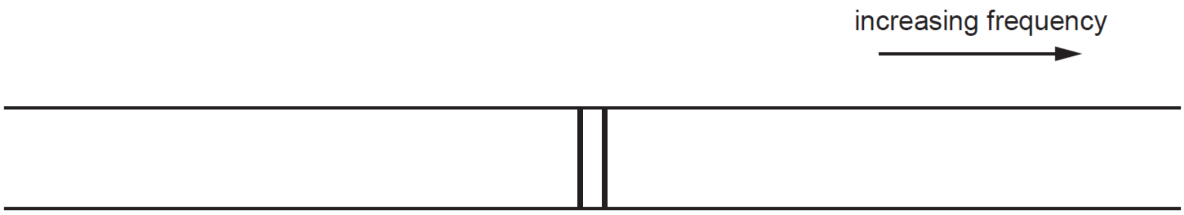

Fig. 7.2

(a) Explain, with reference to photons, why there is a single frequency of electromagnetic radiation that corresponds to each of these transitions.

....

....

.... [2]

(b) **(i)** On Fig. 7.2, draw a line that corresponds to the transition of the electron from n = 2 to n = 1.

Label this line A.

[1]

(ii) On Fig. 7.2, draw a line that corresponds to the transition of the electron from n = 3 to n = 2.

Label this line B.

[1]

(c) The frequency of radiation represented by line A is f_A.
The frequency of radiation represented by line B is f_B.
The energy of the ground state (n = 1) is E_1.

Determine an expression, in terms of f_A, f_B, E_1 and the Planck constant h, for the energy E_3 of the energy level n = 3.

E_3 = ... [2]

[Total: 6]

8 The maximum kinetic energy E_{MAX} of electrons emitted from a metal surface is determined for different wavelengths λ of the electromagnetic radiation incident on the surface.

The variation with $\frac{1}{\lambda}$ of E_{MAX} is shown in Fig. 8.1.

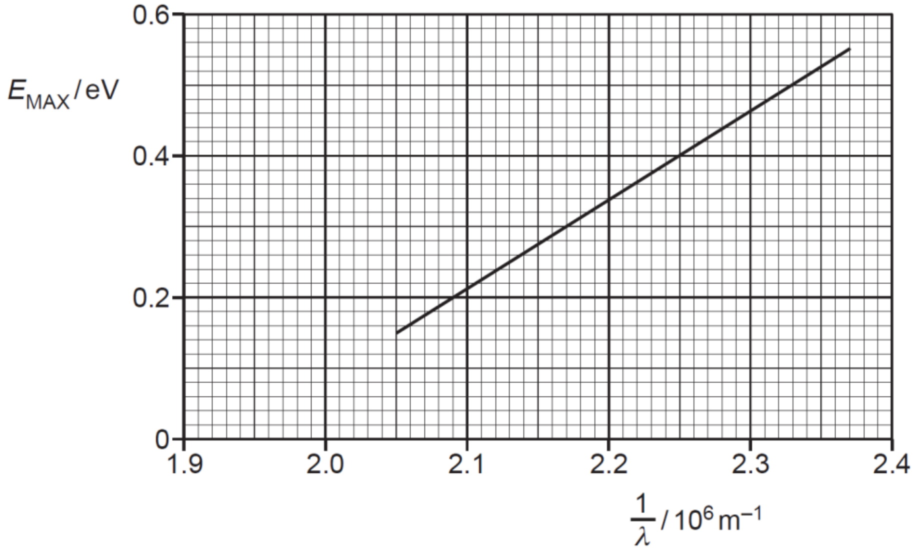

Fig. 8.1

(a) Use the gradient of the line on Fig. 8.1 to determine a value for the Planck constant h.

Explain your working.

h = ... J s [3]

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

On Fig. 8.1, sketch the variation with $\frac{1}{\lambda}$ of E_{MAX}. Label this line X. [1]

(c) The work function energy in eV for some metals is given in Table 8.1.

Table 8.1

metal	work function / eV
tungsten	4.49
magnesium	3.68
potassium	2.40

Determine the metal used in the experiment. Show your working.

....

.... [3]

(d) The intensity of the electromagnetic radiation for one particular frequency is increased.

State and explain the change, if any, in the rate of emission of photoelectrons.

....

.... [1]

[Total: 8]

9 In 2022, the European Space Agency (ESA) launched the Solar Orbiter, a spacecraft designed to study the Sun's surface and its radiation. The spacecraft operates in an elliptical orbit, with its closest approach (perihelion) at 0.28 AU (1 AU = 1.5×10^{11} m) from the Sun on 15 March 2023. The Solar Orbiter observed a significant solar flare, during which its distance from the Sun varied slightly, affecting the power received by its solar panels.

The Sun emits electromagnetic waves where the power output is approximately 3.8×10^{26} W from these waves, excluding other high-energy particles. The Solar Orbiter's solar panels capture this radiation to power its instruments, with the power received depending on the intensity, panel area, and efficiency.

Radiation pressure P_r due to electromagnetic waves is given by:

$$P_r = \left(\frac{I}{c} + R\right)$$

where I is the intensity, c is the speed of light and R is the reflectivity. $R = 0$ for perfect absorption and $R = 1$ for perfect reflection.

The Sun also emits high-energy particles, including alpha particles from nuclear fusion, contributing to radiation pressure on the spacecraft.

The Solar Orbiter's radiation detector measures alpha particle flux from short-lived isotopes produced in solar flares, such as Nitrogen-13, which undergoes alpha decay with a half-life of 20 minutes and beta-plus decay with a half-life of 10 minutes. Beta-plus decay is a process where a proton in a nucleus transforms into a neutron, releasing a positron ${}^{0}_{+1}e$ and a neutrino. For a given sample size, the probability of an alpha decay is 1% and beta-plus decay is 99%.

During the solar flare, the Solar Orbiter's distance from the Sun varied from 0.28 AU to 0.30 AU over 10 hours due to its orbital motion. Data for the Solar Orbiter is provided in Table 9.1.

Table 9.1

parameter	value
distance from Sun	0.28 AU
solar panel area	6.5 m^2
efficiency of solar panels	28%
radiation detector sensitivity	1.2×10^4 counts s^{-1} GBq^{-1}

Table 9.2 shows the percentage contribution of radiation pressure at perihelion.

Table 9.2

source	percentage contribution (%)
electromagnetic waves	99.8
alpha particles	0.15
other particles (Beta, Protons)	0.050

(a) **(i)** Show that the intensity of solar radiation at the Solar Orbiter's perihelion due to electromagnetic waves is 1.7×10^4 W m^{-2}.

intensity = ……………….………… W m^{-2} [2]

(ii) Determine the power output by the Solar Orbiter's solar panels at perihelion due to electromagnetic waves, accounting for their efficiency. Assume that there is perfect absorption.

power output = ……………….…………… W [2]

(b) Radiation pressure is the force per unit area from momentum transfer by electromagnetic waves or particles.

(i) Show that the radiation pressure exerted by alpha particles on the Solar Orbiter's solar panels at perihelion is 8.5×10^{-8} Pa. Assume that there is perfect absorption.

[1]

(ii) Show that kinetic energy

$$E_k = \frac{p^2}{2m}$$

where p and m refer to the momentum and mass respectively.

[2]

(iii) Alpha particles from solar flares typically have energies of 5.0 MeV upon reaching the Solar Orbiter's solar panels. Use the value in **(b)(i)** and the expression in **(b)(ii)**, determine the rate at which alpha particles are incident on the panels.

rate = ……………………..……… particles s^{-1} [3]

(c) At one point in time, the radiation detector measures a count rate of 3.6×10^5 counts s^{-1} due to Nitrogen-13 decay during a solar flare. Calculate the activity of the Nitrogen-13 source in GBq.

activity = ……………………………… GBq [2]

(d) A sample of 2.2×10^{-11} kg of Nitrogen-13 is collected for a study.

(i) Calculate the decay constants λ_α and λ_β of Nitrogen-13 undergoing alpha decay and beta decay respectively.

λ_α = …………………………… min^{-1} [1]

λ_β = …………………..………… min^{-1} [1]

(ii) Show that the effective decay constant λ_{eff} of Nitrogen-13 is $6.9 \times 10^{-2}\ min^{-1}$. [1]

(iii) Using the value in **(d)(ii)**, calculate the number of Nitrogen-13 nuclei remaining after 15 minutes.

number of nuclei = ………………………………… [3]

(iv) $^{13}_{7}N$ decays to form a stable isotope $^{13}_{6}C$. Write the nuclear equation for this decay process.

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

(e) Suggest why the Solar Orbiter's power output from its solar panels varies significantly during its orbit around the Sun.

……….

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

[Total: 20]