RIVER VALLEY HIGH SCHOOL
JC 2 PRELIMINARY EXAMINATIONS

H2 PHYSICS 9749 / 2
PAPER 2

12 SEPTEMBER 2022

2 HOURS

CANDIDATE NAME	

CENTRE NUMBER	S					**INDEX NUMBER**					

CLASS	2	1	J		

INSTRUCTIONS TO CANDIDATES

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO.

Read these notes carefully.
Write your name, centre number, index number and class in the spaces at the top of this page and on all work you hand in.

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.

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

*Answer **all** questions.*

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

FOR EXAMINERS' USE	
Paper 2	
1	**/ 5**
2	**/ 7**
3	**/ 10**
4	**/ 6**
5	**/ 12**
6	**/ 8**
7	**/ 12**
8	**/ 20**
Deduction	
Paper 2	**/ 80**

This document consists of **22** printed pages.

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} J K^{-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	$\phi = -GM / r$
temperature	T / K = T / °C + 273.15
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V} < c^2 >$
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,	$V = \frac{Q}{4\pi\varepsilon_0 r}$
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** the questions in the space provided.

1 **(a)** State what is meant by a *random error*?

…………………………………………………………………………………………

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

(b) A ship at sea is travelling with a velocity of 13 m s^{-1} in a direction 35° east of north in still water, as shown in Fig. 1.1.

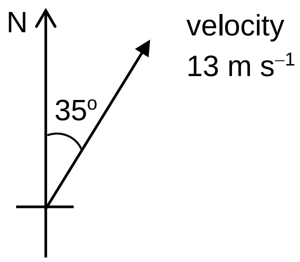

Fig. 1.1

(i) Calculate the north component of the ship's velocity.

north component of velocity = ... m s^{-1} [1]

(ii) The ship's velocity is measured with an uncertainty of $\pm$ 10 %. Its direction is measured with an uncertainty of $\pm$ 1°.

Determine the north component of the velocity with its associated uncertainty.

north component of velocity = ... $\pm$ .... m s^{-1} [3]

2 **(a)** Explain what is meant by a system is in *equilibrium*.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

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

(b) In a children's game, small balls are thrown at wood blocks in order to turn them over. One such block, of mass 300 g, with each side of length 10 cm, is shown in Fig. 2.1 below.

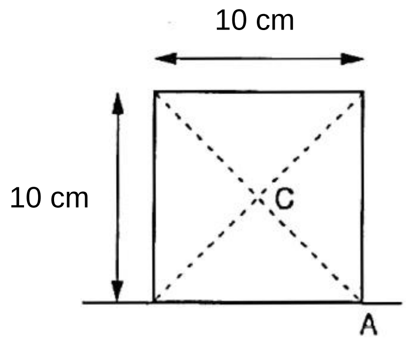

Fig. 2.1

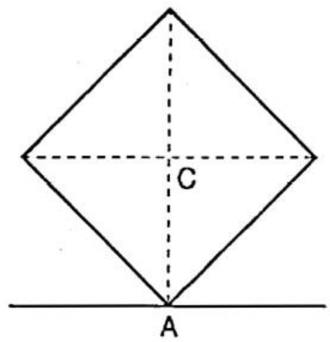

Fig. 2.2

In order to turn the block over, the centre of gravity C must be raised such that that C is vertically above the corner A, as shown in Fig. 2.2.

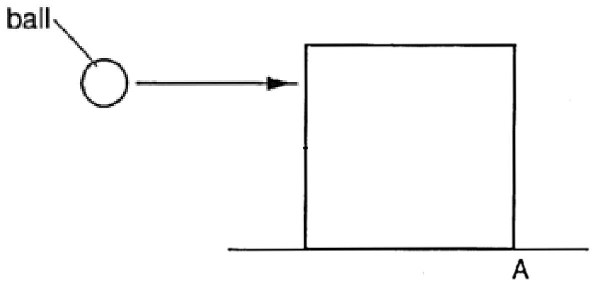

Fig. 2.3

The block is struck by a ball of mass 15 g travelling horizontally 1.0 cm below the top surface of the block as shown in Fig. 2.3. The collision is perfectly elastic and, without sliding, the block turns about the corner A.

(i) Label on Fig. 2.3, the forces acting on the block when the ball just hits the block causing it to turn about corner A.

[2]

(ii) Hence or otherwise, determine the minimum force needed for ball to act on the block in order for the block to turn about A.

force = ... N [3]

3 Fig. 3.1 shows a frictionless piston-cylinder with a built-in heater.

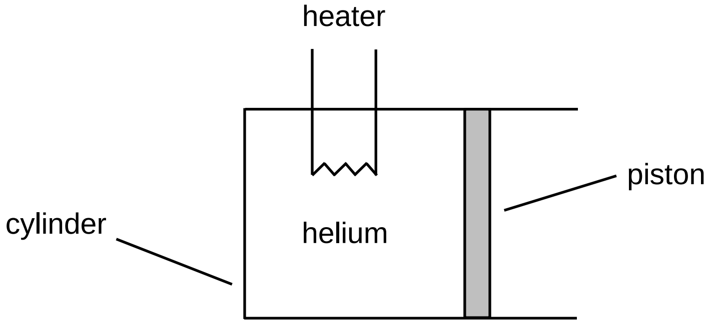

Fig. 3.1

Before the heater is switched on, the cylinder contains 0.60 m^3 of helium gas at pressure 101 kPa and temperature of 28 ^oC. When the heater is switched on for 15 minutes, the gas expands at constant pressure and its temperature rises to 57 ^oC. A heat loss of 7000 J to the surrounding occurs during the process.

Assume the gas behaves like an ideal gas and the heater is rated at 24 W and 120 V.

(a) **(i)** Using the kinetic theory of gases, explain why the volume of the gas expands when it is heated at constant pressure.

....

....

....

....

.... [2]

(ii) On Fig. 3.2, sketch the pressure-volume graph for the process. Label the graph with appropriate values of pressure and volume.

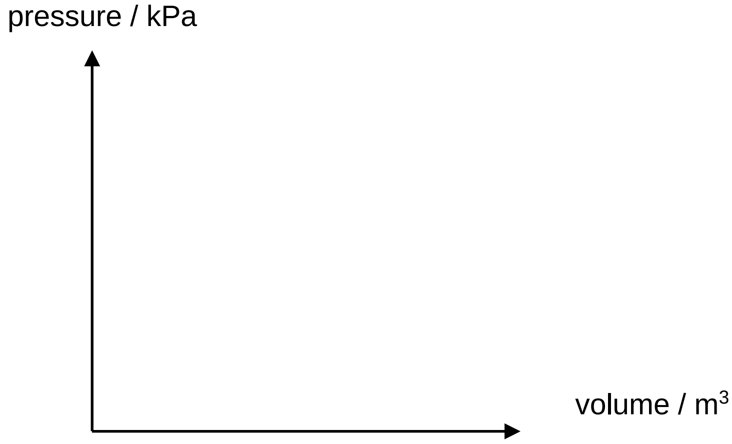

Fig. 3.2

[2]

(iii) Using *first law of thermodynamics*, determine the change in internal energy of the helium gas.

change in internal energy = ... J [3]

(b) The thermodynamic temperature of a gas T is a measure of the average translational kinetic energy of a molecule in the gas. The pressure p of an ideal gas is related to its microscopic quantities by the relationship $pV = \frac{1}{3}Nm\langle c^2 \rangle$ where

V : volume occupied by the gas
N : total number of gas molecues
m : mass of each gas molecule
$\langle c^2 \rangle$: mean square speed of the gas molecules.

(i) By comparing the above relationship with $pV = Nkt$, where k is the Boltzmann constant, show that the average kinetic energy of the molecules is $E = \frac{3}{2}kT$.

[1]

(ii) Hence, calculate the root-mean-square speed of a helium molecule at 57.0 °C. The mass of one mole of helium molecules is 4.00 g.

root-mean-square speed = ... m s^{-1} [2]

4 **(a)** Define *progressive waves.*

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

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

(b) A sound wave is sent from a speaker operating at 1500 W in all directions at a frequency of 850 Hz in a gas.

(i) Fig. 4.1 shows the position of some gas molecules at a particular instant of time. The distance between particles P and Q is 0.600 m.

Fig. 4.1

Calculate the speed of sound in this gas.

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

(ii) Assume that the sound from the speaker strikes the surface of the ear of an adult perpendicularly which has a surface area of 2.1×10^{-3} m^2.

Determine how much power is intercepted by the ear of an adult standing 80.0 m away from the speaker.

power = ... W [3]

5 **(a)** Explain what is meant by *destructive interference*.

....

....

.... [2]

(b) Fig. 5.1 shows two coherent loudspeakers S_1 and S_2 placed 4.0 m apart in an open field on a calm day. D is a detector placed in the same horizontal plane as the loudspeakers. D is placed 12.0 m away from S2. When the loudspeakers are switched on, sound of frequency 1780 Hz is emitted from the two loudspeakers in antiphase. The lines S_1S_2 and S_2D are perpendicular to each other.

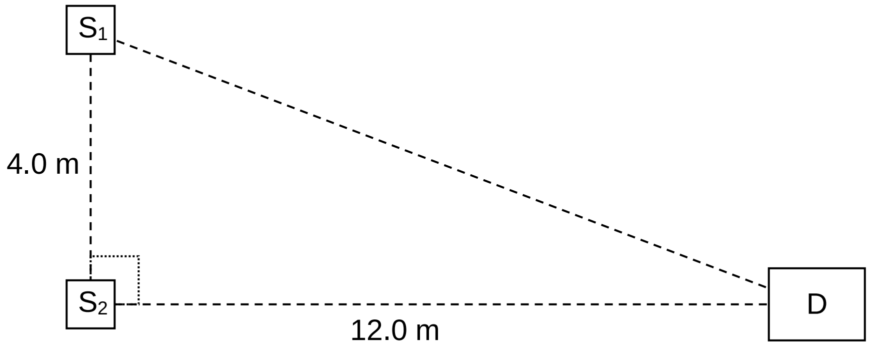

Fig. 5.1

(i) Given that the speed of sound in air is 330 m s^{-1}, calculate the wavelength λ of the sound emitted from S_1 and S_2.

λ = ... m [1]

(ii) Calculate the path difference, in terms of λ, between the sound waves reaching D from S_1 and S_2. You may assume that the two loudspeakers and the detector are point objects.

path difference = ... λ [2]

(iii) Hence, state and explain whether a loud sound would be heard at D.

....

....

....

.... [2]

(c) Light of wavelength 590 nm is incident on a diffraction grating with slits of separation 1.6×10^{-6} m.

(i) Determine the maximum order of the interference pattern that will be observed on a screen placed in front of the grating.

maximum order =...................... [2]

(ii) Another diffraction grating of the same slit separation is placed in front of the original grating such that their slits are perpendicular to one another as shown in Fig. 5.2. A 2-dimensional pattern of bright spots is formed on the screen.

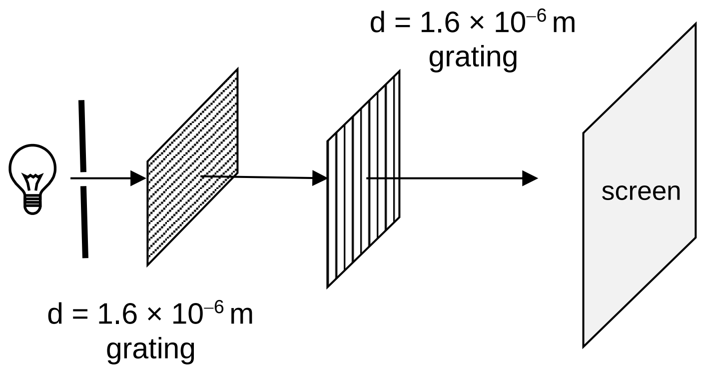

Fig. 5.2

On Fig. 5.3, sketch the pattern obtained, showing clearly the relative separation of the spots.

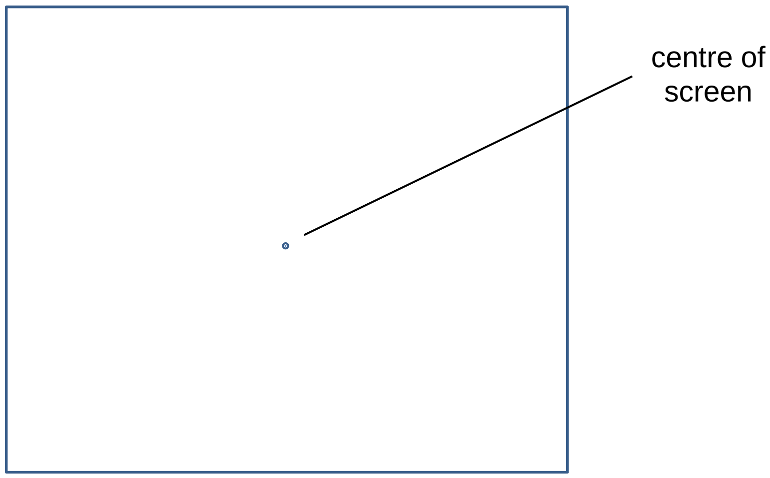

Fig. 5.3

[2]

(iii) State how your answer in **(c)(ii)** will change when a blue light source is used.

....

.... [1]

6 A load resistor R and a diode are connected to an alternating current (a.c.) source as shown in Fig. 6.1.

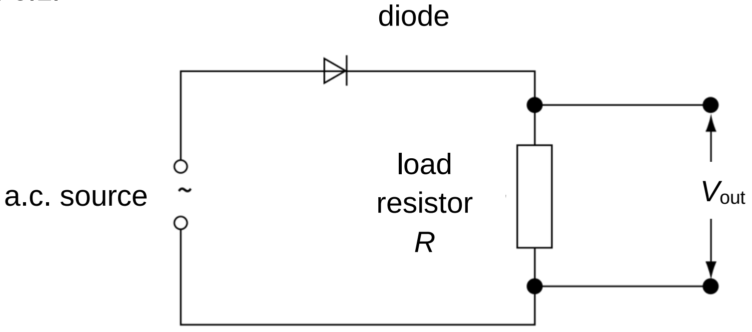

Fig. 6.1

The a.c. source supplies a voltage V, where

$$V = V_0 \sin 100\pi t$$

(a) **(i)** Determine the period of variation of V.

period = ... s [1]

(ii) On Fig. 6.2, sketch the variation with time of V_{out}. Label the time axis.

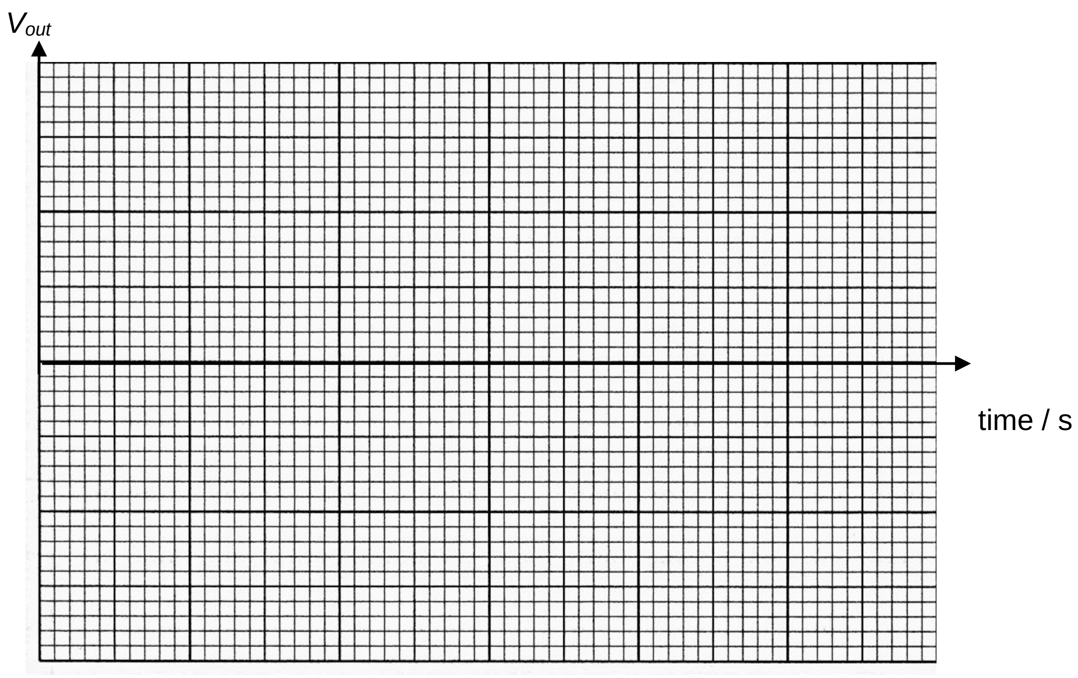

Fig. 6.2

[2]

(b) **(i)** The mean power dissipated in load resistor R is found to be 40 W.

If R = 640 Ω, determine the value of V_0.

V_0 = ... V [3]

(ii) On Fig. 6.3, sketch the variation with time of power dissipated across the load resistor R. Label both axes.

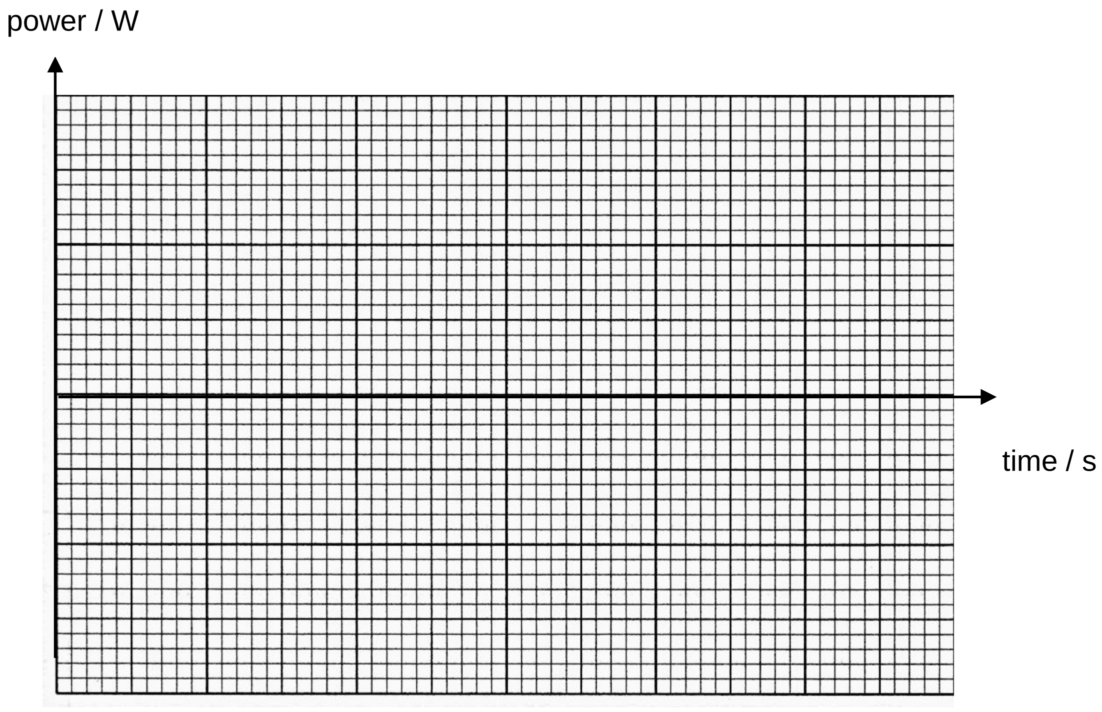

Fig. 6.3

[2]

7 **(a)** In an experiment to investigate the photoelectric effect, a student measures the wavelength λ of the light incident on a metal surface and the maximum kinetic energy E_{max} of the emitted electrons.

(i) The student observes that the emission of electrons is almost instantaneous.

Explain how this observation supports the particulate nature of photon.

....

....

.... [1]

(ii) Suggest why the emitted electrons have a range of energies, from very low to a maximum value of E_{max}.

....

....

.... [1]

(iii) The variation with E_{max} of $\frac{1}{\lambda}$ is shown in Fig. 7.1.

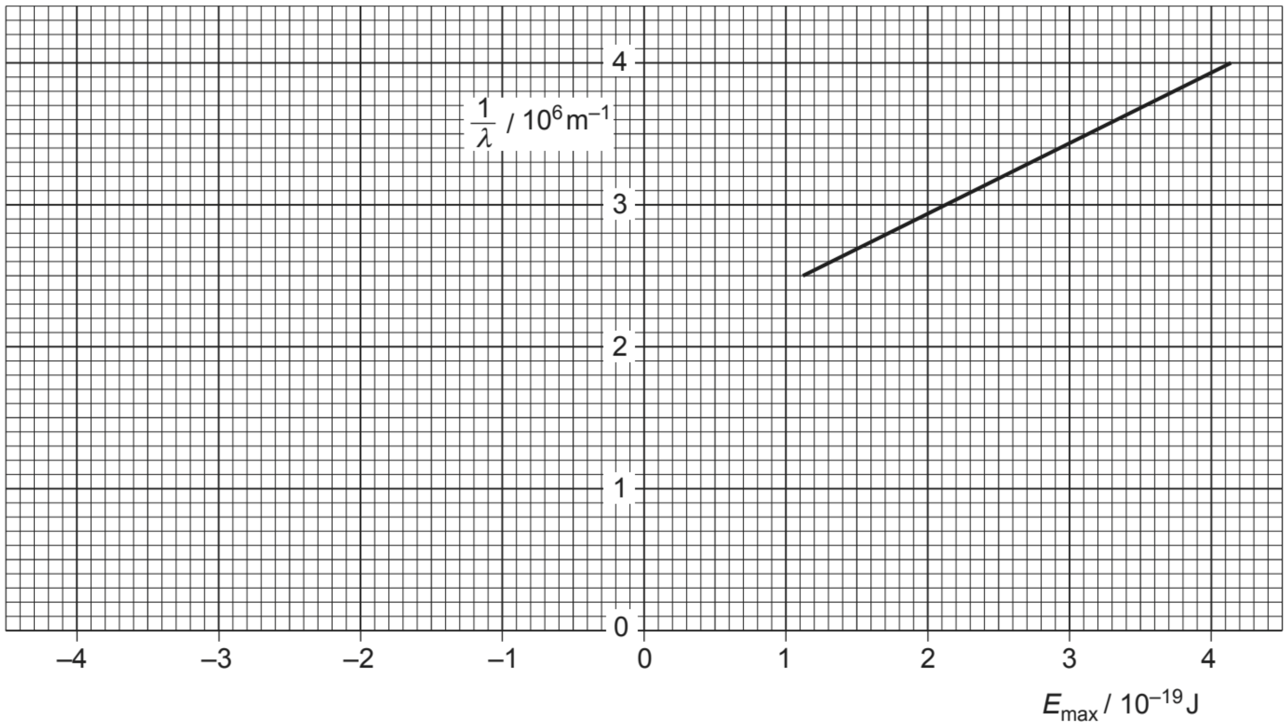

Fig. 7.1

1. Use Fig. 7.1 to determine work function of the metal the student used.

work function = ... J [1]

2. Use Fig. 7.1 to determine a value for the Planck's constant obtained by the student.

Planck's constant = ... J s [2]

(iv) In a separate experiment, the student increases the intensity of a monochromatic light incident on the metal.

State and explain the effect, if any, on E_{max}.

....

....

....

.... [2]

(b) Fig. 7.2 shows three of the energy levels in an isolated hydrogen atom. The lowest energy level is known as the ground state.

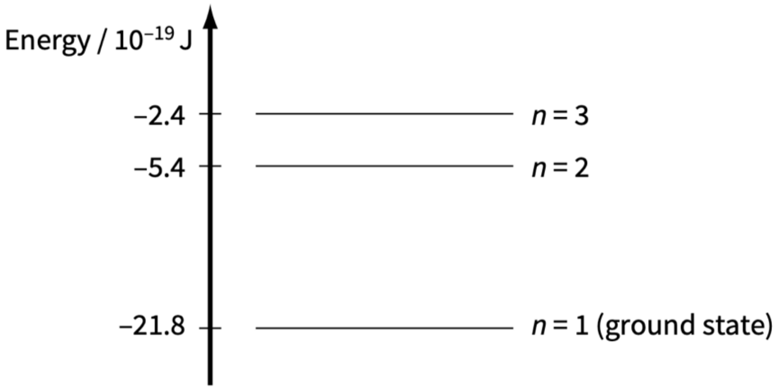

Fig. 7.2

(i) A particular dark spectral line of the hydrogen absorption spectrum has wavelength 663 nm.

Determine the transition that results in this dark line. Show your working clearly.

n = ... to n = ... [3]

(ii) The energy E in each energy levels are labelled with n, the principal quantum number.

Use Fig. 7.2 to show that E is inversely proportional to n^2. Show your working clearly.

[2]

8 While the first nuclear explosion occurred on July 1945, when a plutonium implosion device was tested in New Mexico, it relied on nuclear fission in order to produce the explosive energy. Nuclear fusion on the other hand, is something that laboratories all around the world are still working on for the last few decades. Scientists have managed to produce working nuclear reactors which managed to combine deuterium and tritium for a short period of time. However, they have not yet succeeded in having a working nuclear reactor that is self-sustaining.

Our Sun is the nearest nuclear fusion reactor. To fuse on our Sun, nuclei need to collide with each other at very high temperatures and pressures within the core.

One of two known sets of nuclear fusion reactions by which stars convert hydrogen to helium is the proton-proton chain. It starts with the fusion of two protons into a deuteron which then goes through further reactions as shown in Fig. 8.1.

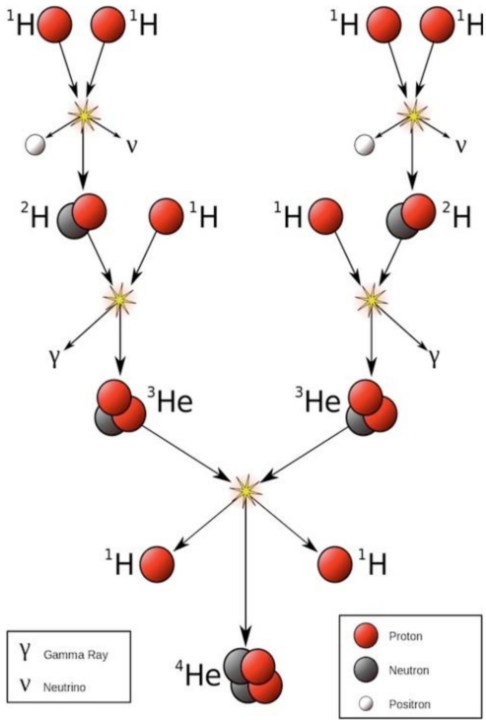

Fig. 8.1

The overall equation is as follows.

$$4\,{}^{1}_{1}\text{H} \rightarrow {}^{4}_{2}\text{He} + 2\,{}^{0}_{+1}\text{e}$$

Our Sun will continue to fuse hydrogen into helium via the proton-proton chain and other reactions until the amount of hydrogen in the core is depleted. Scientists have calculated that based on our Sun's luminosity of about 3.8×10^{26} W and its mass of 2.0×10^{30} kg, it has a predicted lifetime of 10 billion years. When our Sun nears the end of its lifetime, our Sun will grow into in size to become a red giant where it will be become 100 times as large in radius and 1000 times as bright in luminosity.

When our Sun becomes a red giant, it will be able to fuse helium into carbon in its core. Stars that are even more massive will be able to fuse carbon into neon, and into other heavier elements. However even the most massive stars stop fusion when they have an iron core.

(a) **(i)** State one similarity and one difference between nuclear fusion and fission.

Similarity: ……………………………………………………………………………....

……………………………………………………………………………… [1]

Difference: ……………………………………………………………………….....

……………………………………………………………………………… [1]

(ii) Explain what is meant by the term self-sustaining.

………….……………………………………………………………………….....

……………………………………………………………………………… [1]

(iii) Suggest one benefit of nuclear fusion over nuclear fission in terms of power generation.

………….……………………………………………………………………….....

……………………………………………………………………………… [1]

(b) The passage states that nuclei need to collide with each other at very high temperatures and pressure.

Explain why the following are necessary.

(i) High temperatures

……………………………………………………………………………………....

……………………………………………………………………………………....

……………………………………………………………………………… [2]

(ii) High pressures

……………………………………………………………………………………....

……………………………………………………………………………………....

……………………………………………………………………………… [1]

(c) Given that the masses of the atomic particles involved are

m_H = 1.007825 u
m_{He} = 4.002604 u
m_e = 0.000549 u

(i) Determine the difference in mass between the reactants and products in the fusion reaction stated in the passage.

mass = ... kg [2]

(ii) Hence, determine the net energy released in the fusion of four hydrogen nuclei into one helium nuclei.

energy released = ... MeV [1]

(iii) Determine the percentage loss in mass during the fusion.

percentage loss = ... [1]

(iv) Using the mass of the Sun and its luminosity as well as your answers in part **(c)(iii)**, determine the lifespan of our Sun.

Assume that the Sun contained 100% hydrogen at the start and that its core contains 10 % of its mass. Leave your answers to the relevant number of significant figures.

lifespan = ... years [3]

(d) **(i)** In Fig. 8.2, sketch a graph for variation of binding energy per nucleon with nucleon number *A*.

State an approximate value, in MeV for the maximum binding energy per nucleon as well as the corresponding nucleon number.

Fig. 8.2

[3]

(ii) With reference to Fig. 8.2, explain why is it that even the most massive stars stop fusion when they have an iron core.

……………………………………………………………………………………....

……………………………………………………………………………………....

……………………………………………………………………………………....

……………………………………………………………………………… [2]

(iii) However in our universe, it is still possible to find elements with nucleon number higher than iron. Suggest how this is possible.

……………………………………………………………………………………....

……………………………………………………………………………………....

……………………………………………………………………………… [1]

END OF PAPER