DUNMAN HIGH SCHOOL
Preliminary Examination
Year 6

H2 PHYSICS

9749/03

Paper 3   Longer Structured Questions

23 September 2021

2 hours

Candidates answer on the Question Paper

READ THESE INSTRUCTIONS FIRST

Write your centre number, index number, name and class at the top of this page.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Section A
Answer **all** questions.

Section B
Answer any **one** question.

The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or if you do not use appropriate units.

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

For Examiner's Use	
Section A	
1	10
2	8
3	9
4	5
5	8
6	7
7	13
Section B	
8 / 9	20
Total	80

This document consists of **25** printed pages and **1** blank page.

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

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 =	ρgh
gravitational potential,	ϕ =	$-Gm/r$
temperature,	T/K =	$T/^\circ C + 273.15$
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 =	$v_0\cos\omega t$
	=	$\pm\omega\sqrt{x_o^2 - x^2}$
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 =	$\frac{\mu_0 I}{2\pi d}$
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,	λ =	$\frac{\ln 2}{t_{\frac{1}{2}}}$

Section A

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

1 **(a)** Explain what is meant by *acceleration*.

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

(b) A ball is kicked from horizontal ground towards the top of a vertical wall, as shown in Fig. 1.1.

path of ball

ball   *v*   **Fig. 1.1** (not to scale)   wall
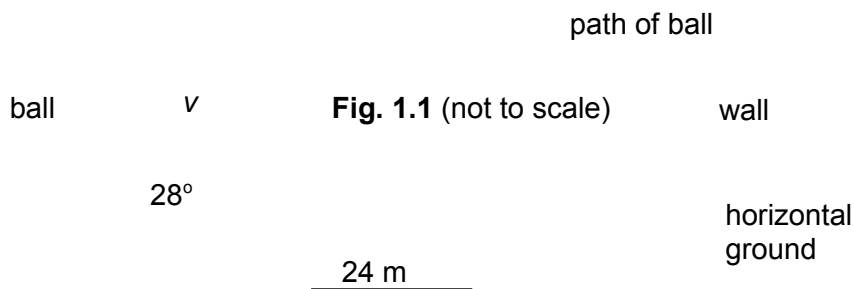
28°

horizontal
ground

24 m

Fig. 1.1 (not to scale)

The horizontal distance between the initial position of the ball and the base of the wall is 24 m. The ball is kicked with an initial velocity *v* at an angle of 28° to the horizontal. The ball hits the top of the wall after a time of 1.5 s. Air resistance may be assumed to be negligible.

(i) Calculate the initial horizontal component v_X of the velocity of the ball.

v_X = ……………………m s^{-1} [1]

(ii) Show that the initial vertical component v_Y of the velocity of the ball is 8.5 m s^{-1}.

[1]

(iii) Calculate the time taken for the ball to reach its maximum height above the ground.

time = …………………… s [2]

(iv) The ball is kicked at time t = 0. On Fig. 1.2, sketch the variation with time t of the vertical component v_Y of the velocity of the ball until it hits the wall. It may be assumed that velocity is positive when in the upward direction.

v_Y / m s^{-1}

[2]

(c) Determine the maximum height of the ball above the ground.

Fig. 1.2   aximum height = …………………… m [2]

(d) A ball of greater mass is kicked with the same velocity as the ball in **(b)**.

State and explain the effect, if any, of the increased mass on the maximum height reached by the ball. Air resistance is still assumed to be negligible.

....

.... [1]

2 (a) Explain what is meant by *weight*.

....

.... [1]

(b) Fig. 2.1 shows a system of two pulleys with one pulley fixed to the ceiling but free to rotate. The other pulley is attached to a load.
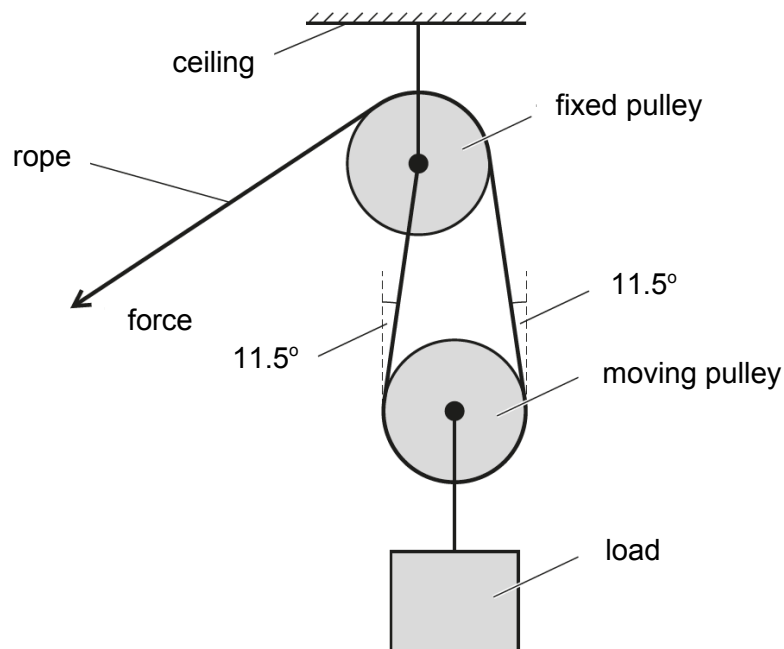

Fig. 2.1 (not to scale)

A force is used to pull the free end of the rope and this lifts the load at a constant speed. The air resistance and friction are negligible. The moving pulley has a mass of 2.40 kg and the load is a box of weight 960 N.

 [Turn over

(i) The tension *T* in the rope is constant along its length. Calculate the tension *T*.

T = …………………… N [3]

(ii) As the rope moves upwards, the tension in the rope changes. Explain how the tension changes.

…..

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

…………………………………………………………………………………………………

[2]

(c) When the pulley system is used, the work done by the force is greater than the gravitational potential energy gained by the load.

(i) Suggest one reason for this.

…..

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

…………………………………………………………………………………………………

[1]

(ii) Suggest one advantage for using the pulley system.

…..

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

………

[1]

3   The volume of air in the cylinder of a car engine is 540 cm^3 at a pressure of 1.1 x 10^5 Pa and a temperature of 27 ^{o}C. The air is suddenly compressed to a volume of 30 cm^3. No heat energy enters or leaves the gas during the compression. The pressure then rises to 6.5 x 10^6 Pa. Assume that air behaves as an ideal gas.

(a) Determine the temperature of the gas after the compression.

temperature = …………………… K [2]

(b) (i) State the *first law of thermodynamics*.

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

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

(ii) Use the law to explain why the temperature of the air changes during compression.

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

……………………………………………………………………………………………

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

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

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

(c) The temperature of a gas depends on the root-mean-square (r.m.s.) speed of its molecules.   Calculate the ratio:

$$\frac{\text{r.m.s. speed of gas molecules at 350 K}}{\text{r.m.s. speed of gas molecules at 300 K}}$$

ratio = …………………… [2]

4   **(a)** A body undergoes simple harmonic motion.

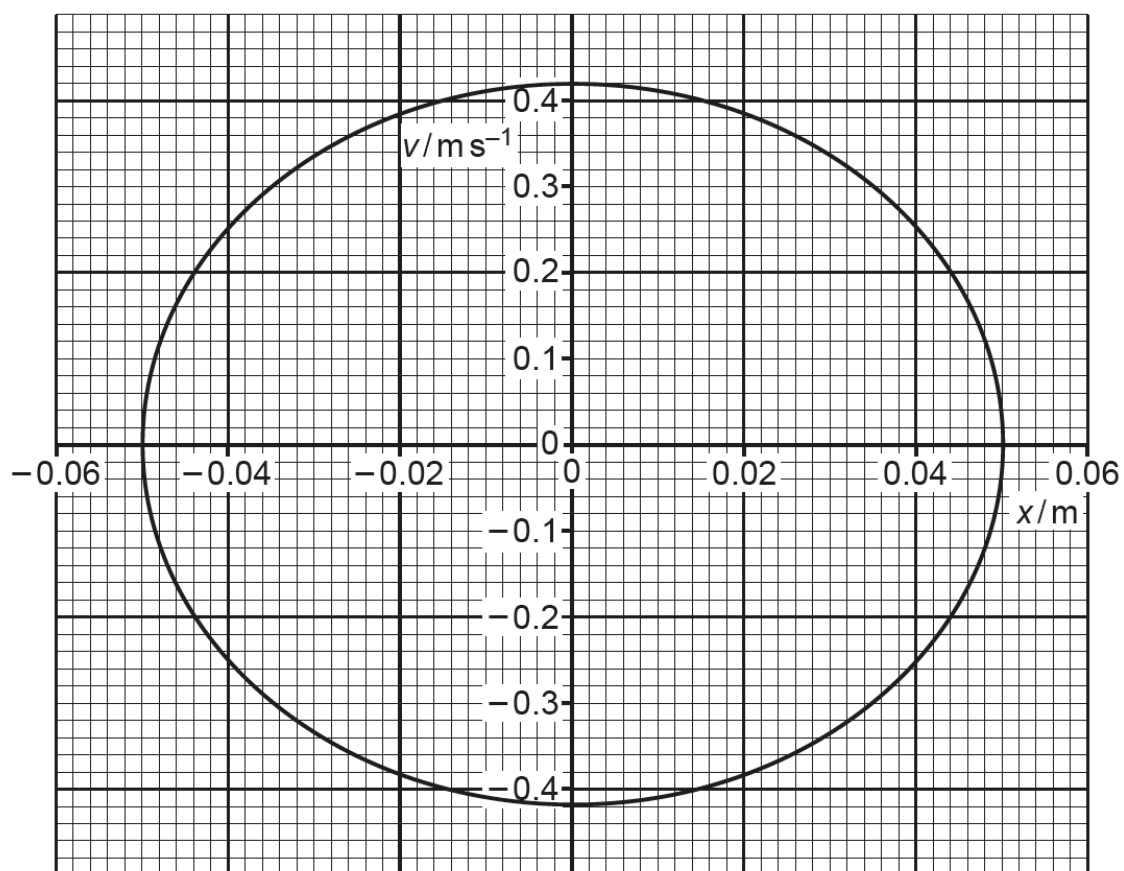The variation with displacement x of its velocity v is shown in Fig. 4.1.

Fig. 4.1

(i)   State the amplitude, x_o, of the oscillations.

x_o = ……………………… m [1]

(ii) Calculate the period, T, of the oscillations.

T = ………………… s [3]

(b) On Fig. 4.1, label a point with letter P where the body has maximum potential energy. [1]

5 **(a)** Explain what is meant by the *principle of superposition.*

....

....

.... [2]

(b) Two identical loudspeakers are driven by the same oscillator of frequency 200 Hz. The loudspeakers are located on a vertical pole, a distance of 4.0 m from each other. A man walks straight towards the lower loudspeaker in a direction perpendicular to the pole, as shown in Fig. 5.1.
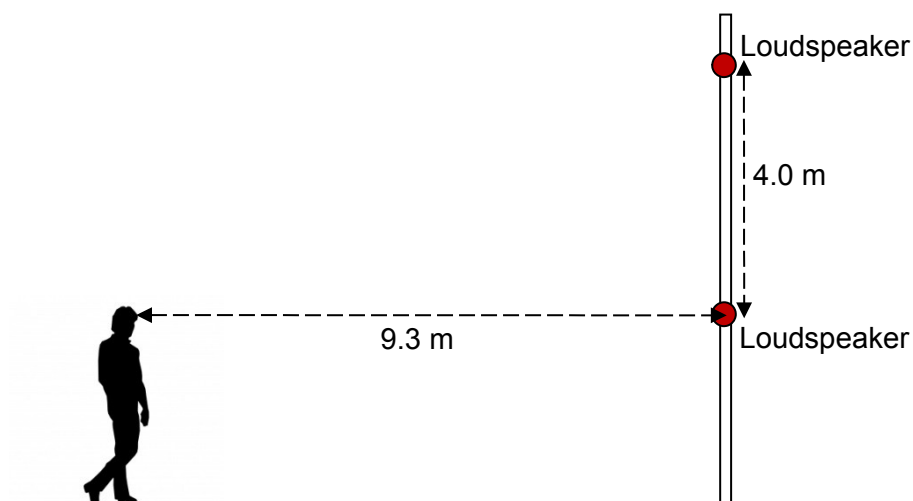

Fig. 5.1 (not to scale)

(i) Calculate the wavelength, λ of the sound emitted by the loudspeaker, if the speed of sound in air is 330 m s^{-1}.

λ = ………………… m [1]

(ii) Determine whether the man will hear a maximum or minimum in sound intensity when he is 9.3 m from the pole. You may ignore any sound reflection from the ground.

[3]

(iii) State two changes that can be made to the set-up in Fig. 5.1 in order to increase the number of intensity fluctuations detected by the man as he walks towards the pole.

1. ....

....

2. ....

....[2]

6 **(a)** Define *electric field strength.*

....

.... [1]

(b) An electron is travelling in a straight line through a vacuum with a constant speed of 1.5×10^7 m s^{-1}. The electron enters a uniform electric field at point A, as shown in Fig. 6.1.

uniform
electric field

electron speed
1.5×10^7 m s^{-1}

Fig. 6.1

The electron continues to move in the same direction until it is brought to rest by the electric field at point B. Distance AB is 2.0 cm.

(i) State the direction of the electric field.

.....

....[1]

(ii) Calculate the magnitude of the deceleration of the electron in the field.

deceleration = …………………… m s^{-2} [2]

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

electric field strength = …………………… V m^{-1} [2]

(c) The electron is at point A at time t = 0.

On Fig. 6.2, sketch the variation with time t of the velocity v of the electron until it reaches point B. Numerical values of v and t do not need to be shown.
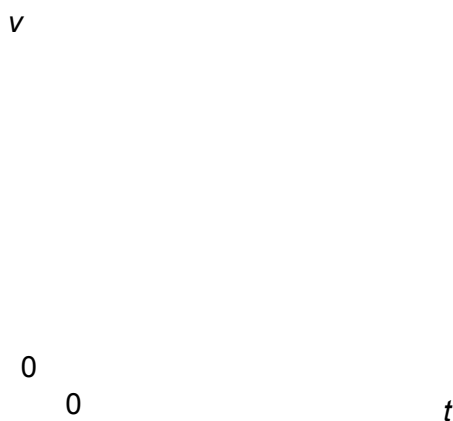
[1]

v

0

0   t

Fig. 6.2

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

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

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

(b) A binary star system consists of two stars S_1 and S_2, each in a circular orbit about a point P, as shown in Fig. 7.1. The two stars rotate with the same angular velocity ω.
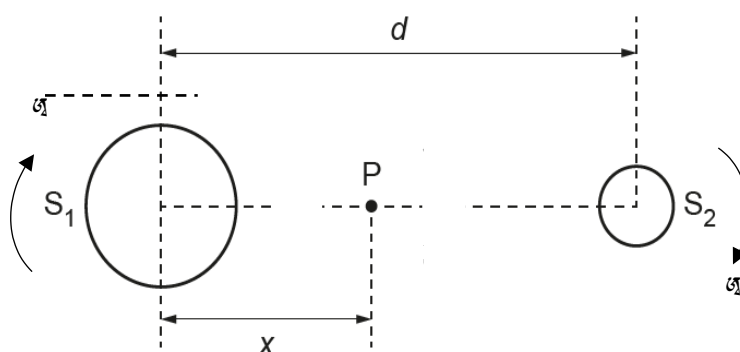

Fig. 7.1

The separation d of the centres of S_1 and S_2 is 1.8×10^{12} m. Point P is at a distance x from the centre of star S_1. The period of rotation of the stars is 44.2 years.

(i) Calculate ω.

ω = …………………… rad s^{-1} [2]

(ii) Show that the ratio of the masses of the stars is given by

$$\frac{\text{mass of } S_1}{\text{mass of } S_2} = \frac{d - x}{x}$$

[2]

**(iii)** The ratio in **(ii)** is 1.5. Determine the mass of S$_1$.

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mass of S_1 = ……………………. kg [4]

(c) **(i)** Define *gravitational potential* at a point.

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

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

(ii) An isolated solid sphere of radius r may be assumed to have its mass M concentrated at its centre. The magnitude of the gravitational potential at the surface of the sphere is $\hat{\phi}$.

On Fig. 7.2, show the variation of the gravitational potential with distance d from the centre of the sphere for values of d from r to $4r$.
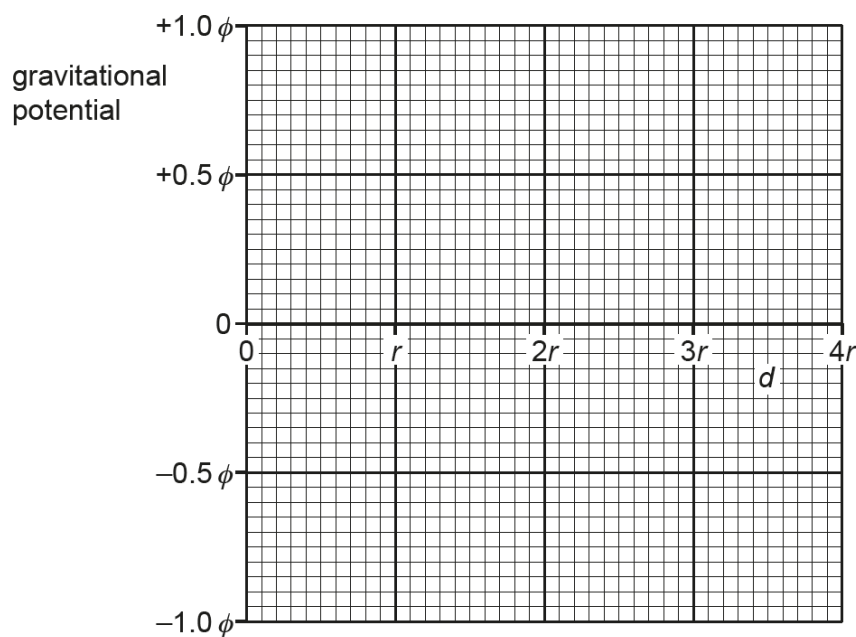
[2]

Fig. 7.2

Section B

Answer **one** question from this section in the spaces provided.

8   **(a)**   The photoelectric effect may be represented by the equation

photon energy = work function energy + maximum kinetic energy of electron.
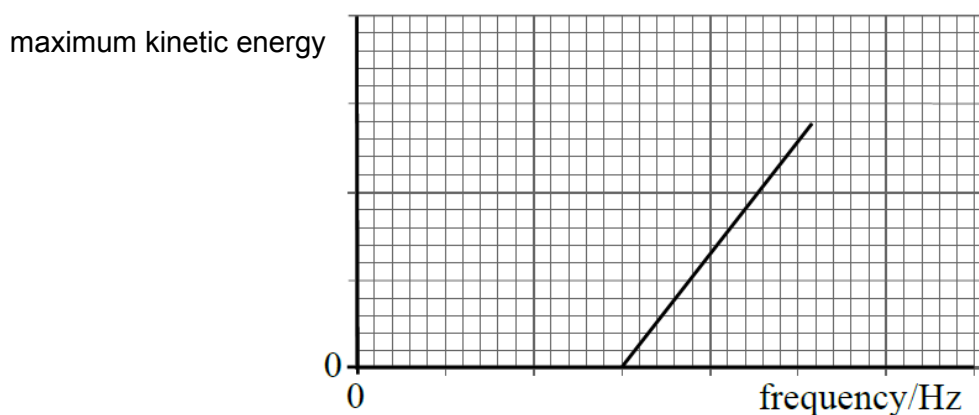
State what is meant by

(i)   *a photon,*

....…..………...

....….. [1]

(ii)   the *work function energy.*

....…..………...

....….. [1]

(b) Fig. 8.1 shows how the maximum kinetic energy of the electrons varies with the frequency of the light shining on a metal surface.

frequency

Fig. 8.1

(i) On Fig. 8.1,

    1. mark the threshold frequency and label it f_0,

[1]

    2. draw a line for a metal which has a higher work function energy.

[1]

(ii) State what information is provided by the gradient of the graph.

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

(iii) Explain why the kinetic energy of the emitted electrons varies up to a maximum value.

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

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

(iv) Explain why the graphs on Fig. 8.1 do not depend on the intensity of the incident radiation.

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

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

(c) Fig. 8.2 shows part of an energy level diagram for a hydrogen atom.

n = 4 ———————— - 0.85 eV

n = 3 ———————— - 1.50 eV

n = 2 ———————— - 3.40 eV

n = 1 ———————— - 13.60 eV

Fig. 8.2 (not to scale)

(i) State the ionisation energy of the atom.

ionisation energy = …………………… eV [1]

(ii) When an electron of energy 12.1 eV collides with the atom (initially at the ground state),

photons of three different energies are emitted.

1. On Fig. 8.2, draw arrows to show the transitions responsible for these photons. [2]

2. Calculate the wavelength of the photon with the smallest energy and state the region of the electromagnetic spectrum this wavelength corresponds to.

wavelength = …………………… m

region of the electromagnetic spectrum = …………………..… [3]

(d) Electrons having a *de Broglie* wavelength 1.2×10^{-10} m are required to investigate the crystal structure of a certain solid.

(i) State what is meant by the *de Broglie wavelength.*

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

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

(ii) Calculate the speed of the electron.

speed = …………………… m s^{-1} [3]

(iii) Suggest how such electrons may assist with an understanding of the crystal structure.

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

……………...

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

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

9 **(a)** An isotope of Americium, $^{241}_{95}Am$, has a half-life of 432.2 years. It undergoes spontaneous

nuclear decay and may be represented by the equation

$$^{241}_{95}Am \rightarrow ^{237}_{93}Np + ^{4}_{2}He$$
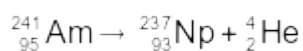
where Neptunium $^{237}_{93}Np$ is a daughter nuclide.

(i) Define *half-life.*

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

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

(ii) Explain what is meant by *spontaneous decay.*

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

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

(iii) Calculate the decay constant of $^{241}_{95}Am$.

decay constant = …………………… s^{-1} [1]

(iv) Calculate the activity of 1.00 g of $^{241}_{95}$Am.

activity = …………………… Bq [3]

(v) Calculate in MeV the total kinetic energy of the decay products, given the following data:

Nuclide	Atomic mass / u
$^{241}_{95}$Am	241.0568229
$^{237}_{93}$Np	237.0481673
$^{4}_{2}$He	4.0026032

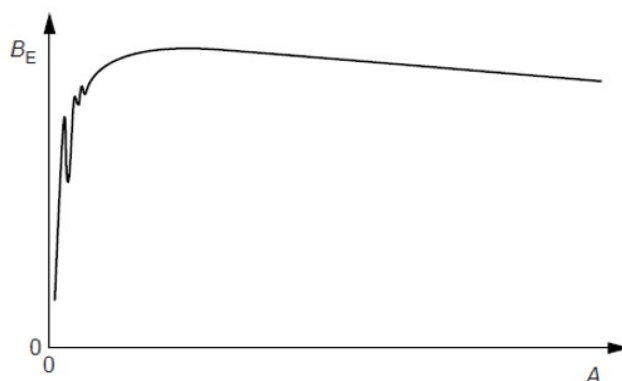total kinetic energy = …………………… MeV [3]

(b) The variation with nucleon number A of the binding energy per nucleon B_E is shown in Fig. 9.1.
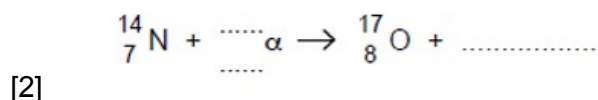
[Turn over

Fig. 9.1

Using Fig. 9.1, explain why fusion of nuclei having high nucleon numbers is not associated with a release of energy.

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

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

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

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

(c) One possible nuclear reaction involves the bombardment of a stationary nitrogen-14 nucleus by an ➜-particle to form oxygen-17 and another particle.

(i) Complete the nuclear equation for this reaction.

$$^{14}_{7}\text{N} + \underset{\cdots}{\cdots}\alpha \rightarrow \, ^{17}_{8}\text{O} + \cdots\cdots\cdots$$

[2]

(ii) The total mass-energy of the nitrogen-14 nucleus and the ➜-particle is less than that of the particles resulting from the reaction. This mass-energy difference is 1.1 MeV.

1. Suggest how it is possible for mass-energy to be conserved in this reaction.

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

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

2. Calculate the speed of an ➜-particle having kinetic energy of 1.1 MeV.

speed = …………………… m s^{-1} [4]

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 [Turn over