Anglo-Chinese Junior College

Physics Preliminary Examination
Higher 2

A Methodist Institution
(Founded 1886)

CANDIDATE NAME		CLASS	

CENTRE NUMBER	S	3	0	0	4	INDEX NUMBER	

PHYSICS **9749/03**

Paper 3 Longer Structured Questions

1 September 2021
2 hours

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

READ THESE INSTRUCTIONS FIRST

Write your Name, Class and Index number 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, graphs or rough working.
Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Section A
Answer **all** questions.

Section B
Answer **one** question only.

You are advised to spend one and a half hours on Section A and half an hour on Section B.

At the end of the examination, fasten all your work securely together.

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

For Examiners' use only	
Section A	
1	/ 9
2	/ 13
3	/ 9
4	/ 13
5	/ 16
Total	/ 60
Section B	
6	/ 20
7	/ 20
Grand Total	/ 80

DATA AND FORMULAE

Data

speed of light in free space,	c	=	3.00×10^{8} m s^{-1}
permeability of free space,	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_o	=	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	=	$\rho g h$
gravitational potential,	ϕ	=	$-\frac{Gm}{r}$
temperature	T / K	=	$T / {}^{o}C + 273.15$
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of of an ideal gas molecule,	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.,	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.,	v	=	$v_o \cos \omega t$
		=	$\pm\,\omega\sqrt{x_o^2 - x^2}$
electric current	I	=	$A\,n\,v\,q$
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	=	$x_o \sin \omega t$
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	=	$\frac{\mu_o N I}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_o n I$
radioactive decay,	x	=	$x_o \exp(-\lambda t)$
decay constant,	λ	=	$\frac{\ln 2}{t_{1/2}}$

[Turn over

For Examiner's Use

Section A

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

1 **(a)** A solid cylinder of height h and density ρ rests on a flat surface as shown in Fig. 1.1.

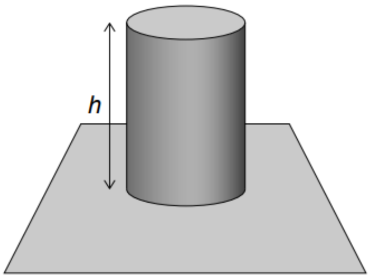


Fig. 1.1

Show that $p_C = h\rho g$ where p_C is the pressure exerted by the cylinder on the surface.

[2]

(b) Fig 1.2 shows a tube of constant circular cross-section, sealed at one end, contains an ideal gas trapped by a cylinder of mercury of length 0.035 m. The whole arrangement is in the Earth's atmosphere. The density of mercury is 1.36×10^4 kg m^{-3}.

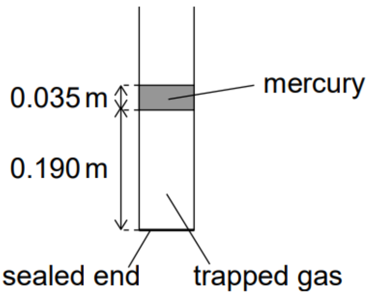


Fig. 1.2

When the mercury is above the gas column the length of the gas column is 0.190 m.

For Examiner's Use

(i) Explain what is meant by *an ideal gas*.

....

....

....

....

.... [2]

(ii) Given

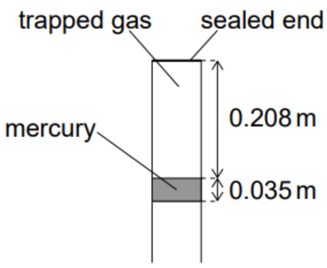
p_o = atmospheric pressure
p_m = pressure due to the mercury column
T = temperature of the trapped gas
n = number of moles of the trapped gas
A = cross-sectional area of the tube

Show that $(p_o + p_m) \times 0.190 = \dfrac{nRT}{A}$.

[1]

For Examiner's Use

(iii) The tube is slowly rotated until the gas column is above the mercury.



The length of the gas column is now 0.208 m. The temperature of the trapped gas does not change during the process.

Determine p_o.

p_o = ... Pa [2]

(iv) Using the First Law of Thermodynamics, explain the heat exchange between the gas and the surrounding during the process mentioned in **(b)(iii)**.

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.... [2]

For Examiner's Use

2 **(a)** State the *principle of conservation of momentum*.

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

(b) Two frictionless trolleys A and B are moving along a horizontal straight line, as illustrated in Fig. 2.1.

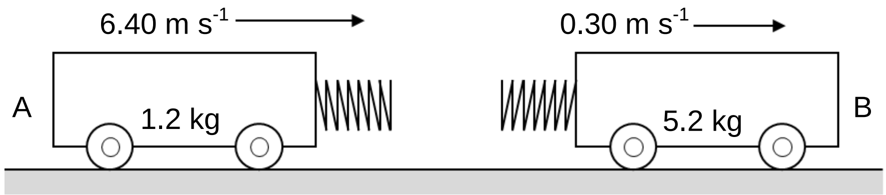

Fig. 2.1

Trolley A has mass 1.2 kg and a velocity of 6.40 m s^{-1}. Trolley B has mass 5.2 kg and a velocity of 0.30 m s^{-1}.

At 0.20 s, the two trolleys collide elastically and are in contact for a duration of 0.47 s and trolley A moves in the opposite direction after the collision.

(i) Show that the velocity of trolley B after the collision is 2.6 m s^{-1}.

[3]

For Examiner's Use

(ii) Calculate the average force F that B exerts on A during the collision.

F = …………………………… N [3]

(iii) Sketch on Fig. 2.2, the velocity-time graph for trolley A. The velocity-time graph of trolley B has been provided.

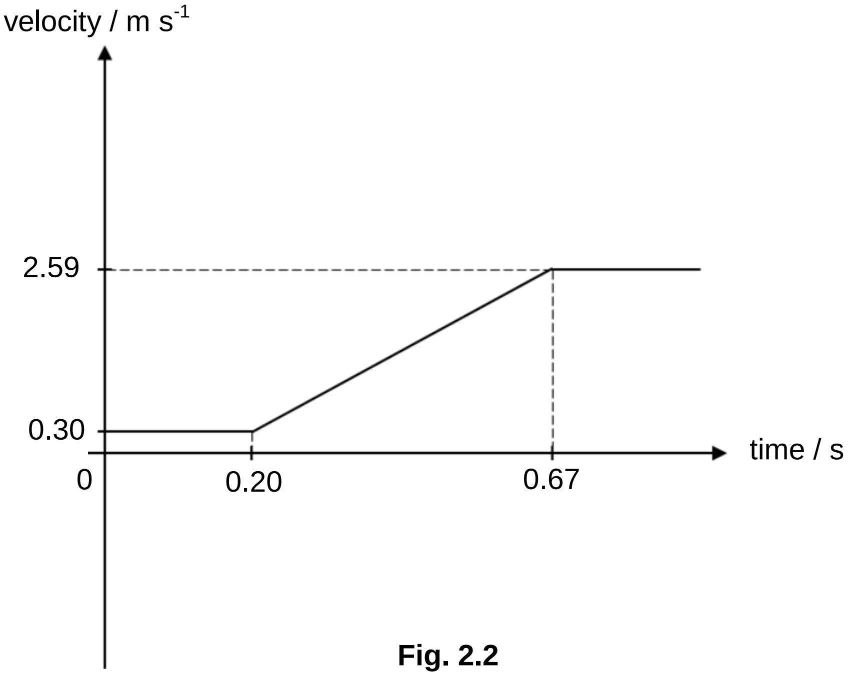

Fig. 2.2

[2]

(iv) Indicate on Fig. 2.2 the time at which the two trolleys are the closest to each other. Label this time as t_c.

[1]

(v) Discuss why the collision is elastic even though the magnitude of the kinetic energy of the system at t_c is not the same as that before the collision.

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……………………………………………………………………………………… [2]

3 **(a)** **(i)** Define *electric field strength* at a point.

……………………………………………………………………………………………

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

(ii) State the relationship between electric field strength at a point and electric potential at the point.

……………………………………………………………………………………………

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

(b) Two point charges A and B are separated by a distance of 7.0 cm in a vacuum, as illustrated in Fig. 3.1.

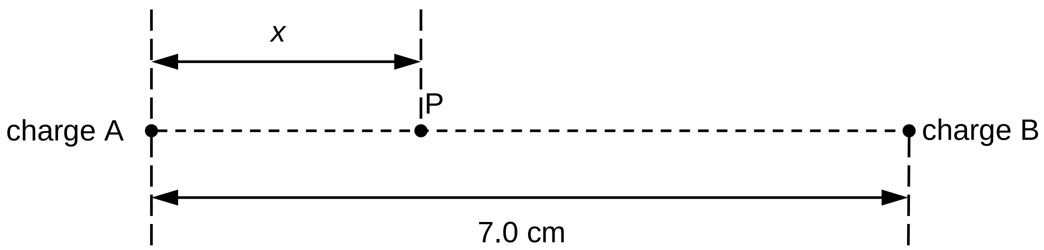

Fig. 3.1

The charge of A is -2.0×10^{-9} C.

A point P lies on the line joining charges A and B. Its distance from charge A is *x*.

For Examiner's Use

The variation with distance x of the electric potential V at point P is shown in Fig. 3.2.

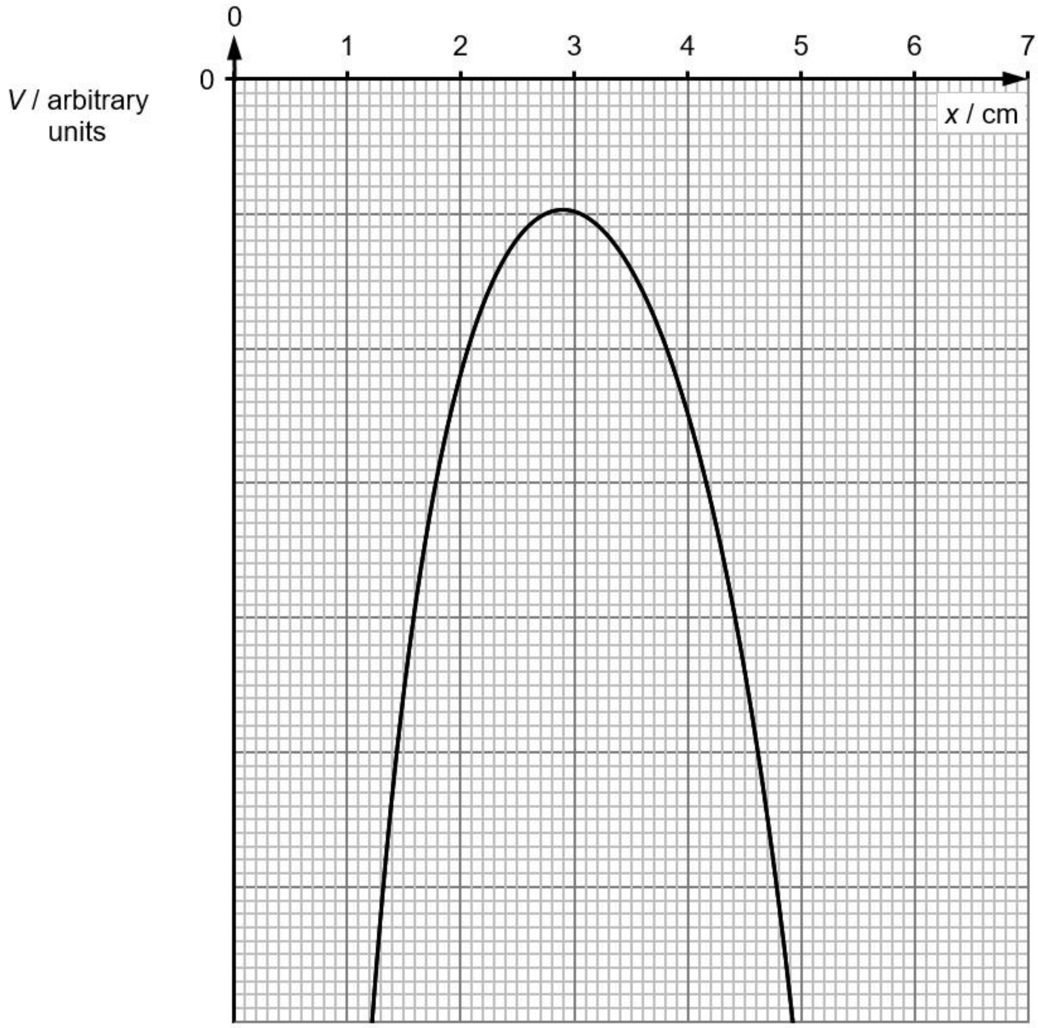

Fig. 3.2

(i) State the value of x where V is a maximum.

x = ... cm [1]

For Examiner's Use

(ii) Hence, determine the charge of B.

charge = …………………………… C [3]

(iii) An electron is initially at rest at point P where x = 2.0 cm.

Describe the subsequent motion of the electron.

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……………………………………………………………………………………

…………………………………………………………………………………… [3]

For Examiner's Use

4 After a gust of strong wind, a building with a height of 160 m starts to sway. Fig. 4.1 shows the variation with x of the force experienced by the top floor of the building F, where x is the distance to the adjacent building.

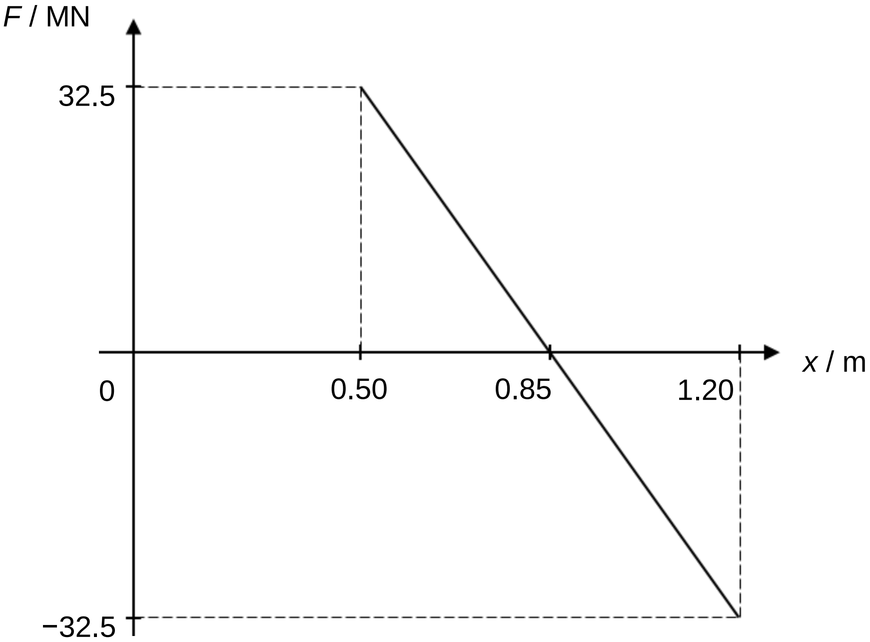

Fig. 4.1

(a) (i) Use Fig. 4.1 to explain how it can be deduced that the top floor of the building oscillates in simple harmonic motion.

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

For Examiner's Use

(ii) The top floor of the building experiences a maximum acceleration of 3.42 m s^{-2}.

1. Determine the amplitude of the oscillation.

amplitude = …………………………… m [1]

2. Determine the frequency at which the wind is blowing at the building.

Explain your answer

………………………………………………………………………………………

……………………………………………………………………………………… [3]

(iii) On the same axes, sketch the variation with *x* of

1. the potential energy of the oscillation. Label this line P.

2. the kinetic energy of the oscillation. Label this line K.

Numerical values for energy are not required.

[2]

For Examiner's Use

(iv) Determine x when $\dfrac{\text{kinetic energy}}{\text{potential energy}} = \dfrac{1}{2}$.

x = …………………………… m [2]

(b) After an earthquake hit the city, it was found that some buildings swayed more and suffered more damage than others.

Suggest why.

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………………………………………………………………………………………………

……………………………………………………………………………………… [2]

For Examiner's Use

5 **(a)** State the *Principle of Superposition*.

………………………………………………………………………………………………

………………………………………………………………………………………………

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

(b) A Young's double slit experiment is set up as shown in Fig 5.1. Monochromatic light of wavelength 650 nm is incident on slit S_0. Light emerging from slits S_1 and S_2 are in phase and the distance between the slits is 1.65 mm. A screen is placed 6.5 m away from the slits.

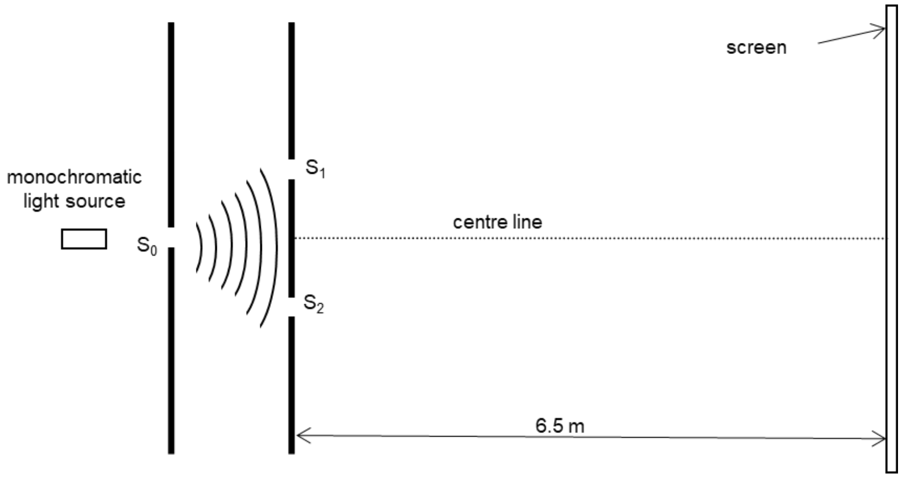

Fig 5.1

(i) Determine the separation of the bright fringes when they are formed on the screen.

separation = ……………………………. m [2]

For Examiner's Use

(ii) Suggest changes to the appearance of the fringes when a darken film is now placed in front of slit S_1.

……………………………………………………………………………………………

……………………………………………………………………………………………

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……………………………………………………………………………………………

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

(iii) The screen is removed and a man stands directly in front of the two slits during day time. The diameter of the pupil of the eyes can be taken to be 3.5 mm.

Determine the maximum distance the man can stand away from the two slits before he can no longer resolve them.

maximum distance = ……………………………. m [2]

(iv) As the diameter of the pupil of the eyes increases during night time, explain if the man is still able to resolve the two slits if he is to stand at the same location as determined in **(b)(iii)**.

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……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

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

For Examiner's Use

(c) The setup is modified as shown in Fig 5.2 to demonstrate single slit diffraction. Monochromatic light of wavelength 550 nm is incident on slit S_0 with slit width of 2.20 µm. A screen is placed 0.7 m away from the slit and the centre of the interference pattern formed on the screen is at W.

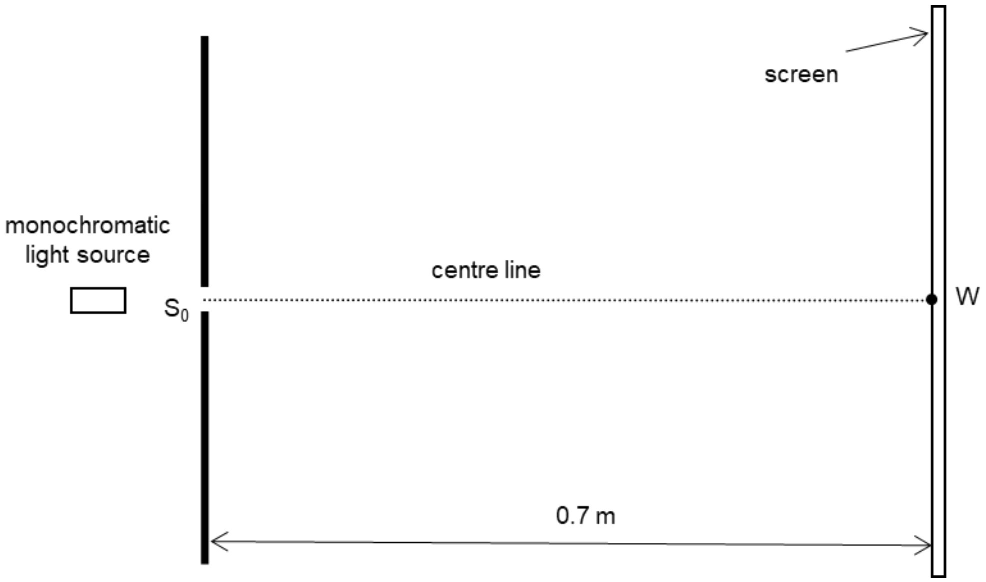

Fig 5.2

(i) Determine the width of the centre bright fringe formed on the screen.

width = …………………………… m [2]

For Examiner's Use

(ii) On Fig 5.3, sketch the variation with distance *x* from point W of the intensity of the light on the screen.

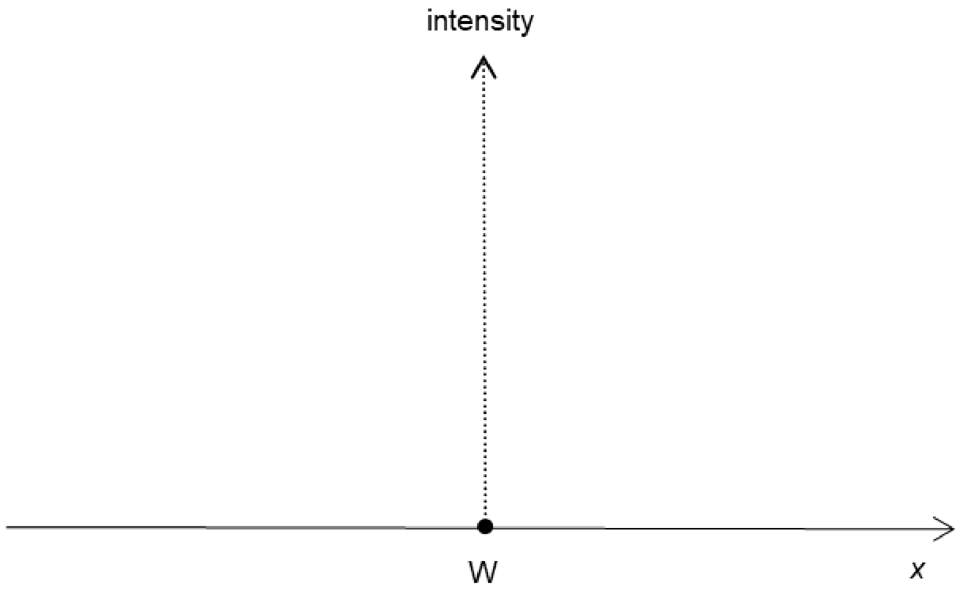

Fig 5.3

[2]

(iii) The amplitude of the light at a point 0.8 m away from S_0 is measured to be A_0. The screen is now moved to a new position such that the point is now 1.1 m away from S_0.

Assuming that the light from S_0 acts like a point source, determine in terms of A_0, the amplitude of the light at the new position.

amplitude = …………………………… A_0 [2]

For Examiner's Use

Section B

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

6 Plutonium-239 has a half-life of 2.41×10^4 years. It decays to uranium-235 by alpha emission.

(a) **(i)** State what is meant by the half-life of plutonium-239.

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

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

(ii) A radioactive sample currently contains 6.2×10^{-9} kg of plutonium-239. Calculate the mass of plutonium-239 the sample would have contained 2000 years ago.

mass = ……………………………. kg [2]

(iii) Calculate the current activity of the sample of plutonium-239.

[3]

For Examiner's Use

(iv) The count rate of the plutonium sample was measured and used to calculate its activity. The value obtained for the activity of the sample was different from the calculated value obtained in **(a)(iii)**.

Give two reasons to account for this difference.

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

……………………………………………………………………………......

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

…………………………………………………………………………….. [2]

(b) Data for the nuclei involved in the decay of plutonium-239 are given in Fig. 4.1.

nucleus	mass / u
α-particle $^{4}_{2}He$	4.00271
uranium-235 $^{235}_{92}U$	235.04393
plutonium-239 $^{239}_{94}Pu$	239.05216

Fig. 4.1

(i) Calculate the amount of energy released from the decay of a single plutonium-239 nucleus.

energy = …………………………… J [3]

(ii) State two harmful effects of being exposed to the radiation from the plutonium sample.

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

……………………………………………………………………………......

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

…………………………………………………………………………….. [2]

For Examiner's Use

(iii) State and explain whether a person standing 40 cm away from the plutonium sample is likely to experience harmful effects due to the radiation from the plutonium sample.

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

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

(d) Uranium-235 has a half-life of 7.04×10^8 years, decaying by alpha emission to form an isotope of thorium. The isotope of thorium has a half-life of 25.5 h, decaying by beta emission to form an isotope of protactinium.

(i) Determine the number of protons and neutrons in the protactinium nucleus formed.

number of protons = …………………………….

number of neutrons = …………………………….

[2]

(ii) Trace amounts of the thorium isotope can still be found in samples of uranium which are 1000 years old.

Suggest an explanation for this phenomenon.

……………………………………………………………………………………………

……………………………………………………………………………………………

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

(e) Fig. 4.2 shows a graph of the variation with mass number of the binding energy per nucleon.

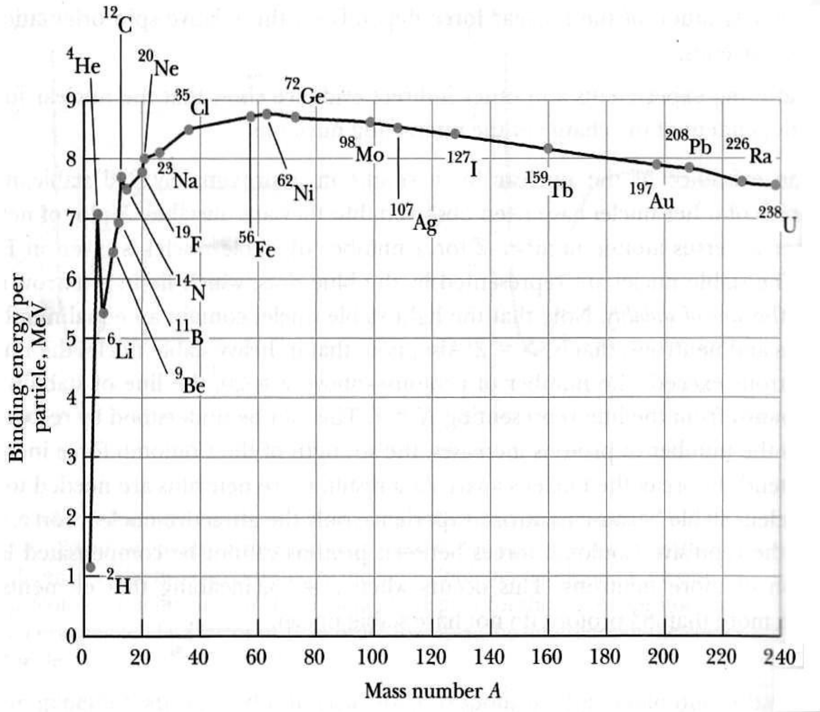

Fig. 4.2

With reference to Fig. 4.2, explain why fusion reactions of plutonium-239 and uranium-235 are not associated with a release of energy.

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

…………………………………………………………………………………………………

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

For Examiner's Use

7 **(a)** Explain why an object moving at a constant speed in a circular path experiences a force towards the centre of the circle.

....

....

....

.... [2]

(b) A trinary star system consists of three stars A, B and C of equal mass M. The three stars are equidistant from one another and rotate at constant speed in a circular path of radius R about the centre X, as illustrated in Fig. 7.1.

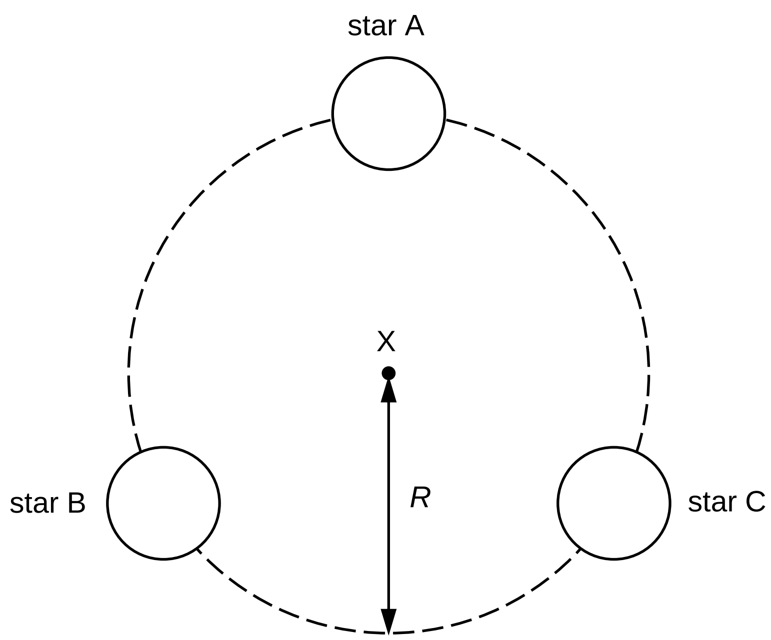

Fig. 7.1 (not to scale)

(i) Show that the centres of any two stars are separated by a distance 1.73R.

[1]

(ii) On Fig. 7.1, draw and label arrows to show the forces acting on star A. [2]

For Examiner's Use

(iii) In terms of G, M and R,

1. determine the gravitational potential energy of the trinary star system.

gravitational potential energy = ………………………… [2]

2. use **(b)(ii)** to determine the resultant force experienced by each star.

resultant force = ………………………… [2]

3. hence determine the kinetic energy of the trinary star system.

kinetic energy = ………………………… [2]

(iv) The speed of each of the three stars suddenly increased by the same

For Examiner's Use

magnitude.

State and explain the subsequent motion of the stars.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

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

(c) A space probe travels in a circular orbit of radius *d* around the trinary star system, as illustrated in Fig. 7.2.

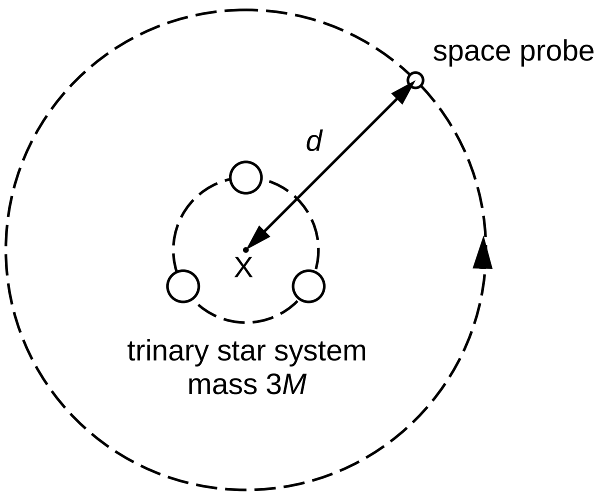

Fig. 7.2 (not to scale)

It can be assumed that the effective mass of the trinary star system is a point mass at its centre and is equal to $3M$.

The mission of the space probe is to observe the trinary star system.

The orbital period of the trinary star system is T.

For Examiner's Use

(i) Discuss the advantage

1. if the orbital period of the space probe is equal to T.

……………………………………………………………………………………

…………………………………………………………………………………… [1]

2. if the orbital period of the space probe is smaller than T.

……………………………………………………………………………………

…………………………………………………………………………………… [1]

3. if the space probe rotates about its own axis with the same period as its orbital period.

……………………………………………………………………………………

…………………………………………………………………………………… [1]

(ii) A small component of the space probe was dislodged from the space probe when it is at the position shown in Fig. 7.2.

On Fig. 7.2, sketch the subsequent path of this component. [1]

(iii) Given that M is 1.39×10^{30} kg and d is 1.05×10^{11} m, determine the minimum velocity required for the space probe to escape the gravitational field of the trinary star system.

minimum velocity = ………………………… m s^{-1} [3]