H

TEMASEK JUNIOR COLLEGE

2022 JC2 PRELIMINARY EXAMINATION

Higher 2

CANDIDATE NAME	

CENTRE NUMBER	S					INDEX NUMBER					

PHYSICS **9749/03**

Paper 3 Longer Structured Questions **13 September 2022**

2 hours

Candidates answer on the Question Paper.

No additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, CG and subject tutor's name on all the 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.

Section A
Answer **all** questions.

Section B
Answer **one** question only

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

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

For Examiner's Use	
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2	
3	
4	
5	
6	
7	
8	
s.f.	
Total	

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} or $(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	e	=	1.60×10^{-19} C
the Planck constant	h	=	6.63×10^{-34} Js
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/°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	=	$x_o \sin\omega t$
velocity of particle in s.h.m.	v	=	$v_o \cos\omega t$
		=	$\pm\omega\sqrt{(x_o^{\,2} - x^2)}$
electric current	I	=	$Anvq$
resistors in series	R	=	$R_1 + R_2 + ...$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + ...$
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	=	$\frac{\mu_o NI}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_o nI$
radioactive decay	x	=	$x_0 \exp(-\lambda t)$
decay constant	λ	=	$\frac{\ln 2}{t_{1/2}}$

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Section A

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

1 (a) A monoatomic ideal gas A is contained in an insulated cylinder to prevent the loss of heat, while monoatomic ideal gas B is contained in a cylinder without any insulation, as shown in Fig. 1.1.

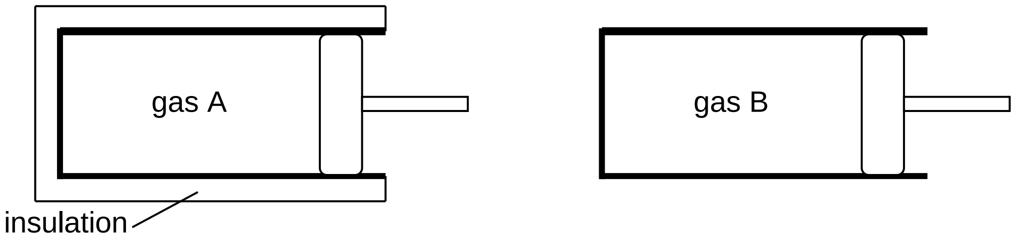

Fig. 1.1

Initially, the two gases have the same volume of 2.90×10^{-4} m^3, the same pressure of 1.05×10^5 Pa and the same temperature of 303 K.

(i) Explain what is meant by the *internal energy* of an ideal gas.

....

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.... [1]

(ii) Determine the number of molecules in gas A.

number of molecules = ... [2]

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(iii) Determine the mean translational kinetic energy of a molecule of gas A.

mean translational kinetic energy = ... J [1]

(b) When gas A is compressed to a volume of 2.10×10^{-4} m^3, its temperature rises to 357 K. Gas B is compressed very slowly to the same volume of 2.10×10^{-4} m^3.

(i) Determine the change in internal energy of gas A during the compression.

change in internal energy = ... J [2]

(ii) Determine the work done on gas A during the compression.

work done on the gas = ... J [1]

(iii) On Fig. 1.2, sketch the variation with volume of the pressure of gas A and gas B. Include appropriate labels, and values of pressure and volume.

[3]

Fig.1.2

2 Fig. 2.1 shows a mass m attached to a spring performing *simple harmonic motion* in the vertical y direction. The spring constant k of the spring is 61.4 N m^{-1}.

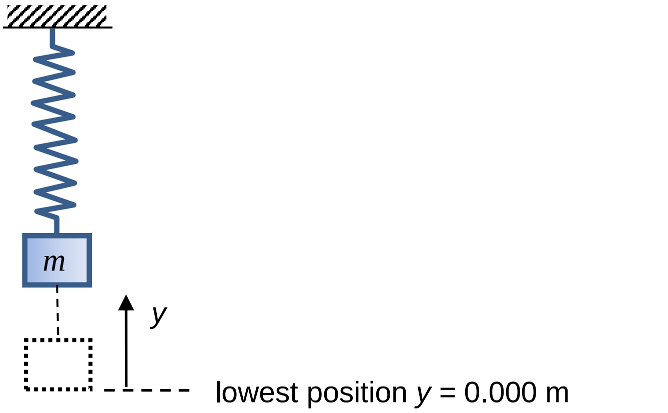

Fig. 2.1

At y = 0.000 m, the lowest point of the oscillation, the gravitational potential energy of the system is defined as 0 J.

As the system oscillates, its total energy is a constant and comprising kinetic energy, elastic potential energy and gravitational potential energy. At different positions y above the lowest position of oscillation, the kinetic energy and the elastic potential energy of the system vary as shown in Fig. 2.2.

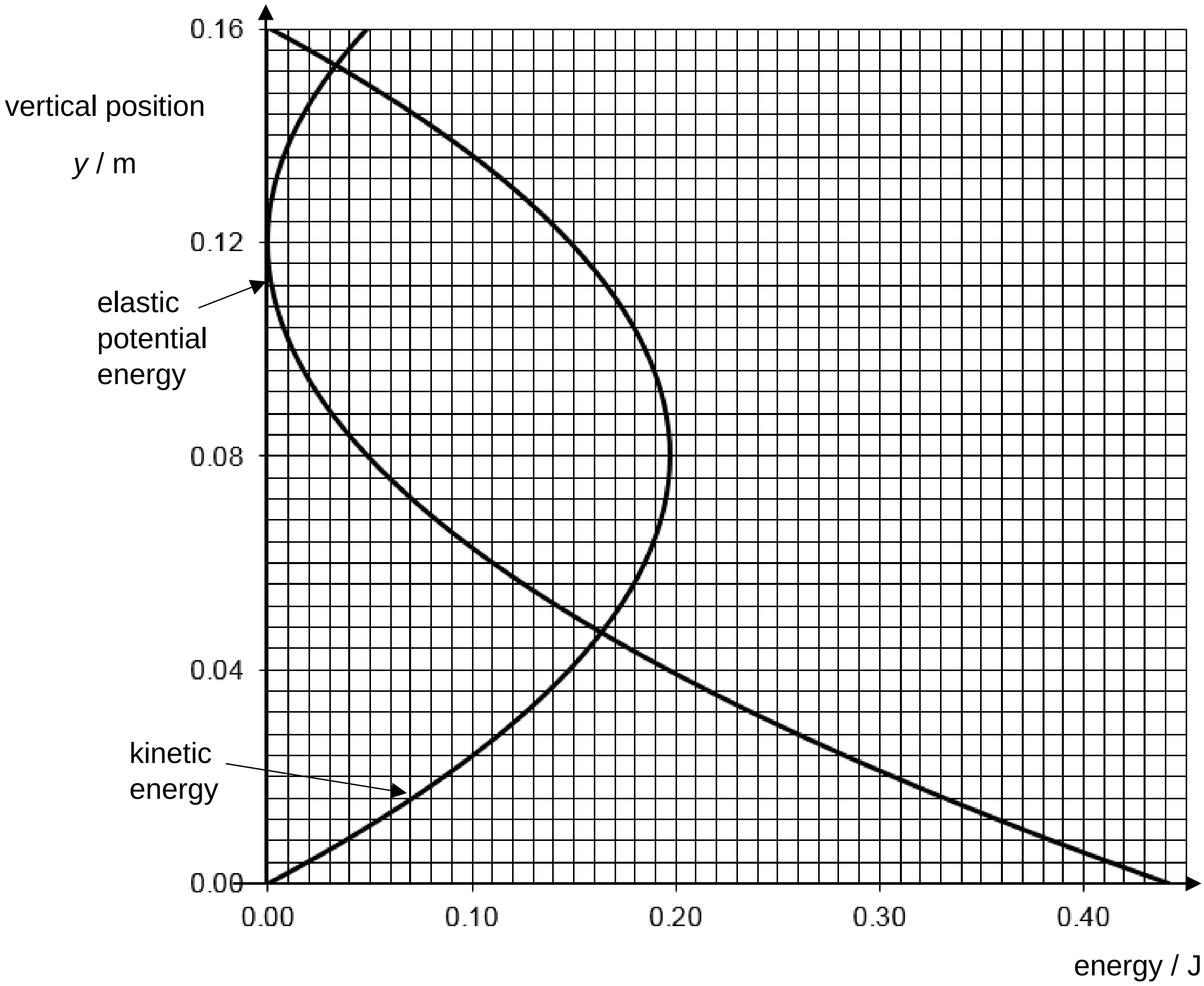

Fig. 2.2

(a) Define *simple harmonic motion*.

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.... [2]

(b) Determine the total energy of the system. Show your working clearly.

total energy = ... J [2]

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(c) Sketch on Fig. 2.2 a graph showing the variation with y of the gravitational potential energy of the system. [2]

(d) Hence or otherwise, show that mass m is 0.250 kg.

m = ... kg [2]

(e) Find the period T of the oscillation.

T = ... s [2]

3 Fig. 3.1 shows two large, vertical parallel plates, A and B, with plate B being connected to earth. An electron was emitted perpendicularly from plate A with an initial velocity v of 4.30×10^6 m s^{-1}. The electron experiences an electric force of 1.12×10^{-16} N towards plate A in the region between the two plates.

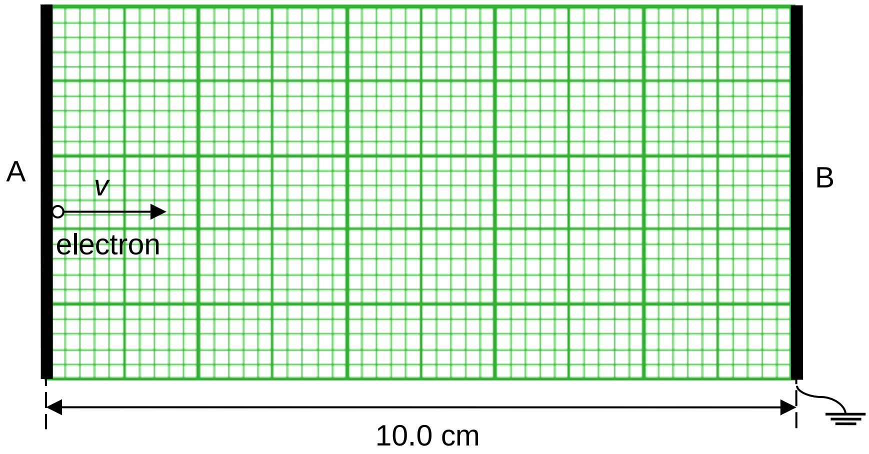

Fig. 3.1

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(a) Calculate the potential of plate A.

potential of plate A = ... V [2]

(b) **(i)** The electron comes to a stop momentarily at a point P. Use your answer in **(a)** to determine the potential at P.

potential at P = ... V [2]

(ii) On Fig. 3.1, draw the equipotential line passing through P. [2]

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(c) Another electron of the same speed is now ejected from plate A towards plate B at an angle less than 90° to plate A. State, with a reason, whether the electron will stop before, at or beyond the equipotential line passing through P.

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.... [2]

(d) A proton is projected with a velocity of 3.5×10^6 m s^{-1} along the axis midway between two parallel plates of length 20 cm as shown in Fig. 3.2. The uniform electric field between the plates has an intensity of 2.0×10^4 N C^{-1} and is directed upward.

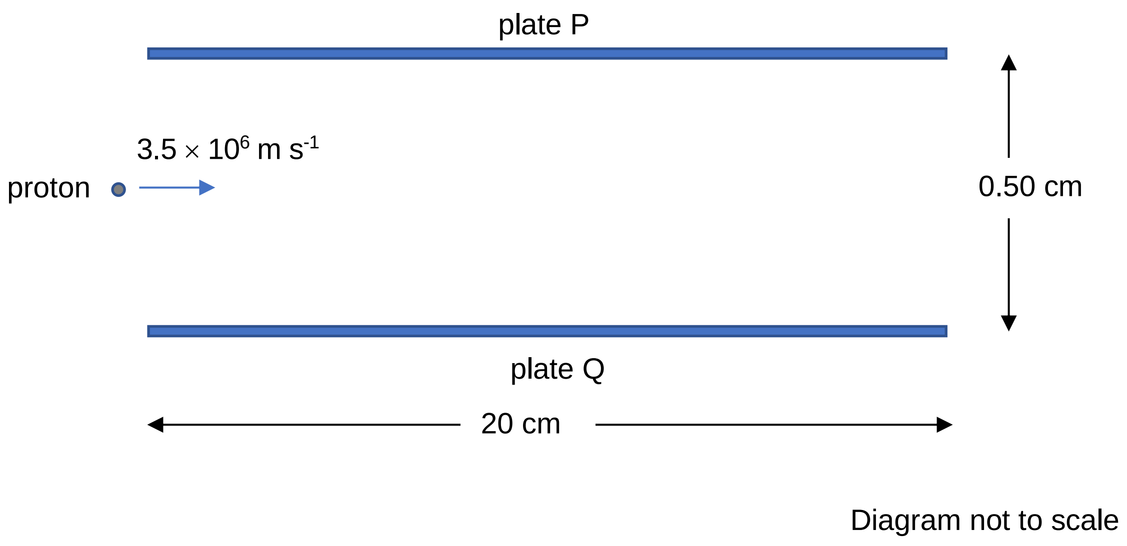

Fig. 3.2

(i) Determine the position where the proton will strike plate P.

proton will strike P at .... cm from point of entry [3]

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(ii) An alpha particle that enters the electric field at the same point and with the same velocity as the proton. Describe and explain with some calculations whether the alpha particle will hit or exit the plates.

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.... [3]

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4 (a) For an alternating current flowing in a heating coil, the average current is zero. Explain why there is heating effect produced in the coil.

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.... [2]

(b) A power station needs to deliver 20.0 MW of power to a city 10.0 km away. This power is generated at 16.0 kV and then stepped up by using a transformer of turn ratio 15:1 before transmission. The resistance per unit length of the transmission cables is 20.0 Ω km^{-1}.

The operator of the station loses $0.10 for every kWh of electrical power lost.

(i) Calculate the power lost during transmission.

power lost = ... W [2]

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(ii) Hence determine the amount of money saved by the station in one day when the energy is transmitted at the stepped-up voltage instead of the generated voltage.

amount saved = $ .... [2]

5 A car of weight 8500 N is travelling at constant speed along a road that is an arc of a circle. In order that the car may travel more easily round the arc, the road is banked at 14° to the horizontal, as shown in Figure 2.1 below.

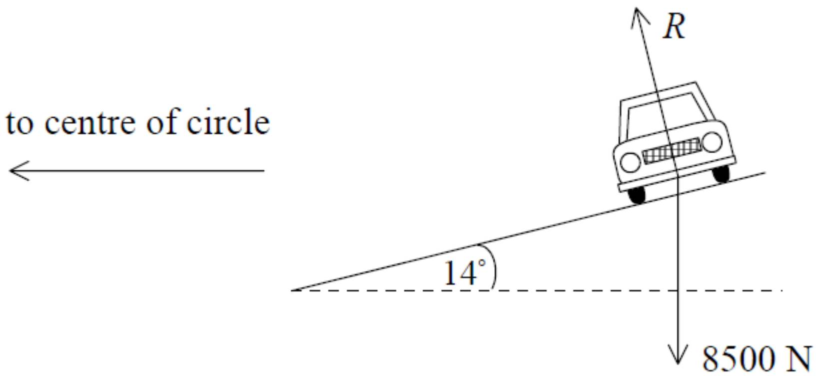

Fig. 5.1

At one particular speed v of the car, there is no frictional force at 90° to the direction of travel of the car between the tyres and the road surface. The reaction force of the road on the car is R.

(a) Show that the horizontal component of the force R is approximately 2100 N.

[2]

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(b) Determine the speed v of the car at which it travels round the arc of radius 150 m without tending to slide.

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

(c) State and explain in which direction the car will tend to slide if it travels round the curve at a speed greater than v.

....

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.... [2]

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6 (a) The energy levels of a hypothetical one-electron atom are given by

$$E_n = -\frac{27.9}{n^2}\ \text{eV}$$

where $n = 1, 2, 3, \ldots$

(i) Describe how line spectra can be explained using the idea of discrete electron energy levels in isolated atoms.

....

....

....

.... [2]

(ii) Explain why the energy of each energy level is negative.

....

....

.... [1]

(iii) Calculate the energies of the four lowest energy levels and construct a clearly labelled energy level diagram in the space below.

[3]

(iv) If the atoms are in the ground state and are bombarded by electrons of kinetic energy 26.5 eV, determine the highest energy level that an atom can reach. Show your working clearly.

highest energy level = ... [2]

(v) Calculate the shortest wavelength of the photons emitted when the atoms subsequently de excites.

shortest wavelength = ...nm [2]

(b) In a modern X-ray tube, electrons are accelerated through a large potential difference and the X-rays are produced when electrons strike a metal target embedded in a large piece of copper.

The emission spectrum of the metal when it is bombarded by a beam of fast-moving electrons is shown in Fig. 6.1.

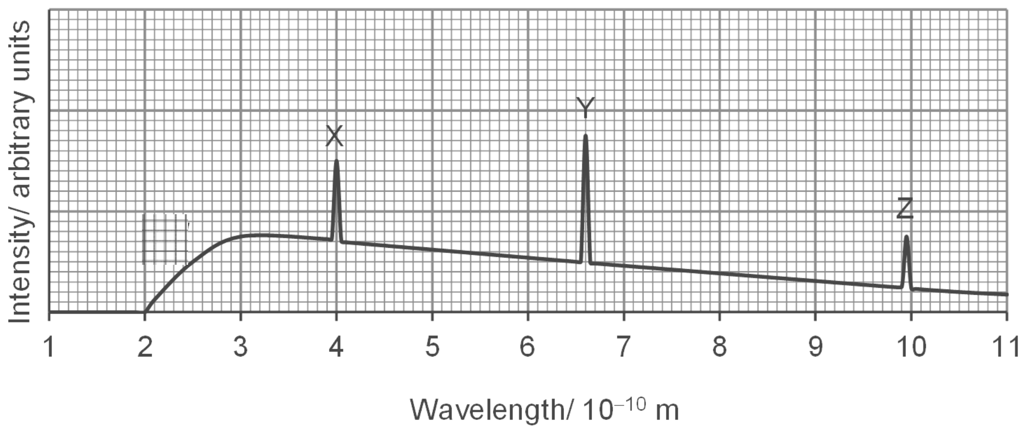

Fig. 6.1

(i) Calculate the accelerating potential of the X-ray tube.

accelerating potential = ... V [2]

(ii) Explain why there are sharp peaks X, Y and Z in the X –ray spectrum.

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....[2]

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Section B

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

7 **(a)** A rocket in outer space far from any other masses is used to propel a satellite. At t = 0, the engines are turned on and gases leave the rear of the rocket with speed v relative to the rocket as shown in Figure 7.1.

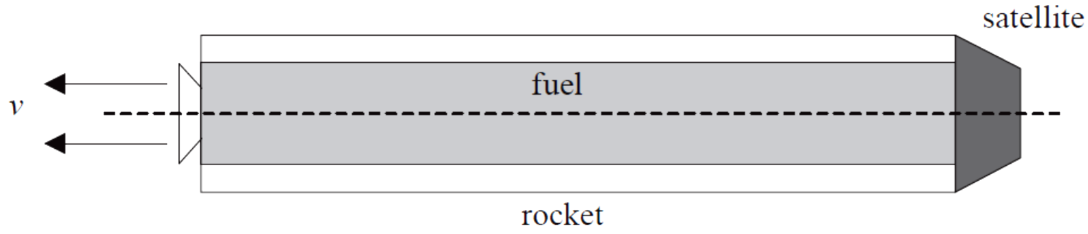

Fig. 7.1

(i) **1.** Explain, in terms of Newton's laws of motion, why the rocket will accelerate.

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.... [2]

2. Outline how the conservation of momentum applies to the motion of the rocket.

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.... [2]

3. The gases leave the rear of the rocket at a constant rate of R kg per second. The mass of the rocket (including fuel) at t = 0 is m. Deduce that the initial acceleration a of the rocket is given by the expression

$$a = \frac{Rv}{m}$$ [3]

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(ii) Figure 7.2 below shows a two-stage rocket that is used to accelerate a satellite that has the same mass as in (i). The rocket has the same mass as the single stage rocket and carries the same mass of fuel as in (i).

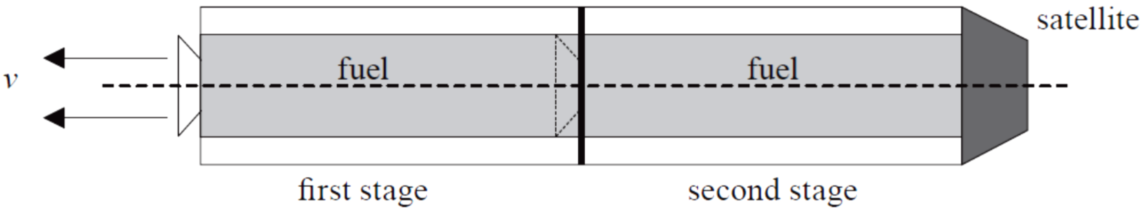

Fig. 7.2

Each stage is discarded after all its fuel has been used. Explain, using your answer to **(i)3**, whether the final speed of the satellite will be larger, equal or smaller than that of the satellite accelerated by the single stage rocket.

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.... [2]

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(b) A girl falls from rest on to the horizontal surface of a trampoline.
Figure 7.3 below shows the variation with time t of the net force F exerted on the girl before, during and after contact with the trampoline.

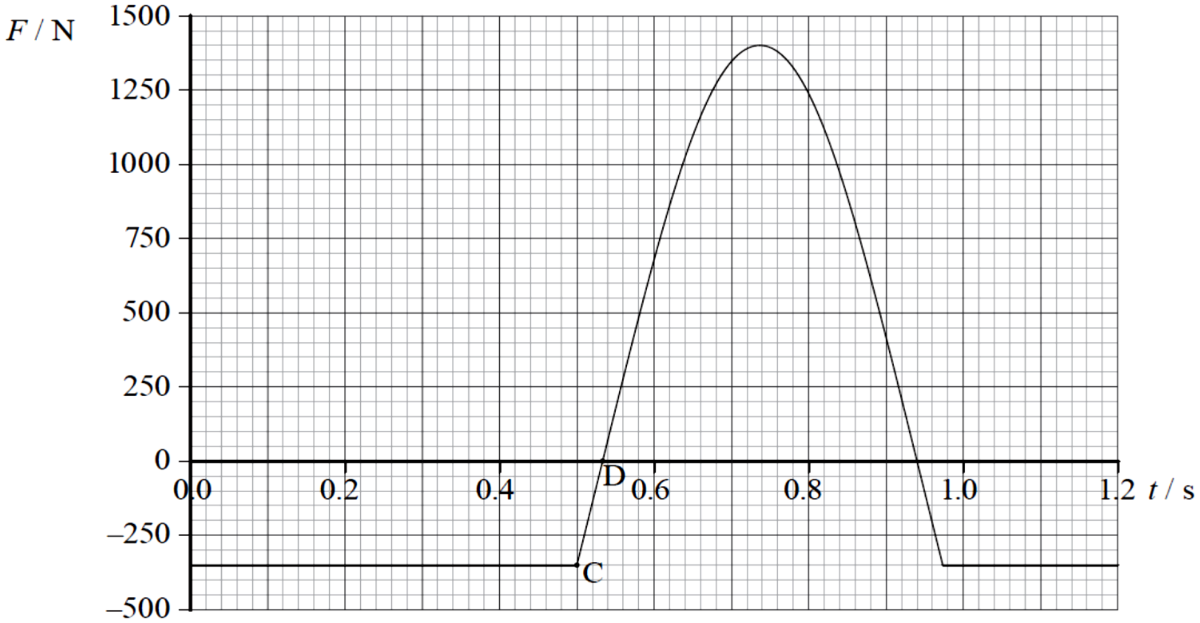

Fig. 7.3

(i) The girl first makes contact with the trampoline at point C. Use data from the graph to

1. show that the mass of the girl is 36 kg. [1]

2. calculate the speed of the girl just before she lands on the trampoline.

speed of the girl just before landing = ... m s^{-1} [1]

3. calculate the maximum contact force on the girl when she is in contact with the trampoline.

maximum contact force = ...N [2]

(ii) From the time between point C and point D,

1. state and explain, with reference to forces acting on the girl, how the speed of the girl is changing.

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.... [3]

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2. show that the change in momentum of the girl is approximately 5 Ns [2]

3. estimate the speed of the girl at point D.

speed of the girl at D = ... m s^{-1} [2]

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8 **(a)** A fusion reaction between a deuterium ($^{2}_{1}H$) nucleus and tritium ($^{3}_{1}H$) nucleus is shown below.

$$^{2}_{1}H + ^{3}_{1}H \longrightarrow ^{4}_{2}He + ^{1}_{0}n$$

For the fusion reaction to occur the separation between the deuterium and tritium nuclei must be less than 10^{-14} m. This means that the average kinetic energy of these hydrogen nuclei needs to be about 70 keV. The energy released by the fusion reaction is 18 MeV.

(i) Calculate the repulsive electrical force between the deuterium and tritium nuclei at a separation of 10^{-14} m.

force = ... N [2]

(ii) Assume that a mixture of these hydrogen nuclei behaves as an ideal gas. Estimate the temperature of the mixture of nuclei required for this fusion reaction.

temperature = ... K [2]

(iii) In practice, fusion occurs at a much lower temperature. Suggest a reason why.

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....

.... [1]

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(iv) Calculate the change in mass in a single fusion reaction.

change in mass = ... kg [2]

(b) A radioisotope that decays forming another isotope is known as a parent isotope and the newly formed isotope is known as the daughter product. For a sample initially made up of pure parent isotope, Fig. 8.2 shows the variation with time t of the activity A of the parent isotope. The daughter product in this case does not decay and is described as 'stable'.

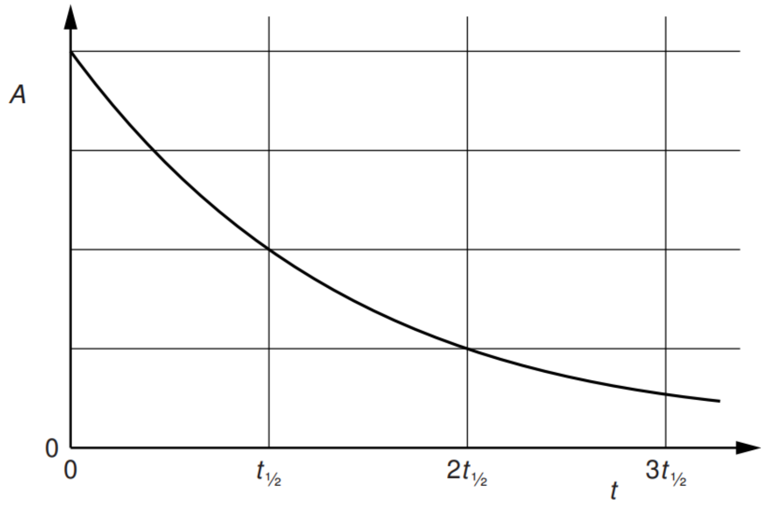

Fig. 8.2

(i) On the axes of Fig. 8.3, sketch a graph to show the variation with time t of the number D of daughter nuclei in the sample.

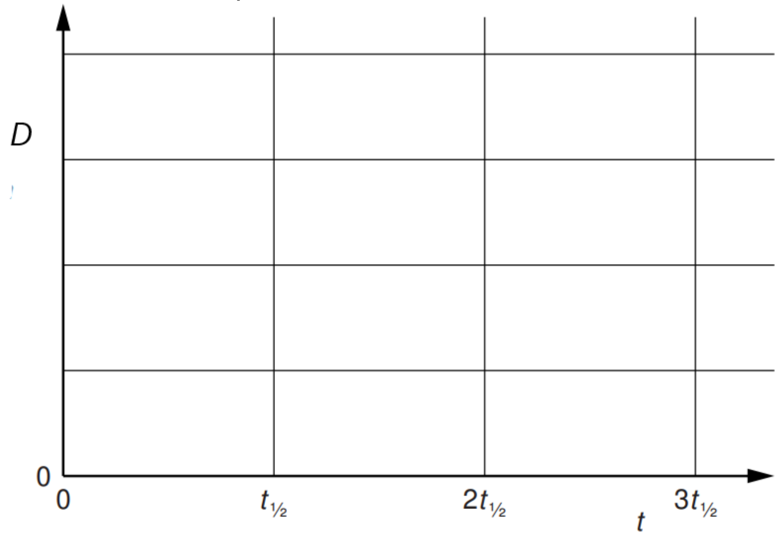

Fig. 8.3

[2]

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(ii) Show that the number of daughter nuclei *D* after time *t* is given by

$$D = N_0(1 - e^{-\lambda t})$$

where N_0 is the original number of parent nuclei and λ is the decay constant of the parent nuclei.

[1]

(iii) The ratio of the number of parent nuclei to number of daughter nuclei can be used to calculate the age of rocks. The uranium isotope ${}^{238}_{92}\mathrm{U}$ is the beginning of a 'radioactive series' that ends with the stable isotope of lead, ${}^{206}_{82}\mathrm{Pb}$.

The half-life of the ${}^{238}_{92}\mathrm{U}$ series is 4.47×10^9 years.

1. Show that a total of eight alpha decays and six beta decays will produce ${}^{206}_{82}\mathrm{Pb}$ from ${}^{238}_{92}\mathrm{U}$.

[2]

2. A rock is assumed to have contained no lead-206 when it was formed. In a sample of the rock, the ratio

$$\frac{\text{number of lead-206 atoms present in rock sample}}{\text{original number of uranium-238 atoms present in rock sample}}$$

is measured to be 0.39.

Calculate the time since formation of rock, assuming that all the lead-206 formed has remained in the rock.

time since formation of rock = ...years [2]

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(iv) The same rock sample also contains uranium-235, which undergoes a series of decays to form the stable isotope lead-207.

The half-life of this $^{235}_{92}U$ series is 7.0×10^8 years. The ratio

$$\frac{\text{number of lead-207 atoms present in rock sample}}{\text{number of remaining uranium-235 atoms present in rock sample}}$$

is measured to be 22.8.

1. Show that the number of daughter nuclei after time t is given by $D = N\left(\frac{1}{e^{-\lambda t}} - 1\right)$

where N is the number of parent nuclei remaining at time t.

[2]

2. Use the equation for D given in **(iv)1** and the data given to calculate the value for the age of the rock based on the uranium-235 decay series.

age of rock = ... years [2]

3. Rocks are often dated using three separate decay series. Suggest and explain two advantages of using three decay series to date rocks rather than just one.

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.... [2]

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