TAMPINES MERIDIAN JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATION

CANDIDATE NAME	( )
CIVICS GROUP	

H2 PHYSICS 9749/02

Paper 2 Structured Questions **11 September 2024**

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

Section B: Structured Questions

READ THESE INSTRUCTIONS FIRST

Write your name and Civics Group in the spaces at the top of the 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.

Answer **all** questions.

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

For Examiners' Use	
1	/ 8
2	/ 8
3	/ 6
4	/ 8
5	/ 10
6	/ 10
7	/ 10
8	/ 20
Deduction	
Total	/ 80

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_o	=	$4\pi \times 10^{-7}$ 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	=	$-\dfrac{GM}{r}$
temperature	T /K	=	T /°C + 273.15
pressure of an ideal gas	p	=	$\dfrac{1}{3}\dfrac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	E	=	$\dfrac{3}{2}kT$
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	=	$R_1 + R_2 + \ldots$
resistors in parallel	$1 / R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential	V	=	$\dfrac{Q}{4\pi\varepsilon_0 r}$
alternating current / voltage	X	=	$x_o \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\dfrac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\dfrac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_0 nI$
radioactive decay	x	=	$x_0 \exp(-\lambda t)$
decay constant	λ	=	$\dfrac{\ln 2}{t_{\frac{1}{2}}}$

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

1 Fig.1.1 shows an elongated block with a square cross sectional area of a particular conducting material.

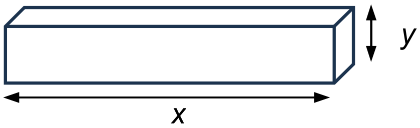

Fig. 1.1

The rate of thermal energy transfer with respect to time, q, through the block is given by

$$q = py^2\left(\frac{T}{x}\right)$$

where p is the thermal conductivity of the material;
y is the length of the square cross-sectional area of the material;
T is the temperature difference between the two ends of the material;
and x is the length of the block.

Fig. 1.2 shows the data obtained in a particular experiment.

quantity	value	percentage uncertainty
T	323 K	± 0.50%
x	1.00 m	± 1.0%
p	237 W m^{-1} K^{-1}	± 2.0%
y	0.200 cm	± 3.0%

Fig. 1.2

(a) Determine the SI base units of p.

SI base units of p = ………………… [2]

(b) Using the values given in Fig. 1.2,

(i) determine the value of q, to three significant figures.

q = ………………… W [2]

(ii) determine the percentage uncertainty of q.

percentage uncertainty of q = …………………% [2]

(c) Use your answer in **(b)** to determine the actual uncertainty in the value of q.

Hence give a statement of q, with its uncertainty, to an appropriate number of significant figures.

q = …………………± …………………W [2]

2 A ball is released from rest at time t = 0 s and falls freely. It hits the ground after falling downwards for 2.0 s. Take the sign convention of up as positive.

(a) State the acceleration of the ball during the fall.

acceleration = ………………… m s^{-2} [1]

(b) Show that the velocity of the ball just before it hits the ground is −20 m s^{-1}.

[1]

After 0.20 seconds upon hitting the ground, the ball rebounds vertically from the ground with a speed of 10 m s^{-1}.

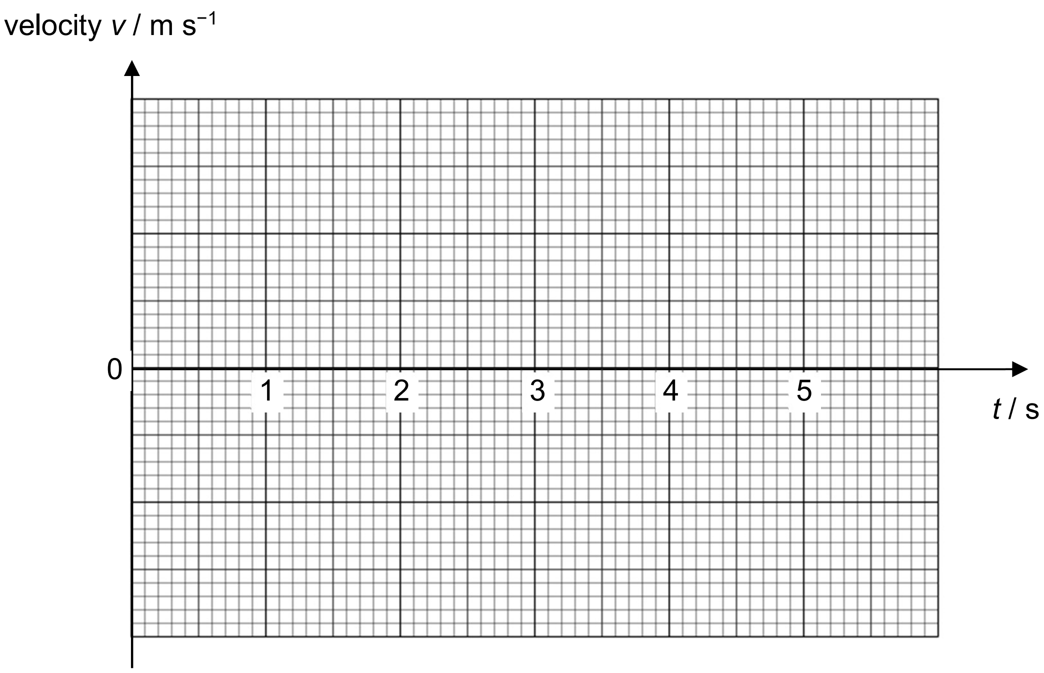

Fig. 2.1

(c) On Fig. 2.1, sketch the graph that shows the variation with time t of the velocity v of the ball up to the moment when the ball hits the ground for the second time.

[3]

(d) On your graph, mark and label the point X where the ball reaches its highest point after the first bounce.

[1]

(e) In real life, there is air resistance.

Describe qualitatively the motion of the falling ball before it hits the ground.

……...

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

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

3 A small metal sphere has a mass of 1.0×10^{-4} kg and charge +2.0 nC. It is placed between two parallel, oppositely-charged horizontal plates and directly above an insulated spring as shown in Fig. 3.1. The electric field strength is 1.5×10^{5} V m^{-1}.

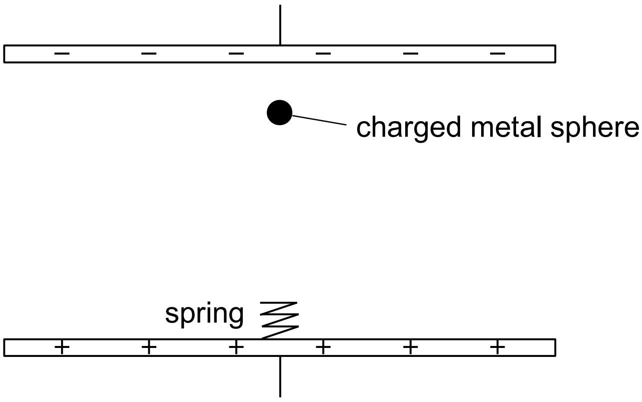

Fig. 3.1

(a) Determine the magnitude and direction of the electric force on the sphere.

magnitude of electric force = ………………… N

direction = …………………… [3]

(b) The sphere is released from rest at a height of 0.50 m above the spring. The sphere hits the spring and causes a maximum compression of 0.015 m.

Determine the spring constant.

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

4 When a body is subject to a periodic driving force in the presence of damping, it moves in a simple harmonic motion.

(a) Explain what is meant by simple harmonic motion.

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

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

Fig. 4.1 shows the variation with frequency of the amplitude of motion of a body subject to a periodic driving force of various frequency.

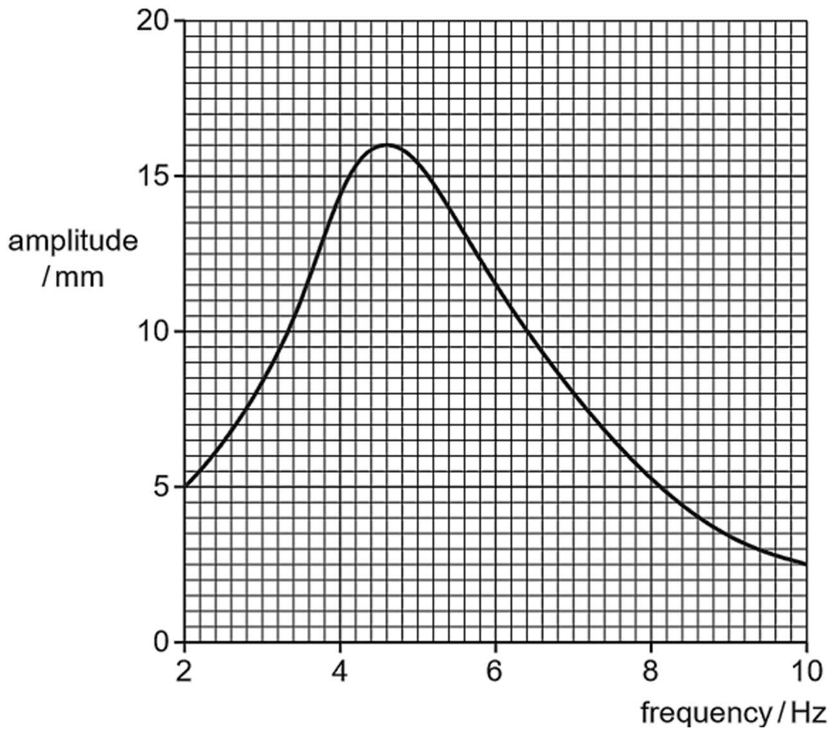

Fig. 4.1

(b) Explain how Fig. 4.1 shows the presence of resonance.

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

(c) State one situation where resonance is useful.

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

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

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

(d) Calculate the maximum speed of the body when the driving frequency is 10.0 Hz.

maximum speed = ………………… m s^{-1} [2]

(e) On the axes of Fig. 4.2, sketch a graph to show the variation with time of the displacement of the body over 2 periods when the frequency is 10 Hz. Mark on the axes with the appropriate values.

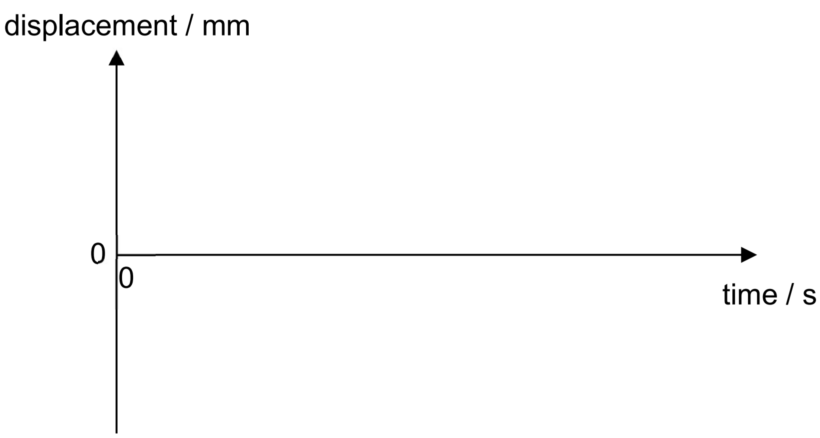

Fig. 4.2

[2]

5 A cell is labelled "9.0 V, 0.450 A h". This may be assumed to mean that the cell has an e.m.f. of 9.0 V, and will supply a current of 0.450 A for one hour before running out of energy.

It is found that a steady current of 0.450 A flows when a 18 Ω resistor is connected across the cell terminals as shown in Fig. 5.1. You can assume that the ammeter in the circuit is ideal.

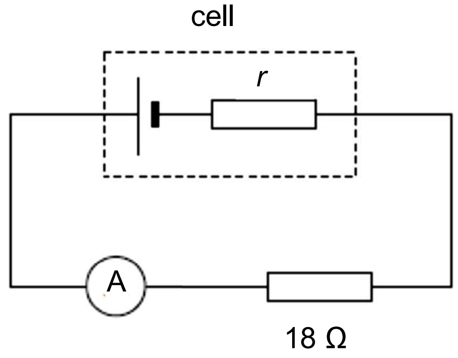

Fig. 5.1

(a) Calculate the cell's internal resistance, r.

r = ... Ω [2]

(b) Calculate the total charge, Q that will flow if the resistor is left connected until the cell has run out of energy.

Q = ... C [2]

(c) Calculate the total energy generated by the cell before it runs out.

total energy = ... J [2]

(d) Calculate the rate of heat generated in the 18 Ω resistor.

rate of heat generated = ………………………… W [2]

(e) Suppose that a resistor of higher resistance had been used instead of the 18 Ω resistor, so that the current was 0.225 A, calculate the resistance of this new resistor.

resistance of new resistor = ………………………… Ω [2]

6 Fig. 6.1 shows a plan view of a cyclotron, which is a device used to accelerate charged particles to high speeds. Protons are emitted between two semicircular discs called dees.

A uniform magnetic field is applied within the dees to cause the protons to move in a circular path. In between the dees there is a rapidly changing electric field applied that attracts the proton to the opposite dee.

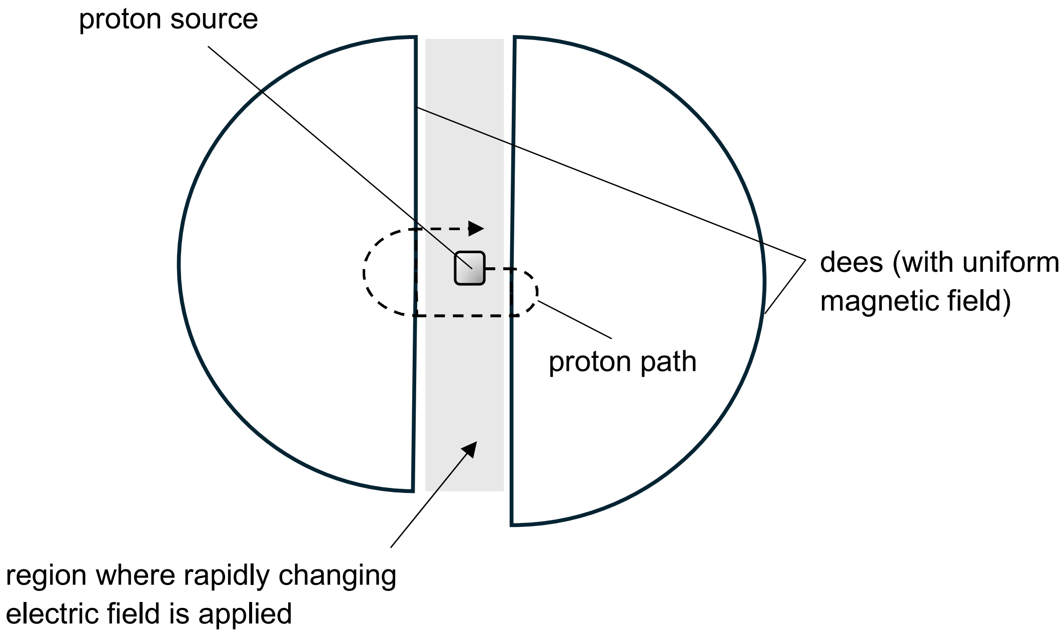

Fig. 6.1

(a) State the direction of the magnetic field in the dees.

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

(b) Show that the time taken for a proton to enter and leave the semicircular dee is given by the expression: $t_D = \dfrac{\pi m}{Bq}$

where m is mass of the proton mass, B is the magnetic flux density acting on the proton and q is the charge of the proton.

[3]

(c) State the effects of the magnetic field and electric field separately on the speed of the proton.

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

(d) State the expression for the time interval between the change in direction of the electric field.

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

(e) The proton source in Fig. 6.1 is now replaced by another source that emits particles that have the same mass as a proton but are oppositely charged.

State and explain the effect, if any, on the path and the value of t_D in **(b)** when **it first enters** the magnetic field compared to that of a proton.

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

7 **(a)** State what is meant by *nuclear fission.*

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………………………………………………………………………………………………

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

(b) A possible nuclear fission reaction is given by:

$${}^{1}_{0}\text{n} + {}^{235}_{92}\text{U} \rightarrow {}^{90}_{38}\text{Sr} + {}^{143}_{54}\text{Xe} + x\,{}^{1}_{0}\text{n}$$

(i) State the number of neutrons produced, *x*.

x = …………………………… [1]

(ii) Fig. 7.1 shows the masses of the nuclides.

nuclide	mass / u
U-235	234.993467
Sr-90	89.886883
Xe-143	142.905749
neutron	1.008665

Fig. 7.1

Show that the energy released in the fission reaction is 171 MeV.

[2]

(c) **(i)** A 500 MW nuclear power plant converts the energy released from nuclear fission into electrical energy with an efficiency of 33%.

Calculate the number of uranium-235 nuclei which undergo fission every second to produce this electrical power.

number of fissions per second = …………………………… [2]

(ii) Calculate the mass of uranium-235 that undergoes fission per day in order to sustain the electrical output in **(c)(i)**.

mass of uranium-235 per day = …………………………… kg [2]

(d) Currently, Singapore relies primarily on fossil fuels such as oil and natural gas for its power generation. Singapore is considering moving away from fossil fuels to alternative energy supplies.

Suggest two reasons why nuclear energy could potentially be a suitable alternative energy source for Singapore.

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

8 **Stars and Galaxies**

The following is a summary of the gravitational and nuclear fusion processes in stars and galaxies.

Interstellar space is not truly empty, but consists of clouds of gas and dust with a density of about 10^{-21} kg m^{-3}. This amounts to about one atom in every cubic centimetre of space. The gas is mainly hydrogen and helium, with other elements making up less than 1% of the gas clouds by mass.

Stars form when hydrogen gas clouds in interstellar space collapse under their own gravitation. Whether an interstellar gas cloud will collapse into a star depends on the temperature and mass of the gas cloud. If the temperature of the gas molecules is too high, the molecules of the gas cloud will have sufficient kinetic energy to escape the gravitational pull of the gas cloud, and the cloud will not collapse. However, if a gas cloud is sufficiently massive and sufficiently cool (10 – 100 K), the cloud can collapse into a star.

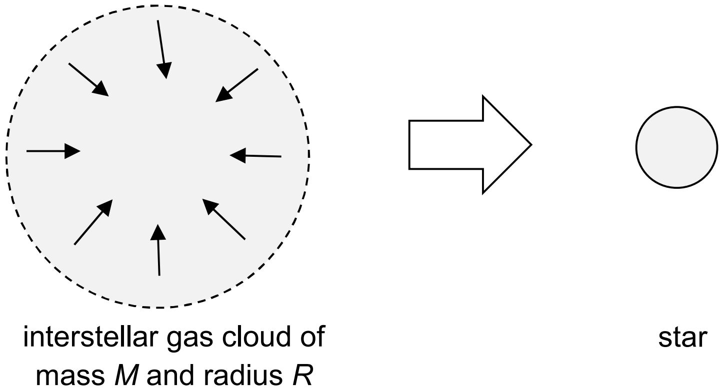

Fig. 8.1

Fig. 8.1 shows a spherical interstellar gas cloud. If the total gravitational potential energy of a given gas cloud exceeds the average kinetic energy of the thermal random motion of its molecules, the gas becomes unstable and tends to collapse. This is known as the Jeans criterion, given by the equation:

$$\frac{3}{2}NkT \leq \frac{GM^2}{R}$$

where M is the total mass of the cloud and R is the radius, N is the number of molecules of gas, k is Boltzmann's constant, and T is the maximum average temperature of the molecules which will allow the gas cloud to collapse into a star.

(a) A spherical interstellar gas cloud has the following properties:

uniform density of 100 hydrogen atoms per cm^3
total mass M of 10^{33} kg

The mass of a hydrogen atom is 1.66×10^{-27} kg.

Show that the radius R of the spherical gas cloud is 1.1×10^{17} m.

[2]

(b) Calculate the maximum average temperature T for the interstellar gas cloud in **(a)** to collapse into a star.

maximum temperature = …………………………… K [2]

(c) A second interstellar gas cloud is observed to have the same volume as the gas cloud in **(a)**, but with higher density. Explain how this difference in density affects the maximum average temperature for this gas cloud to collapse.

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

Stars radiate an enormous amount of power into space. The source of this energy is nuclear fusion in which hydrogen nuclei fuse to produce helium and energy. This process can only take place in the core of the star, as that is where the temperatures and pressures are high enough for the nuclei to come sufficiently close together, frequently enough to react.

The sequence of nuclear fusion reactions that take place in smaller stars is called the proton-proton chain, as shown in the equations below. Most of the energy released in this nuclear fusion chain is produced in the third step of the series of nuclear equations below.

1st step: ${}^{1}_{1}\mathrm{H} + {}^{1}_{1}\mathrm{H} \rightarrow {}^{2}_{1}\mathrm{H} + \mathrm{e}^{+} + \nu$

2nd step: ${}^{1}_{1}\mathrm{H} + {}^{2}_{1}\mathrm{H} \rightarrow {}^{3}_{2}\mathrm{He} + \gamma$

3rd step: ${}^{3}_{2}\mathrm{He} + {}^{3}_{2}\mathrm{He} \rightarrow {}^{4}_{2}\mathrm{He} + 2\,{}^{1}_{1}\mathrm{H} + \gamma$

Fig. 8.2 Proton-proton chain

However, in stars which are much more massive than our Sun, the core's temperature and pressure is high enough to allow the fusion of heavier elements: neon, oxygen, magnesium and silicon in turn, with each step in the fusion chain producing heavier elements. Eventually, iron is produced in the core of these massive stars and that is where the fusion chain stops.

(d) Explain why high temperatures are required for nuclear fusion to occur.

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

(e) The binding energy per nucleon of helium-3 and helium-4 are 2.57 MeV and 7.07 MeV respectively.

Determine the energy released in the third step of the proton-proton fusion chain.

energy released = …………………………… MeV [2]

(f) Calculate the maximum frequency of the gamma photon emitted in the third step of the proton-proton fusion chain.

frequency = …………………………… Hz [2]

(g) Explain why the fusion chain in massive stars does not progress past iron.

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

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

Galaxies are made up of a huge number of stars held together by mutual gravity. There is some debate about how mass is distributed in different galaxies which astronomers hope to resolve by taking measurements of the orbital velocity of stars around the galactic centre of various galaxies.

Three models are proposed. The first model assumes that most of the mass of a galaxy is concentrated in a supermassive point-like galactic core, with the other stars orbiting around it. The second model assumes that the mass of a galaxy is uniformly distributed in a sphere of stars. The third model assumes that the mass of a galaxy is distributed in a non-uniform sphere of stars such that the total mass increases proportionally with distance from the centre.

Plotting the orbital velocity of stars in a galaxy against distance from the galactic centre gives what is called a **rotation curve**. The three different models of galactic mass distribution give rise to three different possible rotation curves, shown in Fig. 8.3.

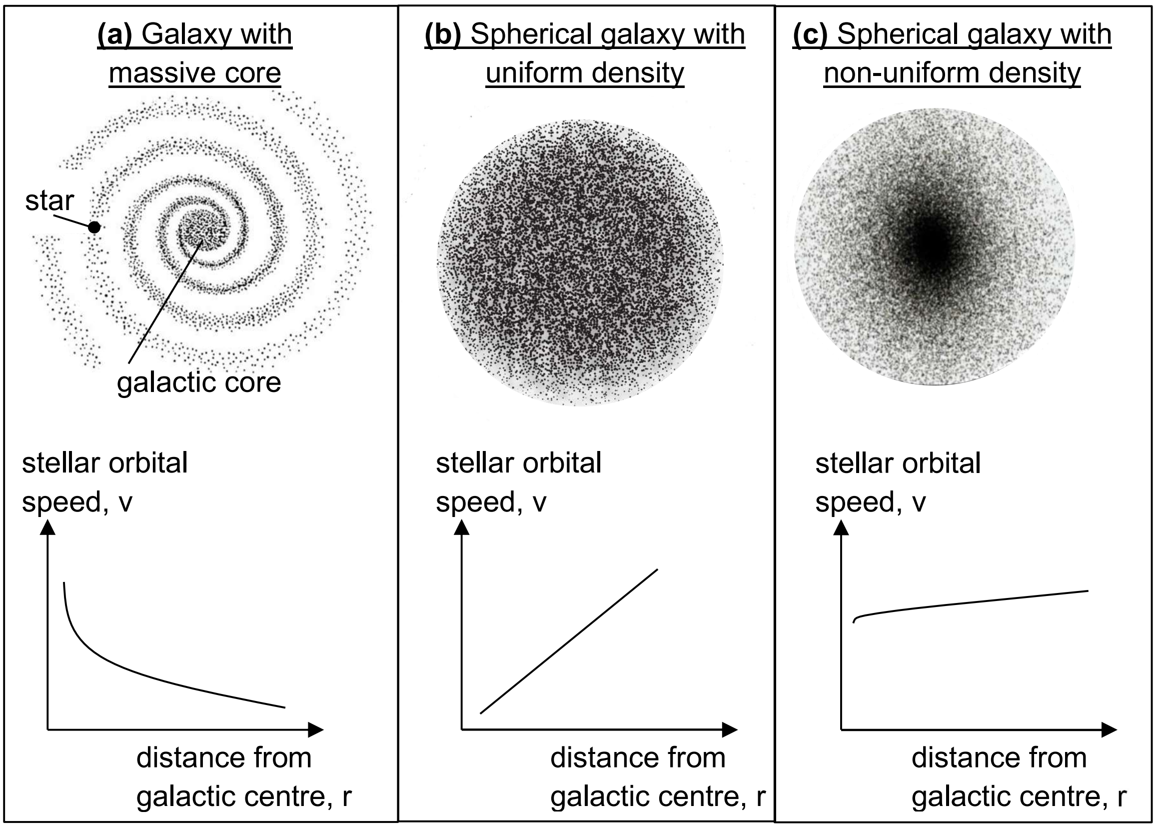

Fig. 8.3 Three models of galactic mass distribution and their associated rotation curves

(h) The first model of galactic mass distribution assumes that most of a galaxy's mass is concentrated in its galactic core.

Fig. 8.3(a) shows a star orbiting a galactic core, with an orbital speed v and an orbital radius r. The mass of the galactic core is M.

By considering gravitational and centripetal forces on the star, show that the orbital speed of the star is given by:

$$v = \sqrt{\frac{GM}{r}}$$

[2]

(i) The second model of galactic mass distribution assumes that a galaxy's mass is distributed as a large sphere of uniform density ρ, as shown in Fig. 8.3(b).

Using the equation in **(h)**, show that the orbital velocity of a star orbiting at the edge of a spherical galaxy of uniform density with a mass M and radius r is given by the relationship:

$$v \propto r$$

[2]

Measurements were made of the orbital velocity of stars in a distant galaxy, Messier 33. The rotation curve obtained from these measurements is shown in Fig. 8.4.

Fig. 8.4 Rotation curve of stars in Messier 33

(j) With reference to Fig. 8.3 and Fig. 8.4, suggest the possible distribution of mass in the galaxy Messier 33.

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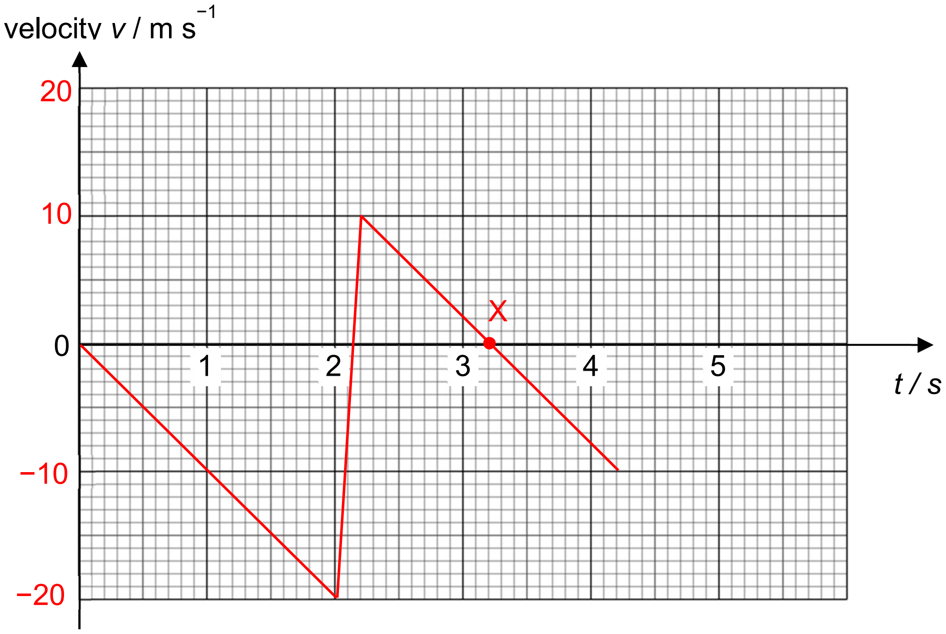
Tampines Meridian Junior College

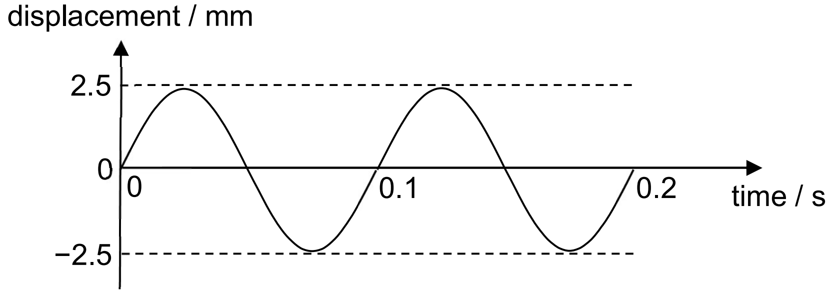
2024 JC2 H2 Physics Preliminary Examination Paper 2- Suggested Solution

1	**(a)**		W = J s^{-1} = kg m^{2} s^{-3} SI base units of $p = \dfrac{\text{kg m}^2\ \text{s}^{-3}}{\text{m K}}$ $= \text{kg m s}^{-3}\ \text{K}^{-1}$	C1 A1
	(b)	**(i)**	$q = py^2\left(\dfrac{T}{x}\right)$ $= (237)(0.0020)^2(\dfrac{323}{1.0})$ $= 0.306$	C1 A1
		(ii)	$\dfrac{\Delta q}{q}x100\% = \left(\dfrac{\Delta p}{p} + 2\dfrac{\Delta y}{y} + \dfrac{\Delta T}{T} + \dfrac{\Delta x}{x}\right)x100\%$ $= 2.0 + (2x3.0) + 0.5 + 1.0$ $= 9.5\%$	C1 A1
	(c)		$\Delta q = \dfrac{9.5}{100}(0.306)$ $= 0.03$ q = 0.31 ± 0.03 (actual uncertainty to 1 s.f as well as dp of q and actual uncertainty must match)	C1 A1

2	(a)	−9.81 m s^{-2}	A1
	(b)	$v = u + at = 0 + (−9.81)(2.0) = −20$ m s^{-1}	A1
	(c)	 first part: straight line from (0, 0) to (2, −20) with marking of −20 on *v*-axis [B1] second part: (2, −20) to (2.2, 10), can be straight or curved [B1] third part: (2.2, 10) to (4.2, −10) straight line [B1]	
	(d)	X marked correctly (at v = 0)	A1
	(e)	Ball falls with smaller acceleration (than *g*) / rate of increase of speed is smaller Time of fall is longer / reaches smaller speed	B1 B1

3	(a)	$F = qE = (2.0 \times 10^{-9})(1.5 \times 10^{5})$ $F = 3.0 \times 10^{-4}$ N direction: upwards	M1 A1 B1
	(b)	Loss in gravitational potential energy $= m\,g\,(h + x)$ Gain in elastic potential energy and electric potential energy $= ½\,k\,x^2 + F_E\,(h + x)$	 C1 C1

		By conservation of energy, $m\,g\,(h + x) = \frac{1}{2}\,k\,x^2 + F_E\,(h + x)$ $(1.0 \times 10^{-4})(9.81)(0.515) = \frac{1}{2}\,k\,(0.015)^2 + (3.0 \times 10^{-4})(0.515)$ $k = 3.12$ N m^{-1} (1 mark if overall correct method to solve using conservation of energy.)	A1

4	**(a)**	(Simple harmonic motion is the motion of a particle about a fixed point such that its) acceleration is proportional to displacement (from a fixed point)	B1
		and always directed towards a fixed point / opposite in direction to the displacement	B1
	(b)	existence of peak amplitude	C1
	(c)	microwave cooking [B1] (cook food using microwave of frequency close to the resonating frequency (of the water molecules in food)) or radio receiver [B1] (receive radio waves when the receiver (circuit) is tuned to the frequency of the radio waves to be received) or magnetic resonance imaging [B1] (generate image for medical diagnosis using radio waves of frequencies close to the resonating frequency (of the atomic nuclei))	
	(d)	max speed $v_0 = \omega x_0 = 2\pi f x_0 = 2\pi \times 10.0 \times 2.5 \times 10^{-3}$	C1
		$= 0.157$ m s^{-1}	A1
	(e)	 shape (sin or cos or any sinusoidal shape) [M1]	

		constant period 0.1 s and constant amplitude 2.5 mm [A1]

5	**(a)**	$E = I(R + r)$ $9.0 = 0.450(18 + r)$ $r = 2.0\ \Omega$	M1 A1
	(b)	$Q = It$ $= 0.450 \times 3600$ $= 1.6 \times 10^3\text{C}$	M1 A1
	(c)	$E_{total} = IVt$ $= 0.450 \times 9.0 \times 3600$ $= 14.6 \times 10^3\text{J}$	M1 A1
	(d)	$P = I^2R$ $= (0.450)^2 \times 18.0$ $= 3.65\ \text{W}$	M1 A1
	(e)	New effective resistance $= \dfrac{V}{I} = \dfrac{9.0}{0.225} = 40.0\ \Omega$ Replacement resistance = 40.0 – 2.0 = 38.0 Ω	M1 A1

6	**(a)**	Magnetic field lines are directed <u>out of the paper</u>.	[A1]
	(b)	Magnetic force provides for centripetal force $Bqv = m\omega^2 r$ [M1] where ω is the angular velocity of the proton. $m\omega^2 r = Bq\omega r$ $\omega = \dfrac{Bq}{m}$ $\because \omega = \dfrac{2\pi}{T}$ [M1] where T is the period of the motion. $T = \dfrac{2\pi m}{Bq}$ [M1] $t_D = \dfrac{1}{2}T = \dfrac{\pi m}{Bq}$ [A0]	

		Alternative working: Magnetic force provides for centripetal force $Bqv = m\frac{v^2}{r}$ [M1] $r = \frac{mv}{Bq}$ [M1] $t_D = \frac{\pi r}{v}$ [M1] $= \frac{\pi m}{Bq}$ [A0]	
	(c)	The magnetic field does not change the speed of the proton. The electric field causes the speed to increase.	[B1] [B1]
	(d)	t_D or $\frac{\pi m}{Bq}$	[A1]
	(e)	Since the charge of the new particle is negative: This particle will make an anticlockwise direction motion within the dees. [B1] Since the mass-to-charge ratio (m/q) of the new particle is the same: This particle will make the same radius within the dees [B1] Since m/q of this new particle is the same: Based on the equation of **(b)** the t_D value will remain same since *B* remains the same. [B1]	

7	**(a)**	Nuclear fission is the splitting / disintegration of a heavy nucleus into two lighter nuclei with approximately equal masses.		A1
	(b)	**(i)**	3 neutrons	A1
	(b)	**(ii)**	Mass difference including neutrons = (234.993467 – 89.886883 – 142.905749 – 2 x 1.008665) x u = 0.183505 u [M1] Energy released = 0.183505 u c^2 = 2.742 x 10^{-11} J = 2.742 x 10^{-11} / (1.6 x 10^{-19}) = 171.375 [M1] = 171 MeV [A0]	
	(c)	**(i)**	Energy required from fission per second = 500 x 10^6 / 0.33 = 1.515 x 10^9 J	C1

			Number of fissions per second required = $1.515 \times 10^9 / (2.742 \times 10^{-11})$ $= 5.53 \times 10^{19}$	A1
	(c)	(ii)	Mass of U-235 undergoing fission per second $= 5.53 \times 10^{19} \times 234.99$ u $= 2.156 \times 10^{-5}$ kg [C1] Mass of U-235 that fissions per day $= 2.156 \times 10^{-5} \times 24 \times 3600 = 1.863 = 1.9$ kg [A1]	
	(e)	Any two of the following: 1. Only a small amount of uranium is required to produce a large amount of electrical energy. This could remove Singapore's reliance on importing large amounts of fossil fuels. 2. The use of nuclear energy is carbon neutral or less polluting unlike the use of fossil fuels. Therefore this compares well with other carbon-neutral alternative energy sources. 3. Nuclear power can potentially generate large amounts of energy to meet Singapore's needs. 4. Nuclear power requires less land area than other alternative energy sources such as solar or wind power. This is suitable for land-scarce Singapore. 5. Nuclear power is more reliable (can be generated 24 hours a day) than other alternative energy sources such as wind or solar which depend on weather conditions. or other reasonable explanations.		B2

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On a life-cycle basis, nuclear power emits just a few grams of CO_2 equivalent per kWh of electricity produced. Whilst estimates vary, the United Nations (UN) Intergovernmental Panel on Climate Change (IPCC) has provided a median value among peer-reviewed studies of 12g CO_2 equivalent/kWh for nuclear, similar to wind, and lower than all types of solar.[2]

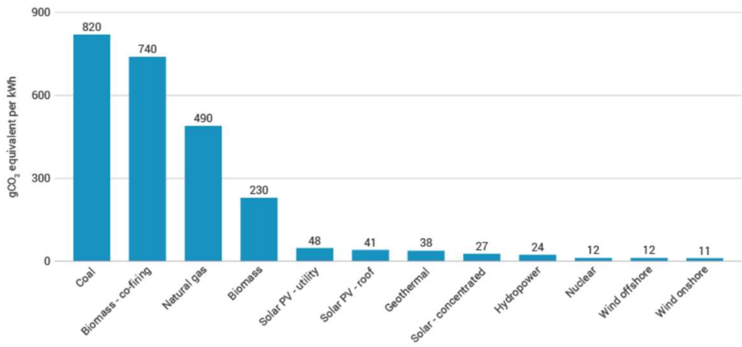

Figure 1: Average life-cycle CO_2 equivalent emissions (source: IPCC)

8	(a)	density of gas cloud = $1.66\times10^{-27}\times100=1.66\times10^{-25}$ kg cm^{-3} $=1.66\times10^{-19}$ kg m^{-3} [C1 if number of molecules obtained as 6.02 x 10^{59}] Volume of gas cloud = $\dfrac{10^{33}}{1.66\times10^{-19}}=6.02\times10^{51}$ m^3 Radius of spherical gas cloud: $\dfrac{4}{3}\pi R^3=6.02\times10^{51}$ $R=1.129\times10^{17}$ m $=1.1\times10^{17}$ m	C1 M1 A0
	(b)	Number of molecules, N = $\dfrac{10^{33}}{1.66\times10^{-27}}=6.02\times10^{59}$ Temperature T: $\dfrac{6.67\times10^{-11}\times\left(10^{33}\right)^2}{1.1\times10^{17}}\geq\dfrac{3}{2}\left(6.02\times10^{59}\right)\left(1.38\times10^{-23}\right)T$ T = 43.7 K (if used 1.1 x 10^{17}) T = 47.4 K (if used 1.129 x 10^{17}) T = 48.6 K (if used more dp) T = 52.5 K (if used 1.1 x 10^{17} to find volume)	C1 A1
	(c)	As the density of the gas cloud increases, the mass of the gas cloud increases since the volume stays the same. (also accept number of molecules increases) From the formula, the maximum (average) temperature for the gas cloud to collapse will also increase. (Since both M and N increases, but M^2 increases more than N, thus the ratio $\dfrac{M^2}{N}$ increases).	M1 A1
	(d)	High kinetic energy is required to overcome the (mutual electrostatic) repulsion between the positively charged nuclei so that they can fuse. Or nuclei must have high speed to collide. Since thus high kinetic energy (of the nuclei) is related to temperature, thus a high temperature is required for fusion.	B1 B1

	(e)	Energy released = total binding energy of products – total binding energy of reactants Energy released = (7.07 x 4) – (2.57 x 3 x 2) = 12.86 MeV = 12.9 MeV	C1 A1
	(f)	The maximum frequency gamma photon is emitted when all the energy released in the fusion reaction is converted into the photon energy. hf = 12.9 MeV $f = \dfrac{12.9\times10^{6}\times1.6\times10^{-19}}{6.63\times10^{-34}}$ $= 3.11\times10^{21}$ Hz	C1 A1
	(g)	Iron has the <u>highest binding energy per nucleon</u> of any element Or Iron is the <u>most stable element</u> Hence, the fusion of iron into heavier elements <u>requires the input of energy</u> / is <u>unlikely to occur spontaneously</u>. Or There is <u>not enough energy / temperature</u> in the stars for fusion of iron.	B1 B1
	(h)	gravitational force provides for centripetal force $\dfrac{GMm}{r^2} = \dfrac{mv^2}{r}$ $v = \sqrt{\dfrac{GM}{r}}$	C1 M1 A0
	(i)	$v = \sqrt{\dfrac{GM}{r}}$ $v = \sqrt{\dfrac{G\left(\dfrac{4}{3}\pi r^3\rho\right)}{r}}$ $v = \sqrt{\dfrac{4}{3}G\pi\rho \times r}$ <u>Since G, π, ρ are constants</u>, so $v \propto r$	C1 M1 A0

	(j)	The mass is uniformly distributed in a sphere nearer the galactic centre and increases proportionally with distance further from the galactic centre. **OR** Messier 33 is likely to have a spherical distribution of mass with uniform density nearer the galactic centre, and non-uniform density further from the galactic centre. (This is because the portion of the rotation curve nearer M33's core shows a proportional relationship, similar to Fig 8.3(b) while the portion of the rotation curve further from M33's core shows an almost horizontal relationship, similar to Fig 8.3(c).)	B1 B1