HWA CHONG INSTITUTION
JC2 Preliminary Examination
Higher 2

CANDIDATE NAME		CT GROUP	20S
CENTRE NUMBER		INDEX NUMBER	

PHYSICS

9749/03

Paper 3 Longer Structured Questions

15 SEP 2021

Candidates answer on the Question Paper.

2 hours

No Additional Materials are required.

INSTRUCTIONS TO CANDIDATES

Write your **Centre number**, **index number, name** and **CT class** clearly 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, paperclips, highlighters, glue or correction fluid.

Section A
Answer **all** questions.

Section B
Answer **one** question only. **Circle** the question number on the cover page.

You are advised to spend one and a half hours 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.

You are reminded of the need for good English and clear presentation in your answers.

IMPORTANT NOTICE

Questions set on the Common Last Topic of the syllabus do not form part of the assessment. They will not be marked by the Examiners.

In Section B you must answer Question 8. There is now no choice of question in this Section.

The total time allowed for this Question Paper has not been changed. The total mark for this Question Paper is still 80.

For Examiner's Use		
SECTION A		
1		9
2		9
3		11
4		8
5		7
6		9
7		7
SECTION B		
8		20
9	---	20
Deductions		
Total		80

This document consists of **22** printed pages (including 1 blank page).

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Data

speed of light in free space, $c = 3.00 \times 10^{8}$ m s^{-1}

permeability of free space, $\mu_o = 4\pi \times 10^{-7}$ H m^{-1}

permittivity of free space, $\varepsilon_o = 8.85 \times 10^{-12}$ F m^{-1} $\approx (1/(36\pi)) \times 10^{-9}$ F m^{-1}

elementary charge, $e = 1.60 \times 10^{-19}$ C

the Planck constant, $h = 6.63 \times 10^{-34}$ J s

unified atomic mass constant, $u = 1.66 \times 10^{-27}$ kg

rest mass of electron, $m_e = 9.11 \times 10^{-31}$ kg

rest mass of proton, $m_p = 1.67 \times 10^{-27}$ kg

molar gas constant, $R = 8.31$ J K^{-1} mol^{-1}

the Avogadro constant, $N_A = 6.02 \times 10^{23}$ mol^{-1}

the Boltzmann constant, $k = 1.38 \times 10^{-23}$ J K^{-1}

gravitational constant, $G = 6.67 \times 10^{-11}$ 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	$\phi = -\frac{Gm}{r}$
temperature	$T/\text{K} = T/{}^\circ\text{C} + 273.15$
pressure of an ideal gas	$P = \frac{1}{3}\frac{Nm}{V} < c^2 >$
mean kinetic energy of a molecule of an ideal gas	$E = \frac{3}{2}kT$
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	$R = R_1 + R_2 + \ldots$
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	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

Section A

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

1 A fixed mass of monatomic ideal gas undergoes the cycle ABCA of changes shown in Fig. 1.1.

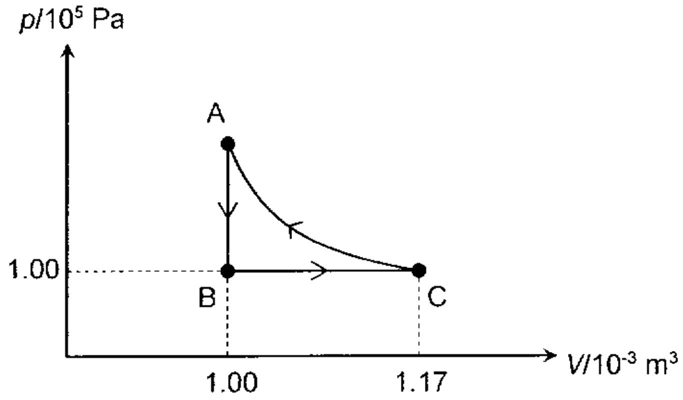


Fig. 1.1 (not to scale)

The temperature of the gas at points A, B and C is 350 K, 300 K and 350 K respectively.

(a) Calculate the amount of gas in moles.

amount of gas = ...mol [2]

(b) Show that the change in internal energy ΔU of the gas during process AB is 25.0 J.

[1]

(c) The answer to part **(b)** is also the amount of heat released by the gas during process AB. Explain why this is so.

....

....[1]

(d) The gas is heated at constant pressure from point B to point C. Calculate the work done by the gas, and the heat supply to the gas from point B to point C.

work done by the gas = ... J

heat supply = ... J

[3]

(e) Deduce whether heat is absorbed or released by the gas during the cycle ABCA. Explain your deduction.

....

....

....

....[2]

2 **(a)** Define simple harmonic motion (s.h.m.).

....

....

....

....[2]

(b) A trolley of mass 700 g oscillates between two stands as shown in Fig. 2.1. As the trolley moves from right to left, it pulls the ticker tape for half a cycle. The timer marks 50 dots per second.

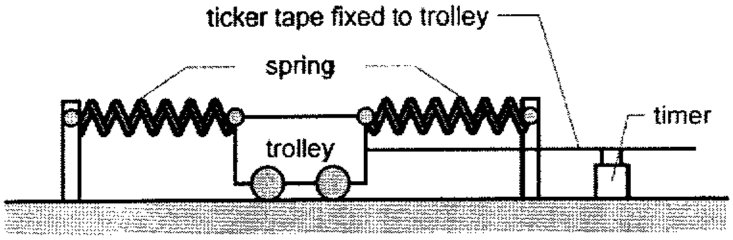


Fig. 2.1

Fig. 2.2 (drawn to scale)

The ticker tape in Fig. 2.2 is drawn to full scale. By making appropriate measurements,

(i) show that the period of oscillation is 0.48 s.

[1]

(ii) determine the amplitude of the oscillation,

amplitude = ... cm [1]

(c) Hence, calculate

(i) the maximum velocity of the trolley,

maximum velocity = ... cm s^{-1} [1]

(ii) the maximum resultant force acting on the trolley,

maximum resultant force = ... N [2]

(d) Sketch in Fig. 2.3 the graph of velocity against displacement for the half-cycle that that ticker tape was pulled through, taking leftward to be the positive direction.

Indicate the starting point on your sketch. There is no need to indicate values.

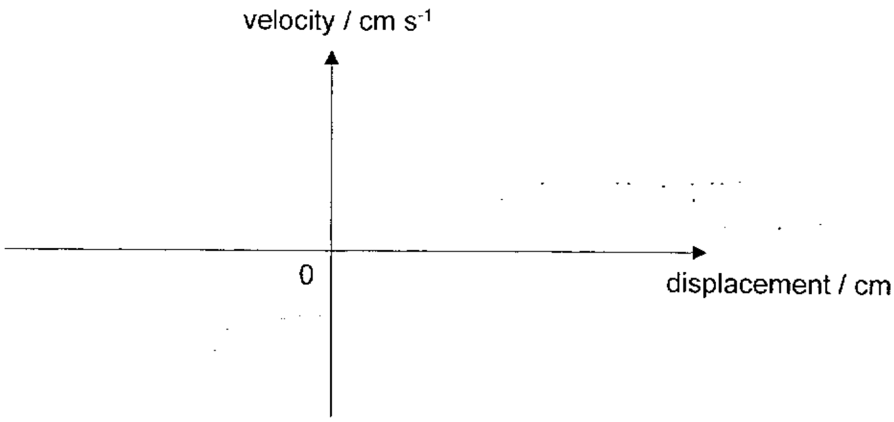


Fig. 2.3

[2]

3 **(a)** State the *principle of superposition*.

....

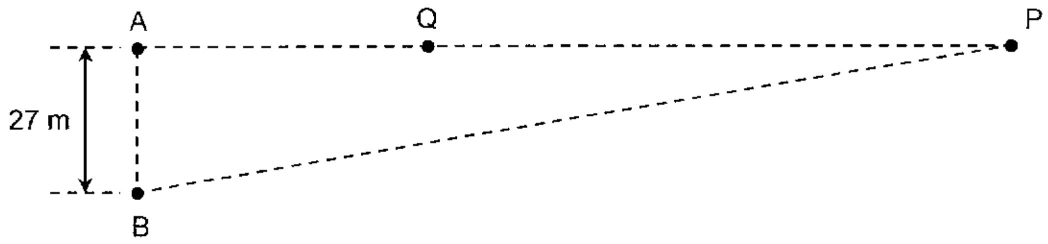
....

....

....[2]

(b) Two microwave transmitters are positioned 27 m apart at points A and B as shown in Fig. 3.1. Operating at different power, they each transmit a microwave of wavelength 4.0 m uniformly in all directions. The two waves emitted are in phase at the transmitters.

Line AB and AP are perpendicular to each other.



(not drawn to scale)

Fig. 3.1

The variation with time t of the displacement x of the microwave arriving at point P is shown in Fig. 3.2.

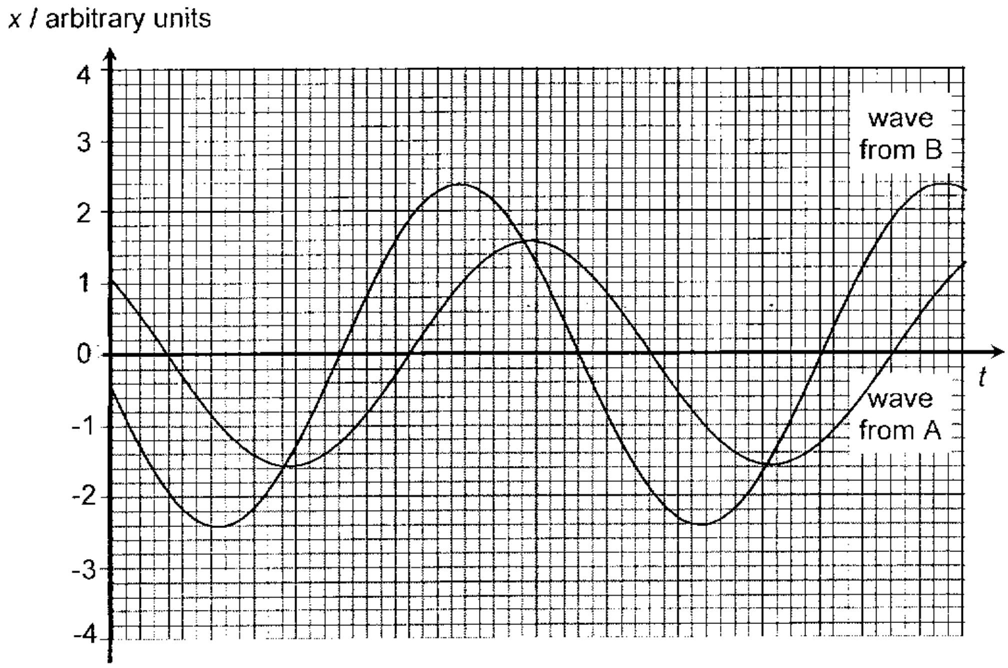


Fig. 3.2

(i) Determine the phase difference between the waves from transmitter A and from transmitter B that arrive at point P.

phase difference = ... rad [2]

(ii) The waves from the two transmitters interfere to form positions of maximum intensity and minimum intensity.

Use Fig. 3.2 to determine, for points of maximum and minimum intensity closest to point P, the ratio

$$\frac{\text{maximum wave intensity}}{\text{minimum wave intensity}}$$

ratio = ... [3]

(c) The path difference between the waves arriving from A and B at Q is 6.5 m.

Determine the number of maxima found along the line between A and Q.

number of maxima = ... [2]

(d) A student thinks that a stationary wave is formed along the line joining A and B. Comment on the student's thought.

....

....

....

....[2]

4 In an adapted version of the Millikan's oil-drop experiment, oil drops are injected at 1.5 m s^{-1} horizontally into a vacuum chamber between two parallel plates, as shown in Fig. 4.1. The plates are 60 mm long and 20 mm apart.

The potential difference between the plates is adjusted so that the oil drops travel horizontally between the two plates.

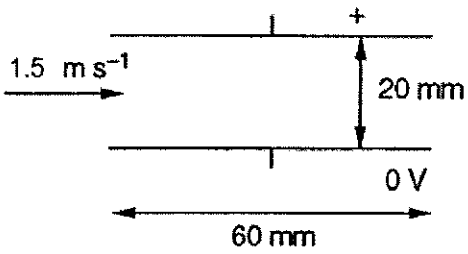


Fig. 4.1

(a) For an oil drop of mass 2.0×10^{-14} kg, carrying a charge of -7.85×10^{-18} C, calculate the potential difference ΔV between the two plates.

ΔV = ... V [3]

(b) The potential difference is now increased to two times the original value.

(i) Explain whether the time taken for the oil drop to pass through the plates is affected by this change.

....

....

....

.... [2]

(ii) Hence show that the oil drop emerges from the plates at a speed of 1.55 m s^{-1}.

[3]

5 **(a)**. Explain what is meant by the *potential difference* across an electrical component.

....

....

....

....[2]

(b) Fig. 5.1 shows the voltage-current variation of two components X and Y.

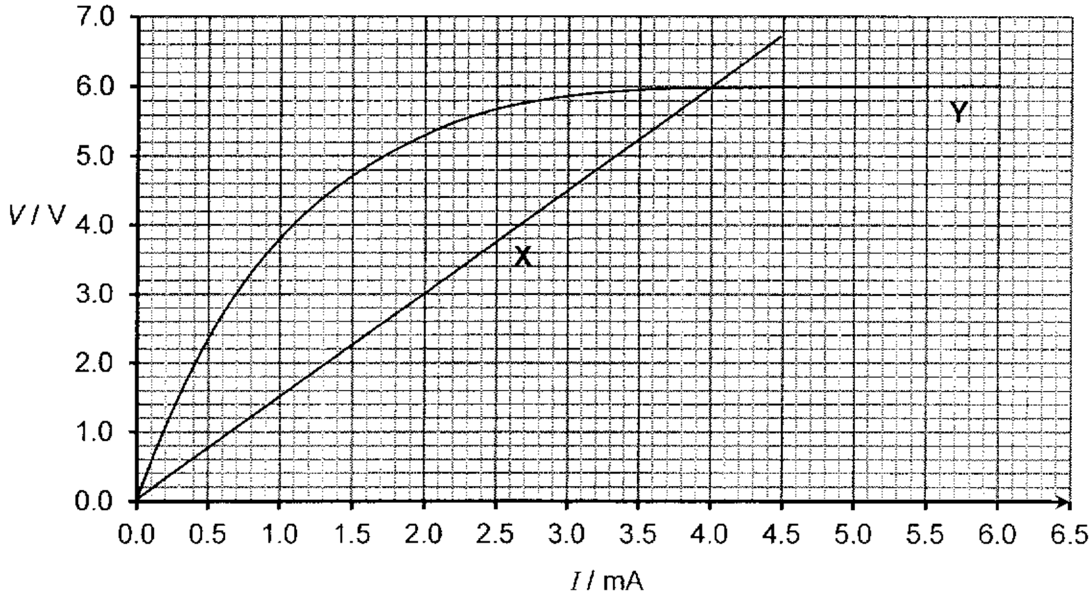


Fig. 5.1

State the maximum and minimum resistance of component Y between $V = 0.0$ V and $V = 6.0$ V.

minimum resistance = ... kΩ

maximum resistance = ... kΩ

[2]

(c) Components X and Y are connected in parallel as shown in Fig. 5.2. The parallel combination is connected in series with a variable resistor R and a cell of e.m.f. 8.0 V and negligible internal resistance.

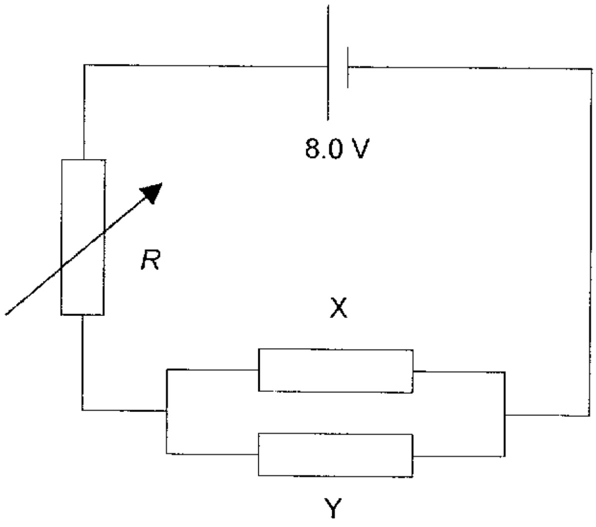


Fig. 5.2

(i) The resistance of the variable resistor R is adjusted until both X and Y are operating at the same resistance. With reference to Fig. 5.1, deduce the voltage across X and Y.

voltage = ... V **[1]**

(ii) Hence, determine the resistance of the variable resistor R.

R = ... Ω [2]

6 **(a)** Define *magnetic flux density* of a magnetic field.

....

....

....

....[2]

(b) Fig. 6.1 shows a solenoid of length 50.0 cm and 1000 turns. It is connected in a circuit in series with a horizontal rectangular loop ABCD, where AB = 20.0 cm and BC = 4.0 cm. The loop is freely pivoted about the axis XY.

When there is no current, the loop is balanced without the use of any rider. When a current of 3.0 A flows as shown in Fig. 6.1, a rider of mass 0.40 g is needed to restore balance.

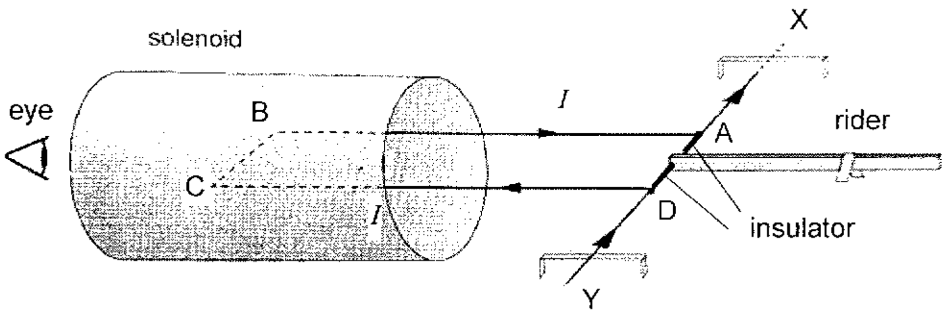


Fig. 6.1

(i) State and explain whether the direction of the current in the solenoid is clockwise or anticlockwise as viewed by the eye.

....

....

....

....[2]

(ii) Calculate the magnetic flux density in the solenoid.

magnetic flux density = ... T [2]

(iii) Determine the magnetic force acting on side BC.

force = ... N [1]

(iv) Determine the distance of the rider from the axis XY when balance is restored.

distance = ... cm [2]

7 An a.c. power supply is connected to a resistor R, as shown in Fig. 7.1.

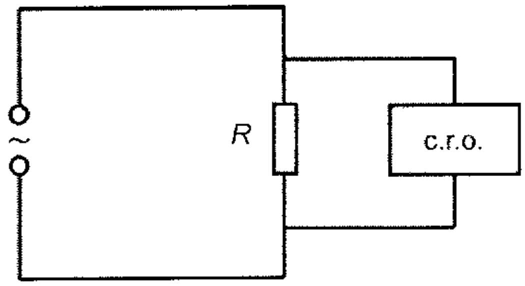


Fig. 7.1

A cathode ray oscilloscope (c.r.o.) is used to show the potential difference (p.d.) across R. The screen of the c.r.o. displays the variation with time of the p.d. across R, as shown in Fig. 7.2.

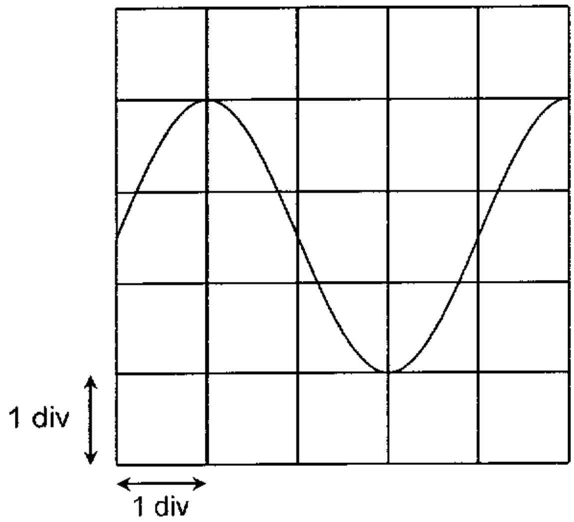


Fig. 7.2

(a) The power supply's voltage V is given by the expression

$$V = 6.0\sin(314t)$$

The voltage V is measured in volts and the time t is measured in seconds.

Determine the Y-gain and time-base of the c.r.o.

Y-gain = ... V / div [1]

time-base = ... ms / div [2]

(b) Now, a diode is connected in series with the resistor R, as shown in Fig. 7.3.

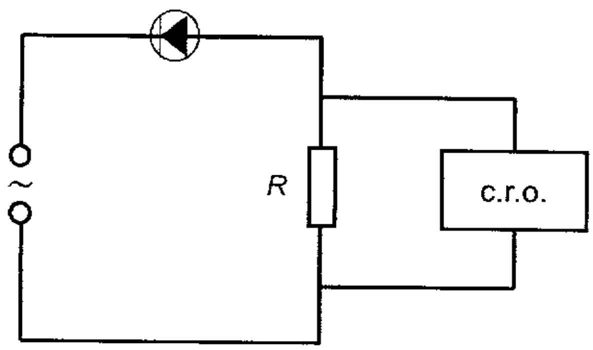


Fig. 7.3

(i) Sketch in Fig. 7.4 the variation with time of the power P dissipated in R when R is 20 Ω. Indicate the peak power value in your sketch.

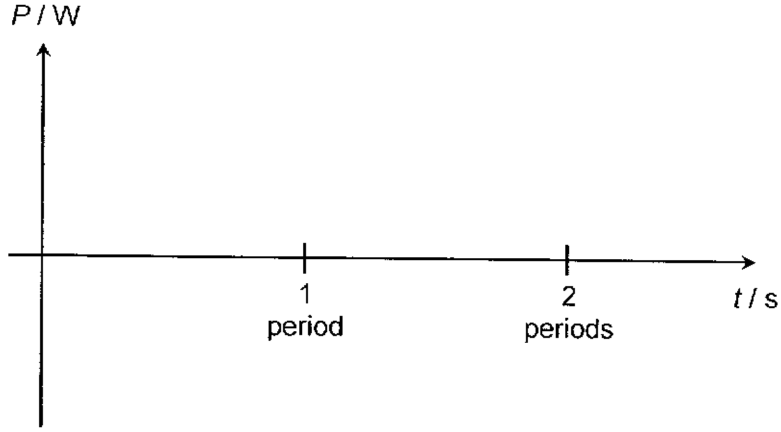


Fig. 7.4

[2]

(ii) Draw a line in Fig. 7.4 to represent the average power dissipated in R.

Hence, show that the root-mean-square current in R is 0.15 A.

[2]

Section B

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

8 **(a)** **(i)** A satellite is orbiting the Earth in a circular orbit with a period of 24 hours. State two circumstances under which this satellite will be a geostationary satellite.

1. ....

....

2. ....

.... [2]

(ii) State one advantage and one disadvantage of geostationary satellites.

Advantage: ....

....

....

....

Disadvantage: ....

....

....

....

[2]

(b) Fig. 8.1 shows a pair of stars of equal mass m which move in circular orbits around their common centre of mass (C.M.).

In this question consider the stars to be point masses situated at their centres.

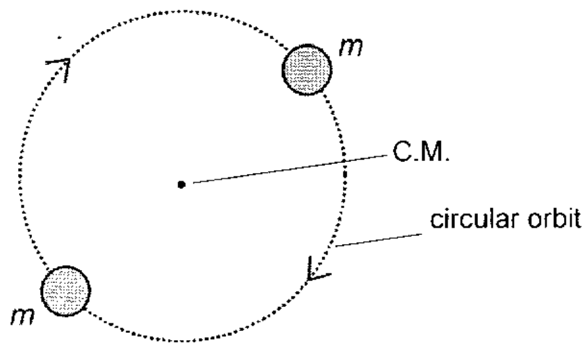


Fig. 8.1

(i) By considering the forces acting on the stars, explain why they must always be diametrically opposite in such an orbit.

....

....

....

....[2]

(ii) The centres of the two stars are separated by a distance R of 3.6×10^{10} m. The stars have an orbital period T of 20.5 days.

Calculate the mass m of each star.

m = ... kg [3]

(c) Saturn is a massive planet with a mass of 5.68×10^{26} kg and radius 5.82×10^{4} km.

(i) Calculate the gravitational potential V_S on the surface of Saturn.

V_S = ... [3]

(ii) State a physical meaning to your answer to part **(c)(i)**.

....

....

....

....[1]

(d) Titan is the largest moon of Saturn. It has a mass of 1.35×10^{23} kg and a radius of 2.58×10^{3} km. The distance between the centres of Titan and Saturn is 1.22×10^{6} km.

(i) A space probe is at the mid-point between Titan and Saturn, heading directly towards Titan. Explain whether the space probe is gaining or losing gravitational potential energy at this point in time.

....

....

....

....[2]

(ii) Point E is the point between the centres of Saturn and Titan where the resultant gravitational field strength is zero. Calculate the distance between point E and the centre of Titan.

distance = ... km [3]

(e) As a result of bombardment of Titan by a meteor, a rock of mass m is ejected with an intial kinetic energy of K_T from Titan's surface.

Let the symbols V_S, V_T and V_E represent the gravitational potential on the surface of Saturn, Titan and at point E respectively.

(i) Using any of the symbols m, K_T, V_S, V_T and V_E, write an inequality that represents the condition for the rock being able to arrive on Saturn.

[1]

(ii) Using any of the symbols m, K_T, V_S, V_T and V_E, write an expression for the kinetic energy K_S of the rock when it arrives on the surface of Saturn.

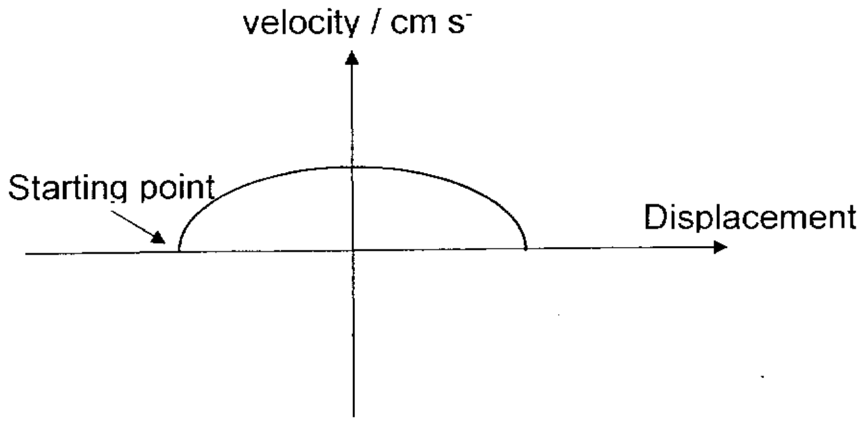
[1]

9 This question is no longer available because of CLT. You must do question 8.

End of Paper 3

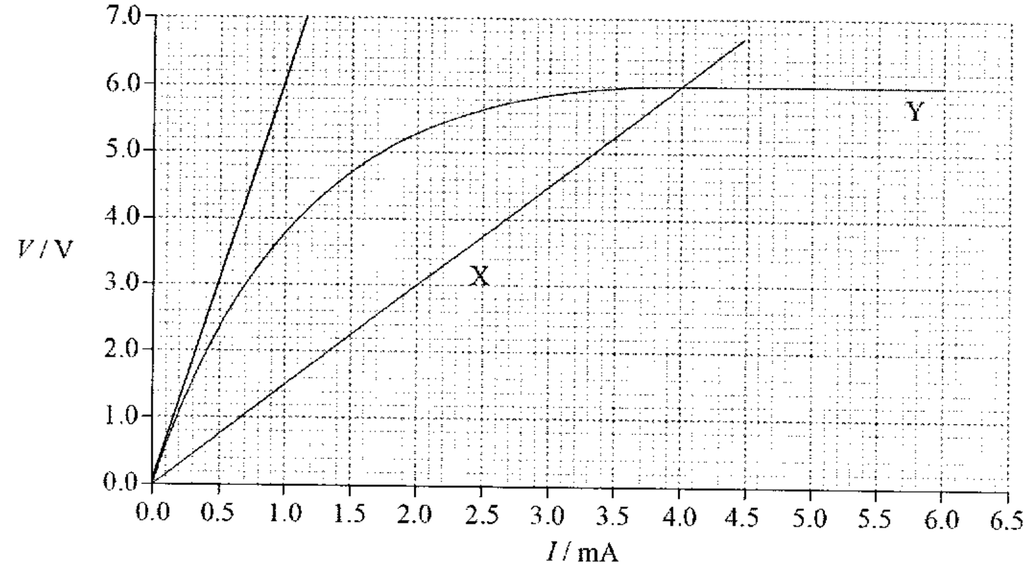
2021 C2 Preliminary Examination H2 Physics Paper 3 Suggested Solutions

1a	Using point B: Apply $PV = nRT$ $(1.00\times10^{5})(1.00\times10^{-3}) = n(8.31)(300)$ $n = 0.0401$ mol Using point C would have yielded n = 0.0402 mol.	1 1
1b	For process AB, temperature decreases from 350 K to 300 K, thus the internal energy decreases. $\Delta U = \frac{3}{2}nR\Delta T = \frac{3}{2}(0.0401)(8.31)(300-350)$ $= -25.0$ J Change in internal energy is 25.0 J.	1
1c	For process AB, the volume remains constant. So work done on gas is zero. From 1st Law of thermodynamics, the decrease in internal energy is also the amount of heat released by the gas during process AB. $\Delta U = Q + 0$	1
1d	Work done on gas from B to C, $W = p_1(V_1 - V_3)$ = $(1.00 \times 10^5)(1.00 \times 10^{-3} - 1.17 \times 10^{-3})$ = – 17.0 J Work done by the gas from B to C = + 17.0 J Increase in internal energy from B to C, ΔU = +25.0 J Heat supply to gas from B to C $Q = \Delta U - W$ = 25.0 + 17.0 = 42.0 J	1 1 1
1e	Heat is released. Net change in internal energy is zero for a cyclic process. i.e. $\Delta U = 0$ Work done on gas during CA is larger than work done by gas during BC. (No work done during AB). Thus W is positive. $\Delta U = Q + W$ Q = - W thus as Q is negative, Heat is released by the gas during the cycle ABCA.	0 1 1

2a	An oscillatory motion where acceleration is directly proportional to displacement (from the equilibrium position), directed towards the equilibrium position.	 1 1
2bi	$0.5T$ => 13 dots $0.5\ T = 12 \times (1/50) = 0.24$ s $T = 0.48$ s	 1
2bii	x_0 = 12.5 cm (first to last dot) / 2 = 6.25 cm	1
2ci	$v_0 = \omega x_0 = \frac{2\pi}{T} x_0$ $v_0 = \frac{2\pi}{0.48}(6.25) = 81.8 \text{ cm s}^{-1}$	 1
2cii	$F_0 = m\omega^2 x_0 = m\left(\frac{2\pi}{T}\right)^2 x_0$ $F_0 = (0.700)\left(\frac{2\pi}{0.48}\right)^2 (0.0625) = 7.50$ **N**	1 1
2d	 	2

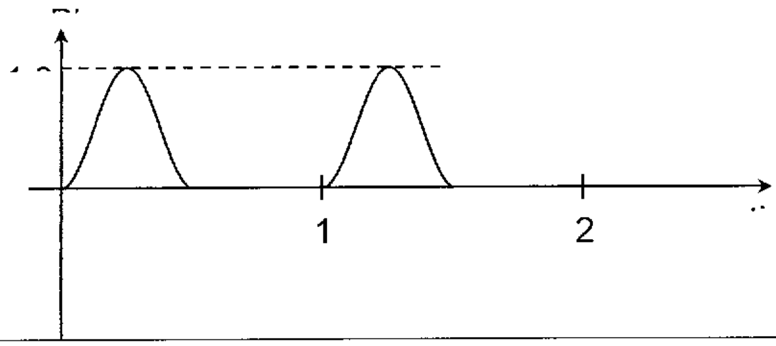
3a	When two (or more) waves overlap, the resultant displacement (at any point and instant) is the (vector) sum of the displacements due to each individual wave (at that point and instant).	2
3bi	$\frac{5}{34} \times 2\pi = 0.924$ rad	2
3bii	Amplitude of maxima $= 2.4 + 1.6 = 4.0$ units Amplitude of minima $= 2.4 - 1.6 = 0.8$ units $= \frac{4.0^2}{0.8^2}$ Ratio of intensity $= 25$	1 1 1
3c	Path difference at Q $= \frac{6.5}{4.0}\lambda = 1.625\lambda$ Path difference at A $= \frac{27}{4.0}\lambda = 6.75\lambda$ Along AQ, maxima are where path difference is 2λ, 3λ, 4λ, 5λ and 6λ. So 5 maxima.	1 1
3d	Even though the two waves are travelling in opposite directions, the amplitude is different. Thus no stationary wave is formed.	1 1

4a	By Newton's Second Law, taking upwards as positive, $F_{net} = m\,a$ $F_E - m\,g = 0$ $q\,E = m\,g$ $q\,(\Delta V/d) = m\,g$ $\Delta V = m\,g\,d\,/\,q = (2.0 \times 10^{-14})\,(9.81)\,(20 \times 10^{-3})\,/\,(7.85 \times 10^{-18})$ $= 500$ V *Arriving at the correct number through incorrect physics does not yield any marks.*	**M1** equation **M1** numbers **A1** answer
4bi	The potential difference is vertically applied. Hence, the electric field acts in the vertical direction. Only the vertical acceleration is affected. Since there is no change in the horizontal forces, horizontal motion is not affected. Hence, the time taken is still equal to 60 mm divided by 1.5 m s^{-1}. *Correct conclusions without a correct explanation are not awarded any marks.*	**B1** **B1**
4bii	$2qE - mg = ma_y$ Since originally, the electric force qE was equal to the weight mg, $2mg - mg = ma_y$ $mg = ma_y$ $a_y = g$ *Students must explicitly and clearly show why $a = g = 9.81$ m s^{-2}.* $v_x = 1.5$ m s^{-1} (unchanged) $t = s_x\,/\,v_x = (60 \times 10^{-3})\,/\,(1.5) = 4.0 \times 10^{-2}$ s $v_y = a_y\,t = (9.81)\,(4.0 \times 10^{-2}) = 0.3924$ m s^{-1} *Students must show, with appropriate formulae, how $v_y = 0.3924$ m s^{-1} is obtained.* $v = (v_x^2 + v_y^2)^{1/2} = 1.55$ m s^{-1} *Students must show, with an appropriate formula, how $v = 1.55$ m s^{-1} obtained.* *Arriving at the correct number by accident does not yield any marks.*	**B1** **B0** **M1** **M1**

5a	It is the energy converted per unit charge from electrical to non-electrical when charge is moved through the component.	1 1
5b	 Minimum resistance $= \frac{6.0}{6.0} = 1.0\ \text{k}\Omega$ Maximum resistance $= \frac{7.0}{1.2 \times 10^{-3}} = 5.8 \times 10^{3}\ \Omega$ = 5.8 kΩ (Accept a big range of answers for maximum resistance because a one-sided tangent is highly subjective)	1 1
5ci	6.0 V	1
5cii	P.d. across $R = 8.0 - 6.0 = 2.0$ V Current through $R = 4.0 + 4.0 = 8.0$ mA Resistance $= \frac{2.0}{8.0 \times 10^{-3}} = 0.25 \times 10^{3}\ \Omega = 0.25\ \text{k}\Omega$	1 1

6a	**Magnetic flux density** of a magnetic field is defined as the **force per unit length per unit current** acting on a **straight** current-carrying conductor placed **perpendicular to a magnetic field**.	2
6bi	Since a counter balance (rider) is needed, force on BC is downward. By Fleming's left-hand rule, the magnetic field is towards the right, which would be due to a current in the clockwise direction as viewed from the eye.	1 1
6bii	$B = \mu_0 nI \quad = \mu_0 \left(\frac{1000}{0.500}\right)(3.0)$ $= 7.5 \times 10^{-3}$ T	1 1
6biii	$F = BIL = 7.54 \times 10^{-3} \times 3.0 \times 0.040$ $= 9.0 \times 10^{-4}$ N	1
6biv	Let the distance of the rider from the axis XY be x. Apply Principle of moments about the axis XY,	1

	$F_{BC}(AB) = mgx$ $x = \dfrac{(9.05\times10^{-4})(0.20)}{(0.40\times10^{-3})(9.81)} = 0.046\text{ m} = 4.6\text{ cm}$	1

7a	12.0 V corresponds to 3 divisions. $12 \div 3 = 4$ V/div $\dfrac{2\pi}{T} = 314 \Rightarrow T = 20$ ms 20 ms corresponds to 4 divisions. $20 \div 4 = 5$ ms/div (Pls do not deduct marks for d.p./ s.f.)	1 1 4
7bi	$P_{pk} = \dfrac{V_{pk}^{2}}{R} = \dfrac{6.0^2}{20} = 1.8$ W  	2
7bii	Horizontal line at 0.45 W. $\langle P \rangle = I_{rms}^{2}R$ $0.45 = I_{rms}^{2}(20)$ $I_{rms} = 0.15$ A	

8ai	Equatorial plane. West to east. (i.e. follow Earth's rotation about its axis)	B1 B1
8aii	Advantages: (either one) 1. As the statellites remain stationary above the same point on Earth, they are ideal for use as communication satellites as they require no tracking to receive signals form Earth. 2. As geostationary satellites are positioned at such a high altitude, they can capture almost the full disk Earth image. Disadvantage: (either one) 1. As geostaionary satellites are positioned at a high altitude, the spatial resolution of their images tends to be not as good as satellites which are much closer to Earth. 2. Since the geostationary satellites are positioned above the equator, they cannot see the north or south poles and are of limited use for latitudes greater than 60-70 degrees north or south.	B1 B1
8bi	For circular orbit, gravitational force of attraction between the stars provides the centripetal force for each other, which are directed towards the centre of the circular orbit.	B1 B1
8bii	Gravitational force provides centripetal force, $\frac{Gmm}{R^2} = m\left(\frac{R}{2}\right)\left(\frac{4\pi^2}{T^2}\right)$ $\therefore m = \frac{2\pi^2 R^3}{T^2 G} = \frac{2\pi^2 (3.6\times10^{10})^3}{(20.5\times86400)^2\, 6.67\times10^{-11}}$ $= 4.4\times10^{30}$ kg Able to calculate angular velocity [1] Able to calculate centripetal force or gravitational force[1] correct answer [1]	
8ci	$V_s = -\frac{GM_s}{R_s}$ $= -\frac{(6.67\times10^{-11})(5.68\times10^{26})}{5.82\times10^{7}}$ $= -651\times10^{6}$ J kg^{-1} $= -651$ MJ kg^{-1}	M1 A1
8cii	651 MJ of work is required to move a 1 kg mass from the surface of Saturn to a point at infinity OR 651 MJ is done by the external force to bring a 1 kg mass from infinity to the surface of Saturn. (Accept other alternative answers, e.g. minimum KE at launch from surface to escape totally etc)	1

8di	The resultant gravitational pull is towards Saturn (since Saturn has a larger mass than Titan) Probe is moving in opposite direction to net gravitational pull, so it is gaining GPE.	1 1
8dii	No resultant gravitational force $\Rightarrow$ no net g $\frac{Gm_S}{{d_S}^2} = \frac{Gm_T}{{d_T}^2}$ $\frac{{d_T}^2}{{d_S}^2} = \frac{m_T}{m_S}$ $\therefore \frac{d_T}{d_S} = \sqrt{\frac{m_T}{m_S}} = \sqrt{\frac{1.35 \times 10^{23}}{5.68 \times 10^{26}}} = 0.0154$ Hence the neutral point is at $\frac{0.0154}{1.0154}(1.22 \times 10^6) = 18{,}500$ km	M1 M1 A1
8ei	$K_T > m(V_E - V_T)$ (Accept $K_T > m\lvert V_E - V_T \rvert$ and $K_T > m(V_T - V_E)$)	1
8eii	$K_S + m(V_T - V_S)$ (Accept $K_S + m\lvert V_T - V_S \rvert$ and $K_S + m(V_S - V_T)$)	1