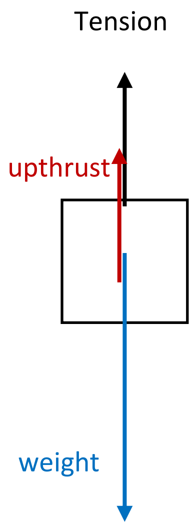
2022 Preliminary Examination Paper 2 Suggested Solution

Qn 1	Answer	Marks
(a) (i)	When mass *M* is placed on the spring, the spring extends by a length of $(L_2 - L_1)$. $mg = k(L_2 - L_1)$ $k = \dfrac{mg}{L_2 - L_1}$ $= \dfrac{(0.0985)(9.81)}{0.037 - 0.013} = 40.3\ \text{N m}^{-1}$	**C1** **M1**
(a) (ii)	$\dfrac{\Delta k}{k} = \dfrac{\Delta m}{m} + \dfrac{\Delta(L_2 - L_1)}{L_2 - L_1} = \dfrac{0.2}{98.5} + \dfrac{0.2 + 0.1}{3.7 - 1.3} = 0.127$ Thus $\Delta k = k \times \dfrac{\Delta k}{k} = 40.3(\dfrac{0.2}{98.5} + \dfrac{0.2 + 0.1}{3.7 - 1.3}) = 5\ \text{N m}^{-1}$ (Do not penalise if Δk is left to a value that is greater than 1 s.f. – this mark will be marked in (a)(iii))	**M1** **A1**
(a)(iii)	$k = (40 \pm 5)\ \text{N m}^{-1}$ Δk expressed to 1 s.f. and k expressed to the same place value as Δk. Allow ecf from **(a)(ii)** and **(a)(iii).**	**A1**
(b)(i)	 Marking Guidance: **B1** – 3 forces drawn with correct direction **B1** – Relative lengths of forces show T+U = W [-1] – Missing labels/legend Note that first B1 mark must be obtained before the second B1 mark can be given. [Point of action is not marked here. But in general, students should know that the upthrust is acting at the centre of buoyancy – c.g. of the liquid displaced and weight is at the c.g. of the cube.]	**B2**
(b)(ii)	Initially (Fig. 1.2), P is inequilibrum, net force on it is zero. Weight = upthrust $W = (0.7V)\rho g$	**M1**
(b)(iii)	After cube Q was connected (Fig. 1.3), at new equilibrium, net force on P is zero. Weight of P = Tension due to string + new upthrust	

	$W = T + U' = T + 0.4V\rho g$ Solving the two equations above gives $T = W - 0.4V\rho g = W - \frac{0.4W}{0.7} = \frac{3}{7}W$ (Shown)	**M1** **M1**
(b)(iii)	Consider the forces acting on cube Q. Resolving the weight of cube Q along the slope, and since it is in equilibrium, T = (3/7) W = W sin (θ) $\Rightarrow$ Solving, θ = 25.4 $^{\circ}$	 **A1**
	[Total : 11 marks]	

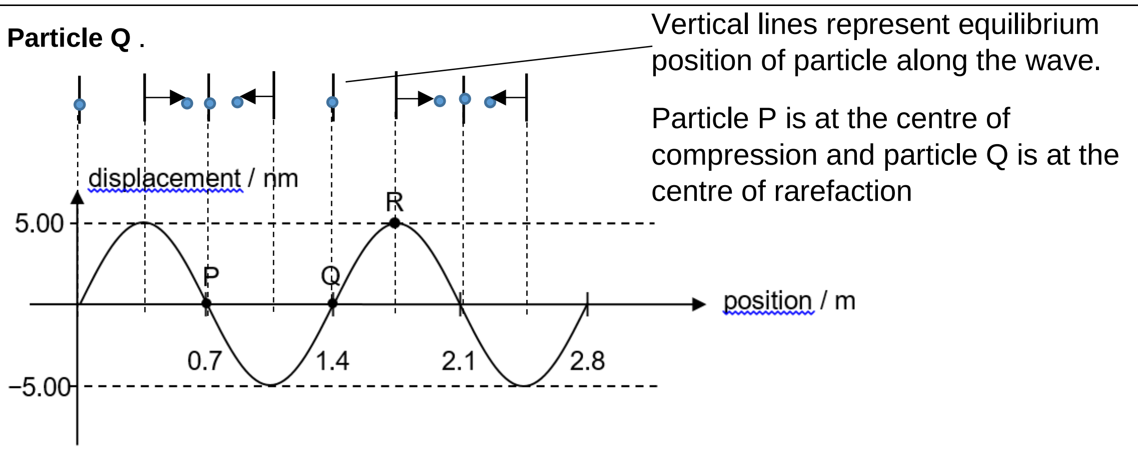
Qn 2	Answer	Marks
(a) (i)	For circular motion, centripetal force is provided by the gravitational force, $$\frac{GM_J m}{R^2} = mR\omega^2$$ $$G\frac{M_J m}{R^2} = mR\left(\frac{2\pi}{T}\right)^2 \Rightarrow T = \sqrt{\frac{4\pi^2 R^3}{GM_J}}$$	**M1** **A1**
(a) (ii)	Since $T^2 \propto R^3$, $$\left(\frac{T_{Th}}{T_{Am}}\right)^2 = \left(\frac{R_{Th}}{R_{Am}}\right)^3 \Rightarrow \left(\frac{0.676}{T_{Am}}\right)^2 = \left(\frac{3.18}{2.62}\right)^3$$ T_{Am} = 0.506 Earth-days	**M1** **A1**
(b)(i)	$$v = \frac{2\pi R}{T} = \sqrt{\frac{GM_J}{R}}$$ <u>OR</u> Since the orbit is circular, centripetal force is provided by gravitational force, hence $$\frac{GM_J m}{R^2} = \frac{mv^2}{R} \Rightarrow v = \sqrt{\frac{GM_J}{R}}$$ A1	**A1**
(b)(ii)	When the mass of the moon decreases, although the gravitational force and centripetal force required both decreases, the condition for orbit, that the gravitational force is **equal** to the centripetal force, is still true. Hence the moon will stay in orbit.	**B1**
(c)(i)	Read off graph with orbital period equal to one Jupiter-day = 0.417 Earth-days Orbital radius of geostationary orbit is <u>2.30 R_J</u>. (Allow : ± ½ smallest div)	**A1**
(c)(ii)	Able to c<u>ontinuously observe</u> the <u>same area</u> on Jupiter for an extended period of time.	**B1**
	[Total : 8 marks]	

<table>
<tr><th>Qn 3</th><th>Answer</th><th>Marks</th></tr>
<tr><td>(a)</td><td>Using $v = f\lambda$

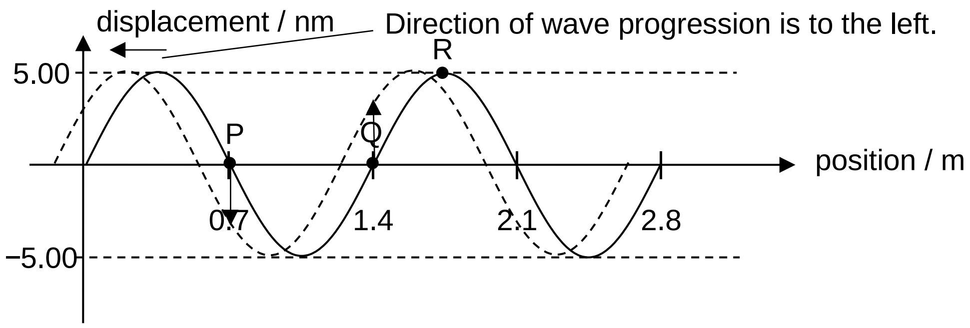
$v = \dfrac{1}{4.0\times10^{-3}}\times1.4$

$= 350$ m s^{-1}</td><td>M1

A1</td></tr>
<tr><td>(b)(i)</td><td>Particle R
(As the particle is undergoing SHM, at the amplitude, the instantaneous velocity of the particle is zero).</td><td>A1</td></tr>
<tr><td>(b)(ii)</td><td>Particle Q .


</td><td>A1</td></tr>
<tr><td>(b)(iii)</td><td>Particle Q.

(As the Fig. 3.2 shows a particle that is initially at equilibrium and is moving up in the next instant. Particle P and Q are both at equilibrium at $t = 0$. To determine which particle is presented above, the subsequent displacement-position graph in the next instant needs to be used. As seen below, since the wave is travelling towards the left, it is clear that particle P will be displaced in the negative direction and particle Q in the positive direction. Hence particle Q is depicted in Fig. 3.2).


</td><td>A1</td></tr>
<tr><td>(c)(i)</td><td>Using equation . $\Delta\phi = \dfrac{\Delta x}{\lambda}\times360^\circ = \dfrac{0.7}{1.4}\times360^\circ$

$= 180^\circ$

Accept working with radians. And answer as π radians</td><td>M1

A1</td></tr>
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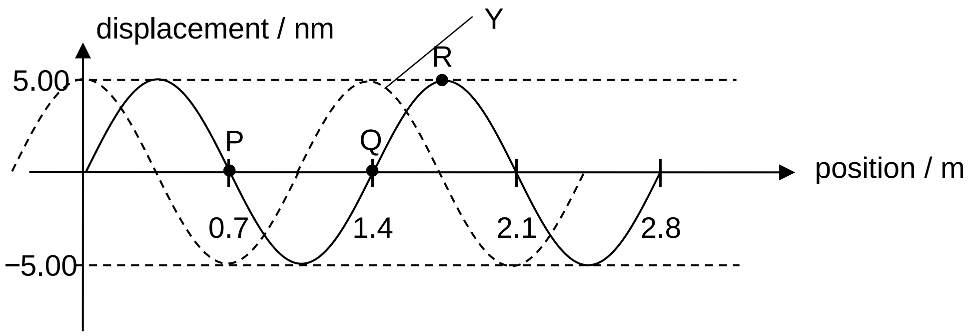
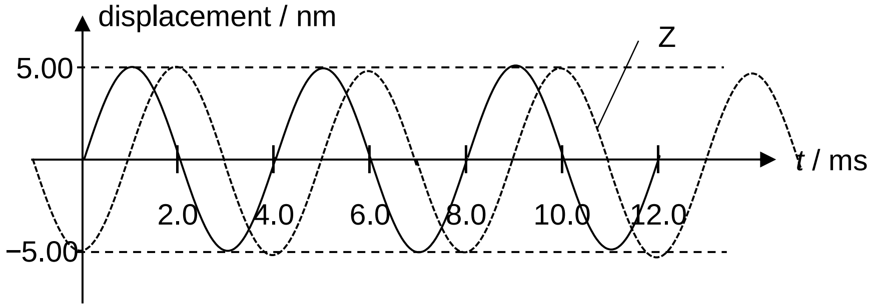
<table>
<tr><td>(c)(ii)</td><td>Distance travelled by wave in 1 ms = vt = $(350)(1 \times 10^{-3}) = 0.35$ m

The graph should have shifted to the left by 0.35 m.

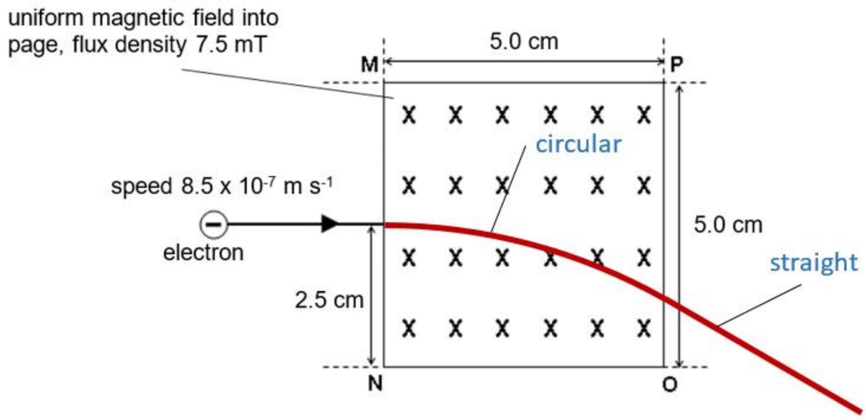


Award mark as long as one full wavelength is drawn with displacement at 5.00 nm at initial position.</td><td>C1

A1</td></tr>
<tr><td>(c)(iii)</td><td>

At t = 0, Particle R is at +5.00 nm displacement so Particle S should be at -5.00 nm displacement (phase difference of π rad).</td><td>A1</td></tr>
<tr><td></td><td>[Total : 10 marks]</td><td></td></tr>
</table>

Qn 4	Answer	Marks
(a)(i)	Power supplied by battery = Energy / time = (11.3 J) /(10 x 60 s) = 0.0188 W	**M1** **A1**
(a)(ii)	From graph, resistance of thermistor = 3.1 kΩ Power dissipated through the resistor and thermistor = Power supplied by battery $\Rightarrow$ 0.0188 = E^2 /(3100+1200) E = 8.99 V	**B1** **M1** **A1**
(b)	From graph, New resistance of thermistor = 2.0 kΩ Since the power delivered is the same, Total resistance before =total resistance after $\Rightarrow$ 3100+1200 = R +2000 $\Rightarrow$ R = 2 300 Ω	**B1** **M1** **A1**
	[Total : 8 marks]	

Qn 5	Answer	Marks
(a)	(Using Fleming's Left hand Rule), the magnetic force will **always be perpendicular to the direction of motion of the charge**. This force will provide the centripetal force for circular motion. Since the **magnitude of the magnetic force is constant**, the **magnitude of the centripetal force is constant**. The electron will describe a uniform circular path. **<u>Or</u>** since the force is always perpendicular to the motion, no work is done by the force on the system and there is no gain in kinetic energy of the electron and hence the electron is in uniform circular motion (or moving at constant speed). B1 – for explaining why the motion is that of a circular one. B1 – for explaining why the motion is uniform	**B1** **B1**
(b)(i)	The magnetic force provides for the centripetal force, $Bqv = \frac{mv^2}{r}$ $r = \frac{mv}{Bq} = \frac{(9.11\times10^{-31})(8.5\times10^{7})}{(7.5\times10^{-3})(1.60\times10^{-19})}$ $= 6.45\times10^{-2}\,\text{m} = 6.5\,\text{cm}$	**M1** **A1**
(b)(ii)	 B1- circular path curving downwards in B-field B1 - emerging at side PO (allow e.c.f.) B1 – straight path after leaving the B-field	**B3**
(b)(iii)	The magnetic force on electron provides the required centripetal force to keep the electron in circular motion. If m is the mass of the electron and ω is the angular velocity of the electron. $Bev = mr\omega^2 = mr\left(\frac{2\pi}{T}\right)^2 \Rightarrow T = \frac{2\pi m}{Be}$ Hence, T is independent of v and r.	**M1**
(b)(iv)	Since period T is independent of the speed and radius of the path taken, the period of both electrons are the same. Hence, <u>the time spent by each electron in the magnetic field</u> simply	**B1**

	<u>depends **on the fraction of the circular path traveled by each electron**</u> within the magnetic field. <u>Electron e_1 travels for less than ¼ of a period in the field, while electron e_2 travels for ½ a period.</u> Hence, <u>**electron e_2 spends a longer time in the magnetic field**.</u>	**A1**
	[Total : 10 marks]	

Qn 6	**Answer**	**Marks**
(a)	The activity of a radioactive source is the <u>rate at which a source of unstable nuclei decays</u> or <u>the number of disintegrations per unit time.</u>	**A1**
(b)(i)	$N = \left(2.40\times10^{-6}\right)\left(\dfrac{6.02\times10^{23}}{235}\right)$ $= 6.148\times10^{15}$	**M1** **A1**
(b)(ii)	Decay constant $\lambda = \dfrac{A}{N} = \dfrac{0.1919}{6.148\times10^{15}}$ $= 3.1213\times10^{-17} = 3.12\times10^{-17}\ s^{-1}$ (to 3 s.f.)	**M1** **A1**
(c)(i)	${}^{42}_{19}K \rightarrow {}^{42}_{20}Ca + {}^{0}_{-1}e + antineutrino$ beta particles are emitted. Accept electrons. Accept: beta with (anti-)neutrino	**A1**
(c)(ii)	Half-life = 12.5 h	**A1**
(c)(iii)	Correct Shape B1 sum of Calcium-42 and Potassium-42 equals 1.0 N_o at $t = 0$, $t=t_{1/2}$ and t = 40 h	**B1** **B1**
(c)(iv)	Four parts Calcium-42 and one part Potassium-42. From the graph, we get 0.8 N_o for Calcium-42 and 0.2 N_o for Potassium-42 giving the age as 29 hours. <u>Alternatively,</u> Ratio of Calcium-42 to Potassium is 4:1 Hence, for K-42, $N = N_o e^{-\lambda t} \Rightarrow t = -\dfrac{t_{1/2}}{\ln 2}\ln(\dfrac{N}{N_o}) = -\dfrac{12.5\text{ h}}{\ln 2}\ln(\dfrac{1}{5})$ M1 $= 29.0$ h A1	**M1** **A1**
	[Total : 11 marks]	

Qn 7	Answer	Marks
(a)(i)	At level flight, there is no resultant vertical force. Hence, lift = weight of aircraft = $\underline{1.5 \times 10^{6}}$ N At constant velocity, the resultant force horizontally is zero. Hence, drag = thrust = $\underline{0.60 \times 10^{6}}$ N	 **A1** **A1**
(a)(ii)	Taking moments about the intersection between the weight and thrust, Torque generated by the lift-weight couple = Torque generated by the thrust-drag couple $\Rightarrow$ $1.5 \times 10^{6} \times 0.75 = 0.60 \times 10^{6} \times d$ $\Rightarrow$ vertical separation d = $\underline{1.9 \text{ m}}$	 **M1** **A1**
(a)(iii)	The <u>horizontal stabiliser</u> with its <u>vertical downward force</u> acting on it and (its long distance from the CG), would provide a <u>(clockwise) moment</u> about the CG to enable the plane to rotate against the downward pitch.	**B1** **B1**
(b)(i)	Air gains momentum when it passes through the jet engine and hence by Newton's 2nd law, there is a force acting on the air by the jet engine. By Newton's 3rd Law, there is an equal in magnitude and opposite in direction force on the jet engine to move the jet engine forward. That is the thrust.	**B1** **B1**
(b)(ii)	|Force on jet engine by air| = |Force on air by the jet engine| = rate of change of momentum of the air = 210 kg s^{-1} x 580 m s^{-1} = 1.22×10^{5} N	 **M1** **A1**
(b)(iii)	Possible reasons include. • Combusted fuel is mixed with the gas before ejection and hence the actual momentum gain is larger. • Pressure difference between the air in front of engine and back of engine can contribute to an additional thrust • The engine needs to exert a forward force on the air to reduce the speed of the air before it is combusted and pressurized, the air exerts a backward force in return and this reduces the thrust. Do not accept : That there is some initial speed of the air as the question in (b)(ii) gives the speed gained.	 **B1**

(c)	Each wing has to provide sufficient lift to support half of the weight. $(P_L - P_U)A = \frac{mg}{2}$ $\Rightarrow \quad P_U = P_L - \frac{mg}{2A} = 7.00\times10^4\text{Pa} - \frac{(2.85\times10^5)(9.81)}{2(360)}$ $= 6.61\times10^4\text{Pa}$ [Only deduct one mark if *mg* is used instead.]	**M1** **A1**
(d)(i)	From the Lift Equation: $L = \frac{1}{2}C_L\rho v^2 S \Rightarrow C_L = \frac{2L}{\rho v^2 S}$ Units of $C_L = \frac{(\text{kg m s}^{-2})}{(\text{kg m}^{-3})(\text{m}^2\text{ s}^{-2})(\text{m}^2)}$ = 1 Hence, C_L is a dimensionless quantity.	**M1** **A1**
(d)(ii)	The aircraft tilts so that the horizontal component of the lift force can provide for the (centripetal) force needed to make the turn. It needs to increase in speed for a larger the lift force ($L = \frac{1}{2}C_L\rho v^2 S$) so that the vertical component of the lift force can support the weight.	**B1** **B1**
(e)(i)	$\frac{L}{D} = \frac{\frac{1}{2}C_L\rho v^2 S}{\frac{1}{2}C_D\rho v^2} = \frac{C_L}{C_D}$	**M1**
(e)(ii)	At maximum lift to drag ratio, most lift is generated (to support the weight) at minimum drag (<u>or</u> per unit drag). Hence, less fuel is wasted to overcome the drag force.	**B1**
(e)(iii) 1.	For angle of attack α = 4°, C_L = 0.45 and C_D = 0.0275 $L/D = C_L/C_D$ = 0.45 / 0.0275 = 16.36 Other possible combinations: <table><tr><th>C_L</th><th>C_D</th><th>L/D</th></tr><tr><td>0.45</td><td>0.03</td><td>15.00</td></tr><tr><td>0.425</td><td>0.0275</td><td>15.45</td></tr><tr><td>0.425</td><td>0.03</td><td>14.20</td></tr></table>	**M1**
(e)(ii)2.	Correct plot B1 A smooth best fit line through the plots with maximum at α = 4° B1	**B2**
	[Total : 22 marks]	