Assessment Schedule – 2007

Scholarship Physics (93103)

Evidence Statement

Question	Evidence	1–4 marks	5–6 marks	7–8 marks
1(a)	A displacement node. The centre of the star will not move. As a place of zero displacement, it must be a node. Alternative: If there is an antinode at the surface, there must be a node at the centre.	Shows some understanding of the underlying physics of he proposed model AND/OR (partially) correct mathematical solution to given problem.	Correct discussion of the underlying physics of the proposed model OR A reasonable understanding of the underlying physics of the proposed model AND (partially) correct mathematical solution to given problem.	Correct discussion of the underlying physics of the proposed model AND Correct mathematical solution to the given problem.
(b)	A standing wave is formed by two travelling waves with the same frequency, amplitude, wavelength and speed, travelling in opposite directions. This is created in this situation by a reflection from the surface (open end of the tube). At the resonant frequency, the reflected wave will meet the incoming wave in such a way that the two wave displacements will constructively sum (form an antinode) at the open end of the tube. The mechanism for the reflection can be explained by considering, a) the particle collisions (some must reflect) or equally validly via a mechanism where the external pressure (atmospheric pressure) is higher than the pressure node that exists at the boundary – this effectively creates a mechanism for particles to be "pulled" down the tube.			
(c)	At the fundamental mode $\lambda = 4R$ $v_{av} = f\lambda$ $v_{av} = f4R$ $f = \frac{1}{T} \Rightarrow v_{av} = \frac{4R}{T}$ $T = \frac{4R}{v_{av}}$			
(d)	$T = \frac{4R}{v_{av}}$ $T = \frac{4R\sqrt{\rho}}{\sqrt{\beta}}$ $T = \frac{4 \times 9 \times 10^{-3} \times 6.96 \times 10^{8} \times \sqrt{1 \times 10^{10}}}{\sqrt{1.33 \times 10^{22}}}$ $T = 20$ s			

Question	Evidence	1–4 marks	5–6 marks	7–8 marks
2(a)	The only ice that will cause a rise in the sea level is the land-based ice. Assumptions: Assume all ice melts and covers Earth's surface uniformly. Ignore the fact that the surface area will slightly increase. Assume that Earth is 70% sea. Area of Earth's surface = $4\pi r^2$ Volume of "new" water = $4\pi r^2 \times x$ where x is the increased depth. $4\pi r^2 \times x = 3.2 \times 10^{16}$ $x = \dfrac{3.2 \times 10^{16}}{4\pi(6.4 \times 10^6)^2}$ $x = 62$ m This calculation assumes all of Earth is sea – say 70% is sea then sea will rise about 90 m.	Thorough understanding of these applications of physics in the real world OR Partially correct mathematical solution to the given problems AND/OR Partial understanding of these applications of physics in the real world.	(Partially) Correct mathematical solution to the given problems AND/OR Partial understanding of these applications of physics in the real world.	Correct mathematical solution to the given problems AND Thorough understanding of these applications of physics in the real world.
(b)	The mass of ice, now water, will have run "downhill" from the land, getting closer to the centre of the Earth (reducing the average radius of the planet). This will mean a lower moment of inertia and therefore an increase in angular speed (since angular momentum is conserved). This would result in a slight decrease in the period. BUT Most of the ice is in Antarctica, close to the axis of rotation and therefore does not hold much angular momentum. On melting and being redistributed around the planet, much of the water will contribute to a radius rise about the equator, producing and increase in the moment of inertia and therefore a decrease in angular speed (since angular momentum is conserved). This would result in a increase in the period.			
(c)(i)	Nuclear power allows us to convert small amounts of mass into quite large and useful amounts of energy without much production of greenhouse gases. The mass of the reactants is slightly more than the mass of the products – the difference in mass is equivalent to a large amount of energy as can be calculated using $E = \Delta mc^2$.			
(ii)	Mass of reactants = $398.60428 \times 10^{-27}$ Mass of products = $398.29518 \times 10^{-27}$ Mass loss = 0.30910×10^{-27} kg Energy released = $mc^2 = 0.30910 \times 10^{-27} \times (3 \times 10^8)^2$ $= 2.7819 \times 10^{-11}$ J In 1 kg the number of Pu atoms will be $1 / 396.92935 \times 10^{-27}$ $= 2.519 \times 10^{24}$ Pu atoms / kg Energy total = $2.519 \times 10^{24} \times 2.7819 \times 10^{-11} = 7.009 \times 10^{13}$ J = 70000 GJ 1 tonne of coal is 30 GJ that is means that 1 kg of Pu is equivalent to 2300 tonnes of coal.			

<table>
<tr><th>Question</th><th>Evidence</th><th>1–4 marks</th><th>5–6 marks</th><th>7–8 marks</th></tr>
<tr><td>3(a)</td><td>

$v = f\lambda$

$\Rightarrow 99.2 \times \frac{4D}{n} = 127.5 \times \frac{4D}{n+2}$

$99.2(n+2) = 127.5$

$n = 7$

$\Rightarrow 340 = 99.2 \times \frac{4D}{7}$

$D = 6.0\,\text{m}$

An equivalent method is to calculate the respective wavelengths and equate them to each harmonic ($\lambda = \frac{4D}{n}$) and see where the two series converge.

</td><td rowspan="3">

Partially correct mathematical analysis of given problems

AND/OR

Incomplete discussion of the underlying physics of the LCR resonant circuit

OR

Correct mathematical analysis of given problems

OR

Thorough discussion of the underlying physics of the LCR resonant circuit.

</td><td rowspan="3">

(Partially) correct mathematical analysis of given problems

AND

Reasonably thorough discussion of the underlying physics of the LCR resonant circuit.

</td><td rowspan="3">

Correct mathematical analysis of given problems

AND

Thorough discussion of the underlying physics of the LCR resonant circuit.

</td></tr>
<tr><td>(b)</td><td>

Doppler Effect – source moving away

$f' = f\frac{v_w}{v_w + v_s}$

$v_s = f\frac{v_w}{f'} - v_w$

$v_s = 530 \times \frac{340}{500} - 340$

$v_s = 20.4\ \text{m s}^{-1}$

Assume free fall:

$v_f^2 = v_i^2 + 2ad$

$d = \frac{v_f^2 - v_i^2}{2a}$

$d = \frac{20.4^2 - 0}{2 \times 9.80}$

$d = 21\ \text{m}$

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

$P = I^2R$ so by looking at why the current varies will help understand this graph. At low frequencies the capacitor has a high reactance as it will become full (or close to full) each time the current flows in a certain direction. The nearly full capacitor will inhibit further current before the direction of current changes and it empties. Thus at low frequencies the current and therefore the power will be low. At high frequencies the inductor will oppose the rapid changes in current, thus it will have a high reactance. So at high frequencies the current and power are small. However the capacitor and inductor voltages (and reactances) are 180 degrees out of phase. At the resonant frequency the inductor and capacitor reactances cancel out. This means that there is a minimum impedance and a maximum current. This will result in a maximum power and a peak in the power-frequency graph.

</td></tr>
</table>

Question	Evidence	1-4 marks	5-6 marks	7-8 marks
4(a)	In order to go round the loop, the centripetal force at the top has to be provided by the weight + reaction force. (In the minimum case the reaction could be zero). Mathematically $\frac{mv^2}{r} \geq mg$	Partially correct mathematical solution to the given problems AND/OR Incomplete discussion of the underlying physics of this application OR Correct mathematical solution to the given problems OR Thorough discussion of the underlying physics of this application.	(Partially) Correct mathematical solution to the given problems AND Reasonably thorough discussion of the underlying physics of this application.	Thorough discussion of the underlying physics of this application AND Correct mathematical solution to the given problems.
(b)	Initial energy = mgh At the top of the loop energy = kinetic energy+potential energy $= \frac{1}{2}mv^2 + mgD$ At top minimum speed $\frac{mv^2}{r} = mg \quad (r = \frac{D}{2})$ $\Rightarrow v^2 = \frac{Dg}{2}$ So combining $mgh = \frac{1}{2}m\frac{Dg}{2} + mgD$ $h = \frac{1}{4}D + D$ $h = \frac{5}{4}D$			
(c)(i)	Pushing the slider means it has more kinetic energy and so requires less potential energy to reach the energy total needed to complete the loop. Therefore less height is needed.			
(ii)	The height is independent of mass (assuming no friction) so no difference.			
(iii)	In the ellipse the radius of curvature at the top is smaller (less than $D / 2$). If the radius is less then less speed is required at the top ($v^2 = rg$). D is the same so potential energy at top is the same but less kinetic energy is required at the top so the total energy is less so the minimum height is lower.			

Question	Evidence	1-4 marks	5-6 marks	7-8 marks
5(a)	When the puck is 4 m in front of Nicole the centre of mass is 4 / 101 m in front of her and the puck is 3.9604 m in front of the CoM. Space Vehicle 2 takes 32.69 s to go 85 m (85 / 2.6). The CoM of Nicole and the puck will travel 196.154 m in this time (32.69 × 6). With the puck being 3.9604 m in front of the CoM, 200.114 m is the greatest reach of the puck and enough to reach the craft in time.	Some understanding of at least two important aspects of the physics of the situation outlined.	Clear understanding of two important aspects of the physics of the situation outlined.	Clear understanding of all important aspects of the physics of the situation outlined.
(b)(i)	From above: At 6.0 m s^{-1} it takes 200 / 6 s for Nicole to reach Space Vehicle 2 (SV2) = 33.33 seconds. Nicole only has the time that SP2 has to move 85 m to make contact – that time is 85 / 2.6 s = 32.69 s. It takes 196 / 6 s (32.67 s) to get within 4 m of SP2. In 32.69 s Nicole only travels 196.154 m (32.69 × 6). Puck has 32.69 – 32.67 seconds (0.02564 s) to move the 4m. This is equivalent to an average velocity of 156 m s^{-1}. Any speed lower than this will result in failure of the mission. Using conservation of momentum: When Nicole fires the puck forwards she will recoil backwards (the CoM will continue at 6 m s^{-1} forwards regardless). Looking at the extreme case: Results in a velocity of Nicole of 7.44 m s^{-1} backwards since she was already going at 6 m s^{-1} forwards she will now go 1.44 m s^{-1} backwards (from conservation of momentum). At this speed it is still possible for a successful mission. As long as the puck and Nicole come to a dead stop at the end of the explosion – the CoM will 0.15384 m further on from the 4 m point at the end of the explosion. This will mean that if the puck can travel greater than 3.84616 m during the explosion then the mission will be a success. The time of the explosion will be $4 / (v_p + v_n)$ so the distance travelled by the puck in relation to the CoM will be $4v_p / (v_p + v_n)$ if this is greater than 3.84616 m then the puck will make it. This will always be the case for velocities greater than about 150 m s^{-1}. Consideration will also be given to answers that show particular physical insight – such as discussion involving the enormous accelerations that would be experienced. The fact that the above model assumes that the puck and Nicole do not recoil when they reach the 4m extension. The fact that energy losses will result in the explosions.			
(ii)	At low velocity the puck does not collide so has no effect. At a speed of 750 m s^{-1} by considering conservation of momentum it can be shown that $4 \times 10^{-5} \times M \times 750$ (downwards) + $M \times 2.6$ (across) = Mv_{new} The acquired momentum will have little effect. (0.03 compared to 2.6). It will result in a torque on SP2. In terms of energy at say 300 m s^{-1} the energy of impact is similar to the kinetic energy of SP2 – there will be considerable damage caused. At higher velocities this effect will obviously be greater.			

<table>
<tr><th>Question</th><th>Evidence</th><th>1-4 marks</th><th>5-6 marks</th><th>7-8 marks</th></tr>
<tr><td>6(a)</td><td>The induced voltage drives a current around the circuit. The current induces a magnetic field in the roller. This induced magnetism is opposed by the external magnetic field – felt as a retarding force on the roller which slows down and stops.

Alternative:
The metal wire completes the circuit so a current exists. As the current exists, energy is lost to the system as heat energy, so the kinetic energy of the roller is converted to heat energy, and it will slow down.</td><td rowspan="5">Shows good understanding of the fundamental processes involved in producing induced voltages

AND/OR

Shows moderate understanding of application of fundamental ideas in a new context.</td><td rowspan="5">Shows good understanding of the fundamental processes involved in producing induced voltages

AND

Shows moderate understanding of application of fundamental ideas in a new context.

OR

Shows clear understanding of application of fundamental ideas in a new context.</td><td rowspan="5">Shows good understanding of the fundamental processes involved in producing induced voltages

AND

Shows clear understanding of application of fundamental ideas in a new context.</td></tr>
<tr><td>(b)</td><td>$\varepsilon = -\frac{\Delta\phi}{\Delta t}$
$\phi = BA \Rightarrow \Delta\phi = B\Delta A$ (B const)
$A = L \times d$
$\varepsilon = -BL\frac{\Delta d}{\Delta t}$
$\varepsilon = -BLv$</td></tr>
<tr><td>(c)</td><td>The original induced voltage will drive a current, which will charge up the capacitor. The voltage across the capacitor will oppose the induced voltage, and when this results in the current ceasing, there will be no opposing force to further slow the roller, and it will continue at a steady speed.</td></tr>
<tr><td>(d)</td><td>At constant velocity, no current exists in the circuit.
Kirchhoff's voltage rule:
Voltage across capacitor = voltage produced by roller
$BLv = Q / C$
$\Rightarrow Q = BLvC$
Units: B has units of kg s^{-1} C^{-1}
L has units of m
v has units of m s^{-1}
C has units of F (equivalent to $C\ V^{-1}$)
Final units are kg m^2 s^{-2} V^{-1} but units of V are J C^{-1} which is kg m^2 s^{-2} C^{-1}
So this shows final unit C on both sides.</td></tr>
<tr><td>(e)</td><td>The capacitor would discharge a current through the roller. This current would result in the roller experiencing a force either towards or away from the capacitor, depending on the current direction. If the induced force is against the direction of the push, then the roller will move in the direction of the greater force. If the induced force is in the direction of the push, the roller will accelerate rapidly towards the capacitor, then the acceleration will reduce until the roller reaches a steady velocity.</td></tr>
</table>