Assessment Schedule – 2006

Scholarship Physics (93103)

Evidence Statement

Question	Mark Allocation	Typical evidence
1 (a)	1 mark for adequate BE definition (mass deficit / E=mc^2). 1 mark for stability – need to mention Fe. 1 mark for fission / fusion description. 1 mark for graph fine structure description or other comments relating to nuclear forces / Coulomb repulsion etc.	Iron is the most stable nuclei as it has the most binding energy per nucleon. This means that if you formed iron from individual protons and neutrons, the mass of the iron nucleus could be less than the total mass of the individual protons and neutrons required. The 'missing' mass has been converted to energy (Einstein's equation $E = mc^2$). To separate the iron nucleus back to its protons and neutrons, you need to supply this energy so it can be converted back into mass. The binding energy per nucleon is the amount of energy which would need to be supplied to each nucleon to separate the nucleus. Small nuclei (eg H, He, C…) have less BE per nucleon than iron, so when they are combined they form bigger nuclei (closer to iron); mass is released as energy. This is called fusion, and is observed in stars. Very large nuclei (eg U, Pu…) also have less binding energy per nucleon than iron. When they are split up into smaller nuclei, these smaller nuclei are closer to iron, so once again mass is converted to energy. This is called fission, and is observed in nuclear power stations. The 'spikes' represent anomalously stable nuclei. The first 'spike' is helium, the others exist at multiples of four nucleons.
1 (bi)	1 mark for correct energy expression. 1 mark for correct answer.	$eV = \frac{1}{2}mv^2$ $v = \sqrt{\frac{2eV}{m}}$ $\lambda = \frac{h}{p} = \frac{h}{m\sqrt{\frac{2eV}{m}}} = \frac{h}{\sqrt{2eVm}} = \frac{6.63\times10^{-34}}{\sqrt{2\times9.11\times10^{-31}\times1\times10^{4}\times1.6\times10^{-19}}}$ $\lambda = 1.228\times10^{-11} m$ $n\lambda = \frac{dx}{L}$ $x = \frac{L}{d}\lambda = \frac{1\times1.228\times10^{-11}}{50\times10^{-9}} = 2.46\times10^{-4} m$
1 (bii)	1 mark for change factor. 1 mark for correct answer.	Electron velocity = $\sqrt{\frac{2eV}{m}} = 5.927\times10^{7} ms^{-1}$ Momentum change factor = $\frac{1}{\sqrt{1-\frac{(5.927\times10^{7})^2}{(3\times10^{8})^2}}} = 1.02$ Relativistic correction is 2% so can be ignored.

Question	Mark Allocation	Typical evidence
2 (a)	2 marks for 40 N. 1 mark for no change to slow/bottom barge with appropriate explanation.	Fast barge must make the coal gain momentum. In 1 second 20 kg added which means to increase its velocity by 2 m s^{-1} requires $Ft = \Delta p = 20 \times 2 = 40$ kg m s^{-1} so in one second this is 40 N. The slow barge requires no extra force as friction is constant. (Total momentum will reduce but the mass reduces proportionally as well.)
2 (b)	2 marks for correct answer.	Force needed for constant velocity same as for at rest: $2T = mg$ ($2T$ as pulley effectively creates two ropes) The tension is therefore $\frac{mg}{2} = 564\,\text{N}$
2 (c)	1 mark for stating that the period depends on the position of the CoM. 1 mark for CoM "tracking" the movement of the water downwards therefore increasing the period. 1 mark for CoM ending up at CoM (bucket) which is closer to the original period.	The period for SHM of a pendulum is independent of mass, and so as the mass of the water / bucket decreases, there should be no change in the time period. However if the height of the bucket is not insignificant compared to the length of the rope, then the effective length of the pendulum will get longer as the centre of mass of the bucket / water gets lower. This increase in length will increase the time period slightly. When the bucket is completely empty, the centre of mass of the bucket will be back near the centre of the bucket, and therefore the length will decrease slightly and the time period will decrease slightly, coming closer to what it was originally.

<table>
<tr><th>Question</th><th>Mark Allocation</th><th>Typical evidence</th></tr>
<tr><td>3 (a)</td><td>1 mark for stating that “g” incorrect.
1 mark for correct period.
1 mark for correct working.</td><td>The mistake is that the value of g used is the gravitational strength at the surface of the Earth; it should be g at the position of the satellite.

$mg_{\text{local}} = \frac{\mathrm{G}Mm}{r^2} \Rightarrow g_{\text{local}} = \frac{\mathrm{G}M}{r^2}$
From above $T = 2\pi\sqrt{\frac{r}{g_{\text{local}}}} \Rightarrow T = 2\pi\sqrt{\frac{r^3}{\mathrm{G}M}}$
At the surface of the Earth $9.8 = \frac{\mathrm{G}M}{\mathrm{R}^2}$
$GM = 9.8R^2$
$\therefore T = 2\pi\sqrt{\frac{r^3}{9.8\mathrm{R}^2}}$
$r = 6.5\mathrm{R}$
$\therefore T = 2\pi\sqrt{\frac{6.5^3\mathrm{R}}{9.8}} = 8.4\times10^4 s$

The period of one day is 8.64×10^4 s.</td></tr>
<tr><td>3 (b)</td><td>1 mark for equatorial orbit.
1 mark for equal period.</td><td>A geosynchronous satellite must be used so that it has a fixed position relative to the observer. A geosynchronous satellite rotates about the centre of mass, and orbits above the equator in order to achieve this. The period of the orbit needs to be equal to the period of rotation of the Earth. All the satellite dishes need to point towards this equatorial position in order to be in direct line with the transmission.</td></tr>
<tr><td>3 (c)</td><td>2 marks for correct analysis.

1 mark for stating period unchanged.</td><td>From the previous question $T = 2\pi\sqrt{\frac{r}{g_{\text{local}}}}$
$\therefore T = 2\pi\sqrt{\frac{r^3}{\mathrm{G}M}}$ as $g_{\text{local}} = \frac{\mathrm{G}M}{r^2}$
$\rho = \frac{M}{V}$ and $V = \frac{4}{3}\pi R^3$
$T = 2\pi\sqrt{\frac{r^3}{\rho G\frac{4}{3}\pi R^3}} = \sqrt{\frac{3\pi}{\rho G}\left(\frac{r^3}{R^3}\right)}$

Since the density is unchanged and the distance scaled down proportionally, there is no change in the period.

An alternative method involves calculating the period and showing that it is unchanged.
In this case the density = 5 500 kg m^{-3}
Radius of the shrunken Earth = 0.1538 m
Mass of the shrunken Earth = 84.4 kg
The period is 84 000 seconds.</td></tr>
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Question	Mark Allocation	Typical evidence
4 (a)	1 mark for path difference. 1 mark for constructive / destructive interference description.	The path lengths that the two beams follow to the receiver will change in length as the receiver moves. When the two path lengths differ by a whole number of wavelengths, constructive interference (high intensity) will occur. When the two path lengths differ by an odd number of ½ wavelengths, destructive interference (low intensity) will occur.
4 (b)	2 marks for correct statement.	Given that there is no phase change on reflection, both beams will arrive having travelled the same distance, and therefore will arrive in phase, resulting in constructive interference.
4 (c)	2 marks for solution as shown or equivalent involving a correct expression for the path difference.	By considering the situation shown, it can be seen that effectively there is a virtual source at position ‘a’ below the desk. Assuming the angles are small, this is analogous to Young’s two slit experiment where $n\lambda = d\sin\theta = \frac{dx}{L}$ (small angle approximation) and $\sin\theta = \frac{y}{s}$ $n\lambda = \frac{dx}{L} = \frac{2ay}{s}$
4 (d)	2 marks for correct statement.	The reflection of light at a hard surface causes a phase reversal. This means the two waves interfering have opposite phase, and so destructive interference takes place.

5 (a)	1 mark for parallel concept. 1 mark for C_{water}. 1 mark for C_{air}.	The empty part of the tank is a capacitor that is in parallel with the full part. $C_{\text{water}} = \dfrac{\varepsilon_0 \varepsilon_r A}{d} = \dfrac{\varepsilon_0 95Wh}{D}$ $C_{\text{air}} = \dfrac{\varepsilon_o A}{d} = \dfrac{\varepsilon_o (H-h)W}{D}$ $C_{\text{Total}} = C_{\text{water}} + C_{\text{air}} = \dfrac{\varepsilon_0 95Wh}{D} + \dfrac{\varepsilon_0 (H-h)W}{D}$ $C_{\text{Total}} = \dfrac{\varepsilon_0 W}{D}(94h + H)$
5 (b)	1 mark for correct answer.	When empty $h = 0$ $C = \dfrac{8.85\times10^{-12}\times1.80\times0.860}{2.90} = 4.72\times10^{-12}\,\text{F}$ When full $h = \text{H}$ $C = \dfrac{8.85\times10^{-12}\times1.80\times95\times0.860}{2.90} = 4.49\times10^{-10}\,\text{F}$
5 (c)	1 mark for correct answer.	At resonance $\omega L = \dfrac{1}{\omega C} \Rightarrow 2\pi f_o L = \dfrac{1}{2\pi f_o C} \Rightarrow f_o^2 = \dfrac{1}{(2\pi)^2 LC}$ Substituting $L = 2.03 \times 10^{-6}$ H and when $C = 4.72 \times 10^{-12}$ F $f_0 = 51.4 \times 10^6$ Hz When $C = 4.49 \times 10^{-10}$ F $f_0 = 5.27 \times 10^6$ Hz
5 (d)	2 marks for time constants specific to circuit. 1 mark for application of the circuit.	When the tank is full (ie capacitance highest), the time constant of the circuit is approximately 1 000 µs. As the voltage pulse lasts much less time than this, the capacitor voltage will never reach 12 V. When the tank is empty the time constant is approx 10 µs the voltage will nearly reach 12 V. How far the voltage does go up to will depend on the time constant, which depends on how full the tank is. It would therefore be possible to calibrate the voltmeter to read the depth of fluid in the tank.

6 (a)	1 mark for correct answer.	ε is the emf induced by a change in flux. $\Delta\phi$ is the amount of magnetic flux change (ΔBA). Δt is the time taken for the change. The negative sign indicates conservation of energy – the induced emf opposes the inducing changes.
6 (b)	1 mark for initial acceleration argument. 1 mark for constant velocity argument. 1 mark for free fall argument.	Initially gravity accelerates it. There is no net induced voltage (and therefore current) while the entire loop is in the field. With one edge out of the field, an induced current will flow, causing a magnetic field that will oppose the causative motion (Lenz's law). This opposing force will, in this particular case, be the same size as the gravitational force; this leads to a period of constant velocity. Once the entire loop is outside the field, the loop will continue to experience only the gravitational force.
6 (c)	1 mark for balance force statement. 1 mark for correct derivation.	$F = BIL = mg$ $V = IR$ $V = \frac{\Delta\phi}{\Delta t} = \frac{\Delta(BA)}{\Delta t} = BvL$ $\Rightarrow v = \frac{IR}{BL} = \frac{mg}{BL}\frac{R}{BL} = \frac{mgR}{B^2L^2}$
6 (d)	1 mark for power due to gravity. 1 mark for electrical power.	Power due to gravity $\frac{W}{t} = \frac{mgh}{t} = mgv$ Electrical Power VI from above $BIL = mg \Rightarrow I = \frac{mg}{LB}$ Power $= \frac{mg}{LB}\ BLv = mgv$ So all the work done by gravity is converted to heat in the wire.