# A2 Challenge Sept/Oct 2013 Solutions

**Q1** a) $m = 1/ (3 \times 10^8)^2 = 1.1 \times 10^{-17}$ kg ☑

b) For a pair, $E = 2mc^2$ ☑ $= 2 \times 9.1 \times 10^{-31} \times (3 \times 10^8)^2 = 1.6 \times 10^{-13}$ J or 1.02 MeV ☑

c) i) Energy in 30y is $30 \times 365 \times 24 \times 3600 \times 2 \times 10^9 = 1.9 \times 10^{18}$ J ☑

Mass equivalent is $1.9 \times 10^{18} / (3 \times 10^8)^2 = 21$ kg ☑

ii) $1.9 \times 10^{18}$J x 4 {☑ for 25% } / $4 \times 10^7 = 1.9 \times 10^{11}$ kg ☑

iii) Any sensible comment indicating that nuclear processes involve very much more energy than chemical ones. ☑

Total 8☑

**Q2** a) Mass = V x ρ = 8 x 20 x 2 x 1000 = $3.2 \times 10^5$ kg ☑

b) $Q = mc\,\Delta T = 3.2 \times 10^5 \times 4200 \times 1 = 1.3 \times 10^9$ J ☑

c) $5000 \times 3600 \times 24 \times 200 = 8.6 \times 10^{10}$ J ☑

d) $\Delta T = 8.5 \times 10^{10} / 1.3 \times 10^9 = 64$K ☑

No losses to the environment ☑

e) It would freeze up and block the heat extraction mechanism ☑ just above freezing point ☑, assuming that the water is adequately circulated.

f) $65^0$C allowing for rounding errors: accept $64^0$C ☑

g) Plainly impractical as open bodies of water in the UK do not reach this temperature. If they did, they would be dangerous for bathing. However, the idea might be useful as a supplement to other energy sources. Alternatively, a dedicated water-filled heat reservoir in conjunction with a solar capture system may have some practical value. Basic answer ☑; expansion on ideas ☑

Total 10 ☑

**Q3** a) i) $\sigma = 0.5$ ☑ $mg / \pi r^2$ ☑ $= 0.5 \times 70 \times 10 / \pi (0.015)^2 = 495$ kPa ☑

(486 kPa with g = 9.8)

ii) Stress doubles ☑; then increases considerably due to impact of running strides. ☑

b) i) As volume scales as the cube of scale factor, 1 000 000 times as big. ☑

ii) Cross sectional areas scale by 10, 000 ☑, so only 100 times the stress, ☑

iii) A Brobingnagian on one foot is dangerously close to the failure stress for his thigh bone: thinner bones in the lower leg would therefore break. ☑ His walk would be likely to be a shuffle maintaining support from both legs, while running would be impossible. ☑ owtte (Not so much so for small Brobdingnagian children!)

c) The converse of the above argument is that small scale models will easily be strong enough to stand up while their full scale counterparts may not ☑. So the model may well be useful to determine whether the geometry works, but to test strength, cross-sections would need to be adjusted to allow for the way in which stresses scale. ☑ Any sensible extension scores.

Total 12 ☑

**Q4** a) $\theta = \sin^{-1}(1 \times 6 \times 10^{-7} / 2 \times 10^{-6}) = 17^0$ ☑

b) i) $6 \times 10^{-6}$ m i.e. add a space and a strip to get the total repeat ☑

ii) $\vartheta = \sin^{-1}(3 \times 6 \times 10^{-7} / 6 \times 10^{-6}) = 17^0$ ☑

iii) zero (as each individual opening contributes zero before any interference between slit outputs can take place). ☑

c) Accept the 'obvious' answer that *d* is a whole number multiple of *b.* ☑ (Closer consideration shows that the effect will occur when *b* and *d* are in a whole number ratio with $b<d$ : at that point $m:n = b:d$ will give a single slit diffraction minimum at the same angle as a predicted grating maximum. e.g. 2nd order minimum coinciding with 5th order 'maximum' if *b* is ⅖*d* etc.).

Total 5 ☑

**Q5** a) i) 2V ☑

ii) $I_{AB} = I_{BC}$. ☑ Voltmeters have high (ideally infinite) resistance and so pass negligible current. ☑ owtte

iii) $V_{AB}$ falls. ☑ Light bulb has a finite resistance and therefore lowers $R_{AB}$ compared with $R_{BC}$, leading to a smaller output across *AB*. ☑

or corresponding argument

b) i) 2V ☑

ii) zero ☑

iii) zero ☑

iv) P:Q = R:S is the required condition ☑

c) i) See Fig 5.4 ☑

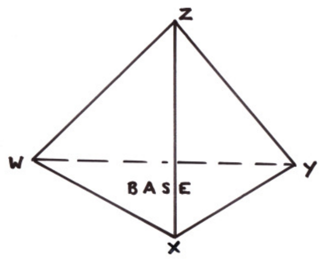


**Fig 5.4**

ii) See Fig 5.5 ☑

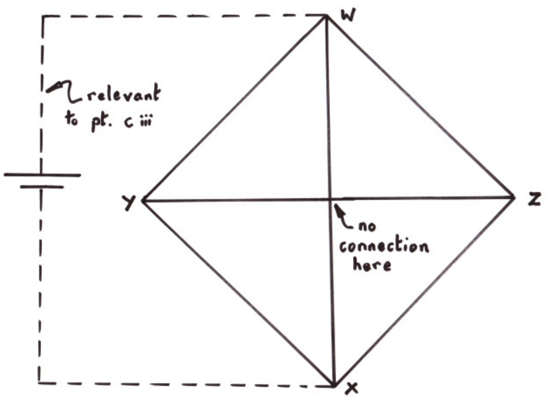


**Fig 5.5**

iii) zero as in (b iii) ☑, so YZ is redundant and may be removed ☑ (This point may appear elsewhere to be credited).

iv) by inspection, **5Ω**, ☑ (answer)as the system now reduces to 20Ω, 20Ω and 10Ω in parallel ☑ credit for any appropriate method.

Total 15 ☑