Answers to exam-style questions

Topic 8

Where appropriate, 1 ✓ = 1 mark

1 D

2 B

3 D

4 B

5 D

6 C

7 A

8 C

9 B

10 C

11 **a** **i** $\Delta m = 235.044 + 1.009 - (139.922 + 93.915 + 2 \times 1.009) = 0.198$ u ✓
$Q = 0.198 \times 931.5 = 184$ MeV ✓
Which is about 180 MeV.

ii 184 MeV, i.e. $184 \times 10^{6} \times 1.6 \times 10^{-19} = 2.9 \times 10^{-11}$ J are produced by a mass of 235.044 u of uranium, i.e. by about 3.9×10^{-25} kg. ✓

So the specific energy is $\frac{2.9 \times 10^{-11}}{3.9 \times 10^{-25}} = 7.4 \times 10^{13}$ J kg^{-1}. ✓

iii The energy produced by the power plant in a year is $800 \times 10^{6} \times 365 \times 24 \times 3600 = 2.52 \times 10^{16}$ J. ✓

The energy produced in the nuclear reactions must then be $\frac{2.52 \times 10^{16}}{0.32} = 7.88 \times 10^{16}$ J. ✓

So the mass of uranium used is $\frac{7.88 \times 10^{16}}{2.9 \times 10^{-11}} \times 3.9 \times 10^{-25} = 1060 \approx 1100$ kg. ✓

b **i** The produced neutrons are very fast and cannot be absorbed by uranium nuclei. ✓
Collisions with moderator atoms slow down the neutrons so they can be absorbed. ✓

ii Control rods control the rate of reactions in various part of the reactor core by being lowered or raised from the core. ✓
They absorb neutrons when they are lowered decreasing the rate or increase it when they are raised. ✓

iii The thermal energy is produced in the moderator by collisions of neutrons with moderator atoms. ✓
The heat exchanger removes this energy by, for example circulating cold water through the moderator. ✓

c Without a moderator neutrons would not be slowed down. ✓
And so could not be used to produce fission and no energy would be produced. ✓

d Advantage: very large specific energy of fuels. ✓
Disadvantage: radioactive nuclear waste difficult to dispose of safely. ✓

12 **a** The mass is $M = \rho V = 1000 \times 4.8 \times 10^{4} \times 38 = 1.8 \times 10^{9}$ kg ✓

b $Mgh = 1.8 \times 10^{9} \times 9.8 \times 225$ ✓
Which equals 4.0×10^{12} J. ✓

c The time to empty the reservoir is $\frac{4.8 \times 10^{4} \times 38}{350} = 5.2 \times 10^{3}$ s. ✓

And so the power developed is $\frac{4.0 \times 10^{12}}{5.2 \times 10^{3}} = 768 \approx 770$ MW. ✓

d The electrical energy supplied is $0.60\times 4.0\times 10^{12}\ \text{J} = 2.4\times 10^{12}\ \text{J} = \dfrac{2.4\times 10^{12}}{3.6\times 10^{6}} = 6.7\times 10^{5}$ kWh. ✓

So the income from this energy is $6.7\times 10^{5}\times 0.12 = 8.0\times 10^{4}$ \$. ✓

The cost to refill the reservoir is $\dfrac{4.0\times 10^{12}}{0.64\times 3.6\times 10^{6}}\times 0.07 = 7.3\times 10^{4}$ \$ leading to a profit of 7000\$. ✓

13 a Primary energy refers to energy that is available but has not been processed in any way like the kinetic energy of air. ✓
Secondary energy refers to energy that has become available as a result of processing as in the case of electrical energy produced in a wind turbine. ✓

b i All the air incident on the wind turbine has been stopped. ✓

ii Turbulence in the air. ✓
Makes some of the air's kinetic energy "wasted" in eddies resulting in a smaller net power output. ✓

c $P = \dfrac{1}{2}\pi\rho_1 R^2 v_1^3 - \dfrac{1}{2}\pi\rho_2 R^2 v_2^3$ ✓

$P = \dfrac{1}{2}\pi\times 1.2\times 12^2\times 8.2^3 - \dfrac{1}{2}\pi\times 1.9\times 12^2\times 5.3^3 = 8.568\times 10^4$ W ✓

The extracted power is then $0.30\times 8.568\times 10^4 = 2.6\times 10^4$ W. ✓

14 a The air above the land is very warm, ✓
and so rises, ✓
giving its place to cooler air form the sea. ✓

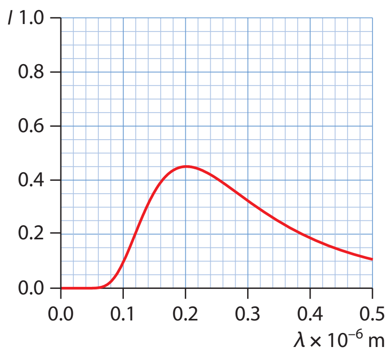
b The air has smaller thermal conductivity than water (and one usually wears clothes when walking!). ✓
And so heat is removed from the body faster in water. ✓

c i A black body is a theoretical body that absorbs all the radiation incident on it. ✓
Reflecting none. ✓

ii The peak wavelength is 2.0×10^{-7} m. ✓

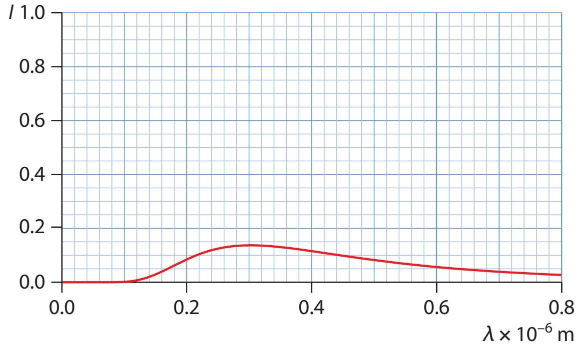
And by Wien's law $T = \dfrac{2.9\times 10^{-3}}{2.0\times 10^{-7}} = 1.4\times 10^{4}$ K. ✓

d i Same peak wavelength. ✓
Half the max height. ✓



ii Peak wavelength shifted to 3.0×10^{-7} m. ✓
Lower in height. ✓

(but ignore amount by which peak is reduced – the area under this curve must be $\left(\frac{3}{2}\right)^4 \approx 5$ times smaller than the original curve)



15 a i σT_1^4 ✓

ii $e\sigma T_2^4$ ✓

iii $e\sigma T_1^4$ ✓

iv $(1-e)\sigma T_1^4$ ✓

b The net power leaving the black body is $\sigma T_1^4 - e\sigma T_2^4 - (1-e)\sigma T_1^4 = \sigma(T_1^4 - T_2^4)$. ✓
At equilibrium this is zero and so $T_1 = T_2$. ✓

16 a i Intensity is the power received per unit area. ✓
The power radiated is received over an area $4\pi d^2$. ✓
Which gives the result.

ii Albedo is the ratio of the scattered intensity to the incident intensity of radiation. ✓

b i Radiation that falls on the earth surface has to pass through a disc of radius R and so the power through the disc is $\pi R^2 S$. ✓
Of this a fraction α is reflected and so the incident power is $\pi R^2 S(1-\alpha)$. ✓
The average power per unit area is then $\frac{\pi R^2 S(1-\alpha)}{4\pi R^2}$. ✓
Which, after simplification, is the result.

ii $S = \frac{3.9 \times 10^{26}}{4\pi \times (1.5 \times 10^{11})^2} = 1379 \text{ W m}^{-2}$ ✓

$$\frac{S(1-\alpha)}{4} = \sigma T^4 \Rightarrow T = \sqrt[4]{\frac{S(1-\alpha)}{4\sigma}} = \sqrt[4]{\frac{1379 \times (1-0.30)}{4 \times 5.67 \times 10^{-8}}} = 256 \text{ K}$$ ✓

c The calculation ignores the greenhouse effect i.e. that greenhouse gases in the atmosphere absorb infrared radiation radiated by the earth. ✓
The gases subsequently re-radiate this radiation in all directions. ✓
Including back down to the surface of the earth warming it further. ✓