Answers to examination-style questions

Answers	Marks	Examiner's tips
1 (a) (i) $\Delta Q = mc\,\Delta\theta$ gives energy lost by water $= 0.20 \times 4200 \times 20$ $= 1.68 \times 10^4$ J	1 1	This is a simple calculation to start off with, where the temperature of some water falls from 20 °C to 0 °C in 10 min.
(ii) Rate of loss of energy $= \dfrac{1.68 \times 10^4}{10 \times 60}$ $= 28$ J s^{-1} (or W)	1	The average rate of loss of energy is the same as the average power loss, which could be measured in W. But you are given a hint about how to do the calculation by being told to answer in J s^{-1} (otherwise the answer could be expressed in J min^{-1}).
(b) (i) $\Delta Q = m\,l$ gives energy to be lost $\Delta Q = 0.20 \times 3.3 \times 10^5 = 6.60 \times 10^4$ J Energy $= P\,t$ gives $6.60 \times 10^4 = 28\,t$ $\therefore$ time taken $t = 2.36 \times 10^3$ s (39.3 min)	1 1	This calculation assumes that energy continues to be lost to the surroundings at the same rate as the average rate calculated in part **(a)(ii)**. In practice this is unlikely, because the temperature difference between the water and the surroundings will decrease as the water cools from 20 °C to 0 °C. Consequently the rate of loss of energy will be lower than assumed, and the time taken for the water to turn completely into ice will be longer.
(ii) *Relevant assumptions*: • energy continues to be lost to the surroundings at the same constant rate • as in **(a)(i)** the temperature of the ice formed does not fall below 0 °C	any 1	
2 (a) Water at 18 °C to water at 0 °C: $\Delta Q = mc\,\Delta\theta = 1.5 \times 4200 \times 18$ $= 1.13 \times 10^5$ J Water at 0 °C to ice at 0 °C: $\Delta Q = ml = 1.5 \times 3.3 \times 10^5$ $= 4.95 \times 10^5$ J $\therefore$ total energy released $= (1.13 \times 10^5) + (4.95 \times 10^5) = 6.08 \times 10^5$ J	1 1 1 1	This process has two stages: reducing the temperature of the water from 18 °C to 0 °C, and then changing the state of all of the water to ice. The energy that has to be given out from each of these stages is calculated separately. The total amount to be removed is then determined by adding these two energies together.
(b) *First point must be included in the answer, plus any one of the following three:* • The ice has to be supplied with energy for it to melt • the bucket and contents stay at 0 °C for longer • the bucket with ice extracts more energy from the cans • the cans are cooled for longer when the bucket contains ice.	1 any 1	The cans of drinks lose energy to the surrounding water. If there is only water in the bucket, the temperature of the water will immediately start to rise above 0 °C. With ice in the bucket, all of the initial energy given out by the cans is required to melt ice; whilst this is happening the temperature of the water remains 0 °C.

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3 (a) *Graph plotted to have*: • axes labelled temperature/°C and time/s with a scale occupying more than half of the area of the graph paper • correct plotting of all 6 points • a best-fit straight line with at least one point on each side of the line.	**3**	Suitable scales would be $0 \rightarrow 300$ s for time and $20 \rightarrow 40$ °C for temperature. Always plot graph points in pencil, because it is easier to correct mistakes. A 300 mm transparent ruler is the best choice when deciding the best straight line to draw, since you can still see the points that are underneath it.
(b) Gradient of graph $= \frac{11.6}{208}$ $= 0.056\ (\pm 0.004)$°C s^{-1}	**1**	When finding the gradient it is important to give clear evidence of how you are using your graph. This is best done by drawing a large gradient triangle and showing the steps in your working.
Gradient determined from a clear triangle drawn over more than half of the length of the line.	**1**	
(c) Power of heater $P = \frac{\Delta Q}{\Delta t} = \frac{mc\Delta\theta}{\Delta t}$ gives $48 = 1.0 \times c \times 0.056$	**1**	This calculation assumes that all of the energy supplied by the electrical heater is passed to the metal block and that none is lost to the surroundings. The gradient of the graph in part **(b)** is $\frac{\Delta\theta}{\Delta t}$.
… from which specific heat capacity c of metal = 860 (± 60) J kg^{-1} K^{-1}	**1**	
(d) $\Delta Q = ml$ gives $48 \times 200 = 32 \times 10^{-3} \times l$	**1**	The same heater is now transferred to a beaker of ice. The energy it supplies ($\Delta Q = Pt$) during 200 s is all assumed to melt some of the ice.
From which specific latent heat of fusion of ice $l = 3.0 \times 10^5$ J kg^{-1}	**1**	
Suitable assumptions include: • no energy passes to the ice from the surroundings • none of the energy from the heater is lost to the surroundings • the temperature of the ice does not change.	**any 1**	The air surrounding the funnel is almost certainly at a higher temperature than the ice, so the ice will be gaining some energy from it. Some of the thermal energy given out by the heater may conduct through it upwards into the surroundings. If the temperature of the ice were to increase, some energy would be needed to cause the change.
4 (a) Thermal energy gained by water $\Delta Q = mc\ \Delta\theta = 0.45 \times 4200 \times 20$	**1**	The energy passed to the water from the hot lump of copper raises the temperature of the water from 15 °C to 35 °C.
$= 3.78 \times 10^4$ J	**1**	
(b) (i) Thermal energy lost by copper $= 3.78 \times 10^4$ J	**1**	Since the question states that the heat capacity of the beaker is negligible, it is assumed that no energy is needed to raise the temperature of the beaker. It is also assumed that there is no exchange of thermal energy with the surroundings whilst the copper is heating the water.
(ii) Fall in temperature $\Delta\theta$ of copper is given by $\Delta Q = mc\Delta\theta$ $\therefore 3.78 \times 10^4 = 0.12 \times 390 \times \Delta\theta$	**1**	
… from which $\Delta\theta = 808$ °C (or K)	**1**	

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(iii) Temperature of copper whilst in flame $= 808 + 35$ $= 843\,°C$ (or 1116 K)	**1**	The copper finished up in the beaker of water at 35 °C. Note that a temperature change of 1 °C is the same as one of 1 K. However, part **(iii)** requires you to calculate, in effect, the **temperature** of the Bunsen burner flame: if you intend to answer this in K, you must add 273 to 843 °C. (0 °C = 273 K)
5 **(a)** Kinetic energy of bicycle and rider $= \frac{1}{2}mv^2 = \frac{1}{2} \times 95 \times 8.0^2$	**1**	Part **(a)** should provide you with two very easy marks.
$= 3.04 \times 10^3$ J	**1**	
(b) **(i)** Energy converted to thermal energy $= 0.60 \times 3040 = 1.82 \times 10^3$ J	**1**	Don't overlook the fact that **only 60%** of the kinetic energy of the bicycle and rider is converted into thermal energy in the brake blocks.
Maximum temperature rise of brake blocks is given by using $\Delta Q = mc\,\Delta\theta$ $\therefore\ 1.82 \times 10^3 = 0.12 \times 1200 \times \Delta\theta$	**1**	
… from which $\Delta\theta = 12.6\,°C$ (or K)	**1**	
(ii) None of the thermal energy in the brake blocks passes to the surroundings.	**1**	Practical braking systems are usually designed so that **as much as possible** of the thermal energy is lost to the surroundings as quickly as possible! This helps to prevent the brakes overheating.
6 **(a)** **(i)** Thermal energy generated in 1 min $E = Pt = 800 \times 60 = 4.80 \times 10^4$ J	**1**	Thermal energy generated by a runner inevitably raises the temperature of the runner's body. This rise in temperature is accompanied by an increase in the rate of loss of thermal energy from the body to the surroundings. A steady body temperature is achieved once the rate of loss of energy equals the rate of production.
(ii) Temperature rise of her body in 1 min is given by $\Delta Q = mc\Delta\theta$ $\therefore\ 4.80 \times 10^4 = 60 \times 3900 \times \Delta\theta$	**1**	
… from which $\Delta\theta = 0.205\,°C$ (or K)	**1**	
(b) Energy lost by perspiration in 1 min $E = Pt = 500 \times 60 = 3.00 \times 10^4$ J	**1**	Evaporation of sweat from the surface of the body is a very effective way of losing energy, because the specific latent heat of vaporisation of water is so very large. This means that a great deal of energy is needed to evaporate the water.
Mass of sweat evaporated in 1 min is given by $\Delta Q = ml$ $\therefore\ 3.00 \times 10^4 = m \times 2.3 \times 10^6$	**1**	
… from which $m = 1.30 \times 10^{-2}$ kg	**1**	
(c) When the runner stops running, her temperature falls because: • she is not generating as much thermal energy per second … • but she is still losing heat at the same rate (or she is still sweating).	**2**	Anyone who has ever done any form of physical exercise will recognise this effect. As soon as you stop the activity, you feel cold.

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7 (a) (i) Consider 1 second …	1	In calculations involving the flow of a liquid or gas, it is usually advantageous to consider what happens in a time of 1 s. In the power station *all* of the water flowing through the system is converted into steam. You should recall that 1 W = 1 J s^{-1}. (Actual power stations normally raise their steam at very high pressure, under which conditions the boiling point of water is much higher than 100 °C.)
Water from 21 °C to 100 °C: $\Delta Q = mc\Delta\theta = 190 \times 4200 \times 79 = 6.30 \times 10^7$ J		
Water at 100 °C into steam at 100 °C: $\Delta Q = ml = 190 \times 2.3 \times 10^6 = 4.37 \times 10^8$ J	1	
∴ energy transferred to water per second = $(6.30 \times 10^7) + (4.37 \times 10^8) = 5.00 \times 10^8$ J ∴ energy is transferred at a rate of 5.00×10^8 W (which is 500 MW)	1	
(ii) Mass of rocks $m = \rho V = 3200 \times 4.0 \times 10^6 = 1.28 \times 10^{10}$ kg	1	You have to remember how to work out mass from density and volume before you can progress to the target of this calculation. Note that, so far in this question, the rocks have been assumed to gain no energy from deeper underground to restore their temperature. But this is to change in part **(b)**!
Energy transfer from rocks in 1 day $= 5.00 \times 10^8 \times 24 \times 3600 = 4.32 \times 10^{13}$ J	1	
Fall in temperature of rocks is given	1	
by $\Delta Q = mc\Delta\theta$ ∴ $4.32 \times 10^{13} = 1.28 \times 10^{10} \times 850 \times \Delta\theta$ … from which $\Delta\theta = 3.97$ °C (or K)	1	
(b) Energy released per decay $= 4.2 \times 10^6 \times 1.6 \times 10^{-19} = 6.72 \times 10^{-13}$ J	1	Begin by converting the energy released per decay into J.
Number of decays required per second $= \dfrac{\Delta N}{\Delta t} = \dfrac{500 \times 10^6}{6.72 \times 10^{-13}} = 7.44 \times 10^{20}$	1	500 MW means 500×10^6 J of energy will be needed in each second.
Decay constant of ^{238}U $\lambda = \dfrac{\ln 2}{T_{1/2}} = \dfrac{\ln 2}{4.5 \times 10^9 \times 365 \times 24 \times 3600} = 4.88 \times 10^{-18}\ s^{-1}$	1	There was plenty of practice in working out the decay constant from the half-life in Chapter 9.
Use of $\dfrac{\Delta N}{\Delta t} = -\lambda N$ gives $7.44 \times 10^{20} = (-)4.88 \times 10^{-18} \times N$ ∴ number of ^{238}U nuclei required in source of energy $N = 1.52 \times 10^{38}$	1	The law of radioactive decay then allows you to work out the number of nuclei that must decay per second.
∴ mass of ^{238}U required = $1.52 \times 10^{38} \times \left(\dfrac{0.238}{6.02 \times 10^{23}}\right) = 6.01 \times 10^{13}$ kg	1	One mole of ^{238}U is has a mass of 0.238 kg and contains N_A atoms, so you can find the mass of 1 atom and hence calculate the mass of ^{238}U that would be required.