Answers to in-text questions

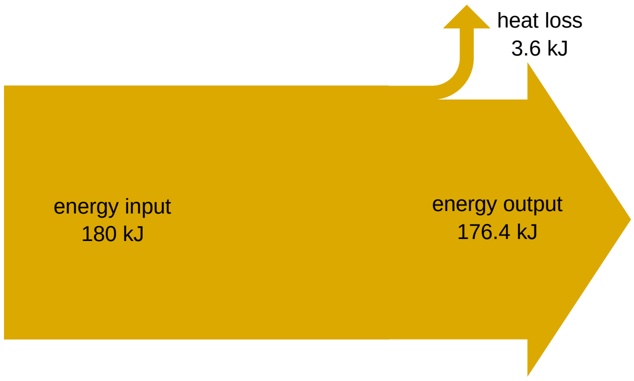
1 **a)** The element conducts thermal energy into the water. The temperature of all the water increases principally because of convection currents. These arise through density variations, as the density of the water decreases with temperature and then rises to circulate throughout the kettle.

b) **i)** Conduction through the walls of the kettle.

ii) Radiation from the metal, and air convection from the hot walls increasing the temperature of the air near the kettle.

c) Give the kettle a shiny/silvery finish as this minimizes the radiation from the surface.

2 Energy transferred from kettle = 2000 × 90 = 180 kJ. Loss is 3.6 kJ.



Alternatively draw using power values 2000 / 40 / 1960 W.

3 **a)** 18 × 0.7 = 13 kW **b)** 175 × 0.7 = 123 kW

Answers to additional problems

1 **a)** The copper (a good conductor) conducts energy quickly to the whole of the pan; the plastic handle (a poor conductor) does not conduct well and keep the end of the handle cool.

b) Metal doors conduct energy well from one side to the other, so allow heat energy to leave a room in the winter when there is a large temperature difference between inside and outside. In summer the room can heat up. Wooden doors are poor conductors and insulate the inside from the outside.

c) A dry cloth is a better thermal insulator than a wet cloth and will not allow energy from the hot object to travel through it.

2 The fleece contains air pockets. The trapped air in the fleece is a poor conductor; the pockets of air make effective convection difficult. Radiation is probably not greatly changed unless the manufacturer of the fleece has covered it in a shiny cover with the tank being black or dark before.

3 Black materials absorb radiation effectively, and this increases the amount of energy transferred by the heating panel. A reflective layer would reflect energy back into the atmosphere.

4 **a)** $^{235}_{92}\text{Ra} \rightarrow ^{92}_{36}\text{Kr} + ^{141}_{56}\text{Ba} + 2^{1}_{0}\text{n}$

b) **i)** $\Delta E = \Delta mc^2 = 3.1 \times 10^{-28} \times (3.00 \times 10^8)^2 = 2.8 \times 10^{-11}$ J **ii)** $\dfrac{1.0 \times 10^3}{2.8 \times 10^{-11}} = 3.6 \times 10^{13}$

c) Both neutrons emitted can go on to cause further fissions, and then a chain reaction can occur as the fissions will themselves give rise to further emitted neutrons that can go on to cause fission and so on.

5
Rate at which natural gas is used = $\dfrac{500 \text{ MJ s}^{-1}}{56 \text{ MJ kg}^{-1} \times 0.29} = 31 \text{ kg s}^{-1}$

6 **a)** Radiation from the Sun enters the Earth's atmosphere and the Earth heats up. The Earth's surface radiates energy according to its temperature (which is lower than that of the Sun). The radiation from the Earth is predominantly infra-red and this radiation is trapped in the atmosphere. The Earth, therefore, has a higher temperature than we would expect.

b) The gases in the atmosphere that absorb the infra-red radiation are typically carbon dioxide, methane, and others. Carbon dioxide is released during many industrial and domestic processes. This increasing level of carbon dioxide in the atmosphere will increase the absorption of the infra-red radiation and as a result, the average Earth temperature will increase even more.

7 Power (energy output per second) = 4.0 GJ s^{-1}
Energy output per year = $4.0 \times 365.25 \times 24 \times 60 \times 60 = 1.26 \times 10^8$ GJ yr^{-1}

Mass of uranium required to provide this output = $\dfrac{1.26 \times 10^8 \text{ GJ yr}^{-1}}{82 \times 10^3 \text{ GJ kg}^{-1}} = 15 \times 10^2 \text{ kg yr}^{-1}$

8 Volume of ice = area × thickness = $(1.5 \times 10^7 \times 10^6 \text{ m}^2) \times (1.5 \times 10^3 \text{ m}) = 2.25 \times 10^{16} \text{ m}^3$
Mass of ice = volume × density = $(2.25 \times 10^{16} \text{ m}^3) \times (920 \text{ kg m}^{-3}) = 2.1 \times 10^{19}$ kg

Volume of water released = $\dfrac{\text{mass of ice}}{\text{density of water}} = \dfrac{2.1 \times 10^{19} \text{ kg}}{1000 \text{ kg m}^{-3}} = 2.1 \times 10^{16} \text{ m}^3$

Sea level change = $\dfrac{\text{new volume of water released}}{\text{ocean area}} = \dfrac{2.1 \times 10^{19} \text{ m}^3}{3.5 \times 10^8 \times 10^6 \text{ m}^2} = 60$ m

9
albedo = $\dfrac{\text{intensity reflected}}{\text{intensity received}}$; $0.3 = \dfrac{\text{intensity reflected}}{1400}$; average reflected intensity = 420 W m^{-2}

10 **a)** **i)** A fuel formed by the conversion of plant tissue through compression and heating below the surface of the Earth.

ii) coal / oil / natural gas

iii) The conversion takes geological time periods to take place; this conversion cannot be carried out at the same rate at which the fuels are consumed.

b) **i)**

ii) Efficiency = 36%

10 **c)** Explanation may include the following:

- Burning the fuel is straightforward;
- Significant amounts of power can be produced;
- The fuel is cheap;
- Due to the above points, the use of fossil fuels are is well established and implementing alternative means of energy production to provide the same power for the existing demand is costly;
- There is significant political opposition to minimizing fossil fuel use, in part due to the lost of industry and jobs relating to fossil fuels.

11 **a)** The volume of fuel consumed every second = $\frac{1.3 \times 10^{-4}\ \text{kg s}^{-1}}{820\ \text{kg m}^{-3}} = 1.6 \times 10^{-7}\ \text{m}^3\ \text{s}^{-1}$;

Power output = $(1.6 \times 10^{-7}\ \text{m}^3\ \text{s}^{-1}) \times (27 \times 10^9\ \text{J m}^{-3}) = 4300\ \text{W}$

b) Energy produced = $4300\ \text{J s}^{-1} \times 60\ \text{s} = 2.6 \times 10^5\ \text{J}$

$E = mc\Delta\theta$; $2.6 \times 10^5 = \text{m} \times 990 \times (32 - 12) = 13\ \text{kg}$

c) The half-life of the short-lived isotope is less than 10 minutes. Therefore, when one hour has elapsed, the short-lived isotope will have halved at least six times, and its activity will be $\frac{1}{2^6}$ of its original value (≈ 2%) at the most. Therefore, when one hour has elapsed, most of the activity is from the long-lived isotope and the half-life is about 0.6 hours.

12 **a)** **i)** Maximum energy = $mgh = V\rho gh = (2.5 \times 10^6\ \text{m}^3 \times 1000\ \text{kg m}^{-3}) \times 9.81 \times 270 = 6.6\ \text{TJ}$

ii) Maximum power = $\frac{V\rho gh}{t} = (350\ \text{m}^3\ \text{s}^{-1} \times 1000\ \text{kg m}^{-3}) \times 9.81 \times 270 = 0.93\ \text{GJ}$

b) **i)** Total loss is 27 + 18 + 6 = 51% of input; system is 49% efficient

ii)