# Solutions for Topic 8 – Energy production

**1. a)** power produced $\left(\frac{24}{0.32}\right) = 75$ MW;

energy produced in a year $(75 \times 10^6 \times 365 \times 24 \times 60 \times 60 =)$ $2.37 \times 10^{15}$ J;

number of reactions required in one year $\left(\frac{2.37 \times 10^{15}}{3.2 \times 10^{-11}}\right) = 7.39 \times 10^{25}$;

mass used $(7.39 \times 10^{25} \times 235 \times 1.66 \times 10^{-27}) \approx 29$ kg

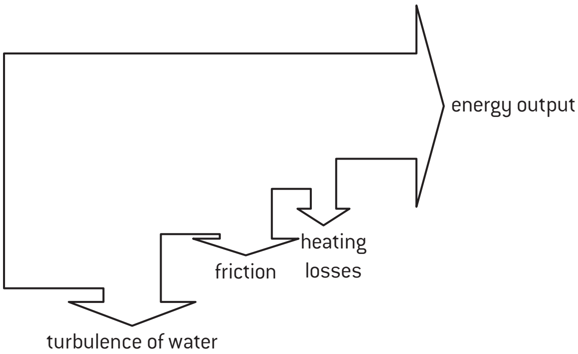
**b)** The reactions produce plutonium from uranium 238. This isotope of plutonium may be used to manufacture nuclear weapons and plutonium is extremely toxic. It can be used as fuel in other reactors.

**2. a)** mass $= 50 \times 5.0 \times 10^4 \times 10^3$
loss in GPE $= 50 \times 5.0 \times 10^4 \times 10^3 \times 310 \times 9.81$
$= 7.6 \times 10^{12}$ J

**b)** flows for 6250 s
$1.2 \times 10^9$ W

**3. a)** 53%

**b)**




**4. a) (i)** U-235 fissions occur with the emission of neutrons with high energy. The neutrons are fast moving and transfer kinetic energy to the moderator. The energy of the core and the moderator are transferred to the coolant.

**(ii)** The heat exchanger allows transfer of thermal energy between the reactor and coolant. The coolant transfers thermal energy to steam and the steam allows the turbine to drive the generator.

**b)** Heating the working fluid in the exchanger ***OR*** cooling the working fluid having passed through the turbine ***OR*** named friction process in power station machinery

**5.** The solar radiation is captured by a disc of area $\pi R^2$ where $R$ is the radius of the Earth but is distributed (when averaged) over the entire Earth's surface which has an area four times as large.

**6. a)** 0.700;

**b)** $I = e\sigma T_a^4$
$= 0.70 \times 5.67 \times 10^{-8} \times 242^4$
$= 136$ W m$^{-2}$

**c)** $\sigma T_e^4 = 136 + 245$ W m$^{-2}$
hence $T_e \left(= \sqrt[4]{\frac{381}{5.67 \times 10^{-8}}}\right) = 286$ K

**7. a)** The Earth radiates photons of infrared frequency. The greenhouse gas molecules vibrate with frequencies in the infra-red region. So because of resonance the photons are absorbed.

Because most incoming radiation consists of photons is in the visible and ultraviolet region. These photons are of much shorter wavelength than those radiated by the Earth and so these cannot be absorbed.

**b)** *Source*: emissions from volcanoes/burning of fossil fuels in power plants or cars
*Sink*: oceans/rivers/lakes/seas/trees

**8. a)** infrared

**b)** The nitrogen oxide in the atmosphere readily absorbs infrared radiation radiated from the surface of Earth. This radiation is then re-radiated in random directions; this prevents the energy radiated from Earth escaping into space.

**9. a) (i)** power per unit area of atmosphere $= e\,\sigma\,T^4$
$= 0.720 \times 5.67 \times 10^{-8} \times 242^4$
$= 140\ \text{W m}^{-2}$

**(ii)** solar power absorbed per unit area at the surface $= 0.720 \times 344$
$= 250\ \text{W m}^{-2}$

**b) (i)** new power radiated by atmosphere $= [0.720 \times 5.67 \times 10^{-8} \times 248^4]$
$= 150\ \text{W m}^{-2}$

**(ii)** new power absorbed by Earth $= (150 + 250) = 400\ \text{W m}^{-2}$

**c)** $400 = 5.67 \times 10^{-8} \times T^4$
$T = 290$ K
to give $\Delta T = 2$ K

**10.** present $\dfrac{I_{out}}{I_{in}} = 0.30$ so present $I_{out} = 102\ (\text{W m}^{-2})$

after doubling new $I_{out} = (340 \times 0.29) = 98.6(\text{W m}^{-2})$
change $= 102 - 98.6$
$= 3.4\ \text{W m}^{-2}$

The estimate assumes that:

all the radiated energy is in the infra-red
all the extra gas absorbs the radiated radiation
no change in radiated power due to Earth temperature change