Environmental Science, Problems Chapter 7

7.1

We have a solar absorber where water is circulating at a flow of $\Phi = 15$ cm^3/s. The area of the absorber is 5.0 m^2. One measures the incoming power to $Q_{\text{in}} = 390$ W/m^2. Calculate the temperature increase of the water after passing the absorber. $C_P = 4.18 \cdot 10^3$ J/kgK. You can assume that 1 cm^3 of water weighs 1 g.

The temperature difference can be calculated using:

$$\Delta T = \frac{Q_{\text{in}} A}{C_P \Phi} = \frac{390 \cdot 5.0}{4.18 \cdot 10^3 \cdot 15 \cdot 10^{-3}} \text{ K} = 31.1\text{K} \approx 31\text{K}$$

Answer: 31°C or 31 K

7.2

There is a wind blowing with at velocity of $u = 12$ m/s. Calculate the power of the wind per m^3.

Using $P_{wind} = T_{wind} \cdot u = \frac{1}{2}\rho \cdot u^3 = \frac{1}{2} \cdot 1.2 \cdot 12^3 \text{ W/m}^3 = 1.04 \text{ kW/m}^3$

Answer: 1.0 kW/m$^{\mathbf{3}}$

7.3

There is a strong wind blowing with the power of 1.0 kW/m^2. A windmill with a large rotator is used to produce electricity. Calculate the maximum power of the windmill per m^2.

Using $P_{exctr} = P_{wind} \cdot \dfrac{16}{27} = 10^3 \cdot \dfrac{16}{27} \text{ kW/m}^{\mathbf{2}} = 593 \text{ W/m}^{\mathbf{2}}$

Answer: 0.59 kW/m$^{\mathbf{2}}$

7.4

There is a waterfall where the flow is 100 m^3/s and falling height of 55 m. Calculate the maximum power.

Using $P = \dfrac{\rho V g h}{t} = 1000 \cdot 100 \cdot 9.82 \cdot 55 \text{ W} = 54 \text{ MW}$

Answer: 54 MW

7.5

A wind is blowing over the Atlantic Ocean where the period of the waves is around 10 s. One finds that some large waves have a height of 12 m. Calculate the maximum power of the waves per meter.

Applying $P \approx 0.5 \cdot H^2 T$ kW $= 0.5 \cdot 12^2 \cdot 10$ kW/m $= 720$ kW/m

Answer: 720 kW/m

7.6

A wind is blowing over the Atlantic Ocean where the period of the waves is T. One finds that some large waves have a height of H m. Later, one observes waves with a maximum height of $2H$. Estimate how much the power has increased.

The power per meter is $P = 0.5 \cdot H^2 \cdot T$ kW/m. Hence, with $H_2 = 2H$ we get $P_2 = 0.5 \cdot (2H)^2 \cdot$ kW/m $= 2^2 P = 4P$, i.e. the power is now 4 times higher.

Answer: 4 times higher

7.7

Looking at nuclear power we try to estimate the energy we can obtain from 1.0 gram of ^{235}U. Use the Einstein mass relation $E = mc^2$.

The energy is given by $E = mc^2 = 10^{-3} \cdot \left(3.00 \cdot 10^8\right)^2$ J $= 90 \cdot 10^{12}$ J

Answer: 90 TJ

7.8

Looking at nuclear power we try to estimate the energy we can obtain from a proton with mass $1.67 \cdot 10^{-27}$ kg. Use the Einstein mass relation $E = mc^2$.

The energy is given by $E = mc^2 = 1.67 \cdot 10^{-27} \cdot \left(3.00 \cdot 10^8\right)^2$ J $= 0.15 \cdot 10^{-9}$ J

Answer: $1.5 \cdot 10^{-10}$ J $= 0.15$ nJ