Ph 12 - Energy and the Environment Homework 5

Chapter 5

Questions and Problems

4. Since power goes as v^3 for windmills: $\left(\frac{15\text{ mph}}{10\text{ mph}}\right)^3 = \frac{27}{8} = 3.375 \Rightarrow (23\text{ kW})(3.375) \simeq$ 78 kW.

5. Windmill diameter is 2 meters, and converts wind energy to electric at 60% of theoretical maximum.

a. From page 134, the theoretical maximum efficiency is 59%. $\Rightarrow$ overall efficiency $= (0.59)(0.6) = 35.4\%$.

Furthermore $\frac{\text{Power}}{\text{Area}}$ (in $\frac{kW}{m^2}$) $= 6.1\times10^{-4}\, v^3$, where v is in meters per second.

1). $10\text{ mph} = 4.4704\text{ m/s} \Rightarrow \frac{P}{A} = (6.1\times10^{-4})(4.4704\text{ m/s})^3 (0.354) = 0.054497\frac{kW}{m^2}$ But $A = \pi r^2 = \pi\left(\frac{2m}{2}\right)^2 = \pi\ m^2$

$\Rightarrow P \simeq 60.607\text{ W} \simeq$ 61 W

2). 20 mph $\rightarrow \left(\frac{20\text{ mph}}{10\text{ mph}}\right)^3 = 8 \Rightarrow P = 484.855\text{ W} \simeq 485\text{ W} \simeq$ 480 W

3). 30 mph $\rightarrow \left(\frac{30\text{ mph}}{10\text{ mph}}\right)^3 = 27 \Rightarrow P = 1.636\text{ kW} \simeq$ 1600 W

b. Dividing each number by 60 W and rounding down: 1) 1 bulb 2) 8 bulbs 3) 27 bulbs.

7. $T_h = 210°C = 483.15\text{ K}$; $T_c = 25°C = 298.15\text{ K} \Rightarrow$ maximum efficiency (aka Carnot efficiency) $= 1 - \frac{298.15K}{483.15K} = 38.3\% = \epsilon$

$\Rightarrow 1-\epsilon = 61.7\%$ comes out as waste heat

8. $T_h = 20°C = 293.15\text{ K}$; $T_c = 278.15\text{ K} \Rightarrow$ Carnot efficiency $= 1 - \frac{278.15K}{293.15K} \simeq 5.12\%$. But 2/3 is used for pumps and other losses!

$\Rightarrow$ overall efficiency $= \frac{1}{3}(5.12\%) \simeq$ 1.7%.

12. From page 150, we are told that 1 lb. of dry plant material produces 7500 Btu when burned $\Rightarrow 1.7445\times10^7$ J/kg conversion.
From 149, a typical pine forest produces 6 g/m²day of plant matter. Assuming we can burn that matter, that gives us a potential $104670\ \frac{J}{m^2\,day} = 1.2115\ \frac{W}{m^2} \Rightarrow$ To produce 1 GW, we need $\frac{10^9\text{ W}}{1.2115\text{ W/m}^2} \simeq 8.25\times10^8\text{ m}^2$.
If we factor in a rough 30% efficiency for converting heat to electricity, the area required becomes roughly $\simeq 2.8\times10^9\text{ m}^2$
$\simeq 2800\text{ km}^2$
$\simeq 1080\text{ mi}^2$

Multiple Choice

6. $\left(\frac{30\text{ m/s}}{10\text{ m/s}}\right)^3 = 27 \Rightarrow$ a). 15. From page 162 $\Rightarrow$ d).

Online Questions

1. $h = 80.6\text{ m}$; $f = 30\,000\text{ m}^3/\text{s}$ of H_2O. Assume $\epsilon = 0.9$ and $\rho_{H_2O} = 1000\text{ kg/m}^3$

a. The water's energy comes from gravitational potential energy. $E = mgh \Rightarrow P = \frac{\Delta m}{\Delta t} gh = \rho f g h$

So the total power from the dam will be $P = (0.9)(1000\text{ kg/m}^3)(30\,000\text{ m}^3/\text{s})(80.6\text{ m})(9.80665\text{ m/s}^2) \simeq 2.13\times10^{10}\text{ W} \simeq 21\text{ GW}$!

b. From a, it produces 21 GW, so it will replace 21 1 GW coal/nuclear plants.

c. There is no right answer for this.

2. $1200\text{ ft}^2 \simeq 111.484\text{ m}^2 \simeq 110\text{ m}^2$ San Diego has an average solar insolation of about 209 W/m².

If we further assume an efficiency of 15% $\Rightarrow$ We can get about $3501.99\text{ W} \simeq 3502\text{ W} = \left(3502\frac{J}{s}\right)\left(\frac{1\text{ kWh}}{3.6\times10^6\text{ J}}\right)\left(24\cdot30\cdot3600\frac{s}{\text{month}}\right)$

$\simeq 2521\frac{\text{kWh}}{\text{month}}$

From the DoE, the average American home uses $920\frac{\text{kWh}}{\text{month}} \Rightarrow$ more than enough!

3. There are trace quantities of Pu from the last supernova that formed our solar system, but the vast majority of Pu comes from nuclear fission in reactors (from lecture a neutron striking U^{238} will produce Pu^{239})

4a. The most commonly used fuel is U^{235}, which must be separated from uranium ore (mostly U^{238}) by centrifuges.
We can also use Pu^{239} in breeder reactors. The plutonium is obtained ~~from~~ as a byproduct of regular reactors.

4b. The same processes (and materials) in part a) can also create a bomb.

5a. A 120 lb person maintains his weight with 1700 Cal/day. One week of fasting is 7(1700) Cal ≈ 11900 Calories lost.
Since 1 lb of fat is roughly 3500 Cal $\Rightarrow \frac{11900 \text{ Cal}}{3500 \frac{\text{Cal}}{\text{lb}}} \approx$ 3.4 lbs of fat lost.

5b. 3 miles a day for 7 days is 21 miles. Since running a mile takes up about 100 Calories ⇒ 2100 Calories burned.
The energy intake is the same, so $\frac{2100 \text{ Cal}}{3500 \text{ Cal/lb}} =$ 0.6 lbs of fat lost.

6. Although we had a similar question last week, you should go more in-depth and discuss indirect forms of solar energy (e.g. power towers).

7. This is an easy lookup question, see the lecture slides: 1) Passive solar heating, 2) Flat-plate direct heating, 3) Thermal electric power 4) Photovoltaics.

8. Again, no correct answer, but you must consider a number of factors (Question 5.8 for example, provides a nice numerical argument against it).