Solutions to Homework 7

1. Problem 2 Page 167 (RK)

   (a) The volume of water is $2000 \times 8000 \times 100 = 1.6 \times 10^9$ m^3. This corresponds to a mass of 1.6×10^{12} kg. The potential energy is $mgh = 1.6 \times 10^{12} \times 9.8 \times 500 = 7.85 \times 10^{15}$ J. If the generator has an efficiency of 90% the electric energy produced is $0.9 \times 7.85 \times 10^{15} = 7.1 \times 10^{15}$ J.

   (b) Power output $P = \frac{7.1 \times 10^{15} \text{ J}}{3.15 \times 10^7 \text{ s}} = 224 \times 10^6$ W =224 MW.

   (c) 224,000 people.

   (d) Convert the energy to kWh first, then multiply by the cost per kWh:

   $$7.1 \times 10^{15} J \times \frac{1\ kWh}{3.6 \times 10^6\ J} \times \frac{\$0.05}{kWh} = \$9.87 \times 10^7 = \$98.7 \text{ Million.}$$

2. Problem 3 Page 167 (RK)

   (a) $1\ kg \times 9.8\ m/s^2 \times 30\ m \times 0.9 = 265$ J.

   (b) Use $\Delta Q = mC\Delta T$, where $C = 4.2$ kJ/°C kg is the heat capacity of water. Find $\Delta Q = 8.4$ kJ. With an efficiency of 3%, the energy output is $0.03 \times 8.4 = 0.252$ kJ = 252 J.

   (c) These are similar amounts of energy, so similar amount of water would be required for equivalent hydro and OTEC plants.

3. Problem 4 Page 167 (RK)

   $P = 23\ kW \times (\frac{15\ mph}{10\ mph})^3 = 78\ kW$.

4. Problem 5 Page 167 (RK)

   We want to use the equation given on page 134

   $$\frac{P_{wind}}{A} = 6.1 \times 10^{-4} v^3$$

   where P_{wind} is the power of the wind in kW, A is the area in m^2 and v is the wind velocity in m/s. The maximum theoretical power output is 0.59 times the power of the wind P_{wind}. On top of that we have an efficiency of 60%, so the equation we will use to find the electric power output is

$$P = 0.6 \times 0.59 \times 6.1 \times 10^{-4} \times A \times v^3$$

The area A of the windmill is $A = \pi(d/2)^2 = 3.14 \times (1\ m)^2 = 3.14\ m^2$.

(a) We need to convert the velocities to m/s. $v_1 = 10\frac{mile}{hr} \times \frac{1609\ m}{mile} \times \frac{hr}{3600\ s} = 4.47$ m/s. $v_2 = 20$ mph $= 8.94$ m/s. $v_3 = 30$ mph $= 13.41$ m/s. Now we just have to plug in

$$P_1 = 0.6 \times 0.59 \times 6.1 \times 10^{-4} \times A \times v_1^3 = 0.060 \text{ kW} = 60 \text{ W}.$$

Analogously, $P_2 = 485$ W and $P_3 = 1636$ W.

(b) (1) 1 bulb, (2) 8 bulbs, (3) 27 bulbs.

5. Problem 9 Page 168 (RK)

   (a) Using examples 5.4 and 5.5, we have 2.13 MW generated at an eciency of 6.7% when the flow rate is 1000 gal/sec. So the flow rate here will be

$$1000\frac{gal}{s} \times \frac{3.8\ l}{gal} \times \frac{10^{-3}\ m^3}{l} \times \frac{1000\ MW}{2.13\ MW} = 1824\ m^3/s$$

   (b) The required pipe area would be $\frac{1824\ m^3/s}{4\ m/s} = 456\ m^2$. Divide by π to find the radius squared, 145 m^2. The diameter is thus $2 \times \sqrt{145} = 24$ m.

6. Problem 12 Page 168 MCQ (RK)

   Using the result on page 152,

$$\frac{15\ ton}{acre} \times \frac{7500\ Btu}{lb} \times \frac{2000\ lb}{ton} = 2.25 \times 10^8\ Btu/acre$$

   The required electrical energy for one year is $10^9\ W \times 3.15 \times 10^7\ s \times 9.49 \times 10^{-4}\ Btu/J = 3 \times 10^{13}\ Btu$. The required thermal energy is three times this amount, or $9 \times 10^{13}\ Btu$. The area needed is $\frac{9 \times 10^{13}\ Btu}{2.25 \times 10^8\ Btu/acre} = 4 \times 10^5\ acre$.

7. Problem 2 Page 168 MCQ (RK)

   Answer **h**.

   $P = \frac{mgh}{t} = \frac{15 \times 9.8 \times 90}{0.1} = 132300$ W.

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8.

Problem 9 Page 169 MCQ (RK)

Answer **b**.

Approximately 70% of the energy extracted (which is 59% of the energy of the wind) can be converted to electricity, for an overall conversion eciency of about 40%.

9. Problem 15 MCQ

Answer **d**.