PHYSICS-2
Elementary Physics of Energy

Homework 8 Solutions
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1. To produce 120 Volts, given that each individual cell gives approximately Volt, around 240 individual cells would be required. Estimate a solar cell efficiency of 15

2. Assuming an insolation of $\frac{1000Btu}{ft^2}$ and an efficiency of .5 means that the effective insolation is $\frac{500Btu}{ft^2}$. The total required energy for heating is $2 \times 50 \times 10^6 Btu$, or $1 \times 10^8 Btu$. Spread over the heating season of 180 days, this requires a daily input of $\frac{1 \times 10^8 Btu}{180} = 5.56 \times 10^5 Btu$. Dividing this by the effective insolation gives a required collector area of: $5.56 \times 10^5 Btu(\frac{ft^2}{500Btu}) = \boxed{1111 ft^2}$.

3. This calculation is similar to Example 4.1 in the text. One Btu will heat one gallon of water, weighing 8lbs, by $1°F$, so:

$$\frac{1200gal}{day} \times \frac{8lbs}{gal} \times \frac{1Btu}{1°Flb} \times 50°F = 4.8 \times 10^5 Btu$$

Assuming an efficiency of .5, twice this amount of energy is required, so the collector area needed is

$$\frac{9.6 \times 10^5 Btu}{1100Btu/ft^2} = \boxed{873ft^2}$$

4. First find the volume of the body of water and determine the mass of water in the volume, and use $U = mgh$ to find the gravitational potential energy stored in the water at that height. Taking 90% of this, we get:

a) $2000m \times 8000m \times 100m = 1.6 \times 10^9 m^3$

$$mgh = (\frac{1000kg}{m^3})(1.6 \times 10^9 m^3)(9.8m/s^2)(500m) = 7.85 \times 10^{15} J$$

$(7.85 \times 10^{15} J)(0.9)(\frac{1MJ}{10^6 J}) = \boxed{7.1 \times 10^9 MJ}$

b) $\frac{7.1 \times 10^9 MJ}{3.15 \times 10^7 s} = \boxed{224MW}$

c) $224MW \times (\frac{1000people}{1MW}) = \boxed{224000\ people}$

d)From the inside cover of the text, $1kWh = 3.60 \times 10^6 J$, so:

$7.1 \times 10^{15} J \times (\frac{1kWh}{3.60 \times 10^6 J})(\frac{\$0.05}{kWh}) = \boxed{\$98.7 Million}$

5. Similar to the last problem, use U=mgh to find the gravitational energy stored, and use $\Delta Q = mc\Delta T$ to find the energy released from cooling the water:

   a) $1kg \times 9.8m/s^2 \times 30m \times 0.90 = \boxed{265J}$

   b) $\Delta Q = mc\Delta T = (1kg)(\frac{4.184kJ}{kg°C})(2°C) = 8.368kJ$

   At an efficiency of .03, this becomes $8.368kJ(.03) = .251kJ = \boxed{251J}$

   c) These are very comparable energies, so you would need a similar amount of water for these equivalent hydro and OTEC plants. If efficiencies change as technology grows, this may change, since there is much more energy stored in hot water than there is in gravitational potential.

6. Using the formula for the power in a windmill from the text on page 134, we can multiply by a simple ratio to "adjust" the value of the power for our situation, essentially substituting in a new value of air velocity for the old value:

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

7. The area of the windmill is $\pi \times (1m)^2 = \pi m^2$. The theoretical maximum is 59%, so we must apply the 60% efficiency to this already lowered theoretical maximum. The speed needs to be converted to m/s to use the expression given on page 134 of the text, which indicates that the mechanical power generated is proportional to v^3.

   $$\frac{10miles}{1hour} \times (\frac{3600s}{1hour})(\frac{5280ft}{1mile})(\frac{1m}{3.28ft}) = 4.47m/s$$

   1) $P = \pi m^2 \times 6.1 \times 10^{-4} \times (4.47m/s)^3 \times 0.6 \times 0.59 = 0.0606kW = \boxed{60.6W}$

   2) The speed is doubled over the previous case, so the power increases by a factor of $2^3 = 8$, so $P = 60.6W(8) = \boxed{485W}$

   3) The speed is tripled over case (1), so the power increases by a factor of $3^3 = 27$, so $P = 60.6W(27) = \boxed{1636W}$

   b) 1) $60.6W \times (\frac{1bulb}{60W}) = 1.01 \; or \; \boxed{1 \; bulb}$

   2) Similarly, this will give $\boxed{8 \; bulbs}$

   3) Similarly, this will give $\boxed{27 \; bulbs}$

8. Notice how in this problem, the specific heat is given per cm^3, rather than per kg. This means you must multiply by the volume of the rock, rather than the mass of the rock.

   $$\frac{2.4J}{cm^{3\circ}C} \times (\frac{100cm}{1m}) \times (240^\circ C - 100^\circ C) = \boxed{336 \times 10^6 J}$$

9. This is an engine problem. We are given the temperatures $T_h \; and \; T_c$, which we must convert to Kelvin by adding 273. We then use them to find the efficiency.

   $$\eta = \frac{T_h - T_c}{T_h} = 1 - \frac{T_c}{T_h} = 1 - \frac{25 + 273}{210 + 273} = 1 - 0.617 = \boxed{0.383}$$

   The percentage of waste heat is given by the amount of heat wasted (Q_c) divided by the total heat input (Q_h). But we know that $\frac{Q_c}{Q_h} = \frac{T_c}{T_h}$, which we already calculated above as $\frac{T_c}{T_h} = \boxed{0.617}$.

10. a) First we must find the volume, and divide by the 6 hours of time to find the volume flow rate in m^3/s.

$$14km^2 \times (\frac{1000m}{1km})^2 \times 12m \times \frac{1}{6hr} \times (\frac{1hr}{3600s}) = \boxed{7778\frac{m^3}{s}}$$

b) Using the flow rate "R" from part (a), we can calculate the cross-sectional area of the pipe using the flow velocity by the relation $R = v \times A$

$$7778\frac{m^3}{s} = 7\frac{m}{s} \times A$$

$$A = \frac{7778m^3}{s} \times \frac{s}{7m} = \boxed{1111m^2}$$