① You cannot use the same heat reservoir as both the hot and cold reservoir. You require two seperate reservoirs for a thermal engine to work. Thermal energy must be taken from the HOT reservoir and exhausted to the COLD reservoir.

② energy, while always being conserved, becomes less useful (it is no longer able to do mechanical work)

ex: a car engine burns gasoline; some of the potential energy of the gasoline is used to perform the mechanical work of the engine, the rest is "lost" as heat - the original energy has been degraded.

③ (a) energy density - the energy that can be obtained from a unit mass of fuel.

(b) $E_p = mgh$

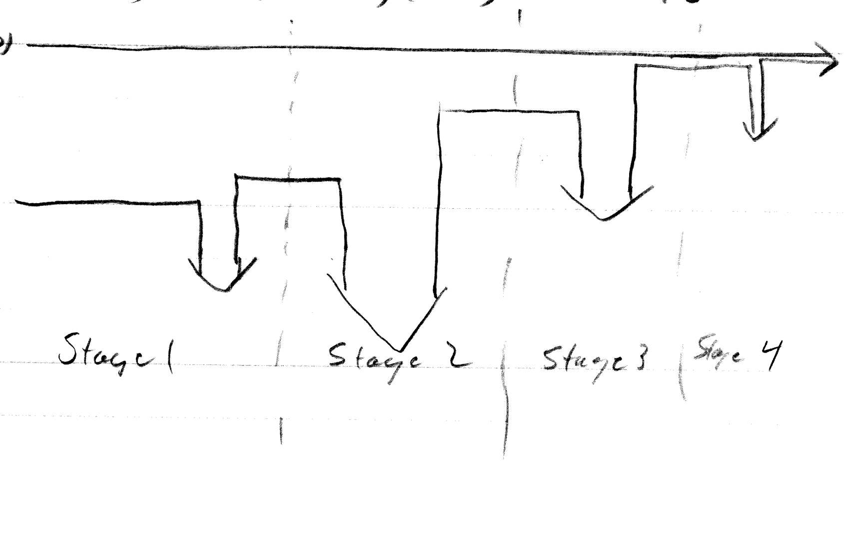
$\frac{E_p}{m} = gh = (9.81\,ms^{-2})(75m) = \underline{740\ J\,kg^{-1}}$

④ (a) 500×10^6 J, 140 kWh, 0.14 mWh

(b) $500 \times 10^6\,J\,(3600 \times 24 \times 365) = 1.6 \times 10^{16}$ J

⑤ (a) $(0.65)(.12)(.40)(.80) = 2.5\%$

(b)



6 (a) $(30\times10^{6}\ \mathrm{J\,kg^{-1}})(10\times10^{6}\ \mathrm{kg\,day^{-1}})(.3) = 9\times10^{13}\ \mathrm{J\,day^{-1}}$

$$\frac{9\times10^{13}\ \mathrm{J\,day^{-1}}}{3600(24)} = \underline{1.0\times10^{9}\ \mathrm{W}}$$

(b) $$\frac{(30\times10^{6}\ \mathrm{J\,kg^{-1}})(10\times10^{6}\ \mathrm{kg\,day^{-1}})}{3600(24)}(.7) = \underline{2.4\times10^{9}\ \mathrm{W}}$$

(c) $Q = mc\Delta T$ $\qquad c_{water} = 4200\ \mathrm{J\,kg^{-1}\,K^{-1}}$

$$\frac{m}{\Delta t} = \frac{Q}{\Delta t\, c\, \Delta T} = \frac{2.4\times10^{9}\ \mathrm{W}}{4200\ \mathrm{J\,kg^{-1}K^{-1}}(5\ \mathrm{K})} = 1.1\times10^{5}\ \mathrm{kg\,s^{-1}}$$

7 $35\times10^{6}\ \mathrm{J}(.40) = 1.4\times10^{7}\ \mathrm{J}$

$$\frac{1.4\times10^{7}\ \mathrm{J}}{20\times10^{3}\ \mathrm{W}} = 700\ \mathrm{s}$$

$s = vt = 9\ \mathrm{m\,s^{-1}}(700\ \mathrm{s}) = 6300\ \mathrm{m} = \underline{6.3\ \mathrm{km}}$

8 $30\times10^{6}\ \mathrm{J}(.40) = 1.2\times10^{7}\ \mathrm{J\,kg^{-1}}$

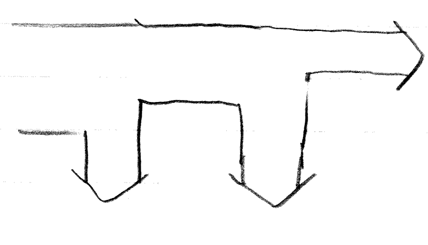
$1\times10^{9}\ \mathrm{W}(3600\times24) = 8.64\times10^{13}\ \mathrm{J\,day^{-1}}$

$$\frac{8.64\times10^{13}\ \mathrm{J\,day^{-1}}}{1.2\times10^{7}\ \mathrm{J\,kg^{-1}}} = \underline{7.2\times10^{6}\ \mathrm{kg\,day^{-1}}}$$

17 (a) $(700\ \mathrm{W\,m^{-2}})(.70)(.50) = 245\ \mathrm{W\,m^{-2}}$

$$\frac{3\times10^{3}\ \mathrm{W}}{245\ \mathrm{W\,m^{-2}}} = \underline{12.24\ \mathrm{m^{2}}}$$

(b)



18 $Q = mc\Delta T$

$= (300\ \mathrm{kg})(4.2\times10^{3}\ \mathrm{J\,kg^{-1}K^{-1}})(323\mathrm{K} - 288\mathrm{K}) = 4.41\times10^{7}\ \mathrm{J}$

$240\ \mathrm{W\,m^{-2}}(.65) = 156\ \mathrm{W\,m^{-2}}(12)(3600) = 6.74\times10^{6}\ \mathrm{J\,m^{-2}}$

$$\frac{4.41\times10^{7}\ \mathrm{J}}{6.74\times10^{6}\ \mathrm{J\,m^{-2}}} = \underline{6.5\ \mathrm{m^{2}}}$$

(19) $Q = mc\Delta T$

$= (150\ kg)(4.2\times10^3\ J\,kg^{-1}K^{-1})(30k) = 1.89\times10^7\ J$

$6000\ Wm^{-2}(.60) = 3600\ Wm^{-2}(4.0\ m^2) = 14400\ W$

$\frac{1.89\times10^7 J}{14400\ W} = \underline{1312.5\ s} = \underline{21.8\ min}$

(21) from graph $P = 100kW$

$(100\times10^3 W)(1000)(3600) = \underline{3.6\times10^{11}\ J}$

(22) $P = \frac{1}{2}\rho A v^3$

(a) $A = \pi r^2$, so A increases by 4 ∴ P increases by a factor of 4

(b) P increases by a factor of 8

(c) P increases by a factor of $4\times8 = 32$

(d) - wind turbine cannot extract all of the available wind power (only 35 - 45%)

- other losses due to friction, and turbulance

(23) (a) $E_k = \frac{1}{2}mv^2$

$m = \rho V$

V = A × distance through turbine.

distance = $v\Delta t$

$V = Av\Delta t$

$m = \rho A v \Delta t$

$E_k = \frac{1}{2}\rho A \Delta t\, v^3$

$P = \frac{work}{t} = \frac{E_k}{t} = \frac{1}{2}\rho A v^3$

(b) all of the kinetic energy of the wind can be used to do work (the wind is stopped by the turbine)

(24) $P_{before} = \frac{1}{2}\rho A v^3 = \frac{1}{2}(1.2\ kg\,m^{-3})(\pi(1.5m)^2)(8ms^{-1})^3 = 2171\ W$

$P_{after} = \frac{1}{2}\rho A v^3 = \frac{1}{2}(1.8\ kg\,m^{-3})(\pi(1.5m)^2)(3ms^{-1})^3 = 171\ W$

$P_{extracted} = P_{before} - P_{after} = 2171 - 171 = \underline{2000 W}$

(25) $P = \frac{1}{2}\rho A v^3 \qquad A = \pi r^2$

$r = \sqrt{\frac{2P}{\rho \pi v^3}} = \sqrt{\frac{2(25\times10^3 W)}{(1.2\ kg m^{-3})\,\pi(9ms^{-1})^3}} = \underline{4.3 m}$

assuming - density of air is constant before and after turbine
- velocity of air is constant before and after turbine

(26) $P = \rho Q g h$
$= (1000\ kg m^{-3})(500\times10^{-3}\ m^3 s^{-1})(9.81\ ms^{-2})(40m) = \underline{2\times10^5\ W}$

(27) $E_p = mgh$
$m = \rho V$
$E_p = \rho V g h$
$P = \frac{Work}{\Delta t} = \frac{E_p}{\Delta t} = \frac{\rho V g h}{\Delta t}$
$Q = \frac{V}{\Delta t}$
$P = \rho Q g h$

(32) (a) sides $(1m)\times(.1m)\times(5\times10^{-3}m) = 5\times10^{-4}\,m^3\,(4) = 0.002\,m^3$

top + bottom $(1m)(1m)(5\times10^{-3}m) = 5\times10^{-3}\,m^3\,(2) = 0.01\,m^3$

Total Volume $= 0.012\,m^3$

$$m = \rho V = (1200\,kg\,m^{-3})(0.012\,m^3) = \underline{14\,kg}$$

(b) $$(800\,Wm^{-2})(.8)(1\,m^2) = \frac{kA(T_1 - T_2)}{x}$$

$$= \frac{(0.3\,Wm^{-1}K^{-1})(1\,m^2)(T_1 - T_2)}{5\times10^{-3}\,m}$$

$$T_1 - T_2 = 10.7\,K\ (°C)$$

$T_2 = 20°C$ $\quad \underline{T_1 = 31°C}$

(c) $$C = C_w + C_{tank}$$

$$= m_w c_w + m_{tank} c_{tank}$$

$$= (100\,kg)(4200\,J\,kg^{-1}K^{-1}) + (14\,kg)(450\,J\,kg^{-1}K^{-1})$$

$$= \underline{4.3\times10^5\,J\,K^{-1}}$$

(d) $$Q_{net} = Q_{gain} - Q_{loss}$$

$$C\Delta T = AI_m\Delta t - \frac{kA(T_1 - T_2)\Delta t}{x}$$

for our case $T_2 = 20°C$

$$C\frac{\Delta T}{\Delta t} = AI_m - \frac{kA(T-20)}{x}$$

(e) $$\frac{\Delta T}{\Delta t} = \frac{AI_m - \frac{kA(T-20)}{x}}{C}$$

$$T = \frac{31+20}{2} = 25.5$$

$$= \frac{(1m^2)(800\,Wm^{-2})(.8) - \frac{(0.3\,Wm^{-1}K^{-1})(1m^2)(25.5-20)}{5\times10^{-3}\,m}}{4.3\times10^5\,J\,K^{-1}}$$

$$= \underline{7.2\times10^{-4}\,K\,s^{-1}}$$

(f) $$\frac{\Delta T}{\Delta t} = 7.2\times10^{-4}\,Ks^{-1}$$

$$\Delta t = \frac{\Delta T}{7.2\times10^{-4}\,Ks^{-1}} = \frac{31-20\,°C}{7.2\times10^{-4}\,Ks^{-1}} = 15\,258\,s = \underline{4.2\text{ hours}}$$