PROBLEM 2

1. Final temperature of house using Method 1

- CV: house air + copper
- assumptions are given + $\Delta PE, \Delta KE = 0$
- 1^{st} law: $\Delta E = \Delta U = \cancel{Q} - \cancel{W} = 0$

+8 $\Delta U = \Delta U_{copper} + \Delta U_{air} = 0$

+3 $\Rightarrow \Delta U_{copper} = m_c c_c (T_2 - T_{1copper}) = -\Delta U_{air} = m_a c_{v_a}(T_{1air} - T_2)$

+2 where $T_2 = T_{2c} = T_{2air}$ @ equilibrium

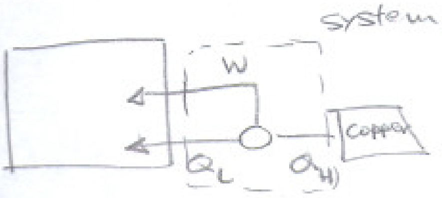
m_c = mass copper $\quad c_c$ = sp. heat of copper
m_a = " air $\quad c_v$ = sp. heat of air @ const V

+1 $= \rho_a V_a = 360$ kg

solving we get: $T_2 = \dfrac{m_a c_{va} T_{1a} + m_c c_c T_{1c}}{m_a c_{va} + m_c c_c}$

+1 $= 287\,K$ (ie., the house heated up by 5°C using Mona's method)

2. Final T using Method 2



instead of sending Q_H into the house directly, we send $Q_L + W$.
however, from 1^{st} law applied to engine $Q_H = Q_L + W$
$\Rightarrow$ the same quantity of energy enters the house as before, and the final equilibrium temperatures will be the same

$\therefore T_2 = 287\,K$ (Recall Joule's paddle-wheel experiment!)

3. Method 3:

Since we are given that the entire process is totally reversible, no exergy is destroyed.

System: copper + house air + surroundings (i.e. everything!)

$$\Delta E_{x_{copper}} + \Delta E_{x_{air}} + \Delta E_{x_{surr}} = 0$$ since no exergy is destroyed

but $\Delta E_{x_{surr}} = 0$ since no intensive properties of the environmt. are affected

+10 (proper formulation of exergy balance)

$$\Rightarrow \Delta E_{x\,copper} = -\Delta E_{x\,air}$$ i.e. exergy lost by copper must equal exergy gained by air if it is a totally reversible process

$$\Delta E_{x\,copper} = E_{x_{2c}} - E_{x_{1c}}$$

since copper is incompressible

$$= m_c\left[u_{2c} - u_{1c} + P_0(\cancel{v_{2c} - v_{1c}}) - T_0(s_{2c} - s_{1c})\right]$$

+2

$$= m_c\left[c_c(T_{2c} - T_{1c}) - T_0 c_c \ln\frac{T_{2c}}{T_{1c}}\right]$$

Volume of house constant (given)

$$\Delta E_{x\,air} = m_a\left[c_{va}(T_{2a} - T_{1a}) + P_0(\cancel{v_{2a} - v_{1a}}) - T_0(s_{2a} - s_{1a})\right]$$

$v_2 = v_1$

$$= m_a\left[c_{va}(T_{2a} - T_{1a}) - T_0\left(c_{va}\ln\frac{T_{2a}}{T_{1a}} + \cancel{R\ln\frac{v_2}{v_1}}\right)\right]$$

+2

$$= m_a\left\{c_{va}(T_{2a} - T_{1a}) - T_0 c_{va}\ln\frac{T_{2a}}{T_{1a}}\right]$$

$$\Rightarrow m_c\left[c_c(T_{2c} - T_{1c}) - T_0 c_c \ln\frac{T_{2c}}{T_{1c}}\right] = m_a\left[T_0 c_{va}\ln\frac{T_{2a}}{T_{1a}} - c_{va}(T_{2a} - T_{1a})\right]$$

+1

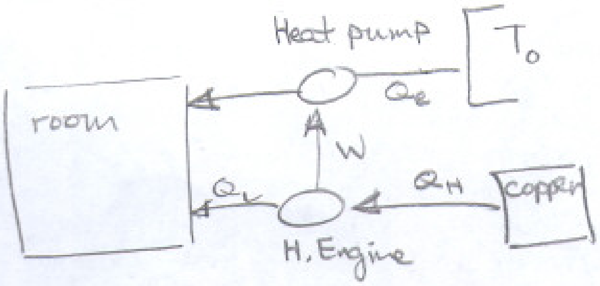
the only unknown is $T_{2c} = T_{2a} = T_2$

it can be verified by substituting into the above equation that $\underline{\underline{T_2 = 294.8\,K}}$

note: the difference between the equations for method (1) and (3) is in the $T_0 \Delta S$ terms only. What does this term represent??

4. equipment set up for totally reversible case:
   - no heat transfer across a temperature difference
   - no silly friction sources like a spinning propeller!
   - take advantage of the work produced by a heat engine between the copper & the room

solution;



note: here we use the work to drive a heat pump which extracts additional heat from the environment. We add an additional amount of energy to the room of the amount Q_e (this is the $T_0 \Delta S$ terms in the above equation!!)