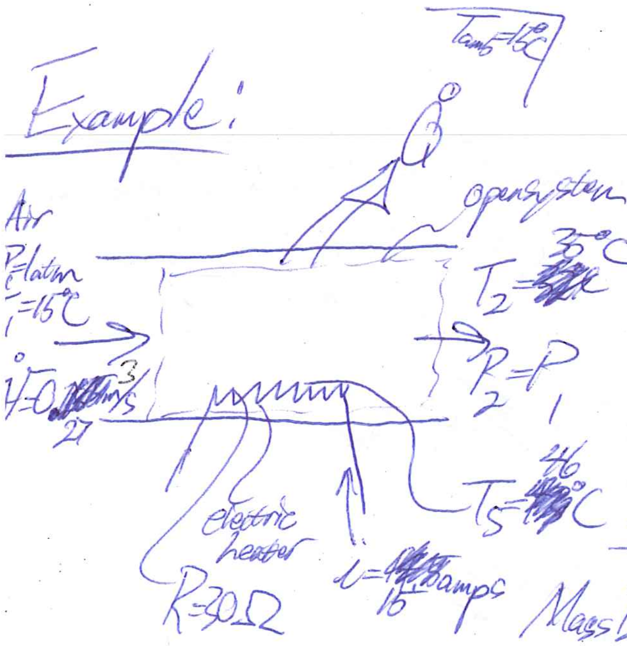
# Example:




Find: A) Rate of heat transfer from the duct

B) rate of entropy generation

How would we start?

Assumptions: 1) Steady State, 2) $\Delta PE$ & $\Delta KE = 0$, 3) ideal gas

Mass Balance: $\dot M_{in} = \dot M_{out} + \frac{dM_{stored}}{dt}$ 0(1) $\quad \dot M_{in} = \frac{\dot V_{in}}{v_{in}}$, $v_{in} = \frac{RT_{in}}{P_{in}}$

Energy Balance: $\dot E_{in} = \dot E_{out} + \frac{dE_{stored}}{dt}$ 0(1) $\Rightarrow \dot Q_{in} + \dot W_{in} + \dot M_{in}\left(h_{in} + \frac{V_{in}^2}{2} + gz_{in}\right) = \dot Q_{out} + \dot W_{out} + \dot M_{out}\left(h_{out} + \frac{V_{out}^2}{2} + gz_{out}\right)$ 0(2)

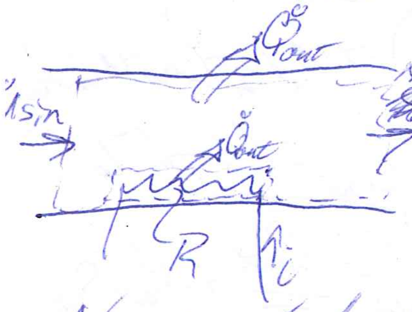
$\dot W_{in} + \dot M_{in} h_{in} = \dot Q_{out} + \dot M_{out} h_{out} \Rightarrow \dot Q_{out} = 106.9\,W$

$\dot W_{in} = I^2 R \qquad c_p T_{in} \qquad c_p T_{out}$

Got to here.

Entropy Balance: How do we choose our system for this? Include the resistor?

Let's first look @ the entropy produced by the heater alone.




Energy balance: $\dot E_{in} = \dot E_{out} + \frac{dE_{stored}}{dt} \Rightarrow \dot W_{in} = \dot Q_{out} = 6750\,W$

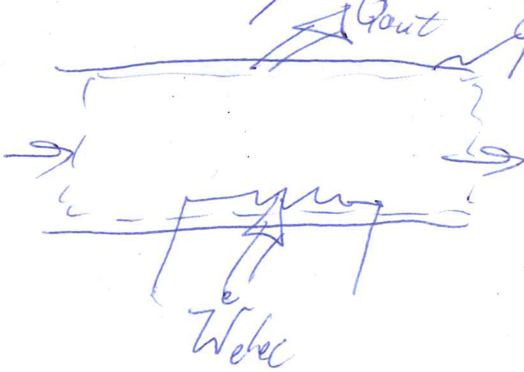
Entropy balance: $\dot S_{in} + \dot S_{gen} = \dot S_{out} + \frac{dS_{stored}}{dt} \Rightarrow \dot S_{gen,Htr} = \frac{\dot Q_{out}}{T_{HTR}} = 21.15\,W/K$

Now to the duct: Entropy balance: $\dot S_{in} + \dot S_{gen} = \dot S_{out} + \frac{dS_{stored}}{dt} \Rightarrow$

$\Rightarrow \dot M_{in} s_{in} + \frac{\dot Q_{in}}{T_{HTR}} + \dot S_{gen,Duct} = \dot M_{out} s_{out} + \frac{\dot Q_{out}}{T_{amb}} \Rightarrow \dot S_{gen,Duct} = 1.526\,W/K$

Total Entropy Generated? $\dot S_{gen,total} = \dot S_{gen,Heater} + \dot S_{gen,duct} = 22.68\,W/K$

Now lets try an entropy balance on the entire duct ⇒ includes all irreversibilities




Entropy Balance: $\dot{S}_{in} + \dot{S}_{Gen} = \dot{S}_{out} + \cancel{\frac{dS_{stored}}{dt}}^{0}$

$$\dot{M}_{in}s_{in} + \dot{S}_{Gen} = \frac{\dot{Q}_{out}}{T_{amb}} + \dot{M}_{out}s_{out}$$

$$\Rightarrow \dot{S}_{Gen} = 22.68\ W/K$$

Why the same? The entropy flow out of the resistor flows into the duct & cancels out. This system definition accounts for all the irreversibilities!

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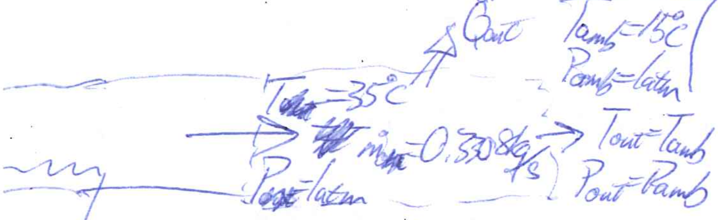
What if we vented the fluid leaving into the cold room, would we have a higher entropy generation?




How would we define the system?
⇒ maximize entropy generation

Energy balance: $\dot{E}_{in} = \dot{E}_{out} + \cancel{\frac{dE_{stored}}{dt}}^{0}$

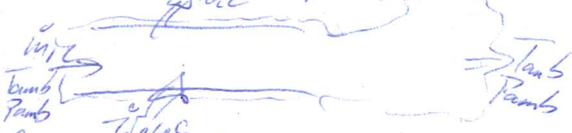
$$\cancel{\dot{Q}_{in}} + \cancel{\dot{W}_{in}} + \dot{M}_{in}\left(h_{in} + \cancel{\frac{V_{in}^2}{2}} + \cancel{gz_{in}}\right) = \dot{Q}_{out} + \cancel{\dot{W}_{out}} + \dot{M}_{out}\left(h_{out} + \cancel{\frac{V_{out}^2}{2}} + \cancel{gz_{out}}\right) \Rightarrow \dot{M}_{in}h_{in} = \dot{Q}_{out} + \dot{M}_{out}h_{out}$$

$$\dot{Q}_{out} = 6646\ W$$

Entropy Balance: $\dot{S}_{in} + \dot{S}_{Gen} = \dot{S}_{out} + \cancel{\frac{dS_{stored}}{dt}}^{0}$ $\Rightarrow \dot{M}_{in}s_{in} + \dot{S}_{Gen} = \frac{\dot{Q}_{out}}{T_{amb}} + \dot{M}_{out}s_{out}$

$$\dot{S}_{Gen,room} = 0.7493\ W/K$$

$$\dot{S}_{Gen,room} + \dot{S}_{Gen,Tot} = 23.43\ W/K$$




@ $T_{amb}$, $P_{amb}$   @ $T_{amb}$, $P_{amb}$

$$\dot{M}_{in}s_{in} + \dot{S}_{Gen} = \dot{M}_{out}s_{out} + \frac{\dot{Q}_{HTR}}{T_{amb}} \Rightarrow \dot{S}_{Gen,check} = 23.43\ W/K$$