Homework 1 : ASEN 3113 Thermo Abdulla AlAmeri

7-15 :

Given :

- Steam Power Plant

- $\dot{Q}_{in} = 280\ GJ/h \times \frac{1\ h}{60\ min} \times \frac{1\ min}{60\ sec}$

$= 7/90\ \frac{GJ}{s}$

- $\dot{Q}_{Loss} = 8\ \frac{GJ}{h}$

- $\dot{Q}_{out} = 145\ GJ/h$

Assumptions :

- ignore Friction and Gravity

- operates in cycle

- Heat Engine Device

- Solve :

(a) Net power output

- $\Delta E_{sys} = [\dot{Q}_{in} - \dot{Q}_{out}] + [\cancel{W_{in}}^{0} - W_{out}]$

$W_{out} = \overbrace{280\ \frac{GJ}{h}}^{\dot{Q}_{in}} - 8\ \frac{GJ}{h} - 145\ \frac{GJ}{h}$

$$W_{out} = 280\ \frac{GJ}{hr} \underbrace{- 8\ \frac{GJ}{hr} - 145\ \frac{GJ}{hr}}_{Q_{out}}$$

$$W_{out} = 127 \times 10^{9}\ \frac{J}{hr} \times \frac{1\ hr}{3600\ s} \times \underbrace{10^{-6}}_{\text{convert to MW}}$$

$$\boxed{= 35.27\ MW}$$

(b) **Thermal Efficiency :**

$$\eta_{th} = \frac{W_{out\,(net)}}{Q_{in}} = \frac{35.27\ MW}{\left(\frac{7}{90} \times 10^{9}\ J/s\right) \times 10^{-6}}$$

$$\boxed{= 0.454 = 45.4\ \%}$$

Reality Check :

Thermal efficiency $\eta_{th} < 1$

which is Expected in Cyclic Heat Engine Devices

7-24

Given

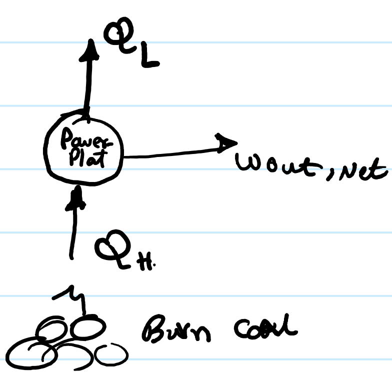
- $W_{net,out} = 1.878 \times 10^{12}\ kWh \times \dfrac{3.6\ MJ}{1\ kWh} = 6.7608 \times 10^{12}\ MJ$
- $\eta_{th} = 0.34$

- Assumption:

  (1) ignore other effects from gravity

  (2) Power Plant can be Modeled as Heat engine (cycle).

- Sketch:



- Solve:

$$\eta_{th} = \frac{\text{Net work out}}{\text{Heat in}} = \frac{W_{Net,out}}{Q_H}$$

Heat in = $\frac{}{Q_H}$

$$Q_H = \frac{W_{net,out}}{\eta_{th}} = \frac{6.7608 \times 10^{12}\ MJ}{0.34} = 1.988 \times 10^{13}\ MJ$$

Makes sense than output

$$W_{Net\,out} = Q_H - Q_L \Rightarrow Q_L = Q_H - W_{net,out}$$

$$= (1.988 \times 10^{13} - 6.76 \times 10^{12})\ MJ = 1.3124\ E12\ MJ$$

$$\approx \boxed{1.312 \times 10^{13}\ MJ} = \boxed{3.645 \times 10^{2}\ Kwh}$$

- ~~Reality~~ check : DONE in Question

7-42:

Given. Conditioner (Refrigerator):

$\dot{Q}_{out} = 750 \ KJ/min = \dot{Q}_L = 12.5 \ KJ/s$

$\dot{W}_{net,in} = 6 \ Kw = 6 \ KJ/s$

Assumption:

- models like fridge cycle
- operates in cycle
- system is Heat Pump

Solve: we know via 1st law of Thermo

$\Delta E_{sys} = Q_{in,net} - W_{in\,Net} = 0$

$\dot{W}_{in,net} = \dot{Q}_H - \dot{Q}_L$

(a) $COP_R = \frac{\text{Desired output}}{\text{required input}} = \frac{\dot{Q}_L}{\dot{W}_{in}} = \frac{12.5 \ Kw}{6 \ Kw}$

$\boxed{= 2.08}$

(b) what goes to outside (Hot) is $\dot{Q}_H$

$\dot{Q}_H = \dot{W}_{in,net} + \dot{Q}_L$

$$Q_H = W_{in,net} + Q_L$$

$$= (12.5 + 6)\ kW = \boxed{18.5\ kW = 1110\ kJ/min}$$

<u>Reality Chk</u>: Numbers seem to be very reasonable ..

7-49

Given: **refrigrator**:

$$\dot{Q}_{in} - \dot{Q}_{out} = \dot{Q}_{net,in} = \dot{Q}_H - \dot{Q}_L$$

$\hookrightarrow \therefore \dot{Q}_{in} = \dot{Q}_L = 800 \, kJ/h = 0.\overline{22} \, kJ/s$

$COP_R = \underline{2.2}$

- **Assumptions**:
  - ideal Refrigrator
  -

- **Solve** $W_{in,net} = ?$

- $\underline{\dot{W}_{in,net}} = \dfrac{\dot{Q}_L}{COP_R} = \dfrac{0.\overline{22} \, kW}{\underline{2.2}} = \dfrac{10}{99} \, kW$

- Since the fridge would only need to run 1/4 of time but draw out the same amount of Heat it must run $\underline{4}$ times better so..

$$\dot{W}_{in\,net} = 4 \times \frac{10}{99} \, kW = \boxed{0.4 \, kW}$$

7-63C: The 4 Processes for Carnot cycle:

1. Reversible isothermal Expansion: Volume ↑ whil Temp is ¢
system is Exposed To Heat Source

2. Reversible Adibatic Exponsion: system Insulated,
Then Volum Rufs ↑, while Temp ↑ too

3. Reversible isothermal compression: Value ↓, while
Temp is Held ¢, By Ejecting Heat immeadilly to
lower Sink

4. Reversible Adibatic Compression: Value ↓, But
System is isolated From Sink, so Temp ↓

69-C

- The thermal Efficiency can Be Expressed

as $\eta_{th} = 1 - \frac{Q_L}{Q_H}$, since Q_H referes

To Heat Coming From Hot sources, as $Q_H \uparrow$,

$\frac{Q_L}{Q_H} \to 0$, since $Q_H \propto T^\circ$, as $T^\circ \uparrow$, $Q_H \uparrow$,

There for the Power-Plant with Higher Temp (600°)C

is more Efficient than 80°C

- This will also Hold if we assume ideal Power Plant

where $\eta_{th_{rev}} = 1 - \frac{T_L}{T_H}$

7.76 :

Given : $T_L = 490\ R$ $T_H = 920\ R$

$\dot{Q}_H = ?$ $\dot{Q}_L = 15 \times 10^3\ Btu/h$ $W_{Net,out} = 4.5\,hp \times \frac{2545\ Btu/h}{1\,hp}$

$= 11452.5\ \frac{Btu}{h}$

The most efficient engine that Runs in cycle is carnot Engine, where the Efficiency is given By

$$\eta_{th,rev} = 1 - \frac{T_L}{T_H} = 1 - \frac{490}{920} = 0.467$$

given $\dot{W}_{Net,out} = \dot{Q}_H - \dot{Q}_L \Rightarrow \dot{Q}_H = \dot{Q}_L + \dot{W}_{Net\,out}$

$$= (11452.5 + 15 \times 10^3)\ \frac{Btu}{hr}$$

$$= 26452.5 = \dot{Q}_H$$

$$\eta_{th} = 1 - \frac{\dot{Q}_L}{\dot{Q}_H} = 1 - \frac{15{,}000\ \cancel{\frac{Btu}{hr}}}{26452.5\ \cancel{\frac{Btu}{hr}}} = 0.432$$

$$\boxed{\eta_{th} < \eta_{th,rev},\ \therefore \text{Engine is Possible}}$$

Reality Check : N/A

79:

Given:

$T_L = 20° C$

$T_H = 140° C$

Assumptions: - Max possible is via Carnot cycle
- ideal, reversible, Heat engine

Solve: $\eta_{th,rev} = 1 - \dfrac{T_L}{T_H} = 1 - \dfrac{(20+273)K}{(140+273)K}$

$= 0.2905 \cong \boxed{29.1\ \%}$

Reality chk: N/A

7-89

Given:

$\dot{Q}_H = 200\ kW$

$T_H = 293\ K$

$\dot{W}_{net,in} = 75\ kW$

$T_L = 273\ K$

Assumptions: - ~~no~~ ignore gravity

Solve: The ideal reversible COP for HP

is $$COP_{HP,rev} = \frac{1}{1 - T_L/T_H} = \frac{1}{1 - \left(\frac{273}{293}\right)} = 14.65$$

$$COP_{HP} = \frac{1}{1 - \frac{\dot{Q}_L}{\dot{Q}_H}} \Rightarrow$$

★

$$\dot{Q}_L = \dot{Q}_H - \dot{W}_{net,in} = (200 - 75)\ kW = \underline{125\ kW}$$

$$COP_{HP} = \frac{1}{1 - \frac{125\ kW}{200\ kW}} = 2.66$$

$$\boxed{COP_{HP} < COP_{HP,rev} \text{ , } \therefore \text{ the claim is valid}}$$

<u>Reality check</u> : N/A

7-103:

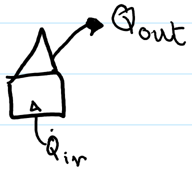
Given:

- $1.055 \ \frac{kW}{C^{\circ}}$
- $\dot{W}_{in,net} = 4 \ kW$
- $T_L = 24^{\circ}C = 297 \ K$

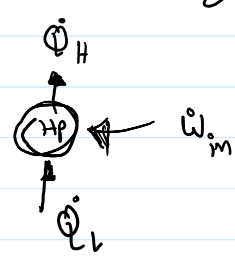
Assumptions:

- reversible Process
- steady, cyclic Process
- Can Be Modeled as Heat Pump

Solve: For the House To stay at the Same Temp, $\Delta E_{sys} = 0$



This $\dot{Q}_{in}$ is Coming From Heat Pump



We know $COP_{HP,rev} = \frac{T_H}{T_H - T_L} = \frac{\dot{Q}_H}{\dot{W}_{net,in}}$

$$\dot{Q}_H = (1.055)(T_H - T_L) \ \frac{kW}{C^{\circ}}$$

$$\frac{(1.055)(T_H - T_L)}{4} = \frac{T_H}{(T_H - T_L)}$$

$$4 \quad = \quad \frac{\quad}{(T_H - T_L)}$$

$$\frac{4T_H}{1.055} = (T_H - T_L)^2 \longrightarrow \frac{4(297)}{1.055} = T_H^2 - 2T_LT_H + T_L^2$$

$$T_L^2 - 2(297)T_L + \left[(297)^2 - \frac{4(297)}{1.055}\right] = 0$$

using Q.f solve for $T_L \rightarrow$

$$T_{L_1} = 263.44\ K^\circ = \boxed{-9.56\ C^\circ}$$

$$T_{L_2} = 330.56\ K^\circ = 57.56\ C^\circ$$

$\therefore$ lowest Possible Temp is $-9.56\ C^\circ$

Quality cck: N/A