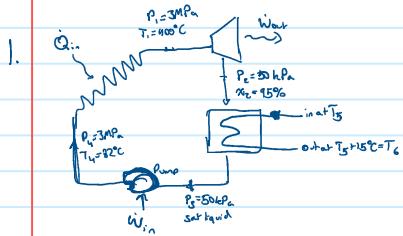


# HW5

Monday, September 29, 2025 9:57 PM



Energy loss, KE, PE negligible

a) Thermal efficiency

$$h_1 \text{ at } 3 \text{ MPa, } 400^\circ\text{C} \rightarrow 3230.9 \frac{\text{kJ}}{\text{kg}}$$

$h_4 \text{ at } 3 \text{ MPa, } 82^\circ\text{C}$

$$\text{At } 2 \text{ MPa, } 82^\circ\text{C}, h = 345.259$$

$$\frac{420.15 - 345.259}{100 - 80} = \frac{x_{15} - 0.05}{82 - 80}$$

$$\text{At } 5 \text{ MPa, } 82^\circ\text{C}, h = 347.237$$

$$\frac{422.72 - 347.237}{100 - 80} = \frac{x_{15} - 0.05}{82 - 80}$$

$$\frac{347.237 - 345.259}{5 - 2.5} = \frac{h_1 - 345.259}{3 - 2.5}$$

$$h_1 = 345.655 \frac{\text{kJ}}{\text{kg}}$$

$$\dot{N}_{\text{out}} = \dot{m}(h_2 - h_1)$$

$$\dot{W}_{\text{in}} = \dot{m}(h_4 - h_3)$$

$$\dot{m}(h_1 - h_2) - (h_4 - h_3) = \dot{W}_{\text{net}}$$

$$\dot{Q}_{\text{in}} = \dot{m}(h_1 - h_4)$$

$$\dot{W}_{\text{net}} = \eta_{\text{th}} = \frac{(h_1 - h_2) - (h_4 - h_3)}{h_1 - h_4} = 24.092\%$$

$h_3 \text{ at } 50 \text{ kPa, sat liquid} =$

$$0.5 \text{ bar} \rightarrow 340.49 \frac{\text{kJ}}{\text{kg}}$$

$$h_2 \text{ at } 50 \text{ kPa, } x_2 = 10\% = 2530.63 \frac{\text{kJ}}{\text{kg}}$$

$$0.15(2445.9 - 340.49) + 340.49$$

b) mass flow rate of the cooling water  $\dot{m}_c = 35^\circ\text{C}$

$$\dot{Q}_{\text{out}}(h_2 - h_3) = \dot{m}_c (146.68 - 83.96)$$

$$\frac{\dot{m}_c}{\dot{m}_c} = 0.028639 \rightarrow 34.919 \frac{\dot{m}_c}{\dot{m}_c}$$

## 2. Tk6-2

System or superheat steam at  $293^\circ\text{C}$ , Condensate temp is  $33^\circ\text{C}$

a)

Ideal machine  $\rightarrow h_f \text{ at } 293^\circ\text{C}$

$$\dot{Q}_{\text{in}} = \dot{m}(h_1 - h_2)$$

$$h_1 = h_2 = 2766.7 \frac{\text{kJ}}{\text{kg}}$$

$$s_1 = s_2 = 5.7721 + \frac{0.70405 - 5.69221}{10} \cdot 3 = 5.76462 \frac{\text{kJ}}{\text{kg}}$$

$$-W_{\text{out}} = \dot{m}(h_2 - h_3)$$

$$h_2 = h_3 + \frac{13440 - 1289.1}{10} = 1505.57 \frac{\text{kJ}}{\text{kg}}$$

$$\text{where } s_2 = s_3, \quad (s_2 - s_1) \times s_3 = s_1 - 33^\circ\text{C}$$

$$W_{\text{in}} = \dot{m}(h_3 - h_4)$$

$$x_2 = 0.6686 \rightarrow h_2 = (h_g - h_f)x_2 + h_f = 175.854 \frac{\text{kJ}}{\text{kg}}$$

$$\text{where } s_2 = s_4, \quad (s_3 - s_2) \times s_4 = s_4 - 33^\circ\text{C}$$

$$h_3 = (h_g - h_f)x_3 + h_f = 167.951 \frac{\text{kJ}}{\text{kg}}$$

$$\frac{W_{\text{out}} - W_{\text{in}}}{\dot{m}_{\text{in}} (h_1 - h_2)} = \frac{\dot{m}_c (h_2 - h_3)}{\dot{m}_{\text{in}} (h_1 - h_2)} = 14.668 \rightarrow \text{Cycle #2}$$

Cycle #1

$$\text{At } 293^\circ\text{C, pressure} = \frac{85.31 - 74.36}{10} \cdot 3 + 74.36 = 27.795 \text{ bar}$$

$$h_1 = h_2 = 2761.04 \frac{\text{kJ}}{\text{kg}}$$

$$h_4 = 1305.57 \frac{\text{kJ}}{\text{kg}} \quad h_3 = h_f(33^\circ\text{C}) = 158.83 \frac{\text{kJ}}{\text{kg}}$$

$$h_2 = 1758.54 \frac{\text{kJ}}{\text{kg}} \quad s_2 = 0.4781$$

$$\text{at } P_3, \quad h_2 = \frac{93.93 - 9.045}{25} \cdot 2.745 + 90.99 = 91.25$$

$$s_2 = \frac{0.1680 - 0.2445}{25} \cdot 2.745 + 0.2445 = 0.2444$$

$$h_{in} = \frac{176.57 - 174.18}{25} \cdot 2.745 + 174.18 = 174.426$$

$$S_{20} = \frac{0.0080 - 0.2445}{25} = 2.745 + 0.2445 = 0.2445$$

$$h_{20} = \frac{174.58 - 174.18}{25} = 2.745 + 0.2445 = 174.426$$

$$S_{30} = \frac{0.0080 - 0.5695}{25} = 2.745 + 0.5695 = 0.5695$$

$$\frac{0.0080 - 0.2445}{25} = \frac{h_2^1 - 91.25}{174.426 - 91.25} \Rightarrow h_2^1 = 146.74 \text{ kJ}$$

$$\text{network} = \dot{W}_{\text{out}} - \dot{W}_{\text{in}} = 944.084 \text{ kW}$$

$$\frac{\dot{Q}_{\text{out}}}{\text{network}} = \boxed{3.621 \frac{\text{kg steam}}{\text{kW hr}}}$$

$$W_{\text{out}} = (h_2^1 - h_3) \dot{m} = 8.41105 \dot{m}$$

$$\frac{\dot{W}_{\text{out}} - \dot{W}_{\text{in}}}{\dot{Q}_{\text{in}}} = \boxed{58.08\%} \text{ for cycle #1}$$

$$Q_{\text{in},1} = (h_1 - h_2) \dot{m} = 1002.5 \text{ J}$$

$$\frac{1002.5}{115.832} = \frac{h_1 - h_2}{1455.47} \frac{\text{kJ}}{\text{kg}}$$

#cycle 3

$$h_3 = h_f + 30\% = 158.32 \frac{\text{kJ}}{\text{kg}}, S_3 = 0.4781$$

at  $P = 5 \text{ MPa}$

$$\frac{h_2^1 - 88.65}{174.426 - 88.65} = \frac{0.4721 - 0.2456}{0.5705 - 0.2456}$$

$$h_2^1 = 143.964 \frac{\text{kJ}}{\text{kg}}$$

$$h_4 = h_{f, 5 \text{ MPa}} = 640.23 \frac{\text{kJ}}{\text{kg}}$$

$$h_5 = h_{g, 5 \text{ MPa}} = 2748.7 \frac{\text{kJ}}{\text{kg}}$$

$$h_{200} + 5 \text{ MPa} = \frac{2801.2 - 2801.8}{2} + 2801.8 = 285.3 \frac{\text{kJ}}{\text{kg}}, S_{200} + 5 \text{ MPa} = \frac{54252 - 6.2568}{2} + 6.2568 = 6.091$$

$$h_{320} + 5 \text{ MPa} = \frac{2952.6 - 3015.4}{2} + 3015.4 = 2989 \frac{\text{kJ}}{\text{kg}}, S_{320} + 5 \text{ MPa} = \frac{61246 - 64553}{2} + 6.4553 = 6.320$$

$$\frac{(285.3) \cdot 13}{40} + 285.3 = h_2^1 = 2895.58 \frac{\text{kJ}}{\text{kg}}, S_1 = \frac{6.320 - 6.091}{40} \cdot 13 + 6.091 = 6.165$$

$$S_2 = S_1$$

$$W_{\text{out}}(h_1 - h_2) \dot{m} = 101261 \text{ J}$$

$$(8.3728 - 0.1918) \times 10.1261 = 6.165$$

$$W_{\text{in}} = (153.964 - 138.33) \dot{m} = 5.634 \text{ m}$$

$$\pi_2 = 0.7199$$

$$Q_{\text{in}} = (h_1 - h_2) \dot{m} = 2742.62$$

$$0.7199 \cdot 2742.62 + 138.33 = h_2 = 1882.97 \frac{\text{kJ}}{\text{kg}}$$

$$\frac{\dot{W}_{\text{out}} - \dot{W}_{\text{in}}}{\dot{Q}_{\text{in}}} = \boxed{5.41 = 36.60\% \text{ for cycle #3}}$$

$$\frac{\dot{Q}_{\text{out}}}{\dot{Q}_{\text{in}}} = \boxed{3.621 \frac{\text{kg steam}}{\text{kW hr}}}$$

$$\text{Carnot efficiency} = 1 - \frac{T_c}{T_h} = 1 - \left( \frac{35277.15}{293 + 273.15} \right) = 0.4594$$

$$= \boxed{45.94\%}$$

Cycle #1      Cycle #2      Cycle #3

$\therefore \eta_{\text{th}}$       38.03%, 45.68%, 36.60%

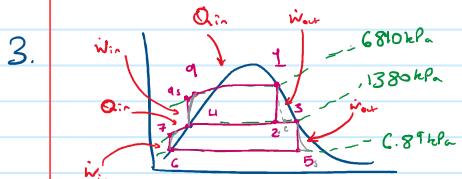
System      3.621, 5.41, 3.58  
kWhr

$Q_{\text{in}, 3 \rightarrow 4} \boxed{1158.85} \text{ --- } 446.266$

$Q_{\text{in}, 4 \rightarrow 1} \boxed{1455.47} \text{ --- } 2255.35$

Advantages / Disadvantages

- Cycle #1 operates on mostly heating and works without impurities; this could be detrimental to the turbine required to get work out as any water could damage the blades. The pump also has to work less hard which could help prolong its use.
- Cycle #2 is a Carnot cycle which achieves maximum efficiency, but is unrealistic with actual machinery and presents lots of hassles/problems in terms of ensuring He fluid is at exactly the state necessary.
- Cycle #3 utilizes sub-cooled and superheated regions of the TS graph. Though this is more lossy throughout & worse efficiency, it is more realistic in terms of what physical machinery could withstand or want to achieve. I would use #3 in real world.



$$1. h_3(1.38 \text{ kPa, state 2}) = \frac{(2+42.2-272.1)}{5} s_3 + 272.1 = 2788.28 \frac{\text{kJ}}{\text{kg}}$$

$$s_3 = 6.4736$$

$$h_{5s} = 2008.6120 \frac{\text{kJ}}{\text{kg}}$$

$$0.9 = \frac{h_3 - h_5}{h_3 - h_{5s}} \quad h_5 = 2086.63$$

$$h_6 = 161.976 \frac{\text{kJ}}{\text{kg}} \quad s_6 = 0.3529$$

$$h_7 = 825.162 \quad h_8 = s_7 = s_{4s} = 2.276 \Rightarrow h_{9s} = 834.5244 \frac{\text{kJ}}{\text{kg}}$$

$$h_1 = 2723.442 \frac{\text{kJ}}{\text{kg}}; s_1 = 5.8216$$

$$0.85 = \frac{h_8 - h_9}{h_8 - h_{9s}}$$

$$h_{2s} = 2481.05 \quad h_2 = 2510.24 \frac{\text{kJ}}{\text{kg}}$$

$$h_9 = 837.953 \frac{\text{kJ}}{\text{kg}}$$

$$\frac{h_1 - h_2}{h_1 - h_{2s}} = 0.9$$

$$h_{2s} = 163.01 \frac{\text{kJ}}{\text{kg}}$$

$$\frac{h_6 - h_7}{h_6 - h_{7s}} = 0.85 \Rightarrow h_7 = 112.856 \frac{\text{kJ}}{\text{kg}}$$

$$h_{7s} = h_7 - h_{7s}$$

$$Q_{in} = \dot{m}(h_7 - h_6)$$

$$W_{in} = \dot{m}(h_7 - h_8)$$

$$W_{out,nr} = 263152 + 782.14 = 9165.81 \frac{\text{kJ}}{\text{kg}}$$

$$W_{in,nr} = 0.88 + 7.801 = 8.681 \frac{\text{kJ}}{\text{kg}}$$

$$Q_{in,nr} = 462.786 + 1940.99 = 2603.29$$

$$\frac{W_{out} - W_{in}}{Q_{in,nr}} = \eta_{th} = 36.76\%$$

2 If ideal machine

$$W_{out} = \dot{m}(h_1 - h_{2s}) \quad W_{in} = \dot{m}(h_{3s} - h_6)$$

$$W_{out} = \dot{m}(h_3 - h_{5s}) \quad W_{in} = \dot{m}(h_{4s} - h_8)$$

$$Q_{in} = \dot{m}(h_8 - h_{2s}) + (h_1 - h_{4s})$$

$$W_{out} = 242.812 + 770.206 = 1063.1 \frac{\text{kJ}}{\text{kg}}$$

$$W_{in} = 1.035 + 9.1774 = 10.212 \frac{\text{kJ}}{\text{kg}}$$

$$Q_{in,nr} = 462.141 + 1939.61 = 2601.75 \frac{\text{kJ}}{\text{kg}}$$

$$\frac{W_{out} - W_{in}}{Q_{in,nr}} = \eta_{th} = 40.47\%$$