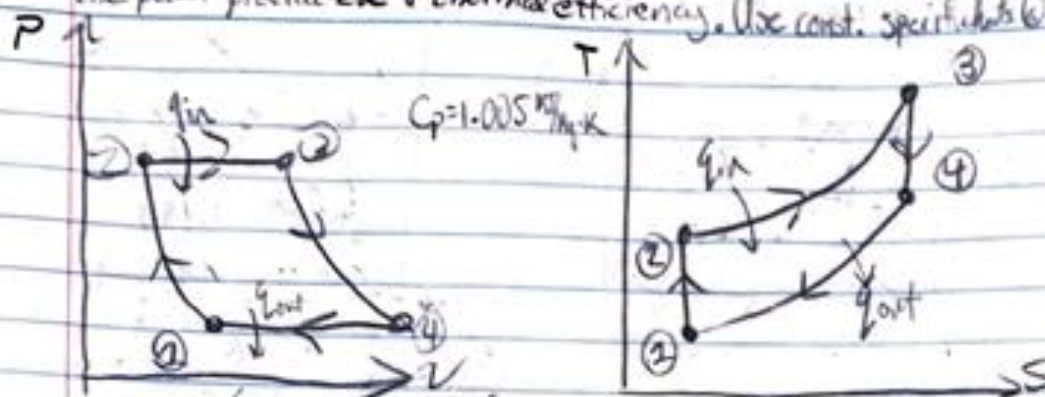


9-88 Aircraft engine operates on a simple ideal Brayton cycle w/ pressure ratio of 10. Heat added to cycle at rate of 500 kW; air passes through engine at rate of 1 kg/s & air beginning of the compression is @ 70 kPa & 0°C. Find the power produced & thermal efficiency. Use const. specific heats @ room T.



$C_p = 1.005 \frac{\text{kJ}}{\text{kg} \cdot \text{K}}$
 1 Isentropic 2 Isobaric 3 Isentropic 4 Isobaric
 $P_1 = 70 \text{ kPa}$ $P_2 = 10 P_1 = 700 \text{ kPa}$ $P_3 = P_2$ $P_4 = 70 \text{ kPa}$
 $T_1 = 273.15 \text{ K}$ $T_2 = 527.37 \text{ K}$ $P_3 = 700 \text{ kPa}$ $T_4 = 559.02 \text{ K}$
 $\dot{m} = 1 \text{ kg/s}$ $\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}$ $T_3 = 1074.88 \text{ K}$ $P_3 = 128.816$ $P_4 = 12.5816$
 $\dot{Q} = \dot{m} C_p (T_3 - T_2) \Rightarrow T_3 = 955.37 \text{ K}$
 $\frac{T_4}{T_3} = \left(\frac{P_4}{P_3}\right)^{\frac{\gamma-1}{\gamma}} \Rightarrow T_4 = 531.258$
 $\dot{Q}_{in} = \dot{m} C_p (T_3 - T_2) = 248.78 \text{ kW}$
 $\dot{Q}_{out} = \dot{m} C_p (T_4 - T_1) = 54.246 \text{ kW}$
 $\dot{W}_{net} = \dot{Q}_{in} - \dot{Q}_{out} = 194.534 \text{ kW}$

a) Power produced by engine?

$$\dot{W}_{net} = \dot{W}_{turbine} - \dot{W}_{compressor} = \dot{m} \times C_p (T_3 - T_4) - \dot{m} \times C_p (T_2 - T_1)$$

$$\dot{P} = \dot{m} \times C_p (T_3 - T_4) - (T_2 - T_1) \Rightarrow \boxed{248.78 \text{ kW}} = \dot{P}$$

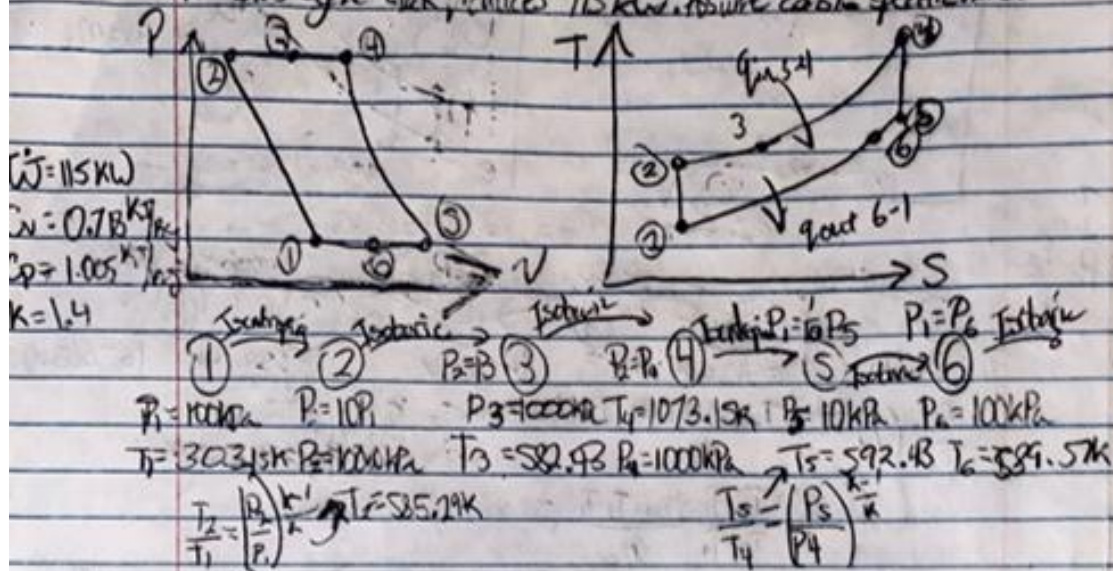
b) Thermal efficiency?

$$\eta_{th} = \frac{\dot{W}_{net}}{\dot{Q}_{in}} = \frac{248.78 \text{ kW}}{500 \text{ kW}} = \boxed{0.498}$$

Q-99

Gas turbine for car designed w/ regenerator. Air enters @ 100 kPa & 30°C. Compressor pressure ratio is 10; max temperature is 300°C. Cold air streams leaves the regenerator 10°C cooler than the hot air stream at inlet for regenerator. Assume both compressor &

Turbine are isentropic. Find heat rates of heat addition & rejection for this cycle when produces 115 kW. Assume constant specific heats.



$$CF = T_3 + T_5 = 10 \Rightarrow T_3 - T_5 = 10 \Rightarrow T_3 = 592.43$$

$$PF = T_5 - T_6 = T_3 - T_2 \Rightarrow T_6 = 589.57 \text{ K}$$

$$\dot{W}_{\text{net}} = \dot{W}_{\text{turbine}} - \dot{W}_{\text{compressor}} = \dot{W}_{\text{net}} = c_p \dot{m} (T_4 - T_5) - (T_2 - T_1)$$

$$\dot{W}_{\text{net}} = 1.005 \text{ kJ/kg} \cdot \text{K} \cdot \dot{m} (1073.15 \text{ K} - 592.43 \text{ K}) - (585.29 \text{ K} - 300 \text{ K})$$

$$\dot{W}_{\text{net}} = 202.225 \text{ kW} \quad \dot{m} = \frac{\dot{W}_{\text{net}}}{T_{\text{net}}} \Rightarrow \dot{m} = \frac{115 \text{ kW}}{202.225 \text{ K}} = \dot{m} = 0.569 \text{ kg/s}$$

a) Rate of heat addition

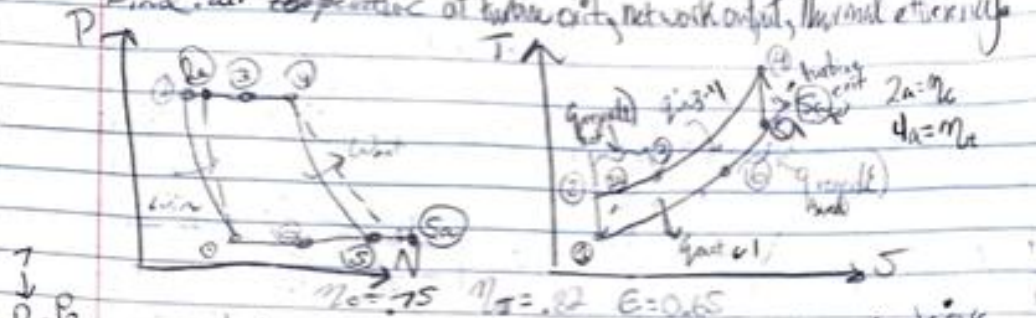
$$\dot{Q}_{\text{in}} = \dot{m} c_p (T_4 - T_3) = 0.569 \text{ kg/s} \cdot 1.005 \text{ kJ/kg} \cdot \text{K} \cdot (1073.15 \text{ K} - 582.43 \text{ K})$$

$$\dot{Q}_{\text{in}} = 293.93 \text{ kW}$$

b) Rate of heat rejection

$$\dot{Q}_{\text{out}} = \dot{m} c_p (T_6 - T_1) = 163.79 \text{ kW} = \dot{Q}_{\text{out } 6-1}$$

Q 107: Brayton cycle w/ regeneration using air. Pressure ratio is 7. Min & max temperatures are 310 & 1150 K. Assume isentropic efficiency of 75% for compressor & for turbine. Effectiveness of 65% for regenerator. Find air temperature at turbine exit, network output, thermal efficiency.



$\eta_c = 0.75$ $\eta_T = 0.75$ $E = 0.65$
 $T_1 = 310 \text{ K}$ $T_4 = 1150 \text{ K}$ $T_5 = 659.54 \text{ K}$ $T_6 = 663.03 \text{ K}$
 $T_2 = 541.50 \text{ K}$ $T_3 = 702.165 \text{ K}$ $T_{5a} = 747.8228 \text{ K}$

$\eta_c = \frac{T_2 - T_1}{T_{2a} - T_1} = \frac{T_2 - T_1}{T_2 - T_1} \cdot \eta_c$
 $\eta_T = \frac{T_4 - T_{5a}}{T_4 - T_5} = \frac{T_4 - T_{5a}}{T_4 - T_5} \cdot \eta_T$
 $T_{5a} = 747.8228 \text{ K}$

$E = \frac{q_{reg, in}}{q_{reg, out}} = \frac{T_3 - T_{2a}}{T_5 - T_{2a}} = \frac{T_3 - T_{2a}}{T_5 - T_{2a}} \cdot E$
 $T_3 = 702.165 \text{ K}$

$q_{reg, in} = q_{reg, out} \Rightarrow h_{3a} - h_{2a} = h_3 - h_2 \Rightarrow C_p(T_{3a} - T_{2a}) = C_p(T_3 - T_2)$
 $T_{2a} = \frac{C_p + T_{5a} - (T_3 - T_2)}{C_p} = \frac{1.005(1150 - 747.8228) - 1.005(617.33 - 310)}{1.005} = 663.0304 \text{ K}$

a) Air temp. at turbine exit:

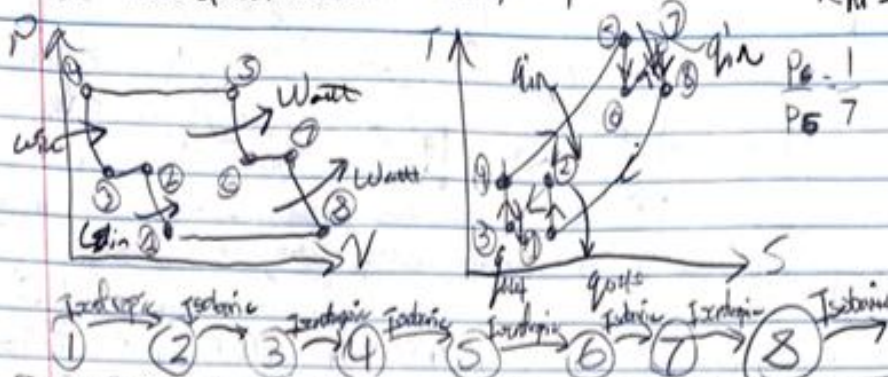
$T_{5a} = 747.8228 \text{ K}$

b) Net work output:

$W_{net} = W_{out} - W_{in} = C_p(T_4 - T_{5a}) - C_p(T_2 - T_1)$
 $W_{net} = 95.279 \text{ kJ/kg}$

$\eta_{th} = \frac{W_{net}}{q_{in}} = \frac{95.279 \text{ kJ/kg}}{450.074 \text{ kJ/kg}} = 0.2117$
 $q_{in} = C_p(T_4 - T_3) = 1.005(1150 - 702.165) = 450.074 \text{ kJ/kg}$

9-119: Regenerative gas-turbine power plant w/ two stages of comp. & two stages of expan. Pressure Ratio = 9. Air enters @ 300K comp. & each stage of turbine @ 1200K. Acc't. for variation of specific heats w/ temp find minimum mass flow rate of air needed to develop net power output of 110 MW. $\dot{m} = \frac{W_{net}}{W_{net}}$



$$T_1 = 300K \quad P_{r1} = 1.70 \quad T_3 = 300K \quad T_2 = T_4 \quad T_5 = 1200K \quad T_7 = 1200K \quad T_8 = 731.53K$$

$$P_{r1} = 1.386 \quad T_2 = 20.262 \quad T_4 = 20.262K \quad P_{r5} = 33 \quad P_{r6} = 34 \quad T_5 = T_7 \quad T_6 = T_8$$

$$P_{r2} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma}{\gamma-1}}$$

$$\ln(P_{r2}) = \frac{\gamma}{\gamma-1} \ln(P_2/P_1)$$

$$P_{r6} = \left(\frac{P_6}{P_5}\right)^{\frac{\gamma}{\gamma-1}} \times P_{r5} \times T_6/P_5 = 731.53K$$

$$\frac{1}{7}$$

$$W_{in,1} = h_2 - h_1 = C_p(T_2 - T_1) = 221.36 \text{ kJ/kg}$$

$$W_{in,2} = h_4 - h_3 = C_p(T_4 - T_3) = 221.36 \text{ kJ/kg}$$

$$W_{out,1} = h_5 - h_6 = C_p(T_5 - T_6) = 470.769 \text{ kJ/kg}$$

$$W_{out,2} = h_7 - h_8 = C_p(T_7 - T_8) = 470.769 \text{ kJ/kg}$$

$$W_{net} = W_{out,1} + W_{out,2} - W_{in,1} - W_{in,2} = 498.818 \text{ kJ/kg}$$

$$\dot{m} = \frac{W_{net}}{W_{net}} = \frac{110 \text{ MW}}{498.818 \text{ kJ/kg}} = \frac{110,000 \text{ kW}}{498.818 \text{ kJ/kg}} = 220.52 \text{ kg/s} = \dot{m}$$

