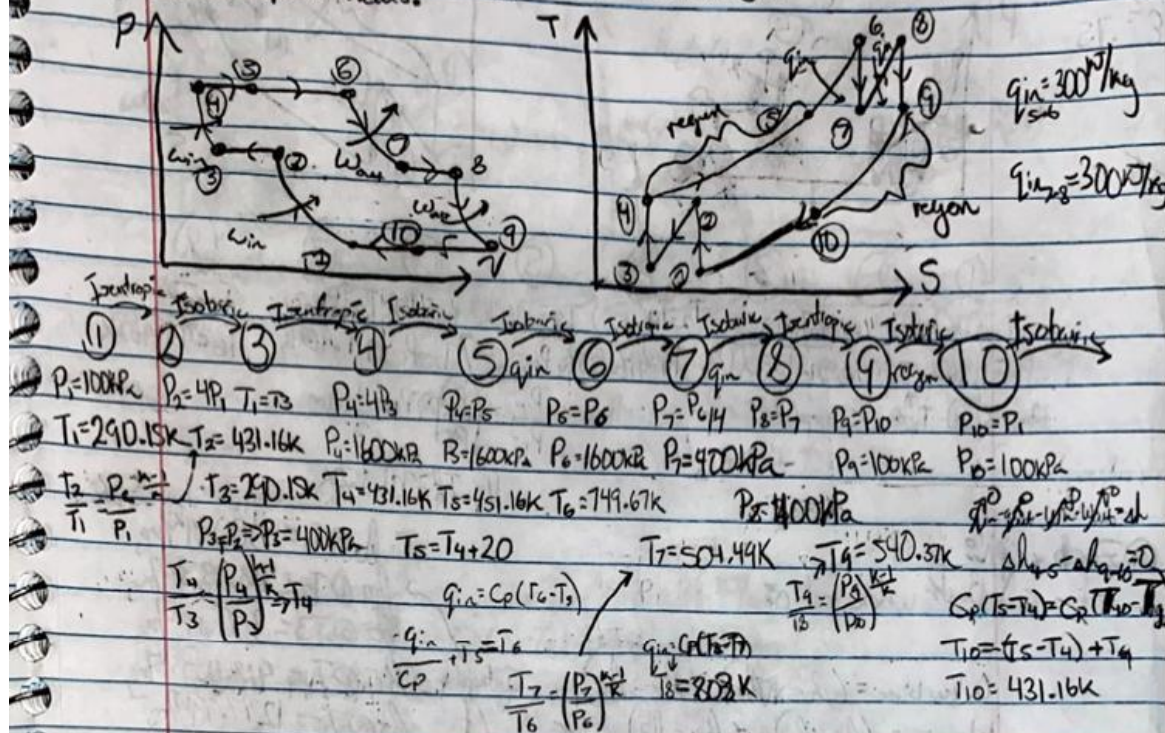


9-123 Air enters gas turbine w/ two stages of compression & two expansion stages @ 100 kPa & 17°C. System uses regenerator also reheating & interesting. The pressure ratio across each compressor is 4; 300 kJ/kg of heat is added to air in each combustion chamber & regenerator operates perfectly while increasing temp of cold air by 20°C. Find systems thermal efficiency. Assume isentropic operations we have specific heats.

1.5



$$\dot{m}_{\text{net}} = \frac{W_{\text{net}}}{q_{\text{in}}}$$

$$W_{\text{net}} = C_p(T_8 - T_9) = 263.94 \text{ kJ/kg}$$

$$W_{\text{net}} = C_p(T_6 - T_7) = 246.44 \text{ kJ/kg}$$

$$W_{\text{net}} = C_p(T_4 - T_3) = 141.715 \text{ kJ/kg}$$

$$W_{\text{net}} = C_p(T_2 - T_1) = 141.735 \text{ kJ/kg}$$

$$q_{\text{in}} = 300 \text{ kJ/kg}$$

$$q_{\text{in}} = 300 \text{ kJ/kg}$$

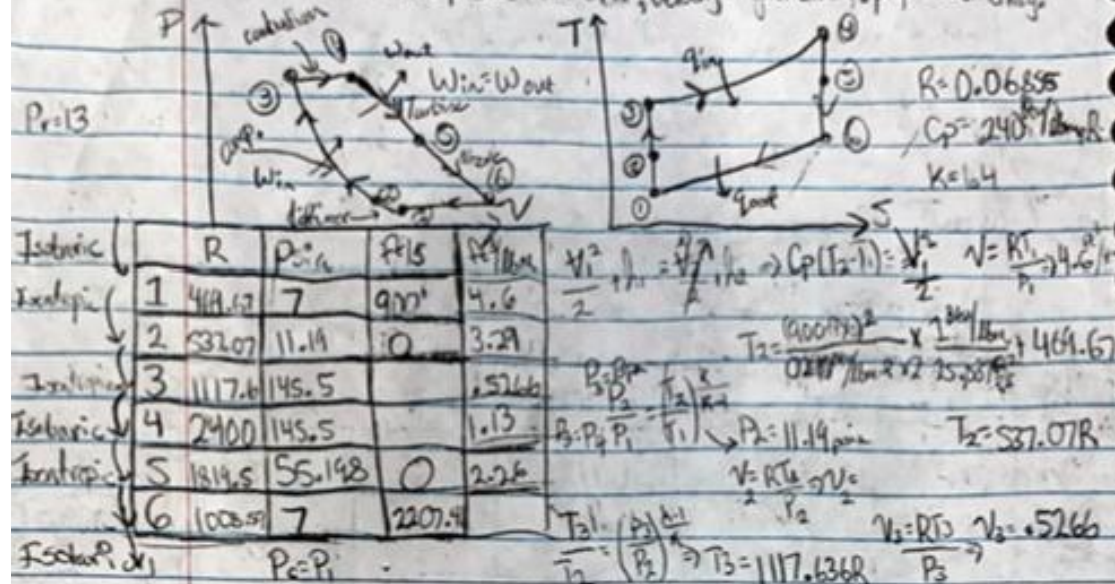
$$W_{\text{net}} = W_{\text{net}} + W_{\text{net}} - W_{\text{in}} - W_{\text{in}} = 226.9 \text{ kJ/kg}$$

$$W_{\text{net}} = 226.9 \text{ kJ/kg}$$

$$\eta = \frac{226.9 \text{ kJ/kg}}{300 \text{ kJ/kg}} = 0.756$$

$$\eta = 0.378$$

9-129E Turbojet flying at velocity of 900 ft/s @ alt. of 20,000 ft. Ambient conditions are 7 psia & 100°F. Pressure ratio across comp. is 8, & temp. at turbine inlet is 2400 R. Ideal gas for all compounds & constant specific heats @ room temp. Find pressure at turbine exit, velocity of gases at exit, & propulsive efficiency.



a) Pressure @ turbine exit:  $P_5 = 55.148 \text{ psia}$

b) Velocity of exhaust gases:  $V_6 = 2207.4 \text{ ft/s}$

c) Propulsive efficiency:  $\eta_p = \frac{W_p}{Q_{in}} = \frac{\dot{m} (V_6 - V_1) V_{aircraft}}{\dot{m} C_p (T_3 - T_2)}$

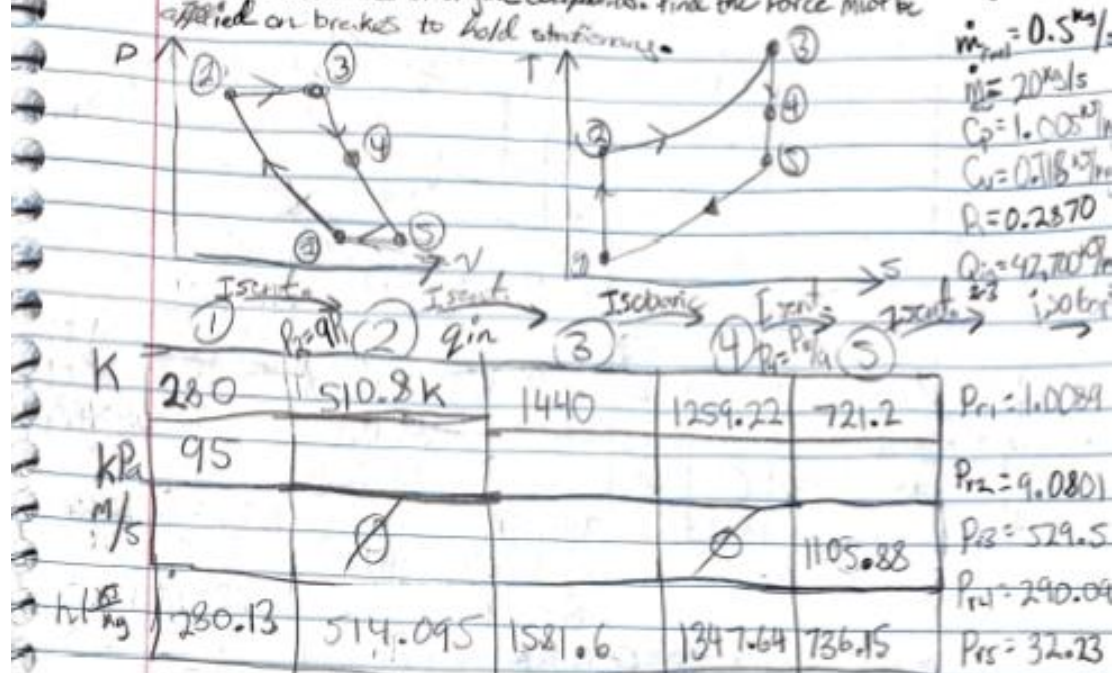
$\eta_p = \frac{W_p}{Q_{in}} = \frac{\dot{m} (V_6 - V_1) V_{aircraft}}{\dot{m} C_p (T_3 - T_2)}$

$\eta_p = \frac{(V_6 - V_1) V_1}{C_p (T_3 - T_2)}$

$\eta_p = \frac{(2207.4 - 900) \cdot 900}{240 (2400 - 1117.6)}$

$\eta_p = 0.1527$

9-135 Aircraft powered by a turbojet engine & pressure ratio of 9. Stationary on ground, held by brakes. Ambient air is 7°C & 95 kPa enters @ 20 m/s. Jet fuel heating value of 42,700 kJ/kg & burned @ rate of 0.5 kg/s. Neglect diffuser & inefficiencies of engine components. Find the force must be applied on brakes to hold stationary.



$$h_1 = 280.13 \text{ kJ/kg} \quad \frac{h_2}{P_2} = \frac{h_3}{P_3} \Rightarrow P_2 = 9.0801 \text{ kPa} \quad T_2 @ P_2 = 510.75 \text{ K}$$

$$P_1 = 1.00889 \text{ (Interpolation)}$$

$$h_2 = 514.095 \text{ kJ/kg}$$

$$q_{in} = h_3 - h_2$$

$$h_3 = \left( \frac{0.9}{20} \right) \times 42,700 \text{ kJ/kg} + 514.095$$

$$h_3 = 1521.6 \text{ kJ/kg} \quad T_3 @ h_3 = 1440 \text{ K}$$

$$w_{p2} - w_{p4} + q_{in} = \frac{1}{P_2} - P_1 \Rightarrow w_{p2} = w_{p4} \quad P_3 @ h_3 = 529.5 \text{ K}$$

$$h_2 - h_1 = h_3 - h_4 \Rightarrow h_4 = 1347.64 \text{ kJ/kg} \quad T_4 @ h_4 = 1259.22 \text{ K}$$

$$P_4 @ h_4 = 290.09 \text{ kPa}$$

$$\frac{P_5}{P_4} = \frac{1}{9} = \frac{P_5}{P_4} \Rightarrow P_5 = 32.23 \text{ kPa}$$

$$h_5 @ P_5 = 736.15 \text{ kJ/kg}$$

$$\text{First Law: } h_4 + \frac{V_4^2}{2} = h_5 + \frac{V_5^2}{2} \Rightarrow \frac{V_5^2}{2} = \frac{V_4^2}{2} + h_4 - h_5$$

$$V_5 = 2000 \sqrt{\frac{736.15 - 1347.64}{2}} = 1105.88 \text{ m/s}$$

$$\dot{m}_{fuel} = 0.5 \text{ kg/s}$$

$$\dot{m}_a = 20 \text{ kg/s}$$

$$C_p = 1.005 \text{ kJ/kg}\cdot\text{K}$$

$$C_v = 0.718 \text{ kJ/kg}\cdot\text{K}$$

$$R = 0.2870 \text{ kJ/kg}\cdot\text{K}$$

$$Q_{in} = 42,700 \text{ kJ/kg}$$

$$\dot{Q}_{in} = 20 \text{ kg/s}$$

$$P_1 = 1.00889$$

$$P_2 = 9.0801$$

$$P_3 = 529.5$$

$$P_4 = 290.09$$

$$P_5 = 32.23$$

$$T_2 @ P_2 = 510.75 \text{ K}$$

$$T_3 @ h_3 = 1440 \text{ K}$$

$$T_4 @ h_4 = 1259.22 \text{ K}$$

$$P_4 @ h_4 = 290.09 \text{ kPa}$$

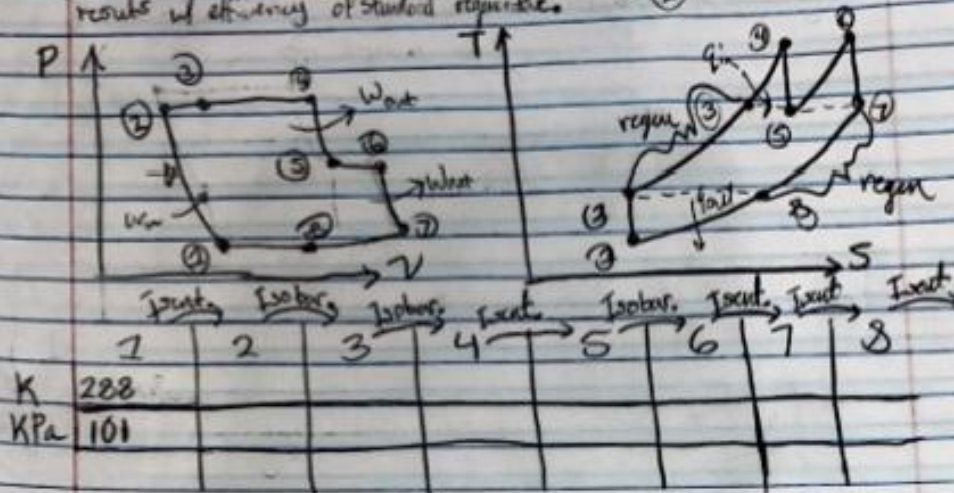
$$F = \dot{m}_a (V_5)$$

$$F = 20 \times 1105.88$$

$$F = 22117.6 \text{ N}$$

9-167

Ideal gas turbine cycle w/ one stage of compression & two stages of turbines & regeneration. Pressure ratio across each turbine stage is the same. High pressure exhaust gas enters regenerator then flows low pressure turbine for expansion to comp inlet pressure. Find thermal efficiency of this cycle as a function of compressor pressure ratio & high pressure turbine to compressor inlet temp ratio. Compare results w/ efficiency of standard regenerative.



$$\frac{P_2}{P_1} = r_p$$

$$\frac{P_4}{P_5} = r_p$$

$$\frac{T_2}{T_1} = \left( \frac{P_2}{P_1} \right)^{\frac{k-1}{k}} \Rightarrow T_2 = r_p^{\frac{k-1}{k}} T_1 \Rightarrow T_2 = T_2$$

$$\frac{T_5}{T_4} = \left( \frac{P_5}{P_4} \right)^{\frac{k-1}{k}} \Rightarrow T_5 = \frac{1}{r_p^{\frac{k-1}{k}}} T_4 \Rightarrow T_5 = T_3 = T_7$$

$$W_{out,4-5} = W_{out,6-7} \Rightarrow h_4 - h_5 = h_6 - h_7$$

$$q_{in} = h_3 - h_2 \Rightarrow h_4 - h_2 \Rightarrow C_p (T_4 - T_2) \Rightarrow C_p \left( \frac{1}{r_p^{\frac{k-1}{k}}} T_4 + T_4 \right) = q_{in,4}$$

$$q_{out} = h_8 - h_1 \Rightarrow h_3 - h_1 \Rightarrow C_p (T_3 - T_1) \Rightarrow C_p \left( r_p^{\frac{k-1}{k}} T_1 - T_1 \right) \Rightarrow q_{out} = C_p \left( r_p^{\frac{k-1}{k}} T_1 - T_1 \right)$$

$$\eta_{th} = \frac{W_{out}}{q_{in}} = \frac{W_{out,4-5} + W_{out,6-7}}{q_{in}} = \frac{C_p (T_4 - T_5) + C_p (T_6 - T_7)}{C_p \left( \frac{1}{r_p^{\frac{k-1}{k}}} T_4 + T_4 \right)} = \frac{C_p \left( T_4 - \frac{1}{r_p^{\frac{k-1}{k}}} T_4 \right) + C_p (T_6 - T_7)}{C_p \left( \frac{1}{r_p^{\frac{k-1}{k}}} T_4 + T_4 \right)}$$

$$\eta_{th} = \frac{-\frac{1}{r_p^{\frac{k-1}{k}}} T_4 + T_6 - r_p^{\frac{k-1}{k}} T_1 + T_1}{\frac{1}{r_p^{\frac{k-1}{k}}} T_4 + T_4}$$

$$\eta_{th} = \frac{r_p^{\frac{k-1}{k}} \frac{(k-1)}{k} T_1 + T_1 + T_6}{r_p}$$

I'm not quite sure this is correct