

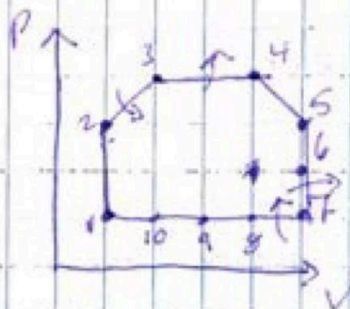
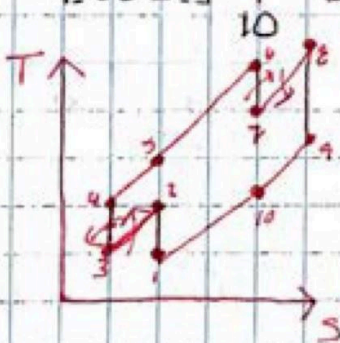
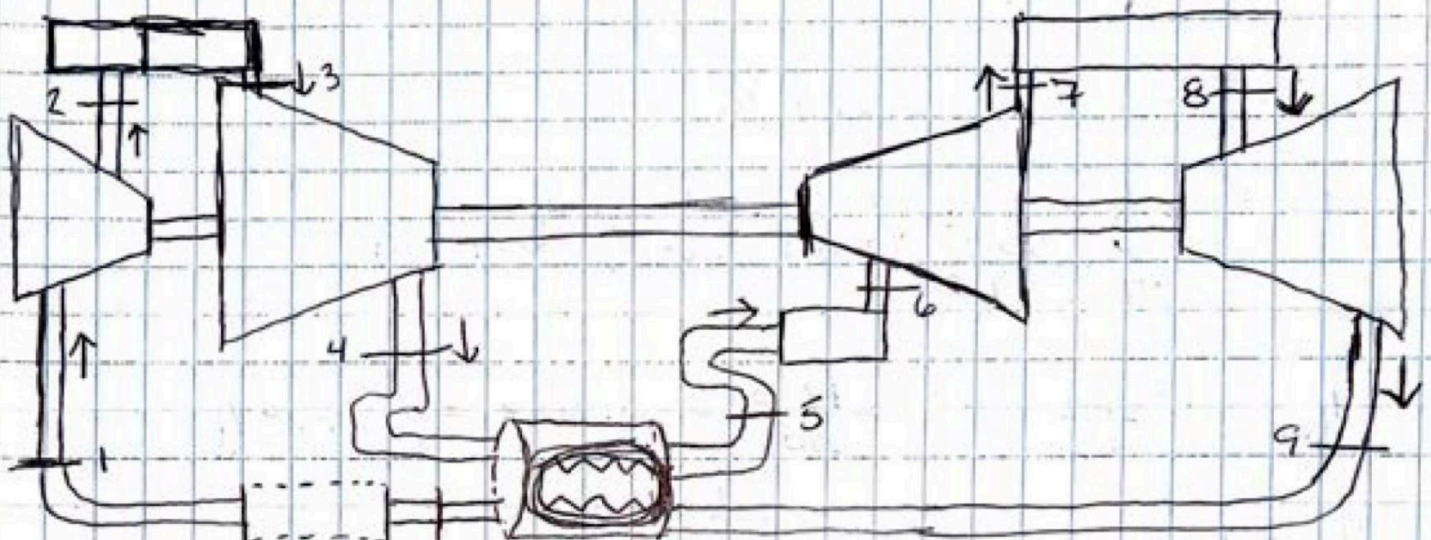
9-123

- 100 kPa + 17°C
- pressure ratio = 4
- 300 kJ/kg of heat added to air in each combustion chamber
- regenerator operates perfectly while $\uparrow$ temp of cold air by 200
- determine systems thermal efficiency.

Kayce Pantalone

HW 1.5

Ch 9) 123, 129, 135, 167



Stages

$$\begin{aligned}
 &1 \rightarrow 2 \rightarrow 3 \rightarrow 4 \rightarrow 5 \rightarrow 6 \rightarrow 7 \rightarrow 8 \rightarrow 9 \rightarrow 10 \\
 &T_1 = 290.1 \text{ K} \quad \left\{ \begin{array}{l} T_2 = 430.9 \\ P_2 = P_1 \end{array} \right. \quad \left\{ \begin{array}{l} T_3 = T_2 \\ P_3 = P_2 \end{array} \right. \quad \left\{ \begin{array}{l} T_4 = T_3 \\ P_4 = P_3 \end{array} \right. \quad \left\{ \begin{array}{l} T_5 = 450.9 \\ P_5 = P_4 \end{array} \right. \quad \left\{ \begin{array}{l} T_6 = 749.4 \\ P_6 = P_5 \end{array} \right. \quad \left\{ \begin{array}{l} T_7 = 500.3 \\ P_7 = P_6 \end{array} \right. \quad \left\{ \begin{array}{l} T_8 = 500.3 \\ P_8 = P_7 \end{array} \right. \quad \left\{ \begin{array}{l} T_9 = 700.2 \\ P_9 = P_8 \end{array} \right. \quad \left\{ \begin{array}{l} T_{10} = 520.2 \\ P_{10} = P_9 \end{array} \right.
 \end{aligned}$$

$$T_2 = T_4 = T_{cr} \quad (K-1)/K = (290)(4)^{0.2857} = 430.9 \text{ K}$$

$$T_5 = T_4 + 20 = 430.9 + 20 = 450.9 \text{ K}$$

$$q_{in} = c_p(T_6 - T_5)$$

$$T_6 = T_5 + \frac{q_{in}}{c_p} = 450.9 + \frac{300}{1.005} = 749.4 \text{ K}$$

$$P_3 = P_4 = (r_p)(P_2) = (13)(11.14) = 145.5 \text{ psia}$$

$$T_3 = T_2 \left(\frac{P_3}{P_2} \right)^{(k-1)/k} = (537.4)(13)^{0.4/1.4} = 1118.3 \text{ R}$$

$$T_5 = T_4 - T_3 + T_2 = 2400 - 1118.3 + 537.4 = 1819.1 \text{ R}$$

$$P_5 = P_4 \left(\frac{T_5}{T_4} \right)^{k/(k-1)} = (145.5) \left(\frac{1819.1}{2400} \right)^{0.4/1.4} = 55.2 \text{ psia}$$

$$b) T_6 = T_5 \left(\frac{P_6}{P_5} \right)^{(k-1)/k} = (1819.1 \text{ R}) \left(\frac{7}{55.2} \right)^{0.4/1.4} = 1008.6 \text{ R}$$

$$V_6 = \sqrt{(2)(0.240)(1819.1 - 1008.6)} \sqrt{\frac{25,037}{1}}$$

$$V_6 = 3121 \text{ ft/s}$$

$$0 = \frac{\dot{m} p (T_6 - T_5) + V_6^2}{2}$$

$$c) W_p = (V_{exh} - V_{inlet} - V_{aircraft})$$

$$= (3121 - 900) \left(\frac{1}{25,037} \right) = 79.8 \text{ BTU/lbm}$$

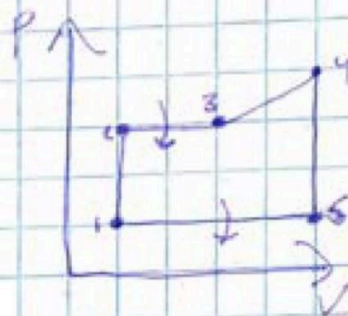
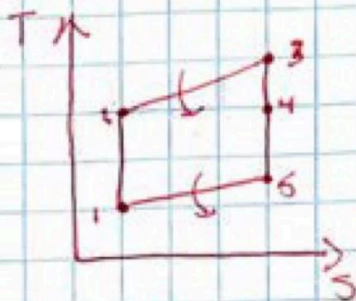
$$q_{in} = h_4 - h_3 = c_p (T_4 - T_3) = (0.24)(2400 - 1118.3) = 307.6 \text{ BTU/lbm}$$

$$\eta_{Th} = \frac{W_p}{q_{in}} = \frac{79.8}{307.6} = 0.259 = 25.9\%$$

9-135

- 7°C
- 16 kg/s
- $v = 300 \text{ m/s}$
- $15,000 \text{ kJ/s}$
- leaves @ 427°C

Determine the thrust produced by this turbojet engine.



Stages

$$\begin{array}{l} \rightarrow 1 \rightarrow 2 \rightarrow 3 \rightarrow 4 \rightarrow 5 \rightarrow \\ T_1 = 290 \text{ K} \quad \left\{ \begin{array}{l} T_2 = 544.07 \\ T_3 = 716.2 \\ T_4 = 1267 \\ T_5 = 861 \end{array} \right. \quad \left\{ \begin{array}{l} h_1 = 290.16 \\ h_2 = 544.07 \\ h_3 = 716.2 \\ h_4 = 1357.7 \\ h_5 = 861 \end{array} \right. \quad \left\{ \begin{array}{l} P_1 = 1.2311 \\ P_2 = 11.08 \\ P_3 = 568.5 \\ P_4 = 63.17 \\ P_5 = 63.17 \end{array} \right. \quad \left\{ \begin{array}{l} v_1 = 300 \text{ m/s} \\ v_2 = 300 \text{ m/s} \\ v_3 = 300 \text{ m/s} \\ v_4 = 300 \text{ m/s} \\ v_5 = 300 \text{ m/s} \end{array} \right. \end{array}$$

$$P_{r2} = \frac{P_2}{P_1} P_1 = (9)(1.2311) = 11.08$$

$$\dot{Q}_{in} = \dot{m}_{fuel} (HV) = (0.5)(42,700) = 21,350 \text{ kJ/s}$$

$$q_{in} = \frac{\dot{Q}_{in}}{\dot{m}} = \frac{21,350}{20} = 1067.5 \text{ kJ/kg}$$

$$q_{in} = h_3 - h_2 \Rightarrow h_3 = h_2 + q_{in} = 544.07 + 1067.5 = 1611.6 \text{ kJ/kg}$$

$$W_{in} = W_{out} \Rightarrow h_2 - h_1 = h_3 - h_4$$

$$\begin{aligned} h_4 &= h_3 - h_2 + h_1 \\ &= 1611.6 - 544.07 + 290.16 \\ &= 1357.7 \text{ kJ/kg} \end{aligned}$$

$$P_{r5} = P_{r3} \left(\frac{P_5}{P_3} \right) = (568.5) \left(\frac{1}{9} \right) = 63.17$$

$$0 = h_5 - h_4 + \frac{V_5^2}{2} - \frac{V_4^2}{2}$$

$$V_5 = \sqrt{2(h_4 - h_5)} = \sqrt{(2)(1357.7 - 888.56) \left(\frac{1000}{1} \right)}$$

$$= 968.6 \text{ m/s}$$

Brake Force = Thrust

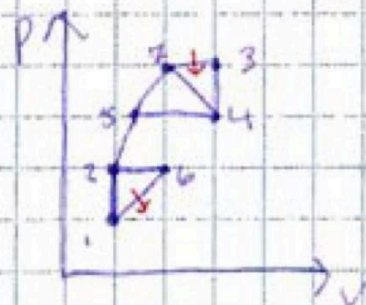
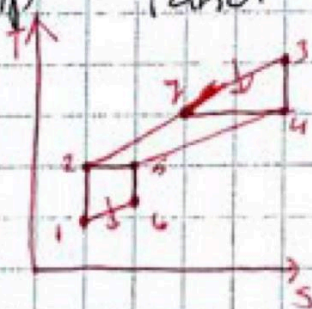
$$\text{Thrust} = \dot{m} (V_{\text{exit}} - V_{\text{inlet}})$$

$$= (20) (968.6 - 0) \left(\frac{1 \text{ N}}{1 \text{ kg} \cdot \text{m/s}^2} \right)$$

$$= \boxed{19,370 \text{ N}}$$

9-167

- pressure ratio = const.
- high pressure turbine $\rightarrow$ regenerator
- $\rightarrow$ low pressure turbine $\rightarrow$ compressor inlet pressure
- Determine thermal efficiency of cycle as a function of the compressor inlet temp ratio.



Stages

① $\rightarrow$ ② $\rightarrow$ ③ $\rightarrow$ ④ $\rightarrow$ ⑤ $\rightarrow$ ⑥ $\rightarrow$ ⑦

$$T_1 \text{ given} \left\{ \begin{array}{l} T_2 = T_5 \\ T_3 = T_4 \\ T_4 = T_3 \\ T_5 = T_2 \\ T_6 = T_0 \left(\frac{p_6}{p_0} \right)^{\frac{\gamma-1}{\gamma}} \\ T_7 = T_4 \end{array} \right.$$

$$h_1 = \text{table } 19 \left\{ \begin{array}{l} h_2 = \text{table } 19 \\ h_3 = \text{table } 19 \\ h_4 = \text{table } 19 \\ h_5 = \text{table } 19 \\ h_6 = \text{table } 19 \\ h_7 = \text{table } 19 \end{array} \right.$$

$$T_8 = T_7 \left(\frac{q_{in}}{c_p} \right) = 504.3 \left(\frac{300}{1.005} \right) = 802.8 \text{ K}$$

$$T_9 = T_8 \left(\frac{1}{r_p} \right)^{\frac{\gamma-1}{\gamma}} = 802.8 \left(\frac{1}{4} \right)^{0.4/1.4} = 540.2 \text{ K} \quad \uparrow 5$$

$$T_{10} = T_9 - 20 = 540.2 - 20 = 520.2 \text{ K}$$

$$q_{in} = 300 + 300 = 600 \text{ KJ/kg}$$

$$\begin{aligned} q_{out} &= c_p (T_{10} - T_1) + c_p (T_2 - T_3) \\ &= (1.005)(520.2 - 290) + (1.005)(430.9 - 290) \\ &= 373.0 \text{ KJ/kg} \end{aligned}$$

$$\eta_{Th} = 1 - \frac{q_{out}}{q_{in}} = 1 - \frac{373.0}{600} = 0.378 = \boxed{37.8\%}$$

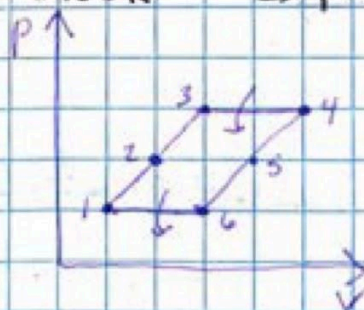
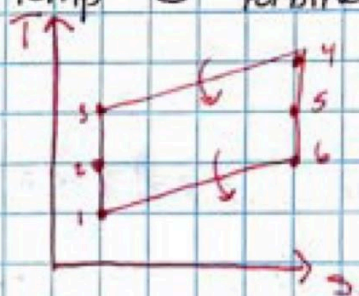
9-129

- $V = 900 \text{ ft/s}$
- alt = 20,000 ft
- 7 psia
- 10°F
- pressure ratio = 13
- temp @ turbine inlet = 2400 R

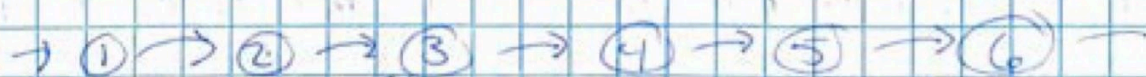
a) pressure @ the turbine exit

b) velocity of the exhaust gases

c) propulsive efficiency



Stages



$$\begin{aligned} T_1 &= 470 \text{ R} & \left\{ \begin{aligned} T_2 &= 557.4 \\ T_3 &= 1418.4 \end{aligned} \right. & \left\{ \begin{aligned} T_4 &= T_3 \\ T_5 &= 1891.1 \end{aligned} \right. & \left\{ \begin{aligned} T_6 &= 2008.6 \text{ R} \end{aligned} \right. \\ P_1 &= 7 \text{ psia} & \left\{ \begin{aligned} P_2 &= 11.15 \\ P_3 &= 145.5 \end{aligned} \right. & \left\{ \begin{aligned} P_4 &= P_3 \\ P_5 &= 55.2 \end{aligned} \right. & \left\{ \begin{aligned} P_6 &= \end{aligned} \right. \\ V_1 &= 900 & & & & \left\{ \begin{aligned} V_6 &= 3121 \end{aligned} \right. \end{aligned}$$

$$a) T_2 = T_1 + \frac{V_1^2}{2} = 470 + \frac{(900)^2}{2} = 557.4$$

$$\eta_{Th} = 1 - \frac{q_{out}}{q_{in}} = 1 - \frac{c_p T_1 \left(r_p^{(\kappa-1)/2\kappa} - 1 \right)}{c_p T_3 \left(1 - r_p^{(1-\kappa)/2\kappa} \right)}$$

$$\eta_{Th} = 1 - \frac{T_1}{T_3} r_p^{(\kappa-1)/2\kappa}$$

$$\boxed{\eta_{Th} = 1 - \frac{T_1}{T_3} r_p^{(\kappa-1)/\kappa}}$$