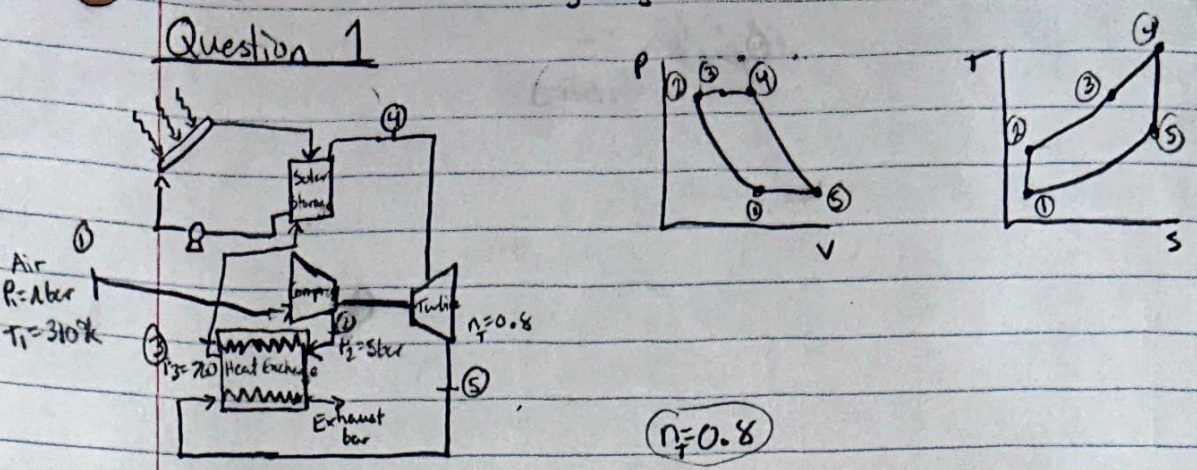
2/23/2025 Michael O'Brien

Test 1

Question 1

5 stages



η_T=0.8

① Isentropic → ② P-Const → ③ P const → ④ Isentropic → ⑤ Econst →

①	②	③	④	⑤
P_1=1 bar	P_2=5 bar	T_3=760 °k	T_4=1140 °k	T_5=? 719.78 k
T_1=310°k	T_2=490.98 k	$P_3=P_2$	$P_4=P_2$	$P_5=P_1$

$\frac{T_2}{T_1}=\left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}}=\frac{T_2}{310}=\left(\frac{5}{1}\right)^{\frac{1.4-1}{1.4}}=490.98\,k$ $\quad \frac{T_5}{1140}=\frac{1}{5}^{\left(\frac{1.4-1}{1.4}\right)}$ $T_5=719.78\,k$

$\eta=\frac{Q_{out}}{Q_{in}}$ $\quad Q_{in}=C_p\cdot(T_4-T_2)$ $\quad Q_{out}=C_p\cdot(T_5-T_1)$

$\eta=\frac{h_1-h_2}{h_1-h_2}=0.8=\frac{T_2-T_4}{T_5-T_4}=0.8=\frac{719.78-1140}{T_5-1140}$

$T_5=1055.96\,K$

$Q_{in}=1.005(1140-490.98)$

$Q_{in}=652.27$ kJ/kg

$Q_{out}=1.005\cdot(719.78-310)$

$Q_{out}=411.83$ kJ/kg

$\frac{411.83}{652.27}=0.631$; $1-0.6313=0.3686$

a) 36.86 %

$\eta=\frac{W_{net}}{Q_{in}}$ $\quad W_{in}=1(h_1-h_2)$ $\quad W_{out}=1(h_3-h_2)$

$\dot{m}=\frac{W_{net}}{W_{net}}$ $\quad W_{net}=W_{out}-W_{in}$

$W_{net}=652.27-411.83$

$W_{net}=240.44$ kJ/kg

$\dot{m}=\frac{500\ kJ/s}{240.44\ kJ/kg}$ $\quad 1\ kW=1\ kJ/s$ $\quad 500\ kJ/s$

$\dot{m}=2.08$ kg/s

Air mass flow rate b)

Heat Exchange Effectiveness $=\frac{actual}{max}$ From $T_2\to T_3$ and $T_5\to T_1$

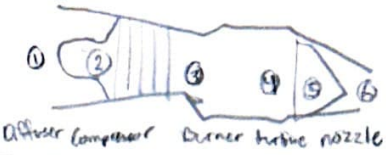
$\frac{(490.98-760)}{(719.78-310)}$

$=-0.656$

$\frac{(760-490.98)}{(719.78-310)}$

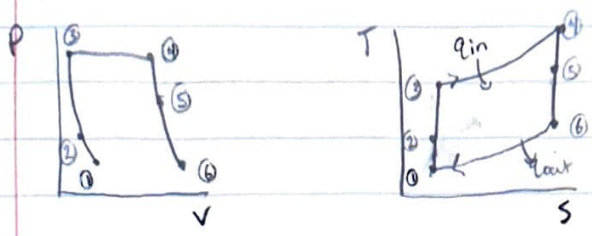
$=0.656$

a) 65.6% effective



Question 2

Turbojet flies with V=900 km/h. Temp is -35°C and P is 40 kPa. Combustion gasses enter turbine at 950°C. Turbine produces 500 kJ/kg of work. Isentropic at 80% for compressor w/ isentropic efficiency of 90%.



D=1.6m

$\eta = 0.8$

$\eta_t = 0.9$

$W_{out} = 500$ kJ/kg

(1) Isentropic (2) Isent (3) Pconst (4) Isent (5) Isent (6)

$V_1 = 900$ km/h = 250 m/s

$P_1 = 40$ kPa

$T_1 = -35°C = 238.15$ K

$T_2 = 269.24$ K

$P_2 = 61.46$ kPa

$P_3 = 2395.48$

$T_3 = 766.75$ K

$T_4 = 950°C = 1223.15$ K

$P_4 = P_3$

*P_5 = ?

*V_6 = ?

$P_6 = P_1$

$T_5 = T_4 - (T_3 - T_2)$

$T_5 = 1223.15\text{K} - (766.75 - 269.24)$

$T_5 = 725.64$ K

$\frac{V_1^2}{2} + h_1 = \frac{V_2^2}{2} + h_2$

$\frac{V_1^2}{2} = c_p(T_2 - T_1)$

$T_2 = 238.15 + \left(\frac{250^2}{2 \cdot 1.005}\right)$

$T_2 = 269.24$ K B)

$\frac{P_2}{P_1} = \frac{T_2}{T_1}^{\frac{k}{k-1}}$

$\frac{P_2}{40\text{kPa}} = \frac{269.24\text{K}}{238.15\text{K}}^{\frac{1.4}{1.4-1}}$

$P_2 = 61.46$ kPa

$\frac{T_3}{T_2} = \frac{P_3}{P_2}^{\frac{k-1}{k}}$

$T_3 = T_2 \cdot \frac{P_3}{P_2}^{\frac{k-1}{k}}$

$766.75\text{K} = 269.24 \cdot \frac{P_3}{61.46}^{\frac{1.4-1}{1.4}}$

$P_3 = 2395.48$ kPa

$\frac{V_5^2}{2} + h_5 = \frac{V_6^2}{2} + h_6$

$V_6 = \sqrt{2 c_p (T_5 - T_6)}$

$V_6 = \sqrt{2 \cdot 1.005 (725.64 - 235.19)}$

$V_6 = 31.39$ m/s

$\frac{P_5}{P_4} = \frac{T_5}{T_4}^{\frac{k}{k-1}}$

$\frac{P_5}{2395.48} = \frac{725.64}{1223.15}^{\frac{1.4}{1.4-1}}$

A) $P_5 = 2063.5$ kPa

$W = c_p(T_3 - T_2)$

$T_3 = T_2 + \frac{W}{c_p}$

$T_3 = 269.24 + \frac{500}{1.005}$

$T_3 = 766.75$ K

$\frac{T_6}{T_5} = \frac{P_6}{P_5}^{\frac{k-1}{k}}$

$\frac{T_6}{725.64} = \frac{40\text{kPa}}{2063.5}$

$T_6 = 235.19$ K

$A = \frac{\pi \cdot 1.6^2}{4}$

$A = 2.01$

$m = 40 \cdot 2.01 \cdot 250$

$m = 20106.19$

$W_p = m(V_6 - V_1)$

$20106.19(31.39 - 250)$

$W = -4395414$