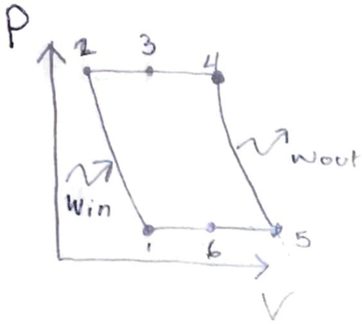
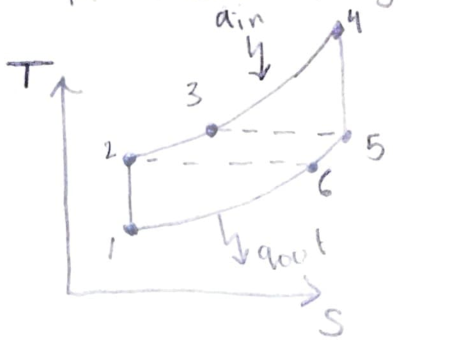
1\. Given

$P_1 = 100$ kPa
$T_1 = 30°C = 303K$
$r_p = \frac{P_2}{P_1} = 10$
$T_{max} = 800°C = 1027K$
$\Delta T_{hot-cold} = 10°C$

Compressor & Turbine are isentropic
Constant C_p & C_v at room temp.
$C_p = 1.005$ kJ/kg·K
$C_v = 0.718$ kJ/kg·K
$k = 1.4$
$R = 0.287$ kJ/kg·K

a)

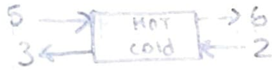




1 ⟶ 2 ⟶ 3 ⟶ 4

$P_1 = 100$ kPa
$T_1 = 303$ k

$P_2 = P_1 r_p$
$P_2 = 1000$ kPa



$P_3 = P_2$
$T_3 = T_5 - 10$
From 5
$T_3 = 92.7$ K

$T_4 = 1027K$ (T_{max})
$P_4 = 10 P_5 = 1000$ kPa

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} \rightarrow T_2 = 585.00 \text{ K}$$

5 ⟶ 6

$P_5 = P_6 = 100$ kPa

$$\frac{T_5}{T_4} = \left(\frac{P_5}{P_4}\right)^{k-1/k} \rightarrow T_5 = 102.7K$$

$P_6 = P_1 = 100$ kPa

$$h_5 - h_6 = h_3 - h_2$$

(Wcomp) (Wturb)

$$C_p(T_5 - T_6) = C_p(T_3 - T_2)$$

$$T_6 = T_5 - (T_3 - T_2)$$

$$= 102.7 - (92.7 - 585)$$

$$T_6 = 595 \text{ K}$$

$$\eta_{th} = 1 - \frac{T_6 - T_1}{T_4 - T_3} = 1 - \left(\frac{595 - 303}{1027 - 92.7}\right)$$

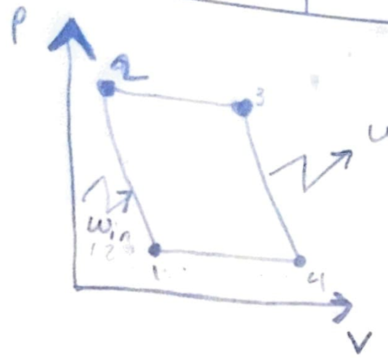
(q_{in}, q_{out})

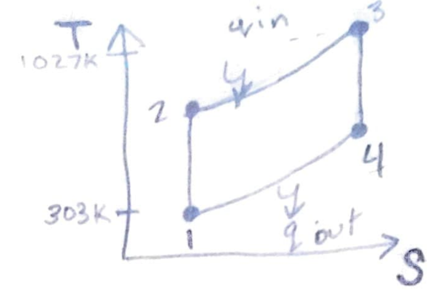
$$\boxed{\eta_{th} = 0.687}$$

$W_{net} = Q_{in} - Q_{in}$

$(934.3) - (292)$

$$\boxed{W_{net} = 642.3k \approx 649.22 \text{ kJ/kg}}$$





b) No Regeneration (same variables)

1 (from a))

$P_1 = 100$ kPa

$T_1 = 303$ K

$h_1 \approx 303.22$

$P_r = 1.467$

2 (from a))

$P_2 = 1000$ kPa

$T_2 = 585$ K

3

$P_3 = 1000$ KPa

$T_3 = 1027$ K

$q_{out} = h_4 - h_1 = c_p(T_4 - T_1)$

$q_{out} = 230.08$ kJ/kg

$q_{in} = h_3 - h_2 = c_p(T_3 - T_2)$

$q_{in} = 441.21$ kJ/kg

4

$P_4 = P_1 = 100$ kPa

$\frac{T_4}{T_3} \left(\frac{P_4}{P_3}\right)^{\frac{k-1}{k}} \Rightarrow T_4 = 531.93$ K

$w_{comp,in} = c_p(T_2 - T_1)$
$= 283.41$ kJ/kg

$w_{Turb,out} = c_p(T_3 - T_4)$
$= 497.55$ kJ/kg

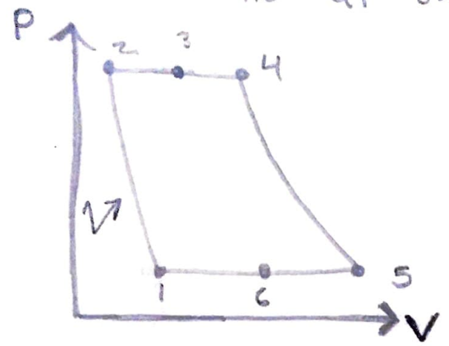
$w_{net} = w_{out} - w_{in} = 214.14$ kJ/kg

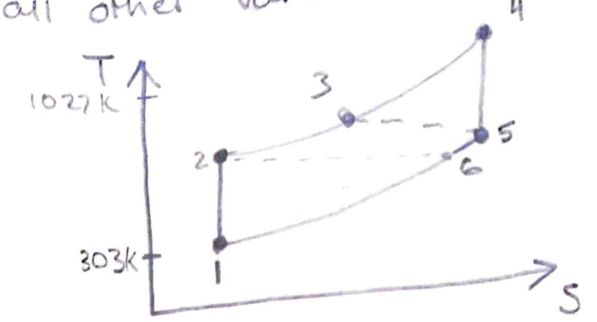
$\eta_{th} = \frac{w_{net}}{q_{in}}$

$\eta_{th} = .931$

$\epsilon = \left(\frac{T_3 - T_2}{T_4 - T_1}\right) = 1.93$

c) Pressure ratio at 8.58 (all other variables same)





1 → 2 → 3

from a)

$P_1 = 100 kPa$

$T_1 = 303 K$

$V_1 = 0.87 m^3/kg$

$P_2 = P_1 r_p$

$P_2 = 858 kPa$

$T_2 = 585K$ (from a))

$V_2 = \frac{RT_2}{P_2} = 0.196 m^3/kg$

$P_3 = P_2 = 858 kPa$

$T_3 = T_5 \ 8.58$

From 5

$T_3 = 547.14 K$

$V_3 = \frac{RT_3}{P_3} = 0.183 m^3/kg$

→ 4 → 5 →

$T_4 = 1027 K$ (Tmax)

$P_4 = 8.58 P_5 = 858 kPa$

$V_4 = \frac{RT_4}{P_4} = 0.34 m^3/kg$

$P_5 = P_6 = 100 kPa$

$\frac{T_5}{T_4} = \left(\frac{P_5}{P_4}\right)^{k-1/k} \rightarrow T_5 = 555.72 K$

$V_5 = \frac{RT_5}{P_5} = 1.59 m^3/kg$

→ 6

$P_6 = P_1 = 100 kPa$ } from a)

$T_6 = T_5 - (T_3 - T_2)$

$= 555.72 - (547.14 - 585)$

$T_6 = 593.58 K$

$\eta_{th} = 1 - \frac{T_6 - T_1}{T_4 - T_3}$

$= 1 - \left(\frac{555.72 - 303}{1027 - 547.14}\right)$

$W_{net} = Q_{out} - Q_{in} = 479.86 - 252.72$

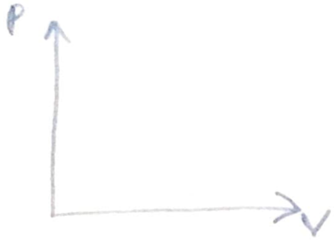
$W_{net} = 227.14 \approx 230.02 kJ/kg$

$\eta_{th} = 1.52$

$\epsilon = \left(\frac{T_6 - T_1}{T_4 - T_3}\right) = .527$

d) $T_{max} = 895.48°C$, (all other variables same)

$= 1168.48\ K$



1 ⟶ 2 ⟶ 3 ⟶

1

from a)

$P_1 = 100\ kPa$

$T_1 = 303\ K$

2

from a)

$P_2 = 1000\ kPa$

$T_2 = 585\ K$

3

5 → HOT → 6

3 ← COLD ← 2

$P_3 = P_2 = 1000\ kPa$

$T_3 = T_5 - 10$

from 5

$T_3 = 595.21\ K$

⟶ 4 ⟶ 5 ⟶

4

$P_4 = 10 P_5 = 1000\ kPa$

$T_4 = 1168.48\ K$ (T_{max})

5

$P_5 = P_6 = 100\ kPa$

$\frac{T_5}{T_4} = \left(\frac{P_5}{P_4}\right)^{\frac{k-1}{k}} \rightarrow T_5 = 605.21 K$

⟶ 6

$P_6 = P_1 = 100\ kPa$

$T_6 = T_5 - (T_3 - T_2)$

$= 605.21 - (595.21 - 585)$

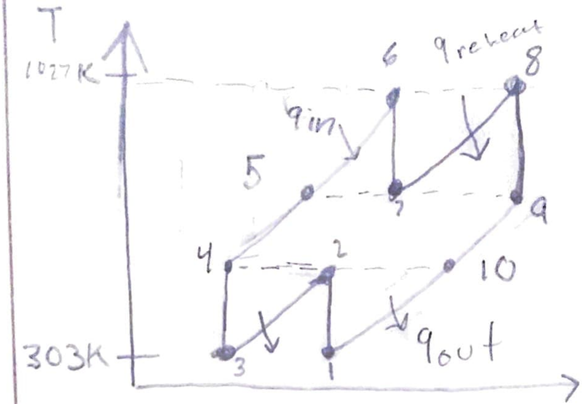
$T_6 = 615.42 K$

$$\eta_{th} = 1 - \frac{T_6 - T_1}{T_4 - T_3}$$

$$= 1 - \left(\frac{615.42 - 303}{1168.48 - 595.21}\right)$$

$$\boxed{\eta_{th} = 0.455}$$

E) TWO stage Intercooler



$\frac{P_6}{P_7} = \frac{P_8}{P_9}$; $\frac{P_2}{P_1} = \frac{P_4}{P_3} = \sqrt{10} = 3.16$

$T_1 = T_3, h_1 = h_3$

$T_2 = T_4, h_2 = h_4$

$T_6 = T_8, h_6 = h_8$

$T_7 = T_5, h_7 = h_5$

$P_1 = 100$ kPa

$T = 303$ K   303(1.005)

$h_1 = 304.52$

$P_{r_1} \approx 1.468$

$P_{r_2} = \sqrt{10}(1.468) = 4.64$ $T_2 \approx 430$ K

$h_2 = 431.43$ kJ/kg

$T_6 = 1027$ K

$h_6 = 1027(1.005)$
$= 1032.14$ kJ/kg

$P_{r_6} \approx 133.3$

$P_{r_7} = \frac{1}{\sqrt{10}}(133.3) = 42.153$

$T_7 \approx 570$ K $h_7 = 572.85$

$W_{comp,in} = 2(h_2 - h_1) = 2(431.43 - 304.52) = 253.82$ kJ/kg

$W_{turb,out} = 2(h_6 - h_7) = 2(1032.14 - 572.85) = 459.29$ kJ/kg

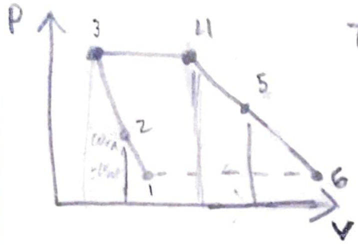
$W_{net} = W_{out} - W_{in} = 459.29 - 253.82 = $ **205.47 kJ/kg**

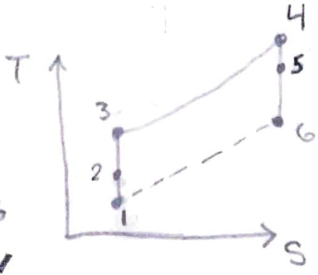
$q_{in} = q_{pri} + q_{reh} = (h_6 - h_5) + (h_8 - h_7) = (1032.14 - 572.85) + (1032.14 - 572.85)$

$q_{in} = 918.58$ kJ/kg

$\eta_{th} = \frac{205.47}{918.58} = .224$

2. a)





Given

$T_1 = -35°C = 238\ K$

$V_{aircraft} = 900\ km/h = 250\ m/s$

$T_{max} = 950°C = 1223\ K$

$P_1 = 40\ kPa$

$D_{inlet} = 1.6\ m$

1

$T = 238\ K$

$P_1 = 40\ kPa$

$h_1 = 239.19\ kJ/kg$

$V_1 = 250\ m/s$

$Pr_1 = 0.6179$

2

$V_2 = 0\ m/s$

$T_2 = T_1 + \frac{V_1^2}{2c_p}\left[\frac{1\ kJ/kg}{1000\ m^2/s^2}\right]$

$T_2 = 262.09$

$Pr_2 = 0.865$

$\frac{P_2}{P_1} = \frac{Pr_2}{Pr_1} \rightarrow P_2 = 55.99\ kPa$