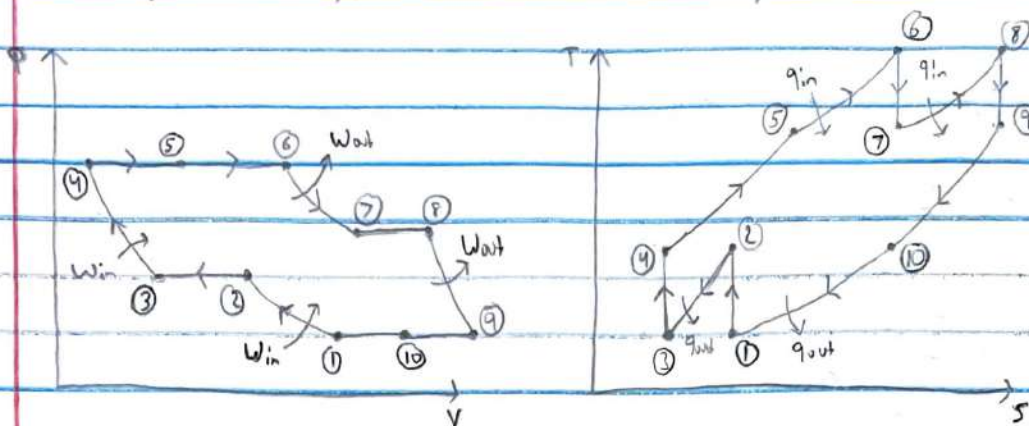


Carnegie Sutton

HW #5

9-123.) $R_p = 4$

C_p, C_v Constant at room temp



$\text{①} \xrightarrow{\text{Isentropic Compression}} \text{②} \xrightarrow{P_{\text{const}}} \text{③} \xrightarrow{\text{Isentropic Compression}} \text{④} \xrightarrow{P_{\text{const}}} \text{⑤} \xrightarrow{P_{\text{const}}} \text{⑥}$
 $P_1 = 100 \text{ kPa} \quad P_2 = 4P_1 = 400 \text{ kPa} \quad P_3 = 400 \text{ kPa} \quad P_4 = 4P_3 = 1600 \text{ kPa} \quad T_5 = T_4 + 20 \text{ K} = 451 \text{ K}$
 $T_1 = 290 \text{ K} \quad T_2 = 431 \text{ K} \quad T_3 = T_1 = 290 \text{ K} \quad T_4 = 431 \text{ K} \quad P_5 = 1600 \text{ kPa}$

$\text{⑥} \xrightarrow{\text{Isentropic Expansion}} \text{⑦} \xrightarrow{P_{\text{const}}} \text{⑧} \xrightarrow{\text{Isentropic Expansion}} \text{⑨} \xrightarrow{P_{\text{const}}} \text{⑩} \xrightarrow{P_{\text{const}}} \text{①}$
 $P_6 = 1600 \text{ kPa} \quad P_7 = \frac{P_6}{4} = 400 \text{ kPa} \quad P_8 = 400 \text{ kPa} \quad P_9 = \frac{P_8}{4} = 100 \text{ kPa} \quad P_{10} = 100 \text{ kPa}$
 $T_6 = 779.5 \text{ K} \quad T_7 = 504 \text{ K} \quad T_8 = 802.5 \text{ K} \quad T_9 = 540 \text{ K} \quad T_{10} = 520 \text{ K}$

Find T_2

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

$$T_2 = 290 \left(\frac{4P_1}{P_1} \right)^{\frac{1.4-1}{1.4}}$$

Find T_4

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

$$T_4 = 290 (1.49)^{\frac{1.4-1}{1.4}}$$

Find T_6

$$q_{in} = h_6 - h_5$$

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

$$300 = 1.005 (T_6 - 451)$$

$$T_6 = 779.5 \text{ K}$$

Find T_7

$$\frac{T_7}{T_6} = \left(\frac{P_7}{P_6} \right)^{\frac{k-1}{k}}$$

$$T_7 = 779.5 \left(\frac{1}{4} \right)^{\frac{1.4-1}{1.4}}$$

Find T_8

$$q_{in} = h_8 - h_7$$

$$q_{in} = C_p (T_8 - T_7)$$

$$300 = 1.005 (T_8 - 504)$$

$$T_8 = 802.5 \text{ K}$$

Find T_9

$$\frac{T_9}{T_8} = \left(\frac{P_9}{P_8} \right)^{\frac{k-1}{k}}$$

$$T_9 = 802.5 \left(\frac{1}{4} \right)^{\frac{1.4-1}{1.4}}$$

Find P_{10}

1st law for regenerator

$$q_{in} - q_{out} + W_{in} - W_{out} = \Delta h$$

$$\Delta h = 0$$

$$\sum h_{in} - \sum h_{out} = 0$$

$$h_4 + h_9 + h_5 + h_{10} = 0$$

$$h_4 + h_9 = h_5 - h_{10}$$

$$c_p(T_4 + T_9) = c_p(T_5 - T_{10})$$

$$(431 + 570) = (451 - T_{10})$$

$$T_{10} = 520 \text{ K}$$

$$\eta = \frac{W_{net}}{q_{in}} = \frac{227.1}{600} = .38 = \boxed{38\%}$$

$$W_{net} = \underset{1 \rightarrow 2}{W_{in}} + \underset{3 \rightarrow 4}{W_{in}} - \underset{6 \rightarrow 7}{W_{out}} - \underset{8 \rightarrow 9}{W_{out}}$$

$$= (h_2 - h_1) + (h_3 - h_4) - (h_6 - h_7) - (h_8 - h_9)$$

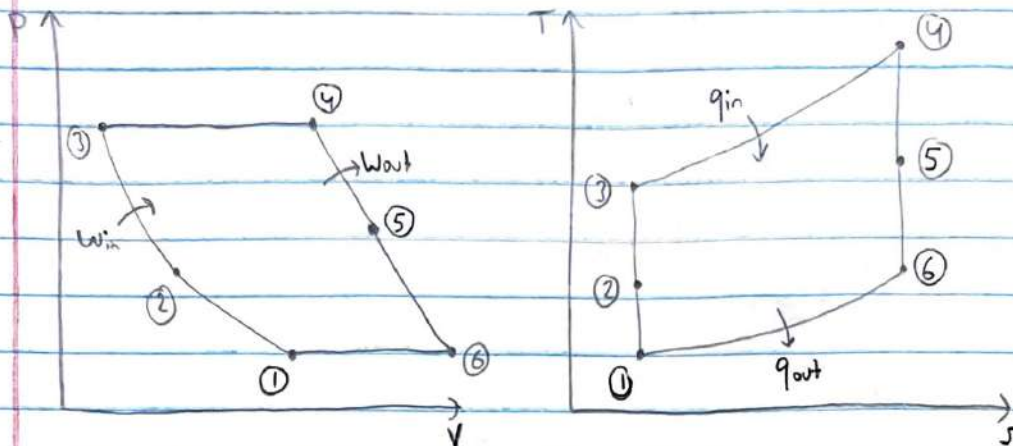
$$= c_p(T_2 - T_1) + c_p(T_3 - T_4) - c_p(T_6 - T_7) - c_p(T_8 - T_9)$$

$$= 141.7 + 141.7 - 246.7 - 263.8$$

$$W_{net} = 227.1 \text{ kJ/kg}$$

$$q_{in} = \underset{5 \rightarrow 6}{q_{in}} + \underset{7 \rightarrow 8}{q_{in}} = 300 + 300 = 600 \text{ kJ/kg}$$

9-129.)



Given: $V = 900 \text{ ft/s} = .274 \text{ km/s} = 274.3 \text{ m/s}$

$h = 20,000 \text{ ft} = 6.096 \text{ km} = 6096 \text{ m}$

$P = 7 \text{ psia} = 48.3 \text{ kPa}$

$T = 10^\circ \text{F} = 260.9 \text{ K}$

$r_p = 13$

$T_{\text{inlet}} = 2700 \text{ R} = 1333 \text{ K}$

C_p, C_v Constant at room temp



$P_1 = 48.3 \text{ kPa}$ $P_2 = 13P_1 = 627.9$ $P_3 = 13P_2 = 8162.7$ $T_4 = 1333 \text{ K}$ $V_5 = 0 \text{ m/s}$ $P_6 = 48.3 \text{ kPa}$

$T_1 = 260.9 \text{ K}$ $V_2 = 0 \text{ m/s}$ $T_3 = 575 \text{ K}$ $P_4 = 8162.7 \text{ kPa}$ $T_5 = 1050 \text{ K}$ $T_6 = 277 \text{ K}$

$V_1 = 274 \text{ m/s}$ $T_2 = 262 \text{ K}$

$V_4 = 0.047 \text{ m/s}$ $P_5 = 7625 \text{ kPa}$ $V_6 = 1.47 \text{ m/s}$

$\gamma = 1.55$

Find T_2

1st law

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

$$\frac{V_1^2}{2} = h_2 - h_1$$

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

$T_2 = 262 \text{ K}$

Find T_3

$$\frac{T_3}{T_2} = \left(\frac{P_3}{P_2}\right)^{\frac{\gamma-1}{\gamma}}$$

$$T_3 = 262 (13)^{\frac{1}{1.55}}$$

Find V_4

$$PV = RT$$

Find T_5

$$W_c = W_T$$

$$c_p(T_3 - T_2) = c_p(T_5 - T_4)$$

$$T_5 = T_4 - (T_3 - T_2)$$

$$P_5 = P_4 \left(\frac{T_5}{T_4}\right)^{\frac{\gamma-1}{\gamma}}$$

Find T_6

$$\frac{T_6}{T_5} = \left(\frac{P_6}{P_5}\right)^{\frac{\gamma-1}{\gamma}}$$

$$T_6 = 1050 (1.47)^{\frac{1}{1.55}}$$

$$a.) P_s = 7625 \text{ kPa}$$

$$b.) \frac{V_s^2}{2} + h_s = \frac{V_6^2}{2} + h_6$$

$$\frac{V_6^2}{2} = C_p (T_s - T_6)$$

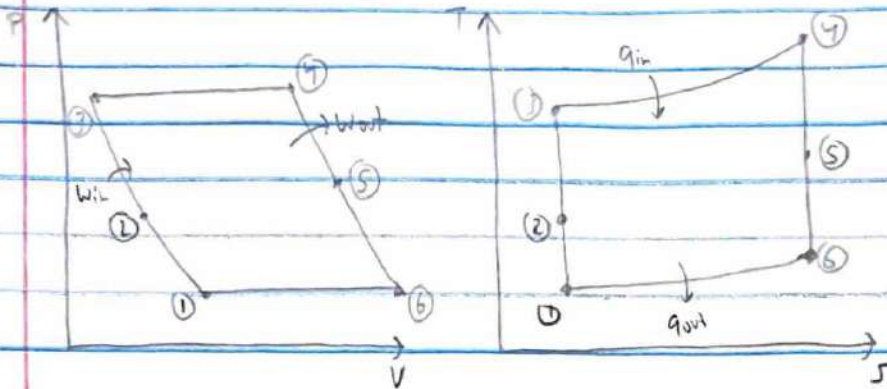
$$V_6 = 40.2 \text{ m/s}$$

$$c.) \eta_p = \frac{\dot{W}_p}{\dot{Q}_{in}}$$

$$\dot{W}_p = \dot{m} (V_6 - V_1) V_1$$

$$\dot{m} = \rho_1 V_1 A_1$$

9-135.)



Given: $r_p = 9$

$$T_1 = 7^\circ\text{C} = 280\text{K}$$

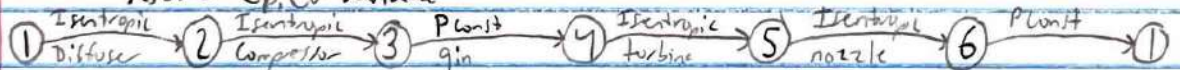
$$P_1 = 95\text{kPa}$$

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

$$\dot{q}_{in} = 42,700\text{ kJ/kg}$$

$$\dot{Q}_{out} = 0.5\text{ kg/s}$$

Assume C_p, C_v variable



$$P_1 = 95\text{kPa} \quad V_2 = 0\text{ m/s} \quad P_2 = 9P_1 = 7695\text{kPa} \quad P_4 = P_5 = 7695\text{kPa} \quad P_5 = \frac{P_2}{9} = 855\text{kPa} \quad P_6 = 95\text{kPa}$$

$$T_1 = 280\text{K} \quad P_{r1} = 9.8 \quad P_{r2} = 573.99 \quad W_T = W_C \quad P_{r5} = 60.7 \quad P_{r6} = 11.6$$

$$h_1 = 280.13\frac{\text{kJ}}{\text{kg}} \quad P_2 = 9P_1 = 855\text{kPa} \quad h_3 = 1592.8\frac{\text{kJ}}{\text{kg}} \quad h_4 = 1347.6\frac{\text{kJ}}{\text{kg}} \quad h_5 = 899.56\frac{\text{kJ}}{\text{kg}} \quad T_6 = 546.5\text{K}$$

$$P_{r1} = 1.0889 \quad T_2 = 521.69\text{K} \quad T_3 = 1464.35\text{K} \quad T_4 = 1665.8\text{K} \quad h_6 = 551.19$$

$$V_1 = 22.1\text{ m/s} \quad h_2 = 525.38\frac{\text{kJ}}{\text{kg}} \quad P_{r4} = 939.76$$

Find P_{r2}

Find h_2 and T_2

Find h_2

Find P_{r5}

$$\frac{P_2}{P_1} = \frac{P_{r2}}{P_{r1}}$$

Interpolated using calculator

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

$$\frac{P_5}{P_4} = \frac{P_{r5}}{P_{r4}}$$

$$\frac{P_2}{P_1} = \frac{P_{r2}}{P_{r1}}$$

$$1067.5 = h_3 - 525.38$$

$$\frac{P_5}{P_4} = \frac{P_{r5}}{P_{r4}}$$

$$9 = \frac{P_{r2}}{P_{r1}}$$

$$\dot{Q}_{in} = 0.5\text{ kg/s} \cdot 42,700\frac{\text{kJ}}{\text{kg}}$$

$$P_{r1} = 1.0889$$

Find P_{r3}

$$\dot{Q}_{in} = 21350\frac{\text{kJ}}{\text{s}}$$

$$P_{r2} = 9.8$$

$$\frac{P_3}{P_2} = \frac{P_{r3}}{P_{r2}}$$

$$\dot{q}_{in} = \frac{\dot{Q}_{in}}{\dot{m}} = \frac{21350\text{ kJ/s}}{20\text{ kg/s}} = 1067.5\frac{\text{kJ}}{\text{kg}}$$

$$\frac{P_3}{P_2} = \frac{P_{r3}}{P_{r2}}$$

$$P_{r3} = 88.2$$

$$\dot{q}_{in} = \frac{\dot{Q}_{in}}{\dot{m}} = \frac{21350\text{ kJ/s}}{20\text{ kg/s}} = 1067.5\frac{\text{kJ}}{\text{kg}}$$

Find v_1

$$P_{r3} = 88.2$$

$$\dot{q}_{in} = \frac{\dot{Q}_{in}}{\dot{m}} = \frac{21350\text{ kJ/s}}{20\text{ kg/s}} = 1067.5\frac{\text{kJ}}{\text{kg}}$$

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

$$\frac{P_3}{P_2} = \frac{P_{r3}}{P_{r2}}$$

$$\dot{q}_{in} = \frac{\dot{Q}_{in}}{\dot{m}} = \frac{21350\text{ kJ/s}}{20\text{ kg/s}} = 1067.5\frac{\text{kJ}}{\text{kg}}$$

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

$$\frac{P_3}{P_2} = \frac{P_{r3}}{P_{r2}}$$

$$\dot{q}_{in} = \frac{\dot{Q}_{in}}{\dot{m}} = \frac{21350\text{ kJ/s}}{20\text{ kg/s}} = 1067.5\frac{\text{kJ}}{\text{kg}}$$

$$V_1 = 22.1\text{ m/s}$$

$$\frac{P_3}{P_2} = \frac{P_{r3}}{P_{r2}}$$

$$\dot{q}_{in} = \frac{\dot{Q}_{in}}{\dot{m}} = \frac{21350\text{ kJ/s}}{20\text{ kg/s}} = 1067.5\frac{\text{kJ}}{\text{kg}}$$

$$W_T = W_c$$

$$h_4 - h_3 = h_2 - h_1$$

$$h_4 = h_2 - h_1 + h_3$$

$$h_4 = 1838.11 \text{ kJ/kg}$$

Find v_s

$$h_4 + \frac{v_4^2}{2} = h_5 + \frac{v_s^2}{2}$$

$$\frac{v_s^2}{2} = h_4 - h_5$$

$$v_s = \sqrt{2(h_4 - h_5)}$$

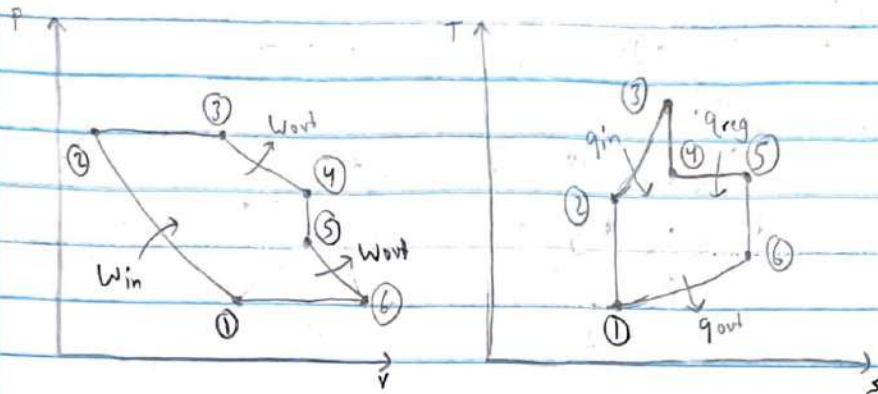
$$v_s = 976.6 \text{ m/s}$$

$$F = \dot{m} (v_{\text{exit}} - v_{\text{inlet}})$$

$$F = 20 (976.6 - 22.1)$$

$$F = 18490 \text{ N}$$

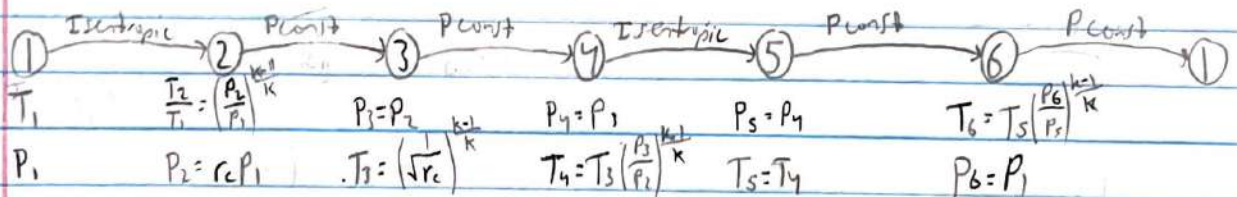
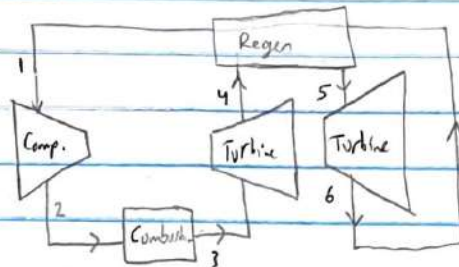
9-167)



Assume C_p, C_v constant

$$r_T = \frac{P_6}{P_1} = \frac{P_6}{P_3}$$

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



$$\eta = \frac{W_{net}}{q_{in}}$$

$$W_{net} = (W_T + W_{T'}) - W_C$$

$$W_{net} = C_p(T_3 - T_4) + C_p(T_5 - T_6) - C_p(T_2 - T_1)$$

$$q_{in} = C_p(T_3 - T_1)$$

$$\eta = \frac{C_p(T_3 - T_4) + C_p(T_5 - T_6) - C_p(T_2 - T_1)}{C_p(T_3 - T_1)}$$

$$\text{Standard cycle: } \eta = 1 - \left(\frac{T_1}{T_3} \right) (r_p)^{\frac{k-1}{k}}$$