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HW 1.3

9-33) Given: Otto cycle

$$r = 8$$

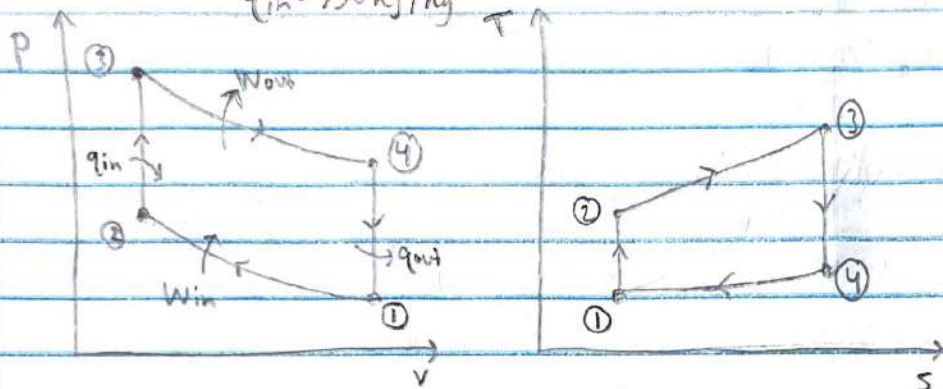
air

c_p, c_v variable

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

$$T_1 = 27^\circ\text{C} = 300^\circ\text{K}$$

$$q_{in} = 750 \text{ kJ/kg}$$



States:

① $\xrightarrow{\text{Isentropic compression}}$ ② $\xrightarrow{\text{Isobaric heat addition}}$ ③ $\xrightarrow{\text{Isentropic expansion}}$ ④ $\xrightarrow{\text{Isobaric heat rejection}}$ ①

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

$$V_2 = \frac{V_1}{r}$$

$$V_3 = 11 \text{ m}^3/\text{kg}$$

$$V_4 = 8V_3$$

$$T_1 = 300 \text{ K}$$

$$V_2 = 11 \text{ m}^3/\text{kg}$$

$$V_{r3} = 75.1$$

$$V_4 = 88 \text{ m}^3/\text{kg}$$

$$V_{r1} = 621.2$$

$$V_{r2} = 75.1$$

$$q_{in} = U_3 - U_2$$

$$V_{r4} = 600.8$$

$$\rightarrow PV = RT$$

$$T_2 = 681.4 \text{ K}$$

$$U_3 = 1247.72 \text{ kJ/kg}$$

$$T_4 = 301.95 \text{ K}$$

$$(95)(V_1) = (0.287)(300)$$

$$P_2 = 1785.67 \text{ kPa}$$

$$T_3 = 1575.7 \text{ K}$$

$$V_1 = 0.91 \text{ m}^3/\text{kg}$$

$$P_{r2} = 26.052$$

$$P_{r1} = 1.3860$$

$$U_2 = 497.72 \text{ kJ/kg}$$

$$\rightarrow \frac{V_2}{V_1} = \frac{V_{r2}}{V_{r1}}$$

Find T_2

Find P_{r2}

$$\frac{11}{.91} = \frac{V_{r2}}{621.2}$$

$$V_{r2} = 75.1$$

T	V_r
680	75.5
T_2	75.1
690	72.56

T	P_{r2}
680	25.85
681.4	P_{r2}
690	27.29

$$U_1 = 214.07 \text{ kJ/kg}$$

$$\frac{T_2 - 680}{690 - 680} = \frac{75.1 - 75.5}{72.56 - 75.5}$$

$$T_2 = 681.4 \text{ K}$$

$$\frac{681.4 - 680}{690 - 680} = \frac{P_{r2} - 25.85}{27.29 - 25.85}$$

$$P_{r2} = 26.052$$

$\frac{P_2}{P_1} = \frac{P_{r2}}{P_{r1}}$	Find U_2	
P_1 P_{r1}	T	U
$P_2 = 26.052$	680	496.62
95 1.3860	681.4	U_2
$P_2 = 1785.67 \text{ kPa}$	690	504.45

$$\frac{681.4 - 680}{690 - 680} = \frac{U_2 - 496.62}{504.45 - 496.62}$$

$$U_2 = 497.72 \text{ kJ/kg}$$

a.) $T_2 = 681.4 \text{ K}$
 $P_2 = 1785.67 \text{ kPa}$

b.) $W_{\text{net}} = W_{\text{out}} - W_{\text{in}}$ $W_{\text{out}} = R(T_4 - T_3) = .287(301.95 - 1547.7) = 51.08 \text{ kJ/kg}$
 $W_{\text{net}} = 51.08 - 15.64$ $W_{\text{in}} = R(T_2 - T_1) = .287(681.4 - 300) = 15.64 \text{ kJ/kg}$
 $W_{\text{net}} = 35.44 \text{ kJ/kg}$

Find T_3	
T	U
1540	1242.43
T_3	1247.72
1560	1260.99

$$\frac{T_3 - 1540}{1560 - 1540} = \frac{1247.72 - 1242.43}{1260.99 - 1242.43}$$

$$T_3 = 1545.7 \text{ K}$$

Find T_4	
T	V_r
300	621.2
T_4	600.8
305	596

$$\frac{T_4 - 300}{305 - 300} = \frac{600.8 - 621.2}{596 - 621.2}$$

$$T_4 = 301.95 \text{ K}$$

c.) $\eta = 1 - \frac{1}{r^{k-1}}$
 $\eta = 1 - \frac{1}{8^{1.4-1}}$
 $\eta = .56 = 56\%$

d.) $\text{MEP} = \frac{W_{\text{net}}}{V_1 - V_2} = \frac{35.44}{.91 - .11} = 44.3 \text{ kPa}$

9-36E) Given: Otto Cycle - air

$$P_1 = 14 \text{ psia} = 96.5 \text{ kPa}$$

$$T_1 = 105^\circ \text{F} = 314 \text{ K}$$

$$T_{\text{max}} = 2400^\circ \text{F} = 1589 \text{ K}$$

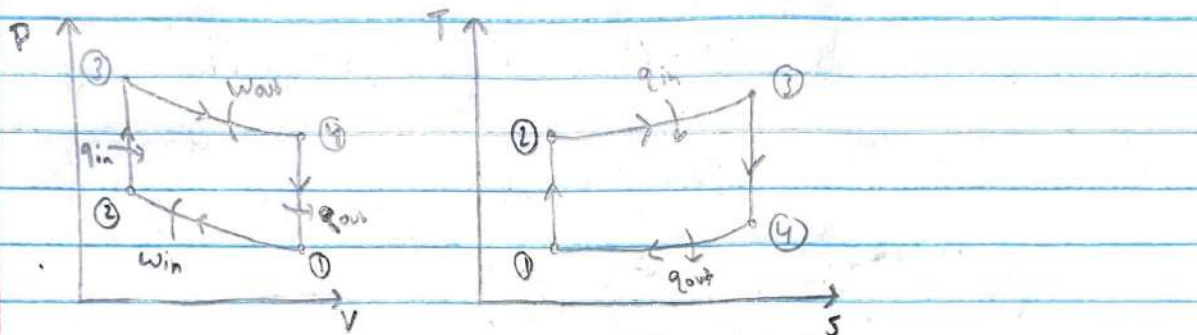
$$Bore = 3.5'' \text{ ID}$$

$$\text{Stroke} = 3.9''$$

$$V_{\text{min}} = 0.098 V_{\text{max}}$$

$$V_{\text{max}} = V_1$$

C_p, C_v Constant at 300K



$$\begin{array}{llll} P_1 = 96.5 \text{ kPa} & V_2 = 0.091 \text{ m}^3/\text{kg} & T_{\text{max}} = 1589 \text{ K} & V_4 = 0.93 \text{ m}^3/\text{kg} \\ T_1 = 314 \text{ K} & T_2 = 795 \text{ K} & V_3 = 0.091 \text{ m}^3/\text{kg} & T_4 = 626.3 \text{ K} \\ V_1 = 0.93 \text{ m}^3/\text{kg} & & & \end{array}$$

$$\begin{array}{lll} PV = RT & \frac{T_2}{T_1} = \left(\frac{V_1}{V_2} \right)^{k-1} & \frac{T_4}{T_3} = \left(\frac{V_3}{V_4} \right)^{k-1} \\ V_1 = \frac{0.285(314)}{96.5} & T_2 = 795 \text{ K} & T_4 = 626.3 \text{ K} \end{array}$$

$$V_1 = 0.93 \text{ m}^3/\text{kg}$$

$$r = \frac{V_1}{V_2} = 10.2$$

$$\begin{aligned} W_{\text{in}} &= \Delta U \\ 1 \rightarrow 2 &= C_v(T_2 - T_1) \\ &= 0.718(795 - 314) \end{aligned}$$

$$W_{\text{in}} = 345.4 \text{ kJ/kg}$$

$$\begin{aligned} W_{\text{out}} &= \Delta U \\ 3 \rightarrow 4 &= C_v(T_4 - T_3) \\ &= 0.718(626.3 - 1589) \end{aligned}$$

$$W_{\text{out}} = -691.2 \text{ kJ/kg}$$

$$\begin{aligned}
 W_{net} &= W_{out} - W_{in} \\
 &= 691.2 - 345.4 \\
 &= 345.8 \text{ kJ/kg}
 \end{aligned}$$

$$P = \frac{W_{net} \times N}{T}$$

9-46) Given: $r = 16$

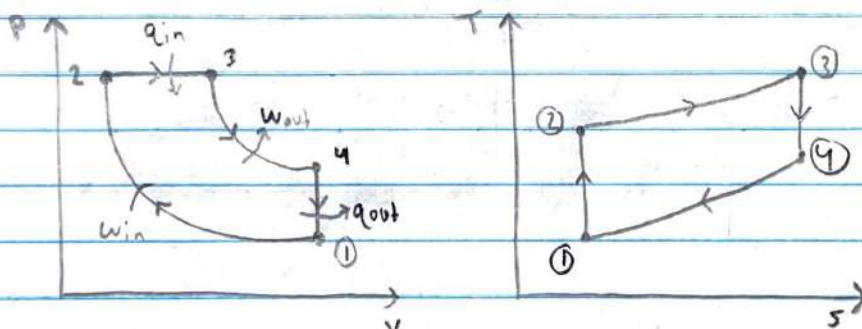
$$r_c = 2$$

Air

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

$$T_1 = 27^\circ\text{C} = 300\text{K}$$

C_p, C_v variable



①	Isentropic compression	②	Isobaric heat addition	③	Isentropic expansion	④	Isobaric heat rejection	①
$P_1 = 95 \text{ kPa}$		$r = 16 = \frac{V_1}{V_2}$		$P_3 = P_2 = 4049.19 \text{ kPa}$		$V_4 = V_1 = .9 \frac{\text{m}^3}{\text{kg}}$		
$T_1 = 300\text{K}$		$V_2 = 0.06 \frac{\text{m}^3}{\text{kg}}$		$r_c = 2 = \frac{V_3}{V_2}$		$V_{r4} = V_{r3} \left(\frac{V_4}{V_3} \right) = 36.63$		
$V_1 = \frac{RT_1}{P_1} = .9 \frac{\text{m}^3}{\text{kg}}$		$V_{r2} = V_{r1} \left(\frac{V_2}{V_1} \right) = 40.96$		$V_3 = .12 \frac{\text{m}^3}{\text{kg}}$		$T_4 = 879.84\text{K}$		
$V_{r1} = 621.2$		$T_2 \rightarrow \text{Interpolate}$		$T_3 = T_2 \left(\frac{V_3}{V_2} \right)$		$P_4 = \frac{RT}{V} = 277.99 \text{ kPa}$		
$P_{r1} = 1.386$		(Used calculator)		$T_3 = 1693\text{K}$		$U_4 = 657.82 \text{ kJ/kg}$		
$U_1 = 214.07 \text{ kJ/kg}$		$= 846.52\text{K}$		$V_{r3} = 4.83$				
		$P_2 = \frac{RT}{V} = 4049.19 \text{ kPa}$		$U_3 = 1385.89 \text{ kJ/kg}$				
		$U_2 = 635.71 \text{ kJ/kg}$		$h_3 = 1871.99 \text{ kJ/kg}$				
		$h_2 = 873.31 \text{ kJ/kg}$						

a) $T_3 = 1693\text{K}$

b) $q_{in} = \text{constant } p = \Delta h = h_3 - h_2 = 998.18 \text{ kJ/kg}$

$q_{out} = \Delta U = U_4 - U_1 = 443.75 \text{ kJ/kg}$

$\eta = 1 - \frac{q_{out}}{q_{in}} = .56 = 56\%$

c) $MEP = \frac{W_{net}}{V_{max} - V_{min}} = \frac{q_{in} - q_{out}}{V_{max} - V_{min}} = \frac{-554.43}{.85} = 652.3 \text{ kPa}$

9-57) Given: 4-cyl, 2 stroke 2.4L

Diesel cycle

$r = 22$

$r_c = 1.8$

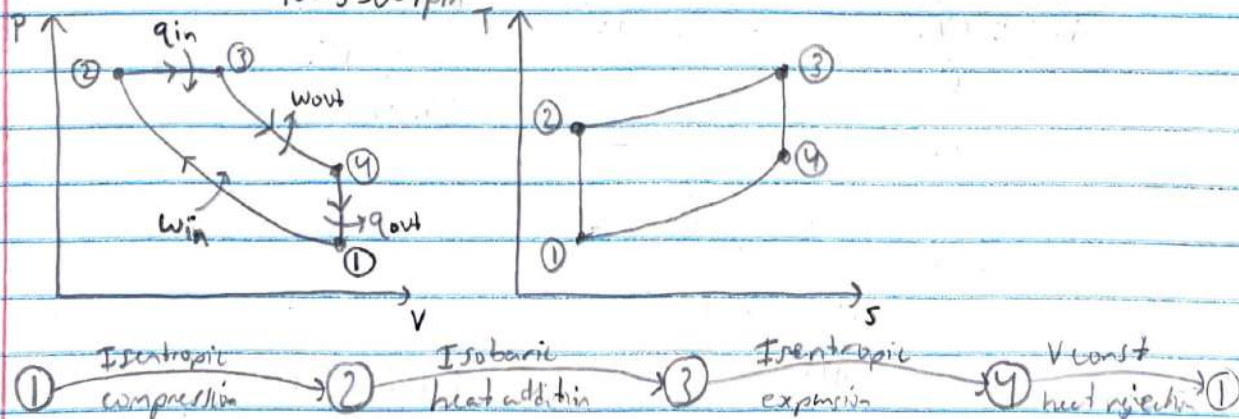
Air

$T_1 = 70^\circ\text{C}$

$P_1 = 97 \text{ kPa}$

Cold-air standard - Constant C_p, C_v at 25°C (298K)

$N = 3500 \text{ rpm}$



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$$① P_1 = 97 \text{ kPa}$$

$$T_1 = 343 \text{ K}$$

$$V_1 = \frac{RT_1}{P_1} = 1.01 \frac{\text{m}^3}{\text{kg}}$$

$$② r = 22 = \frac{V_1}{V_2}$$

$$V_2 = 0.046 \frac{\text{m}^3}{\text{kg}}$$

$$T_2 = T_1 \left(\frac{V_1}{V_2} \right)^{\gamma-1}$$

$$T_2 = 1181 \text{ K}$$

$$P_2 = \frac{RT_2}{V_2} = 7368.4 \text{ MPa}$$

$$③ P_2 = P_3 = 7368.4 \text{ MPa}$$

$$r_c = 1.8 = \frac{V_2}{V_3}$$

$$V_3 = 0.083 \frac{\text{m}^3}{\text{kg}}$$

$$T_3 = T_2 \left(\frac{V_2}{V_3} \right)^{\gamma-1}$$

$$T_3 = 2125.8 \text{ K}$$

$$④ V_4 = V_1 = 1.01 \frac{\text{m}^3}{\text{kg}}$$

$$T_4 = T_3 \left(\frac{V_3}{V_4} \right)^{\gamma-1}$$

$$T_4 = 782.4 \text{ K}$$

$$P_4 = \frac{RT_4}{V_4} = 222.3 \text{ MPa}$$

$$q_{in} = \Delta h = C_p(T_3 - T_2) = 949.5 \text{ J}$$

$$q_{out} = \Delta u = C_v(T_2 - T_1) = 441.6 \text{ J}$$

$$W_{net} = q_{in} - q_{out} = 507.9 \text{ J}$$

$$P = \dot{N} \cdot W_{net} = \frac{7500}{60} \cdot 507.9 = 29627.5 \text{ W} = \boxed{29.627 \text{ kW}}$$

9-59.E) Given: Ideal dual cycle

$$r = 15$$

$$r_c = 1.4$$

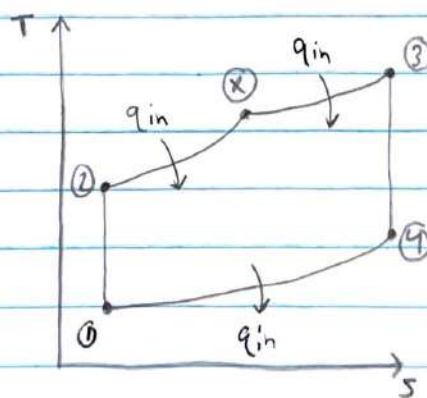
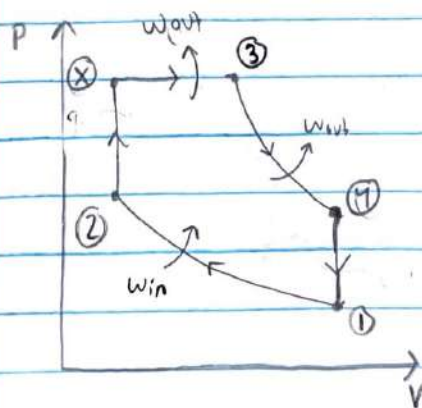
$$r_p = 1.1 \quad (2 \rightarrow x)$$

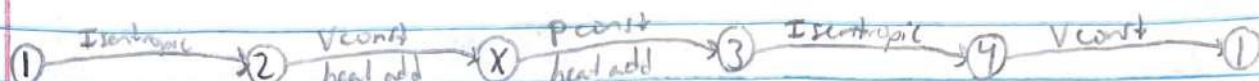
Air

$$P_1 = 14.2 \text{ psia} = 98 \text{ kPa}$$

$$T_1 = 75^\circ\text{F} = 297 \text{ K}$$

C_p, C_v constant at 300 K





$$\begin{aligned}
 T_1 &= 297 \text{ K} & V_2 &= \frac{V_1}{r} & P_x &= r_p P_2 & P_3 &= 4775.76 \text{ kPa} & V_4 &= V_1 = .87 \frac{\text{m}^3}{\text{kg}} \\
 P_1 &= 98 \text{ kPa} & V_2 &= .058 \frac{\text{m}^3}{\text{kg}} & P_x &= 4775.76 \text{ kPa} & V_3 &= V_x r_c = .08 \frac{\text{m}^3}{\text{kg}} & T_4 &= 512.7 \text{ K} \\
 & & T_2 &= 577.7 \text{ K} & V_x &= V_2 = .058 \frac{\text{m}^3}{\text{kg}} & T_3 &= 1731 \text{ K} & P_4 &= 169 \text{ kPa} \\
 V_1 &= \frac{RT_1}{P_1} & P_2 &= 4341.6 \text{ kPa} & T_x &= 965 \text{ K} & & & & \\
 V_1 &= .87 \frac{\text{m}^3}{\text{kg}} & & & & & & & &
 \end{aligned}$$

Find T_2

$$\begin{aligned}
 \frac{T_2}{T_1} &= \left(\frac{V_1}{V_2} \right)^{k-1} \\
 T_2 &= 577.7 \text{ K}
 \end{aligned}$$

Find P_2

$$\begin{aligned}
 P_2 &= \frac{RT_2}{V_2} \\
 P_2 &= 4341.6 \text{ kPa}
 \end{aligned}$$

Find T_x

$$\begin{aligned}
 T_x &= \frac{P_x V_x}{R} \\
 T_x &= 965 \text{ K}
 \end{aligned}$$

Find T_3

$$\begin{aligned}
 T_3 &= \frac{P_3 V_3}{R} \\
 T_3 &= 1731 \text{ K}
 \end{aligned}$$

Find T_4

$$\begin{aligned}
 \frac{T_4}{T_3} &= \left(\frac{V_3}{V_4} \right)^{k-1} \\
 T_4 &= 512.7 \text{ K}
 \end{aligned}$$

Find P_4

$$\begin{aligned}
 P_4 &= \frac{RT_4}{V_4} \\
 P_4 &= 169 \text{ kPa}
 \end{aligned}$$

$$W_{\text{net}} = W_{\text{out}} + W_{\text{out}} - W_{\text{in}}$$

$x \rightarrow 3 \quad \quad 3 \rightarrow 4 \quad \quad 1 \rightarrow 2$

$$W_{\text{net}} = P_x (V_2 - V_x) + kR (T_4 - T_3) - kR (T_2 - T_1)$$

$$W_{\text{net}} = 105.1 \frac{\text{kJ}}{\text{kg}} + 822.3 \frac{\text{kJ}}{\text{kg}} - 583.0 \frac{\text{kJ}}{\text{kg}}$$

$$W_{\text{net}} = 344 \frac{\text{kJ}}{\text{kg}}$$

$$q_{\text{in, net}} = q_{\text{in}} + W_{\text{out}} = \Delta U$$

$2 \rightarrow x \quad \quad x \rightarrow 3$

$$= C_v (T_3 - T_2) + W_{\text{out}}$$

$x \rightarrow 3$

$$= 325.7 \frac{\text{kJ}}{\text{kg}} + 105.1 \frac{\text{kJ}}{\text{kg}}$$

$$q_{\text{in}} = 430.8 \frac{\text{kJ}}{\text{kg}}$$

$$\eta = \frac{W_{\text{net}}}{q_{\text{in}}} = \frac{344}{430.8} = .79 = 79\%$$

9-80E) Given: Brayton Cycle

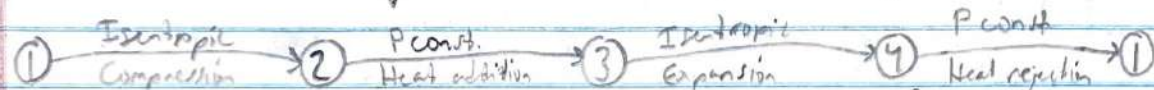
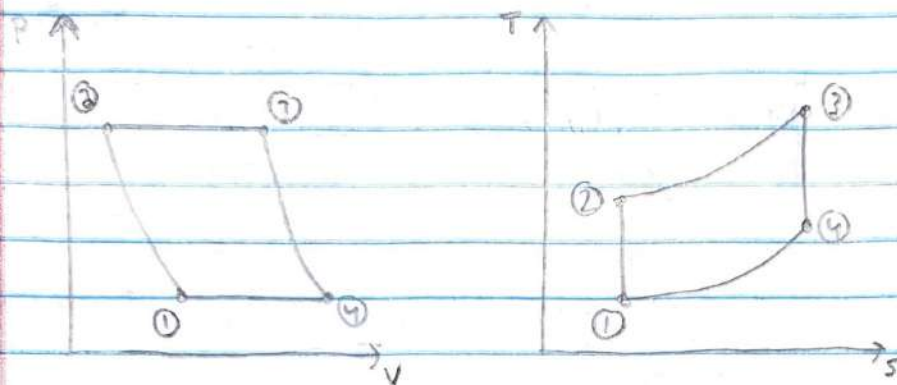
Air

$$r_p = 10$$

$$T_2 = 520R = 289K$$

$$T_4 = 2000R = 1111K$$

C_p, C_v variable



$$T_1 = 289K$$

$$P_2 = 10P_1$$

$$T_3 = 1111K$$

$$P_4 = \frac{P_3}{10}$$

$$P_{r1} = 1.22$$

$$P_{r2} = 12.2$$

$$P_3 = 10P_1$$

$$P_{r4} = 17.4$$

$$h_1 = 289.16$$

$$T_2 = 554K$$

$$P_{r3} = 174.03$$

$$T_4 = 610.94K$$

$$h_2 = 558.91$$

$$h_3 = 1173.84$$

$$h_4 = 618.07$$

Find P_{r1}

Table A-17

(Interpolated using calculator)

Find P_{r2}

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

$$P_{r2} = P_{r1} \left(\frac{P_2}{P_1} \right)$$

$$P_{r2} = 12.2$$

Find $T_2 + T_4$

A-17 interpolate

Find P_{r4}

$$\frac{P_4}{P_3} = \frac{P_{r4}}{P_{r3}}$$

$$P_{r4} = P_{r3} \left(\frac{P_4}{P_3} \right)$$

$$P_{r4} = 17.4$$

Find h_1, h_2, h_3, h_4 - Interpolate

a) $T_2 = 554K$

$$b.) \frac{W_c}{W_r} = \frac{W_{in}}{\frac{W_{out}}{3-27}} = \frac{269.75 \text{ kJ/kg}}{555.77 \text{ kJ/kg}} = \boxed{.49}$$

$$W_{in} = h_2 - h_1 = 269.75 \text{ kJ/kg}$$

$$W_{out} = h_2 - h_4 = 555.77 \text{ kJ/kg}$$

$$c.) \eta = 1 - \frac{1}{r_p^{(k-1)/k}} = .48 = \boxed{48\%}$$