HW 1.3

9.33 - $r = \frac{v_1}{v_2} = 8$ $P_1 = 95 kPa$

$T_1 = 278°C = 551K$

$q_{in} = 750 kJ/kg$

$1 \rightarrow 2$ $T_1 = 551K$

$u_1 = 401.6 kJ/kg$ $v_{r1} = 1.506$

$\frac{v_{r2}}{v_{r1}} = \frac{v_2}{v_1} = \frac{1}{r}$

$v_{r2} = \frac{1.506}{8} = 0.1883$ $v_{r2} = 0.1882 \rightarrow T_2 = 840K$

$u_2 = 670.3 kJ/kg$

$2 \rightarrow 3$

$q_{in} = u_3 - u_2$

$750 = u_3 - 670.3$

$u_3 = 1420.3 kJ/kg$

$u_3 = 1420.3 \rightarrow T_3 = 1539K$

Pressure at state 3

$P_2 = P_1 \cdot r \cdot T_2/T_1$

$P_2 = 95 \cdot 8 \cdot \frac{840}{551}$

$P_2 = 2210 kPa$

$\frac{P_3}{P_2} = \frac{T_3}{T_2}$ $P_3 = 2210 \cdot \frac{1534}{840}$

$P_3 = 3898 kPa$

A) $T_3 = 1534K$

3 → 4 $T_3 = 1534K$

$u_{r3} = 0.0297$

$u_{r4} = u_{r3} \cdot r = 0.0297 \cdot 8 = 0.2376$

$u_{r4} = T_4 = 830k$

$u_4 = 1028\ kJ/kg$

4 → 1 $q_{out} = u_4 - u_1$

$q_{out} = 1028 - 401.6 = 626.4\ kJ/kg$

b) $w_{net} = q_{in} - q_{out}$

$w_{net} = 750 - 626.4$

$w_{net} = 392.4\ kJ/kg$

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

$\eta = \frac{392.4}{750}$

$\eta_{th} = 0.523 = 52.3\%$

d) $MEP = \frac{w_{net}}{v_1 - v_2}$

$v_1 = \frac{RT_1}{P_1} = \frac{0.287 \cdot 551}{95}$

$v_1 = 1.664\ m^3/kg$

$v_2 = \frac{v_1}{r} = \frac{1.664}{8} = 0.208$

$MEP = \frac{392.4}{1.664 - 0.208}$

$MEP = 495\ kPa$

9.36 – $P_1 = 14\ psia$ $T_1 = 105^{\circ}F = 565R$

$T_3 = 2400^{\circ}F = 2860\ R$

Bore $D = 3.5\ in$ Stroke $L = 3.9\ in$

$V_{min} = 0.098V$

$N = 2500\ RPM$ $k = 1.4$

$r = \frac{V_{max}}{V_{min}} = \frac{1}{0.098} = 10.2$

1→2

$T_2 = T_1 r^{k-1}$

$T_2 = 565\,(10.2)^{0.4} = 1430R$

2→3

$T_3 = 2860R$

3→4 $T_3 = 2860R$

3→4 $T_4 = \frac{T_3}{r^{k-1}} = \frac{2860}{2.59} = 1130R$

$q_{in} = Cv(T_3 - T_2)$

$q_{in} = 0.171\,(2860 - 1430) = 244.5\ Btu$

$q_{out} = Cv(T_4 - T_1)$

$q_{out} = 0.171\,(1130 - 565) = 96.6\ Btu$

$W_{net} = q_{in} - q_{out}$

$W_{net} = 147.9\ Btu$

$V_s = \frac{\pi}{4} D^2 L$

$V_s = 37.5 \text{ in}^3$

$V_{max} = \frac{V_s}{1 - 0.096} = 41.6 \text{ in}^3$

$V_{max} = 0.0241 \text{ ft}^3$

$m = \frac{P_1 V_1}{RT_1} = \frac{(14.144)(0.0241)}{0.0687 \cdot 565}$

$m = 1.25 \text{ lbm}$

$W_{cycle} = m w_{net} = 1.25(147.9) = 184.9 \text{ Btu}$

$W_{total} = 6(184.9) = 1107 \text{ Btu}$

$\text{Cycles/sec} = \frac{2500}{2(60)} = 20.83$

$\dot{W} = 1104(20.83) = 23100 \text{ Btu/s}$

$\text{Power} = \frac{23100}{0.707}$

$\text{Power} = 33 \text{ hp}$

9.46) $r=16$ $r_c=2$ $P_1=95\,kPa$ $T_1=278^{\circ}C=551K$

1→2 $T_1=551K$

$u_1=401.6$ $v_{r1}=1.506$

$v_{r2}=\frac{v_{r1}}{r}=\frac{1.506}{16}=0.094$

$v_{r2}=T_2=890K$ $u_2=670kJ/kg$

2→3 $r_c=\frac{v_3}{v_2}=\frac{T_3}{T_2}$ $T_3=r_cT_2=2(890)$

$T_3=1725K$

3→4 $\frac{v_4}{v_3}=\frac{r}{r_c}=\frac{16}{2}=8$

$T_3=1725K$ $v_{r3}=0.0236$

$v_{r4}=8(0.0236)=0.1888$

$v_{r4}=T_4=850K$ $u_4=1020$

B)

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

$\eta=1-\frac{613.4}{900}$

$\eta=0.563=56.3\%$

c) $MEP=\frac{W_{net}}{V_1-V_2}$

$W_{net}=q_{in}-q_{out}=286.6$

$V_1=\frac{RT_1}{P_1}=\frac{0.287(551)}{95}=1.664$

$V_2=\frac{V_1}{r}=0.104$

$MEP=675.9\,kPa$

9.57 - $r=22$ $r_c=1.8$ $P_1=97\,kPa$ $T_1=70°C=343\,K$

$V_d=2.4\,L=2.4\times10^{-3}\,m^3$

$N=3500\,rpm$

1) $T_2=T_1 r^{k-1}$

$T_2=343(22)^{.4}=1180\,K$

$T_3=T_c T_2=1.8(1180)=2124\,K$

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

$T_4=2124\left(\frac{1.8}{22}\right)^{0.4}=783\,K$

$q_{in}=C_p(T_3-T_2)$

$q_{in}=1.005(2124-1180)=949$

$q_{out}=C_v(T_4-T_1)$

$q_{out}=0.719(783-343)=316\,kJ/kg$

$w_{net}=q_{in}-q_{out}=633\,kJ/kg$

$\dot{V}=V_d\frac{N}{60}$

$\dot{V}=2.4\cdot10^{-3}\frac{3500}{60}=0.14$

$\dot{m}=\frac{P_1\dot{V}}{RT_1}=\frac{97(0.14)}{0.287(343)}=0.138\,kg/s$

$\dot{W}=\dot{m}w_{net}$

$\dot{W}=0.138(633)$

$\dot{W}=87.5\,kW$

$=88\,kW$

9.54)

$r = \frac{V_1}{V_2} = 15$ $\quad r_c = \frac{V_4}{V_3} = 1.4$

$\frac{P_3}{P_2} = 1.1$

State 2) $T_2 = T_1 r^{k-1}$

$T_2 = 535 (15)^{0.4} = 1578 R$

State 3) $\frac{T_3}{T_2} = \frac{P_3}{P_2}$ $\quad T_3 = 1.1 \times 1578 = 1736 R$

State 4) $\frac{T_4}{T_3} = \frac{V_4}{V_3} = r_c$

A) $2 \to 3$ $\quad T_4 = 1.4 \times 1736 = 2430 R$

$q_{cv} = C_v (T_3 - T_2)$

$q_{cv} = 0.171 (1736 - 1578) = 27 Btu$

B) $3 \to 4$

$q_{cv} = C_p (T_4 - T_3)$

$q_{cp} = 0.24 (2430 - 1736) = 166.6 Btu$

$q_{in} = 193.6 Btu$

$5 \to 1$) $q_{out} = C_v (T_5 - T_1)$

$q_{out} = 0.171 (943 - 535) = 60.8 Btu$

$W_{net} = q_{in} - q_{out}$

$W_{net} = 123.8 Btu$

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

$\eta = \frac{123.8}{193.6} = \boxed{64\%}$