T6 HOMEWORK SOLUTIONS (WAITZ) (1 OF 2)

A)

LEG	Q	W	
1-2	−	−	(ISOTHERMAL SO $C_v\Delta T=0$, $Q=W$)
2-3	+	0	(CONST. V HEATING)
3-4	0	+	(ADIABATIC EXPANSION)
4-1	−	−	(CONST. P COOLING)

B) LEG 1-2 $q=w$ $w=RT\ln\left(\frac{V_2}{V_1}\right)$

$T_1=300K$, $P_1=100kPa \Rightarrow V_1=\frac{RT_1}{P_1}=0.861\ m^3/kg$

$\frac{P_2}{P_1}=10 \therefore P_2=1000kPa$ $T_2=300K$ (isothermal)

$\therefore V_2=\frac{RT_2}{P_2}=0.0861$

$\boxed{w=-198\ kJ/kg \quad q=-198\ kJ/kg}$

$\boxed{\Delta u=C_v\Delta T=0, \quad \Delta h=C_p\Delta T=0}$

LEG 2-3 $\boxed{w=0}$ (CONST. VOLUME) $\therefore \Delta u=C_v\Delta T=q$

$T_3=1500$ $T_2=300$ $\therefore \Delta u=716.5(1200)=\underline{859.8\ kJ/kg}$

$\Delta h=1003.5(1200)=\underline{1204.2\ kJ/kg}$

$\boxed{q=859.8\ kJ/kg}$

$T_3=1500$, $V_3=0.0861$

$\therefore P_3=RT_3/V_3=5MPa$

LEG 3-4 $pv^\gamma=$CONST.

$q=0$ so $w=-C_v(T_4-T_3)$

$P_3V_3^\gamma=P_4V_4^\gamma$ $P_4=P_1=100kPa$ $P_3=5MPa$

$V_3=0.0861 \therefore V_4=1.41\ m^3/kg$

$\therefore T_4 = \frac{P_4 V_4}{R} = 491\ K$

SO $q = 0$ $\quad w = -76.5(491 - 1500) = 722.7\ kJ/kg$

$\Delta u = -722.7\ kJ/kg$ $\quad \Delta h = C_p(T_4 - T_3) = -1013\ kJ/kg$

LEG 4-1 $\quad P = CONST. \quad dh = \delta q + v\cancel{dp}^{\,0} \quad C_p(T_1 - T_4) = \Delta h = q$

$q = \Delta h = 1003.5(300 - 491) = -191.7\ kJ/kg$ $\quad \Delta u = C_v(T_1 - T_4) = -137\ kJ/kg$

$\Delta u = q - w \quad \therefore w = q - \Delta u = -54.8\ kJ/kg$

C) $W_{cycle} = W_{1-2} + W_{2-3} + W_{3-4} + W_{41}$

$= -198 + 0 + 722.7 - 54.8 = 469.9\ kJ/kg$

D) $\eta = \frac{W_{cycle}}{q_{IN}} = \frac{W_{cycle}}{859.8\ kJ/kg} = 0.547$

E) IN REVERSE, WORK CYCLE = $-469.9\ kJ/kg$

AND ALL SIGNS ON HEAT REVERSED. SO HEAT FLOWS INTO SYSTEM (FROM FOOD SAY) ARE DURING LEGS ②-① & ④-④ $= 198\ kJ/kg + 191.7\ kJ/kg$

$= 389.7\ kJ/kg$

SO 0.83 J COULD BE REMOVED FOR EACH J OF WORK INPUT.