MET 350 : Thermal Apps | HW 1-2 | 25-01-2001

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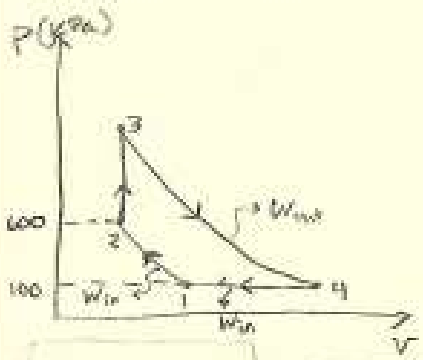
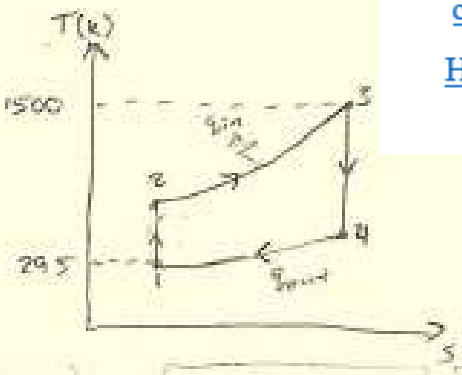
(3) Isentropic Process (Air)





① (1→2)
$P_1 = 100\ kPa$
$T_1 = 295\ K$
$V_1 = .857\ m^3$

② (2→3)
$P_2 = 600\ kPa$
$T_2 = 490\ k$
$V_2 = .234\ m^3$

③ (3→4)
$P_3 = 1839.74\ kPa$
$T_3 = 1500\ k$
$V_3 = V_2 = .234\ m^3$

④ (4→1)
$P_4 = 100\ kpa$
$T_4 = 720\ k$
$V_4 = 2.07\ m^3$

$R_{Air} = .287\ \frac{kJ}{kg \cdot K}$

$$V_1 = \frac{RT_1}{P_1} = \frac{(.287\ \frac{kJ}{kg \cdot K})(295\ K)}{100\ kPa} = .847\ m^3$$

$$\frac{P_2}{P_1} = \frac{P_{r2}}{P_{r1}} \Longrightarrow \frac{600\ kPa}{100\ kPa} = \frac{P_{r2}}{1.3068} \Longrightarrow P_{r2} = 7.8408 \Longrightarrow T_2 = 490\ k$$

$$V_2 = \frac{RT_2}{P_2} = \frac{(.287)(490\ k)}{600\ kPa} = .234\ m^3$$

$$P_3 = \frac{RT_3}{V_3} = \frac{(.287)(1500\ k)}{(.234)} = 1839.74\ kPa$$

$$\frac{P_4}{P_3} = \frac{P_{r4}}{P_{r3}} \Longrightarrow \frac{100\ kPa}{1839.74\ kPa} = \frac{P_{r4}}{601.9} \rightarrow P_{r4} = 32.72 \longrightarrow T_4 = 720\ k$$

$$V_4 = \frac{RT_4}{P_4} \longrightarrow V_4 = 2.0664\ m^3$$

① → ② (Isentropic) ② → ③ (③ → ④ ④ → ① (Isobaric)

Processes:

1→2

$q_{in}^{\nearrow 0} - q_{out}^{\nearrow 0} + w_{in} - w_{out}^{\nearrow 0} = \Delta u \longrightarrow w_{in} = \Delta u = c_v(T_2 - T_1)$

$w_{in} = .718(490 - 295) = 140.01\ \frac{kJ}{kg}$

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2 → 3

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

$q_{in} = C_v(\Delta T) \longrightarrow q_{in} = .718(1500 - 490) = 725.18 \frac{kJ}{kg}$

3 → 4

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

$-W_{out} = .718(720 - 1500) \longrightarrow W_{out} = 560.04 \frac{kJ}{kg}$

4 → 1

$+q_{out} + W_{in} = \Delta u$

$-q_{out} = .718(720 - 295) - 121.3$

$q_{out} = -183.85 \frac{kJ}{kg}$

$W_{in} = P_{1\to4}(\Delta V) = 100\,kPa\,(2.07\,m^3 - .857\,m^3)$

$= 100(1.213)$

$= 121.3 \frac{kJ}{kg}$

$W_{net} = -140.01 \frac{kJ}{kg} - 121.3 \frac{kJ}{kg} + 560.04 \frac{kJ}{kg} = 298.73 \frac{kJ}{kg}$

$q_{in} = 725.18 \frac{kJ}{kg}$

$\eta = \frac{298.73}{725.18} = .411 \longrightarrow 41.1\%$

9-18 $T_1 = 350k$ $T_2 = 1200k$

$P_1 = 150$ kpa

$P_2 = 300$ kpa

$W_{net} = .5kJ$

$P_{max} = ?$

$Q_{in} = ?$

$M_{air} = ?$ $R = .287$ kj/kg·k

from Table A-17

@ 350k - $P_{1r} = 2.379$, $U = 250.02$, $V_r = 422.2$, $S^\circ = 1.85$

@ 1200k - $P_{1r} = 238$, $U = 933.33$, $V_r = 14.48$, $S^\circ = 3.18$

a) $\frac{P_2}{P_1} = \frac{P_{r2}}{P_{r1}}$ P_1 is highest pressure

$P_1 = \frac{P_{r1}}{P_{r2}}(P_2) \rightarrow P_1 = \frac{238}{2.379}(300\text{ kpa}) = \boxed{P_1 = 30.012\text{ Mpa}}$

b) $\eta = \frac{W_{net}}{Q_{in}} = 1 - \frac{T_L}{T_H} \rightarrow \frac{500J}{Q_{in}} = 1 - \frac{350k}{1200k}$

$Q_{in} = \frac{500J}{.7916} = \boxed{Q_{in} = 705.8J}$

c) $\Delta S = (S_2 - S_1) - R\ln\left(\frac{P_2}{P_1}\right)$

$\Delta S = R\ln\left(\frac{P_2}{P_1}\right) \rightarrow .287\ln\left(\frac{300kpa}{150kpa}\right) = .2\text{ kj/kg·k}$

$W = \Delta S(\Delta t)$

$= .2\text{kj/kg·k}\ (1200k - 350k)$

$W = 170\text{ kj/kg}$

$W_{net} = .5kj$, therefore mass $= \frac{.5kJ}{170kJ/kg}$ $\boxed{m = .003kg}$

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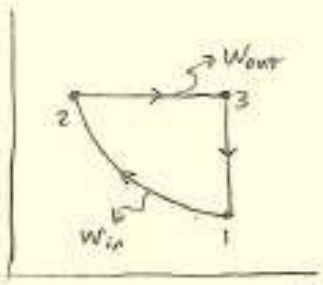
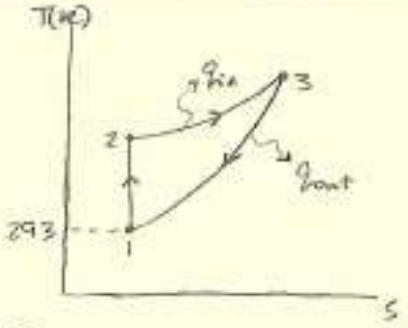
22)





$C_v = 0.7 \frac{kJ}{kg \cdot K}$ $R = 0.2 \frac{kJ}{kg \cdot K}$ $r = 5$

①	②	③
$P_1 =$	$P_2 = P_3$	$P_3 = P_2$
$T_1 = 293 K$	$T_2 = 585.36 K$	$T_3 = 2926.8 K$
$V_1 =$	$V_2 =$	$V_3 = V_1$

$C_v + R = C_p = 1 \frac{kJ}{kg \cdot K}$ $\frac{C_p}{C_v} = k = 1.43$ $r = \frac{V_1}{V_2}$

$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{k-1} \longrightarrow T_2 = T_1 (r)^{k-1} \longrightarrow T_2 = 293(5)^{1.43-1} = 585.36$

$\frac{V_2}{T_2} = \frac{V_3}{T_3} \longrightarrow V_3 T_2 = V_2 T_3 \longrightarrow \left(\frac{V_3}{V_2}\right) T_2 = T_3 \longrightarrow r T_2 = T_3 \longrightarrow 5(585.36) = 2926.8$

Processes

$1 \rightarrow 2$: $q_{in} - q_{out} + W_{in} - W_{out} = C_v (T_2 - T_1)$

$W_{in} = 0.7(585.36 - 293) = 204.652 \frac{kJ}{kg}$

$2 \rightarrow 3$: $q_{in} - q_{out} + W_{in} - W_{out} = C_v (T_3 - T_2)$ $\quad q_{in} = C_p (T_3 - T_2)$

$q_{in} - W_{out} = .7(2926.8 - 585.36)$ $\quad q_{in} = 2341.44 \frac{kJ}{kg}$

$W_{out} = 2341.44 - .7(2926.8 - 585.36) = 702.43 \frac{kJ}{kg}$

$3 \rightarrow 1$: $q_{in} - q_{out} + W_{in} - W_{out} = C_v (T_1 - T_3)$

$-q_{out} = .7(293 - 2926.8) = -1843.66$

$q_{out} = 1843.66 \frac{kJ}{kg}$

$W_{net} = -204.652 + 702.43 = 497.78 \frac{kJ}{kg}$ $\quad \eta = \frac{497.78}{2341.44} = .213 = \boxed{21.3\%}$

$1 \longrightarrow 2 = W_{in} = C_v \left(T_1 (r)^{k-1} - T_1\right) \longrightarrow W_{in} = C_v T_1 \left((r)^{k-1} - 1\right)$

$2 \longrightarrow 3 = W_{out} = C_p \left(r T_1 (r)^{k-1} - T_1 (r)^{k-1}\right) - C_v \left(r T_1 (r)^{k-1} - T (r)^{k-1}\right)$

$W_{out} = C_p T_1 (r)^{k-1} (r-1) - C_v T_1 (r)^{k-1} (r-1)$

$$\eta = \frac{\left[C_p T_1 (r)^{k-1} (r-1) - C_v T_1 (r)^{k-1} (r-1)\right] - \left[C_v T_1 \left((r)^{k-1} - 1\right)\right]}{\left[C_p T_1 (r)^{k-1} (r-1)\right]}$$

9-31

C.R. = 10.5

P_{in} = 9 kpa

T_{in} = 40°C (+273)

n = 2500 rpm

W_{out} = 90 kw

η = ?

Q_{in} = ?

Table A-2

Air @ 300 k C_p = 1.005, C_v = .718

Table A-17

T_1 @ 310 k U_1 = 221.25 V_{r1} = 572.3

$$\eta_{o.H.} = 1 - \frac{1}{r^{k-1}} \rightarrow k = \frac{C_p}{C_v} = \frac{1.005}{.718} = 1.4$$

$$\eta = 1 - \frac{1}{10.5^{(1.4-1)}}$$

$$= 1 - .3904$$

$$\boxed{\eta = 60.9\%}$$

$$\eta = \frac{W_{net}}{Q_{in}} \rightarrow .609 = \frac{90\ kw}{Q_{in}} \rightarrow \boxed{Q_{in} = 147.8\ kw}$$