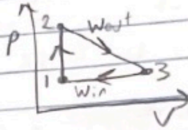
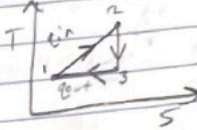
9-13

Nathan CherryS

$m = 0.003\,kg$

1-2





$V_1 = V_2$

$P_1V_1 = RT_1 \qquad \frac{0.287 \cdot 290}{95} = 0.876\,m^3 = V_1$

$P_1 = 95\,kpa$
$T_1 = 290\,°K$
$R = 0.287\,kJ/kg\cdot K$

$V_1 = V_2$

$PV = RT$

$P_2 = 380\,kpa \qquad \frac{380\,kpa \cdot 0.876\,m^3}{0.287\,kJ/kg\cdot k} = 1160\,°K = T_2$

State 1 $\xrightarrow{\text{combustion}}$ State 2 $\xrightarrow{\text{expansion}}$ State 3 $\xrightarrow{\text{exhaust}}$

State 1
$P_1 = 95\,kpa$
$T_1 = 240\,°K$
$V_1 = 0.876\,m^3$

State 2
$V_2 = 0.876\,m^3$
$P_2 = 380\,kpa$
$T_2 = 1160\,°K$

State 3
$P_3 = 95\,kpa$

$Pr_2 @ 1160 = 207.2$

$\frac{P_3}{P_2} = \frac{Pr_3}{Pr_2} = \frac{95\,kpa}{380\,kpa} \cdot 207.2 = 51.8$

↓ interpolate ↓ 800 - 820

$\frac{V_3}{V_1} = \frac{T_3}{T_1}$

$V_3 = 2.467\,m^3$

$T_3 = 816.53553\,°K$

$W = \frac{P_2V_2 - P_1V_1}{1-n} = \frac{R(T_2 - T_1)}{1-n}$

2-3 isentropic expansion

$q_{in} - q_{out} + W_{in} - W_{out} = \Delta U$
$\quad 0 \qquad 0 \qquad 0$

A-17

$-W_{out} = \Delta U \qquad U_2 = 892.91\,kJ/kg$

$-W_{out} = 605\,kJ/kg - 897.91\,kJ/kg \qquad U_3 = 605.9311\,kJ/kg$

$W_{out} = 291.9789\,kJ/kg$

3-1 exhaust and reset

$W_{in} = P_0(V_3 - V_1)$
$= 95\,kpa(2.467\,m^3 - 0.876\,m^3)$
$W_{in} = 151.155\,kJ/kg$

$W_{net} = W_{out} - W_{in}$
$= 291.9789 - 151.155$
$W_{net} = 140.824\,kJ/kg \cdot 0.003\,kg$
$\boxed{W_{net} = 0.4225\,kJ}$

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

1-2 combustion 1st Law $\rightarrow q_{in} - \cancel{q_{out}} + \cancel{W_{in}} - \cancel{W_{out}} = \Delta U$
$\qquad 0 \quad 0 \quad 0$

$q_{in} = \Delta S = s_2^\circ - s_1^\circ - R \cdot \ln\left(\frac{P_2}{P_1}\right)$

$(3.13916 - 1.66802) - 0.287\,kJ/kg\cdot k \cdot \ln\left(\frac{380\,kpa}{95\,kpa}\right)$
$kJ/kg\cdot K$

$q_{in} = 1.0733\,\frac{kJ}{kg\cdot k} \cdot \Delta T_{1-2} = (1160 - 290)\,K \cdot 1.0733\,kJ$

$q_{in} = 933.748\,kJ/kg \cdot 0.003\,kg$
$= 2.8\,kJ$

$\eta_{th} = \frac{0.4225\,kJ}{2.8\,kJ} = 0.151$

$\boxed{15\%}$

9-18 Nathan Chernys

$T_L = 350°K$ $P_1 = 150 kpa$ $W_{net} = 0.5 kJ$

$T_H = 1200°K$ $P_2 = 300 kpa$

→ ① $\xrightarrow{\text{isotherm. comp.}}$ ② $\xrightarrow{\text{Adiabatic compr.}}$ ③ $\xrightarrow{\text{isothermal expans.}}$ ④ $\xrightarrow{\text{Adiabatic expan}}$ A-17

①	②	③	④
low P	low P	high P	High P
high V	low V	low V	High V
		max P	

$350°K = Pr_1 = 2.379$

$1200°K = Pr_3 = 238$

$\frac{P_3}{P_1} = \frac{Pr_3}{Pr_1}$

$P_3 = \frac{238}{2.379} \cdot 300 kpa$

$P_3 = 30012.61 kpa$

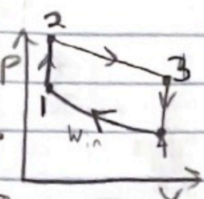
Carnot cycle

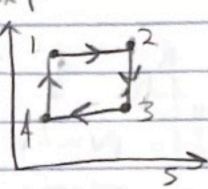
isothermal compression (1)

Adiabatic compression (2)

isothermal expansion (3)

Adiabatic expansion (4)





ⓐ $\boxed{P_{max} = 30 \times 10^3 \text{ Kpa}}$

equation sheet 1 → Carnot cycle η_{th} efficiency → $\eta_{th} = 1 - \frac{T_L}{T_H} = 1 - \frac{350°K}{1200°K} = \boxed{0.70833 = \eta_{th}}$ ⓑ

$\eta_{th} = \frac{W_{net}}{q_{in}} \rightarrow W_{net} = 0.5 kJ$, $\eta_{th} = 0.70833$ $\rightarrow \frac{0.5 kJ}{0.70833} = 0.70588 kJ = q_{in}$

$\Delta S = S_2^\circ - S_1^\circ - R \cdot \ln\left(\frac{P_2}{P_1}\right) \rightarrow 0 = (S_2^\circ - S_1^\circ) - 0.287 \, kJ/kg \cdot K \cdot \ln\left(\frac{300 kPa}{150 kPa}\right)$

$S_2 - S_1 = S_4 - S_3$

$= -0.198933 \, kJ/kg \cdot K$

$S_1 - S_2 = -0.198933 \, kJ/kg \cdot K$

$S_2 - S_1 = .1989 \, kJ/kg \cdot K$

$0.1989 \cdot \Delta T = 0.1989 \, \frac{kJ}{kg \cdot K} \cdot (1200 K - 350 K) = 169.0933 \, kJ/kg$

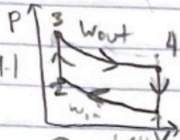
$\frac{W(kJ)}{W_{net}(kJ/kg)} \rightarrow \frac{0.5 kJ}{169.0933 kJ/kg} = \boxed{0.002957 kg}$ ⓒ

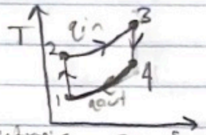
9-22C

Nathan chernys

1) compression stroke → most of the work done
2) expansion stroke →
3) exhaust stroke → Small bit of work to reset system
4) intake stroke →

9-31





$K = 1.4 \rightarrow 1.4-1$

9-30 $r = 9$

→ ① isentropic compression → ② V const → ③ isentropic expansion → ④ V const

$0.87 m^3 = V_1$

$90 kPa = P_1$

$288°K = T_1$

$V_2 = \frac{V_1}{9} = 0.0967 m^3$

$T_2 = 693.55$

$V_3 = 0.0967 m^3$

$1073°K = T_3$

$V_4 = 9V_3 = 0.8703 m^3$

$T_4 = 445.62°K$

ideal gas $PV_1 = RT_1 \rightarrow V_1 = 0.287 \frac{kJ}{kg \cdot K} \cdot 288°K / 95 kPa = V_1 = 0.87 m^3$

compression ratio $r = \frac{V_1}{V_2} = \frac{V_4}{V_3} \rightarrow 9 = \frac{V_1}{V_2}$

$\hookrightarrow V_4 = 9V_3$

const specific heat $\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{k-1}$

$T_2 = \left(\frac{0.87 m^3}{0.0967 m^3}\right)^{1.4-1} \cdot 288°K$

$T_2 = 693.55°K$

$T_4 = T_3 \cdot \left(\frac{V_3}{V_4}\right)^{1.4-1} = 1073°K \cdot \left(\frac{0.0967 m^3}{0.87 m^3}\right)^{0.4} = T_4 = 445.62°K$

work produced → $W_{net} = 105 KW$

Constant sh → $C_v = 0.718 \frac{kJ}{kg \cdot K}$

thermal efficiency → $\eta th = \frac{W_{net}}{Q_{in}}$

$\frac{W_{net}}{\eta th} = Q_{in}$

$\eta th = 1 - \frac{1}{r^{k-1}} = 0.585$

$58\% = \eta th$

heat Addition → $\frac{105 KW}{0.585} = \boxed{179.562 KW = Q_{in}}$

Work of an otto cycle

$W_{net} = Q_{in} - Q_{out} = 105 KW - 179.562 KW = \boxed{-74.562 KW = Q_{out}}$

heat rejection →