

9-13:

Thermo App.

HW 1.2

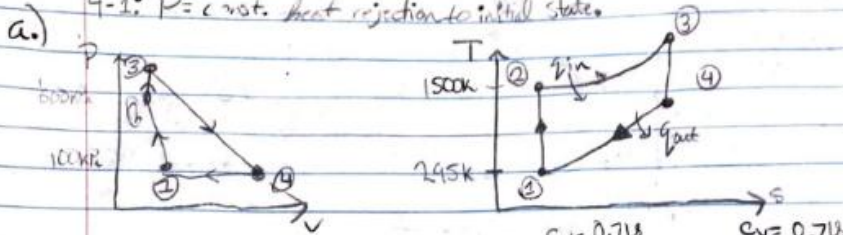
Ch 9 13: An air-standard cycle w/ variable specific heats is executed in closed system. Composed of four processes:

1-2: Isentropic compression from 100 kPa, 22°C to 600 kPa.

2-3: V = const. heat addition to 1500 K.

3-4: Isentropic expansion to 100 kPa.

4-1: P = const. heat rejection to initial state.



$$P_1 = 100 \text{ kPa} \quad P_2 = 600 \text{ kPa} \quad P_3 = 1228.48 \text{ kPa} \quad P_4 = 100 \text{ kPa}$$

$$T_1 = 22^\circ\text{C} \rightarrow 295 \text{ K} \quad T_2 = 492.21 \text{ K} \quad T_3 = 1500 \text{ K} \quad T_4 = 653.87 \text{ K}$$

$$k = 1.4 \quad u_1 = 210.49 \text{ kJ/kg} \quad u_2 = 353.718 \text{ kJ/kg} \quad u_3 = 1205.41 \text{ kJ/kg} \quad u_4 = 476.253 \text{ kJ/kg}$$

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} \Rightarrow T_2 = \left(\frac{600}{100}\right)^{\frac{1.4-1}{1.4}} \times 295 \text{ K} \Rightarrow T_2 = 492.21 \text{ K}$$

$$\frac{P_2}{T_2} = \frac{P_3}{T_3} \Rightarrow P_3 = 1228.48 \text{ kPa}$$

$$\frac{T_4}{T_3} = \left(\frac{P_4}{P_3}\right)^{\frac{k-1}{k}} \Rightarrow T_4 = \left(\frac{100}{1228.48}\right)^{\frac{1.4-1}{1.4}} \times 1500 \text{ K} \Rightarrow T_4 = 653.87 \text{ K}$$

b.) Calc. net work output per unit mass:

$$(q_{in} - q_{out}) + (w_{in} - w_{out}) = \Delta u \Rightarrow w_{net} = -\Delta u$$

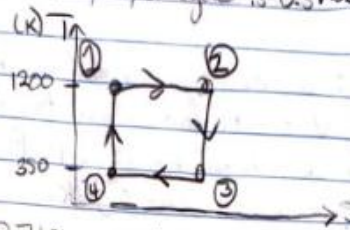
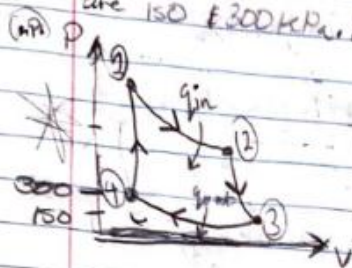
$$w_{net} = 476.253 - 210.49 \Rightarrow w_{net} = 265.763 \text{ kJ/kg}$$

c.) Thermal efficiency: $\eta_{th} = 1 - \frac{q_{out}}{q_{in}} = 1 - \frac{c_v(T_4 - T_1)}{c_v(T_3 - T_2)} = 1 - \frac{0.718(653 - 295)}{0.718(1500 - 492)}$

$$\eta_{th} = 0.644$$

9-18:

9-18: Air-standard Carnot cycle executed in closed system bell crank limits 350 & 1200 K. The pressures before & after isothermal compression are 150 & 300 kPa. Net work output per cycle is 0.5 kJ.



$$T_L = 350 \text{ K}$$

$$T_H = 1200 \text{ K}$$

$C_v = 0.718$ $k = 1.4$
 ① $P_1 = ?$ kPa ② $P_2 = ?$
 $T_1 = 1200 \text{ K}$ $T_2 = ?$
 $S^\circ = 3.1789 \text{ kJ/kg} \cdot \text{K}$
 $P_{r1} = 23.8$ $W_{\text{net}} = 0.5 \text{ kJ}$
 ③ $P_3 = 150 \text{ kPa}$ ④ $P_4 = 300 \text{ kPa}$
 $T_3 = ?$ $T_4 = 350 \text{ K}$
 $P_{r4} = 2.371$

a) Max. pressure in the cycle:

$$\frac{P_2}{P_1} = \frac{P_{r2}}{P_{r1}} = \frac{P_1}{P_4} = \frac{23.8}{2.371} \times 300 = 30,012 \text{ kPa} \Rightarrow 30 \text{ MPa}$$

b) Heat transfer to air: $W_{\text{net}} = 0.5 \text{ kJ}$

$$\eta_{\text{th}} = \frac{W_{\text{net}}}{Q_{\text{in}}} \Rightarrow \eta_{\text{th}} = 1 - \frac{350}{1200} \Rightarrow \eta_{\text{th}} = 0.708$$

$$0.708 = \frac{0.5 \text{ kJ}}{Q_{\text{in}}} \Rightarrow Q_{\text{in}} = \frac{0.5 \text{ kJ}}{0.708} = 0.7062 \text{ kJ} = Q_{\text{in}}$$

c) Mass of air:

$$Q = m \cdot c_v \Delta T \Rightarrow m = \frac{Q}{c_v \Delta T} = \frac{0.7062 \text{ kJ}}{0.718 \text{ kJ/kg} \cdot \text{K} \cdot (1200 \text{ K} - 350 \text{ K})}$$

$$m = 0.00157 \text{ kg}$$

b) $w_{2-3} = q_{23} - \Delta u_{23}$ $q_{23} = 2333.56 \text{ kJ/kg}$
 $\Delta u_{23} = u_2 - u_3 \Rightarrow C_v(T_3 - T_2) \Rightarrow 0.7 \text{ kJ/kg} \cdot (2917.4 \text{ K} - 583.4 \text{ K})$

$w_{23} = 2333.56 \text{ kJ/kg} - 1633.8 \text{ kJ/kg}$ $\Delta u_{23} = 1633.8 \text{ kJ/kg}$

$w_{23} = 699.76 \text{ kJ/kg}$

$q_{23} = 2333.56 \text{ kJ/kg}$

$w_{3-1} = 0$ $V_{01} = \text{const}$

$q_{3-1} = \Delta u_{3-1}$

const vol. $q_{3-1} = C_v \Delta T \Rightarrow q_{3-1} = 0.7 \text{ kJ/kg} \cdot (2917.4 \text{ K} - 293 \text{ K})$

$T_3 = 2917.4 \text{ K}$

$T_1 = 293 \text{ K}$

$q_{3-1} = -1834.98 \text{ kJ/kg}$

c) Find thermal efficiency:

$\eta_{th} = 1 - \frac{w_{net}}{q_{in}} \Rightarrow 1 - \frac{q_{out}}{q_{in}} \Rightarrow \eta_{th} = \frac{1834.98}{2333.56} \Rightarrow 0.786 = \eta_{th}$

d) Thermal efficiency represented as compression ratio & ratio of specific heats k :

$k = \frac{C_p}{C_v}$

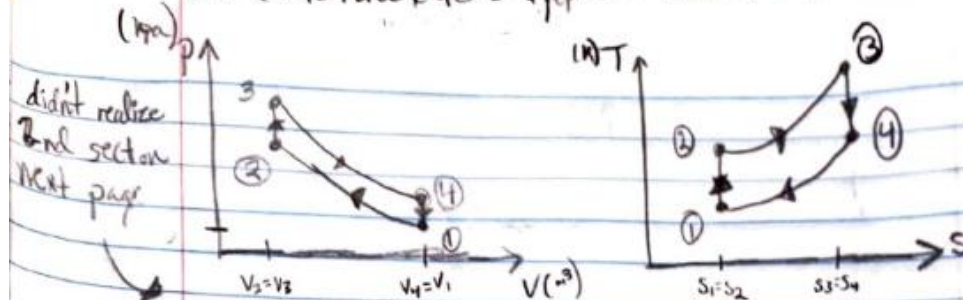
$\eta_{th} = 1 - \frac{q_{out}}{q_{in}} \Rightarrow \eta_{th} = 1 - \frac{C_v(T_3 - T_1)}{C_p(T_3 - T_2)}$

$\eta_{th} = 1 - \frac{1}{k} \times \frac{T_3 - T_1}{T_3 - T_2}$

What about r ?

9-31:

9-31 An ideal Otto cycle has compress ratio of 10.5.
Air @ 90 kPa & 40°C & repeated 2500 times per minute.



Using const. specific heats at room temp. find Thermal efficiency of cycle & rate of heat input if produces 90 kW of Power.

$$W_{net} = 90 \text{ kW}$$

①	②	③	④
$C_p = 1.005 \frac{\text{kJ}}{\text{kg} \cdot \text{K}}$	$P_1 = 90 \text{ kPa}$	$V_2 = V_1 \Rightarrow V_2 = \frac{V_1}{10.5}$	$V_4 = 10.5 V_3$
$C_v = 0.718 \frac{\text{kJ}}{\text{kg} \cdot \text{K}}$	$T_1 = 40^\circ\text{C} \Rightarrow 313 \text{ K}$	$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma}$	
$\gamma = 1.4$	$V_1 = RT_1$	$T_2 = 298.04 \text{ K}$	
$K = 1.4$	$\frac{P_1 V_1^\gamma = P_2 V_2^\gamma}{P_1 V_1 = P_2 V_2}$	$P_2 = 945.0 \text{ kPa}$	
	$\frac{0.227 \times 333}{90} = 0.827$	$V_1 = 1.0619 \text{ m}^3/\text{kg}$	
		$\frac{T_2}{V_2} = \frac{T_1}{V_1} \times V_2$	

a.) Thermal efficiency of cycle:

$$\eta_{th, \text{otto}} = 1 - \frac{1}{r^{\gamma-1}} \Rightarrow 1 - \frac{1}{10.5^{(1.4-1)}} \Rightarrow \boxed{0.6096}$$

b.) rate of heat input if produces 90 kW.

$$\eta_{th} = \frac{W_{net}}{Q_{in}} \Rightarrow Q_{in} = \frac{W_{net}}{\eta_{th}} \Rightarrow Q_{in} = \frac{90 \text{ kW}}{0.6096} \times \frac{3600 \text{ s/hr}}{1 \text{ kW}} = \boxed{531496.06 \text{ kJ/hr}}$$