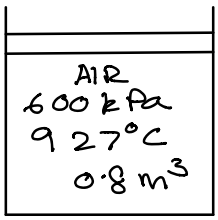
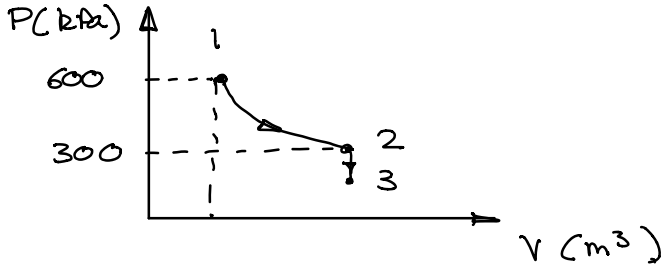
CHE 260 – 2019
QUIZ 1 – SOLUTION

(1)





Mass of air $m = \dfrac{P_1 V_1}{R T_1} = \dfrac{600\ kPa \times 0.8\ m^3}{0.287\ \frac{kJ}{kg\,K} \times (927+273)K}$

$$m = 1.394\ kg$$

For isothermal process

$$w_{12} = P_1 V_1 \ln \frac{V_1}{V_2}$$

For ideal gas with $T_1 = T_2$ $\quad \dfrac{P_1 V_1}{T_1} = \dfrac{P_2 V_2}{T_2} \Rightarrow \dfrac{V_1}{V_2} = \dfrac{P_2}{P_1}$

$$\Rightarrow w_{12} = mRT_1 \ln \frac{P_2}{P_1}$$

$$\Rightarrow w_{12} = 1.394\ kg \times 0.287\ \frac{kJ}{kg\,K} \times 1200K \times \ln \frac{300\ kPa}{600\ kPa}$$

$$w_{12} = -332.8\ kJ$$

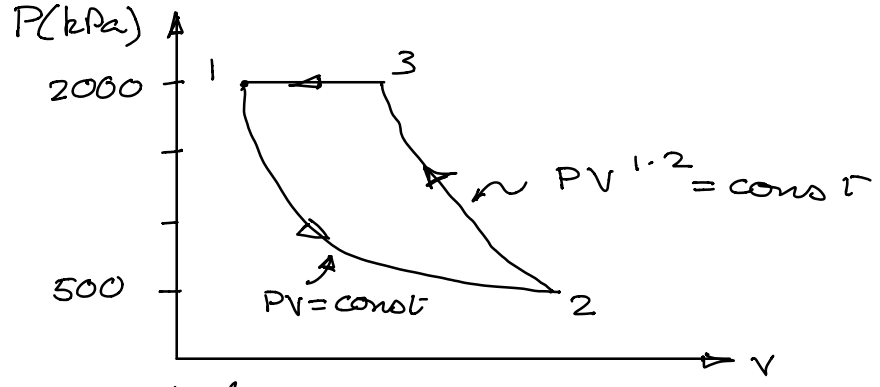
$w_{23} = 0 \Rightarrow w_{13} = w_{12} + w_{23} = -332.8\ kJ$

$$Q_{13} = -W_{13} + mC_V (T_3 - T_1)$$

$$= 332.8\ kJ + 1.394\ kg \times 0.7165\ \frac{kJ}{kg\,K} (300-1200)K$$

$$Q_{13} = -566.1\ kJ$$

(2)



Assuming ideal gas

$$V_1 = \frac{mRT_1}{P_1} = \frac{0.15\,kg \times 0.287\,\frac{kJ}{kg\,K} \times 623\,K}{2000\,kPa} = 0.01341\,m^3$$

$$V_2 = \frac{mRT_2}{P_2} = \frac{0.15\,kg \times 0.287\,\frac{kJ}{kg\,K} \times 623\,K}{500\,kPa} = 0.05364\,m^3$$

Polytropic process $\quad P_2 V_2^{1.2} = P_3 V_3^{1.3}$

$$\Rightarrow \quad 500\,kPa \times (0.05364\,m^3)^{1.2} = 2000\,kPa\; V_3^{1.2}$$

$$\Rightarrow \quad V_3 = 0.01690\,m^3$$

$$W_{12} = P_1 V_1 \ln \frac{V_1}{V_2}$$

$$W_{12} = 2000\,kPa \times 0.01341\,m^3 \ln\left[\frac{0.01341}{0.05364}\right] = -37.18\,kJ$$

$$W_{23} = \frac{P_3 V_3 - P_2 V_2}{n-1}$$

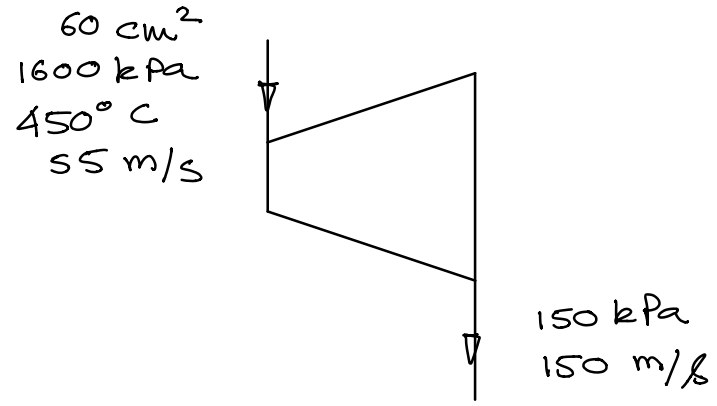
$$W_{23} = \frac{2000\,kPa \times 0.01690\,m^3 - 500\,kPa \times 0.05364\,m^3}{1.2-1} = 34.90\,kJ$$

$$W_{31} = P_3 (V_3 - V_1) = 2000\,kPa\,(0.01690 - 0.01341) = 6.98\,kJ$$

$$W_{net} = W_{12} + W_{23} + W_{31}$$

$$W_{net} = -37.18\,kJ + 34.90\,kJ + 6.98\,kJ = 4.7\,kJ$$

(3)



For Argon $R = 0.20813 \ kJ/kg\,K$

$C_p = 0.5203 \ kJ/kg\,K$.

$$v_1 = \frac{RT_1}{P_1} = \frac{0.20813 \frac{kJ}{kg\,K} \times 723\,K}{1600 \ kPa}$$

$$v_1 = 0.09405 \ m^3/kg$$

$$\dot{m} = \frac{A_1 V_1}{v_1} = \frac{0.006 \ m^2 \times 55 \ m/s}{0.09405 \ m^3/kg} = 3.509 \ \frac{kg}{s}$$

$$\cancel{\dot{Q}}^{\,0} + \dot{W} = \dot{m}\left[(h_2 - h_1) + \frac{V_2^2 - V_1^2}{2}\right]$$

$$\dot{W} = \dot{m}\left[C_p (T_2 - T_1) + \frac{V_2^2 - V_1^2}{2}\right]$$

$$-190 \ kW = 3.509 \frac{kg}{s}\left[0.5203 \frac{kJ}{kg\,K}(T_2 - 450^\circ C) + \frac{(150 \ m/s)^2 - (55 \ m/s)^2}{2 \times 1000 \frac{J}{kJ}}\right]$$

$$\Rightarrow \quad T_2 = 327^\circ C.$$