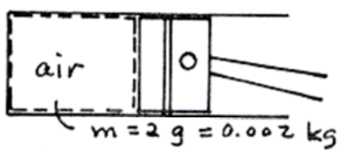
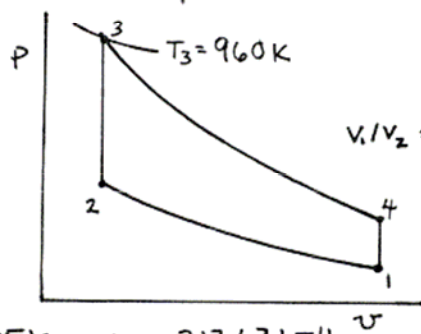
PROBLEM 9.11

KNOWN: An air-standard Otto cycle has a known compression ratio and a specified state at the beginning of compression. The heat addition and the maximum cycle temperature are given.

FIND: Determine (a) the heat rejection, (b) the net work, (c) the thermal efficiency, and (d) the mean effective pressure.

SCHEMATIC & GIVEN DATA:





ENGINEERING MODEL: See Example 9.1.

ANALYSIS: From the given data, $T_1 = 305$ K ; $u_1 = 217.67$ kJ/kg, $v_{r1} = 596.0$. Also, for $T_3 = 960$ K ; $u_3 = 725.02$ kJ/kg, $v_{r3} = 28.40$.
For the isentropic compression

$$v_{r2} = \frac{V_2}{V_1} v_{r1} = \left(\frac{1}{7.5}\right) 596.0 = 79.47$$

Thus, $T_2 = 367.4$ K, $u_2 = 486.77$ kJ/kg. Similarly, for the expansion

$$v_{r4} = \frac{V_4}{V_3} v_{r3} = \frac{V_1}{V_2} v_{r3} = (7.5)\, 28.40 = 213.0$$

Thus, $T_4 = 458.7$ K, $u_4 = 329.01$ kJ/kg.

(a) Consider an energy balance for process 2-3

$$Q_{23} = m(u_3 - u_2) = (0.002\text{ kg})(725.02 - 486.77)\text{ kJ/kg} = 0.4765$$

And, for process 4-1

$$Q_{41} = m(u_4 - u_1) = (0.002\text{ kg})(329.01 - 217.67)\text{ kJ/kg}$$
$$= 0.2227\text{ kJ} \quad \longleftarrow Q_{41}$$

(b) The net work is

$$W_{cycle} = Q_{23} - Q_{41} = 0.4765 - 0.2227 = 0.2538\text{ kJ} \quad \longleftarrow W_{cycle}$$

(c) The thermal efficiency is

$$\eta = \frac{W_{cycle}}{Q_{23}} = 0.533\ (53.3\%) \quad \longleftarrow \eta$$

(d) To determine the mean effective pressure, first find V_1

$$V_1 = \frac{mRT_1}{p_1} = \frac{(0.002\text{ kg})\left(\frac{8.314}{28.97}\frac{\text{kJ}}{\text{kg}\cdot\text{K}}\right)(305\text{ K})}{(85\text{ kPa})}\left|\frac{1\text{ kPa}}{10^3\text{ N/m}^2}\right|\left|\frac{10^3\text{ N}\cdot\text{m}}{1\text{ kJ}}\right| = 2.06\times10^{-3}\text{ m}^3$$

Thus

$$\text{mep} = \frac{W_{cycle}}{V_1 - V_2} = \frac{W_{cycle}}{V_1(1 - V_2/V_1)} = \frac{(0.2538\text{ kJ})}{(2.06\times10^{-3}\text{ m}^3)(1 - 1/7.5)}\left|\frac{10^3\text{ N}\cdot\text{m}}{1\text{ kJ}}\right|\left|\frac{1\text{ kPa}}{10^3\text{ N/m}^2}\right|$$
$$= 142.2\text{ kPa} \quad \longleftarrow \text{mep}$$