Problem 1

**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:**

**ASSUMPTIONS:** Same as in Example 9.1

**ANALYSIS:** From the given data, 

\[ T_1 = 305\,\text{K} \quad u_1 = 217.67\,\text{kJ/kg} \quad u_{m1} = 596.0 \]

Also, for \( T_2 = 960\,\text{K} \quad u_2 = 725.02\,\text{kJ/kg} \quad u_{m2} = 28.40 \)

For the isentropic compression,

\[ u_{r3} = u_3 \quad u_{r4} = u_4 = \frac{u_3}{(\frac{5}{3})} \]

Thus, \( T_3 = 367.4\,\text{K} \quad u_3 = 486.77\,\text{kJ/kg} \)

Similarly, for the expansion,

\[ u_{r5} = u_5 \quad u_{r6} = u_6 = \frac{u_5}{(\frac{7}{5})} \]

Thus, \( T_4 = 458.7\,\text{K} \quad u_4 = 329.01\,\text{kJ/kg} \)

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

\[ Q_{2-3} = m(u_3 - u_2) = (0.002\,\text{kg})(725.02 - 486.77)\,\text{kJ/kg} = 0.4765 \]

And, for process 4-1,

\[ Q_{4-1} = m(u_4 - u_1) = (0.002\,\text{kg})(329.01 - 217.67)\,\text{kJ/kg} = 0.2227\,\text{kJ} \]

(b) The net work is

\[ W = Q_{2-3} - Q_{4-1} = 0.4765 - 0.2227 = 0.2538\,\text{kJ} \]

(c) The thermal efficiency is

\[ \eta = \frac{W}{Q_{2-3}} = 0.533 (53.3\%) \]

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

\[ V_i = \frac{mRT_1}{P_i} = \frac{(0.002\,\text{kg})(18.84\,\text{kJ/kg})}{1\,\text{kPa}} \left( \frac{18.84\,\text{kJ/kg}}{1\,\text{kPa}} \right)^{-1} = 2.06 \times 10^{-3}\,\text{m}^3 \]

Thus

\[ \text{mep} = \frac{W}{V_i(1 - n)} = \frac{(0.2538\,\text{kJ})}{(2.06 \times 10^{-3}\,\text{m}^3)(1 - 1.14)} = 142.2\,\text{kPa} \]
PROBLEM # 2

KNOWN: An air-standard Diesel cycle has a specified state at the beginning of compression and a known pressure and temperature at the end of heat addition.

FIND: Determine (a) the compression ratio, (b) the cutoff ratio, (c) the thermal efficiency, and (d) the mean effective pressure.

SCHEMATIC & GIVEN DATA:

ASSUMPTIONS: See Example 9.2.

ANALYSIS: Begin by fixing each principal state in the cycle (Table A-12).

State 1: \( T_1 = 300 \text{ K} \), \( P_1 = 95 \text{ kPa} \) \( \Rightarrow \) \( u_1 = 214.07 \text{ kJ/kg} \), \( v_1 = 621.2 \), \( P_r = 1.3860 \)

State 2: For the isentropic compression
\[
P_r = Pr \left( \frac{P_2}{P_1} \right) = 1.3860 \left( \frac{3200}{95} \right) = 105.04
\]
Thus, \( T_2 = 979.6 \text{ K} \), \( v_2 = 26.193 \), \( h_2 = 1022.82 \text{ kJ/kg} \)

State 3: \( T_3 = 2150 \text{ K} \), \( P_3 = 7100 \text{ kPa} \) \( \Rightarrow \) \( h_3 = 2440.3 \text{ kJ/kg} \), \( v_3 = 2.175 \)

State 4: For the isentropic expansion
\[
v_4 = \frac{v_3}{v_2} \cdot v_3 = 22.98 \Rightarrow T_4 = 1031 \text{ K} \), \( u_4 = 785.75 \text{ kJ/kg} \)

(a) The compression ratio is
\[
r = \frac{v_2}{v_1} = \frac{621.2}{26.193} = 23.19
\]

(b) The cutoff ratio is
\[
r_c = \frac{v_3}{v_2} = \frac{2150}{979.6} = 2.19
\]

(c) The thermal efficiency is
\[
\eta = \frac{\text{Work in}}{\text{Heat in}} = \frac{(h_2-h_1) - (u_4-u_1)}{h_3-h_2}
\]
\[
= \frac{2440.3 - 1022.82}{(785.75 - 214.07)} = 0.597 (59.7\%)
\]