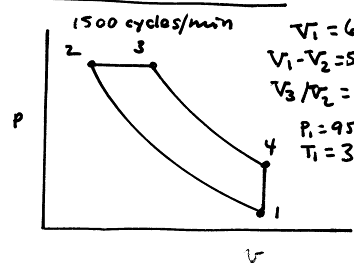
PROBLEM 9.27*

KNOWN: Operating data are provided for an internal combustion engine modeled as an air-standard Diesel cycle.

FIND: Determine the net work per cycle, the power developed, and the thermal efficiency.

SCHEMATIC & GIVEN DATA:



$V_1 = 6.0$ liter

$V_1 - V_2 = 5.6$ liter

$V_3 / V_2 = 2.4$

$p_1 = 95$ kPa

$T_1 = 300$ K

ASSUMPTIONS:

See Example 9.2

ANALYSIS: Using given data, the compression ratio is obtained as follows:

$V_2 = V_1 - 5.6 = 6.0 - 5.6 = 0.4$ liter

$$\Rightarrow \frac{V_1}{V_2} = \frac{6.0}{0.4} = 15$$

Next, data are obtained at each principal state:

State 1: From Table A-22 at $T_1 = 300$ K, $u_1 = 214.07$ kJ/kg, $v_{r1} = 621.2$.

State 2: For the isentropic compression

$$v_{r2} = \frac{V_2}{V_1} v_{r1} = \frac{621.2}{15} = 41.41 \Rightarrow h_2 = 869.63 \text{ kJ/kg}, \; T_2 = 843\text{ K}$$

State 3: Since pressure is constant for process 2-3,

$$\frac{T_3}{T_2} = \frac{V_3}{V_2} \Rightarrow T_3 = (2.4)(843) = 2023\text{ K} \Rightarrow h_3 = 2280.85 \frac{\text{kJ}}{\text{kg}}, \; v_{r3} = 2.6743$$

State 4: For the isentropic expansion

$$\frac{v_{r4}}{v_{r3}} = \frac{V_4}{V_3} = \frac{\overset{= V_1}{V_4}}{V_2} \cdot \frac{V_2}{V_3} = (15)\left(\frac{1}{2.4}\right) = 6.25, \Rightarrow v_{r4} = (6.25)(2.6743) = 16.714$$

$$\Rightarrow u_4 = 884.96 \text{ kJ/kg}$$

The mass is obtained using the ideal gas model equation of state

$$m = \frac{p_1 V_1}{R T_1} = \frac{(95\times10^3 \text{ N/m}^2)(6.0 \text{ liters})}{\left(\frac{8314}{28.97} \frac{\text{N}\cdot\text{m}}{\text{kg}\cdot\text{K}}\right)(300\text{ K})} \left|\frac{10^{-3}\text{ m}^3}{1 \text{ liter}}\right| = 6.62\times10^{-3}\text{ kg}$$

For any cycle, $W_{cycle} = Q_{cycle}$. Processes 1-2 and 3-4 involve no heat transfer; so, $Q_{cycle} = Q_{23} - Q_{41}$, where $Q_{23} = m[h_3 - h_2]$, $Q_{41} = m(u_4 - u_1)$

Thus, $W_{cycle} = (6.62\times10^{-3}\text{kg})[(2280.85 - 869.63) - (884.96 - 214.07)] \text{ kJ/kg}$

$= 4.901$ kJ per cycle ← W_{cycle}

The power developed is

$$\dot{W}_{cycle} = \left(1500 \frac{\text{cycles}}{\text{min}}\right)\left(4.901 \frac{\text{kJ}}{\text{cycle}}\right) \left|\frac{1 \text{ min}}{60 \text{ s}}\right| \left|\frac{1\text{ kW}}{1 \text{ kJ/s}}\right| = 122.53 \text{ kW}$$ ← power

The thermal efficiency is

$$\eta = \frac{W_{cycle}}{\underset{= Q_{23}}{Q_{in}}} = \frac{4.901 \text{ kJ/cycle}}{6.62\times10^{-3}(2280.85 - 869.63) \text{ kJ/cycle}} = \frac{4.901}{9.3423} = 0.525 \, (52.5\%)$$ ← η