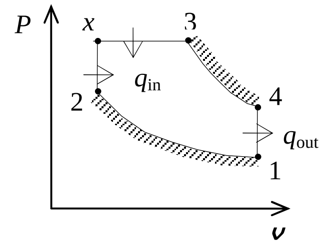
9-54 An ideal dual cycle has a compression ratio of 14 and cutoff ratio of 1.2. The thermal efficiency, amount of heat added, and the maximum gas pressure and temperature are to be determined.

Assumptions **1** The air-standard assumptions are applicable. **2** Kinetic and potential energy changes are negligible. **3** Air is an ideal gas with constant specific heats.

Properties The properties of air at room temperature are c_p = 1.005 kJ/kg·K, c_v = 0.718 kJ/kg·K, R = 0.287 kJ/kg·K, and k = 1.4 (Table A-2).

Analysis The specific volume of the air at the start of the compression is

$$v_1 = \frac{RT_1}{P_1} = \frac{(0.287\ \text{kPa}\cdot\text{m}^3/\text{kg}\cdot\text{K})(253\ \text{K})}{80\ \text{kPa}} = 0.9076\ \text{m}^3/\text{kg}$$



and the specific volume at the end of the compression is

$$v_2 = \frac{v_1}{r} = \frac{0.9076\ \text{m}^3/\text{kg}}{14} = 0.06483\ \text{m}^3/\text{kg}$$

The pressure at the end of the compression is

$$P_2 = P_1\left(\frac{v_1}{v_2}\right)^k = P_1 r^k = (80\ \text{kPa})(14)^{1.4} = 3219\ \text{kPa}$$

and the maximum pressure is

$$P_x = P_3 = r_p P_2 = (1.5)(3219\ \text{kPa}) = \mathbf{4829\ kPa}$$

The temperature at the end of the compression is

$$T_2 = T_1\left(\frac{v_1}{v_2}\right)^{k-1} = T_1 r^{k-1} = (253\ \text{K})(14)^{1.4-1} = 727.1\ \text{K}$$

and $$T_x = T_2\left(\frac{P_3}{P_2}\right) = (727.1\ \text{K})\left(\frac{4829\ \text{kPa}}{3219\ \text{kPa}}\right) = 1091\ \text{K}$$

From the definition of cutoff ratio

$$v_3 = r_c v_x = r_c v_2 = (1.2)(0.06483\ \text{m}^3/\text{kg}) = 0.07780\ \text{m}^3/\text{kg}$$

The remaining state temperatures are then

$$T_3 = T_x\left(\frac{v_3}{v_x}\right) = (1091\ \text{K})\left(\frac{0.07780}{0.06483}\right) = \mathbf{1309\ K}$$

$$T_4 = T_3\left(\frac{v_3}{v_4}\right)^{k-1} = (1309\ \text{K})\left(\frac{0.07780}{0.9076}\right)^{1.4-1} = 490.0\ \text{K}$$

Applying the first law and work expression to the heat addition processes gives

$$\begin{aligned} q_{\text{in}} &= c_v(T_x - T_2) + c_p(T_3 - T_x) \\ &= (0.718\ \text{kJ/kg}\cdot\text{K})(1091 - 727.1)\text{K} + (1.005\ \text{kJ/kg}\cdot\text{K})(1309 - 1091)\text{K} \\ &= \mathbf{480.4\ kJ/kg} \end{aligned}$$

The heat rejected is

$$q_{\text{out}} = c_v(T_4 - T_1) = (0.718\ \text{kJ/kg}\cdot\text{K})(490.0 - 253)\text{K} = 170.2\ \text{kJ/kg}$$

Then, $$\eta_{\text{th}} = 1 - \frac{q_{\text{out}}}{q_{\text{in}}} = 1 - \frac{170.2\ \text{kJ/kg}}{480.4\ \text{kJ/kg}} = \mathbf{0.646}$$