9-2C It is less than the thermal efficiency of a Carnot cycle.

9-9C The MEP is the fictitious pressure which, if acted on the piston during the entire power stroke, would produce the same amount of net work as that produced during the actual cycle.

9-13C Stroke is the distance between the TDC and the BDC, bore is the diameter of the cylinder, TDC is the position of the piston when it forms the smallest volume in the cylinder, and clearance volume is the minimum volume formed in the cylinder.

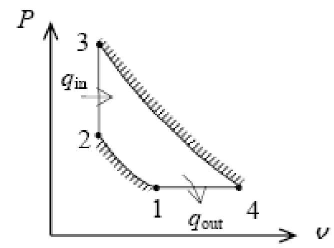
9-53C Cutoff ratio is the ratio of the cylinder volumes after and before the combustion process. As the cutoff ratio decreases, the efficiency of the diesel cycle increases.

9-15 The four processes of an air-standard cycle are described. The cycle is to be shown on P-v and T-s diagrams, and the net work output and the thermal efficiency 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 variable specific heats.

Properties The properties of air are given in Table A-17.

Analysis (*b*) The properties of air at various states are



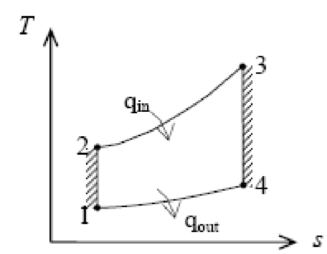
$$T_1 = 300\text{K} \longrightarrow \begin{matrix} h_1 = 300.19 \text{ kJ/kg} \\ P_{r_1} = 1.386 \end{matrix}$$

$$P_{r_2} = \frac{P_2}{P_1} P_{r_1} = \frac{800 \text{ kPa}}{100 \text{ kPa}}(1.386) = 11.088 \longrightarrow \begin{matrix} u_2 = 389.22 \text{ kJ/kg} \\ T_2 = 539.8 \text{ K} \end{matrix}$$

$$T_3 = 1800 \text{ K} \longrightarrow \begin{matrix} u_3 = 1487.2 \text{ kJ/kg} \\ P_{r_3} = 1310 \end{matrix}$$

$$\frac{P_3 v_3}{T_3} = \frac{P_2 v_2}{T_2} \longrightarrow P_3 = \frac{T_3}{T_2} P_2 = \frac{1800 \text{ K}}{539.8 \text{ K}}(800 \text{ kPa}) = 2668 \text{ kPa}$$

$$P_{r_4} = \frac{P_4}{P_3} P_{r_3} = \frac{100 \text{ kPa}}{2668 \text{ kPa}}(1310) = 49.10 \longrightarrow h_4 = 828.1 \text{ kJ/kg}$$



From energy balances,

$$q_{\text{in}} = u_3 - u_2 = 1487.2 - 389.2 = 1098.0 \text{ kJ/kg}$$

$$q_{\text{out}} = h_4 - h_1 = 828.1 - 300.19 = 527.9 \text{ kJ/kg}$$

$$w_{\text{net,out}} = q_{\text{in}} - q_{\text{out}} = 1098.0 - 527.9 = \mathbf{570.1 \text{ kJ/kg}}$$

(*c*) Then the thermal efficiency becomes

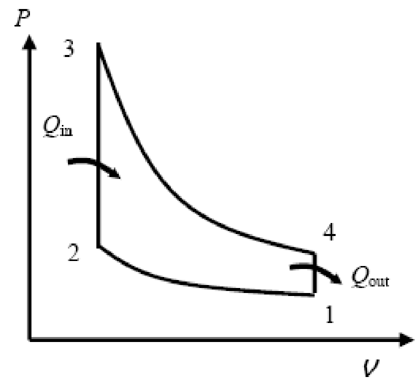
$$\eta_{\text{th}} = \frac{w_{\text{net,out}}}{q_{\text{in}}} = \frac{570.1\text{kJ/kg}}{1098.0\text{kJ/kg}} = \mathbf{51.9\%}$$

9-42 A gasoline engine operates on an Otto cycle. The compression and expansion processes are modeled as polytropic. The temperature at the end of expansion process, the net work output, the thermal efficiency, the mean effective pressure, the engine speed for a given net power, and the specific fuel consumption 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 850 K are $c_p = 1.110$ kJ/kg·K, $c_v = 0.823$ kJ/kg·K, $R = 0.287$ kJ/kg·K, and $k = 1.349$ (Table A-2b).

Analysis (*a*) Process 1-2: polytropic compression



$$T_2 = T_1\left(\frac{v_1}{v_2}\right)^{n-1} = (333\text{ K})(10)^{1.3-1} = 664.4\text{ K}$$

$$P_2 = P_1\left(\frac{v_1}{v_2}\right)^{n} = (100\text{ kPa})(10)^{1.3} = 1995\text{ kPa}$$

Process 2-3: constant volume heat addition

$$T_3 = T_2\left(\frac{P_3}{P_2}\right) = (664.4\text{ K})\left(\frac{8000\text{ kPa}}{1995\text{ kPa}}\right) = 2664\text{ K}$$

$$q_{in} = u_3 - u_2 = c_v(T_3 - T_2)$$
$$= (0.823\text{ kJ/kg}\cdot\text{K})(2664 - 664.4)\text{K} = 1646\text{ kJ/kg}$$

Process 3-4: polytropic expansion.

$$T_4 = T_3\left(\frac{v_3}{v_4}\right)^{n-1} = (2664\text{ K})\left(\frac{1}{10}\right)^{1.3-1} = \mathbf{1335\text{ K}}$$

$$P_4 = P_3\left(\frac{v_2}{v_1}\right)^{n} = (8000\text{ kPa})\left(\frac{1}{10}\right)^{1.3} = 400.9\text{ kPa}$$

Process 4-1: constant voume heat rejection.

$$q_{out} = u_4 - u_1 = c_v(T_4 - T_1) = (0.823\text{ kJ/kg}\cdot\text{K})(1335 - 333)\text{K} = 824.8\text{ kJ/kg}$$

(*b*) The net work output and the thermal efficiency are

$$w_{net,out} = q_{in} - q_{out} = 1646 - 824.8 = \mathbf{820.9\text{ kJ/kg}}$$

$$\eta_{th} = \frac{w_{net,out}}{q_{in}} = \frac{820.9\text{ kJ/kg}}{1646\text{ kJ/kg}} = \mathbf{0.499}$$

(*c*) The mean effective pressure is determined as follows

$$v_1 = \frac{RT_1}{P_1} = \frac{(0.287\text{ kPa}\cdot\text{m}^3/\text{kg}\cdot\text{K})(333\text{ K})}{100\text{ kPa}} = 0.9557\text{ m}^3/\text{kg} = v_{max}$$

$$v_{min} = v_2 = \frac{v_{max}}{r}$$

$$\text{MEP} = \frac{w_{net,out}}{v_1 - v_2} = \frac{w_{net,out}}{v_1(1-1/r)} = \frac{820.9\text{ kJ/kg}}{(0.9557\text{ m}^3/\text{kg})(1-1/10)}\left(\frac{\text{kPa}\cdot\text{m}^3}{\text{kJ}}\right) = \mathbf{954.3\text{ kPa}}$$

(d) The clearance volume and the total volume of the engine at the beginning of compression process (state 1) are

$$r = \frac{V_c + V_d}{V_c} \longrightarrow 10 = \frac{V_c + 0.0022\ \text{m}^3}{V_c} \longrightarrow V_c = 0.0002444\ \text{m}^3$$

$$V_1 = V_c + V_d = 0.0002444 + 0.0022 = 0.002444\ \text{m}^3$$

The total mass contained in the cylinder is

$$m_t = \frac{P_1 V_1}{R T_1} = \frac{(100\ \text{kPa})/0.002444\ \text{m}^3)}{(0.287\ \text{kPa}\cdot\text{m}^3/\text{kg}\cdot\text{K})(333\ \text{K})} = 0.002558\ \text{kg}$$

The engine speed for a net power output of 70 kW is

$$\dot{n} = 2\frac{\dot{W}_{\text{net}}}{m_t w_{\text{net}}} = (2\ \text{rev/cycle})\frac{70\ \text{kJ/s}}{(0.002558\ \text{kg})(820.9\ \text{kJ/kg}\cdot\text{cycle})}\left(\frac{60\ \text{s}}{1\ \text{min}}\right) = \mathbf{4001\ rev/min}$$

Note that there are two revolutions in one cycle in four-stroke engines.

(e) The mass of fuel burned during one cycle is

$$\text{AF} = \frac{m_a}{m_f} = \frac{m_t - m_f}{m_f} \longrightarrow 16 = \frac{(0.002558\ \text{kg}) - m_f}{m_f} \longrightarrow m_f = 0.0001505\ \text{kg}$$

Finally, the specific fuel consumption is

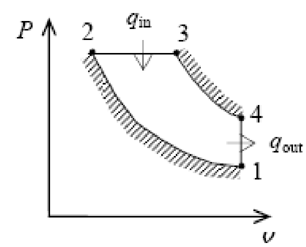
$$\text{sfc} = \frac{m_f}{m_t w_{\text{net}}} = \frac{0.0001505\ \text{kg}}{(0.002558\ \text{kg})(820.9\ \text{kJ/kg})}\left(\frac{1000\ \text{g}}{1\ \text{kg}}\right)\left(\frac{3600\ \text{kJ}}{1\ \text{kWh}}\right) = \mathbf{258.0\ g/kWh}$$

9-55 An ideal diesel cycle has a compression ratio of 18 and a cutoff ratio of 1.5. The maximum temperature of the air and the rate of heat addition 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 $R = 0.287$ kPa·m^3/kg·K, $c_p = 1.005$ kJ/kg·K, $c_v = 0.718$ kJ/kg·K, and $k = 1.4$ (Table A-2a).

Analysis We begin by using the process types to fix the temperatures of the states.



$$T_2 = T_1\left(\frac{v_1}{v_2}\right)^{k-1} = T_1 r^{k-1} = (290\text{ K})(18)^{1.4-1} = 921.5\text{ K}$$

$$T_3 = T_2\left(\frac{v_3}{v_2}\right) = T_2 r_c = (921.5\text{ K})(1.5) = \mathbf{1382\ K}$$

Combining the first law as applied to the various processes with the process equations gives

$$\eta_{th} = 1 - \frac{1}{r^{k-1}}\frac{r_c^k - 1}{k(r_c - 1)} = 1 - \frac{1}{18^{1.4-1}}\frac{1.5^{1.4} - 1}{1.4(1.5 - 1)} = 0.6565$$

According to the definition of the thermal efficiency,

$$\dot{Q}_{in} = \frac{\dot{W}_{net}}{\eta_{th}} = \frac{200\text{ hp}}{0.6565}\left(\frac{0.7457\text{ kW}}{1\text{ hp}}\right) = \mathbf{227.2\ kW}$$