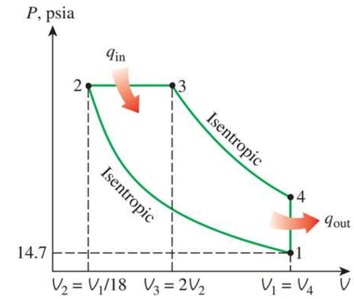
Given:
An ideal Diesel cycle with air as the working fluid has a compression ratio of 18 and a cutoff ratio of 2. At the beginning of the compression process, the working fluid is at 14.7 psia, 80°F, and117 in3.

$r := 18$ $r_c := 2$ $P_1 := 14.7\ \text{psi}$ $T_1 := 80\ °\text{F}$ $V_1 := 117\ \text{in}^3$



Required:
Utilizing the cold-air-standard assumptions, determine the temperature and pressure of air at the end of each process, the net work output and the thermal efficiency, and the mean effective pressure.

Solution:
Since the cold-air-standard assumption may be used, air may be treated as having constant specific heats at room temperature. Furthermore, the properties of air may be found from Table A-2E(a). This is shown below.

$R_{air} := 0.06855\ \frac{\text{BTU}}{\text{lbm}\ °\text{Ra}}$ $c_p := 0.240\ \frac{\text{BTU}}{\text{lbm}\ °\text{Ra}}$ $c_v := 0.171\ \frac{\text{BTU}}{\text{lbm}\ °\text{Ra}}$ $k := 1.4$

The volumes for each state may be determined using the compression ratio and cutoff ratio. This is shown below.

$r = \frac{V_1}{V_2}$ $V_2 := \frac{V_1}{r} = 6.500\ \text{in}^3$

$r_c = \frac{V_3}{V_2}$ $V_3 := r_c \cdot V_2 = 13.00\ \text{in}^3$

$V_4 := V_1 = 117.0\ \text{in}^3$

Since the process from 1 to 2 is isentropic and has constant specific heats, the following is true.

$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{k-1}$ $\boxed{T_2 := T_1 \cdot \left(\frac{V_1}{V_2}\right)^{k-1} = 1715\ °\text{Ra}}$ $\boxed{T_2 = 1255\ °\text{F}}$

$\frac{P_2}{P_1} = \left(\frac{V_1}{V_2}\right)^{k}$ $\boxed{P_2 := P_1 \cdot \left(\frac{V_1}{V_2}\right)^{k} = 840.8\ \text{psi}}$

From state 2 to 3, the pressure is constant so

$\boxed{P_3 := P_2 = 840.8\ \text{psi}}$

The Ideal Gas Law may be use to determine the temperature at state 3.

$P \cdot V = m \cdot R \cdot T$

$const = \frac{m \cdot R}{P}$ thus $\frac{V_2}{T_2} = \frac{V_3}{T_3}$ $\boxed{T_3 := T_2 \cdot \frac{V_3}{V_2} = 3430\ °\text{Ra}}$ $\boxed{T_3 = 2970\ °\text{F}}$

Since the process from 3 to 4 is isentropic and has constant specific heats, the following is true.

$\frac{T_4}{T_3} = \left(\frac{V_3}{V_4}\right)^{k-1}$ $\boxed{T_4 := T_3 \cdot \left(\frac{V_3}{V_4}\right)^{k-1} = 1424\ °\text{Ra}}$ $\boxed{T_4 = 964.5\ °\text{F}}$

$\frac{P_4}{P_3} = \left(\frac{V_3}{V_4}\right)^{k}$ $\boxed{P_4 := P_3 \cdot \left(\frac{V_3}{V_4}\right)^{k} = 38.79\ \text{psi}}$

Solution (contd.):
The mass contained in the cycle may be determined by the Ideal Gas law at state 1.

$$P \cdot V = m \cdot R \cdot T \qquad \text{so} \qquad m := \frac{P_1 \cdot V_1}{R_{air} \cdot T_1} = 4.979 \cdot 10^{-3} \text{ lbm}$$

The process from state 2 to 3 is the heat addition stage of the cycle. Since there is boundary work that occurs during this process, the heat added is

$$Q_{in} = m \cdot \left(h_3 - h_2\right)$$

$$Q_{in} := m \cdot c_p \cdot \left(T_3 - T_2\right) = 2.049 \text{ BTU}$$

The process from state 4 to 1 is the heat rejection stage of the cycle. Since the process is a constant volume process, the heat rejected is

$$Q_{out} = m \cdot \left(u_4 - u_1\right)$$

$$Q_{out} := m \cdot c_v \cdot \left(T_4 - T_1\right) = 0.7530 \text{ BTU}$$

The net work of the cycle is then

$$\boxed{W_{net} := Q_{in} - Q_{out} = 1.296 \text{ BTU}}$$

The thermal efficiency is given by

$$\boxed{\eta_{th} := \frac{W_{net}}{Q_{in}} = 63.25\ \%}$$

The mean effective pressure is given by

$$\boxed{MEP := \frac{W_{net}}{V_1 - V_2} = 109.5 \text{ psi}}$$