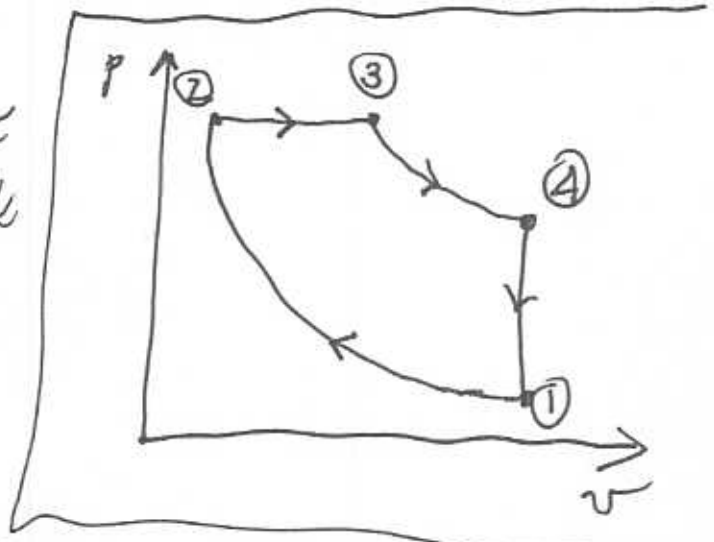
9.20 Air-standard Diesel cycle with constant specific heats (evaluated at 300K)



GIVEN $P_1 = 95\,kPa$ $T_1 = 300K$

$P_3 = 7.2\,MPa$ $T_3 = 2150K$

(a) $r = \frac{v_1}{v_2} = ?$

~~For~~ This is air, an ideal gas, with constant (c_p, c_v). Hence we can use Eq. (6.45)-(6.47) for the isentropic processes

$pv = RT$

$v_1 = \frac{RT_1}{P_1}$ ← known / ← known

Eq. (6.45) $\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{(k-1)/k}$

$P_2 = P_3$ $\frac{T_2}{T_1} = \left(\frac{P_3}{P_1}\right)^{\frac{k-1}{k}}$

Table A-20

$c_p = 1.005\,kJ/kg\cdot K$

$c_v = .718\,kJ/kg\cdot K$ $\Big\}$ $k = 1.400$

$T_2 = 1033K$

$\frac{v_1}{v_2} = \frac{RT_1/P_1}{RT_2/P_2} = \frac{T_1/P_1}{T_2/P_3}$

$r = 22.01$

9.20 (b) The cutoff ratio $r_c = \frac{v_3}{v_2}$

$$v_3 = \frac{RT_3}{P_3} \qquad v_2 = \frac{RT_2}{P_2}$$

$$r_c = \frac{T_3/P_3}{T_2/P_2} = \frac{T_3}{T_2} = \underline{\underline{2.08}}$$

(c) $\eta = ?$ $\quad \eta = \frac{w_{cyc}/m}{q_{23}/m} = 1 - \left(\frac{u_4 - u_1}{h_3 - h_2}\right)$

$$\eta = 1 - \frac{c_v(T_4 - T_1)}{c_p(T_3 - T_2)} = 1 - \frac{(T_4 - T_1)}{k(T_3 - T_2)}$$

T_1: known; k: known; T_3: known; T_2: known

$$\frac{T_4}{T_3} = \left(\frac{v_3}{v_4}\right)^{k-1} \qquad \frac{v_3}{v_4} = \frac{v_3}{v_1}$$

$$r = \frac{v_1}{v_2} \qquad r_c = \frac{v_3}{v_2}$$

$$\frac{v_3}{v_1} = \frac{r_c}{r} = \frac{2.08}{22.01} = 0.0946$$

$$\frac{T_4}{T_3} = (.0946)^{1.40-1} = .389$$

$$T_4 = 837\text{K}$$

$$\eta = 1 - \frac{1}{1.40}\left[\frac{837\text{K} - 300\text{K}}{2150\text{K} - 1033\text{K}}\right] = \underline{\underline{0.657}}$$

9.20 (d) $mep = ?$ $= \dfrac{W_{cyc}}{v_1 - v_2} = \dfrac{W_{cyc}/m}{v_1 - v_2} = \dfrac{W_{cyc}/m}{v_1(1 - v_2/v_1)}$

$$mep = \frac{W_{cyc}/m}{v_1\left(1 - \frac{1}{r}\right)} = ?$$

$W_{cycle}/m = ?$

② → ③ $\quad \Delta U = Q - W \Rightarrow \dfrac{W}{m} = \dfrac{Q}{m} - \dfrac{\Delta U}{m}$

$$\frac{W_{23}}{m} = \frac{Q_{23}}{m} - (u_3 - u_2)$$

$$\frac{Q_{23}}{m} = T ds \qquad T ds = dh - v dp \;(0 \text{ for } ② \to ③)$$

$$\frac{Q_{23}}{m} = h_3 - h_2$$

$$\frac{W_{23}}{m} = h_3 - h_2 - (u_3 - u_2)$$

$$\frac{W_{34}}{m} = u_3 - u_4$$

$$W_{12} = u_2 - u_1$$

$$\frac{W_{cycle}}{m} = h_3 - h_2 - (u_3 - u_2) + u_3 - u_4 - (u_2 - u_1)$$

$$\frac{W_{cyc}}{m} = h_3 - h_2 - (u_4 - u_1) = c_p(T_3 - T_2) - c_v(T_4 - T_1)$$

9.20(d) continued

$$v_1 = \frac{RT_1}{P_1} = \frac{\left(0.287 \frac{kJ}{kg \cdot K}\right)(300K)}{95 kPa} = 0.906 \, m^3/kg$$

$$mep = \frac{\left(1.005 \frac{kJ}{kg \cdot K}\right)(2150K - 1033K) - \left(.718 \frac{kJ}{kg \cdot K}\right)(837K - 300K)}{(.906 \, m^3/kg)\left(1 - \frac{1}{22.01}\right)}$$

$$mep = \frac{737 \, kJ/kg}{.865 \, m^3/kg}$$

$$\boxed{mep = 852 \, kPa}$$