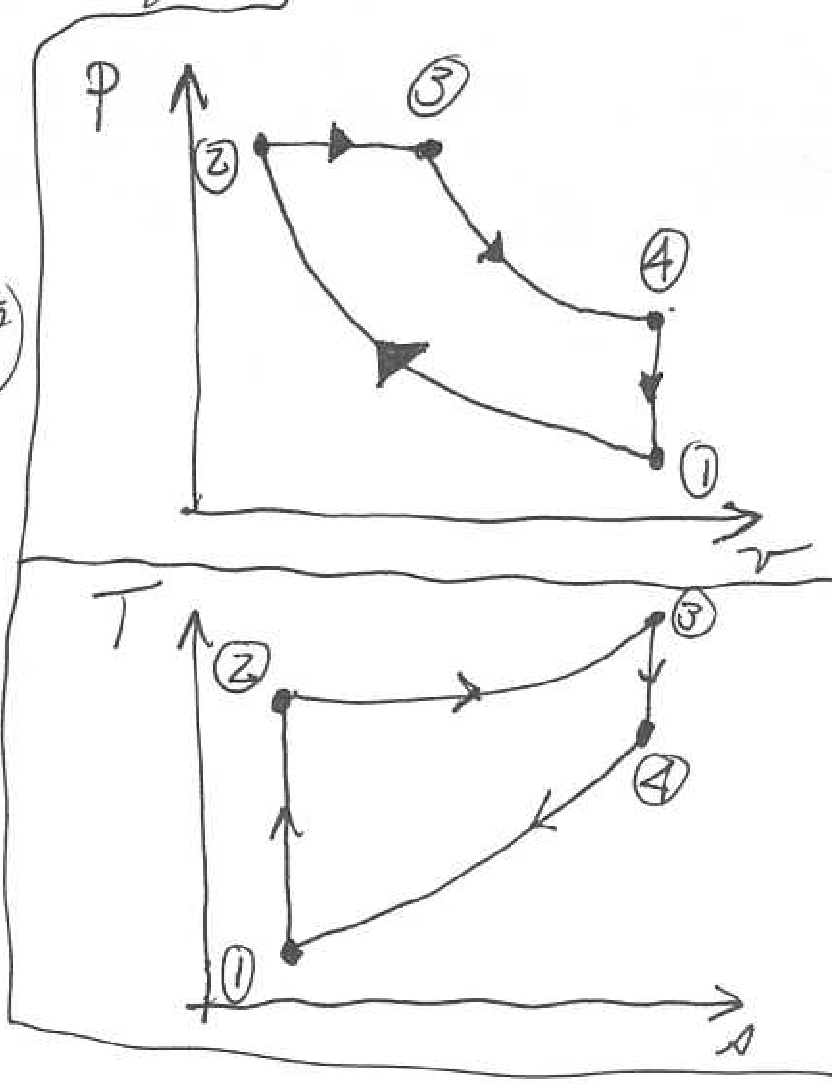
9.19 Air-Standard Diesel Cycle



GIVEN

$P_1 = 95 kPa$

$T_1 = 300 K$

At the end of heat addition ... (state 3)

$P_3 = 7.2 MPa$

$T_3 = 2150 K$

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

Ideal gas, air, so

$R = 0.287\ kJ/kg \cdot K$

$$v_1 = \frac{RT_1}{P_1} = \frac{(.287\ kJ/kg \cdot K)(300 K)}{95 kPa}$$

$v_1 = 0.906\ m^3$

similarly,

$v_3 = 0.086\ m^3$

(1) → (2) is an isentropic process so:

$$\frac{v_2}{v_1} = \frac{v_{r2}}{v_{r1}} \quad \text{and} \quad \frac{P_2}{P_1} = \frac{P_{r2}}{P_{r1}}$$

$P_2 = P_3 = 7200 kPa$

From A-22 $\quad P_{r1} = 1.386 \quad v_{r1} = 621.2$

9.19 continued

$$\frac{W_{2-3}}{m} = \int p\,dv = p_2(v_3 - v_2) = 339\ \frac{kJ}{kg}$$

3-4 $\Delta U = Q - W$ ($Q = 0$) $\frac{W_{3-4}}{m} = u_3 - u_4$

Need State (4)

3 → 4 is isentropic

$$\frac{v_3}{v_4} = \frac{v_{r3}}{v_{r4}} \qquad v_{r3} = 2.175$$

$$v_{r4} = v_{r3}\frac{v_4}{v_3} = v_{r3}\frac{v_1}{v_3} = 22.9$$

→ $T_4 = 1032K$; $u_4 = 786.7\ kJ/kg$

$T_3 = 2150K$; $u_3 = 1823.8\ kJ/kg$

$$\frac{W_{3-4}}{m} = u_3 - u_4 = 1037\ kJ/kg$$

$\frac{W_{1-2}}{m} = u_2 - u_1$ $\qquad T_1 = 300K \quad u_1 = 214.07\ kJ/kg$

$$\frac{W_{1-2}}{m} = 742\frac{kJ}{kg} - 214.07\ kJ/kg = 527.9\ kJ/kg$$

$$\boxed{\frac{W_{net}}{m} = 848.1\ kJ/kg}$$

→

9.19 continued

$$P_{r2} = P_{r1}\frac{P_2}{P_1} = (1.386)\left(\frac{7200\ kPa}{95\ kPa}\right) = 105$$

From A-22 $\Rightarrow$ $T_2 = 980K$, $v_{r2} = 26.73$, $u_2 = 742\frac{kJ}{kg}$

$$\frac{v_2}{v_1} = \frac{v_{r2}}{v_{r1}} \Rightarrow \frac{v_2}{.906 m^3} = \frac{26.73}{621.2} \qquad \underline{v_2 = .0389\ m^3}$$

$$\boxed{r = \frac{v_1}{v_2} = 23.2}$$

(b) The cutoff ratio =?

cutoff ratio $\triangleq r_c = V_3/V_2$

$$\frac{V_3}{V_2}\ \frac{v_3}{v_2} = \frac{0.086 m^3}{0.0389 m^3}$$

$$\boxed{r_c = 2.21}$$

(c) $\eta = ?$ $\qquad \dfrac{W_{net}/m}{Q_H/m}$

$$\frac{W_{net}}{m} = \frac{W_{2-3}}{m} + \frac{W_{3-4}}{m} - \frac{W_{1-2}}{m}$$

9.19 continued

$\frac{Q_H}{m} = ?$

2-3 $\Delta U = Q - W$

$$u_3 - u_2 = \frac{Q_{2-3}}{m} - \frac{W_{2-3}}{m}$$

$$\frac{Q_{2-3}}{m} = u_3 - u_2 + p(v_3 - v_2)$$

$$\frac{Q_{2-3}}{m} = \frac{Q_H}{m} = 1421.8 \text{ kJ/kg}$$

$$\eta = \frac{W_{net}/m}{Q_H/m} = \frac{848.1 \text{ kJ/kg}}{1421.8 \text{ kJ/kg}} = 0.597$$

(d) mep = ?

$$mep = \frac{W_{net}/m}{v_1 - v_2} = \frac{848.1 \text{ kJ/kg}}{.906 m^3 - .0389 m^3}$$

mep = 978 kPa