2. The engine in Problem 1 is a three-liter V6 engine operating at 2400 RPM. At this speed the mechanical efficiency is 84%.

Calculate :

(a) Brake power. [kW]

(b) Torque. [N-m]

(c) Brake mean effective pressure. [kPa]

(d) Friction power lost. [kW]

(e) ~~Bsfc~~ Brake specific fuel consumption. [gm/kW-hr]

(f) Volumetric efficiency [%]

(g) Output displacement. [kW/L]

Ans: $\frac{V_d + V_c}{V_c} = 9.5$ where V_d = Displacement volume, m^3

V_c = Clearance volume, m^3

$\frac{V_d}{V_c} + 1 = 9.5$ $\quad V_d = \frac{3}{6} \times 1000\ cm^3 = 500\ cm^3$ per cylinder

$\frac{V_d}{V_c} = 8.5 \quad \therefore V_c = \frac{V_d}{8.5} = \frac{500}{8.5} = 58.8\ cm^3.$

$\therefore V_1 = V_d + V_c = (500 + 58.8)\ cm^3 = 558.8\ cm^3$

m_1 = mass of charge $= \frac{V_1}{v_1} = \frac{558.8 \times 10^{-6}}{1.025}\ \cancel{kg}\ m^3/(m^3/kg) = 5.45 \times 10^{-4}\ kg$

Brake power $= w_i \times \eta_m \times m \times \frac{N}{60} \times \frac{1}{2}$ kW where, w_i = indicated work/kg of charge

η_m = mechanical efficiency

$= 1395 \times 0.84 \times 5.45 \times 10^{-4} \times \frac{2400}{60 \times 2}$ kW

m = mass of charge, kg

N = Speed of engine, RPM

= 12.8 kW/cylinder.

$\therefore$ Total = 6×12.8 kW = 76.8 kW

Torque, τ (N-m),

$\frac{2\pi N}{60} \times \tau = 12.8 \times 1000$

$\therefore \tau = \frac{12.8 \times 1000 \times 60}{2 \times \pi \times 2400}$ N-m

= 50.9 N-m per cylinder.

$\therefore$ Total = $6 \times 50.9 = 305.4$ N-m

Brake mean effective pressure $= \frac{1395 \times 0.84}{500 \times 10^{-6}}\ \cancel{kPa} \times 5.45 \times 10^{-4}$ kPa

= 1277 kPa

Friction power lost $= 6 \times 5.45 \times 10^{-4} \times 1395 \times 0.16 \cancel{kW} \times \frac{N}{120}$ kW

$= 14.6$ kW

Brake specific fuel consumption

$$bsfc = \frac{\dot{m}_f \times 1000 \times 3600}{W_b}$$ where $\dot{m}_f$ = kg/sec

$$m_f = \frac{m}{16.5} = \frac{5.45 \times 10^{-4}}{16.5} \text{ kg}$$

$$= 3.3 \times 10^{-5} \text{ kg}$$

$$\dot{m}_f = 3.3 \times 10^{-5} \times \frac{N}{120} \text{ kg/sec}$$

$$= 6.61 \times 10^{-4} \text{ kg/sec}$$

$$= \frac{6.61 \times 10^{-4} \times 1000 \times 3600}{12.8}$$

$= 186$ gm/kW-hr

Volumetric efficiency

$$= \frac{m_a}{\rho_a V_d}$$

$$= \frac{\cancel{(5.45 \times 10^{-4})/15.5}\; 3.3 \times 10^{-5} \times 15.5}{1.18 \times 500 \times 10^{-6}}$$

$= 0.867 = 86.7\%$

output per displacement

$$= \frac{12.8}{500 \times 10^{-3}} \text{ kW/L}$$

$= 25.6$ kW/L

(a) Brake power $= 76.8$ kW

(b) Torque $= 305.4$ N-m

(c) bmep $= 1277$ kPa

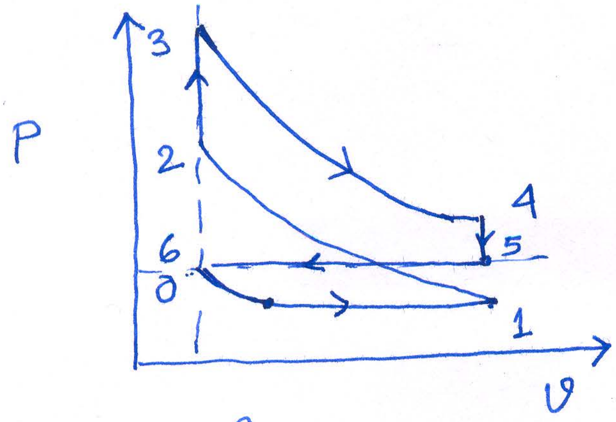
(d) Friction power lost $= 14.6$ kW

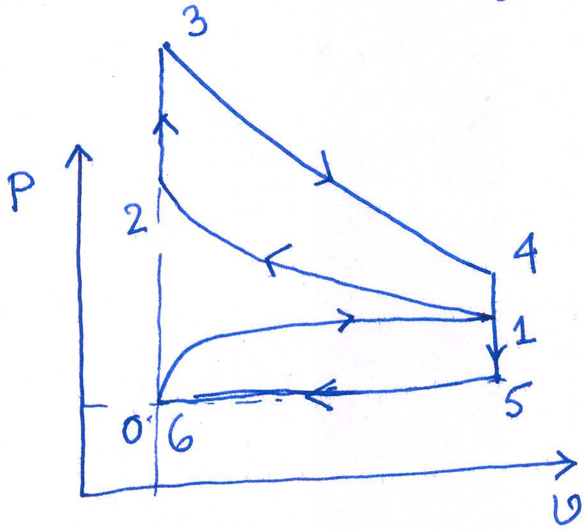
(e) bsfc $= 186$ gm/kW-hr

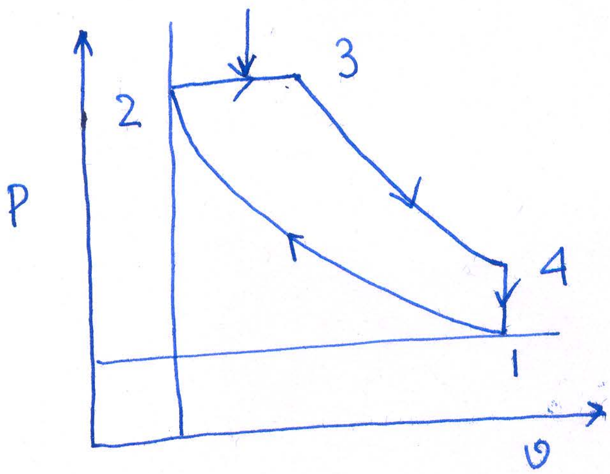
(f) $\eta_v = 86.7\%$

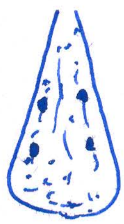
(g) output displacement $= 25.6$ kW/L

Part load condition









$\cancel{{}_1q_2} - {}_1w_2 = \cancel{0}\; u_2 - u_1$

mm

${}_1w_2 = -c_v(T_2 - T_1)$

$\cancel{{}_1q_2 - {}_1w_2}$ ${}_1q_2 = 0$

${}_2q_3 - {}_2w_3 = u_3 - u_2$ ${}_2w_3 = P_2(v_3 - v_2)$

${}_2q_3 = u_3 - u_2 + P_2(v_3 - v_2)$

$= (u_3 + P_3 v_3) - (u_2 + P_2 v_2)$

$= h_3 - h_2$ $Q_a \eta_c = (AF+1)\, c_p (T_3 - T_2)$

$= c_p(T_3 - T_2)$

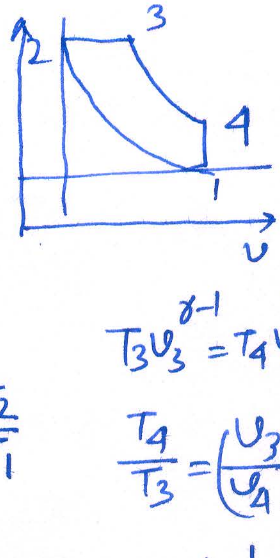
${}_3w_4 = c_v(T_3 - T_4)$

${}_4q_1 = c_v(T_4 - T_1)$ $T_1 v_1^{\gamma-1} = T_2 v_2^{\gamma-1}$

$\eta_{th} = 1 - \dfrac{c_v(T_4 - T_1)}{c_p(T_3 - T_2)}$ $\dfrac{T_2}{T_1} = \left(\dfrac{v_1}{v_2}\right)^{\gamma-1}$

$= r_c^{\gamma-1}$

$= 1 - \dfrac{1}{\gamma} \dfrac{T_1\left(\frac{T_4}{T_1} - 1\right)}{T_2\left(\frac{T_3}{T_2} - 1\right)}$



$= 1 - \dfrac{1}{\gamma} \cdot \dfrac{1}{r_c^{\gamma-1}} \cdot \left(\dfrac{\beta^{\gamma} - 1}{\beta - 1}\right)$ $\dfrac{v_3}{v_2} = \beta$ (cutoff ratio)

$= \dfrac{T_3}{T_2}$

$\eta_{th} = 1 - \dfrac{1}{r_c^{\gamma-1}}$

$T_3 v_3^{\gamma-1} = T_4 v_4^{\gamma-1}$

$\dfrac{T_4}{T_1} = \dfrac{T_4}{T_3} \times \dfrac{T_3}{T_2} \times \dfrac{T_2}{T_1}$ $\dfrac{T_4}{T_3} = \left(\dfrac{v_3}{v_4}\right)^{\gamma-1}$

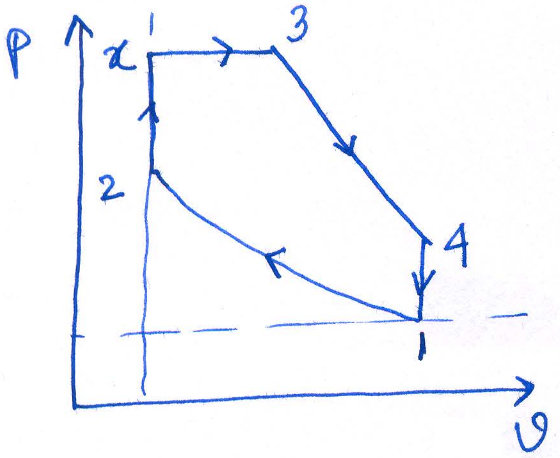
$= \cancel{\dfrac{v_4}{v_3}}\left(\cancel{\dfrac{v_4}{v_3}}\right)$

$= \left(\dfrac{v_3}{\cancel{v_4}}\right)^{\gamma-1} \cdot \dfrac{v_3}{v_2} \cdot \left(\dfrac{\cancel{v_1}}{v_2}\right)^{\gamma-1}$

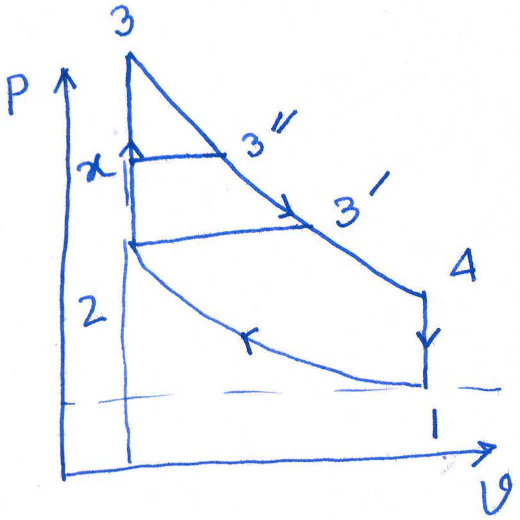
$= \dfrac{v_3^{\gamma}}{v_2^{\gamma}} = \beta^{\gamma}$

Dual Cycle

Limited Pressure Cycle



$$q_{in} = {}_{2}q_{x} + {}_{x}q_{3}$$



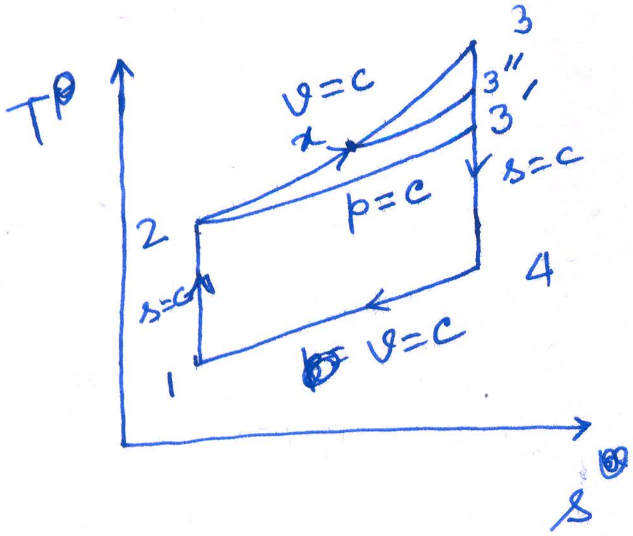
r_c = same

same heat rejection

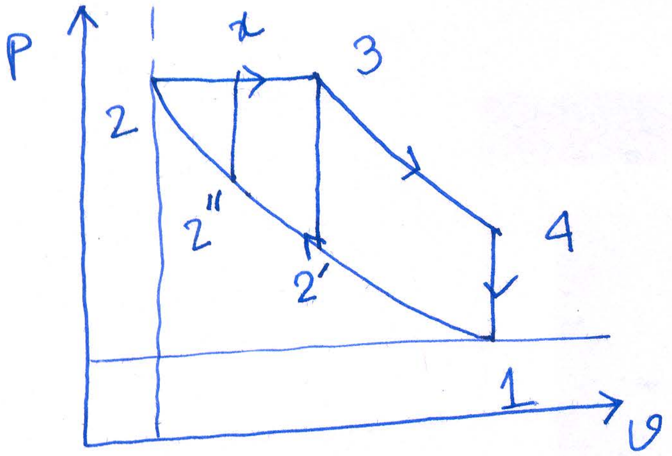
1-2-3-4-1 SI

1-2-3'-4-1 CI

$$\eta_{SI} > \eta_{Dual} > \eta_{CI}$$



Same Peak pressure
Same heat rejection



1-2-3-4-1 Diesel Cycle
1-2'-3-4-1 otto (SI) "
1-2''-x-3-1 Dual "