AE234 Quiz 5 SOHAM SHIRISH PHANSE 19D170030.

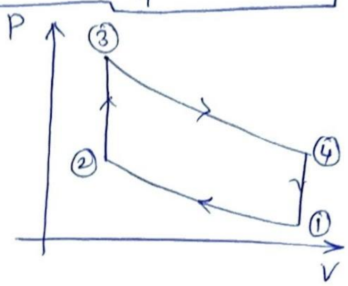
Q1. $r = 9:1$, $P_1 = 100$ kPa and $T_1 = 298$ K

cylinder volume = $V_{max} = V_1 = 2000 cm^3 = 2000 \times 10^{-6} m^3$
$= 2 \times 10^{-3} m^3$

$Q_{isochoric} = 4 \times 10^3$ J

we have $V_1 = 2 \times 10^{-3} m^3 = V_4$ and $\boxed{V_2 = V_3 = \frac{2}{9} \times 10^{-3} m^3}$

using $P_1 V_1^\gamma = P_2 V_2^\gamma$ (adiabatic)



$P_2 = 100 \times 10^3 \times \left(\frac{V_1}{V_2}\right)^\gamma = 100 \times 10^3 \times (9)^{1.4}$

$= 2167 \times 10^3$ Pascal $\boxed{P_2 = 2167 \text{ kPa}}$

$\therefore$ and $\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$ $\therefore T_2 = \frac{P_2 V_2 T_1}{P_1 V_1}$

$\therefore T_2 = \frac{2167 \text{ kPa}}{100 \text{ kPa}} \times \frac{1}{9} \times 298 = \boxed{717.5177 \text{ K.} = T_2}$

$\therefore Q_{isochoric} = mC_v(T_3 - T_2)$

But we have
$P_1 V_1 = mRT$ $(R = 287.1)$

$\therefore m = \frac{100 \times 10^3 \times 2 \times 10^{-3}}{287.1 \times 298} = 2.337 \times 10^{-3}$ kg

$\therefore 4 \times 10^3 = 2.337 \times 10^{-3} \times \frac{287.1}{0.4} \times (T_3 - T_2)$

$\therefore 2384.668 = T_3 - T_2$ $\therefore \boxed{T_3 = 3102.186 \text{ K}}$

and $\frac{P_3}{T_3} = \frac{P_2}{T_2}$ $\therefore P_3 = \frac{P_2}{T_2} \times T_3 = \frac{2167 \text{ kPa}}{717.5177} \times 3102.186$

$\boxed{P_3 = 9369.02 \text{ kPa}}$

and again 3 → 4 isentropic, $\therefore$ we get

$\therefore P_3 V_3^\gamma = P_4 V_4^\gamma$ But $V_3 = V_2$ and $V_4 = V_1$ & $\frac{V_4}{V_3} = \frac{V_1}{V_2} = 9$

$\therefore P_4 = P_3 \left(\frac{V_3}{V_4}\right)^\gamma = 9369.02 \text{ kPa} \left(\frac{1}{9}\right)^{1.4}$

$\therefore \boxed{P_4 = 432.269 \text{ kPa}}$ and $\frac{P_3 V_3}{T_3} = \frac{P_4 V_4}{T_4}$ we get,

$T_4 = \cancel{P_3 V_3} \quad \frac{P_4 V_4}{P_3 V_3} T_3 \quad \ldots$ ideal gas

$$T_4 = \frac{432.269 \text{ kPa}}{9369.02 \text{ kPa}} \cdot \frac{V_4}{V_3} \times 3102.186 \text{ K}$$

$\therefore T_4 = 0.046138 \times 9 \times 3102.186 = 1288.163027$

$\therefore \boxed{T_4 = 1288.163027 \text{ K}}$

$\rightarrow Q_{isochoric} = mC_v(T_4 - T_1)$

$(4 \rightarrow 1)$ blowdown $= 2.337 \times 10^{-3} \times \frac{287.1}{0.4} \times (1288.16 - 298)$

$Q_{isochoric \; 4 \rightarrow 1} = 1660.88 \text{ J} = \boxed{1.66 \text{ kJ} = Q_{4 \rightarrow 1}}$

$\therefore$ we have $\eta = 1 - \frac{T_1}{T_2} = 1 - \frac{298}{717.5177} = 0.58467$

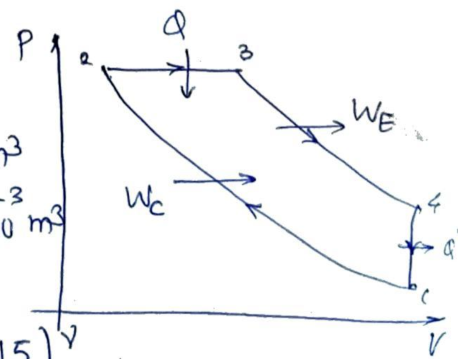
$\therefore \boxed{\eta = 58.467 \%}$

Q2 diesel cycle implementation

we have $r = \frac{15}{1} = \frac{V_1}{V_2} \quad \therefore \boxed{V_1 = 2 \times 10^{-3} \text{ m}^3 = V_4}$

~~$V_2 = \left(\frac{2}{15} \times 10^{-3} \text{ m}^3\right) = V_3$~~

and $\frac{V_1}{V_2} = \frac{15}{1} \quad \therefore \boxed{V_2 = \frac{2}{15} \times 10^{-3} \text{ m}^3}$



so we have now,

$P_1 = 100 \text{ kPa}, \; T_1 = 298 \text{ K}, \; V_1 = 2 \times 10^{-3} \text{ m}^3$

again isentropic process & $V_2 = \frac{2}{15} \times 10^{-3} \text{ m}^3$

$\therefore P_2 V_2^{\gamma} = P_1 V_1^{\gamma} \qquad P_2 = P_1 \frac{V_1^{\gamma}}{V_2^{\gamma}} = P_1 (15)^{\gamma}$

$\therefore P_2 = 100 \text{ kPa} \times (15)^{1.4} = \boxed{4431.265 \text{ kPa} = P_2}$

again use ideal gas law and do,

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \qquad T_2 = \frac{P_2V_2}{P_1V_1}T_1 = \frac{4431.265\ kPa}{100\ kPa} \times \frac{1}{15} \times 298$$

$\therefore \boxed{T_2 = 880.344\ K}$ Now ② → ③ we have isobaric heat addition $\therefore$ $Q_{isobaric} = mC_p(T_3 - T_2)$

again $m = \frac{P_1V_1}{RT_1} = \frac{100\times10^3 \times 2\times10^{-3}}{287.1 \times 298} = 2.337\times10^{-3}\ kg$

$\therefore Q_{isobaric} = 2.337\times10^{-3} \times \frac{1.4\times287.1}{0.4} \times (T_3 - T_2)$

But as isobaric we have, $\boxed{P_2 = P_3 = 4431.265\ kPa}$

$\therefore \frac{T_2}{V_2} = \frac{T_3}{V_3} \quad \therefore \frac{880.344}{\frac{2}{15}\times10^{-3}} = \frac{T_3}{V_3}$

Now we know that the heat rejection step is common to both cycles, hence amount of heat rejected is identical

$\therefore Q_{isochoric\ rejected} = 1.66\times10^3\ J = mC_v(T_4 - T_1)$

$\therefore 1.66\times10^3 = 2.337\times10^{-3}\times\frac{287.1}{0.4}\times(T_4 - 298)$

$\therefore \boxed{T_4 = 1287.637\ K}$ also $\boxed{V_1 = V_4 = 2\times10^{-3}\ m^3}$

$\therefore$ ~~T_4~~ $\boxed{P_4 = 432.269\ kPa}$ from previous analysis

But ③ → ④ is isentropic and $P_3 = 4431.265\ kPa$

$\therefore P_3V_3^\gamma = P_4V_4^\gamma \qquad V_3^\gamma = \frac{P_4}{P_3}(V_4)^\gamma = \frac{432.269}{4431.265}\times(2\times10^{-3})^{1.4}$

$\therefore V_3^\gamma = 1.624\times10^{-5} \qquad V_3^{1.4} = V_3^{\frac{7}{5}} = (1.624\times10^{-5})$

$\therefore V_3 = (1.624\times10^{-5})^{5/7} = 3.79\times10^{-4} = 0.379\times10^{-3}\ m^3$

$\therefore \boxed{V_3 = 0.379\times10^{-3}\ m^3} \quad \boxed{P_3 = 4431.265\ kPa}$

$\therefore T_3 = \frac{P_3V_3}{mR} = \frac{4431.265\ kPa \times 3.79\times10^{-4}\ m^3}{2.337\times10^{-3}\times287.1} = 2503.08K$

$T_3 = 2503.08\ K$

$\therefore\ Q_{isobaric} = 2.348\,(T_3 - T_2)$

$= 3810.72\ J = \boxed{3.8\ kJ = Q_{isobaric}\ \ ② \rightarrow ③}$

$\therefore$ now we have,

expansion ratio. $r_e = \dfrac{V_4}{V_3} = \dfrac{2\times10^{-3}}{0.379\times10^{-3}} = 5.277$

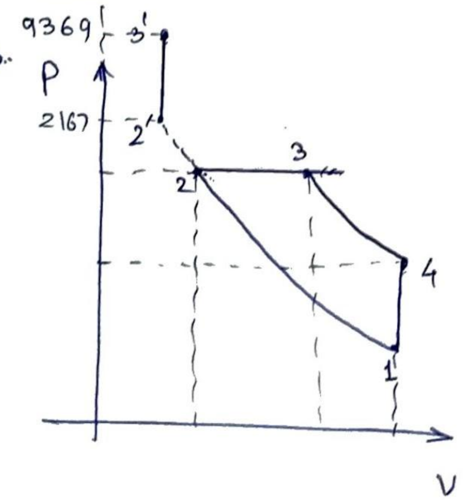
cut-off ratio : $r_c = \dfrac{V_3}{V_2} = \dfrac{0.379\times10^{-3}}{\frac{2}{15}\times10^{-3}} = 2.84.$

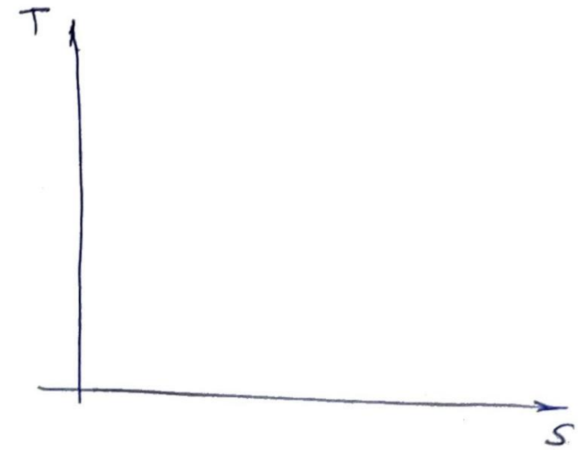
$$\eta_{diesel} = 1 - \frac{1}{(15)^{0.4}\times 1.4}\left(\frac{(2.84)^{1.4}-1}{2.84-1}\right)$$

r_k = expansion ratio = 15

$\therefore\ \boxed{\eta_{diesel} = 0.5648}$ $\quad\therefore\ \boxed{\eta_{diesel} = 56.48\ \%}$

Q3.





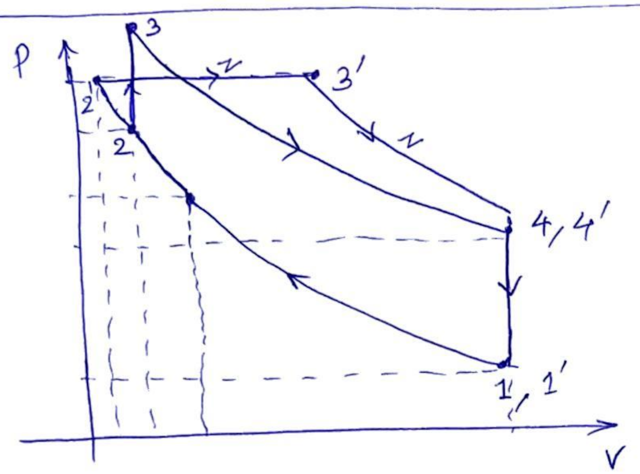
Q3. we have

Otto

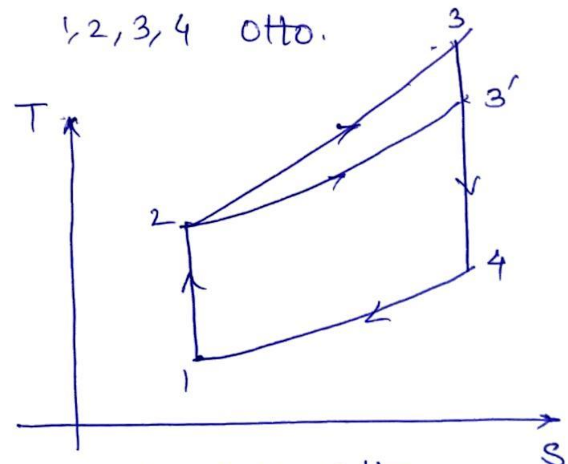
P_1	P_2 (kPa)	P_3 (kPa)	P_4	V_1	V_2 (10^{-3} m^3)	V_3 (10^{-3} m^3)	V_4	T_1	T_2	T_3	T_4
100	2167	9369	432	2	$\frac{2}{9}$	$\frac{2}{9}$	2	298	717	3102	1288

Diesel.

P_1	P_2	P_3	P_4	V_1	V_2	V_3	V_4	T_1	T_2	T_3	T_4
100	4431	4431	432	2	$\frac{2}{15}$	0.38	2	298	880	2503	1288.



1', 2', 3', 4' diesel.
1, 2, 3, 4 Otto.



1, 2, 3, 4 Otto
1', 2', 3', 4' diesel