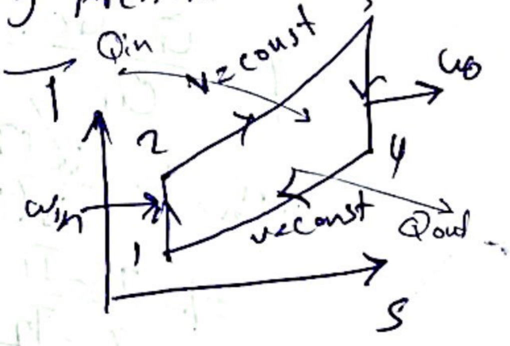
In the Petrol engine a mixture of air and Petrol is drawn into the cylinder, compressed by the piston, then ignited by an electrical spark. The hot gases expand, Pushing the piston and are then swept out to exhaust, and the cycle recommen with the ~~xxx~~ induction of fresh charge of Petrol and air

In the air standard cycle the working substance is assumed to be air throughout, all processes are assumed to be reversible, and source of heat supply and the sink for heat rejection are assumed to be external to air

Three cycles will be discussed in this suction

① otto cycle
② Diesel cycle
③ Dual combustion cycle

③ otto cycle, Constant volume, $\boxed{\text{or}}$ Petrol Engine Cycle
This cycle sometimes referred to as the otto cycle after Dr. otto in 1876. The cycle originally developed by Frenchman named Beau de Rochas in 1862.

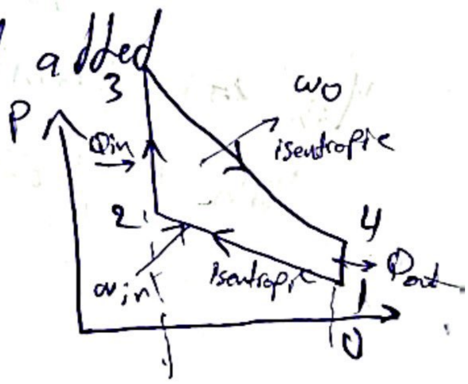


$\boxed{1-2}$ Isentropic Compression $Pv^{\gamma} = C$

$Q = W + \Delta U \quad Q = 0$

$W = -\Delta U = mc_v(T_2 - T_1)$

$\boxed{2-3}$ Reversible constant Volume heat added



$Q = W + \Delta U \quad W = 0$

$Q = \Delta U = mc_v(T_3 - T_2)$

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$\boxed{3-4}$ Isentropic expansion $PV^{\gamma} = c$

$Q = W + \Delta U \qquad Q = 0$

$Q = \Delta U = mc_v (T_3 - T_4)$

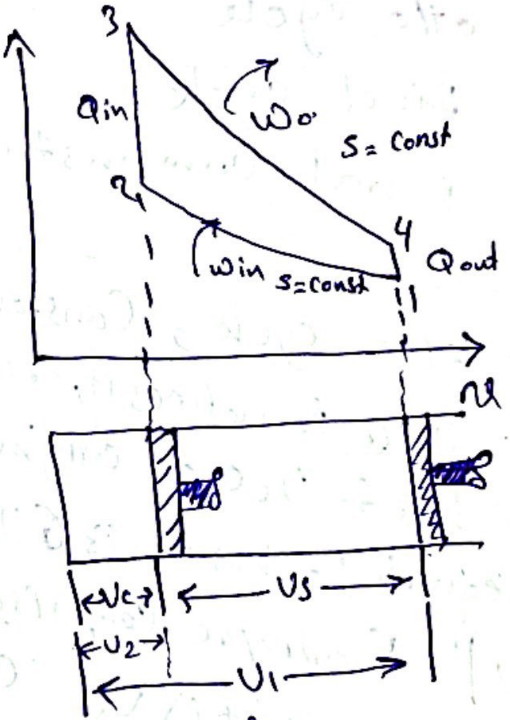
$\boxed{4-1}$ Reversible constant volume heat rejection

$Q = W + \Delta U \qquad W = 0$

$Q = \Delta U = mc_v (T_4 - T_1)$

$$\boxed{\text{Volume ratio} = r_v = \frac{V_1}{V_2} > 1}$$

$$r_v = \frac{\text{Swept } v + \text{Clearnce } v}{\text{Clearnce } v}$$



V_s = Swept v

V_c = Clearnce v

$V_1 = V_s + V_c$

Thermal efficiency $= \eta_{th} = \frac{\text{Network}}{\text{Head Added}}$

$$\eta_{th} = \frac{Q_1 - Q_2}{Q_1} = 1 - \frac{Q_2}{Q_1}$$

$$\eta_{th} = 1 - \frac{\cancel{C_v}(T_4 - T_1)}{\cancel{C_v}(T_3 - T_2)}$$

$$= 1 - \frac{T_4 - T_1}{T_3 - T_2}$$

η_{th} in terms of volume compression ratio

$$\boxed{\eta_{th} = 1 - \frac{1}{r_v^{\gamma - 1}}}$$ Prove it H.W

Ex:- In an air standard otto cycle the max. and min. temperature are 1400 °C & 15 °C. The heat supplied per kg of air is 800 kJ. Calculate the compression ratio and the thermal efficiency. Calculate also the ratio of max. to min pressure.

Sol:-

Max. Temp $T_3 = 1400 + 273 = 1673\ K$

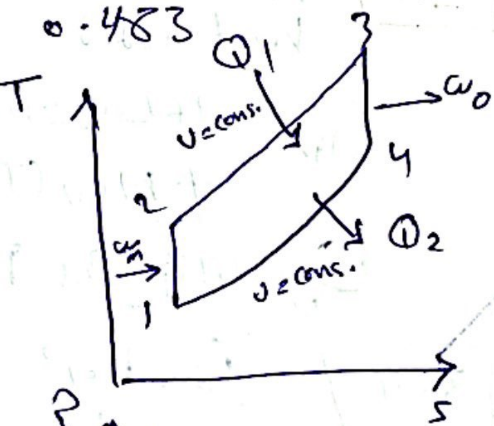
Min. Temp $T_1 = 15 + 273 = 288\ K$

$Q_1 = m c_v (T_3 - T_2)$

$800 = 1 * 0.717 (1673 - T_2) \Rightarrow T_2 = 557.2\ K$

$r_v = \frac{v_1}{v_2} = \left(\frac{T_2}{T_1}\right)^{\frac{1}{\gamma-1}} = \left(\frac{557.2}{288}\right)^{\frac{1}{1.4-1}} = 5.2$

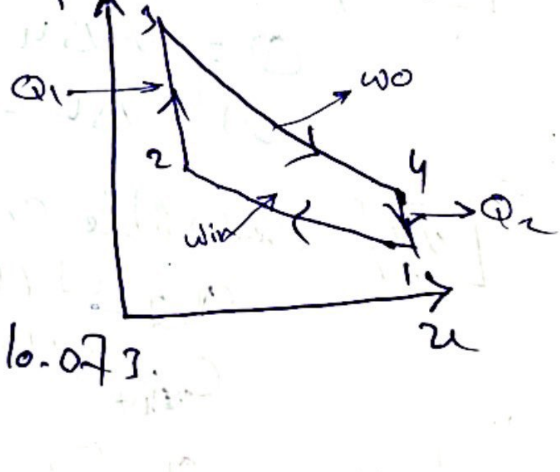
$\eta_{th} = 1 - \frac{1}{r_v^{\gamma-1}} = 1 - \frac{1}{(5.2)^{1.4-1}} = 0.483$



$\frac{P_{max}}{P_{min}} = \frac{P_3}{P_1} = \frac{P_3}{P_2} \cdot \frac{P_2}{P_1}$

$\frac{P_3 v_3}{T_3} = \frac{P_2 v_2}{T_2} \Rightarrow v = C$

$\frac{P_3}{P_2} = \frac{T_3}{T_2} = \frac{1673}{557.2} = 3$

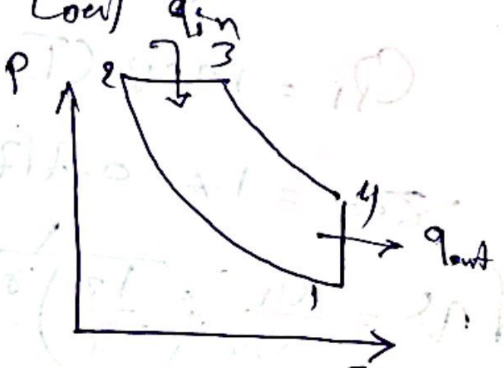


$\frac{P_2}{P_1} = \left(\frac{T_2}{T_1}\right)^{\frac{\gamma-1}{\gamma}} = \left(\frac{557.2}{288}\right)^{\frac{1.4-1}{1.4}} = 10.073$

$\frac{P_{max}}{P_{min}} = \frac{P_3}{P_1} = \frac{P_3}{P_2} \cdot \frac{P_2}{P_1} = 3 * 10.073 = 30.24$

(4) The disel Cycle:-

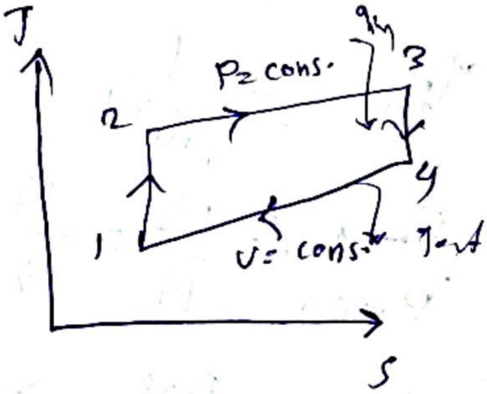
The diesl engines in use today which are called diesel engines are far removed from the original engine invented by Diesel in 1892. Disel worked on the ~~[illegible]~~ Ideal of Spontanous ignition of powdered coal, which was blasted in to the cylinder by compression air. Oil became the accepted fuel in compression ignition engines, and the oil was originally blasted into the cylinder in the same way that diesel has intended to injected the powder coal



$\boxed{1-2}$ / Isentropic Comp. $Pv^{\gamma}=c$

$$Q=W+\Delta U \qquad Q=0$$
$$W=-\Delta U=mc_v(T_2-T_1)$$

$\boxed{2-3}$ / Reversible Constat Press. heat added



$$Q_{in}=W+\Delta U=mR(T_3-T_2)+mc_v(T_3-T_2)$$
$$Q_{in}=mC_p(T_3-T_2)$$

$\boxed{3-4}$ / Isentrop expan. $Pv^{\gamma}=c.$

$$Q=W+\Delta U \qquad Q=0$$
$$W=-\Delta U=mc_v(T_3-T_4)$$

$\boxed{4-1}$ / Reversible constant volume heat rejected

$$Q_{out}=W+\Delta U \qquad W=0$$
$$Q_{out}=\Delta U=mC_v(T_4-T_1)$$

$$\eta_{th}=\frac{Q_1-Q_2}{Q_1}=1-\frac{Q_2}{Q_1}=1-\frac{\cancel{m}c_v(T_4-T_1)}{\cancel{m}C_p(T_3-T_2)}$$

$$\eta_{th}=1-\frac{(T_4-T_1)}{\gamma(T_3-T_2)}$$

$\beta = \frac{v_3}{v_2}$ Cut-off ratio

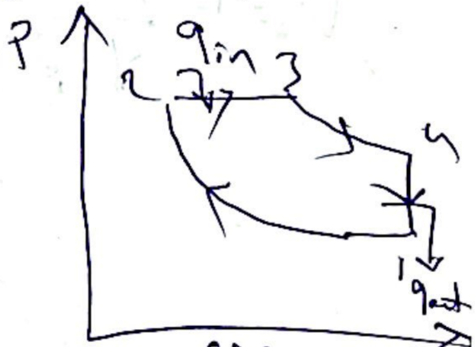
$r_v = \frac{v_1}{v_2}$ Compression ratio

It is desired to derived the thermall efficiency law in terms of volume compression ratio, since this ratio is know

$$\eta_{th} = 1 - \frac{\beta^{\gamma} - 1}{\gamma\, r_v^{\gamma-1} (\beta - 1)}$$

Ex:-

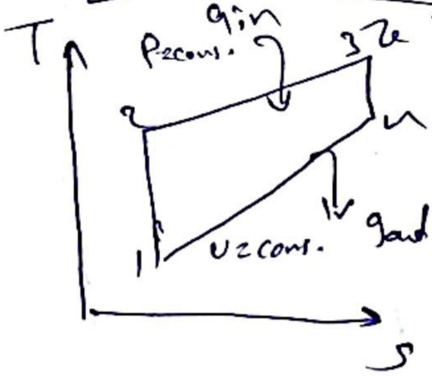
A diesel engine has an inlet temperature of 15 C° and inlet pressure of 1 bar. the compression ratio is 12:1 The maximum cycle temperature is 1100C°. Calculate the air standard thermal efficiency based on diesel cycle



Sol:-

Comp. Ratio $= \frac{v_1}{v_2} = 12$ $T_1 = 288\,k$

$T_3 = 1373\,k$ $P_1 = 100\,kPa$



$$\eta_{th} = 1 - \frac{Q_2}{Q_1} = 1 - \frac{C_v (T_4 - T_1)}{C_p (T_3 - T_2)}$$

$$T_2 = \left(\frac{v_1}{v_2}\right)^{\gamma-1} \cdot T_1$$

$$T_2 = 12^{0.4} * 288 = 778.1\,K$$

$$P_2 = \left(\frac{v_1}{v_2}\right)^{\gamma} \cdot P_1 = 12^{0.4} * 100 = 3242.3\ KPa$$

$$\frac{T_4}{T_3} = \left(\frac{v_3}{v_4}\right)^{\gamma-1} = \left(\frac{v_3}{v_2} \cdot \frac{v_2}{v_1}\right)^{\gamma-1} = \left[\frac{T_3}{T_2} \cdot \frac{v_2}{v_1}\right]^{\gamma-1}$$

$$T_4 = T_3\left(\frac{T_3}{T_2}\cdot\frac{v_2}{v_1}\right)^{\gamma-1} = 1373\left(\frac{1373}{778.112}\cdot\frac{1}{12}\right)^{1.4-1}$$

$T_4 = 638\ K$

$$\eta_{th} = 1 - \frac{c_v}{c_p}\left[\frac{T_4 - T_1}{T_3 - T_2}\right] \Rightarrow 1 - \frac{0.717(638-288)}{1.005(1373-778.1)}$$

$= 0.576$

<u>or</u>

$$\eta_{th} = 1 - \frac{\beta^{\gamma}-1}{\gamma r_e^{\gamma-1}(\beta-1)}, \quad \beta = \frac{v_3}{v_2} = \frac{T_3}{T_2} = \frac{1373}{778.1}$$

$= 1.764$

$r_e = 12$

$$\eta_{th} = 1 - \frac{\beta^{\gamma}-1}{\gamma r_e^{\gamma-1}(\beta-1)} = 1 - \frac{1.764^{1.4}-1}{1.4 * 12^{1.4-1} * (1.764-1)} = 0.579$$

(5) The Dual Combustion Cycle

Modern oil engine although still called diesel engines are more closely derived from and engine invented by Ackroyed – stuart in 1888. All-oil engines today use Solid injection of fuel, the fuel is injected by a spring loaded injector the fuel pump being operate by a Cam driven from the engine Crank Shaft

$\boxed{1-2}$ adiabatic Reversible compression PV^{γ}

$$Q = W + \Delta U \qquad Q = 0$$

$$W = mc_v (T_2 - T_1)$$

$\boxed{2-3}$ Reversible Constant volume heat added Q_1

$$Q = W + \Delta U \qquad W = 0$$

$$Q_1 = mc_v (T_3 - T_2)$$

$\boxed{3-4}$ Reversible Constant pressure heat added Q_2

$$Q = W + \Delta U$$

$$Q_2 = mc_p (T_4 - T_3)$$

$\boxed{4-5}$ adiabatic Reversible expansion PV^{γ}

$$Q = W + \Delta U \qquad Q = 0$$

$$W = mc_v (T_4 - T_5)$$

$\boxed{5\text{-}1}$ Reversible constant volume heat rejected Q

$$Q = W + \Delta U \qquad W = 0$$

$$Q_3 = m c_v (T_5 - T_1)$$

Volume ratio in dual compression cycle

1. Compression ratio $r_c = \frac{V_1}{V_2}$
2. Ratio of pressure during heat added at constant volume $\alpha = \frac{P_3}{P_2}$
3. Ratio of volume during heat added at constant pressure $\beta = \frac{V_4}{V_3} = \frac{V_4}{V_2}$

thermal efficiency :-

$$\eta_{th} = \frac{\text{Net work}}{Q_1} = \frac{Q_1 - Q_2}{Q_1}$$

$$\eta_{th} = 1 - \frac{Q_3}{Q_1 + Q_2}$$

$$\eta_{th} = 1 - \frac{c_v (T_5 - T_1)}{c_v (T_3 - T_2) + c_p (T_4 - T_3)}$$

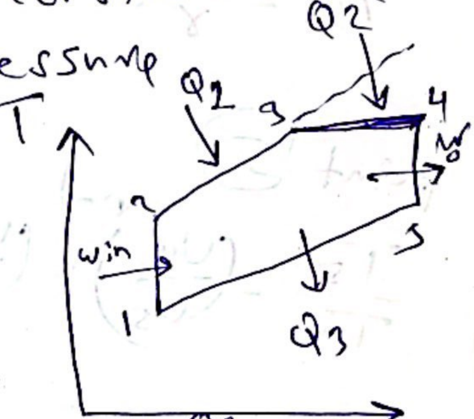
$$= 1 - \frac{(T_5 - T_1)}{(T_3 - T_2) + \gamma (T_4 - T_3)}$$

$$\Rightarrow \eta_{th} = 1 - \frac{\alpha \cdot \beta^{\gamma} - 1}{[(\alpha - 1) + \gamma \alpha (\beta - 1)] r_c^{\gamma - 1}}$$

Prove that

EX :-

An oil engine takes air at 1.01 bar, 20°C and maximum pressure is 69 bar. the compression ratio is 18:1. Calculate the air standard thermal efficiency based on the dual combustion cycle assuming that the heat added at constant volume is equal to that at constant pressure

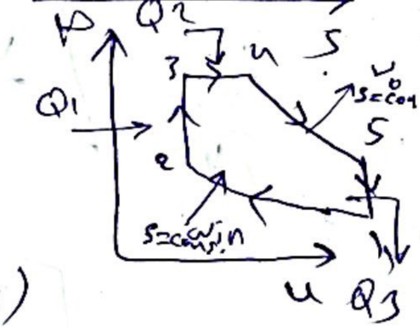


Sol:-

$P_1 = 1.01\,bar$ $\quad P_3 = P_4 = 69\,bar$

$T_1 = 293\,K$

$\frac{V_1}{V_2} = 18$



$Q_1 = Q_2$

$\eta_{th} = 1 - \frac{Q_3}{Q_1 + Q_2} = 1 - \frac{T_5 - T_1}{(T_3 - T_2) + \gamma (T_4 - T_3)}$

Point (1)

$P = 1.01\,bar$ $\quad T_1 = 298\,K$

Point (2)

$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1} \Rightarrow T_2 = (18)^{1.4-1} * 293 = 931\,K$

$Q = 0$ & $S = cons.$

$P_2 = \left(\frac{V_1}{V_2}\right)^{\gamma} \cdot P_1 = (18)^{1.4} * 1.01 = 57.8\,bar$

Point (3)

$P_3 = 69\,bar$

$\frac{P_2 V_2}{T_2} = \frac{P_3 V_3}{T_3}$ $\quad V = C$

$\therefore T_3 = \frac{P_3}{P_2} \cdot T_2 \Rightarrow T_3 = \frac{69}{57.8} * 931 = 1112\,K$

Point 4

$P_4 = P_3 = 69$ bar

$Q_1 = Q_2$

$C_v(T_3 - T_2) = C_p(T_4 - T_3)$

$T_4 = \frac{1}{\gamma}(T_3 - T_2) + T_3 \Rightarrow T_4 = \frac{1}{1.4}(1112 - 931) + 1112$

$T_4 = 1241$ K.

Point 5

$\frac{T_5}{T_4} = \left(\frac{V_4}{V_5}\right)^{\gamma-1} = \left(\frac{V_4}{V_1}\right)^{\gamma-1}$ $Q = 0$ of Isentropic

$S = $ cons

$$\frac{T_5}{T_4} = \left[\frac{V_4}{V_3} \cdot \frac{V_3}{V_2} \cdot \frac{V_2}{V_1}\right]^{\gamma-1}$$

$$= \left[\frac{T_4}{T_3} \times 1 \times \frac{V_2}{V_1}\right]^{\gamma-1}$$

$$T_5 = \left(\frac{1241}{1112} \times 1 \times \frac{1}{18}\right)^{0.4} \times T_4 = 408\text{K}$$

$T_5 = 408$K

$$\eta_{th} = 1 - \frac{T_5 - T_1}{(T_3 - T_2) + \gamma(T_4 - T_3)}$$

$$= 1 - \frac{408 - 293}{(1112 - 931) + 1.4(1241 - 1112)}$$

$= 0.681$