Q1.]

Ritu Patil
Roll No: 190103066

→ $N = 3300$ rpm $CR = 9.6$

Combustion ends at 20° aTDC

Length of rod = 16 mm

a) Bore and stroke length = ?
b) Average piston speed = ?
c) Clearance volume of one cylinder = ?
d) piston speed at end of combustion = ?
e) Distance from TDC = ?
f) Volume of combustion chamber = ?

→ Soln :

a) As it is a square SI engine
$\therefore B = S$

$$V_d = \frac{V_{total}}{6} = \frac{3L}{6} = 0.5L = 500\,cm^3$$

$$\frac{\pi}{4} B^2 S = \frac{\pi}{4} B^3 = 500$$

$\therefore B = 8.60\,cm$ (Bore)

$S = 8.60\,cm$ (Stroke length)

b) $$\bar{U}_p = 2SN = (2\ \text{stroke/rev})(0.0860\ \text{m/stroke})\left(\frac{3300}{60}\ \frac{\text{rev}}{\text{s}}\right)$$

$$= 9.46\ \text{m/s}$$

c) $$9.6 = \frac{V_d + V_c}{V_c}$$

$$9.6 = 1 + \frac{500}{V_c}$$

$$\therefore V_c = \frac{500}{8.6}$$

$$\therefore \boxed{V_c = 58.1395\ cm^3}$$

d) Crank offset: $a = \frac{S}{2} = \frac{8.60}{2}\,cm = 4.3\,cm$

$$R = \frac{r}{a} = \frac{1.6}{4.3} = 0.3721 \quad (r = 16\,mm)$$

$$\frac{U_p}{\bar{U}_p} = \frac{\pi}{2}\sin\theta\left[1 + \frac{\cos\theta}{\sqrt{R^2 - \sin^2\theta}}\right] \qquad \theta = 20^\circ\ (\text{given})$$

$$\frac{U_p}{\bar{U}_p} = \frac{\pi}{2}\sin(20^\circ)\left[1 + \frac{\cos 20^\circ}{\sqrt{(0.3721)^2 - \sin^2 20^\circ}}\right]$$

$$U_p = \bar{U}_p\,(3.981)$$

$$\therefore \boxed{U_p = 37.66\ m/s}$$

e) To find piston position:

$$s = a\cos\theta + \sqrt{r^2 - a^2\sin^2\theta}$$

$$= (0.0430\,m)\cos 20^\circ + \sqrt{(1.6\times10^{-2})^2 - (0.043)^2\sin^2 20^\circ}$$

$$= \underline{\underline{0.0467\,m}}$$

$$\text{Distance from TDC } (x) = r + a - s$$

$$= (1.6 + 4.3 - 4.67)$$

$$= \underline{\underline{1.23\ cm}}$$

f) $$\frac{V}{V_c} = 1 + \frac{1}{2}(r_c - 1)\left[R + 1 - \cos\theta - \sqrt{R^2 - \sin^2\theta}\right]$$

$$= 1 + \frac{1}{2}(9.6 - 1)\left[0.3721 + 1 - \cos 20^\circ - \sqrt{(0.3721)^2 - \sin^2 20^\circ}\right]$$

$$\frac{V}{V_c} = 2.229$$

$$V = 2.229\,V_c = 2.229\,(58.1395)$$

$$\therefore V = \underline{\underline{129.600\ cm^3}}$$

Q2] Given :

→ 3L V6 spark (square engine) Mechanical efficiency (η_m) = 82%

Rate : 3300 rpm

Brake Torque = 205 N.m

Air enters at : 80 KPa , 57°C

a) Brake Power :

$$\dot{W}_b = 2\pi N T = (2\pi \text{ rad/rev}) \left(\frac{3300}{60} \frac{\text{rev}}{\text{s}}\right)(205 \text{ N·m})$$

$$= 70842.91 \text{ W}$$

$$\boxed{\dot{W}_b = 70.842 \text{ KW}}$$

b) Indicated Power : $\dot{W}_i = \frac{\dot{W}_b}{\eta_m} = \frac{70.842}{0.82} = \boxed{86.393 \text{ kW}}$

c) Brake mean effective pressure :

$$bmep = \frac{4\pi T}{V_d}$$

As the engine is the same as in (Q1)

$\therefore$ $V_d = 3L$

$$bmep = \frac{\left(4\pi \frac{\text{rad}}{\text{cy.}}\right) \times 205 \text{ N·m}}{(0.003 \text{ m}^3/\text{cy})} = \boxed{858.701 \text{ KPa}}$$

d) $imep = \frac{bmep}{\eta_m} = \boxed{1047.197 \text{ KPa}}$

e) Friction mean effective pressure = imep - bmep = 1047.197 - 858.701

$= \boxed{188.496 \text{ KPa}}$

f) Power lost to friction : $A_p = \frac{\pi}{4} B^2 = 0.00581 \text{ m}^2$ for one cylinder

$$\dot{W}_f = \dot{W}_i - \dot{W}_b$$

$$= (86.393 - 70.842) \text{ kW}$$

$$\therefore \boxed{\dot{W}_f = 15.551 \text{ kW}}$$

g) Brake power per unit mass of gas in the cylinder :

It can be assumed that the gas entering the cylinders of BDC is air :

$$m_a = \frac{P V_{BDC}}{RT} = \frac{P(V_d + V_c)}{RT}$$

$$= \frac{(80\ kPa)(0.0005 + 0.000129)m^3}{\left(0.287\ \frac{kJ}{kg\text{-}K}\right)(330\ K)}$$

$$= \underline{0.000531\ kg}$$

Brake Power per unit mass $= \frac{\dot{W}_b}{m_a} = \frac{70.842}{0.000531}\ kW = \boxed{133.412\ \frac{MW}{kg}}$

h) Brake Specific Power : $(BSP) = \frac{\dot{W}_b}{A_p}$

$$= \frac{70.842}{\frac{\pi}{4}(0.086)^2 \times 6} = \boxed{2032.6\ kW}$$

i) Brake output per displacement :

$$BOPD = \frac{\dot{W}_b}{V_d} = \frac{70.842\ kW}{3L}$$

$$= \boxed{23.614\ kW/L}$$

j) Engine specific volume : $= \frac{V_d}{\dot{W}_b}$

$$= \boxed{0.0423\ L/kW}$$

Q3] Given : 3L square engine $\therefore B = S$; 4 stroke cycle $(n=4)$ → No. of rev/cycle = $\boxed{2}$; N = 3300 rpm

AF ratio = 15, $\eta_c = 97\%$

a) Rate of fuel flow in to the engine. = ?

$$\dot{m}_a = \frac{\eta_v \rho_a V_d N}{n}$$

$V_d = \frac{\pi}{4} B^2 S$ also $V_d = \frac{n L}{m}$ (n - no. of Litre; m - no. of cylinder)

$= \frac{3L}{6} = \underline{\underline{0.5 L}}$

From previous question :
we get : $\underline{\dot{m}_a = 0.000531 \text{ kg}}$

$$\dot{m}_f \text{ per cylinder } \left(\frac{\dot{m}_a}{AF}\right) = \frac{0.000531}{AF} = \frac{0.000531}{15} = 0.0000354 \text{ kg/cycle.}$$

$\dot{m}_f$ per cylinder × No. of cylinder × N × No. of rev/cycle.

$$\dot{m}_f = 0.0000354 \times 6 \times \frac{3300}{60} \times 2 = \underline{0.023364 \text{ kg/s}}.$$

b) Brake Thermal efficiency :
$$\eta_{BTE} = \frac{\dot{W}_b}{\dot{m}_f Q_{cv} \eta_c} = \frac{70.807}{0.023364 \times Q_{cv} \times 0.97}$$

($\dot{W}_b$ - Brake power)

$\therefore Q_{cv} = 44 \text{ MJ/kg}$

$$= \frac{70.807 \times 10^3}{0.023364 \times 44 \times 10^6 \times 0.97}$$

$$= \underline{\underline{7.1\%}}$$

c) Indicated thermal efficiency = $\eta_I = \frac{\eta_{BTE}}{\eta_m} = \frac{7.1}{0.82} = \underline{\underline{8.66\%}}$

d) Volumetric efficiency : $\eta_v = \frac{m_a}{\rho_a V_d} = \frac{0.0000354}{\underset{V_d}{0.0005} \times \underset{\rho_a}{1.2}} = \boxed{5.9\%}$

e) Brake specific fuel consumption :

$$BSFC = \frac{\dot{m}_f}{\dot{W}_b} = \frac{0.023364}{70.842} = 3.2974 \times 10^{-4} \text{ kg/kWs}$$

$$= 3.2974 \times 10^{-4} \times 3600 \text{ kg/kwh}$$

$$\therefore \boxed{BSFC = 1.187 \text{ kg/kwh}}$$

Q4] → 4 cylinder

$B = 55$ mm $\quad S = 90$ mm $\quad$ (W) Brake Load = 155 N

$N = 3000$ rpm $\quad$ Brake Torque arm $(R) = 360$ mm $= 0.36$ m $\quad \dot{m}_f = 6.75$ L/hr (fuel consumption)

1	2	3	4
111 N	106.5 N	104.2 N	111 N

a) Engine Torque: $T = WR = 155 \times 0.36$

$= 55.8$ Nm

b) Brake Mean Effective Pressure:

$$\frac{P_b A S K N}{2} = 2\pi N T$$

$$\therefore P_b = \frac{4\pi \cancel{N} T}{ASK\cancel{N}} = \frac{4\pi T}{ASK} = \frac{4 \times 3.14 \times 55.8}{ASK}$$

(area)

$$A = \frac{\pi}{4} B^2 = \frac{\pi}{4} \times (55 \times 10^{-3})^2 = 2.3758 \times 10^{-3} \, m^2$$

$$\therefore = \frac{4 \times 3.14 \times 55.8}{2.3758 \times 10^{-3} \times 90 \times 10^{-3} \times 4}$$

$S = 90 \times 10^{-3}$ m

$K = 4$

$$\therefore \boxed{P_b = 819.833 \text{ kPa}}$$

c) Brake thermal efficiency:

$$\eta_{BTE} = \frac{BP}{\dot{m}_f Q_{cv}}$$

$$BP = 2\pi N T = 2\pi \left(\frac{3000}{60}\right) \times 55.8 = 17.53 \text{ kW}$$

$$\eta_{BTE} = \frac{17.53 \times 10^{+3}}{\cancel{6.75} \times \dot{m}_f Q_{cv}}$$

from the data in book specific gravity of petrol = 0.735

$\therefore (Q_{cv})_{petrol} = 44200$ kJ/kg

$$\dot{m}_f = \frac{6.75}{3600} \times 1 \times 0.735$$

$$= 1.378 \times 10^{-3} \text{ kg/s}$$

$$\therefore \eta_{BTE} = \frac{17.53 \times 10^3}{(1.378 \times 10^{-3}) \times (44200 \times 10^3)}$$

$$\therefore \boxed{\eta_{BTE} = 0.2878}$$

specific fuel consumption.

d) $SFC = \frac{\dot{m}f}{BP} = \frac{1.378 \times 10^{-3}}{11.53} \times 3600 = \underline{0.28298\ kg/kW.h}$

e) Mechanical efficiency : $\eta m = ?$

$IP_1 = BP - BP_1 = \underline{44N}$

$IP_2 = BP - BP_2 = 155 - 106.5 = \underline{48.5\ N}$

$IP_3 = BP - BP_3 = 155 - 104.2 = \underline{50.8\ N}$

$IP_4 = BP - BP_4 = 155 - 111 = \underline{44\ N}$

$IP = IP_1 + IP_2 + IP_3 + IP_4$

$= 44 + 48.5 + 50.8 + 44$

$\boxed{IP = 187.3N}$

$\eta m = \frac{BP}{IP} = \frac{155}{187.3} = \underline{82.75\%}$

f) $\frac{bmep}{Imep} = \eta m$ (Indicated mean effective pressure = ?)

$\therefore$ ~~Am~~ $Imep = \frac{bmep}{\eta m} = \frac{819.833\ kPa}{0.8275} = \underline{990.73\ KPa}$

Volumetric efficiency = ?

g) Assuming $AF = 14.5$

$\Rightarrow \dot{m}a = 14.5\ \dot{m}f = 14.5 \times 1.378 \times 10^{-3} = \underline{0.019981\ kg/s}$

Volume drawn per unit time:

$\dot{V} = \frac{0.019981 \times 287 \times 288}{10^5 \times 1.013} = 0.0163\ m^3/s.$

$\therefore \quad P\dot{V} = \dot{m}a\ RT$

Swept volume of engine $= ALn\ m^3/cycle = \frac{ALnN}{2}\ m^3/min$

$= \frac{2.3758 \times 10^{-3} \times 0.09 \times 4 \times 3300}{2 \times 60} = 0.0235\ m^3/s$

So: $\eta v = \frac{\dot{V}}{Vs} = \frac{0.0163}{0.0235} = 0.6936$ or $\underline{69.36\%}$

Q5] 4 cylinder, 2.5L $N = 3000$ rpm $r_c = 8.6$ $\eta_m = 85\%$

$\frac{S}{B} = 1.03$ $AF = 15$ $\eta_c = 98\%$

100 KPa and $60^\circ \rightarrow 333.15$ K

a) $V_d = \frac{2.5L}{4} = 0.000625\ m^3$

$CR = 8.6 = \frac{V_d + V_c}{V_c} =$ ∴ From here: $V_c = 0.00008223684\ m^3$

$V_d = \frac{\pi}{4} B^2 (S) = \frac{\pi}{4}(B^3)(1.03) = 0.000625$

$\therefore \boxed{B = 0.0278\ m}$

$\therefore \boxed{S = 0.02863\ m}$

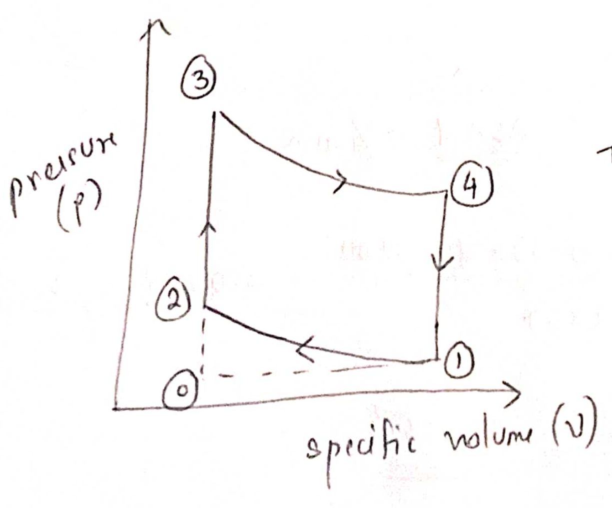
Also: $P_1 V_1 = m_{a+f} R T_1$; where $V_1 = (V_d + V_c)$

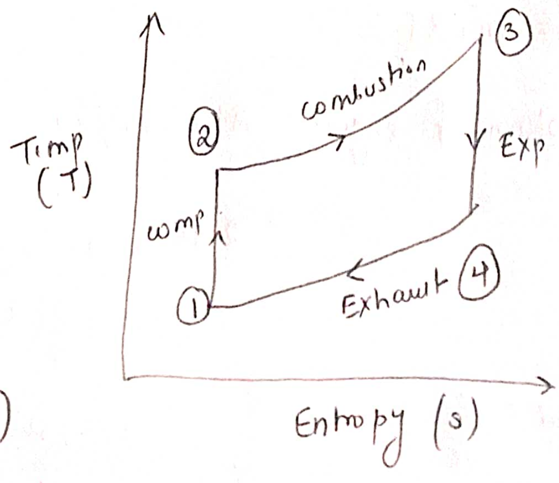
$\therefore m_{a+f} = \frac{(100 \times 10^3)(V_d + V_c)}{(0.287)(333.15)} = (0.73968 \times 10^{-3})$ kg

$\eta_{thermal} = 1 - \frac{1}{(CR)^{k-1}} = 1 - \frac{1}{(8.6)^{1.35-1}} = 0.5291 = \boxed{52.91\%}$ thermal efficiency.

$m_{air} = 15\left(\frac{m_{a+f}}{16}\right) = \boxed{0.00069\ kg}$

$m_{fuel} = \frac{1}{16}(m_{a+f}) = \boxed{0.00005\ kg}$





Stage 2 : $P_2 = P_1(CR)^k = (100)(8.6)^{1.35} = \boxed{1826.3\,kPa}$

$T_2 = T_1(CR)^{k-1} = (333.15)(8.6)^{0.35} = \boxed{707.48\,K}$

Stage 3 : $Q_{in} = m_f\, Q_{cv}\, \eta_c = (M_{mix})\, C_v\, (T_3 - T_2)$

$Q_{cv} = 44\, MJ/kg$

$\eta_c = 98\%$ $\therefore$ From Here $\boxed{T_3 = 3915\,K}$

and as combustion in SI engine is considered a const volume process

$$\therefore \frac{P_2}{T_2} = \frac{P_3}{T_3}$$

$$\therefore P_3 = P_2\left(\frac{T_3}{T_2}\right) = \boxed{10111\,kPa}$$

Stage 4 : $T_4 = T_3\left(\frac{1}{CR}\right)^{k-1} = \boxed{1844\,k}$

and $P_4 = P_3\left(\frac{1}{CR}\right)^{k} = \boxed{544\,kPa}$

$$V_4 = \frac{m_{mix}\, R\, T_4}{P_4} = \boxed{0.000707\, m^3}$$

$$W_{34} = \frac{m_{mix}\, R(T_3 - T_4)}{k-1} = \boxed{1.257\, kJ}$$

$$W_{12} = \frac{m_{mix}\, R(T_2 - T_1)}{k-1} = \boxed{0.227\, kJ}$$

$(W_{net} = W_{34} - W_{12})$

$$Q_{in} = m_f\, Q_{cv}\, \eta_c = \underline{\underline{2.134\, kJ}}$$

$$\eta_t = \left(\frac{W_{net}}{Q_{in}}\right) \sim \frac{1.03}{2.134} = \boxed{48\%}$$

Q6.] Truck Engine $\Rightarrow$ $\eta_c = (0.98)$

$CR = 16$; $T_{max} = 2400°C$

At start of compression = 55°C and 100 kPa

a) $V_d = \frac{4L}{4\,cy} = 1\,lt = 0.001\ m^3$

$CR = 16$; $V_c \Rightarrow 0.0000667\ m^3$

$m_{mix} = \frac{P(V_t + V_c)}{RT} = 0.00112\ kg$

$m_{mix} = (m_f + m_a)$ $\quad m_f = 0.0000578\ kg$

$T_1 = 60 + 273.15 = 333.15\ K$

$P_1 = \boxed{100\ KPa}$

State 2: $T_2 = 879\ K$; $P_2 = 4222\ K$ $\quad Q_{in} = m_f\, Q_{cv}\, \eta_c = \boxed{2.46\,kJ}$

State 3 : $m_{mix}\, C_p\,(T_3 - T_2) \Rightarrow T_3 = 3208\ K$

$V_3 = \frac{m_{mix}\, R T_3}{P_3} = 0.000097\ m^3$

$Q_{2x} = m_{mix}\, C_v\,(T_x - T_3) \Rightarrow T_x = 2217\ K$

$P_x = \frac{m R T_x}{V_x} = 10650\ kPa.$

State 4 : $V_x = V_1 = 0.0010667\ m^3$ $\quad T_4 = T_3 \left(\frac{V_3}{V_1}\right)^{k-1} = 18816\ kPa$

$P_4 = P_3 \left(\frac{V_3}{V_4}\right)^{k} = 418\ kPa$

State 5 : $T_5 = T_4 \left(\frac{P_5}{P_4}\right)^{\frac{k-1}{k}} \Rightarrow T_5 = 957\,K$

$\boxed{\cancel{\eta_t = 60.7\%}}$

~~Wnet = Wx3~~ $\quad W_{net} = W_{x3} + W_{3x} - W_{12}$

$W_x = P(V_2 - V_x)$; $\quad W_{3x} = \frac{mR(T_4 - T_3)}{1-k}$

$W_R = \frac{mR(T_1 - T_2)}{1-k}$ $\quad \therefore W_{net} = 1.495\ kJ$

$Q_{in} = m_{mix}\, Q_{cv}\, \eta_c = 2.46\ kJ$

$\therefore \boxed{\eta_t = 60.7\%}$

Q7] $\rightarrow$ $V_d = \frac{4l}{4} = 1L = 0.001\,m^3$

$CR = 1 + \frac{V_d}{V_c}$ $\quad V_c = 62.5\,cm^3$

$V = V_d + V_c$

$V = 0.0010625\,m^3$

$P_1 = 100\,KPa$

$T_1 = 60°C = 333\,K$

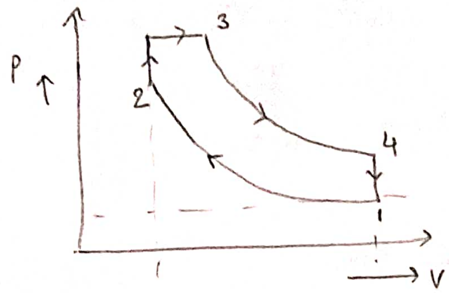
$m_m = \frac{PV}{RT} = \frac{100 \times 10^3 \times 0.0010625}{283 \times 333}$

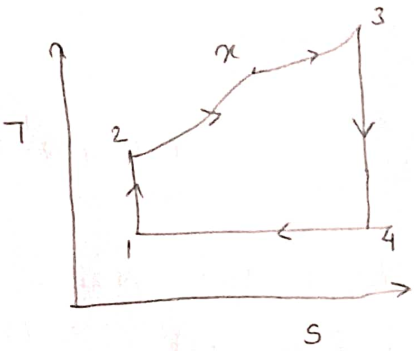
$m_m = 0.00111\,kg$

$AF = 18$

$m_f = \frac{1}{18} \times 0.00111$

$m_f = 0.000062\,kg$





$P_2 = P_1 (r_c)^n$

$= 100 (16)^{1.35}$

$= 4222.42\,kPa$

$T_2 = T_1 (r_c)^{n-1} = 879\,K$

$Q_{in} = m_f\, Q_{cv}\, \eta_c = 0.000062 \times 44 \times 10^6 = \underline{2.728\,kJ}$

$Q_{2-x} = Q_{x-3} = \frac{2.728}{2} = 1.364\,kJ$

$Q_{x-3} = m_m\, C_p (T_3 - T_x)$

$Q_{2-x} = m_m\, C_v (T_x - T_2)$

$1.23 = 0.00111 \times 0.821 \times (T_x - 879)$

$\boxed{T_x = 2228.75\,K}$

$Q_{x-3} = 1.23 = 0.00111 \times 1.108 (T_3 - 2228.71) =$

$\boxed{T_3 = 3228.80\,K}$

State 3 : $\dfrac{P_x}{P_3} = \dfrac{T_x}{T_2} = \dfrac{2228.705}{879}$

$P_x = P_3 = 10705.948$ kPa

$V_3 = \dfrac{m_m R T_3}{P_3}$

$= \dfrac{0.00111 \times 287 \times 3228.80}{10705.448 \times 10^3}$

$= \underline{0.000096 m^3}$

State 4 : $V_4 = V_1 = 0.0010667 m^3$

$\dfrac{T_4}{T_3} = \left(\dfrac{V_3}{V_1}\right)^{k-1}$

$T_4 = \left(\dfrac{0.000096}{0.0010667}\right)^{0.35} \times 3228.80$

$\therefore \boxed{T_4 = 1390 K}$

$\dfrac{P_4}{P_3} = \left(\dfrac{V_3}{V_1}\right)^{k} \Rightarrow P_4 = 414.79$ kPa

$W_{net} = W_{34} + W_{x3} - W_{12}$

$W_{x3} = P_3 (V_3 - V_x) \longrightarrow V_3 \left(\dfrac{T_x}{T_3}\right) \quad (P_x = P_3$

$= 10705.94 \times 10^3 \times 0.000096 \left(1 - \dfrac{2228.75}{3228.80}\right)$

$\boxed{W_{x3} = 318 J}$

$\therefore W_{net} = 1297 + 314 - 226$

$W_{net} = 1385 J$

$\boxed{W_{net} = 1.385 kJ}$

q8.]

Given:

Isoctane burnt with 110% theoretical air in 3-cylinder

Calculate: a) Air fuel ratio b) Fuel air ratio c) equivalence ratio

→ a) $C_8H_{18} + 12.5O_2 + 12.5 \times 3.76 N_2 \longrightarrow 8CO_2 + 9H_2O + 12.5 \times 3.76 N_2$

$C_8H_{18} + 13.75O_2 + 13.75 \times 3.76 N_2 \longrightarrow 8CO_2 + 9H_2O + 13.75 \times 3.76 N_2 + 1.25O_2$ } 110%

$\therefore AF = \frac{ma}{mf} = \frac{NaMa}{Nf\,Mf}$

$Na = 13.75 \qquad Ma = (32 + 3.76 \times 28) = 137.28$

$Nf = 1 \qquad Mf = 114$

i) $A/F = \frac{13.75 \times 137.28}{114} = 16.6$

ii) $FA = \frac{\cancel{13.75}.1}{AF} = \frac{1}{16.6} = 0.0602$

iii) $\phi = \frac{FA_{act}}{FA_{str}}$

$FA_{stoic} = \frac{m\,Nf\,Mf}{Na\,Ma}$

$Nf = 1 \qquad Na = 12.5$

$FA_{stoic} = 0.066$

$\phi = \frac{0.0602}{0.066} = 0.91$ Lean fuel

9.] Gasoline: 18% Butane + 72% triptane + rest isodecane.

Sensitivity = ?

Anti-knock index = ?

→

Fuel	RON	MON	%
Butane	99	80	18
Triptane	112	101	72
Isodecane	113	92	10

ON Blend

RON = $0.18 \times 99 + 0.72 \times 112 + 0.1 \times 113 = 109.76$

MON = $0.18 \times 80 + 0.72 \times 101 + 0.1 \times 92 = 96.32$

$AKI = \frac{109.76 + 96.32}{2} = 103.04$

FSensitivity $= 109.76 - 96.32 = 13.44 \geq 10$

10] → CI engine running at 1700 rpm.

Combustion starts at 14° bTDC

Ignition delay = 5.2° CA

Start of fuel injection = ?

Ignition delay time = ?

$$ID = \frac{\text{Crank angle}}{\text{crank speed}} = \frac{\left(\frac{5.2}{360}\right)}{\left(\frac{1700}{60}\right)} = \underline{\underline{0.51 \text{ ms}}}$$

Fuel injection (in. C.A) = 5.2 + 14

= $\underline{\underline{19.2° CA}}$

Q11]

→ <u>Given</u> :

Spark plug fired at $18°$ bTDC Offset = 8 mm

Engine speed = 1750 rpm

Engine rotation = $8°$

Flame termination = $12°$ aTDC

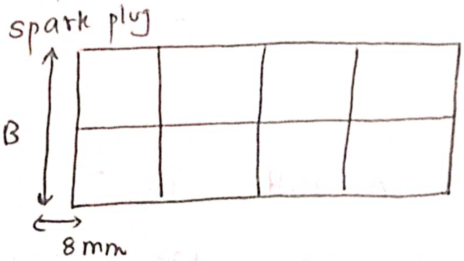
Bore diameter (B) = 86 mm

<u>Calculate</u> : a) Effective flame speed = ?

b) Advancement of Ignition timing = ?

<u>Given</u> : flame front speed $\propto$ 0.85N

Engine speed then increased to 3000 rpm



<u>Soln</u> : $D = \frac{B}{2} + 8 = \frac{86}{2} + 8 = \underline{\underline{51 \text{ mm}}}$

$$V_f = \frac{D}{t}$$

Frame probation = $22°$ engine rotation.

$$t = \frac{\left(\frac{22}{360}\right) \text{rev}}{\left(\frac{1750}{60}\right) \text{rev/s}} = 0.002095 \text{ sec.}$$

$$V_f = \frac{\left(\frac{51}{1000}\right)}{0.002095} = \underline{\underline{24.343}} \text{ m/s} \quad \text{- Effective Flame speed.}$$

b) $N_1 = 1750$ rpm ; $N_2 = 3000$ rpm

$V_{f1} = 24.343$ m/s ; $V_{f2} \propto 0.85N$

$$\Rightarrow \frac{V_{f2}}{V_{f1}} = 0.85\left(\frac{N_2}{N_1}\right)$$

$$\therefore V_{f2} = 0.85\left(\frac{3000}{1750}\right)(24343) = \underline{\underline{35.471 \text{ m/s}}}$$

$$t = \frac{D}{V_{f_2}} = \frac{51 \times 10^{-3}\ m}{35.471} = 0.001438\ secs.$$

$$\theta = 360 \times t \times N$$

$$= \frac{360 \times 0.001438 \times 3000}{60} =$$

$$\boxed{\theta = 25.884^\circ}$$

Termination = 12° aTDC ; 8° start of combustion.

propation = $25.884^\circ - 12^\circ = \underline{13.884^\circ}$ bTDC

spark plug = $\underline{21.884^\circ}$ bTDC

$\therefore$ Advancement of ignition timing = $\underline{3.884^\circ}$

Q13]

→ Given :

- Ignition delay = 4°CA

Combustion starts : 1.5° aTDC

- 6-cylinder engine
- operating ~~sp~~ rate : 980 rpm

Total displacement = 15L

compression ratio = 16

Stoke of engine = twice the bore size.

Calculate:

a) Average piston speed = ?

b) start of fuel injection = ?

c) Ignition time delay = ?

a) $S = 2B$ $\quad \therefore \quad \frac{\pi}{4} B^2 S \times 6 = 15 \times 10^{-3}$

$$\frac{\pi}{4} \times 2B^3 \times 6 = 15 \times 10^{-3}$$

$$\therefore \boxed{\begin{aligned} B &= 116.75 \text{ mm} \\ S &= 233.5 \text{ mm} \end{aligned}}$$

$$\overline{U_p} = 2NS = 2 \times \frac{980}{60} \times 233.5 \times 10^{-3} = \boxed{7.627 \text{ m/s}}$$

c) $$\underset{(\text{time})}{ID} = \frac{\left(\frac{4}{360}\right) \text{rev}}{\left(\frac{980}{60}\right) \text{rev/s}} = \boxed{0.6802 \text{ ms}}$$

b) Start of fuel injection = ID + start of combustion

$= \cancel{0.6802} + \cancel{1.5}$

$= -4 + \underset{aTDC}{\underline{1.5}} = \boxed{2.5° \text{ bTDC}}$

Q14] → 3L 5 cylinder 4 stroke

volume efficiency = 82%

2800 rpm

Stroke = 1.1 (Bore size)

$T_g = 2300°C$

$T_{cl} = 195°C$
(T_w)

Convective Heat Transfer wall to the cylinder wall

→ At 1247.5°C

$\mu = 4.81 \times 10^{-5}$ kg/ms

$k = 0.0809$ W/m°C

$C_1 = 0.035$

$C_2 = 0.8$

$$\text{Volume} = \frac{3L}{5} = 0.6\,L = 600\,cm^3$$

$$S = 1.1B$$

$$V = \frac{\pi}{4}B^3 \times 1.1 = 600$$

$$\therefore B = 8.86\ cm$$

$$A_p = 61.65\ cm^2$$

$$\rho_a = 1.63\ kg/m^3 \ @_{195°C}$$

$$\dot{m}_a = \frac{\eta_{vo}\,\rho_a\,V_d \times N}{n} = \frac{0.82 \times 1.83 \times 0.0006 \times 2800}{60 \times 2} = \boxed{0.024\ kg/s}$$

$$\dot{m}_L = \frac{\dot{m}_a}{14.6} = \boxed{0.0014} = \cancel{0.6}\ kg/s.$$

$$Re = \left(\frac{\dot{m}_a + \dot{m}_L}{A_p\,\mu_g}\right)B = \frac{0.0224 \times 0.0886}{61.65 \times 10^{-4} \times 4.81 \times 10^{-5}} = \boxed{6693}$$

$$Nu = 0.035 \times (6693) \times 0.8 = \boxed{40.23} \qquad (Nu = C_1 \times Re \times C_2)$$

$$\frac{h_g B}{k} = Nu \quad \therefore h_g = \frac{Nu\,k}{B} = \frac{40.23 \times 0.0801}{0.0886} = \boxed{36.73}$$

$$q = \underset{?}{34.88} \times (2300 - 195) = \boxed{77316.65\ W/m^2} \qquad (q = (T_g - T_w))$$

Q 15]

$\longrightarrow \quad \dot{m}a = \frac{n_u \rho_a V_d N}{n}$

Given: 12 cylinder 2 stroke CI engine ; N = 530 rpm (k) (n)

$\therefore k = 12$

$n = 2$

B.P = 2450 kW

B = 240 mm

S = 320 mm

efficiency = 98%

$\eta_c = 0.98$

a) Mass flow rate fuel into the engine :

$$\dot{m}a = \frac{n_u \rho_a V_d N}{\eta} = \frac{0.98 \times 1.18 \times V_d \times 530 \text{ (rpm)}}{60 \times 2}$$

$$V_d = 12 \times \frac{\pi}{4} \times (0.32) \times (0.24)^2 \qquad \left[\text{As } V_d = K \left[\frac{\pi B^2 S}{4}\right] \right]$$

($\frac{\pi}{4} B^2 S$; K = No. of cylinders)

$\therefore V_d = 0.174 \, m^3$

$\rho_a = 1.18 \, kg/m^3$

$$\therefore \dot{m}a = \frac{\eta_u \rho_a V_d N}{\eta} = \frac{0.98 \times 1.18 \times 0.174 \times 530}{60 \times 2} = 0.92 \, kg/s$$

$$\dot{m}f = \frac{0.92}{AF} = \frac{0.92}{14.6} = \boxed{0.063 \, kg/s}$$

b) Specific emission of hydrocarbons due to unburnt fuel :

$$\dot{m}_{unburnt} = (1 - 0.98)\,\dot{m}f = 0.02(\dot{m}f) =$$

$$= (1 - n_c)\,\dot{m}f = 0.02(0.063) = 1.26 \, gm/s$$

$$(SE)_{HC} = \frac{\dot{m}_{unburnt}}{W_b} = \frac{1.26 \times 10^{-3}}{2450} \frac{gm}{\cancel{s}} \times 3600 \left(\frac{\cancel{s}}{hr}\right)$$

(W_b: ~~Brake Power~~)

$= 1.851 \, gm/kW\,hr.$

c) Emission index of hydrocarbons due to unburnt fuel :

$$(EI)_{HC} = \frac{\dot{m}_{unburnt}}{\dot{m}f} = \frac{1.26 \times 10^{-3}}{0.063} = 0.02$$

9.16] $p = 7$ bar $(847°C \Rightarrow T) \Rightarrow 847 + 273 K = 1120 K$

$\bar{R} = 8.314$ kJ/kg K $M = 28.97$

→ From data table

At $T = 300K$; $u = 214$ kJ/kg K ; $s = 1.7$ kJ/kg K

At $T = 1120K$; $u = 862.8$; $s = 0.9$

but : $v = \left(\frac{\bar{R}}{M}\right)\left(\frac{T}{p}\right)$ — (A) $v_0 = \frac{\bar{R}}{m}\left(\frac{T_0}{p_0}\right)$ — (B)

① $u - u_0 = 648.8$ kJ/kg

from (A) and (B) ② $\Rightarrow p_0 (v - v_0)$

$$\frac{\bar{R}}{M}\left(\frac{p_0 T}{p} - T_0\right)$$

$$\frac{8.314}{28.97}\left(\frac{1.013 \times 1120}{7} - 300\right)$$

③ $T_0(s - s_0)$ where $s - s_0 = s(T) - s(T_0) - \frac{\bar{R}}{m}\ln\left(\frac{p}{p_0}\right)$

$= 0.245$

$T_0(s - s_0) \Rightarrow 300(0.245) = 73.57$ kJ/kg

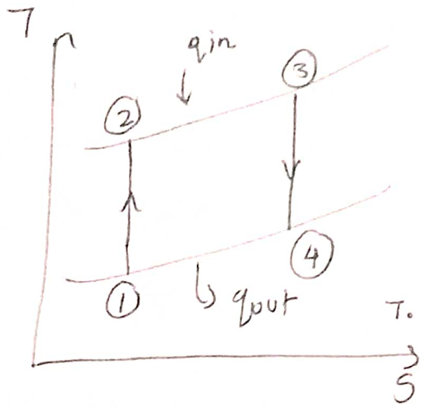
$\therefore e = 648.8 - 39.58 - 73.57$

$\therefore e = 535.643$ kJ/kg

Q17] $p_1 = 1$ bar $\quad T_1 = 30°C = 303K$

$p_3 = 8$ bar $\quad T_3 = 900°C = 1073K$

$\rho_{23} = 100$ mm.



a) $\eta = 1 - \frac{1}{(r)^{\frac{\gamma-1}{\gamma}}}$ $\quad r = \frac{p_3}{p_1} = 8$ $\quad \gamma = 1.4$ $\quad c_p = 1.005\ kJ/kg$

$\therefore \boxed{\eta = 0.448}$

b) $WR = \frac{W_T - W_C}{W_T}$ $\quad W_T = C_p(T_3 - T_4)$ $\quad W_C = C_p(T_2 - T_1)$

$\frac{T_2}{T_1} = r^{\frac{\gamma-1}{\gamma}}$

$T_2 = (1.81)\ T_1$

Here $T_4 > T_2$ $\quad T_2 = 548.86\ K$

$W_T = 482.58\ kJ/kg$

$W_C = 247.09\ kJ/kg$

$\frac{T_3}{T_4} = r^{\frac{\gamma-1}{\gamma}}$

$\therefore T_4 = \frac{T_3}{1.81}$

$WR = \frac{482.58 - 247.09}{482.58}$ $\quad \therefore T_4 = 592.81$

$= \boxed{0.487}$

c) $\frac{W_{net}}{Q_{in}} = 0.448$

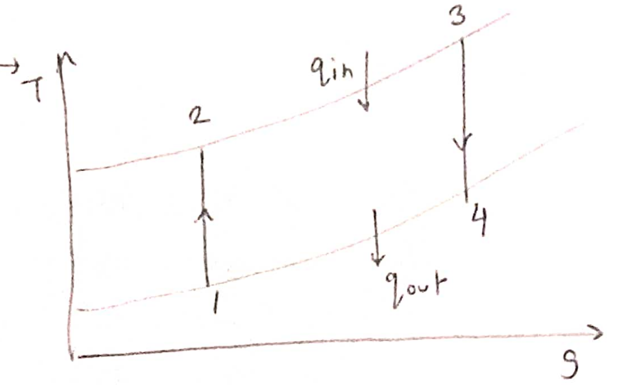
$W_{net} = 0.448 \times 100 = \boxed{44.8\ MJ/s}$

d) $X_{heat} = \int_{T_0}^{T_4} \left(1 - \frac{T_0}{T}\right) \delta Q$ $\quad \Rightarrow \dot{m} c_p (T_4 - T_0) - \dot{m} C_p T_0 \ln\left(\frac{T_4}{T_0}\right)$

$Q_{in} = \dot{m} C_p (T_3 - T_2)$ $\quad \therefore T_0 = 300K$

$\dot{m} = 189.84\ kg/s$ $\quad \Rightarrow \boxed{16.88\ MW}$

18.] →



$T_3 = 1000 + 273 = 1273 k$

$T_1 = 25 + 273 = 298 K$

$t = \frac{T_3}{T_1} = 4.271$

a) $$\left(\frac{W}{c_p T}\right)_{opt} = t\left(1 - \frac{1}{\sqrt{t}}\right) - \left(\sqrt{t} - 1\right)$$

$$= 4.271\left(1 - \frac{1}{\sqrt{4.271}}\right) - \left(\sqrt{4.271} - 1\right)$$

$$= 4.271 \times 0.576 - (1.066)$$

$$= \underline{\underline{1.137}}$$

$T = 25°C \Rightarrow 273 + 25 = \underline{\underline{298 k}}$

$c_p = 1.005 \ kJ/kg$

$W_{opt} = 1.137 \times 293 \times 1.005 = \underline{\underline{340.52 \ kJ/kg}}$

b) $(r_{opt})^{\frac{\gamma-1}{\gamma}} = \sqrt{t} \Rightarrow r_{opt} = (t)^{\frac{\gamma}{2(\gamma-1)}}$

$\gamma = 1.4$ [for air]

$r_{opt} = (4.271)^{\frac{1.4}{0.8}} = 12.68$

c) $\eta_b = 1 - \sqrt{\frac{T_1}{T_3}} = 1 - \sqrt{\frac{298}{1273}} = \underline{\underline{0.516}}$

d) $\eta_c = 1 - \frac{T_1}{T_3} = 1 - \frac{298}{1273} = 0.765$

$\frac{\eta_b}{\eta_c} = \frac{0.516}{0.765} = \underline{\underline{0.674}}$

21.] Given:

compression ratio = 9.2

Turbine inlet temperature = 1350 K

$\eta_i = 0.93$

$\eta_c = 0.85$

$\eta_t = 0.9$

$\eta_j = 0.95$

$\eta_b = \eta_m = 0.98$

Δp_b = 4% of compressor delivery pressure

Exhaust pressure loss = 0.03 bar.

$P_a = 0.22$ bar

$T_a = 220K$

$M = 0.8$

Now, stagnation condition:

$$\frac{C_a^2}{2C_p} = \frac{(0.8 \times 299.5)^2}{2 \times 1.005 \times 1000} = 28.56K$$

$$T_{01} = T_a + \frac{C_a^2}{2C_p} = 251.86 \text{ K}$$

$$P_{01} = P_a\left[1 + \eta_i \frac{C_a^2}{2C_p T_a}\right]^{\gamma/\gamma-1} = 0.3927 \text{ bar}.$$

At outlet from compressor

$$P_{02} = \left(\frac{P_{02}}{P_{01}}\right) P_{01} = 9.2 \times 0.3927 = 3.613 \text{ bar}$$

and $$T_{02} = T_{01} + \frac{T_{01}}{\eta_c}\left[\left(\frac{P_{02}}{P_{01}}\right)^{\frac{\gamma-1}{\gamma}} - 1\right] = 514.16K$$

$$W_t = \frac{W_c}{\eta_m} \quad \text{Hence: } T_{03} - T_{04} = \frac{C_{pa}(T_{02} - T_{01})}{C_{pg}\,\eta_m}$$

$$\therefore \boxed{T_{04} = 1115.7K}$$

$$P_{03} = P_{02}\left(1 - \frac{\Delta P_b}{P_{02}}\right) = 3.613(1 - 0.04)$$

$$\underline{P_{03} = 3.4685}$$

$$T_{04}' = T_{03} - \frac{1}{\eta_t}(T_{03} - T_{04}) = \underline{1089.6\,K}$$

$$\Rightarrow P_{04} = P_{03}\left(\frac{T_{04}'}{T_{03}}\right)^{\gamma/\gamma-1}$$

$$= \underline{1.4626\ bar}$$

Nozzle pressure ratio $= \dfrac{P_{04}}{P_a} = \underline{5.5194}$

Critical pressure ratio $= \dfrac{P_{04}}{P_c} = \dfrac{1}{\left[1 - \frac{1}{\eta_3}\left(\frac{\gamma-1}{\gamma+1}\right)\right]^{-}} = \underline{1.9168}$

Nozzle pressure ratio $>$ critical pressure ratio $\Rightarrow$ Nozzle is choking

$$T_5 = T_c = \left(\frac{2}{\gamma+1}\right) T_{04} = 957.665\,K$$

$$P_5 = P_c = P_{04}\left(\frac{1}{P_{04}/P_c}\right) = 0.7631\ bar$$

$$\rho_5 = \frac{P_c}{RT_c} = 0.2776\ kg/m^3$$

$$C_5 = (\gamma R T_c)^{1/2} = (1.33 \times 0.287 \times 957.665 \times 1000)^{1/2} = \underline{604.6\ ms^{-1}}$$

$$\frac{A_5}{m} = \frac{1}{\rho_5 C_5} = 0.0060$$

Specific Thrust $F_5 = (C_5 - C_4) + \dfrac{A_5}{m}(P_c - P_a) = 661.72\ Ns/K$

$F_{theoretical} = 0.0144 \Rightarrow$

$$f = \frac{f_{theoretical}}{70} = 0.0198$$

$$SFC = \frac{F}{F_J} = 0.1079$$