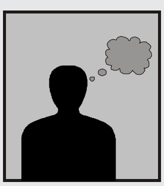
ESE GATE PSUs

State Engg. Exams

MADE EASY

Workbook 2025



Detailed Explanations of Try Yourself *Questions*

Mechanical Engineering

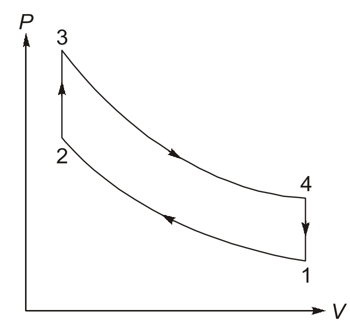
Internal Combustion Engines

MADE EASY PUBLICATIONS

1 Air Standard Cycle

Detailed Explanation *of* Try Yourself Questions

T1 : Solution



Given:

$$T_3 = 1400°C = 1673 \text{ K}$$
$$T_1 = 15°C = 288 \text{ K}$$
$$Q_s = 800 \text{ kJ}$$
$$Q_s = c_v(T_3 - T_2)$$
$$c_p - c_v = R$$
$$c_v = 1.005 - 0.287 = 0.718 \text{ kJ/kgK}$$
$$T_2 = T_3 - \frac{Q_s}{c_v}$$
$$= 1673 - \frac{800}{0.718} = 558.8 \text{K}$$

For process $1 \rightarrow 2$,

$$T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$$

or, Compression ratio,

$$r = \frac{V_1}{V_2} = \left(\frac{T_2}{T_1}\right)^{\frac{1}{\gamma-1}} = \left(\frac{558.8}{288}\right)^{\frac{1}{0.4}} = 5.24396 \qquad \textbf{Ans.}$$

$$\eta = 1 - \frac{1}{r^{\gamma-1}} = 1 - \frac{1}{(5.2438)^{0.4}} = 0.4846$$

$\therefore$ Cycle efficiency,

$$\eta = \mathbf{48.46\%} \qquad \textbf{Ans.}$$

For process $2 \rightarrow 3$,

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

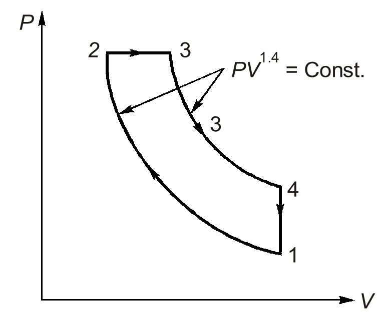
or

$$P_3 = \frac{T_3}{T_2} \times P_1\left(\frac{T_2}{T_1}\right)^{\frac{\gamma}{\gamma-1}}$$

$$\frac{P_3}{P_1} = \frac{1673}{558.8} \times \left(\frac{558.8}{288}\right)^{\frac{1.4}{0.4}} = 2.9939 \times 10.175$$

$$\frac{P_3}{P_1} = 30.462 \text{ or } \frac{P_{max}}{P_{min}} = 30.462$$ **Ans.**

T2 : Solution



Given: Compression ratio, $r = \frac{V_1}{V_2} = 17$

$$\frac{c_P}{c_V} = \gamma = 1.4$$

or $$V_3 - V_2 = 0.1\,(V_1 - V_2)$$

or $$\frac{V_3}{V_2} - 1 = 0.1\left(\frac{V_1}{V_2} - 1\right)$$

or Cut-off ratio, $\rho = \frac{V_3}{V_2} = 0.1 \times 16 + 1 = 2.6$

$$\eta_{Diesel} = 1 - \frac{1}{r^{\gamma-1}}\left[\frac{r_c^{\gamma} - 1}{\gamma(r_c - 1)}\right]$$

Where r_c is cut-off ratio and r is compression ratio

$$= 1 - \frac{1}{17^{0.4}}\left[\frac{2.6^{1.4} - 1}{1.4(2.6-1)}\right] = 1 - \frac{1}{17^{0.4}}\left(\frac{3.81-1}{1.4 \times 1.6}\right)$$

$$= 0.596 \text{ or } 59.6\%$$

T3 : Solution (c)

Considering the engine to be spark ignition engine;

Stroke length, $l = 250 \text{ mm} = 0.25 \text{ m}$

Bore dia: $d = 200 \text{ mm} = 0.2 \text{ m}$

Clearance volume, $V_c = 0.001 \text{ m}^3$

$\gamma = 1.4$

Displacement volume, $V_s = \frac{\pi}{4} d^2 \times l = \frac{3.14}{4} \times (2)^2 \times 0.25$

$= 7.85 \times 10^{-3} \text{ m}^3$

Total volume in the cylinder, $V_1 = V_c + V_s = 0.001 + 7.85 \times 10^{-3}$

$= 8.85 \times 10^{-3} \text{ m}^3$

Compression ratio, $r = \frac{V_1}{V_c} = \frac{8.85 \times 10^{-3}}{0.001} = 8.85$

$\therefore$ Air-standard cycle efficiency, $\eta = 1 - \frac{1}{r^{\gamma-1}} = 1 - \frac{1}{(8.85)^{1.4-1}}$

$$= 1 - \frac{1}{8.85^{0.4}} = 0.5819 \approx \mathbf{58.2\%}$$

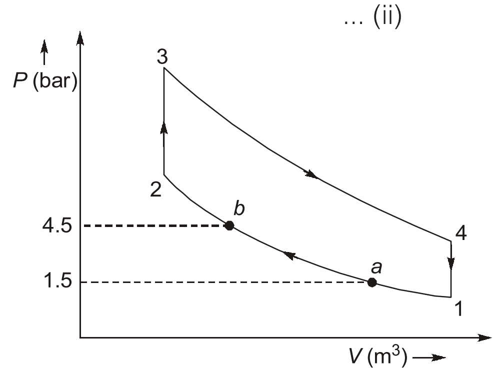
T4 : Solution

$$V_a = V_2 + 0.75\,(V_1 - V_2) = 0.75V_1 + 0.25V_2$$
$$V_b = V_2 + 0.25\,(V_1 - V_2) = 0.25V_1 + 0.75V_2$$

$$\therefore \quad \frac{V_a}{V_2} = 0.75r + 0.25 \qquad \text{... (i)}$$

$$\frac{V_b}{V_2} = 0.25r + 0.75 \qquad \text{... (ii)}$$

$$\frac{V_a}{V_b} = \frac{0.75r + 0.25}{0.25r + 0.75}$$



Also, Compression process follows $PV^{1.4} = C$

$$\therefore \quad \frac{P_b}{P_a} = \left(\frac{V_a}{V_b}\right)^{1.4}$$

$$\Rightarrow \quad \frac{4.5}{1.5} = \left(\frac{0.75r + 0.25}{0.25r + 0.75}\right)^{1.4}$$

$$\frac{0.75r + 0.25}{0.25r + 0.75} = 2.192$$

$$0.75r + 0.25 = 0.5479r + 1.644$$

$$0.2021r = 1.394$$

$$r = 6.89$$

$$\text{Efficiency, } \eta = 1 - \frac{1}{r^{\gamma-1}} = 1 - \frac{1}{(6.89)^{0.4}}$$

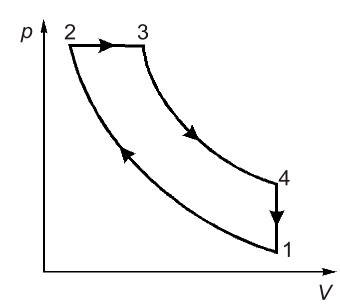
$$= 0.5381 = 53.81\%$$

T5 : Solution

Given, $p_1 = 1$ bar, $p_2 = 32.42$ bar

$$\gamma = \frac{c_p}{c_v} = 1.4$$

$$\frac{V_4}{V_3} = \frac{V_1}{V_3} = 8$$



For process 1–2, $p_1 V_1^{\gamma} = p_2 V_2^{\gamma}$

$$\therefore \quad \left(\frac{V_1}{V_2}\right)^{\gamma} = \frac{p_2}{p_1} = 32.42$$

or $$\frac{V_1}{V_2} = (32.42)^{1/1.4} = 11.999 \approx 12$$

$\therefore$ Compression ratio, $r = 12$

Cut-off ratio,

$$r_c = \frac{V_3}{V_2} = \frac{V_1}{8} \times \frac{12}{V_1} = 1.5$$

$$\eta_{Diesel} = 1 - \frac{1}{r^{\gamma-1}}\left[\frac{r_c^{\gamma}-1}{\gamma(r_c-1)}\right] = 1 - \frac{1}{12^{0.4}}\left[\frac{1.5^{1.4}-1}{1.4\times 0.5}\right]$$

$$= 0.596 = \mathbf{59.6\%}$$

POINTS TO REMEMBER

- Here, in this problem, cut-off ratio,

$$r_c = \frac{V_3}{V_2} = \frac{V_3}{V_2}\times\frac{V_1}{V_1} = \frac{V_1}{V_2}\times\frac{V_3}{V_1}$$

So, cut-off ratio, $r_c = r \times \frac{1}{r_e} \quad \left(r_e = \frac{V_4}{V_3} = \frac{V_1}{V_3}\right)$

$$\therefore \quad r_c = \frac{r}{r_e}$$

- So, it is important to note that compression ratio is equal to the multiplication of cut-off ratio and expansion ratio and the value of cut-off ratio, expansion ratio and compression ratio are always greater than 1.

T6 : Solution

As given compression ratio (CR) diesel 15 to 21

r = 1.3, cut off ratio r_c = 2

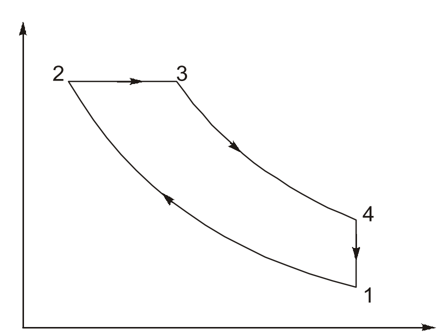
$$\eta_{d,\ r=21} = 1 - \left(\frac{1}{r}\right)^{\gamma-1} \times \frac{(\rho^{\gamma}-1)}{\gamma(\rho-1)} = 54.87\%$$

$$\eta_{d,\ r=15} = 1 - \left(\frac{1}{r}\right)^{\gamma-1} \times \frac{(\rho^{\gamma}-1)}{\gamma(\rho-1)} = 50.08\%$$

$$\eta_{d,\ r=21} - \eta_{d,\ r=15} = (54.87 - 50.08)\% = 4.8\%$$

T7 : Solution

$$\frac{\text{Ratio of clearance volume}}{\text{Swept volume}} = \frac{V_c}{V_s} = \frac{1}{15}$$



$$r = 1 + \frac{V_s}{V_c} = 1 + 15 = 16$$

$$\rho - 1 = 0.1 \times (r-1)$$

$$= 0.1 \times (16-1) = 1.5$$

$$\Rightarrow \quad \rho = 2.5$$

$$\eta_I = 1 - \frac{1}{r^{(\gamma-1)}} \times \frac{\rho^{\gamma}-1}{\gamma(\rho-1)}$$

$$= 1-\frac{1}{(16)^{0.4}}\times\frac{(2.5)^{1.4}-1}{1.4(2.5-1)} = 59.05\%$$

If new specific heat is increasd by 10% then,

$$C_V = 1.1\times 0.717 = 0.7887$$

$\because$ $$C_P - C_V = R$$

$\Rightarrow$ $$C_P = 0.287 + 0.7887 = 1.0757$$

$\therefore$ $$\gamma' = \frac{C_P}{C_V} = \frac{1.0757}{0.7887} = 1.363$$

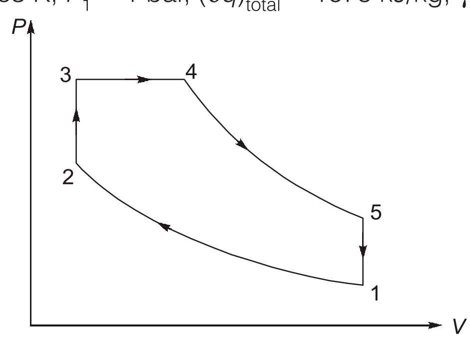
$$\eta_{II} = 1-\frac{1}{(16)^{0.363}}\times\frac{(2.5)^{1.363}-1}{1.363(2.5-1)} = 55.54\%$$

Percentage decrease in efficiency $= \eta_I - \eta_{II}$

$= (59.05 - 55.54)\% = 3.51\%$

T8 : Solution

Given: $r = 13$, $T_1 = 90°C = 363$ K, $P_1 = 1$ bar, $(\delta q)_{total} = 1675$ kJ/kg, $\gamma = 1.4$, $R = 0.287$ kJ/kg-K



$$C_V = \frac{R}{\gamma-1} = \frac{0.287}{0.4} = 0.718 \text{ kJ/kg–K}$$

$$C_P = \frac{\gamma R}{\gamma-1} = \frac{1.4\times 0.287}{0.4} = 1.005 \text{ kJ/kg–K}$$

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

$\Rightarrow$ $$T_2 = 363\times(13)^{0.4} = 1012.71 \text{ K}$$

$\because$ $$(\delta q)_V = C_V(T_3 - T_2) = \frac{1675}{2} = 837.5$$

$\Rightarrow$ $$0.718\,(T_3 - 1012.71) = 837.5$$

$$T_3 = 2179.14 \text{ K}$$

$$(\delta q)_P = C_P(T_4 - T_3) = 837.5$$

$$= 1.005\,(T4 - 2179.14) = 837.5$$

$$T_4 = 3012.47 \text{ K}$$

So, Maximum temperature, $T_4 = 3012.47 \text{ K}$

2. $(V_4 - V_3) = \%p\,(r-1)$

$$\Rightarrow \quad \left(\frac{V_4}{V_3} - 1\right) = \frac{p}{100}(13-1)$$

$$\left(\frac{T_4}{T_3} - 1\right) = \frac{p}{100}(13-1) \qquad [\because \text{Process 3-4 is isobaric}]$$

$$\Rightarrow \quad \frac{3012.47}{2179.14} - 1 = \frac{p}{100} \times 12$$

$$\Rightarrow \quad p = 3.186\%$$

So, percentage of the stroke at which cut-off occurs is 3.186%.

■■■■

2 Combustion & Knocking in SI and CI Engines

Detailed Explanation of Try Yourself Questions

T1 : Solution (b)

Time taken by first stage of combustion, $T_1 = 1 \text{ ms} = 1 \times 10^{-3}$

$$\text{Initial speed} = 1000 \text{ rpm}$$

$$\text{New speed} = 2000 \text{ rpm}$$

$$\text{Spark advance, } \theta_2 - \theta_1 = \omega_2 T_1 - \omega_1 T_1$$

$$= \frac{2\pi \times 2000}{60} \times 10^{-3} - \frac{2\pi \times 1000}{60} \times 10^{-3}$$

$$= \frac{2\pi \times 1000}{60} \times 10^{-3}$$

$$= \frac{2 \times 180 \times 1000 \times 10^{-3}}{60} = 6^\circ$$

$\therefore$ New spark timing = 15 + 6 = 21° btdc

■■■■

3 Analysis and Injection of Fuel and Fuel Emission

Detailed Explanation of Try Yourself Questions

T1 : Solution

In case of perfect combustion.

$$C_8H_{18} + \left\{O_2 + \frac{19}{21}N_2\right\} \rightarrow aH_2O + b\,CO_2 + d\,N_2$$

(Assuming 100 parts of air curtains 21 parts of oxygen by volume.)

Balancing above reaction.

C: $8 = b$

H: $18 = 2a \Rightarrow a = 9$

O: $2c = a + 2b = 9 + 2(8) = 25 \Rightarrow c = 12.5$

N_2: $\frac{79}{21}c = d \Rightarrow d = 47.024$

So, balanced equation is

$$C_8H_{18} + 12.5\left\{O_2 + \frac{79}{21}N_2\right\} \rightarrow 9\,H_2O + 8\,CO_2 + 47.024\,N_2$$

$$(A/F)_{stoichiometric} = \frac{12.5\left[32 + \frac{79}{21}\times 28\right]}{8(12)+18(1)} = \frac{1757.87}{114} \approx 15.42$$

Since combustion products contain unburnt oxygen, lean mixture is supplied.

Given: Volume of CO_2 and unused O_2 in exhaust gases is same $\Rightarrow$ Number of moles of CO_2 and unused O_2 are also same. [Avegadro's law: equal volume of gases at same temperature and pressure certain equal number of molecules.]

Thus, actual reaction is

$$C_8H_{18} + c\left\{O_2 + \frac{79}{21}N_2\right\} \rightarrow 9\,H_2O + 8\,CO_2 + 8\,O_2 + f\,N_2$$

Balancing O: $2e = 9 + 16 + 16$

$$e = 20.5$$

Balancing N_2: $$\frac{79}{21}e = f$$

$$f = 77.12$$

Actual reaction: $C_8H_{18} + 20.5\left\{O_2 + \frac{79}{21}N_2\right\} \rightarrow 9\,H_2O + 8\,CO_2 + 8\,O_2 + 77.12\,N_2$

∴ $$(A/F)_{act} = \frac{20.5\left[32 + \frac{79}{21} \times 28\right]}{8(12) + 18(1)} = 24.696$$

By equivalence ratio, $\phi = 1$, engine is operating at stoichiometric air fuel ratio.

Given mass of fuel = 1 kg

∴ Number of moles of fuel, $\eta_{fuel} = \frac{\text{Mass}}{\text{Molecular weight}} = \frac{1000\text{ g/m}}{8(12) + 18(1)\text{ gm/mol}} = 8.772$

Since, stoichiometric reaction may be re-written as

$$8.772C_8H_{18} + 109.65\left\{O_2 + \frac{79}{21}N_2\right\} \rightarrow 79.948\,H_2O + 70.176\,CO_2 + 412.494\,N_2$$

(i) Total moles of mixture = 8.772 + 109.65 = 118.422

Let 'V_m' be the volume of mixture, then

$$P_m V_m = n\bar{R}T_m \qquad (\bar{R} = 8314\text{ J/kmolK})$$

or $$(100 \times 10^3) \times V_m = 118.422 \times 8314 \times (70 + 273)$$

$$V_m = 3377.0425\text{ m}^3$$

(ii)Total moles of products of combustion = 79.948 + 70.176 + 412.494 = 562.618

Let 'V_C' be volume of products of combustion,

$$P_C V_C = n\bar{R}T_C$$

or, $$10^5 \times V_C = 562.618 \times 8314 \times (127 + 273)$$

$$V_C = 18710.42\text{ m}^3.$$

Note: Such large values of volumes are justified as values are computed for 1 kg of fuel.

■■■■

4 Testing & Performance of IC Engine

Detailed Explanation of Try Yourself Questions

T1 : Solution

$$\text{mep} = \frac{W}{V_s} = \frac{W}{V_1 - V_C}$$

$$= \frac{23.625 \times 10^5 \times V_C}{5.5V_C - V_C} = \frac{23.625 \times 10^5 V_C}{4.5V_C}$$

$$= 5.25 \times 10^5 \text{ Pa} = 5.250 \text{ bar}$$

T2 : Solution

$$\text{Volumetric efficiency} = \frac{\text{actual volume}}{\text{swept volume}}$$

$$= \frac{V_a}{V_s} = 0.9$$

$\therefore$ $V_a = 0.9\ V_s$

mass of air,

$$m_a = \rho_{air}\ V_a = 0.9\ V_s$$

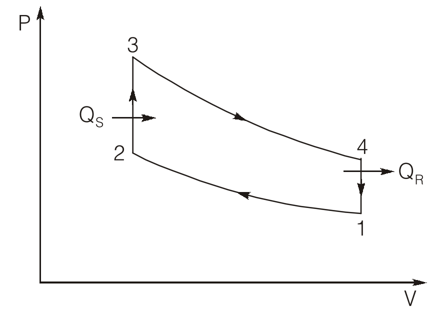
$$m_f = 0.05 \times 0.9\ V_s = 0.045\ V_s$$

$$\eta_{thermal} = \frac{p_{mep} \times LAN}{m_f \times C.V}$$ Where LAN = Swept volume

$\Rightarrow$ $$0.3 = \frac{p_{mep} \times V_s}{0.045V_s \times 45 \times 10^6}$$

$\therefore$ $p_{mep} = 6.075$ bar

T3 : Solution



$P_1 = 100$ kPa

Compression ratio, $r = 10$

$T_1 = 27 + 273 = 300$ K

Heat added, $Q_s = 1500$ kJ/kg

Heat rejected, $Q_R = 700$ kJ/kg

Specific gas constant for air, $R = 0.287$ kJ/kg.K

$$\text{Mean effective pressure} = \frac{\text{Work done in cycle}}{\text{Swept volume}}$$

Compression ratio,

$$r = V_1/V_2 = 10$$

$$V_1 = 10\, V_2$$

$$\text{Swept volume} = V_1 - V_2$$

$$= V_1 - V_1/10 = 9/10\ V_1$$

For initial air

$$P_1 V_1 = R T_1$$

$$\Rightarrow \quad V_1 = \frac{RT_1}{P_1} = \frac{0.287\ \text{kJ/kgK} \times 300\ \text{K}}{100\ \text{kPa}}$$

$$= 0.861\ \text{m}^3/\text{kg}$$

$$\text{Swept volume} = 9/10 \times V_1 = 9/10 \times 0.861$$

$$= 0.7749\ \text{m}^3/\text{kg}$$

Work done in cycle, $W_{net} = Q_{supply} - Q_{rej}$

$$= 1500 - 700 = 800\ \text{kJ/kg}$$

$$\text{Mean effective pressure} = \frac{W_{net}}{\text{Swept volume}}$$

$$P_{mep.} = \frac{800\ \text{kJ/kg}}{0.7749\ \text{m}^3/\text{kg}} = 1032.39\ \text{kPa}$$

T4 : Solution

$$\text{Work done} = \text{Area under the cycle}$$

$$= \frac{1}{2} \times 3 \times 0.02 = 0.03\ \text{kNm}$$

$$\text{mep} = \frac{\text{Work done}}{\text{Volume}} = \frac{0.03}{0.02} = \mathbf{1.5\ kPa}$$

T5 : Solution

Given: Brake power, $BP = 368$ kW, Friction Power, $FP = 73.6$ kW, $\dot{m}_F = 180$ kg/hr, $(A/F) = 20 : 1$

$CV = 42000$ kJ/kg

Indicated Power, $IP = BP + FP = 368 + 73.6 = 441.6$ kW

Mechanical efficiency, $\eta_m = \frac{BP}{IP} = \frac{368}{441.6} = 0.833$ or 83.3%

$$\dot{m}_a = \text{Air consumption rate} = 180 \times 20 = 3600\ \text{kg/hr}$$

Indicated thermal efficiency, $\eta_{ith} = \frac{IP}{\dot{m}_F \times CV} = \frac{441.6}{\frac{180}{3600} \times 42000} = 21.03\%$

Brake thermal efficiency, $\eta_{bth} = \frac{BP}{\dot{m}_F \times CV} = \frac{368}{\frac{180}{3600} \times 42000} = 17.52\%$

T6 : Solution

Given: n = 4 cylinders, Cylinder diameter, d = 64 mm, Stroke length, l = 90 mm,

Fuel consumption, $\dot{V}_F = 7.5 \text{ litres/hr} = \frac{7.5 \times 10^{-3}}{3600} \text{ m}^3\text{/sec} = 2.083 \times 10^{-6} \text{ m}^3\text{/sec}$

Speed, $N = 2400$ rpm

$CV = 11400 \text{ Kcal/kg} = 11400 \times 4.187 \text{ kJ/kg} = 47731.8 \text{ kJ/kg}$

Density of fuel, $\rho_F = 717 \text{ kg/m}^3$

Brake drum diameter, $D = 73.5$ cm

Rope diameter, $d_r = 2.5$ cm

Spring balance reading, $T_1 = 60$ kg

$T_2 = 8 \text{ kg at } N' = \frac{N}{3} \text{ rpm}$

Mechanical efficiency, $\eta_m = 0.80$

Let, r_m be the effective radius, $r_m = \frac{73.5}{2} + \frac{2.5}{2} = 38 \text{ cm}$

Torque, $T = (60 - 8) \times 9.81 \times 0.38 = 193.85 \text{ N-m}$

$$BP = \frac{2\pi N' T}{60}$$

As, $N' = \frac{N}{3} = \frac{1}{3} \times 2400 = 800 \text{ rpm}$

$$BP = \frac{2 \times \pi \times 800 \times 193.85}{60} = 16.24 \text{ kW}$$

Fuel flow rate, $\dot{m}_F = \rho_F \times \dot{V}_F = 717 \times 2.083 \times 10^{-6} = 1.4935 \times 10^{-3} \text{ kg/sec}$

Brake thermal efficiency, $\eta_{bth} = \frac{BP}{\dot{m}_F \times CV} = \frac{16.23}{1.4935 \times 10^{-3} \times 47731.8} = 0.227 \text{ or } 22.7\%$

$$\eta_m = 0.80 = \frac{BP}{IP}$$

$$IP = \frac{BP}{0.80} = \frac{16.24}{0.80} = 20.3 \text{ kW}$$

Let P_{im} be the indicated mean effective pressure,

$$P_{im} \times V_s \times \frac{N}{2 \times 60} = IP$$

$$P_{im} \times \frac{\pi}{4} \times (0.064)^2 \times (0.090) \times 4 \times \frac{2400}{2 \times 60} = 20.3 \times 10^3 = 8.764 \text{ bar}$$

T7 : Solution

Given: I.P. at full load = 50 kW

Brake sfc = 0.286 kg/kWh

Let, Brake power (B.P.) at full load = x kW

B.P. at 75% of load = $0.75x$ kW

I.P. at 75% of load = $(0.75x + \text{F.P.})$ kW

At 75% load,

$$\eta_{mech} = \frac{0.75x}{0.75x + F.P.} = 0.7$$

$$\therefore \quad \text{F.P.} = \frac{0.75x}{0.7} - 0.75x = \frac{0.225x}{0.7} = 0.3214x$$

F.P. remains constant at all loads.

At full load, I.P. = B.P. + F.P. = 50

$$x + 0.3214x = 50$$

$$\Rightarrow \quad x = \frac{50}{1.3214} = 37.84 \text{ kW}$$

$$\therefore \quad \text{B.P.} = 37.84 \text{ kW}$$

$$\text{F.P.} = 0.3214 \times 37.84 = 12.16 \text{ kW}$$

$$\eta_{mech} = \frac{\text{B.P.}}{\text{I.P.}} = \frac{37.84}{50} = 0.7568 = 75.68\%$$

$$\because \quad \eta_{i\,th} = \frac{0.3}{0.7568} = 0.3964 = 39.64\%$$

$$\text{Indicated sfc} = \text{bsfc} \times \eta_{mech}$$

$$= 0.286 \times 0.7568 = 0.216 \text{ kg/kWh}$$

At half load,

$$\text{B.P.} = \frac{37.84}{2} = 18.92 \text{ kW}$$

$$\text{F.P.} = 12.16 \text{ kW}$$

$$\eta_{mech} = \frac{\text{B.P.}}{\text{I.P.}} = \frac{\text{B.P.}}{\text{B.P.} + \text{F.P.}} = \frac{18.92}{18.92 + 12.16}$$

$$= 0.609 = 60.9\%$$

T8 : Solution

$$\text{Brake power} = \text{Brake torque} \times \text{Angular velocity}$$

$$P = T\omega$$

or

$$T = \frac{P}{\omega} = \frac{P}{\left(\frac{2\pi N}{60}\right)} = \frac{10{,}000}{\frac{2\pi \times N}{60}} = \frac{10000}{400} = \mathbf{25\ Nm}$$

T9 : Solution (a)

Given data:

$$n = \frac{N}{2} \text{ for four-stroke engine}$$

Stroke volume, $V_s = 0.0259 \text{ m}^3$

Power, $P = 950$ kW

Speed, $N = 2200$ rpm

We know that power output,

$$P = \frac{p_m A l n x}{60} \text{ kW} = \frac{p_m V_s n x}{60}$$

where P is in kW; p_m is in kPa; V_s is in m^3

$$n = \frac{N}{2} \text{ rpm}$$

$$x = 1, \text{ number of cylinder}$$

$$\therefore \quad 950 = \frac{p_m \times 0.0259}{60} \times \frac{N}{2} \times 1$$

$$950 = \frac{p_m \times 0.0259 \times 2200}{120}$$

or $p_m = 2000 \text{ kPa} = \mathbf{2\ MPa}$

T10 : Solution

Given: Stroke volume, $V_s = 1.75 l = 1.75 \times 10^{-3} \text{ m}^3$

Power developed, BP = 26.25 kW

Speed, $N_{actual} = 506$ rpm

Mean effective pressure, $P_{mep} = 600 \text{ kN/m}^2$

Number of cylinders, $k = 6$

Brake power, $$\text{BP} = P_{mep} \times V_s \times k \times \frac{N}{2 \times 60}$$

$$\Rightarrow \quad 26.25 = 600 \times 1.75 \times 10^{-3} \times 6 \times \frac{N}{120}$$

$$\Rightarrow \quad N = 500 \text{ rpm}$$

But, $N_{actual} = 506$ rpm

$$\text{Number of misfires} = \frac{506 - 500}{2} = \frac{6}{2} = 3$$

T11 : Solution (c)

<u>Method I:</u>

$$(\text{B.P.})_{1,2,3,4} = 3037 \text{ kW}$$

$$(\text{I.P.})_{1,2,3,4} = (\text{B.P.})_{1,2,3,4} + (\text{F.P.})_{1,2,3,4} \quad \text{... (i)}$$

Number 1 cylinder not firing,

$$(B.P.)_{2, 3, 4} = 2102 \text{ kW}$$

$$(I.P.)_{2, 3, 4} = (B.P.)_{2, 3, 4} + (F.P.)_{1, 2, 3, 4} \quad \text{... (ii)}$$

Eq. (ii) – Eq. (i), we get

$$(I.P.)_{1, 2, 3, 4} - (I.P.)_{2, 3, 4} = (B.P.)_{1, 2, 3, 4} + (B.P.)_{2, 3, 4}$$

$$(I.P.)_1 = 3037 - 2102 = 935 \text{ kW}$$

Similarly, number 2 cylinder not firing,

$$(B.P.)_{1, 3, 4} = 2102 \text{ kW}$$

$$\therefore \quad (I.P.)_2 = (B.P.)_{1, 2, 3, 4} - (B.P.)_{1, 3, 4}$$

$$= 3037 - 2102 = 935 \text{ kW}$$

Number 3 cylinder not firing,

$$(B.P.)_{1, 2, 4} = 2100 \text{ kW}$$

$$\therefore \quad (I.P.)_3 = (B.P.)_{1, 2, 3, 4} - (B.P.)_{1, 2, 4}$$

$$= 3037 - 2100 = 937 \text{ kW}$$

Number 4 cylinder not firing,

$$(B.P.)_{1, 2, 3} = 2098 \text{ kW}$$

$$\therefore \quad (I.P.)_4 = (B.P.)_{1, 2, 3, 4} - (B.P.)_{1, 2, 3}$$

$$= 3037 - 2098 = 939 \text{ kW}$$

Total I.P.,

$$(I.P.)_{1,2,3,4} = (I.P.)_1 + (I.P.)_2 + (I.P.)_3 + (I.P.)_1$$

$$= 935 + 935 + 937 + 939$$

$$= 3746 \text{ kW}$$

Mechanical efficiency,

$$\eta_m = \frac{(B.P.)_{1,2,3,4}}{(I.P.)_{1,2,3,4}} = \frac{3037}{3746}$$

$$= 0.8107 = \mathbf{81.07\%}$$

<u>**Method II:**</u>

Given:

Brake power with 4-cylinder, 4B = 3037 kW

Brake power with 3-cylinder,

$$3B = \frac{2102 + 2102 + 2100 + 2098}{4} = 2100.5 \text{ kW}$$

Indicated power, I.P.

$$= 4(4B - 3B) = 4(3037 - 2100.5)$$

$$= 4 \times 936.5 = 3746 \text{ kW}$$

Mechanical efficiency,

$$= \frac{B.P}{I.P.} = \frac{3037}{3746} = 0.8107 = 81.07\%$$

T12 : Solution

Given:

$$\text{Brake load} = 30 \text{ kg}$$
$$\text{Drum diameter, } d = 900 \text{ mm}$$
$$\text{Speed, } N = 2000 \text{ rpm}$$
$$\text{Motor power, } P = 5 \text{ kW}$$
$$\text{Motor rating, } \eta_{motor} = 0.8$$
$$\text{B.P.} = T \times \omega$$
$$= 30 \times 9.81 \times 0.45 \times 2\pi \times \frac{2000}{60}$$
$$= 27737.12 = 27.73 \text{ kW}$$
$$\text{F.P.} = 5 \times 0.8 = 4 \text{ kW}$$
$$\text{I.P.} = 27.73 + 4 = 31.73 \text{ kW}$$
$$\eta_{mech} = \frac{\text{B.P.}}{\text{I.P.}} = \frac{27.73}{31.73} = 0.8737 = 87.37\%$$

■■■■