ESE GATE

State Engg. Exams

MADE EASY Workbook 2026

Detailed Explanations of Try Yourself *Questions*

Mechanical Engineering

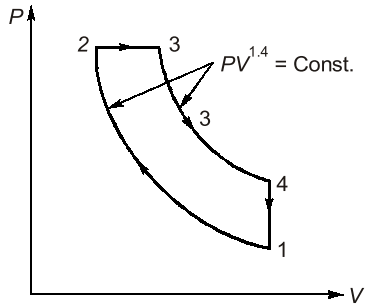
Internal Combustion Engines

MADE EASY PUBLICATIONS

1 Air Standard Cycle

Detailed Explanation of Try Yourself Questions

T1 : Solution



Given: 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

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

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

T2 : Solution

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

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

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

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

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

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

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

T3 : Solution

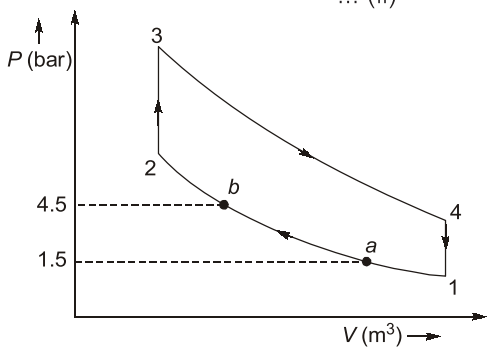
$V_a = V_2 + 0.75\,(V_1 - V_2) = 0.75V_1 + 0.25V_2$

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

$\therefore \quad \dfrac{V_a}{V_2} = 0.75r + 0.25 \quad \ldots (i)$

$\dfrac{V_b}{V_2} = 0.25r + 0.75 \quad \ldots (ii)$

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



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

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

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

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

$0.75r + 0.25 = 0.5479r + 1.644$

$0.2021r = 1.394$

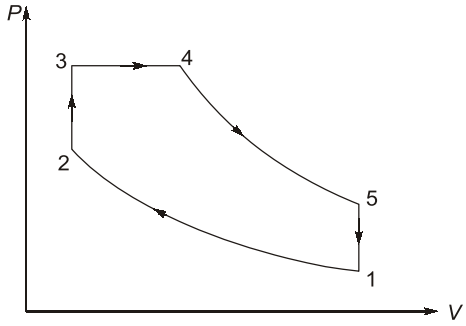
$r = 6.89$

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

$= 0.5381 = 53.81\%$

T4 : 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



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

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

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

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

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

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

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

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

$$= 1.005\,(\text{T4} - 2179.14) = 837.5$$

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

So, Maximum temperature, $T_4 = 3012.47$ K

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

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

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

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

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

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

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2 Combustion & Knocking in SI and CI Engines

Detailed Explanation of Try Yourself Questions

T1 : Solution

Mechanical efficiency = η_m = 90% = 0.9

Motor efficiency = η_{motor} = 0.75

Frictional power = $FP = 4 \times 0.75 = 3$ kW

$$\therefore \quad \eta_m = \frac{BP}{IP} = \frac{BP}{BP + FP}$$

$$\Rightarrow \quad 0.9 = \frac{BP}{BP + 3}$$

$$\Rightarrow BP \times 0.9 + 0.9 \times 3 = BP$$

$$\Rightarrow \quad BP = 27 \text{ kW}$$

Also, $BP = T \times \omega$

$$\Rightarrow \quad 27 = T \times 2\pi \times \frac{1000}{60}$$

$$\Rightarrow \quad T = 0.25783 \text{ kNm} = 257.83 \text{ Nm}$$

Mass on dynamometer = m kg

Drum diameter = 1 m

Drum radius = 0.5 m

$$T = m \times g \times r$$

$$\Rightarrow \quad 257.83 = m \times 9.81 \times 0.5$$

$$\Rightarrow \quad m = 52.56 \text{ kg}$$

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