

ESE

GATE

State Engg. Exams

MADE EASY
WORKBOOK 2027



**Detailed Explanations of
Try Yourself Questions**

Mechanical Engineering
Internal Combustion Engines



1

Air Standard Cycle



Detailed Explanation of Try Yourself Questions

T1 : Solution

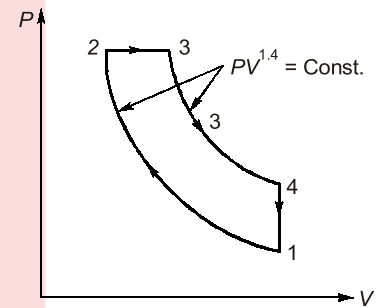
Given: Compression ratio, $r = \frac{V_1}{V_2} = 17$

$$\frac{C_P}{C_V} = \gamma = 1.4$$

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, $\rho = \frac{V_3}{V_2} = 0.1 \times 16 + 1 = 2.6$



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

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

$$\begin{aligned} &= 7.85 \times 10^{-3} \text{ m}^3 \\ \text{Total volume in the cylinder, } V_1 &= V_c + V_s = 0.001 + 7.85 \times 10^{-3} \\ &= 8.85 \times 10^{-3} \text{ m}^3 \end{aligned}$$

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

$$\begin{aligned} \therefore \text{ Air-standard cycle efficiency, } \eta &= 1 - \frac{1}{r^{\gamma-1}} = 1 - \frac{1}{(8.85)^{1.4-1}} \\ &= 1 - \frac{1}{8.85^{0.4}} = 0.5819 \approx \mathbf{58.2\%} \end{aligned}$$

T3 : Solution

$$\begin{aligned} V_a &= V_2 + 0.75(V_1 - V_2) = 0.75V_1 + 0.25V_2 \\ V_b &= V_2 + 0.25(V_1 - V_2) = 0.25V_1 + 0.75V_2 \end{aligned}$$

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

$$\frac{V_b}{V_2} = 0.25r + 0.75 \quad \dots (ii)$$

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

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

$$\begin{aligned} \therefore \frac{P_b}{P_a} &= \left(\frac{V_a}{V_b} \right)^{1.4} \\ \Rightarrow \frac{4.5}{1.5} &= \left(\frac{0.75r + 0.25}{0.25r + 0.75} \right)^{1.4} \end{aligned}$$

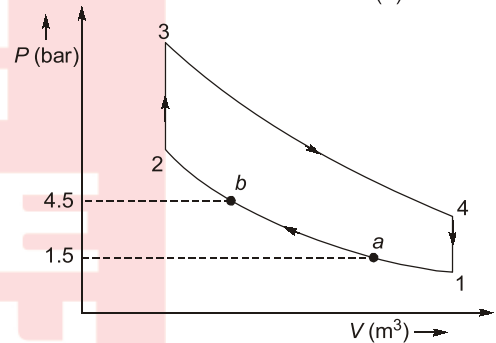
$$\frac{0.75r + 0.25}{0.25r + 0.75} = 2.192$$

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

$$0.2021r = 1.394$$

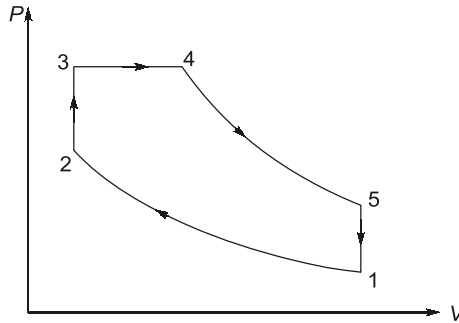
$$r = 6.89$$

$$\begin{aligned} \text{Efficiency, } \eta &= 1 - \frac{1}{r^{\gamma-1}} = 1 - \frac{1}{(6.89)^{0.4}} \\ &= 0.5381 = 53.81\% \end{aligned}$$



T4 : Solution

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



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

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

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

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

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

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

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

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

$$= 1.005(T_4 - 2179.14) = 837.5$$

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

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

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

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

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

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

$$\Rightarrow p = 3.186\%$$

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



2

Combustion & Knocking in SI and CI Engines



Detailed Explanation of Try Yourself Questions

T1 : Solution

Mechanical efficiency = $\eta_m = 90\% = 0.9$

Motor efficiency = $\eta_{\text{motor}} = 0.75$

Frictional power = $FP = 4 \times 0.75 = 3 \text{ kW}$

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

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

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

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

Also, $BP = T \times \omega$

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

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

Mass on dynamometer = $m \text{ kg}$

Drum diameter = 1 m

Drum radius = 0.5 m

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

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

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

