RIB RANK IMPROVEMENT BATCH
MECHANICAL ENGINEERING

RIB-R | T5

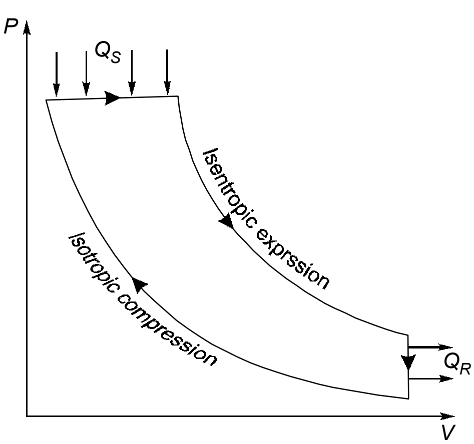
Session 2019-20 | S.No. : 010719_GH1A

ANSWER KEY ➤ Internal Combustion Engine

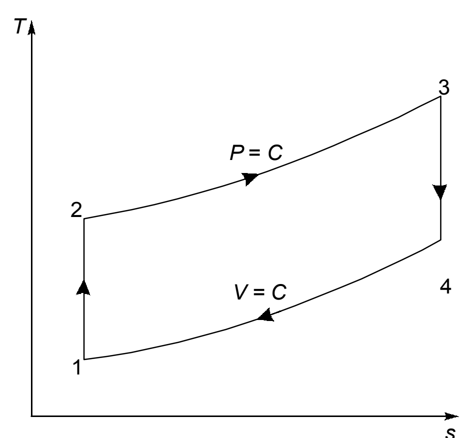
1.	(b)	7.	(d)	13.	(b)	19.	(d)	25.	(a)
2.	(d)	8.	(c)	14.	(c)	20.	(a)	26.	(b)
3.	(a)	9.	(d)	15.	(a)	21.	(b)	27.	(d)
4.	(b)	10.	(c)	16.	(c)	22.	(a)	28.	(b)
5.	(c)	11.	(c)	17.	(a)	23.	(c)	29.	(c)
6.	(d)	12.	(a)	18.	(b)	24.	(d)	30.	(a)

DETAILED EXPLANATIONS

2. (d)



Diesel cycle on $P-V$ coordinate



Diesel cycle on $T-s$ coordinate

3. (a)

$$\text{Mean piston speed, } \bar{S}_P = 2\,L\,N$$
$$= 2 \times 0.1 \times \frac{2000}{60}$$
$$= 6.67 \text{ m/s}$$

4. (b)

$$\text{Compression ratio, } r = \frac{V_s + V_C}{V_C}$$
$$= \frac{280 + 30}{30}$$
$$= \frac{310}{30} = 10.33$$

5. (c)

$$\eta_{\text{mechanical}} = \frac{\text{Brake power}}{\text{Indicated power}}$$
$$bp = 0.8\, ip$$
$$\text{Frictional power} = 28 \text{ kW} = ip - bp$$
$$28 \text{ kW} = ip - 0.8\, ip$$
$$ip = \frac{28}{0.2} = 140 \text{kW}$$
$$\text{Brake power} = 0.8 \times 140 = 112 \text{ kW}$$

6. (d)

The parameter which can be used for comparison of performance of the diesel engines is volumetric efficiency because it indicates the breathing or inhaling capacity. Higher volumetric efficiency, the more air sucked in and consequently more fuel burnt.

7. (d)

$$N = 1800 \text{ rpm (same for 2–stroke or 4–stroke)}$$
$$Q = 1.6 \text{ ms (duration of injection)}$$
$$\text{Duration of injection, } t = \frac{\theta}{360} \times \frac{60}{N}$$
$$1.6 \times 10^{-3} = \frac{\theta}{360} \times \frac{60}{1800}$$
$$\theta = 17.28°$$

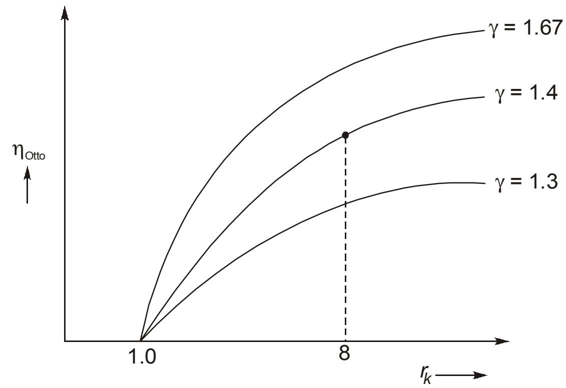
8. (c)

Turning moment diagram will be uniform for multi–cylinder engine and therefore size of flywheel required will be smaller.

11. (c)

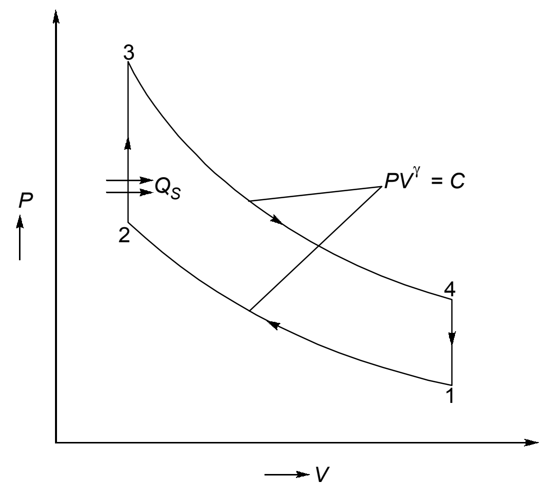
We can observe that the thermal efficiency curve is rather steep at low compression ratios but flattens out starting with a r_k of about 8.

Therefore, the increase in thermal efficiency with the compression ratio is not that pronounced at high compression ratios.



Variation of η vs r_k for Otto cycle

12. (a)



$$T_1 = 35°C = 273 + 35 = 308 \text{ K}$$

$$Q_s = 2100 \text{ kJ/Kg}$$

$$r_k = 8, \; r = 1.4$$

$$\frac{V_1}{V_2} = 8, \qquad V_1 = \frac{RT_1}{P_1}$$

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1} = 8^{\,0.4} = 2.3$$

$$T_2 = 2.3 \times 3.8 = 708.4 \text{ K}$$

$$Q_S = c_v\,(T_3 - T_2) = 2100$$

$$T_3 - 708.4 = \frac{2100}{0.718} = 2925\text{K}$$

$$T_3 = T_{max} = 2925 + 708.4 \approx 3633 \text{ K} = 3360°\text{C}$$

13. (b)

Compression ratio for the stated condition is given by

$$r_k = \left(\frac{T_{\text{maximum}}}{T_{\text{minimum}}}\right)^{\frac{1}{2(\gamma-1)}}$$

$$T_{max} = 3200°C = 3200 + 273 = 3473 \text{ K}$$

$$T_{min} = 25°C = 25 + 273 = 298 \text{ K}$$

$$r_k = \left(\frac{3473}{298}\right)^{\frac{1}{2\times 0.4}} = 21.53$$

14. (c)

$$\text{Compression ratio, } r_k = \frac{v_1}{v_2} = 15$$

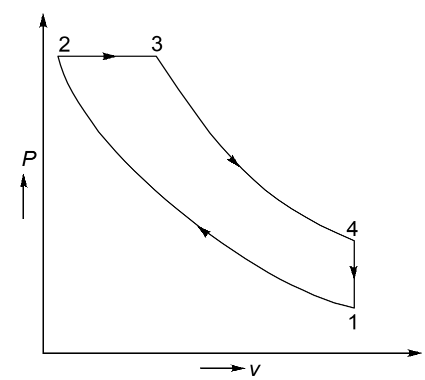
$$v_3 - v_2 = 0.05\,(v_1 - v_2)$$

$$= 0.05\,(15v_2 - v_2)$$

$$= 0.05 \times 14\, v_2$$

$$= 0.7\, v_2$$

$$v_3 = 1.7\, v_2$$



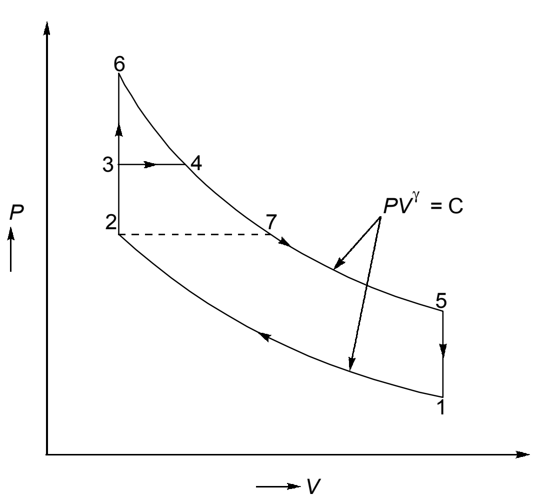
$$\text{cut-off ratio, } r_c = \frac{v_2}{v_3} = 1.7$$

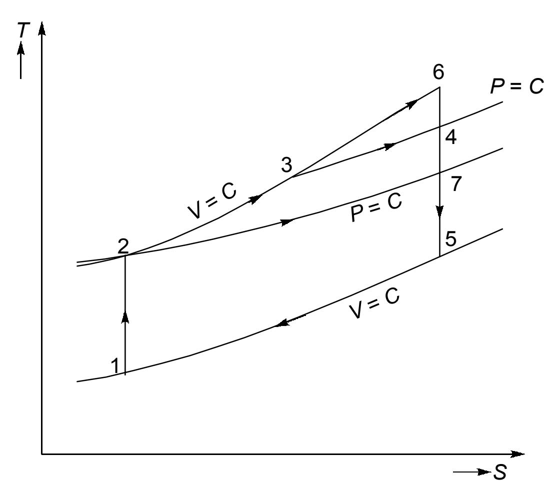
$$\eta_{\text{Diesel}} = 1 - \frac{1}{\gamma}\frac{1}{r_k^{\gamma-1}} \times \left[\frac{r_c^{\gamma} - 1}{r_c - 1}\right]$$

$$= 1 - \frac{1}{1.4} \times \frac{1}{(15)^{0.4}}\left[\frac{1.7^{1.4} - 1}{1.7 - 1}\right]$$

$$= 0.61936 \text{ or } 61.94\%$$

16. (c)





Above figure shows the comparison of Otto, Diesel and Dual cycles for the same compression ratio and heat rejection. We have

$$1-2-6-5 = \text{Otto cycle}$$
$$1-2-7-5 = \text{Diesel cycle}$$
$$1-2-3-4-5 = \text{Dual cycle}$$

Area under 2 – 6 represents heat addition for the Otto cycle (X)

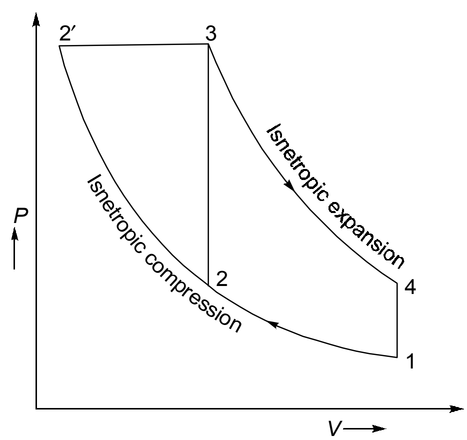
Area under 2 – 7 represents heat addition for the Diesel cycle (Z)

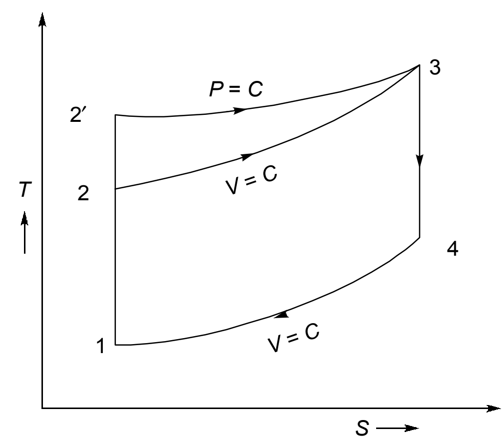
Area under 2 – 3 – 4 represents heat addition for the Dual cycle (Y)

We can see that $X > Y > Z$. Hence, the correct answer is (c).

17. (a)

For the same peak pressure, peak temperature and heat rejection, we can see that heat supplied in diesel engine is more than otto engine.





$$Q_s \text{ (Otto cycle heat addition)} = \text{Area under } 2 \rightarrow 3$$
$$Q_s' \text{ (Diesel cycle heat addition)} = \text{Area under } 2' \rightarrow 3$$

$$\eta_{\text{Otto}} = 1 - \frac{Q_R}{Q_S}$$

$$\eta_{\text{Diesel}} = 1 - \frac{Q_R}{Q_S'}$$

As $Q_s' > Q_s$, $\eta_{\text{Otto}} < \eta_{\text{Diesel}}$

Here, thermal stresses corresponds to peak temperature and mechanical stress corresponds to peak pressure. Therefore, the Diesel cycle efficiency is greater than the Otto cycle efficiency when both engines are built to withstand the same thermal and mechanical stress.

18. (b)

$$\text{Brake power, } BP = \frac{P_{bm} LAnk}{60 \times 1000} kW$$

Here, $k = 4$, $n = \dfrac{N}{2}$ for 4 – stroke.

$$BP = \frac{4P_{bm}LAN}{120\times1000} \times kW = \frac{P_{bm}A}{1000}\times\frac{2LN}{60}$$

$$\text{Mean piston speed, } \bar{S}_p = \frac{2LN}{60} = 7m/s$$

$$BP = \frac{650\times10^3\times\frac{\pi}{4}\times0.11^2}{1000}\times7$$

$$= 43.24 \text{ kW}$$

19. (d)

$$\text{Fuel consumption rate, } \dot{m}_f = 0.30\times60 \text{ kg} = 18 \text{ kg/h}$$

$$\text{A/F Ratio} = \frac{\dot{m}_a}{\dot{m}_f} = 15, \dot{m}_a = 15\times18 = 270 \text{kg/h or } 4.5 \text{ kg/min}$$

$$V_{disp} = k\left(\frac{\pi}{4}D^2L\right) = 4\times\frac{\pi}{4}\times0.12^2\times0.10 = 4.524\times10^{-3}\text{m}^3$$

$$\eta_V = \frac{\dot{m}_a/\rho_a}{V_{disp}N/2} = \frac{4.5\times\frac{1}{1.15}}{4.524\times10^{-3}\times\frac{2000}{2}} = 0.8649 \text{ or } 86.5\%$$

20. (a)

$$\text{Fuel consumption rate, } \dot{m}_f = 0.02\times125 \text{ kg/h}$$

$$\text{Density of fuel, } \rho_f = 850 \text{ kg/m}^3$$

$$\text{Volumetric flow rate} = \frac{\dot{m}_f}{\rho_f} = \frac{25}{850} = 0.0294\text{m}^3/\text{h}$$

Volume of fuel injected per cycle per cylinder is given as

$$v_f = \frac{0.294}{\frac{3000}{2}\times60\times6} = 5.444\times10^{-8}\text{m}^3$$

$$[1 \text{ m}^3 = 100 \text{ litre} = 1\times10^6 \text{ mL}]$$

$$v_f = 5.444\times10^{-8}\times1\times10^6 \text{ mL}$$

$$= 0.0544 \text{ mL}$$

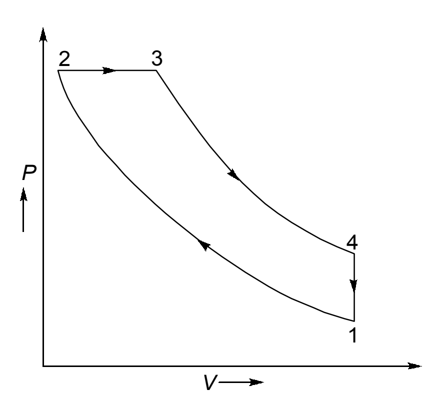
21. (b)

$$\text{Pressure ratio} = \frac{P_2}{P_1} = 34$$

$$P_1V_1^{1.3} = P_2V_2^{1.3} \text{ or}$$

$$\frac{V_1}{V_2} = r = \left(\frac{P_2}{P_1}\right)^{\frac{1}{1.3}} = (34)^{\frac{1}{1.3}} = 15.07$$

$$\text{Expansion ratio} = \frac{V_4}{V_3} = 7$$



$$\text{Cut–off ratio, } r_c = \frac{V_3}{V_2} = \frac{V_1}{V_2} \times \frac{V_3}{V_4}$$

$$= 15.07 \times \frac{1}{7} \qquad [V_1 = V_4]$$

$$= 2.153$$

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

$$= 1 - \frac{1}{(15.07)^{0.3}}\left[\frac{(2.153)^{1.3} - 1}{1.3 \times (2.153 - 1)}\right]$$

$$= 0.4944 \text{ or } 49.44\%$$

22. (a)

$$\text{Power} = \frac{P_m LAnk}{60000}$$

$$\text{Power} = \frac{10 \times 10^5 \times 0.1 \times \frac{\pi}{4} \times 0.06^2 \times \frac{4000}{2} \times 2}{60{,}000} = 18.8495 \text{ kW}$$

23. (c)

$$\text{Power} = \frac{P_m LAnk}{60{,}000} \text{kW}$$

$$n = \frac{N}{2}, k = 1, A = \frac{\pi}{4} D^2$$

$$P_m = \frac{28 \times 60 \times 1000}{0.2 \times \frac{\pi}{4} \times 0.16^2 \times \frac{2500}{2} \times 1} \times 10^{-5} = 3.342 \text{ bar}$$

24. (d)

$$\text{Brake power} = \frac{2\pi NT}{60000}$$

$$= \frac{2\pi \times 360 \times 600 \times 0.5}{60{,}000} = 11.31 \text{kW}$$

$$\text{Indicated power, ip} = \frac{360 \times 10^3 \times 0.3 \times \frac{\pi}{4} \times 0.2^2 \times 360 \times 1}{60{,}000}$$

$$= 20.36 \text{ kW}$$

$$\eta_{ith} = \frac{IP}{\dot{m}_f \times CV} \qquad \eta_m = \frac{BP}{IP} \times 100$$

$$= \frac{20.36}{\frac{4.5}{3600} \times 42 \times 10^3} \qquad = \frac{11.31}{20.36} \times 100$$

$$\eta_m = 55.55\%$$

$$= 0.3877 \text{ or } 38.77\%$$

25. (a)

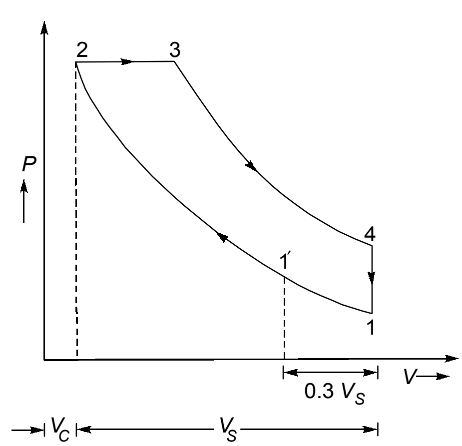
$$\text{Indicated power} = (90-65)+(90-65.5)+(90-64.5)+(90-65)$$
$$= 25 + 24.5 + 25.5 + 25$$
$$= 100 \text{ kW}$$
$$\eta_m = \frac{\text{Brake power}}{\text{Indicated power}}$$
$$= \frac{90}{100} = 0.9 \textit{ or } 90\%$$

26. (b)

$$\text{Displaced volume, } V_{disp} = 3\times\frac{\pi}{4}\times 0.12^2 \times 0.13$$
$$= 4.41 \times 10^{-3} \text{ m}^3$$
$$\text{Volumetric efficiency, } \eta_V = \frac{\dot{m}_a/\rho_a}{V_{disp}\dfrac{N}{2}}$$
$$1.5 = \frac{\dot{m}_a}{1.2\times 4.41\times 10^{-3}\times\dfrac{1600}{2}\times 60}$$
$$\dot{m}_a = 381.024 \text{ kg/h}$$
$$\frac{\dot{m}_a}{\dot{m}_f} = 14.9$$
$$\dot{m}_f = \frac{381.024}{14.9} = 25.57 \text{ kg/h}$$

27. (d)

$$V_C = V_2 = 30 \text{ cc}$$
$$\text{Compression ratio, } r = \frac{V_S+V_C}{V_C} = 1+\frac{V_S}{V_C}$$
$$V_S = (r-1)\times 30 = 570 \text{ cc}$$



At the end of 30% of compression stroke,

$$V_1' = V_C + (V_S - 0.3\ V_S)$$
$$= V_C + 0.7\ V_S$$
$$= 30 + 0.7 \times 570 = 429 \text{ cc}$$

28. (b)

$$\text{Compression ratio, } r = \frac{V_1}{V_2} = \left(\frac{T_2}{T_1}\right)^{\frac{1}{\gamma-1}}$$
$$= \left(\frac{377+273}{47+273}\right)^{\frac{1}{0.4}}$$
$$= \left(\frac{650}{320}\right)^{2.5}$$
$$= 5.88$$

$$\eta_{\text{Otto}} = 1 - \frac{1}{r^{\gamma-1}} = 1 - \frac{1}{(5.88)^{0.4}} = 0.5077 \text{ or } 50.77\%$$

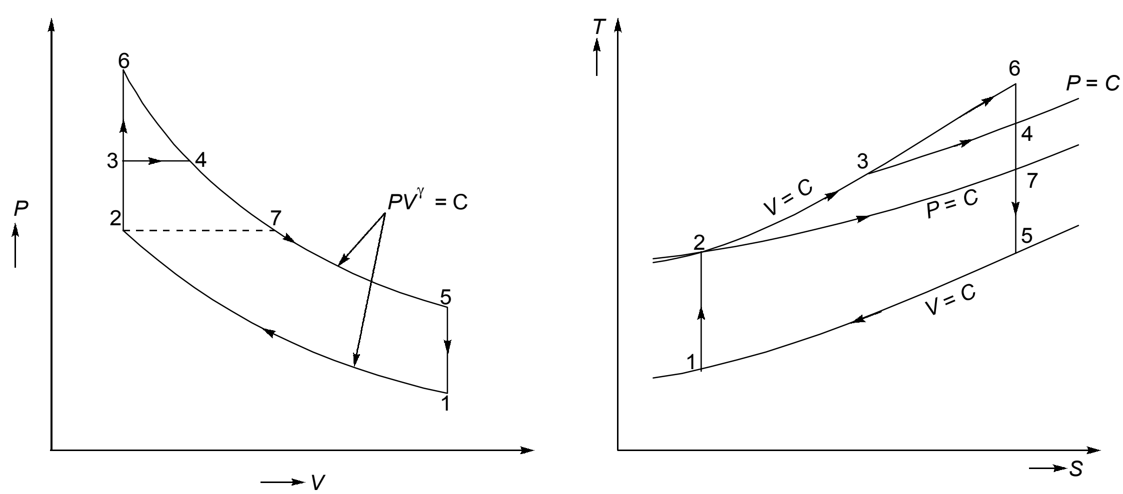
29. (c)

Mean Effective pressure for Otto cycle is given as

$$P_m = \frac{P_1\, r(r_p - 1)(r^{\gamma-1} - 1)}{(\gamma - 1)(r - 1)}$$

$$P_m \propto (r_p - 1) \text{ (for } \gamma = \text{constt \& } r = \text{constt)}$$

30. (a)



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