

# CLASS TEST

S.No. : 03 GH1\_ME\_B\_230619

Internal Combustion Engine



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# CLASS TEST 2019-2020

## MECHANICAL ENGINEERING

Date of Test : 23/06/2019

### ANSWER KEY > Internal Combustion Engine

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

## Detailed Explanations

1. (d)

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

$$V_c = 0.1 V_s$$

$$r = 1 + \frac{V_s}{0.1 V_s} = 1 + 10 = 11$$

$$\eta = 1 - \frac{1}{(r)^{\gamma-1}} = 1 - \frac{1}{(11)^{1.4-1}} = 0.6167 = 61.7 \%$$

3. (c)

swept volume of one cylinder,

$$\begin{aligned} (V_s) &= \frac{\pi}{4} d^2 \times l \\ &= \frac{\pi}{4} (6.8)^2 \times 7.5 = 272.38 \text{ cm}^3 \end{aligned}$$

then cubic capacity of the engine = Total swept volume of all cylinders  
 =  $272.38 \times 4 = 1089.5 \text{ cc}$

4. (a)

$$(\uparrow)\eta = 1 - \frac{1}{r^{\gamma-1}(\uparrow)}$$

5. (b)

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

$$\Rightarrow \begin{aligned} T_2 &= 719.085 \text{ K} & T_3 &= 1120 + 273 = 1393 \text{ K} \\ Q &= c_v(T_3 - T_2) = 483.87 \text{ kJ/kg} \end{aligned}$$

7. (c)

$$\eta_{\text{thermal}} = \frac{\text{Output}}{\text{Input}} = \frac{4 \times 10^3}{12 \times 10^3} = \frac{1}{3} = 33.33\%$$

8. (b)

$$\frac{BP}{IP} = 0.75$$

$$IP - BP = 20$$

$$0.25 IP = 20$$

$$IP = 80 \text{ kW}$$

$$\text{Brake power, } BP = 0.75 \times IP = 80 \times 0.75 = 60 \text{ kW.}$$

12. (c)

$$\begin{aligned} D &= 40 \text{ mm} = (0.04 \text{ m}) \\ L &= 60 \text{ mm} = 0.06 \text{ m} \\ N &= 600 \text{ rpm} \\ T_1(W) &= 800 \text{ N} \\ T_2(S) &= 400 \text{ N} \\ D_d &= 1 \text{ m} \end{aligned}$$

∴ Radius of dynamometer pulley,

$$R = \frac{D_d}{2} = 0.5 \text{ m}$$

∴ Torque on the pulley,  $T = (T_1 - T_2)R = (800 - 400) \times 0.5 = 200 \text{ N-m}$

$$\text{Brake power} = \frac{2\pi NT}{60,000} = \frac{2\pi \times 600 \times 200}{60,000} = 12.56 \text{ kW}$$

13. (d)

$$\text{Compression ratio} = \frac{\text{Total volume}}{\text{Clearance volume}}$$

$$\text{Total volume} = \text{clearance volume} + \text{swept volume}$$

$$\text{Swept volume} = \frac{\pi}{4} D^2 L = \frac{\pi}{4} \times 15^2 \times 30 = 5301.44 \text{ cm}^3$$

$$\text{Compression ratio} = 1 + \frac{\text{Swept volume}}{\text{Clearance volume}} \quad \dots(1)$$

$$\text{Clearance volume} = \frac{9000}{6} = 1500 \text{ cm}^3$$

$$\text{Compression ratio} = 1 + \frac{5301.44}{1500} = 4.53$$

14. (b)

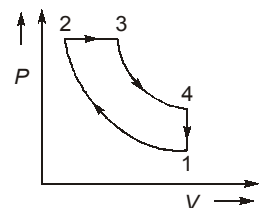
$$\frac{V_1}{V_2} = 15$$

$$V_3 - V_2 = 0.08(V_1 - V_2)$$

$$\left(\frac{V_3}{V_2} - 1\right) = 0.08\left(\frac{V_1}{V_2} - 1\right)$$

$$r_c = \frac{V_3}{V_2} = 0.08 \times 14 + 1 = 2.12$$

$$\begin{aligned} \eta_{\text{Diesel}} &= 1 - \frac{1}{r^{\gamma-1}} \left[ \frac{r_c^\gamma - 1}{\gamma(r_c - 1)} \right] = 1 - \frac{1}{15^{0.4}} \left[ \frac{2.12^{1.4} - 1}{1.4(2.12 - 1)} \right] = 1 - \frac{1.86}{1.568 \times 2.95} \\ &= 0.5978 = 59.78\% \end{aligned}$$



15. (a)

$$\begin{aligned}
 P_1 &= 100 \text{ kPa} \\
 V_1 &= ? \\
 T_1 &= 27^\circ\text{C} = 300 \text{ K}
 \end{aligned}$$

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1} = (6)^{0.4} = 2.047$$

$$T_2 = 2.047 \times 300 = 614.1 \text{ K} = 341.1^\circ\text{C}$$

$$Q_{2-3} = c_v(T_3 - T_2) = 1170 \text{ kJ/kg}$$

$$T_3 - T_2 = \frac{1170}{0.717} = 1631.8$$

$$T_3 = 1631.8 + 614.1 = 2245.9 \text{ K} = 1972.9^\circ\text{C}$$

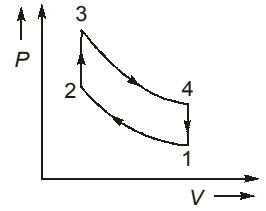
$$\frac{P_3}{P_2} = ?$$

$$\frac{P_2}{P_1} = r^\gamma = 6^{1.4} = 12.28$$

$$P_2 = 12.28 \times 10^5 \text{ N/m}^2$$

$$\frac{P_3}{P_2} = \frac{T_3}{T_2} = \frac{2245.9}{614.1} = 3.65$$

$$P_3 = 3.65 \times 12.28 \times 10^5 = 44.82 \text{ bar} \approx 45 \text{ bar}$$



17. (a)

$$T_1 = 25 + 273 = 298 \text{ K}$$

The hottest temperature is  $T_4 = 1360 \text{ K}$ 

$$r_c (\text{cut-off ratio}) = 1.15$$

$$r (\text{compression ratio}) = 18$$

$$\begin{aligned}
 T_2 &= T_1 r^{\gamma-1} = 298(18)^{0.4} \\
 &= 947 \text{ K}
 \end{aligned}$$

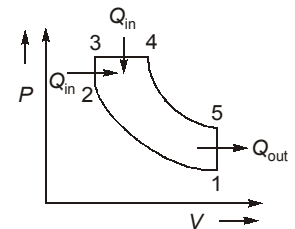
$$T_3 = \frac{V_3 T_4}{V_4} = \frac{T_4}{r_c} = \frac{1360}{1.15} = 1183 \text{ K}$$

$$\frac{P_3}{P_2} = \alpha (\text{Pressure ratio}) = \frac{T_3}{T_2} = 1.25$$

$$\text{Thermal efficiency } (\eta_{\text{th}}) = 1 - \frac{1}{r^{\gamma-1}} \left[ \frac{\alpha r_c^\gamma - 1}{(\alpha - 1) + \alpha \gamma (r_c - 1)} \right]$$

$$= 1 - \frac{1}{(18)^{0.4}} \left[ \frac{1.25 \times 1.15^{1.4} - 1}{(1.25 - 1) + (1.25 \times 1.4)(1.15 - 1)} \right] = 0.68 = 68\%$$

$$\begin{aligned}
 W_{\text{net}} &= \eta \times Q_{\text{input}} = 0.68 \times 1 \\
 &= 0.68 \text{ kJ/cycle}
 \end{aligned}$$



18. (b)

Brake power (BP) = 75 kW,  
 Brake thermal efficiency ( $\eta_{bth}$ ) = 35%  
 Mechanical efficiency ( $\eta_m$ ) = 90% (IP = Indicated Power)  
 = 40,000 kJ/kg

$$\eta_{bth} = \frac{BP \times 3600}{m \times C_v} \times 100$$

$$35 = \frac{75 \times 3600}{m \times 40,000} \times 100$$

$$m = 19.285 \text{ kg/hr}$$

$$\text{Fuel consumption per brake power per hour} = \frac{m}{BP} = \frac{19.285}{75} = 0.257 \text{ kg/kW-hr}$$

19. (c)

$$\text{Indicated specific fuel consumption} = \frac{\text{Mechanical efficiency} \times \text{Fuel consumption/hr}}{\text{Break Power}}$$

$$= \frac{0.85 \times 10 \times 3600}{10^3 \times 180} = 0.17 \text{ kg/kWh}$$

20. (a)

$$\text{Power} = \frac{P_m L A n}{60,000} \text{ kw}$$

As four stroke

$$n = \frac{N}{2} = 1000 \text{ rpm}$$

$$P_m = \frac{93 \times 60000}{0.0259 \times 1000} = 215444.0154 \text{ N/m}^2 = 2.154 \text{ bar}$$

21. (b)

Crank radius = 50 mm  
 Diameter of cylinder = 90 mm  
 Swept volume = ?  
 $\therefore L = 2r = 2 \times 50 \text{ mm} = 100 \text{ mm}$

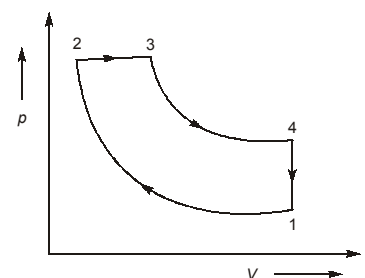
$$\text{Swept volume} = \frac{\pi D^2 L}{4} = \frac{\pi}{4} \times (90)^2 \times 100 \times 10^{-3} = 636.172 \text{ cm}^3$$

22. (b)

$$\Rightarrow T_1 V_1^{\gamma-1} = T_2 V_2^{\gamma-1}$$

$$\Rightarrow T_2 = T_1 \left( \frac{V_1}{V_2} \right)^{\gamma-1}$$

$$\Rightarrow T_2 = 340(20)^{0.4} = 1126.92 \text{ K}$$



$$\begin{aligned}\text{Stroke volume} &= (V_1 - V_2) \\ V_3 - V_2 &= 0.1(V_1 - V_2)\end{aligned}$$

$$\frac{V_3}{V_2} = 0.1(20 - 1) + 1 = 2.9$$

Heat addition takes place at constant pressure ( i.e. process 2-3)

$$\frac{V_3}{V_2} = \frac{T_3}{T_2}$$

$$\begin{aligned}\Rightarrow T_3 &= 2.9 \times 1126.92 \\ &= 3268 \text{ K}\end{aligned}$$

23. (d)

From derivation,

$$\eta = 1 - \left(\frac{1}{r}\right)^{\gamma-1}$$

$$\text{or } \eta = 1 - \left(\frac{V_2}{V_1}\right)^{\gamma-1}$$

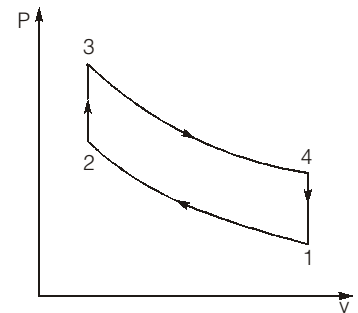
$$\therefore \eta = 1 - \frac{T_1}{T_2}$$

$$\eta = \frac{WD}{HA} = \frac{WD}{WD + HR} = \frac{1}{1 + HR/WD}$$

$$\text{or } \eta = \frac{HA - HR}{HA} = 1 - \frac{HR}{HA}$$

$$\text{or } \eta = 1 - \frac{mc_v(T_4 - T_1)}{mc_v(T_3 - T_2)}$$

$$\therefore \eta = 1 - \frac{T_4 - T_1}{T_3 - T_2}$$



24. (c)

$$\eta_{\text{cycle}} = 1 - \sqrt{\frac{T_{\min}}{T_{\max}}} = 1 - \sqrt{\frac{300}{1073}} = 47.12\%$$

$$W_{\max} = C_p [\sqrt{T_{\max}} - \sqrt{T_{\min}}]^2 = 1.005 [\sqrt{1073} - \sqrt{300}]^2 = 239.47 \text{ kJ/kg}$$

25. (b)

$$\frac{T_2}{T_1} = \frac{T_3}{T_4} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}$$

$$\therefore T_2 = 300(5)^{0.4/1.4} = 475.146 \text{ K}$$

$$T_4 = \frac{1000}{(5)^{0.4/1.4}} = 631.385 \text{ K}$$

$$\text{Work ratio} = \frac{W_T - W_C}{W_T} = 1 - \left( \frac{T_2 - T_1}{T_3 - T_4} \right) = 1 - \frac{475.145 - 300}{1000 - 631.385} = 0.524$$

Alternate,

$$\text{Work ratio, } W_r = 1 - \frac{T_{\min}}{T_{\max}} (r_p)^{\frac{\gamma-1}{\gamma}}$$

$$W_r = 1 - \frac{300}{1000} \times (5)^{0.4}$$

$$W_r = 0.524$$

26. (a)

$$r = 7.5 = 1 + \frac{V_s}{V_c}$$

$$\therefore \frac{V_c}{V_s} = \frac{1}{6.5}$$

$$\text{Indicated work done} = 19.5 \times 10^5 \times V_c = \text{IMEP} \times V_s$$

$$\Rightarrow \text{IMEP} = \frac{19.5 \times 10^5 \times V_c}{V_s} = \frac{19.5 \times 10^5}{6.5} = 3 \times 10^5 = 3 \text{ bar}$$

$$\Rightarrow \text{BMEP} = \eta_m \times \text{IMEP} = 0.85 \times 3 = 2.55 \text{ bar}$$

27. (b)

$$\text{Stroke volume, } V_s = \frac{\pi}{4} d^2 L = \frac{\pi}{4} \times 20^2 \times 25 = 7853.98 \text{ cm}^3$$

$$\text{Compression ratio, } r = 1 + \frac{V_s}{V_c} = 1 + \frac{7853.98}{1570}$$

$$r = 6$$

$$\gamma = \frac{C_p}{C_v} = \frac{1.005}{0.717} = 1.4$$

$$\text{Air standard efficiency} = 1 - \frac{1}{r^{\gamma-1}} = 1 - \frac{1}{6^{0.4}} = 0.512 = 51.2\%$$

28. (d)

When cylinder 1 is not firing then power is 2102 kW and when all cylinders are firing then power is 3037 kW.

Hence power supplied by cylinder No. 1 = 3037 - 2102 = 935 kW

Similarly power supplied by cylinder No. 2 = 3037 - 2102 = 935 kW

Similarly power supplied by cylinder No. 3 = 3037 - 2100 = 937 kW

Similarly power supplied by cylinder No. 4 = 3037 - 2098 = 939 kW

$$IP_{\text{total}} = 935 + 935 + 937 + 939 = 3746$$

$$\text{Hence } \eta_{\text{mech}} = \frac{3037}{935 + 935 + 937 + 939}$$

$$\eta_{\text{mech}} = \frac{BP}{IP} = \frac{3037}{3746} = 0.8107$$

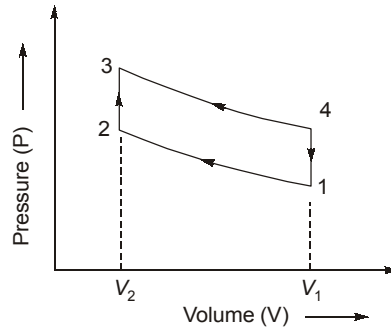
$$\therefore \eta_{\text{mech}} = 81.07\%$$

29. (c)

Compression ratio( $r$ ) = 8

$$v_1 = 0.9 \text{ m}^3/\text{kg}$$

$$r = \frac{V_1}{V_2}$$



$$\Rightarrow v_2 = \frac{0.9}{8} = 0.1125 \text{ m}^3/\text{kg}$$

Work done = Mean effective pressure  $\times$  swept volume

$$1575 \times 10^3 = P_m \times (0.9 - 0.1125)$$

$$\Rightarrow P_m = 20 \text{ bar}$$

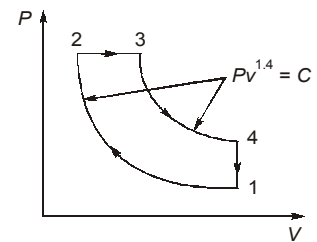
30. (d)

$$\frac{V_1}{V_2} = 17, \quad \frac{C_p}{C_v} = \gamma = 1.4$$

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



$$\eta_{\text{diesel}} = 1 - \frac{1}{r^{\gamma-1}} \left[ \frac{r_c^\gamma - 1}{\gamma(r_c - 1)} \right] = 1 - \frac{1}{17^{0.4}} \left[ \frac{2.6^{1.4} - 1}{1.4(2.6 - 1)} \right]$$

$$= 1 - \frac{1}{17^{0.4}} \left[ \frac{3.81 - 1}{1.4 \times 1.6} \right] = 0.596 \text{ or } 59.6 \%$$

