S.No. : 07 GH1_ME_D_170919

Internal Combustion Engine

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CLASS TEST 2019-2020

MECHANICAL ENGINEERING

Date of Test : 17/09/2019

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)

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

$$V_c = 0.1\ V_s$$

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

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

3. (c)

swept volume of one cylinder,

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

$$= \frac{\pi}{4}(6.8)^2 \times 7.5 = 272.38\ \text{cm}^3$$

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)

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

$\Rightarrow$ $T_2 = 719.085\ \text{K}$ $\qquad T_3 = 1120 + 273 = 1393\ \text{K}$

$$Q = c_v(T_3 - T_2) = 483.87\ \text{kJ/kg}$$

7. (c)

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

8. (b)

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

$$IP - BP = 20$$

$$0.25\ IP = 20$$

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

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

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12. (c)

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

∴ Radius of dynamometer pulley,

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

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

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

Total volume = clearance volume + swept volume

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

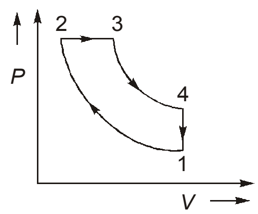
$$\text{Compression ratio} = 1 + \frac{\text{Swept volume}}{\text{Clearance volume}} \qquad ...(1)$$

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

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

14. (b)

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



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

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

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

$$\eta_{Diesel} = 1 - \frac{1}{r^{\gamma-1}}\left[\frac{r_c^{\gamma} - 1}{\gamma(r_c - 1)}\right] = 1 - \frac{1}{15^{0.4}}\left[\frac{2.12^{1.4} - 1}{1.4(1.12)}\right] = 1 - \frac{1.86}{1.568 \times 2.95}$$

$$= 0.5978 = 59.78\%$$

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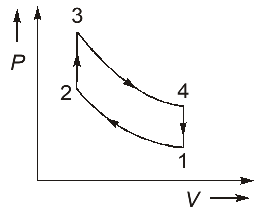
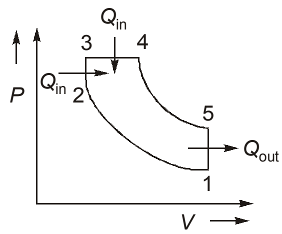
15. (a)



$$P_1 = 100 \text{ kPa}$$
$$V_1 = ?$$
$$T_1 = 27°\text{C} = 300 \text{ K}$$
$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1} = (6)^{0.4} = 2.047$$
$$T_2 = 2.047 \times 300 = 614.1 \text{ K} = 341.1°\text{C}$$
$$Q_{2-3} = c_v(T_3 - T_2) = 1170 \text{ kJ/kg}$$
$$T_3 - T_2 = \frac{1170}{0.717} = 1631.8$$
$$T_3 = 1631.8 + 614.1 = 2245.9 \text{ K} = 1972.9°\text{C}$$
$$\frac{P_3}{P_2} = ?$$
$$\frac{P_2}{P_1} = r^{\gamma} = 6^{1.4} = 12.28$$
$$P_2 = 12.28 \times 10^5 \text{ N/m}^2$$
$$\frac{P_3}{P_2} = \frac{T_3}{T_2} = \frac{2245.9}{614.1} = 3.65$$
$$P_3 = 3.65 \times 12.28 \times 10^5 = 44.82 \text{ bar} \simeq 45 \text{ bar}$$

17. (a)



$$T_1 = 25 + 273 = 298 \text{ K}$$
The hottest temperature is $T_4 = 1360$ K
$$r_c\text{(cut-off ratio)} = 1.15$$
$$r\text{(compression ratio)} = 18$$
$$T_2 = T_1 r^{\gamma-1} = 298(18)^{0.4}$$
$$= 947 \text{ K}$$
$$T_3 = \frac{V_3 T_4}{V_4} = \frac{T_4}{r_c} = \frac{1360}{1.15} = 1183 \text{ K}$$
$$\frac{P_3}{P_2} = \alpha\,\text{(Pressure ratio)} = \frac{T_3}{T_2} = 1.25$$
$$\text{Thermal efficiency } (\eta_{th}) = 1 - \frac{1}{r^{\gamma-1}}\left[\frac{\alpha r_c^{\gamma} - 1}{(\alpha - 1) + \alpha\gamma(r_c - 1)}\right]$$
$$= 1 - \frac{1}{(18)^{0.4}}\left[\frac{1.25 \times 1.15^{1.4} - 1}{(1.25 - 1) + (1.25 \times 1.4)(1.15 - 1)}\right] = 0.68 = 68\,\%$$
$$W_{net} = \eta \times Q_{input} = 0.68 \times 1$$
$$= 0.68 \text{ kJ/cycle}$$

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18. (b)

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

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

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

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

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

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)

$$\text{Power} = \frac{P_m LAn}{60{,}000} \text{ kw}$$

As four stroke

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

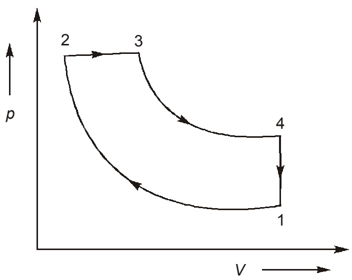
$$P_m = \frac{93 \times 60000}{0.0259 \times 1000} = 215444.0154 \text{ N/m}^2 = 2.154 \text{ bar}$$

21. (b)

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

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

22. (b)



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

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

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

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$$\text{Stroke volume} = (V_1 - V_2)$$

$$V_3 - V_2 = 0.1(V_1 - V_2)$$

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

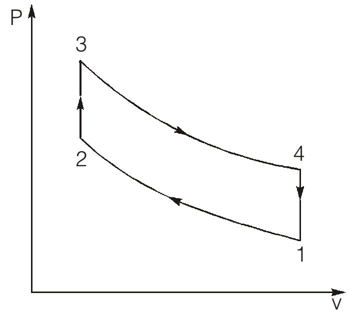
Heat addition takes place at constant pressure (i.e. process 2-3)

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

$$\Rightarrow \quad T_3 = 2.9 \times 1126.92 = 3268 \text{ K}$$

23. (d)

From derivation,



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

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

∴ $$\eta = 1 - \frac{T_1}{T_2}$$

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

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

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

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

24. (c)

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

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

25. (b)

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

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

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

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

Alternate,

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

$$W_r = 1 - \frac{300}{1000} \times (5)^{\frac{0.4}{1.4}}$$

$$W_r = 0.524$$

26. (a)

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

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

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

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

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

27. (b)

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

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

$$r = 6$$

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

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

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

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

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

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

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

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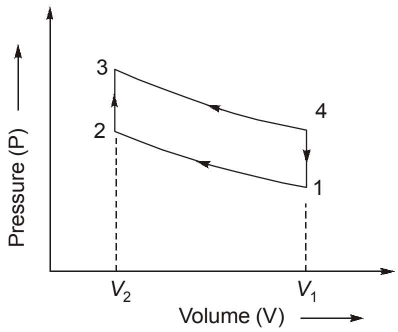
29. (c)

$$\text{Compression ratio}(r) = 8$$

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

$$r = \frac{v_1}{v_2}$$



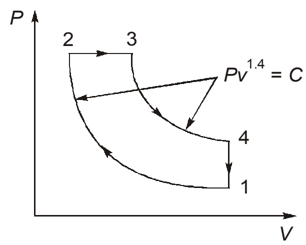
$$\Rightarrow \quad v_2 = \frac{0.9}{8} = 0.1125 \text{ m}^3/\text{kg}$$

$$\text{Work done} = \text{Mean effective pressure} \times \text{swept volume}$$

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

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

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

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

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

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