CLASS TEST

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INTERNAL COMBUSTION ENGINE

MECHANICAL ENGINEERING

Date of Test : 21/09/2022

ANSWER KEY ➤

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

DETAILED EXPLANATIONS

3. (b)

$$V_S = \frac{\pi}{4}d^2L = \frac{\pi}{4} \times \frac{d^3}{1.1} = 245$$

$$d^3 = 343$$

$$\Rightarrow \quad d = 7\text{ cm}$$

$$L = \frac{d}{1.1} = \frac{7}{1.1} = 6.36\text{ cm}$$

6. (a)

C_8H_{18} → iso-octane
C_7H_{16} → normal-heptane
$C_{16}H_{34}$ → normal-cetane
$C_{11}H_{10}$ → α - methyl nepthalene

7. (c)

Cam shaft runs at half the speed of crankshaft.

11. (a)

$$\frac{bp}{ip} = 0.8, \qquad fp = 20\text{ kW}$$

$$ip - bp = 20$$

$$ip - 0.8 \times ip = 20$$

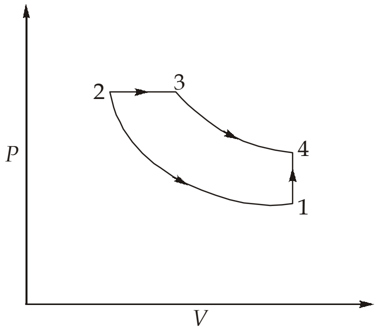
$$\text{or} \quad ip = 20 \times 5 = 100\text{ kW}$$

$$bp = ip - fp = 100 - 20 = 80\text{ kW}$$

12. (c)

SI engines are quantity governed engines.

18. (b)



Compression ratio, $r = \frac{V_1}{V_2} = 15$

Expansion ratio, $r_e = \frac{V_4}{V_3} = 10$

Cut-off ratio, $r_c = \frac{r}{r_e} = \frac{V_1/V_2}{V_4/V_3} = \frac{V_3}{V_2} = \frac{15}{10} = 1.5 \qquad [V_1 = V_4]$

$$\text{Air standard efficiency, } \eta = 1-\frac{1}{\gamma}\frac{1}{r^{\gamma-1}}\left[\frac{r_c^{\gamma}-1}{r_c-1}\right] = 1-\frac{1}{1.4}\times\frac{1}{15^{0.4}}\left[\frac{1.5^{1.4}-1}{1.5-1}\right]$$
$$= 0.6305 = 63.05\%$$

19. (b)

$$\text{Indicated power, } IP = P_{\text{eff imep}}\times V_s\times\frac{(\text{Number of explosion})}{\text{Time of test}} \quad \text{... (i)}$$

Now, effective indicated mean effective pressure,

$$P_{\text{eff, imep}} = P_{\text{imep}} - P_{\text{pumping mep}}$$
$$= 6.4 - 0.6 = 5.8 \text{ bar}$$

From equation (i),

$$IP = 5.8\times10^5\times\frac{\pi}{4}\times\frac{0.25^2\times(1.9\times0.25)\times3300}{1000\times40\times60}$$
$$= 18.594 \text{ kW}$$

$$\text{Brake power, } BP = (m_b\times g)\times r_d\times\left(\frac{2\pi\times\text{Number of revolution}}{\text{Time of test}}\right)$$

$$= 90\times9.81\times0.8\times\frac{2\pi\times8080}{1000\times40\times60}$$
$$= 14.941 \text{ kW}$$

$$\text{Mechanical efficiency, } \eta_m = \frac{BP}{IP} = \frac{14.941}{18.594} = 0.8035 = 80.35\%$$

20. (c)

$$\text{Heat supplied/kg} = c_v(T_3 - T_2) + c_p(T_4 - T_3) \text{ ... (i)}$$

$$\frac{T_2}{T_1} = \left(\frac{V_2}{V_1}\right)^{\gamma-1} = (10)^{1.4-1}$$

$$T_2 = (10)^{0.4}\times 300$$
$$= 753.57 \text{ K} = 480.57°\text{C}$$

Now, from equation (i),

$$878 = 0.717(987 - 480.57) + 1.004(T_4 - 987)$$
$$T_4 = 1499.84°\text{C} = 1772.84 \text{ K}$$

$$\text{Cut-off ratio, } r_c = \frac{V_4}{V_3}$$

For constant pressure process (3–4)

$$\frac{V_4}{V_3} = \frac{T_4}{T_3}$$

So, $$r_c = \frac{T_4}{T_3} = \frac{1772.84}{1260} = 1.407 \qquad [\because T_3 = 987°\text{C} = 1260 \text{ K}]$$

21. (d)

$$V_s = \frac{\pi}{4} \times 0.06^2 \times 0.1$$

$$= 2.83 \times 10^{-4} \text{ m}^3/\text{cylinder}$$

$$= 283 \text{ cc/cylinder}$$

$$\text{Compression ratio, } r = \frac{V_s + V_c}{V_c} = \frac{283 + 60}{60} = 5.72$$

$$\eta_{\text{air-std}} = 1 - \frac{1}{(r)^{\gamma - 1}} = 0.5021 = 50.21\%$$

$$\eta_{bth} = \eta_{\text{relative}} \times \eta_{\text{air-std}} = 0.5021 \times 0.52$$

$$= 0.2611 = 26.11\%$$

$$\text{BP} = \frac{2\pi NT}{60} = \frac{2\pi \times 3000 \times 65}{1000 \times 60} = 20.420 \text{ kW}$$

$$\eta_{bth} = \frac{BP(\text{Brake power})}{Q_s(\text{Heat supplied})} = \frac{BP}{\dot{m}_f \times CV}$$

$$\dot{m}_f = \frac{20.420 \times 3600}{0.2611 \times 43 \times 1000} = 6.547 \text{ kg/ hr}$$

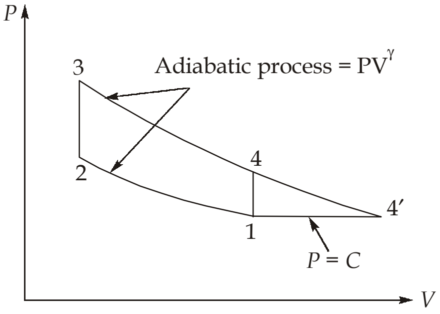
22. (c)

$$\text{Efficiency of Otto cycle} = 1 - \frac{1}{(r)^{\gamma - 1}} \text{ (where, } r = \text{compression ratio)}$$

$$\eta_{\text{Otto}} = 1 - \frac{1}{(6)^{1.4 - 1}} = 0.5116 = 51.16\%$$

$$\text{Expansion ratio, (e)} = \frac{V_4'}{V_2} = \frac{V_4'}{V_3} = \left(\frac{P_3}{P_4'}\right)^{1/\gamma} = \left(\frac{P_3}{P_1}\right)^{1/\gamma}$$

$$= \left(\frac{20}{1}\right)^{1/1.4} = 8.497$$



$$\text{Compression ratio, } r = 6$$

Efficiency of Atkinson cycle is given by

$$\eta_{\text{Atkinson}} = 1 - \gamma \frac{(e - r)}{(e^{\gamma} - r^{\gamma})} = 1 - 1.4 \frac{(8.497 - 6)}{(8.497^{1.4} - 6^{1.4})}$$

$$= 0.5466 = 54.66\%$$

So, Difference in efficiencies = 54.66 – 51.16 = 3.5%

23. (a)

We know that, $$\eta_{bth} = \frac{BP}{m_f \times CV}$$

Given, $$\frac{m_f / hr}{BP} = 0.5 \text{ kg/kW-hr} = \frac{0.5}{3600} \text{ kg/ sec} - \text{kW}$$

$$\eta_{bth} = \frac{1}{\frac{m_f}{BP} \times CV} = \frac{3600}{0.5 \times 43000} = 0.1674 = 16.74\%$$

$$\eta_m = \frac{\eta_{bth}}{\eta_{ith}}$$

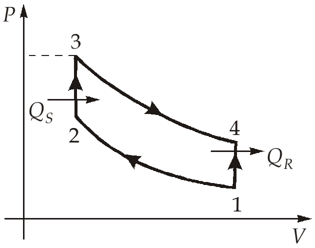
$$\eta_{ith} = \text{Indicated thermal efficiency} = \frac{16.74}{0.8} = 0.20930 = 20.93\%$$

24. (c)

Work done per cycle, W = Heat added – Heat Rejected

$$= Q_S - Q_R$$

$$= C_v(T_3 - T_2) - C_v(T_4 - T_1)$$



For isentropic compression and expansion processes

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

and $$\frac{T_3}{T_4} = r^{\gamma - 1}$$

Let $$\gamma - 1 = x$$

So, $$W = C_v(T_3 - T_1 r^x) - C_v\left(\frac{T_3}{r^x} - T_1\right)$$

For maximum output:

$$\frac{dW}{dr} = 0$$

$$\Rightarrow -T_1 x\, r^{x-1} \times C_v - C_v \times T_3(-x) \times r^{-x-1} = 0$$

$$T_1 \times x = T_3 \frac{r^{-x-1}}{r^{x-1}} \times x$$

$$\frac{T_3}{T_1} = r^{2x}$$

$$r = \left(\frac{T_3}{T_1}\right)^{\frac{1}{2x}} = \left(\frac{T_3}{T_1}\right)^{\frac{1}{2(\gamma-1)}} = \left(\frac{T_3}{T_1}\right)^{\frac{1}{2(1.4-1)}} = \left(\frac{T_3}{T_1}\right)^{\frac{5}{4}}$$

25. (b)

Compression ratio (r) $$= \frac{V_1}{V_2} = \frac{400}{50} = 8$$

So, efficiency of Otto cycle $$\eta_{Otto} = 1 - \frac{1}{(r)^{\gamma - 1}} = 1 - \frac{1}{(8)^{1.4-1}} = 0.5647$$

$$\eta_{Otto} = \frac{\text{Output power}}{\text{Heat Input}}$$

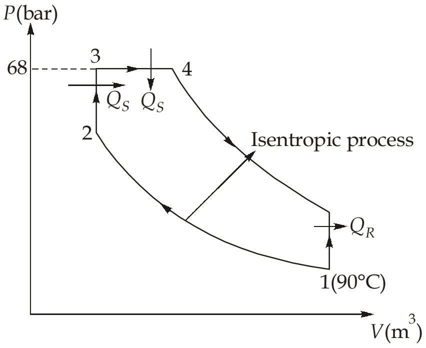
Heat input $$= \frac{100}{0.5647} = 177.077 \text{ kW}$$

26. **(a)**

For process 1-2:

$$\frac{T_2}{T_1} = \left(\frac{v_1}{v_2}\right)^{\gamma-1} = (r)^{\gamma-1} = 9^{0.4} = 2.408$$

$$T_2 = (90 + 273) \times 2.408$$
$$= 874.18 \text{ K}$$



$$\frac{P_2}{P_1} = \left(\frac{v_1}{v_2}\right)^{\gamma}$$

$$P_2 = 1 \times 9^{1.4} = 21.674 \text{ bar}$$

$$\frac{P_3}{P_2} = \frac{T_3}{T_2}, \Rightarrow \frac{68}{21.674} = \frac{T_3}{874.18}$$

$$T_3 = 2742.65 \text{ K}$$

Heat added at constant volume (Q_{sv}):

$$c_v(T_3 - T_2) = 0.71\ (2742.65 - 874.18)$$

$$Q_{sv} = 1326.615 \text{ kJ/kg}$$

Total heat added = Heat added at constant pressure + Heat added at constant volume.

$$Q_{sp} = Q_s - Q_{sv} = 1750 - 1326.615$$
$$= 423.38 \text{ kJ/kg}$$

$$T_4 = T_3 + \frac{423.38}{c_p} = 2742.65 + \frac{423.38}{1.005}$$

$$= 3163.94 \text{ K}$$

27. **(a)**

Bore of the engine cylinder, D = 300 mm = 0.3 m

Stroke length, L = 450 mm = 0.45 m

Engine rpm, N = 300 rpm

Indicated mean effective pressure, P_{imep} = 6 bar = 600 kPa

Net brake load, (W – S) = 1.5 kN

Diameter of brake drum, D_b = 1.8 m

Brake rope diameter, d = 2 cm = 0.02 m

Indicated power, IP:

$$\text{IP} = \frac{P_{\text{imep}}LANK}{120} \text{ kW} \qquad \left[\text{Here, } K = \frac{1}{2}\right]$$

$$\text{IP} = \frac{600 \times 0.45 \times \frac{\pi}{4} \times 0.3^2 \times 300}{120} = 47.71 \text{ kW}$$

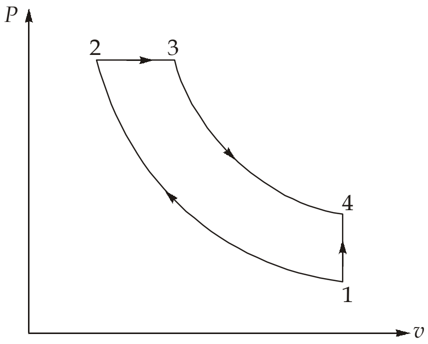
Brake power, BP:

$$BP = \frac{(W-S)\pi(D_b+d)N}{60} = \frac{1.5\times\pi(1.8+0.02)\times 300}{60} = 42.88\text{ kW}$$

Mechanical efficiency:

$$\eta_m = \frac{BP}{IP} = \frac{42.88}{47.71} = 0.8987 \text{ or } 89.87\%$$

28. (c)



$$\frac{\text{Mass of air}}{\text{Mass of fuel}} = \frac{\dot{m}_{air}}{\dot{m}_{fuel}} = 30$$

$T_1 = 27°C = 27 + 273 = 300$ K

$\gamma = 16$

$$CV = 42000 \text{ kJ/kg}$$

From the process 1-2 :

$$T_2 = T_1\, r^{\gamma-1} = 300\,(16)^{0.4}$$
$$= 909.4 \text{ K}$$

For constant pressure process 2-3,

$$\text{Heat supplied} = \dot{m}_{air} c_P (T_3 - T_2) = m_{fuel} \times CV$$

$$T_3 - T_2 = \frac{m_f}{m_a}\times\frac{CV}{c_P} = \frac{1}{30}\times\frac{42000}{1.005} = 1393$$

$$T_3 = 1393 + 909.4 = 2302.4 \text{ K}$$

$$\text{Cut-off ratio, } \rho = \frac{V_3}{V_2} = \frac{T_3}{T_2} = \frac{2302.4}{909.4} = 2.53$$

$$\eta_{th} = 1 - \frac{1}{r^{\gamma-1}}\left[\frac{\rho^\gamma - 1}{\gamma(\rho-1)}\right]$$

$$= 1 - \frac{1}{16^{0.4}}\left[\frac{2.53^{1.4} - 1}{1.4\times 1.53}\right] = 0.5892 \text{ or } 58.92\%$$

29. (b)

We know that,

$$\eta_m = \frac{\eta_{bth}}{\eta_{ith}} = \frac{\text{Brake thermal efficiency}}{\text{Indicated thermal efficiency}}$$

$$\eta_{bth} = 0.85 \times 0.6 = 0.51$$

and $$\eta_{bth} = \frac{BP}{\dot{m}_f \times C.V.} \text{ or } \eta_{bth} = \frac{1}{SFC\times C.V.}$$

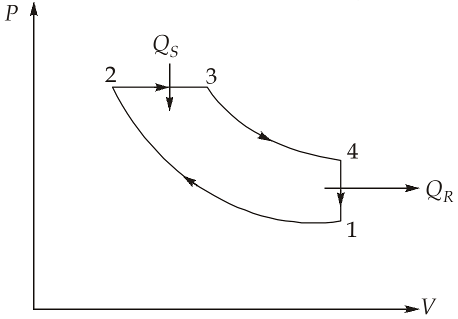
$$SFC = \frac{1}{\eta_{bth}\times C.V.} = \frac{1}{0.51\times 40} = 0.049 \approx 0.05$$
$$= 0.05 \text{ kg/MJ}$$

$$= \frac{0.05 \text{ kg/ s}}{10^3 \text{ kJ/ s}} = \frac{0.05\times 3600 \text{ kg/ hr}}{10^3 \text{ kW}} = 0.18 \text{ kg/kW-hr}$$

30. **(d)**

Heat addition at constant pressure, $Q_s = (m_a + m_f) \times c_p\,(T_3 - T_2)$

$$m_f \times \text{CV} = m_a \times c_p\,(T_3 - T_2) (\because\ m_a + m_f \approx m_a)$$



$$\text{CV}\times\frac{m_f}{m_a} = c_p\,(T_3 - T_2)$$

$$\frac{\text{CV}}{AFR\times c_p} = (T_3 - T_2) \qquad \text{[where, AFR is air fuel ratio]}$$

$$T_3 = T_2 + \frac{\text{CV}}{AFR\times c_p} = 800 + \frac{40\times 10^3}{25\times 1} = 2400\ \text{K}$$

$$\text{Cut-off ratio, } \rho = \frac{T_3}{T_2} = \frac{2400}{800} = 3$$

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