CLASS TEST

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INTERNAL COMBUSTION ENGINE

MECHANICAL ENGINEERING

Date of Test : 04/08/2022

ANSWER KEY

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

DETAILED EXPLANATIONS

2. (d)

$$\text{Initial efficiency, } \eta_i = 1-\frac{1}{(r)^{\gamma-1}} = 1-\frac{1}{(10)^{0.4}} = 0.60189$$

$$\eta_i = 60.19\%$$

When γ decreases by 1.5%, value of new γ is:

$$\gamma_n = 1.4\times\frac{(100-1.5)}{100} = 1.379\,\%$$

New efficiency is

$$\eta_f = 1-\frac{1}{(r)^{\gamma_n-1}} = 1-\frac{1}{(10)^{0.379}} = 0.5822$$

$$\eta_f = 58.22\%$$

$$\text{So, change in efficiency is } = \frac{58.22-60.19}{60.19} = -0.0327 = -3.27\%$$

Efficiency decreases by 3.27%.

3. (d)

As
$$\eta_{\text{Otto}} = 1-\frac{1}{r^{\gamma-1}} = 1-\frac{1}{(5.7)^{1.4-1}} = 1-\frac{1}{(5.7)^{2/5}} = 1-\frac{1}{(32.49)^{1/5}} \simeq 0.5$$

Also
$$\eta = \frac{W}{Q_s} = 0.5$$

$\Rightarrow$ $W = 350 \times 0.5 \simeq 175$ kJ

4. (d)

As
$$\eta_m = \frac{B.P.}{I.P.} \quad \text{or} = \frac{B.P.}{B.P.+F.P.} = 0.85$$

As friction power, (F.P.) = 30 kW

$$\Rightarrow \quad \frac{B.P.}{B.P.+30} = 0.85$$

or B.P. = 170 kW

$\Rightarrow$ I.P. = B.P. + F.P. = 200 kW

5. (c)

Orsat apparatus is used to determine products of only dry constituents of combustion by volume.

6. (a)

Heat input = 46000 × 0.2 = 9200 kJ/min

Brake power = 40 kW = 2400 kJ/min

Heat loss in cooling water = 1600 kJ/min

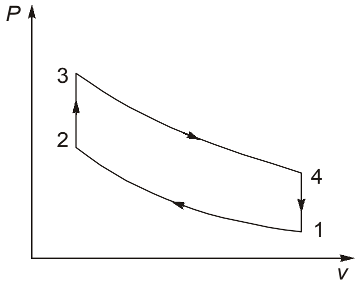
Other combined heat losses = 9200 – 2400 – 1600 = 5200 kJ/min

8. (a)

As the compression ratio increases the pressure also increases and so does the temperature. With increased temperature the auto ignition temperature of the fuel is reached and this causes fuel to ignite and this causes detonation in SI engines.

9. (d)

$$T_1 = 293\text{ K}, r = 8$$



$$P_1 = 1\text{ bar}$$
$$T_2 = T_1 \times (r)^{\gamma - 1}$$
$$= 293 \times (8)^{1.4 - 1} = 673\,\text{K}$$

Net heat addition during 2 –3 = $C_v(T_3 - T_2)$

$\Rightarrow$ $1800 = 0.718\ (T_3 - 673)$

$\Rightarrow$ $T_3 = 3180\text{ K}$

Also, $P_2 = P_1(r)^{\gamma} = 1 \times (8)^{1.4} = 18.38\text{ bar}$

Now, $P_3 = \dfrac{T_3}{T_2} \times P_2 = 18.38 \times \dfrac{3180}{673} = 86.8\text{ bar}$

10. (c)

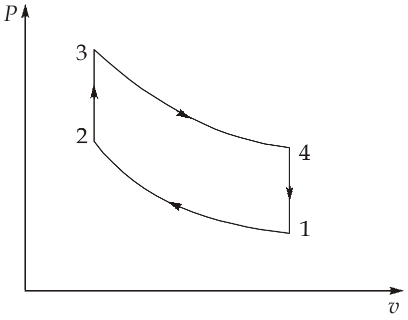
$$\eta_1 = 1 - \frac{1}{(5)^{\gamma-1}} = 1 - \frac{1}{(5)^{0.4}} = 1 - 0.5253 = 0.4747$$

$$\eta_2 = 1 - \frac{1}{(7)^{\gamma-1}} = 1 - \frac{1}{(7)^{0.4}} = 1 - 0.491 = 0.5409$$

$$\%\text{ increase} = \frac{\eta_2 - \eta_1}{\eta_1} = \frac{0.5409 - 0.4747}{0.4747} = 0.139 \simeq 14\%$$

11. (d)

$$T_1 = 27 + 273$$
$$T_1 = 300\text{ K}$$
$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{(\gamma-1)/\gamma}$$
$$\frac{T_2}{T_1} = (12)^{(1.4-1)/1.4}$$
$$T_2 = 610.181\text{ K}$$



as 2 – 3 constant volume process

$$\frac{P_2}{P_3} = \frac{T_2}{T_3}$$

$$T_3 = \frac{P_3}{P_2} \times T_2 = \frac{35}{12} \times 610.181$$

$$T_3 = 1779.694 \text{ K}$$

$$r = \frac{V_1}{V_2} = \left(\frac{P_2}{P_1}\right)^{1/\gamma}$$

$$r = 5.899$$

$$\eta_{\text{otto}} = \frac{W_{net}}{Q_s} = 1 - \frac{1}{(r)^{\gamma-1}} = 1 - \frac{1}{(5.89)^{1.4-1}} = 0.508$$

$$Q_s = c_v\,(T_3 - T_2) = 0.718 \times (1779.69 - 610.18) = 839.71 \text{ kJ/kg}$$

$$W_{\text{net}} = Q_s \times \eta_{\text{otto}} = 839.71 \times 0.508 = 426.58 \text{ kJ/kg}$$

$$W_{\text{net}} = P_{imep} \times v_1\left(1 - \frac{1}{r}\right); \qquad \left[v_s = v_1 - v_2 = v_1\left(1 - \frac{v_2}{v_1}\right)\right]$$

$$426.58 = P_{imep} \times \frac{RT_1}{P_1}\left(1 - \frac{1}{5.89}\right)$$

$$426.58 = P_{imep} \times \frac{0.287 \times 300}{100}\left(1 - \frac{1}{5.89}\right)$$

$$P_{\text{imep}} = 586.77 \text{ kPa} = 5.96 \text{ bar}$$

12. (c)

At full load:

$$bp + fp = 40 \text{ kW} \qquad \ldots(1)$$

at half load, $bp = 0.5 \times bp$ at full load

$$\eta_m = 0.65 = \frac{0.5 \times bp}{0.5bp + fp}$$

$$0.5bp = 0.65\,(0.5bp + fp)$$

$$0.5bp = 0.325bp + 0.65 \times fp$$

$$fp = \frac{0.175}{0.65} \times bp = 0.27bp$$

Put in equation (1)

$$bp + 0.27bp = 40$$

$$bp = 31.5 \text{ kW}$$

$$fp = 8.5 \text{ kW}$$

Mechanical efficiency at full load, $\eta_m = \dfrac{bp}{bp + fp} = \dfrac{31.5}{40}$

$$\eta_m = 78.8\%$$

Indicated thermal efficiency at full load

$$\eta_{\text{ith}} = \frac{\eta_{bth}}{\eta_m} = \frac{0.3}{0.788} = 0.381 = 38.1\%$$

13. **(a)**

Air standard efficiency for petrol engine,

$$\eta_{air} = 1-\frac{1}{(r)^{\gamma-1}} = 1-\frac{1}{(8)^{1.4-1}}$$

$$\eta_{air} = 0.56472$$

$$\eta_{indicated} = \eta_{air} \times \eta_{relative}$$

$$= 0.56472 \times 0.90$$

$$\eta_{indicated} = 0.50825$$

$$\eta_{brake} = \eta_{indicated} \times \eta_{mechanical}$$

$$= 0.50825 \times 0.75$$

$$\eta_{brake} = 0.38119$$

Brake specific fuel consumption

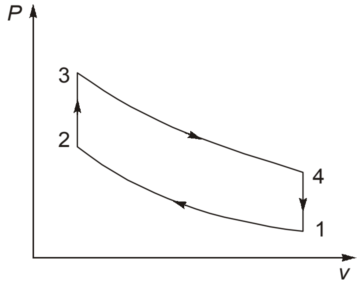
$$BSFC = \frac{3600}{\eta_{brake} \times CV} = \frac{3600}{0.38119 \times 40 \times 10^3}$$

$$BSFC = 0.2361 \text{ kg/h-kW}$$

14. **(a)**

$$T_1 = 15 + 273 = 288 \text{ K}$$

$$\frac{V_1}{V_2} = 8 \text{ (Given)}$$



Now,

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

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

$$T_2 = 288 \times (8)^{1.4-1} = 661.65 \text{ K}$$

$$\text{Heat supplied} = C_v[T_3 - T_2]$$

$$\Rightarrow \quad 1000 = 0.718[T_3 - 661.65]$$

$$\Rightarrow \quad T_3 = 2054.4 \text{ K or } 1781.4^\circ\text{C}$$

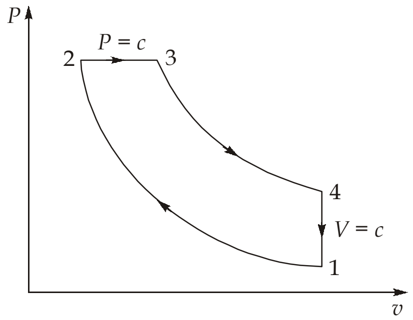
15. **(c)**

$$V_a = \frac{\pi}{4}d^2L = \frac{\pi}{4} \times 25^2 \times 37.5 = 18407.8 \text{ cc}$$

$$r = 1+\frac{V_s}{V_c} = 1+\frac{18407.8}{1500} = 13.27$$

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

$$r_c = \frac{V_3}{V_2}$$



$$\text{Cut-off volume} = V_3 - V_2 = 0.05V_s = 0.05 \times 12.27V_c$$

$$V_2 = V_c$$

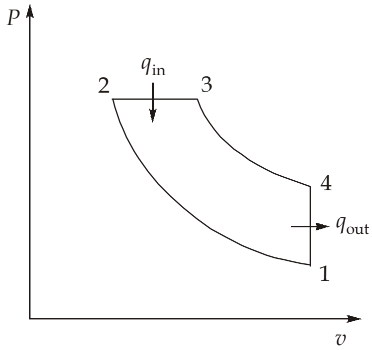
$$V_3 = 1.6135V_c$$

$$r_c = \frac{V_3}{V_2} = 1.6135$$

$$\eta = 1 - \frac{1}{13.27^{0.4}} \times \frac{1.6135^{1.4} - 1}{1.4 \times (1.6135 - 1)}$$

$$= 0.6052 = 60.52\%$$

16. **(c)**



The properties of air at room temperature are $c_p = 1.005$ kJ/kgK, $c_v = 0.718$ kJ/kgK, $R = 0.287$ kJ/kgK and $\gamma = 1.4$

$$T_2 = T_1\left(\frac{V_1}{V_2}\right)^{\gamma-1} = (293\text{K})(20)^{0.4} = 971.1\text{K}$$

Process 2-3: constant pressure heat addition,

$$\frac{P_3V_3}{T_3} = \frac{P_2V_2}{T_2} \Rightarrow \frac{V_3}{V_2} = \frac{T_3}{T_2} = \frac{2200\text{K}}{971.1\text{K}} = 2.265 \qquad (\text{given } T_3 = 2200 \text{ K})$$

Process 3-4: isentropic expansion,

$$T_4 = T_3\left(\frac{V_3}{V_4}\right)^{\gamma-1} = T_3\left(\frac{2.265V_2}{V_4}\right)^{\gamma-1} = T_3\left(\frac{2.265}{r}\right)^{\gamma-1}$$

$$= (2200)\left(\frac{2.265}{20}\right)^{0.4} \qquad [\because V_4 = V_1]$$

$$= 920.6\text{ K}$$

$$q_{\text{in}} = h_3 - h_2 = c_p(T_3 - T_2) = (1.005)(2200 - 971.1) = 1235.04\text{ kJ/kg}$$

$$q_{\text{out}} = u_4 - u_1 = c_v(T_4 - T_1) = (0.718)(920.6 - 293) = 450.6\text{ kJ/kg}$$

$$w_{\text{net, out}} = q_{\text{in}} - q_{\text{out}} = 1235 - 450.6 = 784.4\text{ kJ/kg}$$

$$\eta_{\text{th}} = \frac{w_{\text{net,out}}}{q_{in}} = \frac{784.4\text{ kJ/kg}}{1235.04\text{ kJ/kg}} = 63.5\%$$

17. (d)

The expression for the Otto cycle efficiency,

$$\eta_{\text{otto}} = 1 - \frac{1}{r^{\gamma-1}}$$

Substitution of the values:

Compression ratio, r = 10.0, and

Ratio of heat capacities, γ = 1.4, gives

$$\eta_{\text{otto}} = 1 - \frac{1}{10.0^{1.4-1}} = 0.602 = 60.2\%$$

$$\eta_{\text{brake}} = \eta_i \times \eta_{\text{mech}} = 0.5 \times \eta_{\text{otto}} \times \eta_{\text{mech}} = 0.5 \times 0.602 \times 0.9 = 0.271$$

Equation can be used to calculate the specific fuel consumption (SFC).

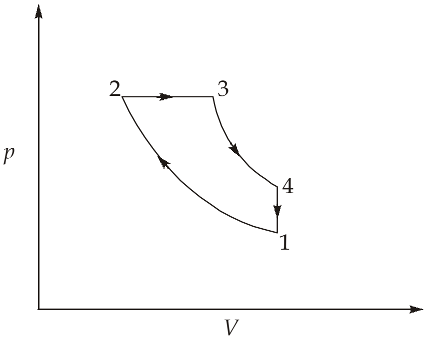
$$\text{sfc} = \frac{1}{(\eta_{\text{brake}} \times CV)} = \frac{1}{(0.271 \times 44)} = 83.9\text{ g/MJ}$$

18. (b)

$$V_1 = 16V_2 \qquad V_3 = 2V_2$$

$$V_s = V_1 - V_2 = (r-1)V_2 = 15V_2$$

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



Consider the process 1-2

$$p_2 = p_1\left(\frac{V_1}{V_2}\right)^{\gamma} = 1 \times 16^{1.4} = 48.5\text{ bar}$$

$$p_2 = p_3 = 48.5\text{ bar}$$

$$p_4 = p_3\left(\frac{V_3}{V_4}\right)^{1.4} = 48.5 \times \left(\frac{2}{16}\right)^{1.4} = \frac{48.5}{8^{1.4}} = 2.64\text{ bar (Since, } V_4 = V_1)$$

$$p_m = \frac{1}{V_s}\left[\frac{p_3V_3 - p_4V_4}{\gamma-1} - \frac{p_2V_2 - p_1V_1}{\gamma-1}\right]$$

$$= \frac{V_2}{V_s}\left[\frac{p_3\left(\frac{V_3}{V_2}\right) - p_4\left(\frac{V_4}{V_2}\right)}{\gamma-1} - \frac{p_2 - p_1\left(\frac{V_1}{V_2}\right)}{\gamma-1}\right]$$

$$= \frac{1}{15}\times\left[\frac{48.5\times2-2.64\times16}{1.4-1}-\frac{48.5-1\times16}{1.4-1}\right]$$

$$= 3.71 \text{ bar}$$

20. (d)

- In CI engines fuel is injected near the end of compression stroke during a period of some 20 to 35 degrees of crank angle.
- Low self ignition temperature of fuel decreases the tendency of knock in CI engines.

21. (b)

As indicated power, $\text{I.P} = nB.P - (\Sigma B.P_i)$

or $\text{I.P} = nB.P - (B.P_1 + B.P_2)$

$\Rightarrow$ $\text{I.P} = 2 \times 15 - (6.75 + 7.25)$

$\text{I.P} = 16 \text{ kW}$

So, $$\eta_m = \frac{B.P}{I.P} = \frac{15}{16} = 0.9375$$

$\Rightarrow$ $\eta_m = 93.75\,\%$

22. (c)

Increasing the engine speed increases knocking in diesel engines, while decreases knocking in petrol engine.

23. (a)

$$\eta_{bth} = \frac{BP}{m_f \times CV}$$

$$\Rightarrow \quad m_f = \frac{50}{0.25\times44000}$$

$$= 4.545 \times 10^{-3} \text{ kg/sec}$$

$$= 16.36 \text{ kg/hr}$$

$$= \frac{16.36}{0.74}$$

$$= 22.1\ l/\text{hr}$$

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

$$\left\{\eta_m = \frac{b.P.}{i.P.} = \frac{\eta_{bth}}{\eta_{ith}}\right\}$$

$$= \frac{0.25}{0.75} = 33.3\ \%$$

24. (b)

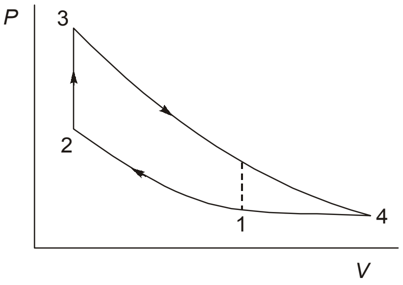
Given,

$T_1 = 300$ K

$P_1 = 1 \text{ bar} = P_4$

$r = 6$

$P_3 = 18$ bar



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

$$= \left(\frac{18}{1}\right)^{1.4} = 57.2$$

$$\text{Compression ratio} = \frac{V_1}{V_2} = r = 6$$

Efficiency of Atkinson cycle,

$$\eta = 1 - \gamma\frac{(e-r)}{(e^{\gamma} - r^{\gamma})} = 1 - 1.4 \times \frac{(57.2-6)}{(57.2^{1.4} - 6^{1.4})}$$

$$= 74.06\ \%$$

26. (a)

Given data:

$$\text{Number of cylinder}: x = 4$$
$$\text{Bore}: d = 70\text{ mm} = 7\text{ cm}$$
$$\text{Stroke}: l = 75\text{ mm} = 7.5\text{ cm}$$
$$\text{Compression ratio}: r = 8$$

$$\text{Cubic capacity of the engine} = \frac{\pi}{4}d^2lx$$

$$= \frac{3.14}{4} \times (7)^2 \times 7.5 \times 4$$

$$= 1153.95\text{ cm}^3 \simeq \mathbf{1154\ cc}$$

Displacement volume of each cylinder,

$$V_s = \frac{\pi}{4}d^2l = \frac{3.14}{4} \times (7)^2 \times 7.5 = 288.48\text{ cm}^3$$

$$\text{Compression ratio}: r = \frac{V_c + V_s}{V_c}$$

$$V_c r = V_c + V_s$$
$$V_c r - V_c = V_s$$
$$V_c(r-1) = V_s$$

or $$V_c = \frac{V_s}{r-1} = \frac{288.48}{8-1} = \mathbf{41.21\ cc}$$

27. (b)

$$D = 600\text{ mm} = 0.6\text{ m}$$
$$d = 26\text{ mm} = 0.026\text{ m}$$
$$W = 200\text{ N}$$
$$S = 30\text{ N}$$
$$N = 500\text{ rpm}$$

$$T = (W - S)\frac{(D+d)}{2}$$

$$= (200-30)\frac{(0.6+0.026)}{2} = 53.21\text{ Nm}$$

$$\text{Brake power}: bp = \frac{2\pi NT}{60}$$

$$= \frac{2 \times 3.14 \times 500 \times 53.21}{60} = 2784.65\text{ W} = 2.78\text{ kW}$$

28. **(c)**

Given data

$$\frac{m_f}{m_a} = 0.06$$

$$\eta_v = 92\% = 0.92$$

$$\eta_{i,th} = 32\% = 0.32$$

$$\text{C.V.} = 50000 \text{ kJ/kg}$$

$$\rho_{air} = 1.2 \text{ kg/m}^3$$

$$\eta_v = \frac{\text{Actual volume}}{\text{Swept volume}} = \frac{V_a}{V_s} = 0.92$$

or $V_a = 0.92\ V_s$

Mass of air: $m_a = \rho_{air}\ V_a$

$$= 1.2 \times 0.92\ V_s = 1.104\ V_s$$

Mass of fuel : $m_f = 0.06 \times m_a = 0.06 \times 1.104\ V_s$

$$= 0.0662\ V_s$$

$$\eta_{i,th} = \frac{p_m \times LA}{m_f \times C.V.}$$

$$0.32 = \frac{p_m \times V_s}{0.0662 V_s \times 50000}$$

or $p_m = 1059.2 \text{ kPa} = \mathbf{1.06\ MPa}$

29. **(d)**

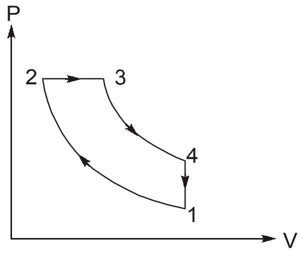
Cut-off ratio; $(r_c)_1 = 4$

$(r_c)_2 = 8$

Compression, $r = 12$

$$\eta_1 = 1 - \frac{1}{r^{\gamma-1}}\left[\frac{r_{c_1}^{\gamma} - 1}{\gamma(r_{c_1} - 1)}\right]$$

$$= 1 - \frac{1}{(12)^{1.4-1}}\left[\frac{4^{1.4} - 1}{1.4(4-1)}\right] = 0.474$$



$$\eta_2 = 1 - \frac{1}{r^{\gamma-1}}\left[\frac{r_{c_2}^{\gamma} - 1}{\gamma(r_{c_2} - 1)}\right]$$

$$= 1 - \frac{1}{(12)^{0.4}}\left[\frac{8^{1.4} - 1}{1.4(8-1)}\right] = 0.343$$

$$\text{Loss in efficiency} = \frac{\eta_1 - \eta_2}{\eta_1} \times 100$$

$$= \frac{0.474 - 0.343}{0.474} \times 100 = 27.62\%$$

30. **(a)**

Given data:

$$n = \frac{N}{2} \text{ for four-stroke engine}$$

$$V_s = 0.0259 \text{ m}^3$$

$$P = 950 \text{ kW}$$

$$N = 2200 \text{ rpm}$$

We know that power output,

$$P = \frac{A\,.\,l\,.\,n\,.\,x.\,p_m}{60} \text{ kW} = \frac{p_m V_s n x}{60}$$

where P is in kW

p_m is in kPa

V_s is in m^3

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

$$x = 1, \text{ number of cylinder}$$

$\therefore$

$$950 = \frac{p_m \times 0.0259}{60} \times \frac{N}{2} \times 1$$

$$950 = \frac{p_m \times 0.0259 \times 2200}{120}$$

or

$$p_m = 2000 \text{ kPa} = 2 \text{ MPa}$$

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