CLASS TEST

SL.: 01SPME_ABCD_02082023

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INTERNAL COMBUSTION ENGINE

MECHANICAL ENGINEERING

Date of Test : 02/08/2023

ANSWER KEY

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

DETAILED EXPLANATIONS

1. (b)

A good CI engine fuel should have a short ignition lag and will ignite more quickly.

5. (c)

The pour point indicates the lowest temperature at which an oil stops flowing to the pump, bearings or cylinder walls. It is particularly important for immediate oil circulation in respect of starting of engines in very cold climate with gravity lubricating systems. The fluidity is a factor affecting of pour point and viscosity of the cold oil.

7. (a)

Given data:

Compression ratio: $r = 10$

$$\eta_{Otto} = 1 - \frac{1}{r^{\gamma-1}} = 1 - \frac{1}{10^{1.4-1}}$$

$$= 1 - \frac{1}{10^{0.4}} = 0.6018 \text{ or } 60.18\%$$

9. (b)

Crank radius, r = 50 mm

Diameter of cylinder, D = 90 mm

Swept volume = ?

∴ Stroke length, L = 2r = 2 × 50 mm = 100 mm

$$\text{Swept volume} = \frac{\pi}{4} D^2 L$$

$$= \frac{\pi}{4} \times (90)^2 \times 100 \times 10^{-3}$$

$$= 636.172 \text{ cm}^3$$

10. (c)

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

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

$$\text{Work output} = 19.5 \times 10^5 \times V_c$$

$$= \text{IMEP} \times V_s$$

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

$$\Rightarrow \quad \text{BMEP} = \eta_m \times \text{IMEP}$$

$$= 0.85 \times 3 = 2.55 \text{ bar}$$

11. (d)

$$\text{Fuel consumption per hour} = 0.250 \times 90 = 22.5 \text{ kg}$$

$$\therefore \quad \text{Fuel consumption per cylinder} = \frac{22.5}{6} = 3.75 \text{ kg/hr}$$

$$\text{Fuel consumption per cycle per cylinder} = \frac{3.75}{60 \times \left(\frac{2500}{2}\right)} = 5 \times 10^{-5} \text{ kg} = 0.05 \text{ gm}$$

13. (d)

Given data:

$$bp = 12 \text{ kW}$$

$$\eta_{b,th} = 28\% = 0.28$$

$$\text{C.V.} = 40000 \text{ kJ/kg}$$

$$\eta_{b,\,th} = \frac{bp}{m_f \times C.V.}$$

$$0.28 = \frac{12}{m_f \times 40000}$$

or $m_f = 1.071 \times 10^{-3}$ kg/s $=$ **3.85 kg/hour**

14. (c)

Net brake power: $bp_{1,2} = 10$ kW

Brake power of cylinder-1,

$$bp_1 = 4.75 \text{ kW}$$

Brake power of cylinder-2,

$$bp_2 = 4 \text{ kW}$$

Net indicated power,

$$ip_{1,2} = bp_{1,2} + fp$$

$$= 10 + fp \quad \ldots(1)$$

Indicated power of cylinder-1, when spark cut-off of cylinder-2,

$$ip_1 = bp_1 + fp$$

$$ip_1 = 4.75 + fp \quad \ldots(2)$$

Indicated power of cylinder-2,

$$ip_2 = ip_{1,2} - ip_1$$

$$= 10 - 4.75 = 5.25 \text{ kW}$$

Indicated power of cylinder-2, when spark cut-off of cylinder-1,

$$ip_2 = bp_2 + fp$$

$$= 4 + fp \quad \ldots(3)$$

Indicated power of cylinder-1,

$$ip_1 = ip_{1,2} - ip_2$$

$$= 10 - 4 = 6 \text{ kW}$$

Net indicated power: $ip_{1,2} = ip_1 + ip_2$

$$= 6 + 5.25 = 11.25 \text{ kW}$$

Mechanical efficiency: $\eta_m = \dfrac{\text{Net brake power}}{\text{Net indicated power}}$

$$= \frac{bp_{1,2}}{ip_{1,2}} = \frac{10}{11.25} = 0.8888 = \mathbf{88.88\%}$$

15. (c)

Given data:

$$V_s = 0.0259\ \text{m}^3$$
$$P = 950\ \text{kW}$$
$$N = 2200\ \text{rpm}$$

We know that power output,

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

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

16. (b)

$$\text{Let BP at full load} = x\ \text{kW}$$
$$\text{BP at 70\% of load} = 0.70x\ \text{kW}$$
$$\text{IP at 70\% of load} = 0.70x + \text{FP}$$

At 70% load $$\eta_m = \frac{0.70x}{0.70x + FP} = 0.80$$

$\Rightarrow$ $$0.70x = 0.56x + 0.80\text{FP}$$
$$0.14x = 0.80\ \text{FP}$$
$$\text{FP} = 0.175x$$

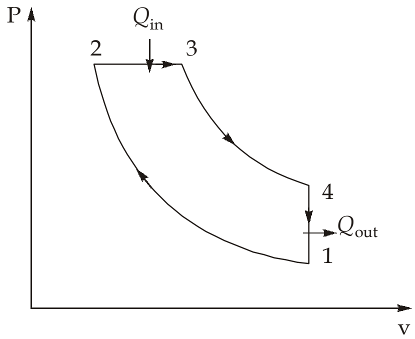
Since, FP remains constant at all loads

At full load $$\text{IP} = \text{BP} + \text{FP} = 50$$
$$x + 0.175\,x = 50$$

$$x = \frac{50}{1.175} = 42.55\ \text{kW}$$

17. (c)

Given, $$r = 18,\ \alpha_c = 1.9,\ T_1 = 40°\text{C}$$
$$T_2 = T_1 (r)^{\gamma - 1}$$



$$= (40 + 273)(18)^{0.4} = 994.6 \text{ K}$$

and, $$T_3 = \alpha_c T_2 \qquad (\because\ P_2 = P_3)$$

$$T_3 = 1.9 \times 994.6 = 1889.76 \text{ K}$$

$$T_4 = T_3\left(\frac{v_3}{v_4}\right)^{\gamma-1} = T_3\left(\frac{1.9v_2}{v_4}\right)^{\gamma-1}$$

$$= 1889.76\times\left(\frac{1.9}{18}\right)^{0.4} = 768.77 \text{ K}$$

$$m = \frac{P_1V_1}{RT_1} = \frac{99\times0.002}{0.287\times313} = 2.2 \times 10^{-3} \text{ kg}$$

$$Q_{in} = m(h_3 - h_2) = mc_p(T_3 - T_2)$$

$$= 2.2 \times 10^{-3} \times 1.005\ (1889.76 - 994.6) = 1.98 \text{ kJ}$$

$$Q_{out} = mC_v(T_4 - T_1)$$

$$= 2.2 \times 10^{-3} \times 0.718(768.77 - 313) = 0.719 \text{ kJ}$$

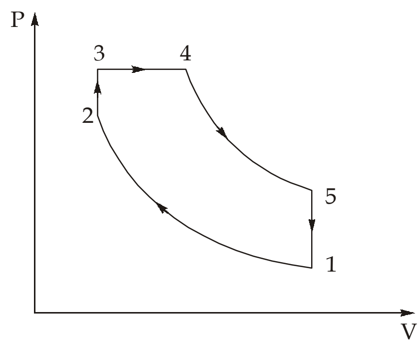
$$W_{net} = Q_{in} - Q_{out} = 1.98 - 0.719 = 1.26 \text{ kJ}$$

$$\text{Power} = 57.4 \text{ kW} = n \times W_{net}$$

$$57.4 = \frac{N}{60}\times1.26$$

$$N = 2733.33 \text{ rpm}$$

18. (a)



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

$$= (14)^{1.4-1} = 2.873$$

$$T_1 = 16 + 273 = 289 \text{ K}$$

$$T_2 = 2.873 \times 289 = 830.5 \text{ K}$$

For process 2 to 3 ($V = C$)

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

$\Rightarrow$ $$T_3 = \frac{P_3}{P_2}\times T_2 = \frac{60}{P_2}\times830.5$$

and $$\frac{P_2}{P_1} = \left(\frac{V_1}{V_2}\right)^{\gamma} = (14)^{1.4} = 40.23$$

$$P_2 = 40.23 \times 1 = 40.23 \text{ bar}$$

$$\Rightarrow \quad T_3 = \frac{60 \times 830.5}{40.23} = 1238.54 \text{ K}$$

Given $$(Q_s)_{V=C} = (Q_s)_{P=C}$$

$$\Rightarrow \quad c_v(T_3 - T_2) = c_p(T_4 - T_3)$$

$$\Rightarrow \quad 0.718(1238.54 - 830.5) = 1.005(T_4 - 1238.54)$$

$$\Rightarrow \quad T_4 = \frac{0.718 \times 408.044}{1.005} + 1238.54 = 1530.058 \text{ K}$$

Now $$\frac{V_4}{V_3} = \frac{T_4}{T_3} = \frac{1530.058}{1238.54} = 1.2354$$

$$\therefore \quad \frac{V_5}{V_4} = \frac{V_1}{V_4} = \frac{V_1}{V_2} \times \frac{V_3}{V_4} = \frac{14 \times 1}{1.2354} = 11.332$$

$$\frac{T_4}{T_5} = \left(\frac{V_5}{V_4}\right)^{\gamma-1} = (11.332)^{0.4} = 2.640755$$

$$T_5 = \frac{1530.058}{2.640755} = 579.402 \text{ K}$$

$$\therefore \quad \text{Heat supplied} = c_v(T_3 - T_2) + c_p(T_4 - T_3)$$

$$= 2c_v(T_3 - T_2)$$

$$= 2 \times 0.718(1238.54 - 830.5)$$

$$= 585.94 \text{ kJ/kg}$$

$$\text{and heat rejected} = c_v(T_5 - T_1) = 0.718(579.402 - 289) = 208.508 \text{ kJ/kg}$$

$$\therefore \quad \eta = 1 - \frac{Q_{rej}}{Q_s} = 1 - \frac{208.508}{585.94} = 0.6442 \text{ or } 64.42\%$$

19. (d)

Air consists of 21% oxygen and 79% nitrogen thus for each mole of oxygen in air there are 3.76 moles of nitrogen.

The chemical reaction of combustion of methane is given as

$$CH_4 + 2O_2 + 7.52\, N_2 \rightarrow CO_2 + 2H_2O + 7.52\, N_2$$

$$16 \text{ kg of } CH_4 \text{ requires} = 2 \times 32 + 7.52 \times 28$$

$$= 274.56 \text{ kg of air}$$

$$\Rightarrow \quad \text{A/F ratio} = \frac{274.56}{16} = 17.16$$

$$\text{The density of the air} = \frac{P}{RT} = \frac{1.01 \times 10^5}{287 \times 295} = 1.1929 \text{ kg/m}^3$$

$$\text{Volume of air required per kg of fuel} = \frac{17.16}{1.1929} = 14.38 \text{ m}^3\text{/kg of fuel}$$

20. (a)

Given: $P_1 = 1$ bar, $T_1 = T_2 = 300$ K

$P_3 = 15$ bar, $T_3 = 700$ K

Compression ratio, $\frac{V_1}{V_2} = \frac{V_1}{V_3} = \frac{V_4}{V_3} = r$

Net work done $= W_{expansion} - W_{compression}$

$= RT_3 \log_e r - RT_1 \log_e r$

$= R(T_3 - T_1)\log_e r$

Assume 1 kg of air at the beginning of compression process.

$$v_1 = \frac{RT_1}{P_1} = 287 \times \frac{300}{10^5} = 0.861 \text{ m}^3/\text{kg}$$

$$v_2 = v_3 = \frac{RT_3}{P_3} = 287 \times \frac{700}{15 \times 10^5} = 0.134 \text{ m}^3/\text{kg}$$

$$r = \frac{v_1}{v_2} = 6.425$$

Stroke volume $= v_1 - v_2 = 0.727$ m^3/kg

$W = R(T_3 - T_1)\log_e r = 287 \times (700 - 300)\log_e 6.425$

$= 213.55$ kJ/kg of air

$$\text{Mean effective pressure} = \frac{\text{Work done}}{\text{Stroke volume}} = \frac{213.55}{0.727} = 2.94 \text{ bar}$$

21. (c)

$$\eta_m = 0.8 = \frac{b.p}{i.p.} \Rightarrow i.p. = \frac{50}{0.8} = 62.5 \text{ kW}$$

$$\Rightarrow \quad \eta_{ith} = 0.35 = \frac{i.p.}{\dot{V}_f (C.V.)_f} \Rightarrow \dot{V}_f = \frac{62.5}{34 \times 1000 \times 0.35}$$

$$\dot{V}_f = 5.252 \times 10^{-3} \text{ m}^3/\text{s}$$

$$\Rightarrow \quad \frac{A}{F} = \frac{10}{1} \Rightarrow \frac{\dot{V}_a}{\dot{V}_f} = 10 \Rightarrow \dot{V}_a = 0.05252 \text{ m}^3/\text{s}$$

$$\eta_v = \frac{(\dot{V}_a)_{air}}{\dot{V}_s} = \frac{0.05252}{2000 \times 10^{-6} \times \frac{N}{120}} = 0.7$$

$$\Rightarrow \quad N = 4501.71 \text{ rpm}$$

22. (c)

$$\text{Compression ratio} = \text{expansion ratio} \times \text{cut-off ratio}$$
$$r = 15 \times 1.5$$
$$r = 22.5$$

Now,
$$\eta_{\text{air-std}} = 1 - \frac{1}{r^{\gamma-1}} \frac{\rho^{\gamma} - 1}{\gamma(\rho - 1)}$$
$$\eta_{\text{air-std}} = 1 - \frac{1}{22.5^{0.4}} \times \frac{1.5^{1.4} - 1}{1.4(1.5-1)}$$
$$\eta_{\text{air-std}} = 0.6858$$

Now,
$$\eta_{\text{rel}} = \frac{\eta_{\text{bth}}}{\eta_{\text{air-std}}}$$
$$\eta_{\text{bth}} = 0.4 \times 0.6858$$
$$\eta_{\text{bth}} = 0.27432$$
$$\frac{BP}{\dot{m}_f \times CV} = 0.27432$$
$$\dot{m}_f = \frac{30 \times 3600}{0.27432 \times 42000}$$
$$\dot{m}_f = 9.3738 \text{ kg/h}$$

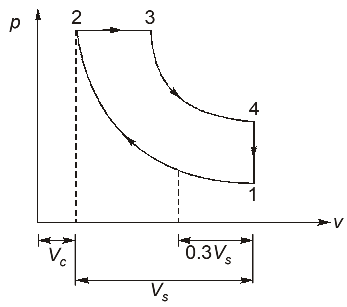
23. (b)

$$\text{Brake power} = T\omega = \frac{300 \times 2\pi \times 500}{60 \times 10^3} \text{kW}$$
$$BP = 15.7 \text{ kW}$$

Calculating indicated power:

$$\text{Spring constant} = \frac{10 \times 10^4 Pa}{1.4 \text{ mm}} = 71.43 \text{ kPa/mm}$$
$$\text{Indicated pressure} = \frac{\text{Area of indicator diagram}}{\text{Length of indicator diagram}} \times \text{Spring constant}$$
$$\text{Indicated pressure} = \frac{500}{60} \times 71.43 = 595.24 \text{ kPa}$$
$$\text{Indicated pressure} = 595.24 \times \frac{LAN}{60 \times 2} = 595.24 \times \frac{0.3 \times \frac{\pi}{4} \times 0.2^2 \times 500}{60 \times 2} = 23.375 \text{ kW}$$
$$\eta_m = \frac{bp}{i.p} \times 100 = 67.165\%$$

24. (b)



$$V_c = V_2 = 30 \text{ cm}^3$$

$$r = 20 = 1+\frac{V_s}{V_c}$$

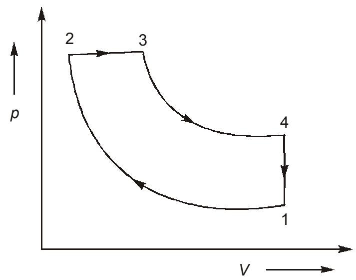
$$V_s = 570 \text{ cm}^3$$

After 30% of compression stroke

$$V_1' = V_c + 0.7\ V_s$$

$$= 30 + 0.7 \times 570 = 429 \text{ cm}^3$$

25. (b)



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

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

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

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

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

$$\frac{V_3}{V_2} = 0.1(20-1) = 1.9$$

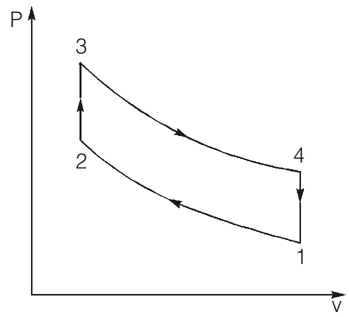
Heat addition takes place at constant pressure (i.e. process 2-3)

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

$$\Rightarrow \quad T_3 = 1.9 \times [1126.92]$$

$$= 2141.14 \text{ K}$$

26. (d)



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

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

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

27. (b)

for N_2 gas, $\gamma = 1.66$

$$\text{Compression ratio, } r = \frac{\nu_1}{\nu_2} = \frac{\nu_1}{0.125\nu_1} = 8$$

∴ $$\eta_{th} = 1-\frac{1}{(r)^{\gamma-1}} = 1-\frac{1}{(8)^{1.66-1}} = 0.7465$$

Now $$\eta_{th} = \frac{W_{net}}{Q_{in}}$$

⇒ $$W_{net} = 0.7465 \times 150 = 111.9765 \text{ kW}$$

$$= \frac{111.9765\times 1000}{746} = 150.10 \text{ hP}$$

28. (c)

With the increase of load in CI engine, cut off ratio increases.

30. (c)

Upper limit of compression ratio in SI engine is fixed by antiknock quality of the fuel.

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