CLASS TEST

S.No.: 01SKME_ABCDEFGHI_10925

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IC ENGINE

MECHANICAL ENGINEERING

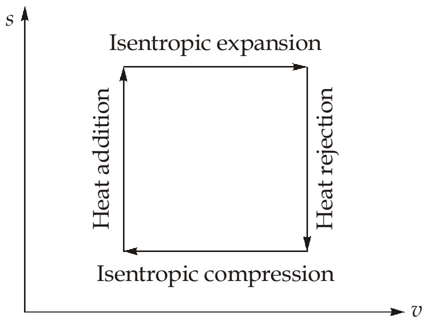
Date of Test : 10/09/2025

ANSWER KEY

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

DETAILED EXPLANATIONS

2. (b)



3. (c)

$$\text{for } N_2 \text{ gas}, \gamma = 1.66$$

$$\text{Compression ratio, } r = \frac{v_1}{v_2} = \frac{v_1}{0.125v_1} = 8$$

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

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

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

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

4. (a)

$$BP = \frac{2\pi NT}{60 \times 1000} = \frac{2\pi \times 2500 \times 12}{60 \times 1000} = 3.14 \text{ kW}$$

$$\text{Friction power} = 3.5 - 3.14 = 0.358 \text{ kW}$$

$$\%\text{loss} = \frac{0.358}{3.5} \times 100 = 10.22\ \%$$

5. (b)

$$\eta_m = \frac{\text{Brake power}}{\text{Indicated power}}$$

$$\Rightarrow \quad \text{Indicated power} = \frac{\text{Brake power}}{\eta_m} = \frac{60}{0.8} = \frac{60}{8} \times 10 = 75 \text{ kW}$$

7. (b)

$$\eta = 1 - \frac{1}{(r)^{\gamma-1}} = 1 - \frac{1}{(9)^{0.5}} = 1 - \frac{1}{3} = 0.6667$$

$$\therefore \quad \eta = 67\ \%$$

9. **(d)**

Using characteristic gas equation

$$Pv = RT$$

$$v_1 = \frac{RT_1}{P_1} = \frac{287 \times 300}{1 \times 10^5} = 0.861 \text{ m}^3/\text{kg}$$

$$v_2 = \frac{0.861}{14} = 0.0615 \text{ m}^3/\text{kg}$$

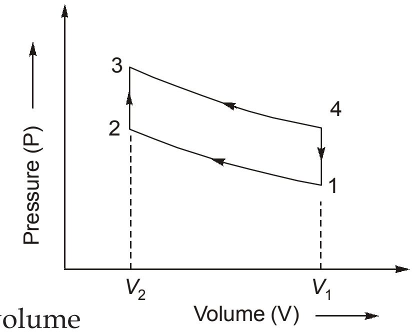
$$\text{Swept volume} = v_1 - v_2 = 0.861 - 0.0615 = 0.7995 \text{ m}^3/\text{kg}$$

10. **(b)**

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

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

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



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

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

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

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

11. **(c)**

$$\eta_I = 1 - \frac{1}{(r_1)^{r-1}} = 1 - \frac{1}{(4)^{0.4}} = 0.4256$$

$$\eta_{II} = 1 - \frac{1}{(r_2)^{r-1}} = 1 - \frac{1}{(6)^{0.4}} = 0.5116$$

$$\% \text{ Increase in thermal efficiency} = \frac{\eta_{II} - \eta_I}{\eta_I} \times 100 = \frac{0.5116 - 0.4256}{0.4256} \times 100 = 20.2\%$$

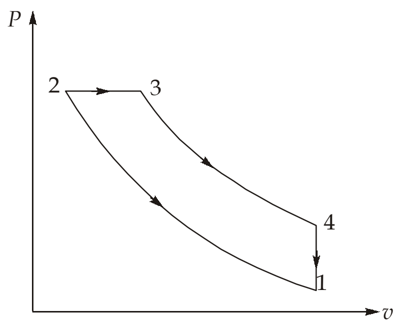
12. **(d)**

Given: $r = 14$, $R = 287$ J/kgK, $c_p = 1005$ J/kgK, $\gamma = 1.4$

$$T_1 = 27°\text{C} = 300 \text{ K}$$

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

$$Q = c_p (T_3 - T_2)$$



$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1} = (r)^{\gamma-1} = (14)^{1.4-1} = 2.8737$$

$$T_2 = 300 \times 2.8737 = 862.11 \text{ K}$$

$$\frac{T_3}{T_2} = \frac{v_3}{v_2} = 2$$

$$T_3 = 2T_2 = 1724.22 \text{ K}$$

$$Q = c_p (T_3 - T_2) = 1.005 \times (1724.22 - 862.11) = 866.4 \text{ kJ/kg}$$

13. (b)

Let BP at full load = x kW

BP at 70% of load = $0.70x$ kW

IP at 70% of load = 0.70x + FP

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

$\Rightarrow$ $0.70x = 0.56x + 0.80FP$

$0.14x = 0.80$ FP

FP = $0.175x$

FP remains constant at all loads

At full load IP = BP + FP = 50

$x + 0.175\,x = 50$

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

14. (d)

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

The chemical equation 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 kg of CH_4 requires = 2 × 32 + 7.52 × 28

= 274.56 kg of air

$\Rightarrow$ A/F ratio $= \dfrac{274.56}{16} = 17.16$

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

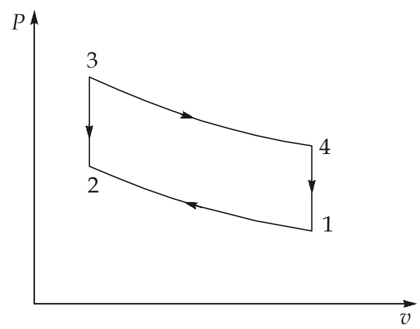
Volume of air required per kg of fuel $= \dfrac{17.16}{1.1929} = 14.38\ \text{m}^3/\text{kg of fuel}$

15. (a)

If $V_2 = V_3 = 1,\ V_1 = V_4 = r$

$$\frac{P_2}{P_1} = \left(\frac{V_1}{V_2}\right)^{\gamma} = (r)^{\gamma} = \frac{P_3}{P_4}$$

$$\therefore \quad \frac{P_3}{P_2} = \frac{P_4}{P_1} = \frac{140}{95} = 1.473$$



Work done = area of P-v diagram

$$= \frac{P_3v_3 - P_4v_4}{\gamma-1} - \frac{P_2v_2 - P_1v_1}{\gamma-1}$$

$$= \frac{1}{\gamma-1}\left[P_4r\left(\frac{P_3}{P_4\times r}-1\right) - P_1r\left(\frac{P_2}{P_1\times r}-1\right)\right]$$

$$= \frac{r}{\gamma-1}\left[P_4\left(r^{\gamma-1}-1\right)-P_1\left(r^{\gamma}-1\right)\right] = \frac{r}{\gamma-1}\left(r^{\gamma-1}-1\right)\left(P_4-P_1\right)$$

$$= \frac{7}{1.4-1}\left[(7)^{1.4-1}-1\right](140-95) = 927.60 \text{ kJ}$$

Length of diagram $= r - 1 = 7 - 1 = 6$

$$\text{mep} = \frac{\text{area of diagram}}{\text{length of the diagram}} = 927.60/6 = 154.6 \text{ kPa}$$

16. (b)

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

$$\Rightarrow \quad \eta_{ith} = 0.35 = \frac{i.p.}{\dot{V}_f\,(C.V.)_f} \Rightarrow \dot{V}_f = \frac{62.5}{34\times1000\times0.35}$$

$$\dot{V}_f = 5.252\times10^{-3} \text{ m}^3/\text{s}$$

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

$$\eta_v = \frac{(\dot{V}_a)_{air}}{\dot{V}_s} = \frac{0.05252}{2000\times10^{-6}\times\frac{N}{120}} = 0.7$$

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

17. (d)

Compression ratio = expansion ratio × cut-off ratio

$$r = 15\times1.5$$

$$r = 22.5$$

Now, $$\eta_{air\text{-}std} = 1-\frac{1}{r^{\gamma-1}}\frac{\rho^{\gamma}-1}{\gamma(\rho-1)}$$

$$\eta_{air\text{-}std} = 1-\frac{1}{22.5^{0.4}}\times\frac{1.5^{1.4}-1}{1.4(1.5-1)}$$

$$\eta_{air\text{-}std} = 0.6858$$

Now, $$\eta_{rel} = \frac{\eta_{bth}}{\eta_{air\text{-}std}}$$

$$\eta_{bth} = 0.4\times0.6858$$

$$\eta_{bth} = 0.27432$$

$$\frac{BP}{\dot{m}_f\times CV} = 0.27432$$

$$\dot{m}_f = \frac{30\times3600}{0.27432\times42000}$$

$$\dot{m}_f = 9.3738 \text{ kg/h}$$

18. (a)

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

$$\Rightarrow \quad m_f = \frac{50}{0.25\times44000} = 4.545 \times 10^{-3} \text{ kg/sec} = 16.36 \text{ kg/hr}$$

$$= \frac{16.36}{0.74} = 22.1\ l/\text{hr}$$

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

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

19. (a)

In four stroke cycle there is one effective working stroke in every two revolution of the engine crankshaft i.e. $n = \frac{N}{2}$

$$\text{Indicated power} = \frac{P_m LAnk}{1000} kW$$

$$= \frac{4.5\times10^5 \times 0.25 \times \frac{\pi}{4} \times 0.2^2 \times \frac{360}{2\times60} \times 1}{1000} = 10.6 \text{ kW}$$

$$\text{Indicated thermal efficiency} = \frac{i.p.}{m_f \times CV} = \frac{10.6}{\frac{5}{3600}\times44000} = 17.35\ \%$$

20. (b)

$$\eta_v = \frac{V_a}{V_S} = 0.9$$

$$\Rightarrow \quad V_a = 0.9\ V_s$$

mass of air, $m_a = \rho_{air} \times V_a = 1.0 \times 0.9\ V_S = 0.9\ V_S$

$$\frac{m_f}{m_a} = \frac{F}{A}$$

$$\Rightarrow \quad m_f = \frac{F}{A} \times m_a = 0.05 \times 0.9\ V_S = 0.045\ V_S$$

$$\eta_{th} = \frac{P_{mep} \times V_S}{m_f \times CV} = \frac{6\times10^5 \times V_S \times 100}{0.045 \times V_S \times 45000 \times 1000} = 29.63\ \%$$

21. (d)

$$\eta_{\text{Otto}} = 1 - \left(\frac{v_c}{v_c + v_s}\right)^{\gamma - 1}$$

$$v_C = 196.3 \text{ cm}^3$$

$$v_s = \frac{\pi}{4} \times D^2 L = \frac{\pi}{4} \times 10^2 \times 15 = 1178.097 \text{ cm}^3$$

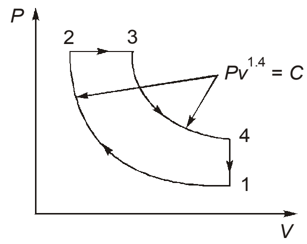
$$\gamma = 1.4$$

$$\therefore \quad \eta_{\text{Otto}} = 1 - \left(\frac{196.3}{196.3 + 1178.097}\right)^{1.4 - 1} = 0.5408$$

$$\therefore \quad \eta_{\text{Otto}} = 54.08\%$$

$$\therefore \quad \text{Work output} = \eta_{\text{Otto}} \times (\text{Heat supplied}) = 0.5408 \times 1800 \text{ kJ} = 973.58 \text{ kJ}$$

22. (b)



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

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

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

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

23. (a)

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

$$BP = 15.7 \text{ kW}$$

Calculating indicated power:

$$\text{Spring constant} = \frac{10 \times 10^4\, Pa}{1.4 \text{ mm}} = 71.43 \text{ kPa/mm}$$

$$\text{Indicated pressure} = \frac{\text{Area of indicator diagram}}{\text{Length of indicator diagram}} \times \text{Spring constant}$$

$$\text{Indicated pressure} = \frac{500}{60} \times 71.43 = 595.24 \text{ kPa}$$

$$\text{Indicated power} = 595.24 \times \frac{LAN}{60 \times 2} = 595.24 \times \frac{0.3 \times \frac{\pi}{4} \times 0.2^2 \times 500}{60 \times 2} = 23.375 \text{ kW}$$

$$\eta_m = \frac{bp}{i.p} \times 100 = 67.165\%$$

24. (a)

Stoichiometric reaction:

$$C_4H_{10} + \frac{13}{2}\left(O_2 + \frac{79}{21}N_2\right) \rightarrow 5H_2O + 4CO_2 + \frac{13}{2}\times\frac{79}{21}N_2$$

When 75% excess air is used:

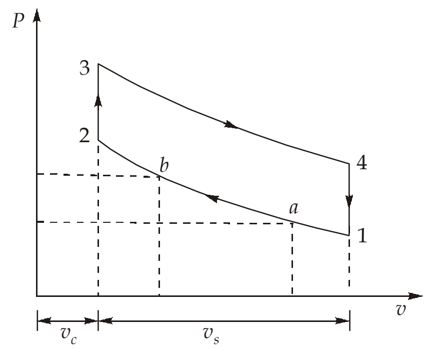
Moles of air per mole of butane $= 1.75\times\frac{13}{2} = 11.375$

$$C_4H_{10} + 11.375\left(O_2 + \frac{79}{21}N_2\right) \rightarrow 5H_2O + 4CO_2 + 4.875O_2 + 11.375\times\frac{79}{21}N_2$$

Mass percent of CO_2 in dry exhaust $= \dfrac{4m_{CO_2}}{4m_{CO_2} + 4.875m_{O_2} + 11.375\times\frac{79}{21}m_{N_2}}\times 100$

$$= \frac{4\times 44}{4\times 44 + 4.875\times 32 + 11.375\times\frac{79}{21}\times 28}\times 100 = 11.5020\%$$

25. (c)



For compression, $pV^{1.3} = C$

Now, $V_a = V_c + V_s - 0.05\,V_s$

$V_a = V_c + 0.95\,V_s$

and $V_b = V_c + V_s - 0.75\,V_s$

$V_b = V_c + 0.25\,V_s$

Now, $P_aV_a^{1.3} = P_bV_b^{1.3}$

$$\frac{V_a}{V_b} = \left(\frac{P_b}{P_a}\right)^{1/1.3}$$

$$\frac{V_c + 0.95V_s}{V_c + 0.25V_s} = \left(\frac{4.8}{1.2}\right)^{1/1.3}$$

$$C = \frac{V_c}{V_s} = 0.1175$$

$$r = \frac{1}{C} + 1 = 9.5$$

$$\eta_{airstd} = 1 - \frac{1}{r^{\gamma-1}} = 0.5936$$

$$\eta_{rel} = \frac{\eta_{bth}}{\eta_{airstd}}$$

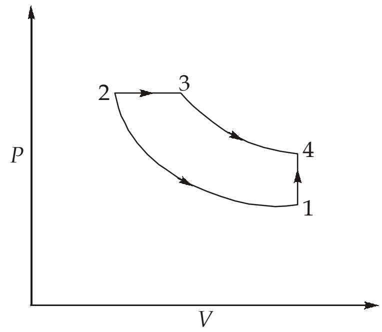
$\Rightarrow$ $\eta_{bth} = 0.3562$

Now $\eta_{bth} = \dfrac{bp}{\dot{m}_f \times CV} \Rightarrow \dfrac{\dot{m}_f}{bp} = \dfrac{1}{\eta_{bth}\times CV}$

So, specific fuel consumption $= \dfrac{\dot{m}_f}{bp}\times 3600 = \dfrac{3600}{\eta_{bth}\times CV}$

$sfc = 0.241$ kg/kWh

26. (d)



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

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

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

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

$= 0.6305 = 63.05\%$

27. (b)

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

Now, effective indicated mean effective pressure,

$P_{\text{eff, imep}} = P_{\text{imep}} - P_{\text{pumping mep}}$

$= 6.4 - 0.6 = 5.8$ bar

From equation (i),

$$IP = 5.8\times10^5 \times \frac{\pi}{4} \times \frac{0.25^2 \times (1.9\times0.25)\times 3300}{1000\times40\times60}$$

$= 18.594$ kW

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

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

$= 14.941$ kW

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

28. (c)

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

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

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

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

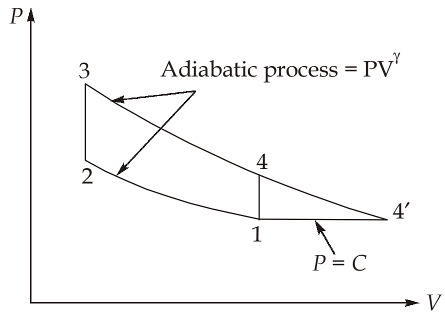
29. (d)

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

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

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

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



Compression ratio, $r = 6$

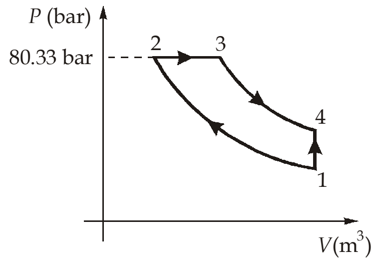
Efficiency of Atkinson cycle is given by

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

$$= 0.5466 = 54.66\%$$

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

30. (c)



$$P_1 = 1 \text{ bar}$$
$$T_1 = 300 \text{ K}$$
$$P_2 = P_3 = 80.33 \text{ bar}$$
$$\frac{T_2}{T_1} = (r)^{\gamma - 1} \text{ or } \frac{P_2}{P_1} = r^{\gamma} \qquad \left(\text{where, } r = \frac{V_1}{V_2}\right)$$

So, $r = \left(\frac{80.33}{1}\right)^{1/1.4} = 22.94$

$$T_2 = T_1 \times (22.94)^{1.4 - 1} = 1050.44 \text{ K}$$

Heat energy added, $Q = C_p(T_3 - T_2)$

$$2000 = 1.005(T_3 - 1050.44)$$
$$T_3 = 3040.489 \text{ K}$$

Cut-off volume ratio, $\rho = \frac{V_3}{V_2} = \frac{T_3}{T_2} = \frac{3040.489}{1050.44} = 2.894$

So, efficiency of diesel cycle

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

$$= 1 - \frac{1}{(22.94)^{0.4}} \frac{\left((2.894)^{1.4} - 1\right)}{1.4(2.894 - 1)} = 0.63089 = 63.08\%$$

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