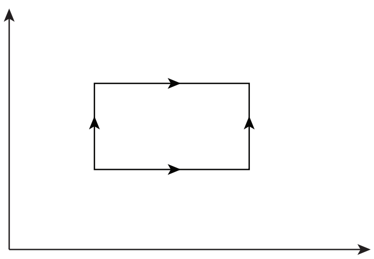
Number of Questions 25 **Time:60 min.**

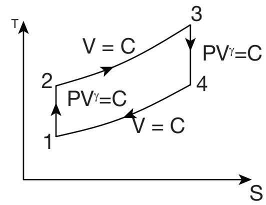
Directions for questions 1 to 25: Select the correct alternative from the given choices.

1. The temperature of an ideal Otto cycle at the beginning and end of compression are 55°C and 378°C respectively. The compression ratio of the cycle will be
   (A) 6.23 (B) 6.66
   (C) 5.55 (D) 5.22
2. An air standard Otto cycle has the following shape on a thermodynamic property plane. The *x* and y coordinates respectively are

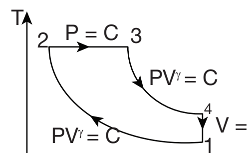


   (A) *T* and *S* (B) *S* and *V*
   (C) *S* and *P* (D) *V* and *P*
3. In a gas turbine cycle, the turbine output is 800 kJ/kg, heat supplied is 1200 kJ/kg and heat rejected is 600 kJ/kg. The thermal efficiency of the cycle is
   (A) 33.34% (B) 60%
   (C) 43.34% (D) 50%
4. A Carnot engine absorbs 400 J of heat from a reservoir at the temperature of boiling point of water and rejects heat to a reservoir at triple point of water. The efficiency of the engine is
   (A) 99% (B) 26.8%
   (C) 37.4% (D) 55.55%
5. The efficiency of a simple gas turbine can be improved by using a regenerator because
   (A) work of compression is reduced
   (B) heat required to be supplied is reduced
   (C) work output of the turbine is increased
   (D) heat rejected is increased
6. Brayton cycle with infinite number of feed water heater (regeneration) stages would approximates a
   (A) Otto cycle (B) Ericsson cycle
   (C) Carnot cycle (D) Stirling cycle
7. For a gas turbine power plant, identify the correct pair of statements.
   P. High air-fuel ratio is required as compared to steam power plant.
   Q. Good compatibility with solid fuel.
   R. Work ratio is very less as compared to steam power plant.
   S. Works on the principle of Brayton cycle.
   (A) *P* and *S* (B) *P*, *R* and *S*
   (C) *R* and *S* (D) *P* and *R*
8. The *T–S* plot of a direct injection diesel engine is

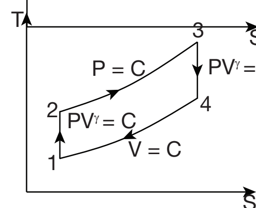
(A)



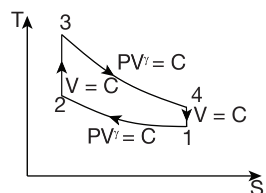
(B)



(C)

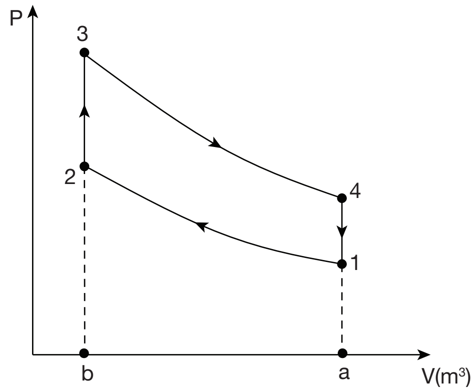


(D)



9. A 4-stroke diesel engine, when running at 1500 rpm has an injection duration of 1.5 ms. What is the corresponding duration of the crank angle in degrees?
   (A) 13.5° (B) 18°
   (C) 19.5° (D) 15.5°
10. By higher, Octane number of SI fuel, it is meant that the fuel has
   (A) higher calorific value (B) longer ignition delay
   (C) lower flash point (D) higher volatility
11. Cylinder diameter and stroke of an engine working on an Otto cycle are 220 mm and 240 mm respectively. If the clearance volume is 1500 cm^3 then the air standard efficiency of the cycle will be
   (A) 54.3% (B) 47.3%
   (C) 58.2% (D) 50.23%
12. A SI engine works with a compression ratio of 6. The fuel has a calorific value of 42000 kJ/kg. If the relative efficiency of the engine is 50% of the air standard efficiency then the indicated fuel consumption (in kg/kW-hr) will be
   (A) 0.465 (B) 0.335
   (C) 0.381 (D) 0.312

13. A P-V diagram of SI engine is shown below.



The area of 3-4-a-b is (3705 V_b) kJ and area of 1–2–b–a is (1345 V_b) kJ where V_b is clearance volume in m^3. If the swept volume is 4.5 times the clearance volume then the mean effective pressure (in bar) of the cycle is

(A) 5.98 (B) 5.244
(C) 6.21 (D) 5.56

14. Match List-I (Cycle) with List-II (Consisting process) and choose the correct code given below.

List-I		List-II	
P.	Lenoir cycle	**1.**	Two isothermal and two constant pressure.
Q.	Atkinson cycle	**2.**	Two isothermal and two isochoric
R.	Stirling cycle	**3.**	One isochoric, one isobaric, one isentropic.
S.	Ericsson cycle	**4.**	Two isentropic, two isochoric and one isobaric.

	P	*Q*	*R*	*S*
(A)	3	4	1	2
(B)	3	4	2	1
(C)	4	3	2	1
(D)	4	3	1	2

15. Cylinder bore and stroke of a diesel engine are 300 mm and 375 mm respectively. If the clearance volume is 2000 cm^3 with fuel cut-off occurring at 5% of the stroke then the ideal efficiency of the diesel engine will be

(A) 56.66% (B) 63.36%
(C) 59.62% (D) 61.35%

16. An engine working on diesel cycle has the inlet pressure and temperature as 1 bar and 17°C. The pressure at the end of the compression is 35 bar and the expansion ratio is 5. The heat added to the cycle (in kJ/kg) will be

(A) 1039.67 (B) 1377.75
(C) 1234.67 (D) 1100.67

17. A four stroke petrol engine produces 36.8 kW of brake power with mechanical efficiency of 80%. If brake specific fuel consumption is 0.4068 kg/kW-hr and calorific value of the fuel is 42 MJ/kg then the brake thermal efficiency of the engine will be

(A) 31% (B) 19%
(C) 26% (D) 21%

18. For a SI engine, the given fuel-air ratio is 0.067. For a brake power of 73.6 kW at a brake thermal efficiency of 20%, if the density of air is 1.15 kg/m^3, how much volume of air is required every hour? (calorific value of fuel is 42 MJ/kg)

(A) 409.37 (B) 470.78
(C) 416.23 (D) 387.36

19. A turbo charged four-stroke diesel engine has a displacement volume of 0.03 m^3. The engine has an output of 970 kW at 2200 rpm. The mean effective pressure (in MPa) is closest to

(A) 1.531 (B) 2.163
(C) 1.224 (D) 1.763

20. A gas turbine plant operates on the Brayton cycle with temperature limit of 300 K and 1173 K. The maximum work done (in kJ/kg) and corresponding cycle efficiency will be

(A) 288 and 40.6% (B) 288 and 49.4%
(C) 312 and 49.4% (D) 312 and 40.6%

21. In an ideal Brayton cycle, air enters at 1 bar and 300 K and is compressed to 6 bar. If the maximum cycle temperature is 1200 K, then the work ratio and cycle efficiency respectively are

(A) 0.583 and 40.1% (B) 0.861 and 40.1%
(C) 0.583 and 51.16% (D) 0.861 and 51.16%

22. An open cycle gas turbine uses a fuel of calorific value 41000 kJ/kg with air fuel ratio of 100:1 and develops a net output of 100 kJ/kg of air. The thermal efficiency of the cycle is

(A) 19.62% (B) 24.39%
(C) 27.37% (D) 16.45%

23. In an ideal Brayton cycle, atmospheric air at 1 bar and 310 K is compressed to 10 bar. The maximum temperature in the cycle is limited to 1200 K. If the heat is supplied at the rate of 90 MW, the mass flow rate (in kg/s) of air required in the cycle is

(A) 149 (B) 109
(C) 126 (D) 94

24. A gas engine has swept volume of 320 cm^3 and clearance volume of 30 cm^3. Its mechanical efficiency is 0.90. If the volumetric efficiency is 0.88, the volume of the mixture (in cm^3) taken in per stroke is

(A) 302.4 (B) 219.7
(C) 264 (D) 281.6

25. The order of values of thermal efficiency of Otto, Diesel and Dual cycle, when they have same maximum pressure and temperature and same heat rejection, is given by

(A) $\eta_{otto} > \eta_{diesel} > \eta_{dual}$ (B) $\eta_{diesel} > \eta_{dual} > \eta_{otto}$
(C) $\eta_{dual} > \eta_{diesel} > \eta_{otto}$ (D) $\eta_{otto} > \eta_{dual} > \eta_{diesel}$

Answer Keys

1. C	**2.** B	**3.** D	**4.** B	**5.** B	**6.** A	**7.** B	**8.** C	**9.** A	**10.** B
11. A	**12.** B	**13.** B	**14.** B	**15.** D	**16.** C	**17.** D	**18.** A	**19.** D	**20.** B
21. A	**22.** B	**23.** A	**24.** D	**25.** B					

Hints and Explanations

1. $r = \frac{V_1}{V_2} = \left(\frac{T_1}{T_2}\right)^{\frac{1}{\gamma-1}} = \left(\frac{378+273}{55+273}\right)^{\frac{1}{0.4}}$

$\Rightarrow \quad r = 5.55$ Choice (C)

2. Two isentropic and two constant volume process. Choice (B)

3. $\eta = \frac{W_{net}}{Q_{add}} = 1 - \frac{Q_{rej}}{Q_{add}} \Rightarrow \eta = 1 - \frac{600}{1200} = 50\%$ Choice (D)

4. $\eta = 1 - \frac{T_2}{T_1} = 1 - \frac{273.15}{(100+273.15)}$

$\Rightarrow \quad \eta = 0.26796$ or 26.8% Choice (B)

5. Choice (B)

6. Choice (A)

7. Choice (B)

8. $1-2 \rightarrow$ Isentropic compression process
$2-3 \rightarrow$ Constant pressure heat addition
$3-4 \rightarrow$ Isentropic expansion process
$4-1 \rightarrow$ Constant volume heat rejection Choice (C)

9. The time for injection $= \frac{\theta}{360} \times \frac{60}{N}$

$0.0015 = \frac{\theta}{360} \times \frac{60}{1500} \Rightarrow \theta = 13.5^o$ Choice (A)

10. Choice (B)

11. Swept volume, $V_S = \frac{\pi}{4} D^2 L = \frac{\pi}{4} \times 22^2 \times 24$

$\Rightarrow \quad V_S = 9123.185\ cm^3$
Compression ratio, $r = 1 + \frac{V_S}{V_C} = 1 + \frac{9123.185}{1500} = 7.082$

$\eta_{std} = 1 - \frac{1}{(r)^{\gamma-1}} = 1 - \frac{1}{(7.082)^{0.4}}$

$\Rightarrow \quad \eta_{std} = 0.543$ or 54.3% Choice (A)

12. $\eta_{std} = 1 - \frac{1}{(r)^{\gamma-1}}$

$\Rightarrow \quad \eta_{std} = 1 - \frac{1}{(6)^{0.4}} = 0.5116$

Relative efficiency $= \frac{\text{Indicated thermal efficiency}}{\text{Air-standard efficiency}}$

$\eta_{ith} = 0.5 \times 0.5116 = 0.256$

now $\eta_{ith} = \frac{ip}{CV \times \dot{m}}$

$\Rightarrow \quad \frac{\dot{m}}{ip} = \frac{1}{CV \times n_{ith}} = \frac{1}{42000 \times 0.256}$

$\Rightarrow \quad \frac{\dot{m}}{ip} = \frac{1}{42000 \times 0.256} \times 3600\ \text{kg/kW-hr}$

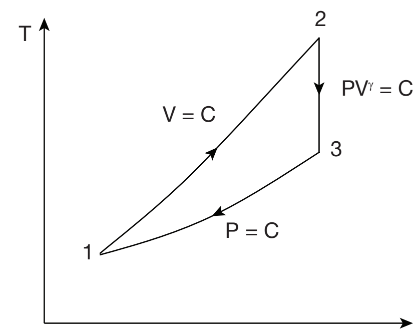
$\Rightarrow$ isfc = 0.335 kg/kW-hr Choice (B)

13. $p_m = \frac{\text{Net work}}{\text{Swept volume}}$

$\Rightarrow \quad p_m = \frac{3705V_b - 1345V_b}{4.5V_b} = 524.44\ kPa$

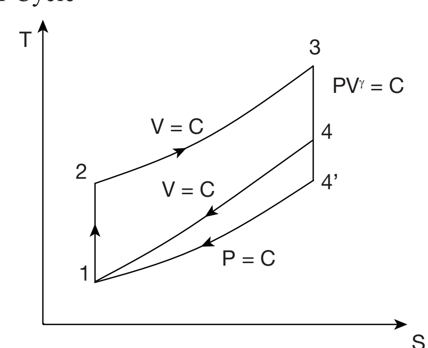
$\Rightarrow \quad p_m = 5.244 \times 10^5$ Pa
or $p_m = 5.244$ bar Choice (B)

14.



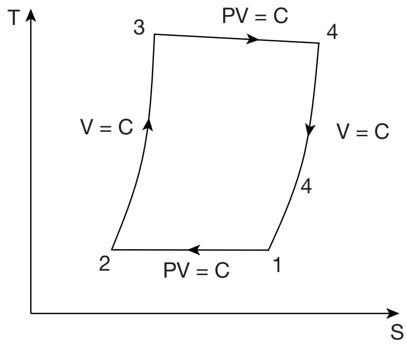
(P) Lenior Cycle

(*P*) Lenior Cycle



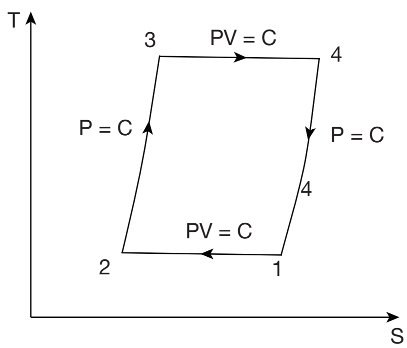
(Q) Atkinson Cycle

(*Q*) Atkinson Cycle



(R) Stirling Cycle

(R) Stirling Cycle



(S) Ericison Cycle

(S) Ericison Cycle

Choice (B)

15. $V_S = \frac{\pi}{4} D^2 L = \frac{\pi}{4} \times 30^2 \times 37.5$

$\Rightarrow$ $V_S = 26507.188 \text{ cm}^3$

$$r = 1 + \frac{V_S}{V_C} = 1 + \frac{26507.188}{2000} = 14.25$$

$r_C = V_3/V_2$

Cut-off volume, $V_C = V_3 - V_2$

$\Rightarrow$ $V_3 - V_2 = 0.05\ (V_S)$

$= 0.05 \times 13.25 \times V_C$

$V_2 = V_C$

$V_3 = 1.6625\ V_C$

$$r_C = \frac{V_3}{V_2} = 1.6625$$

$$\eta = 1 - \frac{1}{14.25^{0.4}} \times \left[\frac{1.6625^{1.4} - 1}{1.4(1.6625 - 1)}\right]$$

$\Rightarrow$ $\eta = 0.6135$ or 61.35% Choice (D)

16. Given:

$P_1 = 1$ bar $P_2 = 35$ bar

$T_1 = 17°\text{C} = 290$ K, $R_e = 5$

$Q_{\text{add}} = mC_P(T_3 - T_2)$

$$\textbf{1 – 2: } \frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}$$

$\Rightarrow$ $T_2 = 290 \times (35)^{\frac{0.4}{1.4}}$

$\Rightarrow$ $T_2 = 800.867$ K

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

$$\therefore \quad r = \frac{V_1}{V_2} = (35)^{\frac{1}{1.4}} = 12.67$$

$$r_c \times r_e = r \Rightarrow r_c = \frac{r}{r_e} = \frac{12.67}{5} = 2.534$$

$T_3 = R_c \times T_2 = 2.534 \times 800.867$

$\Rightarrow$ $T_3 = 2029.397$ K

$Q_{\text{add}} = 1.005 \times [2029.397 - 800.867]$

$\Rightarrow$ $Q_{\text{add}} = 1234.67$ kJ/kg Choice (C)

17. Given:

$bp = 36.8$ kW, $\eta_m = 0.8$

$bsfc = 0.4068$ kg/kW-hr, $CV = 42$ MJ/kg

$$bsfc = \frac{m_f}{b.p} \Rightarrow m_f = bsfc \times b.p = 0.4068 \times 36.8$$

$\Rightarrow$ $m_f = 0.0041584$ kg/sec

$$\eta_{\text{bth}} = \frac{b.p}{m_f \times CV} = \frac{36.8}{0.0041584 \times 42000}$$

$\Rightarrow$ $\eta = 0.2107$ or 21.07% Choice (D)

18. $\eta_{\text{bth}} = 0.2 = \frac{b.p}{m_f \times CV} \Rightarrow m_f = \frac{73.6}{0.2 \times 42000}$

$\Rightarrow$ $m_f = 0.008762$ kg/sec

Now, $\frac{m_f}{m_a} = 0.067 \Rightarrow m_a = \frac{0.008762}{0.067}$

$\Rightarrow$ $m_a = 0.130776$ kg/sec

$\Rightarrow$ $m_a = 470.794$ kg/hr

Volume of air, $V_a = \frac{m_a}{\rho_a} = \frac{470.794}{1.15}$

$\Rightarrow$ $V_a = 409.37 \text{ m}^3/\text{hr}$ Choice (A)

19. $V_S = V_1 - V_2 = 0.03 \text{ m}^3$, $W_{\text{net}} = 970$ kW, $N = 2200$ rpm

For four-stroke engine

$$ip = \frac{p_m \times LANK}{60 \times 2} \Rightarrow 970 = \frac{p_m \times 0.03 \times 2200 \times 1}{60 \times 2}$$

$\Rightarrow$ $p_m = 1.763$ MPa Choice (D)

20. $(W_{\text{net}})_{\max} = C_P \left(\sqrt{T_{\max}} - \sqrt{T_{\min}}\right)^2$

$= 1.005\left[\sqrt{1173} - \sqrt{300}\right]^2$

$(W_{\text{net}})_{\max} = 288$ kJ/kg

$$\eta_{\text{cycle}} = 1 - \sqrt{\frac{T_{\min}}{T_{\max}}} = 1 - \sqrt{\frac{300}{1173}}$$

$\Rightarrow$ $\eta_{\text{cycle}} = 0.49427$ Choice (B)

21. $\eta_{cycle} = 1 - \dfrac{1}{(r_p)^{\frac{\gamma-1}{\gamma}}} = 1 - \dfrac{1}{(6)^{\frac{0.4}{1.4}}}$

$\Rightarrow$ $\eta_{cycle} = 0.401$ or 40.1%

Now

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} \Rightarrow T_2 = 300 \times \left(\frac{6}{1}\right)^{\frac{0.4}{1.4}} = 500.55\,\text{K}$$

$$\frac{T_3}{T_4} = \left(\frac{P_3}{P_4}\right)^{\frac{\gamma-1}{\gamma}} = (r_P)^{\frac{\gamma-1}{\gamma}} \Rightarrow T_4 = \frac{1200}{(6)^{\frac{0.4}{1.4}}}$$

$\Rightarrow$ $T_4 = 719.2$ K

$W_T = C_P(T_3 - T_4)$

$\Rightarrow$ $W_T = 1.005\ (1200 - 719.2)$

$\Rightarrow$ $W_T = 483.204$ kJ/kg

$W_C = C_P(T_2 - T_1) = 1.005\ (500.55 - 300)$

$\Rightarrow$ $W_C = 201.55$ kJ/kg

$$\text{Work ratio} = \frac{W_T - W_C}{W_T} = \frac{483.204 - 201.555}{483.204}$$

$\Rightarrow$ $W.R = 0.583$ Choice (A)

22. $\eta = \dfrac{W_{net}}{Q_{add}} = \dfrac{100 \times \dot{m}_a}{\dot{m}_f \times 41000}$

$\Rightarrow$ $\eta = \dfrac{100 \times 100}{41000} = 0.2439$

or $\eta = 24.39\%$ Choice (B)

23. $T_1 = 310\ K$, $P_1 = 1$ bar

$P_2 = 10$ bar, $T_3 = 1200$ K

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

$\Rightarrow$ $T_2 = 310 \times (10)^{\frac{0.4}{1.4}}$

$\Rightarrow$ $T_2 = 598.516$ K

Now $\dot{m} \times C_P \times (T_3 - T_2) = 90$ MW

$\Rightarrow$ $\dot{m} \times 1.005 \times (1200 - 598.576) = 90 \times 10^3$

$\Rightarrow$ $\dot{m} = 148.88$ kg/s ~ 149 kg/s Choice (A)

24. $\eta_{volumetric} = \dfrac{\text{Actual volume of air sucked}}{\text{Theoretical volume of air suked}}$

$\therefore$ $\dfrac{V_{actual}}{320} = 0.88$

$V_{actual} = 281.6\ \text{cm}^3$ Choice (D)

25. W_{net} decreases from diesel cycle to Otto cycle because net area is decreasing. Hence efficiency also decreases. Choice (B)