Thermodynamics and its Applications Test 4

Number of Questions 35 **Time:60 min.**

Directions for questions 1 to 35: Select the correct alternative from the given choices.

1. A system consists O_2 in gaseous state. The minimum number of independent intensive variables required to fix the given state will be

(A) 0 (B) 1
(C) 2 (D) 3

2. Substance having constant chemical composition throughout the volume is known as

(A) Ideal gas (B) Homegenous substance
(C) Real gas (D) Pure substance

3. A new scale °N is divided in such a way that the freezing point of ice is 100°N and the boiling point is 400°N. The temperature of 150°C will be

(A) 650°N (B) 550°N
(C) 450°N (D) 350°N

4. If a process is following $PVk = C$, then match list I (Process) and list – II (k) and choose the correct code given below the list.

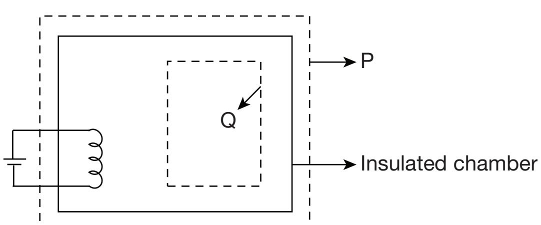
	List-I (Process)		List-II (k)
P	Constant volume	1	1
Q	Constant pressure	2	∞
R	Isothermal	3	0
S	Adiabatic	4	γ

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

5. The flow energy of 0.2 m^3/min of a fluid crossing a boundary to a system is 20 kW. The pressure at this point in kPa is

(A) 300 (B) 100
(C) 3000 (D) 6000

6. An electric heater is put inside an insulated chamber containing a gas. Considering the system boundaries P and Q as shown in figure, then



(A) Heat transfer across P and Q
(B) Heat transfer across P, work transfer across Q
(C) Work transfer across P, heat transfer across Q
(D) Work transfer across P and Q

7. A gas (ideal) flows reversibly through a control volume is having a capacity to do 100 kJ of work. The flow is considered to be isothermal. If the same gas (ideal) is kept in a chamber and consider as closed system and a reversible process is going on isothermally with same initial and final condition, then work done will be

(A) 100 kJ (B) zero
(C) 200 kJ (D) 50 kJ

8. Consider a steady flow of air through a insulated porous plug. Air enters the plug at 100 kPa and 150 m/s and leaves the plug at 50 kPa. Assuming air to be ideal gas and neglect potential energy changes and no work transfer occurring, the velocity at exit in m/s is

(A) 50 (B) 200
(C) zero (D) 150

9. In a given process of an ideal gas, $\delta W = 0$ and $\delta Q < 0$, then for the gas

(A) the temperature will increase
(B) the temperature will decrease
(C) the volume will increase
(D) the pressure will remain constant

10. A gas turbine cycle operates on the Brayton cycle between 320 K and 1123 K. The maximum work done per kg of air (in kJ/kg) is

(A) 245.3 (B) 175.24
(C) 341.7 (D) 216.3

11. A heat engine operates between two reservoir at temperature of 1000 K and 500 K. If it is possible to change the temperature of either reservoir by 50 K, then the maximum increase in efficiency is

(A) 0.025 (B) 0.05
(C) 0.10 (D) 0.075

12. The temperature of an ideal gas increases from 20°C to 40°C while the pressure stays the same. What happens to the volume of the gas?

(A) It doubles (B) It quadruples
(C) It is cut to one-half (D) It slightly increases

13. At critical point, the enthalpy of vaporization is

(A) dependent on temperature only
(B) maximum
(C) minimum
(D) zero

14. The statement that the entropy of a pure substance in complete thermodynamic equilibrium becomes zero at the absolute zero of temperature is known as

(A) Zeroth law of thermodynamics
(B) First law of thermodynamics
(C) Second law of thermodynamics
(D) Third law of thermodynamics

15. An ideal gas at 30°C is heated at constant pressure till its volume becomes three times. What would be then the temperature of gas?
(A) 636°C (B) 909°C
(C) 90°C (D) 363°C

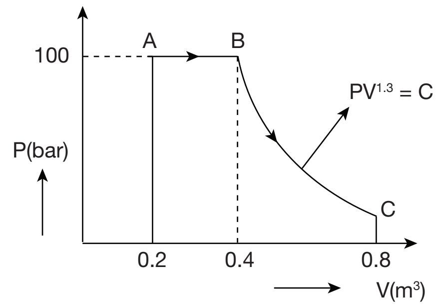
16. Air is going on two process separately. One process is isothermal and other is adiabatic process. When drawing both the process in *P-V* plot, what is the ratio of slope (adiabatic curve) to slope (isothermal curve)? (For air-C_p = 1.005 kJ/kg K; C_v = 0.718 kJ/kg K)
(A) –1.4 (B) 1.4
(C) –1 (D) 1

17. An electric motor drives a stirrer fitted with a horizontal cylinder. The cylinder of 40 cm diameter contains helium restrained by a frictionless piston. During the stirring of fluid for 20 min the piston moves outward slowly by a distance of 40 cm against the atmospheric pressure of 1 bar. The current supplied to the motor is 0.5 ampere from a 24-V battery. If internal energy change for the piston movement process is 5 kJ, then heat transferred due to movement of piston in kJ is
(A) 12.4 (B) 19.4
(C) 10 (D) 14.4

18. An average car consumes about 6 litres of diesel a day, and the capacity of the full tank of a car is about 60 litres. Assuming density of diesel = 0.8 kg/Litre and calorific value of diesel = 42000 kJ/kg, the energy supplied to the car per day (kJ/day) is
(A) 33600 (B) 201600
(C) 42000 (D) 2016000

19. A 20 m^3 tank contains nitrogen at 25°C and 800 kPa. Some nitrogen is allowed to escape until the pressure in the tank drops to 600 kPa. If the temperature at this point is 20°C, the amount of nitrogen that has escaped is
(A) 180.82 kg (B) 137.93 kg
(C) 42.9 kg (D) 44.4 kg

20. A gas system following an expansion process as shown in figure. The total work done by gas system in MJ is



(A) 4.5 (B) 5.7
(C) 6.5 (D) 5.0

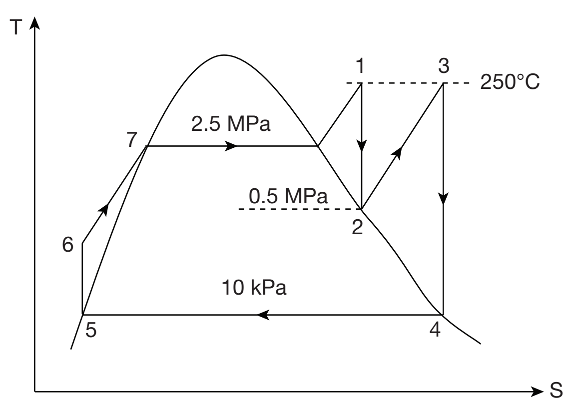
21. 5 kg of water at 50°C are mixed with 7 kg of water at 110°C in a steady flow process. The change in entropy in kJ/kg-K is
(A) 0.472 (B) 0.116
(C) 0.175 (D) 0.514

22. The entropy of saturated water at a pressure of 2.8 bar is given in the table. The saturation temperature corresponding to this pressure is 132°C. The entropy of dry saturated steam at the same pressure in kJ/kg-K is

P(bar)	u_f(kJ/kg)	u_g(kJ/kg)	h_f(kJ/kg)	h_g(kJ/kg)	S_f(kJ/kg-K)
2.8	431.6	2569.1	551.44	2721.5	1.67

(A) 5.358 (B) 7.028
(C) 9.416 (D) 12.036

23. T-S diagram of power station with reheat has been shown



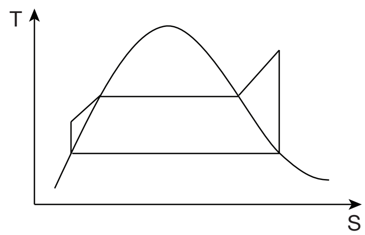
Enthalpies at state 1, 2, 3, 4, 5 and 6 are 2880.1 kJ/kg, 2602.3 kJ/kg, 2960.7 kJ/kg, 2369.6 kJ/kg, 191.83 kJ/kg, 194.68 kJ/kg respectively.
Specific steam consumption (in kg/kW-hr) is
(A) 12.96 (B) 9.651
(C) 4.1568 (D) 6.1291

24. A series combination of two Carnot's engines operate between the temperatures of 180°C and 20°C if the engine produces equal amount of work, then the intermediate temperature is
(A) 80°C (B) 90°C
(C) 100°C (D) 110°C

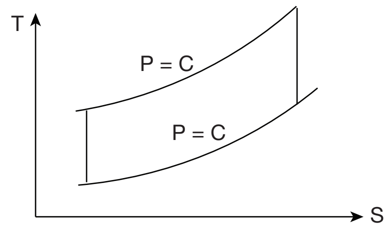
25. For a steady flow process from state 1 to 2, enthalpy changes from h_1 = 550 kJ/kg to h_2 = 150 kJ/kg and entropy changes from S_1 = 1.3 kJ/kg-K to S_2 = 0.8 kJ/kg-K. Surrounding environmental temperature is 300 K. Neglect change in kinetic and potential energy. The change in availability of the system is (in kJ/kg)

(A) 200 (B) 100
(C) 180 (D) 90

26. (1)



(2)



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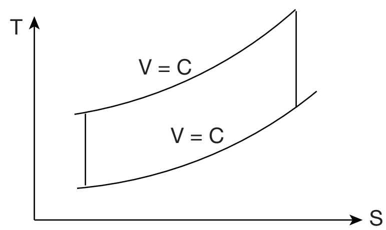

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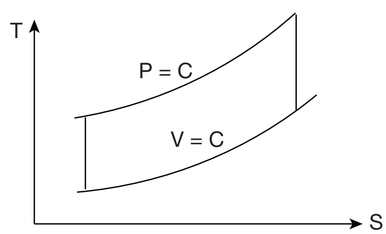


The correct sequence of the given four cycles on *T-S* plane in Figure (1), (2), (3), (4) is
(A) Ranking, Otto, Diesel, Brayton
(B) Ranking, Otto, Brayton, Diesel
(C) Otto, Ranking, Brayton, Diesel
(D) Ranking, Brayton, Otto, Diesel

27. A tank containing air is stirred by a paddle wheel. The work input to the paddle wheel is 4000 kJ and the heat transferred to the surrounding from the tank is 2000 kJ. The external work done by the system is
(A) 4000 kJ (B) 2000 kJ
(C) Zero (D) 6000 kJ

28. The ratio of the clearance volume to the displacement volume of a reciprocating compressor is 0.08. Specific volume at inlet and outlet of compressor are 0.05 and 0.025 m/kg respectively. Volumetric efficiency of the compressor is
(A) 76% (B) 92%
(C) 37% (D) 47.5%

29. An open cycle constant pressure gas turbine uses a fuel of calorific value 42000 kJ/kg, with air full ratio of 70:1 and develops a net output of 120 kJ/kg of air. The thermal efficiency of the cycle is
(A) 2%
(B) 24%
(C) 20%
(D) None of these

30. The mechanical efficiency of a single-cylinder four-stroke engine is 80%. The frictional power is estimated to be 20 kW. Brake power (in kW) developed by engine is
(A) 20 (B) 100
(C) 120 (D) 80

31. The loss of available energy associated with the transfer of 1500 kJ of heat from a constant temperature system at 800 K to another at 600 K when the environment temperature is 300 K is
(A) 222.5 kJ (B) 187.5 kJ
(C) 250 kJ (D) 175.5 kJ

Common Data Question 32 and 33:
A six cylinder, four stroke spark ignition engine of 10 cm × 12 cm (bore stroke) with a compression ratio of 6 is tested at 4800 rpm on a dynamometer of arm 55 cm. During a 10 minute test, the dynamometer reads 45 kg and engine consumed 5 kg of petrol of *CV* 45 MJ/kg. The carburetor received air at 29°C and 1 bar at the rate of 10 kg/min.

32. The brake mean effective pressure (in bar) is
(A) 16.2 (B) 32.4
(C) 4.04 (D) 5.39

33. The brake specific fuel consumption (in kg/kWh)
(A) 0.246 (B) 0.314
(C) 0.267 (D) 0.331

Linked Data Questions 34 and 35:
A diesel engine having a cylinder with bore 280 mm, stroke 400 mm and a clearance volume of 2000 cc, with fuel cut-off occurring at 5% of the stroke. Assume $\gamma = 1.4$ for air.

34. The value of compression ratio is
(A) 15.315 (B) 14.415
(C) 12.315 (D) 13.315

35. Ideal efficiency of the cycle is
(A) 52.67% (B) 60.56%
(C) 64.12% (D) 58.62%

Answer Keys

1. C	**2.** D	**3.** B	**4.** A	**5.** D	**6.** C	**7.** A	**8.** D	**9.** B	**10.** A
11. B	**12.** D	**13.** D	**14.** D	**15.** A	**16.** B	**17.** C	**18.** B	**19.** C	**20.** A
21. C	**22.** B	**23.** C	**24.** C	**25.** A	**26.** D	**27.** C	**28.** B	**29.** C	**30.** D
31. B	**32.** D	**33.** A	**34.** D	**35.** B					

Hints and Explanations

1. According to Gibb's phase rule

$P + F = C + 2$

P = Number of phases

F = Degree of freedom or minimum number of variable required.

C = Number of component

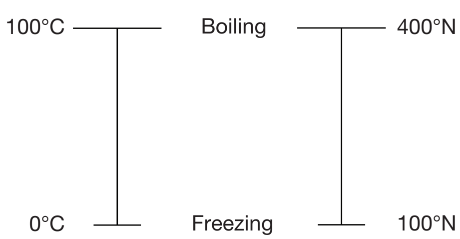
O_2 has $P = 1$ and $C = 1$

$\therefore \quad 1 + F = 1 + 2$

$\Rightarrow \quad F = 2$ Choice (C)

2. Choice (D)

3.



$°N = a°C + b$

$100 = a(0) + b$

$\therefore \quad b = 100$

$400 = a(100) + 100$

$\therefore \quad a = 3$

Now, $°N = 3(150) + 100$

$°N = 550$ Choice (B)

4. PV^k = constant

(1) constant volume process

$(PV^k)^{1/k} = C^{1/k}$

$P^{1/k}\, V$ = constant

$\therefore$ when $k = \infty$, $P^0\, V$ = constant

$\therefore$ V = constant

(2) constant pressure process

$k = 0$, $PV^0 = C$

$\Rightarrow$ P = constant

(3) Isothermal process

$k = 1$, PV^1 = constant

(4) Adiabatic process

$k = \gamma$, $PV^\gamma = C$ Choice (A)

5. Flow energy $= 20\dfrac{kJ}{s}$

Flow rate $= 0.2\dfrac{m^3}{\text{min}}$

$\therefore$ Pressure $= \dfrac{\text{flow energy} \times 60}{\text{flow rate}}$

$= \dfrac{20 \times 60}{0.2}$

= 6000 kPa Choice (D)

6. Choice (C)

7. For an isothermal process of an ideal gas, open system work is equal to closed system work because a rectangular hyperbola when projected on p-axis and v-axis give same area. Choice (A)

8. $\dot{m}\left[h_1 + \dfrac{C_1^2}{2} + gz_1\right] + Q = \dot{m}\left[h_2 + \dfrac{C_2^2}{2} + gz_2\right] + W$

$Q = 0$ (insulated)

$W = 0$

$h_1 = h_2$ (porous plug)

$z_1 = z_2$

$\therefore \quad C_1 = C_2 = 150$ m/s Choice (D)

9. $\delta Q = \delta W + dU$

$\delta Q = -ve$, $\delta W = 0$ and $U = f(T)$

$\therefore \quad T_2 - T_1 = -ve$

$T_2 = T_1 + (-ve)$

$\therefore \quad T_2$ decreases Choice (B)

10. $W_{\max} = C_P\left[\sqrt{T_{\max}} - \sqrt{T_{\min}}\right]^2$

$= 1.005\left[\sqrt{1123} - \sqrt{320}\right]^2$

= 2454.3 kJ/kg Choice (A)

11. $\eta = 1 - \dfrac{T_2}{T_1} = 1 - \dfrac{500}{100} = 0.5$

After changing the sink temperature we get,

$\eta = 1 - \dfrac{(500 - 50)}{1000} = 0.55$

$\therefore$ Increase in efficiency = 0.55 – 0.5

= 0.05 Choice (B)

12. $PV = mRT$

$V\ \mu\ T$ or $V = \dfrac{mRT}{P}$

$\therefore$ if $T = (20 + 273) = 293$ K then

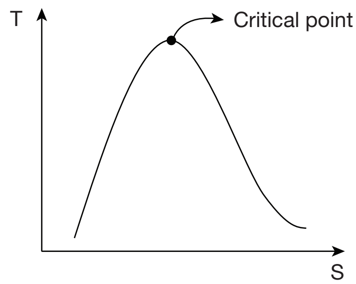
$V_1 = 293\dfrac{mR}{P}$

and if $T = (40 + 273) = 313$ K then

$V_2 = 313\dfrac{mR}{P} \qquad \left\{\dfrac{mR}{P} = cons\tan t\right\}$

Therefore volume slightly increases. Choice (D)

13.



Choice (D)

14. Choice (D)

15. $\dfrac{V_1}{T_1} = \dfrac{V_2}{T_2}$

$\Rightarrow \dfrac{V_1}{(30+273)} = \dfrac{3V_1}{T_2}$

$\Rightarrow \quad T_2 = 909$ K = 636°C Choice (A)

16. **<u>Isothermal process</u>**

$PV = C$

Slope on $P–V$ plot is dP/dV

$\therefore \quad PdV + VdP = 0$

$\therefore \quad dP/dV = -P/V$ ------- (1)

<u>Adiabatic process</u>

$PV^{\gamma} = C$

$P(\gamma V^{\gamma-1})dV + V^{\gamma} dP = 0$

� $\dfrac{dP}{dV} = -\dfrac{\gamma P}{V}$ ----------- (2)

From equation (1) and (2)

$\dfrac{(dP/dV)\,adiabatic}{(dP/dV)\,isothermal} = \gamma$

$\gamma = 1.4$ Choice (B)

17. Work done by the fluid on atmosphere

$\delta W = PdV$

$\Rightarrow \quad \delta W = 10^5 \times \dfrac{\pi}{4} \times 0.4^2 \times 0.4$

$\therefore \quad \delta W = 5$ kJ

$dU = 5$ kJ (given)

and $\delta Q = \delta W + dU$ (1st law)

$\therefore \quad \delta Q = 5 + 5 = 10$ kJ Choice (C)

18. Mass of diesel used per day by the car is

$m_{\text{diesel}} = (\rho V)_{\text{diesel}} = (0.8 \text{ kg/L})(6 \text{ L/day})$

$\therefore \quad m_{\text{deisel}} = 4.8$ kg/day

Energy supplied to the car/day, $E = (md_{\text{iesel}}) \times C.V$

$\therefore \quad E = (4.8 \text{ kg/day}) \times (42000 \text{ kJ/kg})$

$E = 201600$ kJ/day Choice (B)

19. $PV = mRT$

$R = \dfrac{\overline{R}}{M} = \dfrac{8.314}{28} = 0.29693$ kJ/kg – K

Now, $m_1 = \dfrac{800 \times 20}{0.29693 \times 298} = 180.822$ kg

Nitrogen is escaped until the pressure in the tank drops to 600 kPa.

$\therefore m_2 = \dfrac{600 \times 20}{0.29693 \times 293}$ {∵ Volume = Constant}

$m_2 = 137.93$ kg

Amount of nitrogen escaped = 180.822 – 137.93

= 42.9 kg Choice (C)

20. Work done for $A – B$ (P = constant)

$W_{A\text{-}B} = P(V_2 - V_1) = 10000(0.4 - 0.2)$

$W_{A\text{-}B} = 2000$ kJ

Work done for $B–C$ ($PV^{1.3} = C$)

$W_{B\text{-}C} = \dfrac{P_1V_1 - P_2V_2}{n - 1} = \dfrac{P_BV_B - P_CV_C}{n - 1}$

$P_B V_B^{1.3} = P_C V_C^{1.3} \Rightarrow P_C = 10000\left(\dfrac{0.4}{0.8}\right)^{1.3}$

$\therefore \quad P_C = 4061.262$ kPa

$\therefore \quad W_{B\text{-}C} = 2503.3$ kJ

Total work done = 2000 + 2503.3

= 4.5033 MJ Choice (A)

21. Let T_f be the final temperature of mixture.

Energy balance:-

$m_1 \times C \times (T_f - 50) = m_2 \times C \times (110 - T_f)$

$\Rightarrow \quad 5 \times (T_f - 50) = 7 \times (110 - T_f)$

$\Rightarrow \quad T_f = 85°\text{C} = 358\ K$

$\Delta S = m_1 C_p \ln\dfrac{T_f}{T_1} + m_2 C_p \ln\dfrac{T_f}{T_2}$

$= 5 \times 4.187 \times \ln\left[\dfrac{358}{323}\right] + 7 \times 4.187 \times \ln\left[\dfrac{358}{383}\right]$

= 0.1754 kJ/K Choice (C)

22. $S_{fg} = \dfrac{h_{fg}}{T_{sat}}$

$\Rightarrow S_g - S_f = \dfrac{h_g - h_f}{T_{sat}}$

$\Rightarrow S_g - 1.67 = \dfrac{2721.5 - 551.44}{(132 + 273)}$

$\Rightarrow S_g = 7.028$ kJ/kg-K Choice (B)

23. $W_{net} = W_T - W_P$

Now, $W_T = (h_1 - h_2) + (h_3 - h_4)$

$\Rightarrow \quad W_T = (2880.1 - 2602.3) + (2960.7 - 2369.6)$

= 868.9 kJ/kg

and $W_P = (h_6 - h_5) = (194.68 - 191.83)$

= 2.85 kJ/kg

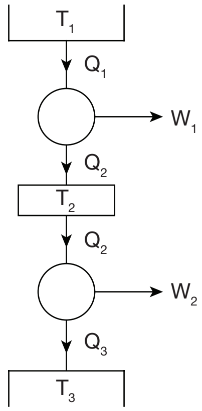
$\therefore \quad W_{net} = 868.9 - 2.85 = 866.05$ kJ/kg

$SSC = \dfrac{3600}{W_{net}} = \dfrac{3600}{866.05}$

= 4.1568 kg/kW-hr

Choice (C)

24.



T_1 = Source temperature
T_2 = Intermediate temperature
T_3 = Sink temperature
$\because$ $W_1 = W_2$ (given)
$\therefore$ $Q_1 - Q_2 = Q_2 - Q_3$

or $Q_2\left[\frac{Q_1}{Q_2}-1\right]=Q_2\left[1-\frac{Q_3}{Q_2}\right]$

For Carnot cycle:- $\frac{Q_1}{T_1}=\frac{Q_2}{T_2}=\frac{Q_3}{T_3}$

$\therefore \frac{T_1}{T_2}-1=1-\frac{T_3}{T_2}$

$\therefore T_2=\frac{T_1+T_3}{2}$

$=\frac{180+20}{2}=100^oC$ Choice (C)

25. Availability for a flow process = $(h_1 - h_2) - T_o(S_1 - S_2)$
= (500 – 150) – 300(1.3 – 0.8) = 200 kJ/kg Choice (A)

26. Choice (D)

27. This is a case of irreversible constant volume process or isochoric process. In an irreversible constant volume process, the system does not perform work. Choice (C)

28. $\eta_v = 1 + C - C\left(\frac{V_1}{V_2}\right)$ = 1 + 0.08 – 0.08$\left(\frac{0.05}{0.025}\right)$

= 0.92 = 92% Choice (B)

29. $\eta = \frac{W}{Q_{add}}$

$\Rightarrow \eta = \frac{120}{m_f \times CV}$

$\Rightarrow \eta = \frac{120}{\frac{1}{70}\times 42000} = 20\%$ Choice (C)

30. $\eta_m = \frac{bp}{ip} = 0.8$ ------------ (1)

and $ip - bp = 20$ kW ------ (2)

From equation (1) and (2)
$ip - (0.8 \times ip) = 20$
$\Rightarrow$ $ip = 100$ kW
$\therefore$ $bp = ip - fp = 100 - 20$
$\Rightarrow$ $bp = 80$ kW Choice (D)

31. $\Delta s = \frac{-1500}{800} + \frac{1500}{600} = 0.625$

$I = 300 \times 0.625 = 187.5$ kJ Choice (B)

32. Brake power, $BP = \frac{2\pi NT}{60\times 10^3}$ kW

Now, $T = F \times r$
$\Rightarrow$ $T = 45 \times 9.81 \times 0.55 = 242.8$ N-m

$\therefore$ $BP = \frac{2\pi \times 4800 \times 242.8}{60\times 10^3}$

$\Rightarrow$ $BP = 122.044$ kW
Brake mean effective pressure, p_m

$p_m = \frac{BP \times 60}{L \times A \times \frac{N}{2} \times n}$

$\Rightarrow p_m = \frac{122.044 \times 10^3 \times 60}{0.12 \times \frac{\pi}{4} \times 0.1^2 \times \frac{4800}{2} \times 6}$

$\Rightarrow$ $P_m = 5.39$ bar Choice (D)

33. BSFC = $\frac{m_f}{BP}$

Now, $m_f = \frac{5}{10} \times 60 = 30\,\text{kg/hr}$

$\therefore BSFC = \frac{30}{122.044} = 0.246\frac{\text{kg}}{\text{kWh}}$ Choice (A)

34. $V_s = \frac{\pi}{4}d^2\,L = \frac{\pi}{4}\times 0.28^2 \times 0.4$

$\Rightarrow$ $V_s = 0.02463\ m^3$
$\Rightarrow$ $V_s = 24630\ cm^3$

Compression ratio, $r = 1 + \frac{V_s}{V_c}$

$= 1 + \frac{24630}{2000}$

= 13.315 Choice (D)

35. Cut-off volume = $V_3 - V_2 = 0.05\ V_s$
= 0.05 × 12.315 × V_c and $V_2 = V_c$
$V_3 = 1.61575\ V_c$

$\therefore r_c = \frac{V_3}{V_2} = 1.61575$

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

$= 1 - \frac{1}{13.315^{0.4}}\left[\frac{1.61575^{1.4}-1}{1.4(1.61575-1)}\right] = 60.56\%$ Choice (B)