Thermodynamics Test I

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

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

1. If the density of the system is very low i.e, number of molecules present in a particular volume is low then which kind of approach will be suitable for analysis of thermodynamic behavior of the system?
(A) Classical
(B) Both classical & Statistical
(C) Statistical
(D) None of the above

2. The work required for compression is 6 MJ. At the time of process heat transfer is 3 MJ to the surrounding. Change in internal energy during the process is
(A) 9 MJ (B) 3 MJ
(C) –3 MJ (D) –9 MJ

3. An ideal gas undergoes a throttling process (1 – 2). Which relationship holds good for the process (1 – 2)
(1) $h_1 = h_2$ (2) $p_1 = p_2$
(3) $s_1 = s_2$ (4) $T_1 = T_2$
(h = enthalpy, p = pressure, s = entropy, T = Temperature)
(A) (1) and (2) (B) (1) and (3)
(C) (1) and (4) (D) (1), (2), (3) and (4)

4. Two engines which are working as a refrigerator and arranged in series. The $(COP)_1$ of first one is 4 and $(COP)_2$ of second one is 3. The (COP) of complete system is
(A) 3.25 (B) 4
(C) 3 (D) 1.5

5. The correct sequence of the decreasing order of the value of characteristic gas constant for the given gases is
(A) hydrogen, nitrogen, air
(B) nitrogen, air, hydrogen
(C) air, nitrogen, hydrogen
(D) air, hydrogen, nitrogen

6. A system of 100 kg mass undergoes a process in which its entropy increases from 0.3 kJ/kg.K to 0.4 kJ/kg.K and at the same time entropy at the surrounding decreases from 80 kJ/K to 75 kJ/K. The process is
(A) Reversible & Isothermal
(B) Irreversible
(C) Reversible
(D) Impossible

7. For a heat engine operating on the Carnot cycle, the work output is 1/4th of the heat transferred to the sink. The efficiency of the engine is
(A) 20% (B) 33.3%
(C) 40% (D) 50%

8. A tank containing air is stirred by a paddle wheel. The work input to the paddle wheel is 9000 kJ and the heat transferred to the surrounding form the tank is 3000 kJ. The external work done by the system is
(A) Zero (B) 9000 kJ
(C) 3000 kJ (D) 6000 kJ

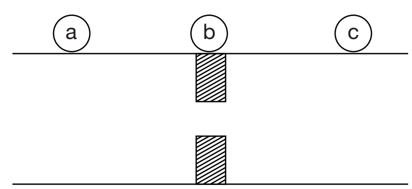
9. Change in enthalpy in a closed system is equal to heat transferred. The reversible process takes place at constant.
(A) Temperature (B) Internal energy
(C) Pressure (D) Entropy

10. In a reversible isothermal expansion process the fluid expands from 10 bar and 2 m^3 to 0.2 bar and 10 m^3. During the process the heat supplied is 100 kW. The work done during the process is
(A) 33.3 kW (B) 100 kW
(C) 80 kW (D) 20 kW

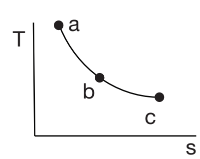
11. A block (specific heat at constant pressure = 200 J/K) having mass of 800 gms with initial temperature of 100°C is placed in a water reservoir at 10°C. the entropy change of the universe (in J/K) will be
(A) 0.095 (B) 0.044
(C) 0.067 (D) 6.702

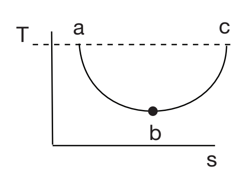
12. The internal energy of a certain system is a function of temperature alone and is given by the formula $E = 25 + 0.25t$ kJ. If this system executes a process for which the work done by it per degree temperature increase is 0.75 N.m. The heat interaction per degree temperature increase in kJ is
(A) 1.00 (B) –1.00
(C) 0.50 (D) –0.50

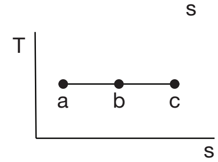
13. The throttling process undergone by an ideal gas across on outline is shown by it's states in the following diagram.

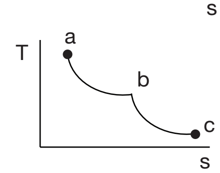


It can be represented by the figure

(A)


(B)


(C)


(D)


14. Air enters with mass flow rate of 0.70 kg/sec and a specific enthalpy of 290 kJ and leaves with 450 kJ. Inlet and outlet velocity are 6 m/sec and 2 m/sec respectively. What is the power input to the compressor if heat transfer to the surrounding is neglected.

(A) 120 kW (B) 118 kW
(C) 115 kW (D) 112 kW

15. A heat engine which is working as Carnot engine converts 1/6 of the heat input into work. When the temperature of the sink is decreased by 70°C its efficiency becomes doubled. Then the temperature of source reservoir is

(A) 2035 K (B) 2058°C
(C) 2058 K (D) 1785 K

16. 20 liters of water is heated with 4 kW heater which is on for 20 minutes. The heat capacity of water is 4.2 kJ/kg.K then the increase of the water temperature in °C is

(A) 57.14 (B) 2.7
(C) 4.0 (D) 25.25

17. An insulated box containing 0.5 kg of a gas having C_V = 0.98 kJ/kg.K falls from a balloon 4 km above the earth surface. The temperature rise of the gas when the box hits the ground is

(A) 0 K (B) 20 K
(C) 40 K (D) 60 K

18. An inventor states that his new conceptual engine, while operating between temperature limits of 377°C and 27°C will reject 50% of heat absorbed form the source. Which type of cycle will this engine have?

(A) Carnot cycle (B) Stirling cycle
(C) Impossible cycle (D) Possible cycle

19. In which one of the following process in a closed system the thermal energy transferred to a gas is completely converted to internal energy resulting in an increase in gas temperature?

(A) Isochoric process (B) Adiabatic process
(C) Isothermal process (D) Free expansion

20. A balloon which is initially collapsed and flat is slowly filled with a gas at 100 kPa so as to form it into a sphere of 1 m radius. The work done by the gas in the balloon during the filling process is

(A) 428.9 kJ (B) 418.9 kJ
(C) 420.9 kJ (D) 416.9 kJ

21. A Carnot engine operates between 327°C and 27°C. If the engine produces 300 kJ of work the entropy change during heat addition is

(A) 0.5 kJ/K (B) 1.0 kJ/K
(C) 1.5 kJ/K (D) 2.0 kJ/K

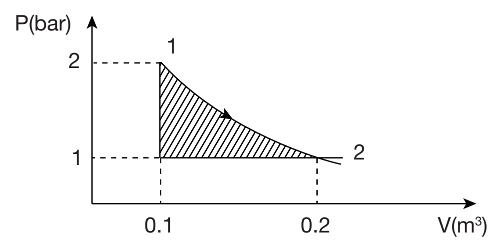
22. The thermal efficiency of a Carnot heat engine is 30%. If the engine is reversed in operation to work as a heat pump with same operating conditions then what will be the COP for heat pump?

(A) 0.30 (B) 2.33
(C) 3.33 (D) Can't be calculate

23. An insulated tank contains 0.25 kg of gas initially with an internal energy of 200 kJ/kg. Additional gas with an internal energy of 300 kJ/kg and an enthalpy of 400 kJ/kg enters the tank until the total mass of gas contained is 1 kg. The final internal energy (in kJ/kg) of the gas in the tank is

(A) 250 (B) 275
(C) 350 (D) None of these

24. An ideal gas undergoes an isothermal expansion form state 1 to 2 as shown in the figure.



The area of shaded region is 1000 N.m. Then the amount of work done during the process is

(A) 14100 N.m (B) 14000 N.m
(C) 11000 N.m (D) 10100 N.m

25. A series combination of two Carnot engines operate between the temperatures of 180°C and 20°C. If the engines produce equal amount of work then the intermediate temperature is

(A) 80°C (B) 90°C
(C) 100°C (D) 110°C

Answer Keys

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

Hints and Explanations

1. When density is low, behavior of each molecules of the system can be taken into consideration for the analysis of thermodynamic behavior. This kind of approach is known as statistical thermodynamics. Choice (C)

2. Given data – Work required $W = –6$ MJ
Heat transfer $Q = –3$ MJ
From 1st law
$Q_{1\text{-}2} = \Delta U + W_{12}$
$\Delta U = –3 + 6 = 3$ MJ
$U_2 – U_1 = 3$ MJ Choice (B)

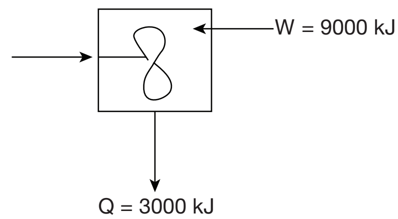
3. For an ideal gas if process (1–2) undergoes a throttling process, entropy increases temperature and enthalpy remain same
i.e, $T_1 = T_2$
$h_1 = h_2$ Choice (C)

4. Given data
$(\text{COP})_1 = 4$
$(\text{COP})_2 = 3$
$$(\text{COP}) = \frac{(COP)_1\,(COP)_2}{1+(COP)_1+(COP)_2} = \frac{12}{1+4+3} = 1.5$$
Choice (D)

5. Characteristic gas constant
$$= \frac{\text{Univeral gas constant}}{\text{molecular weight}}$$
$$R_{gas} = \frac{8.314\text{ kJ/kgK}}{\text{mol. wt.}}$$
$$\Rightarrow \quad R_{gas} \propto \frac{1}{\text{mol. wt.}}$$
Hydrogen – 2
Nitrogen – 28
Air –29 Choice (A)

6. Given m = 100 kg
Entropy of system $S_1 = 0.3 \times 100 = 30$ kJ/K
$S_2 = 0.4 \times 100 = 40$ kJ/K
Entropy of surrounding $S_1 = 80$ kJ/K
$S_2 = 75$ kJ/K
$(\Delta S)_{univ} = (\Delta S)_{sys} + (\Delta S)_{surr}$
$= (40 – 30) + (75 – 80)$
$(\Delta S)_{univ} = 5$
Since (ΔS) universe > 0
So, process is irreversible Choice (B)

7. $W = 1/4\ Q_{rejected}$
$Q_{add} = Q_{rej} = 1/4\ Q_{rej}$
$Q_{add} = (1 + 1/4)\ Q_{rej} = 5/4\ Q_{rej}$
$$\eta = 1 - \frac{Q_{rej}}{Q_{add}} = 1 – 4/5$$
$\eta = 20\%$ Choice (A)

8. 

This is case of constant volume process or an isochoric process, so system will not expand.
In an irreversible constant volume process, the system doesn't perform work on the surrounding at the expense of its internal energy. Choice (A)

9. $\delta Q = du + pdv$
At constant pressure
$(\delta Q) = d(u + pv) = dh$
Hence heat transferred at constant pressure increase the enthalpy at a system Choice (C)

10. For rev isothermal process
$du = 0$
$\therefore \quad \delta Q = du + \delta W$
$\delta Q = \delta W$
$\therefore$ Work done during the process
$= 100$ kW Choice (B)

11. Given: = 800 gms = 0.8 kg
$C_p = 200$ J/K
$T = 100°C$
$T\infty = 10°C$
$(\Delta s)_{universe} = (\Delta s)_{sys} + (\Delta s)_{sur}$
$$= m C_p\, \ell n \frac{T_f}{T_i} + \frac{m\, C_p\, dT}{T}$$
$$= 0.8 \times 0.2 \times \ell n \frac{(10+273)}{(100+273)} + \frac{0.8 \times 0.2 \times (100-10)}{(10+273)}$$
$= 6.7023$ J/K Choice (D)

12. $E = 25 + 0.25t$
$$\frac{dE}{dt} = 0.25 \text{ kJ/°C}$$
$$\text{and } \frac{dW}{dt} = 0.75 \text{ kJ/°C}$$
1st law $Q_{12} = \Delta E + W_{12}$
or $\delta Q = \delta E + \delta W$
$\delta Q = 0.25 + 0.75$
$\delta Q = 1.00$ kJ/°C Choice (A)

13. Applying steady flow energy equation
For throttling process $W = 0$, $C = 0$
$$h_a + \frac{V_a^2}{g} = h_b + \frac{V_b^2}{2} = h_c + \frac{V_c^2}{2}$$
(assume $Z_a = Z_b = Z_c$)

For gas $C_p T_a + \frac{V_a^2}{2} = C_p T_b + \frac{V_b^2}{2} = C_p T_c + \frac{V_c^2}{2}$

As $V\ T\downarrow$

From continuity equation $Q = AV$

For process 1 – 2 $A\downarrow V\ T\downarrow$

For process 2 – 3

$A\ V\downarrow T$ Choice (B)

14. Power input to compressor

$$m\left(h_1 + \frac{V_1^2}{2000}\right) + Q_{1-2} = m\left(h_2 + \frac{V_1^2}{2000}\right) + W_{1-2}$$

$$0.7\left(290 + \frac{6^2}{2000}\right) + 0 = 0.7\left(450 + \frac{2^2}{2000}\right) + W_{1-2}$$

$W_{1-2} = -112$ kW Choice (D)

15. $\frac{T_1 - T_2}{T_1} = 1/6$

$5T_1 = 6T_2$

$T_1 = 1.2T_2$ (1)

Now, $\frac{T_1 - (T_2 - (70+273))}{T_1} = 1/3$

$\frac{T_1 + T_2 + 343}{T_1} = 1/3$

$3T_1 = 3T_2 - 1029$

From (1)

$0.6T_2 = 1029$

$T_2 = \frac{1029}{0.6}$

$T_2 = 1715$ K

$T_1 = 2058$ K Choice (C)

16. $Q = m\ C_p\ \Delta T$

$4 \times 10^3 \times 20 \times 60 = 10^3 \times 0.02 \times 4.2 \times 10^3 \times \Delta T$

$\Delta T = 57.14$°C Choice (A)

17. Change is internal energy

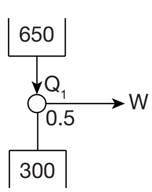
= Change in potential energy

$mC_v dT = mgh$

$dT = \frac{9.81 \times 4000}{0.98 \times 10^3} = 40$ K

$dT = 40$ K Choice (C)

18.



$\therefore \quad \eta_c = 1 - \frac{300}{650}$

$\eta_c = 0.538$

Claimed efficiency = $\eta = WQ_1$

$\eta = 0.5$

$\therefore \quad \eta < \eta_c$

The cycle is possible Choice (D)

19. 1st law

$\delta Q = du + \delta w$

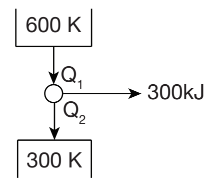
$\delta w = 0$ only for isochoric process

i.e, constant volume process. Choice (A)

20. $W = \int -VdP = -\int VdP$

$= \left(\frac{4}{3}\pi r^3\right)(100) = 418.9$ kJ Choice (B)

21.



$\eta = \frac{T_1 - T_2}{T_1} = \frac{W}{Q_1}$

$\frac{W}{Q_1} = 1 - \frac{300}{600} = 0.5$

$Q_1 = \frac{300}{0.5} = 600$ KJ

$\therefore$ Change in entropy head addition

$= \frac{Q_1}{T_1} = \frac{600}{600} = 1$ kJ/K Choice (B)

22. Given $\eta_{H.E} = 30\%$

$1 - \frac{Q_2}{Q_1} = 0.3$

$\Rightarrow \quad \frac{Q_2}{Q_1} = 0.7$

$COP = \frac{1}{1 - \frac{Q_2}{Q_1}}$

$(COP)_{H.P} = \frac{1}{1 - 0.7}$

$(COP)_{H.P} = 3.33$ Choice (C)

23. Final internal energy of gas

U = $\frac{m_1u_1 + m_2u_2}{m_1 + m_2}$ ($m_1 = 0.25$ kg and $m_2 = 0.75$ kg)

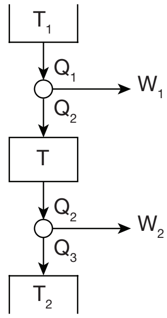
$U = 275$ kJ/kg Choice (B)

24. For steady flow

$W = -V\int dp = (2 - 1) \times 0.1 \times 10^5 + 1000$

= 11000 N.m Choice (c)

25. Source Temp – T_1
Intermediate Temp – T
Sink Temp – T_2
According to question
$W_1 = W_2$



$Q_1 - Q_2 = Q_2 - Q_3$

$$\frac{Q_1 + Q_3}{2} = Q_2$$

$$\Rightarrow \quad T = \frac{T_1 + T_2}{2} = \frac{180 + 20}{2}$$

$T = 100°C$

Choice (C)