THERMODYNAMICS TEST 2

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

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

1. An engine is exchanging heat with two reservoir, one at 1000 K and other is ambient condition which is at 300 K. If the amount of heat added to the engine will be 2000 kJ then the available energy of the engine (in kJ) will be
(A) 1800 (B) 1600
(C) 2000 (D) 1400

2. A Carnot engine is rejecting heat to atmosphere at 27°C. If the change in entropy of the cycle throughout the cycle is 0.326 kJ/K then the unavailable energy (in kJ) will be
(A) 105.7 (B) 97.8
(C) 91.6 (D) 81.2

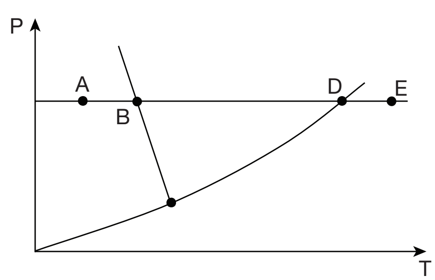
3. At its critical point, any substance will
(A) change directly from solid to vapor
(B) exits in all three phase
(C) behaves as an ideal gas
(D) looses phase distinction between liquid and solid.

4. Steam is expanded in reversible adiabatic process in a turbine from superheated state to dry saturated state. If the expansion occurs irreversibly between the same pressure limit then the final state of the steam will be
(A) dry saturated (B) wet
(C) superheated (D) cannot be determined

5. When ice melts into water at a constant temperature of 0°C, then its volume will
(A) decrease (B) increase
(C) remains constant (D) none of the above

6. A rigid vessel consists of H_2O at 221.2 bar pressure and 0.00317 m^3/kg specific volume. Slowly the pressure decreases upto 100 bar. The final state of the system will be
(A) superheated (B) subcooled
(C) wet (D) saturated liquid

7. A *P-T* diagram of water is shown below. Locate the region or point at which vaporization of water at 100°C takes place at constant pressure.



(A) *B* to *D* (B) *A* to *B*
(C) *A* to *B* (D) *A* to *D*

8. Below the triple point, which of the following transformation is CORRECT?
(A) solid to liquid (B) liquid to vapor
(C) solid to vapor (D) none of the above

9. Which one of the following equation is CORRECT?
(A) $h = (1 - x)\, h_f + x\, h_g$ (B) $h = h_f + h_g$
(C) $h = x\, h_f + (1 - x)\, h_g$ (D) $h = x(h_f + h_g)$

10. Which combination of the following statements is CORRECT?
The incorporation of regenerative feed heating:
(A) always increase the dryness fraction of steam at condenser inlet.
(B) always increase the mean temperature of heat addition.
(C) always decrease the thermal efficiency of the plant.
(D) always increase the specific work output.

11. Air is expanding through a very small opening in a pipe from pressure and temperature of 10 bar and 800 K to a pressure of 2 bar. Assume air to be an ideal gas and temperature of surroundings as 300 K. The irreversibility associated with the expansion process (in kJ/kg) will be
(A) 132.63 (B) 145.91
(C) 124.61 (D) 138.57

12. A solid sphere of diameter 0.2 m is at 300°C and cooled to the atmospheric temperature of 27°C. Properties of the sphere are given as follows: density = 2700 kg/m^3, specific heat = 1 kJ/kg-K. The irreversibility associated with the process (in kJ) will be
(A) 963.34 (B) 1031.39
(C) 891.24 (D) 602.21

13. A heat engine operates between 1000 K reservoir and dead state at 300 K. If the engine receives 500 kJ of heat from the reservoir and its output is 25 kJ then which of the following statement is CORRECT?
(A) It is a reversible engine and irreversibility is zero.
(B) It is an irreversible engine and irreversibility is 625 kJ.
(C) It is a reversible cycle and irreversibility is 625 kJ.
(D) Engine is not possible.

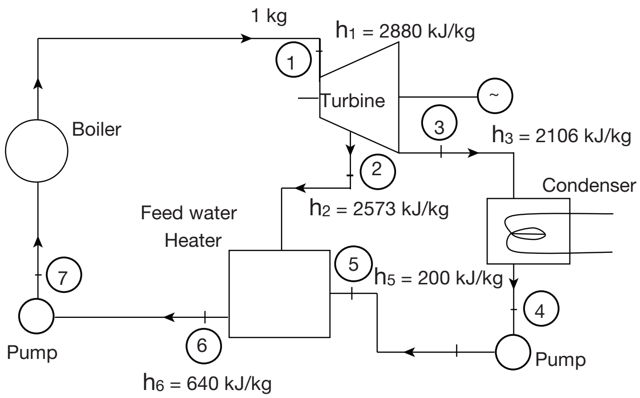
14. Air is expanding from an initial state of 10 bar, 500 K to a final state of 2 bar, 300 K. Assume dead state at 1 bar and 288 K. The maximum useful work obtained (in kJ/kg) will be
(A) 129.72 (B) 161.32
(C) 112.4 (D) 141.3

15. Air enters a turbine at a pressure of 700 kPa, 65°C with a velocity of 90 m/s and leaves the turbine at 140 kPa, 5°C with a velocity of 60 m/s. If 2 kJ/kg heat is lost

to the surrounding from the turbine then the available energy (in kJ) will be
(Take the surrounding state at 25°C and 1 bar and assume mass flow rate is 1 kg/s)

(A) 149 (B) 156
(C) 132 (D) 144

16. A schematic diagram of regenerative Rankine cycle is shown below.



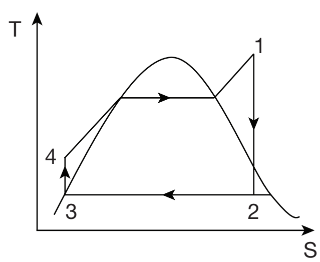
The mass (in kg) which is bled off (m_b) from the turbine at an intermediate stage and turbine work (in kJ/kg) will be

(A) 0.185 and 774 (B) 0.185 and 687.4
(C) 0.241 and 687.3 (D) 0.241 and 786.3

17. At the exit of the turbine, the ratio of density of liquid to vapor which are present in the steam is 900. If the ratio of volume of vapor to liquid is 4000 then the dryness fraction of the steam will be

(A) 0.621 (B) 0.873
(C) 0.725 (D) 0.816

18. In a simple Rankine cycle, steam enters the turbine in superheated state. It is shown in the below diagram.



The properties of the state of the steam is given in a table.

State	h(kJ/kg)	s(kJ/kg-K)
1	3642	7
4	200	0.7

If the temperature of state 2 is 40°C then the maximum thermal efficiency of the cycle will be

(A) 31.63% (B) 42.71%
(C) 37.31% (D) 46.39%

19. An ideal regenerative Rankine cycle using dry saturated steam at 427°C and pressure 140 bar at the inlet to the turbine and condensing temperature of 37°C and saturation pressure of 4 kPa. If the heat added to the cycle is 3000 kJ then the net work output of the cycle (in kJ) is

(A) 1671.43 (B) 1732.6
(C) 1936.24 (D) 1424.46

20. An ideal reheat Rankine cycle operates between the pressure limits of 10 kPa and 8 MPa, with reheat being done at 4 MPa. The inlet temperature of both turbines is 500°C. The total turbine work is 1413 kJ/kg. The enthalpy of steam at inlet of high pressure turbine is 3399 kJ/kg and enthalpy of water at the exit from the pump is 191 kJ/kg. If the efficiency of the cycle is 0.4 then the heat added (in kJ/kg) in the reheating process will be

(A) 208.5 (B) 251.5
(C) 324.5 (D) 376.3

21. The value of enthalpy of steam at the inlet and outlet of a steam turbine in a Rankine cycle are 3200 kJ/kg and 1200 kJ/kg respectively. Neglecting pump work, the specific steam consumption in kg/kW-hr is

(A) 0.01 (B) 0.03
(C) 0.13 (D) 1.3

22. A pure substance at 10 MPa and 500°C is having a specific enthalpy of 3200 kJ/kg and specific internal energy of 2870 kJ/kg. Its specific volume (in m³/kg) is ______

(A) 0.053 (B) 0.033
(C) 0.066 (D) 0.0587

23. Saturated water vapor enters an reversible adiabatic turbine at 2 MPa and dry saturated state and leaves at 0.1 MPa. The mass flow rate of water vapor is 25 kg/s. The power produced by the turbine in MW is

Pressure (bar)	Saturation temperature (°C)	Specific enthalpy (kJ/kg)		Specific entropy (kJ/kg-K)	
		h_f	h_g	S_f	S_g
2	120.23	504.68	2706.6	1.530	7.127
0.1	45.81	191.81	2584.6	0.6492	8.15

(A) 12.36 (B) 9.36
(C) 11.21 (D) 14.32

24. In an ideal steam power cycle with the same inlet pressure, the low dryness fraction of steam in the expansion process can be avoided by
(P) providing superheat
(Q) providing regeneration
(R) providing reheat
(S) lowering the condenser pressure
Which of the following is CORRECT?
(A) *P* and *Q* (B) *P* and *R*
(C) *P* and *S* (D) *P*, *Q* and *R*

25. Match List-I (Process of steam) with List-II (Effects due to the process)

List-I		List-II	
P.	As saturation pressure increases	1.	Dryness fraction increases
Q.	As specific volume increases	2.	Saturation temperature increases
R.	Cooling at constant pressure	3.	Pressure decrease
S.	Throttling of steam	4.	Entropy decreases

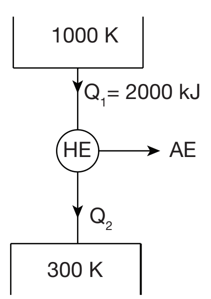
	P	*Q*	*R*	*S*
(A)	1	2	3	4
(B)	2	1	3	4
(C)	2	1	4	3
(D)	1	2	4	3

Answer Keys

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

Hints and Explanations

1.

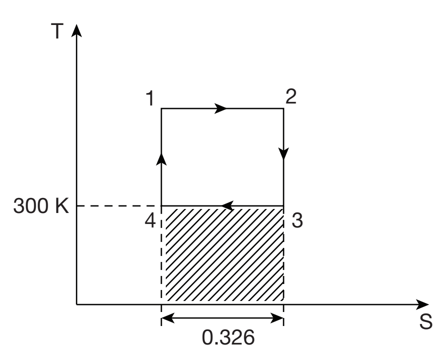


$$A.E = Q_1\left[1-\frac{T_0}{T_1}\right]$$

$$\Rightarrow \quad A.E = 2000\left[1-\frac{300}{1000}\right]$$

$\Rightarrow$ $A.E = 1400$ kJ Choice (D)

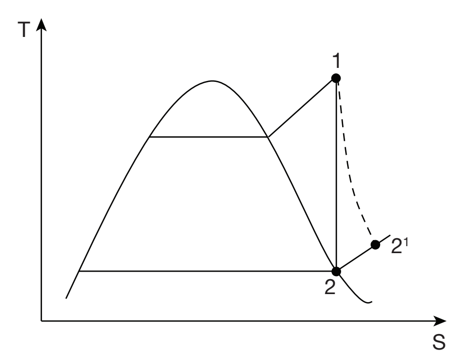
2.



$UAE = 300 \times 0.326 = 97.8$ kJ Choice (B)

3. At critical point, liquid directly converts to vapor since the latent heat is zero. Choice (D)

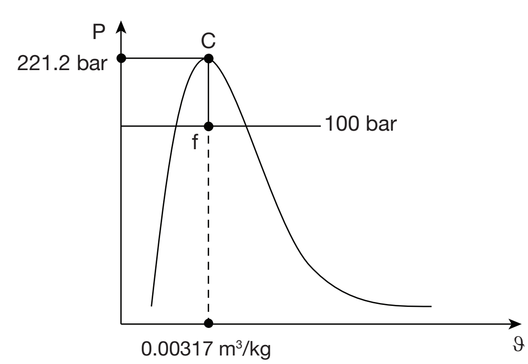
4. In an irreversible process, the entropy of the system always increases. Therefore the curve shifts to the right always and hence it is superheated region.
$1-2 \rightarrow$ Reversible adiabatic
$1-2^1 \rightarrow$ Irreversible adiabatic



Choice (C)

5. There is decrease in volume when ice melts. This is peculiarity of water. Choice (A)

6.



Given state of the system is the critical state. Hence the initial state of H_2O in the system is 'C' in the diagram. When pressure decrease of the system in the rigid vessel its volume remains constant. Hence upto 100 bar the state of the system is wet. Choice (C)

7. At B, melting of ice takes place at 0°C.
$A - B \rightarrow$ Solid (ice) heating
$B - D \rightarrow$ Liquid heating
At $D \rightarrow$ Vaporization of water at 100°C. Choice (D)

8. Choice (C)

9. $h = h_f + x\,h_{fg} = h_f + x(h_g - h_f)$
$\Rightarrow \quad h = (1 - x)\,h_f + x\,h_g$ Choice (A)

10. Always the mean temperature of heat addition increases and efficiency also increases. Choice (B)

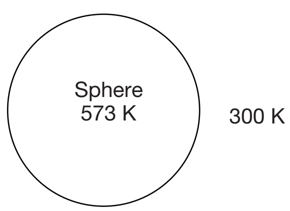
11. Given:
Throttling of ideal gas (air)
$h_1 = h_2 \Rightarrow T_1 = T_2 \qquad \{\because h = f(T)\}$
$I = T_0(\Delta S)_{univ} \Rightarrow I = T_0[(\Delta S)_{sys} + (\Delta S)_{surr}]$
$\because \quad dQ = 0$ for throttling; $(\Delta S)_{surr} = 0$

$$\therefore \quad I = T_0(\Delta S)_{sys} \Rightarrow I = T_0\left[C_P \ln\frac{T_2}{T_1} - R\ln\frac{P_2}{P_1}\right]$$

$$\Rightarrow \quad I = T_0\,R\ln\frac{P_1}{P_2} = 300 \times 0.287 \times \ln\left(\frac{10}{2}\right)$$

$\Rightarrow \quad I = 138.57$ kJ Choice (D)

12.



$$V_1 = V_2 = \frac{4}{3}\pi R^3 = \frac{4}{3}\times\pi\times 0.1^3$$

$\Rightarrow \quad V_1 = V_2 = 4.188 \times 10^{-3}$ m^3
Now $m = r \times V = 2700 \times 4.188 \times 10^{-3}$
$\Rightarrow \quad m = 11.3$ kg
$Tds = dU + PdV \Rightarrow Tds = dU$ [V = constant]

$$\Rightarrow \quad (\Delta S)_{sys} = mC\ln\frac{T_2}{T_1} = 11.3 \times 1 \times \ln\frac{300}{573}$$

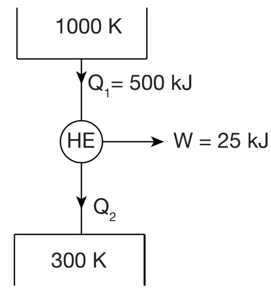
$\Rightarrow \quad (\Delta S)_{sys} = -7.3122$ kJ/K

$$(\Delta S)_{surr} = \frac{Q}{T} = \frac{mC(573-300)}{300}$$

$$\Rightarrow \quad (\Delta S)_{surr} = \frac{11.3\times1\times273}{300} = +10.283\text{ kJ/K}$$

$(\Delta S)_{univ} = (\Delta S)_{sys} + (\Delta S)_{surr} = -7.3122 + 10.283$
$\Rightarrow \quad (\Delta S)_{univ} = 2.9708$ kJ/K
$I = T_0(\Delta S)_{univ} = 300 \times 2.9708$
$\Rightarrow \quad I = 891.24$ kJ Choice (C)

13.



$(\Delta S)_{univ} = (\Delta S)_{sys} + (\Delta S)_{surr}$
$(\Delta S)_{sys} = 0$ [cycle]
$\therefore \quad (\Delta S)_{univ} = (\Delta S)_{surr}$

$$\Rightarrow \quad (\Delta S)_{univ} = \frac{500}{1000} + \frac{475}{300} \qquad [Q_2 = 500 - 25 = 475\text{ kJ}]$$

$\Rightarrow \quad (\Delta S)_{univ} = 2.0834$ kJ/K > 0
$\because \quad (\Delta S)_{univ} > 0$, therefore cycle is irreversible.
$\therefore \quad I = T_0(\Delta S)_{univ} = 300 \times 2.0834$
$\Rightarrow \quad I = 625$ kJ Choice (B)

14. $P_1 = 1000$ kPa, $T_1 = 500$ K, $P_2 = 200$ kPa, $T_2 = 300$ K, $P_0 = 100$ kPa, $T_0 = 288$ K
$(W_{max})_{useful} = W_{max} - W_{surr}$
$\Rightarrow \quad (W_{max})_{useful} = U_1 - U_2 - T_0(S_1 - S_2) - P_0(V_2 - V_1)$
$\Rightarrow \quad (W_{max})_{useful} =$

$$C_V(T_1 - T_2) - T_0\left[C_P\ln\frac{T_2}{T_1} - R\ln\frac{P_2}{P_1}\right] - P_0\left[\frac{RT_2}{P_2} - \frac{RT_1}{P_1}\right]$$

$$= 0.718(500 - 300)$$

$$-288\left[\left\{1.005\times\ln\left(\frac{300}{500}\right) - 0.287\times\ln\left(\frac{200}{1000}\right)\right\}\right] - 100 \times$$

$$0.287\left[\frac{300}{200} - \frac{500}{1000}\right]$$

$\Rightarrow \quad (W_{max})_{useful} = 129.72$ kJ/kg Choice (A)

15. $(W_{max}) = (H_1 - T_0S_1) - (H_2 - T_0S_2)$

$$+\frac{m\left(C_1^2 - C_2^2\right)}{2000} + \frac{mg\left(z_1 - z_2\right)}{1000}$$

$$\Rightarrow \quad (W_{max}) = mC_P(T_1 - T_2) + T_0(S_2 - S_1) + \frac{m\left(C_1^2 - C_2^2\right)}{2000}$$

$$\Rightarrow W_{max} = \left[1\times1.005\times(65-5)\right]$$

$$+\left[298\left\{mC_P\ln\frac{T_2}{T_1} - mR\ln\frac{P_2}{P_1}\right\}\right] + \left[\frac{1\times\left(90^2 - 60^2\right)}{2000}\right]$$

$$= 62.55 + \left[298\times1\left\{1.005\ln\frac{278}{338} - 0.287\times\ln\frac{140}{700}\right\}\right]$$

$$+\left[\frac{90^2 - 60^2}{2000}\right]$$

$W_{max} = 143.92$ kJ Choice (D)

16. $(1 - m_b)h_5 + m_b\, h_2 = h_6$

$(1 - m_b) \times 200 + m_b \times 2573 = 640$

$\Rightarrow$ $200 - 200\, m_b + 2573\, m_b = 640$

$\Rightarrow$ $m_b = 0.18542$ kg

Turbine work, $W_T = (h_1 - h_2) + (1 - m_b)\,(h_2 - h_3)$

$\Rightarrow$ $W_T = (2880 - 2573) + (1 - 0.18542)\,(2573 - 2106)$

$W_T = 687.41$ kJ/kg   Choice (B)

17. Given:

$$\frac{\rho_L}{\rho_V} = 900 \ and \ \frac{V_V}{V_L} = 4000$$

Now dryness fraction, $x = \dfrac{m_v}{m_V + m_L} = \dfrac{\rho_V \times V_V}{\rho_V V_V + \rho_L V_L}$

$$\text{or } x = \frac{1}{1 + \frac{\rho_L}{\rho_V} \cdot \frac{V_L}{V_V}} = \frac{1}{1 + 900 \times \frac{1}{4000}}$$

$\Rightarrow$ $x = 0.8163$ Choice (D)

18. Mean temperature of heat addition, T_{mA}

$$T_{mA} = \frac{h_1 - h_4}{S_1 - S_3} = \frac{h_1 - h_4}{S_1 - S_4}$$

$$\Rightarrow \quad T_{mA} = \frac{3642 - 200}{7 - 0.7} = 546.35\,\text{K}$$

$$\text{Now, } \eta = 1 - \frac{T_{rej}}{T_{mA}} = 1 - \frac{T_2}{T_{mA}} = 1 - \frac{(40 + 273)}{546.35}$$

$\Rightarrow$ $\eta = 0.4271$ or 42.71%   Choice (B)

19. For ideal regenerative cycle,

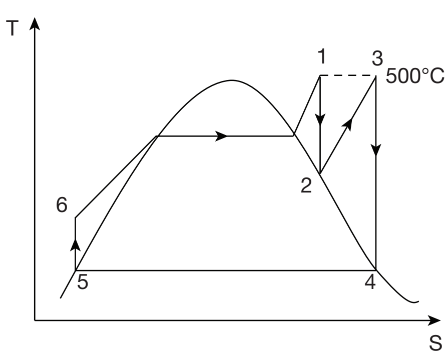
$$\eta = 1 - \frac{T_{rej}}{T_{add}} = 1 - \frac{(37 + 273)}{(427 + 273)}$$

$$\Rightarrow \quad \eta = 0.55714 = \frac{W_{net}}{Q_{add}}$$

$\Rightarrow$ $W_{net} = 0.55714 \times 3000$

$= 1671.43$ kJ   Choice (A)

20.



$h_1 = 3399$ kJ/kg, $h_6 = 191$ kJ/kg

$(h_1 - h_2) + (h_3 - h_4) = 1413$ kJ/kg

$$\eta = \frac{\text{Work done}}{\text{Heat added}} \Rightarrow 0.4 = \frac{1413}{(h_3 - h_2) + (h_1 - h_6)}$$

$$0.4 = \frac{1413}{(h_3 - h_2) + (3399 - 191)}$$

$\Rightarrow$ $(h_3 - h_2) = 324.5$ kJ/kg   Choice (C)

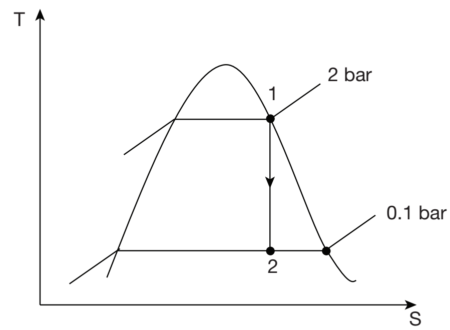
21. $SSC = \dfrac{3600}{2000} = 1.3$ kg/kW-hr   Choice (D)

22. $h = u + \rho v$

$\Rightarrow$ $3200 = 2870 + [(10 \times 10^3) \times v]$

$\Rightarrow$ $v = 0.033$ m³/kg   Choice (B)

23.



$h_1 = (h_g)_{2bar} = 2706.6$ kJ/kg

Now $S_1 = S_2 = [S_f + x\, S_{fg}]_{0.1\text{ bar}}$

$\Rightarrow$ $7.127 = 0.6492 + x\,[8.15 - 0.6492]$

$\Rightarrow$ $x_2 = 0.8636$

$h_2 = (h_f + x_2\, h_{fg})_{0.1\text{ bar}}$

$\Rightarrow$ $h_2 = 191.81 + 0.8636\,(2584.6 - 191.81)$

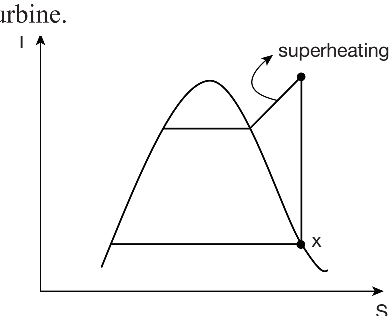
$\Rightarrow$ $h_2 = 2258.223$ kJ/kg

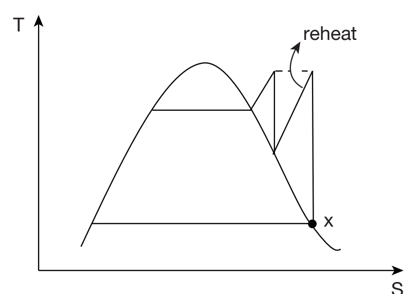
Power produced, $W = \dot{m}\,(h_1 - h_2)$

$\Rightarrow$ $W = 25 \times (2706.6 - 2258.223)$

$\Rightarrow$ $W = 11.209$ MW   Choice (C)

24. In both the case dryness fraction 'x' increases at the exit of turbine.





Choice (B)

25. Choice (C)