

**Thermodynamics (XE-E)**

Q.1 - Q.7 Multiple Choice Question (MCQ), carry ONE mark each (for each wrong answer: $-1/3$).

Q.1	A refrigerator working on a reversed Carnot cycle has a Coefficient of Performance (COP) of 4. If it works as a heat pump and consumes work input of 1 kW, the heating effect will be:
(A)	1 kW
(B)	4 kW
(C)	5 kW
(D)	6 kW

Q.2	The liquid phase of a pure substance is termed as _____, if its temperature is lower than the saturation temperature corresponding to its pressure P.
(A)	super-heated liquid
(B)	sub-cooled liquid
(C)	metastable liquid
(D)	flashing liquid



Q.3	Two air streams of mass flow rates \dot{m}_1 and \dot{m}_2 enter a mixing chamber and exit after perfect mixing. The corresponding temperatures of the inlet streams are T_1 and T_2 , respectively. Heat loss rate from the mixing chamber to the surrounding is \dot{Q} . Assume that the process is steady, specific heat capacity is constant, and air behaves as an ideal gas. Identify the correct expression for the final exit temperature T_3 after mixing. The mass specific heat capacities of the gas at constant volume and constant pressure are c_v and c_p , respectively. Neglect the bulk kinetic and potential energies of the streams.
(A)	$T_3 = \frac{\dot{m}_1 T_1 + \dot{m}_2 T_2}{\dot{m}_1 + \dot{m}_2} - \frac{\dot{Q}}{c_v(\dot{m}_1 + \dot{m}_2)}$
(B)	$T_3 = \frac{\dot{m}_1 T_1 + \dot{m}_2 T_2}{\dot{m}_1 + \dot{m}_2} + \frac{\dot{Q}}{c_p(\dot{m}_1 + \dot{m}_2)}$
(C)	$T_3 = \frac{\dot{m}_1 T_1 + \dot{m}_2 T_2}{\dot{m}_1 + \dot{m}_2} - \frac{\dot{Q}}{c_p(\dot{m}_1 + \dot{m}_2)}$
(D)	$T_3 = \frac{\dot{m}_1 T_1 + \dot{m}_2 T_2}{\dot{m}_1 + \dot{m}_2} + \frac{\dot{Q}}{c_v(\dot{m}_1 + \dot{m}_2)}$



Q.4	<p>If</p> <p>h is the mass specific enthalpy, s is the mass specific entropy, P is the pressure, T is the temperature, C_V is the mass specific heat at constant volume, C_P is the mass specific heat at constant pressure, β is the coefficient of thermal expansion, v is the mass specific volume, κ is the isothermal compressibility,</p> <p>then the partial derivative $\left(\frac{\partial h}{\partial s}\right)_P =$</p>
(A)	$\left(T - \frac{1}{\beta}\right) \left(\frac{C_P}{C_V}\right)$
(B)	$\left(T - \frac{1}{\beta}\right)$
(C)	$T \left(1 - \frac{v\beta}{\kappa C_V}\right)$
(D)	T



Q.5	<p>If</p> <p>v is the mass specific volume, s is the mass specific entropy, P is the pressure, T is the temperature, then using Maxwell relations, $\left(\frac{\partial s}{\partial P}\right)_T =$</p>
(A)	$\left(\frac{\partial v}{\partial T}\right)_P$
(B)	$-\left(\frac{\partial v}{\partial T}\right)_P$
(C)	$\left(\frac{\partial v}{\partial T}\right)_s$
(D)	$-\left(\frac{\partial v}{\partial T}\right)_s$

Q.6	<p>A closed system consists of a solution of liquid water and ethanol in equilibrium with its vapours. Using the Gibbs phase rule, the degree of freedom of the system is:</p>
(A)	0
(B)	1
(C)	2
(D)	3

Q.7	<p>For a real gas passing through an insulated throttling valve, the outlet temperature of the gas _____ with respect to the inlet temperature.</p>
(A)	is always higher
(B)	is always lower
(C)	may be higher, lower or same
(D)	is always same



Q.8 Multiple Select Question (MSQ), Carry ONE mark each (no negative marks).

Q.8	Atmospheric air with Dry Bulb Temperature (DBT) of 24°C and Relative Humidity of 35%, entering in a circular duct (assume no pressure drop in the duct) is heated by an electrical resistance arrangement inside the duct. The DBT of air measured at the outlet of the duct is equal to 30°C . Considering the flow to be steady, which of the following statement(s) is (are) correct as regards to the outlet air, with respect to the inlet air?
(A)	There is no change in the Relative Humidity
(B)	There is no change in the Dew Point Temperature
(C)	There is no change in the Specific Humidity
(D)	There is no change in the Specific Enthalpy



Q.9 Numerical Answer Type (NAT), carry ONE mark each (no negative marks).

Q.9	<p>A cylinder of volume 1 m^3 contains a mixture of CO_2 (20% by mol) and O_2 (80% by mol) at 100 kPa and 300 K. This cylinder is connected to a 1 MPa pressure line carrying N_2 at 300 K. The cylinder is filled isothermally till the pressure of gas mixture inside it becomes 500 kPa, and then the filling is stopped. The amount of N_2 gas that has entered the cylinder is _____ (in mole, 2 decimal places).</p> <p>The universal gas constant is 8.3145 J/(mol K).</p>
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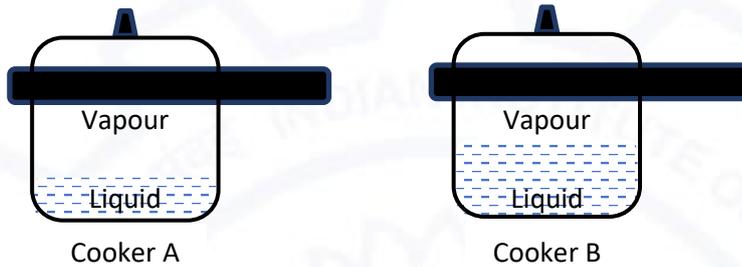
Q. 10 – Q. 13 Multiple Choice Question (MCQ), carry TWO marks each (for each wrong answer: – 2/3).

<p>Q. 10</p>	<p>The saturation pressure P_{sat} of a pure liquid is represented by an equation of the form:</p> $\ln P_{sat} = A - (B/T),$ <p>where, A and B are constants, and T is the absolute temperature. For this substance, which of the following expression for specific entropy difference between the saturated vapour and the saturated liquid phase (s_{fg}) is correct?</p> <p>Note: Subscripts f and g refer to saturated liquid and saturated vapour phases, respectively, and v_{fg} is the specific volume difference between the saturated vapour and the saturated liquid phases.</p>
<p>(A)</p>	$s_{fg} = v_{fg} \frac{BP_{sat}^2}{T^2}$
<p>(B)</p>	$s_{fg} = v_{fg} \frac{BP_{sat}}{T^2}$
<p>(C)</p>	$s_{fg} = v_{fg} \frac{BP_{sat}}{T^3}$
<p>(D)</p>	$s_{fg} = v_{fg} \frac{BP_{sat}^3}{T^2}$

<p>Q. 11</p>	<p>For a refrigeration cycle, the ratio of actual COP to the COP of a reversible refrigerator operating between the same temperature limits is 0.8. The condenser and evaporator temperatures are 51°C and -30°C, respectively. If the cooling capacity of the plant is 2.4 kW, then the power input to the refrigerator is:</p> <p>(COP: Coefficient of Performance)</p>
<p>(A)</p>	<p>1.00 kW</p>
<p>(B)</p>	<p>1.33 kW</p>
<p>(C)</p>	<p>1.25 kW</p>
<p>(D)</p>	<p>2.08 kW</p>



Q. 12 Two identical pressure cookers, Cooker A and Cooker B, each having a total internal capacity of 6 litres are available. Cooker A is filled with 2 litres of liquid water at 110°C and Cooker B is filled with 4 litres of liquid water at 110°C . The remaining space in both the cookers is filled with saturated water vapour in equilibrium with the liquid water. If g represents the specific Gibbs free energy, and subscripts v and l represent the saturated vapour and the saturated liquid phases, respectively, which of the following expressions is correct?



(A) $g_{v,A} > g_{l,B}$

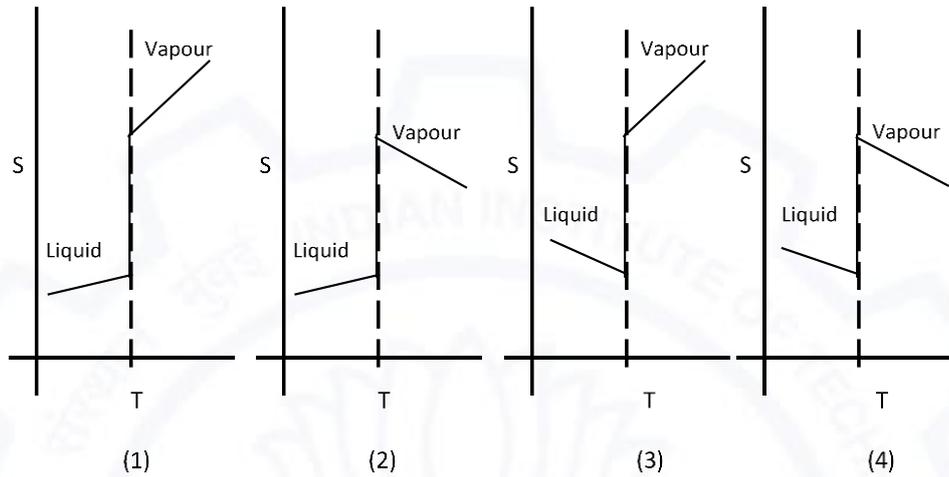
(B) $g_{v,A} < g_{l,B}$

(C) $g_{v,A} = g_{l,B}$

(D) $g_{l,B} = 2 g_{l,A}$



Q. 13 Four different Entropy (S) - Temperature (T) diagrams, representing liquid to vapour phase transition process of a pure substance in a closed system under constant pressure are shown. The diagram, which correctly represents the process, is:



(A)	1
(B)	2
(C)	3
(D)	4



Q. 14 – Q. 22 Numerical Answer Type (NAT), carry TWO marks each (no negative marks).

Q. 14	<p>Air having a mass flow rate of 2 kg/s enters a diffuser at 100 kPa and 30°C, with a velocity of 200 m/s. Exit area of the diffuser is 400 cm² while the exit temperature of the air is 45°C. The rate of heat loss from the diffuser to the surrounding is 8 kJ/s. The pressure at the diffuser exit is _____ kPa (2 decimal places).</p> <p>For air, the characteristic gas constant is 287 J/(kgK) and specific heat capacity at constant pressure is 1005 J/(kgK). Assume air to be an ideal gas and the flow in the diffuser is steady.</p>
Q. 15	<p>For the Refrigerant R-134 (at 1 MPa and 50°C), the difference between the specific volume computed by assuming it to be an ideal gas and its actual specific volume is: $v_{ideal} - v_{actual} = 4.529 \times 10^{-3} \text{ m}^3/\text{kg}$. If the compressibility factor associated with this state is $Z = 0.84$, then $v_{com} - v_{actual} =$ _____ $\times 10^{-3} \text{ m}^3/\text{kg}$ (3 decimal places).</p> <p>Here v_{com} is the specific volume calculated using the compressibility factor.</p> <p>For Refrigerant R-134 (at 1 MPa and 50°C): The characteristic gas constant: 0.0815 kJ/(kgK), The critical pressure and temperature are, respectively, $P_{cr} = 4.059 \text{ MPa}$ and $T_{cr} = 374.2 \text{ K}$.</p>
Q. 16	<p>A mixture of air and water vapour enters a steady-flow adiabatic saturator at 50°C and 100 kPa. It leaves the saturator in a completely saturated state at temperature of 25°C and pressure of 100 kPa. Liquid water enters the saturator at 25°C. If air is considered to be an ideal gas, with constant specific heat capacity, the relative humidity of the air entering the saturator is _____ % (1 decimal place).</p> <p>Use the following data:</p> <p>at 25°C $h_f = 104.87 \text{ kJ/kg}$, $h_g = 2547.17 \text{ kJ/kg}$, $P_{sat} = 3.161 \text{ kPa}$ at 50°C $h_f = 209.31 \text{ kJ/kg}$, $h_g = 2592.06 \text{ kJ/kg}$, $P_{sat} = 12.335 \text{ kPa}$ Specific heat capacity of air at constant pressure $C_p = 1.005 \text{ kJ/(kgK)}$</p>



Q. 17 Air at a pressure of 1 MPa and 300 K is flowing in a pipe. An insulated evacuated rigid tank is connected to this pipe through an insulated valve. The volume of the tank is 1 m³. The valve is opened and the tank is filled with air until the pressure in the tank is 1 MPa. Subsequently, the valve is closed. Consider air to be an ideal gas and neglect bulk kinetic and potential energy. The final temperature of air in the tank is _____ K (1 decimal place).

Specific heat capacity of air at constant pressure $C_p=1.005$ kJ/(kgK) and characteristic gas constant for air = 0.287 kJ/(kgK)

Q. 18 A cylinder of volume 0.1 m³ is filled with 100 mol of propane (C₃H₈) at 2 MPa. If propane is assumed to obey the van der Waals equation of state, then its temperature is _____ K (1 decimal place).

The van der Waals constants for propane are: $a = 939.2$ kPa (m³/kmol)² and $b = 0.0905$ m³/kmol. The universal gas constant is 8.3145 J/(mol K).

Q. 19 A frictionless piston cylinder device contains 1 kg of an ideal gas. The gas is compressed according to $Pv^{1.3} = \text{constant}$ (P is pressure and v is mass specific volume), from 100 kPa, 250 K, till it reaches a temperature of 500 K. The heat transfer from the piston cylinder device to its surroundings is _____ kJ (2 decimal places).

The characteristic gas constant is 287 J/(kgK) and the ratio of specific heat capacities is 1.4.

Q. 20 A 0.8 m³ insulated rigid tank contains 1.5 kg of an ideal gas at 100 kPa. Electric work is done on the system until the pressure in the tank rises to 135 kPa. The loss in availability (exergy) associated with the process is _____ kJ (2 decimal places).

For the ideal gas, the characteristic gas constant is 188.9 J/(kgK) and the specific heat capacity at constant volume is 680 J/(kgK). The temperature of the dead state is 298 K.

Q.21 A rigid tank contains 1.0 kg of pure water consisting of liquid and vapour phases in equilibrium at 10 bar. If the liquid and vapour phase each occupies one half of the volume of the tank, then the net enthalpy of the contents of the tank is _____ kJ (1 decimal place).

For saturated liquid and vapour at 10 bar, the thermodynamic data table provides the following values:

$v_f = 1.127 \times 10^{-3}$ m³/kg, $v_g = 194.3 \times 10^{-3}$ m³/kg,
 $h_f = 762.6$ kJ/kg, $h_g = 2776.2$ kJ/kg



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| Q.22 | An air-standard Diesel cycle with a compression ratio of 16 takes air at 1 bar and 300 K. If the maximum temperature in the cycle is 2100 K, then the thermal efficiency of the cycle is _____ % (1 decimal place).
The ratio of the specific heat capacities of air is 1.4. |
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END OF THE QUESTION PAPER

