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XE (E): Q. 1 – Q. 9 carry one mark each & Q. 10 – Q. 22 carry two marks each.

Notation used:
P : pressure, V : volume, T : temperature, s : specific entropy, h : specific enthalpy, C_p : molar heat capacity at constant pressure, C_v : molar heat capacity at constant volume, R : universal gas constant

Q.1 When a fixed mass of air-water vapour mixture is heated at constant pressure,

(A) both relative and specific humidity decrease.
(B) relative humidity decreases, but specific humidity remains unchanged.
(C) specific humidity decreases, but relative humidity remains unchanged.
(D) both relative and specific humidity increase.

Q.2 For a reversible isothermal expansion of one mole of an ideal gas from state 1 to state 2, the magnitude of work done is

(A) $RT\ln\left(\frac{P_1}{P_2}\right)$ (B) $P_2V_2 - P_1V_1$

(C) $R\ln\left(\frac{V_1}{V_2}\right)$ (D) 0

Q.3 The statement which is NOT a consequence of the first law of thermodynamics is

(A) Heat is a path function
(B) Energy is a property of a system
(C) Energy of an isolated system is not conserved
(D) A perpetual motion machine of the first kind is not possible

Q.4 For a refrigerator absorbing heat Q_L from a cold region and rejecting heat Q_H to a hot region, the coefficient of performance is written as

(A) $\frac{Q_L}{Q_H - Q_L}$ (B) $\frac{Q_H}{Q_H - Q_L}$

(C) $\frac{Q_H - Q_L}{Q_L}$ (D) $\frac{Q_L}{Q_H}$

Q.5 The value of the compressibility factor at the critical point evaluated using the van der Waals equation of state is

(A) $\frac{2}{7}$ (B) $\frac{5}{8}$ (C) $\frac{3}{8}$ (D) $\frac{1}{7}$

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Q.6 The vapour pressure of a liquid at 8 °C is 2.7 kPa. Its enthalpy of vaporization is constant and equal to 42700 kJ/kmol. Take R = 8.314 kJ/kmol.K. The temperature (in °C) at a vapour pressure of 13.5 kPa is

(A) 58.7 (B) 51.4 (C) 44.3 (D) 35.2

Q.7 One kmol of an ideal gas (C_p = 21 kJ/kmol.K) undergoes a constant pressure process from 300 K to 500 K. The molar entropy of the gas at 300 K is 150 kJ/kmol.K. The molar entropy (in kJ/kmol.K) at 500 K (up to 1 decimal place) is _____.

Q.8 A spring, having a spring constant of 350 kN/m, is initially compressed by 0.4 cm. The work required (in J) to compress it by another 0.6 cm (up to 1 decimal place) is _____.

Q.9 An ideal gas has a molar mass of 40 kg/kmol. Take R = 8.314 kJ/kmol.K. At a pressure of 2 bar and a temperature of 300 K, the volume (in m^3) of 1 kg of this gas (up to 2 decimal places) is _____.

Q.10 Consider the following statements for an ideal gas undergoing a reversible non-flow process:

P. If the process is adiabatic, the change in enthalpy of the gas is necessarily zero.
Q. If the process is adiabatic, the change in entropy of the gas is necessarily zero.
R. If the process is isothermal, the change in enthalpy of the gas is necessarily zero.
S. If the process is isothermal, the change in entropy of the gas is necessarily zero.

Which one of the following options is valid?

(A) Only P is correct (B) Only S is correct
(C) Only Q and R are correct (D) Only P and S are correct

Q.11 An ideal Otto cycle (O) and an ideal diesel cycle (D) have the same maximum temperature and reject equal amounts of heat. Also, the working fluid enters at the same state before compression. One of the following statements always true about their efficiencies (η) is

(A) $\eta_O > \eta_D$ (B) $\eta_O = \eta_D$
(C) $\eta_O < \eta_D$ (D) $\eta_O = 1 - \eta_D$

Q.12 A reversible engine receives 75 kJ/s of energy from a reservoir at 750 K and does 12 kJ/s of work. The heat is rejected to two reservoirs at 650 K and 550 K. The rate of heat rejection (in kJ/s) to the reservoir at 650 K is

(A) 11 (B) 31 (C) 41 (D) 52

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Q.13 A gas obeys the following equation of state:

$$P(\bar{v}-b)=RT+\frac{aP^2}{T},$$

where $\bar{v}$ is molar volume, and a, b are constants with values $a=10^{-5}$ J.K/Pa^2.kmol and $b=8\times10^{-2}$ m^3/kmol. Take C_p = 30 kJ/kmol.K. At 10 bar and 500 K, the value of the Joule-Thomson coefficient (in K/Pa) is

(A) -2×10^{-6} (B) -4×10^{-6} (C) 2×10^{-6} (D) 4×10^{-6}

Q.14 In an ideal Rankine cycle, steam enters the turbine at 10 MPa and 500 °C (h = 3375.1 kJ/kg, s = 6.5995 kJ/kg.K). It is cooled in the condenser at a pressure of 10 kPa. At 10 kPa, h_f = 191.81 kJ/kg, s_f = 0.6492 kJ/kg.K, h_g = 2583.9 kJ/kg and s_g = 8.1488 kJ/kg.K. The heat rejected in the condenser (in kJ/kg) is

(A) 1898 (B) 3796 (C) 949 (D) 2847

Q.15 Methane has compressibility factor value of 0.9 at reduced pressure of 1.0 and reduced temperature of 1.5. For propane, the critical temperature and pressure are 369.8 K and 42.48 bar, respectively. Take R = 8.314 kJ/kmol.K. Applying the principle of corresponding states, the molar volume of propane (in m^3/kmol) at the same reduced pressure and temperature is

(A) 0.355 (B) 0.526 (C) 0.791 (D) 0.977

Q.16 A rigid insulated vessel is divided into two compartments by a partition. One compartment contains 12 kg of oxygen at 200 kPa and 280 K. The other compartment contains 26 kg of carbon dioxide at 400 kPa and 360 K. The specific heats at constant volume in kJ/kg.K for oxygen and carbon dioxide are 0.662 and 0.653, respectively. The partition is removed and the gases are allowed to mix. Considering both gases are ideal, the final temperature (in K) of the mixture (up to 1 decimal place) is _____.

Q.17 Moist air having 60% relative humidity, enters a steady-flow air-conditioning unit at 102 kPa and 30 °C. The volume flow rate of the moist air entering the unit is 0.1 m^3/s. The moist air leaves the unit at 95 kPa and 15 °C with a relative humidity of 100%. Liquid condensate leaves the unit at 15 °C.

For water: at 15 °C, h_f = 62.982 kJ/kg, h_g = 2528.3 kJ/kg, P_{sat} = 1.7057 kPa.
at 30 °C, h_f = 125.74 kJ/kg, h_g = 2555.6 kJ/kg, P_{sat} = 4.2469 kPa.

For air, specific heat at constant pressure is 1.004 kJ/kg.K and the specific gas constant is 0.287 kJ/kg.K.

Neglecting heat leakage to the surrounding, the magnitude of heat extracted (in kW) from the air stream (up to 2 decimal places) is _____.

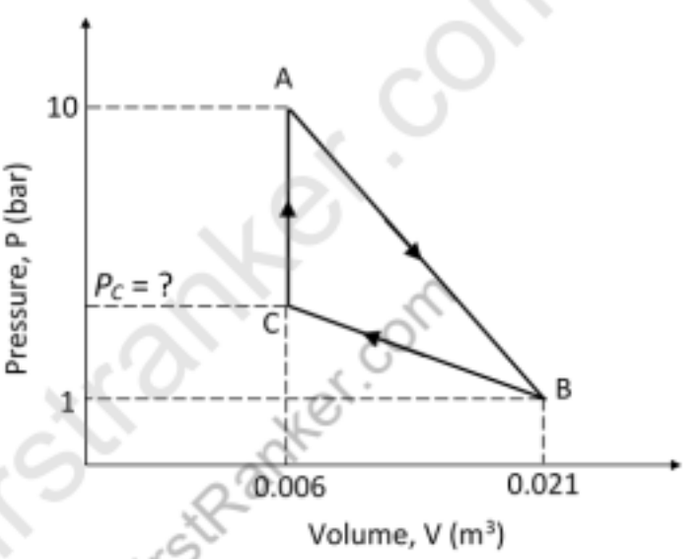
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Q.18 Air at 150 kPa and 323 K is filled in a rigid vessel of 0.05 m^3 capacity. For air, assumed as an ideal gas, specific heat at constant volume is 0.7163 kJ/kg.K and the specific gas constant is 0.287 kJ/kg.K. Neglect kinetic and potential energy changes. If 30 kJ of heat is added, the final temperature (in K) of air (up to 1 decimal place) is _____.

Q.19 Superheated steam at 2 bar and 300 °C, with an enthalpy of 3072.1 kJ/kg, enters a horizontal adiabatic nozzle with negligible velocity and leaves at 0.2 bar as saturated vapour with an enthalpy of 2609.9 kJ/kg. Assuming steady flow and neglecting the potential energy changes, the exit velocity (in m/s) of the steam (up to 1 decimal place) is _____.

Q.20 A given mass of a simple compressible substance undergoes a reversible cycle, as shown in the P-V diagram. The magnitude of the net work done during the cycle is 3 kJ. The pressure (in bar) at point C (up to 1 decimal place) is _____.



Q.21 One kmol of an ideal gas at 300 K and 10 bar is reversibly heated in a constant volume process to 500 K. It is then reversibly and isothermally expanded to 2 bar. Take C_v = 20.8 kJ/kmol.K and R = 8.314 kJ/kmol.K. The total heat supplied (in kJ) to the gas (up to 1 decimal place) is _____.

Q.22 A rigid container is completely filled with a liquid having a constant isothermal compressibility of $1.09\times10^{-4}\ \text{bar}^{-1}$ and a constant coefficient of volume expansion of $1.12\times10^{-3}\ \text{K}^{-1}$. The liquid is initially at 300 K and 1 bar. Heat is supplied to the liquid to raise its temperature to 350 K. Assuming that no phase change occurs, the final pressure (in bar) of the liquid (up to 1 decimal place) is _____.

END OF THE QUESTION PAPER

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