(b) On the basis of the data and the chemical reactions given below, find the heat of formation of $ZnSO_4$ from elements.

$Zn + S = ZnS$,	H_1 = - 44 kcal/kmol
$2\ ZnS + 3\ O_2 = 2\ ZnO + 2\ SO_2$	H_2 = -221.88 kcal/kmol
$2\ SO_2 + O_2 = 2\ SO_3$	H_3 = -46.88 kcal/kmol
$ZnO + SO_3 = ZnSO_4$	H_4 = -55.10 kcal/kmol

7 + 5 = 12

Group - E

8. (a) Calculate the internal energy of the wet steam of quality 0.8 at 1 bar.

(b) In a 1-MW steam power plant, superheated steam at 2800 kPa and 598 K enters the turbine and it is expanded to the condenser pressure of 5 kPa. Assuming an isentropic turbine efficiency of 85% and an isentropic pump efficiency of 80% determine the following
(i) The ideal Rankine cycle efficiency for the stated conditions
(ii) The thermal efficiency of the plant
(iii) The rate of steam consumption.

3 + 9 = 12

9. (a) Discuss the air-standard otto cycle and develop an expression for efficiency of the cycle.

(b) Discuss with a schematic diagram the working principle of vapour compression refrigeration cycle. How to determine the COP of the refrigeration cycle.

6 + 6 = 12

(***N.B. Steam table and Mollier diagram should be allowed in examination hall after proper verification***)

M.TECH/REEN/2ND SEM/REEN 5202/2017

ADVANCED ENGINEERING THERMODYNAMICS
(REEN 5202)

Time Allotted: 3 hrs **Full Marks: 70**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and Any 5 (five) from Group B to E, taking at least one from each group.

Candidates are required to give answer in their own words as far as practicable.

Group – A
(Multiple Choice Type Questions)

1. Choose the correct alternative for the following: **10 × 1=10**

(i) Adiabatic compression of a saturated water vapour makes it
(a) superheated (b) saturated liquid
(c) sub-cooled liquid (d) supercritical fluid.

(ii) Mollier diagram is a plot of
(a) temperature vs enthalpy (b) temperature vs entropy
(c) temperature vs humidity (d) enthalpy vs entropy.

(iii) Sound wave propagation in air exemplifies an ___ process
(a) isothermal (b) adiabatic (c) isobaric (d) isochoric.

(iv) The efficiency of an Otto engine compared to that of a Diesel engine for the same compression ratio will be
(a) more (b) less (c) same (d) cannot be predicted.

(v) The ratio of adiabatic compressibility to isothermal compressibility is
(a) 1 (b) >>1 (c) <1 (d)2.

(vi) The compressibility factor of a real gas is
(a) 1 (b) >1
(c) <1 (d) none of the above.

(vii) At higher temperatures, molal heat capacity for most of the gases (at constant pressure)
(a) varies linearly with temperature
(b) increases with increase in temperature
(c) decreases with increase in temperature
(d) is independent of temperature.

(viii) Vaporization of liquid mixture is an ____ process
(a) exothermic (b) endothermic
(c) isentropic (d) isenthalpic.

(ix) Domestic refrigerator usually works on
(a) reverse carnot cycle
(b) air refrigeration cycle
(c) absorption refrigeration cycle
(d) vapour compression refrigeration cycle.

(x) The quantitative effect of temperature on chemical equilibrium is given by
(a) Le-Chatelier's principle (b) Arhenius equation
(c) Clapeyron equation (d) Van't Hoff equation.

Group - B

2. (a) Derive a general energy balance equation of open system. Give an example of a system where rate of useful work obtained from an open system is equal to the rate of change of total enthalpy of the system.

(b) In a power plant operating in steady state, an adiabatic steam turbine receives 1 kg/s of superheated steam at 3 MPa and 400 ºC. The steam enters the turbine with a velocity of 10 m/s at an elevation of 10 m above the ground level. The steam leaves the turbine at 0.1 bar with 10% moisture content. The velocity of steam at the exit is 30 m/s and the exit is at an elevation of 4 m above the ground level. Calculate the power output of the turbine.

(4 + 2) + 6 = 12

3. (a) What do you understand by flow work? How is it different from displacement work?

(b) Show that the theoretical work required for an adiabatic single stage compressor working with an ideal gas is given by

$$W = \frac{\gamma RT_{in}}{\gamma - 1}\left[1 - \left(\frac{P_{out}}{P_{in}}\right)^{\frac{\gamma-1}{\gamma}}\right]$$

where, P_{in} and P_{out} are pressures of the gas entering and leaving the compressor respectively, T_{in} is the inlet temperature of the gas and γ is the heat capacity ratio of the ideal gas.

5 + 7 = 12

Group - C

4. (a) Show that for an irreversible process $\Delta S > \int \frac{dQ}{T}$. (Symbols bear usual significance)

(b) A rigid insulated tank of volume 3m^3 is divided into two compartments by a removable partition of negligible volume. One compartment of volume 1m^3 contains Oxygen at 500K and 10bar while 2nd one contains Nitrogen at 800K and 20bar. The partition is removed and the gas is allowed to mix. After mixing calculate total change of entropy of the process. Assume both gases to be ideal with γ = 1.4

5 + 7 = 12

5. (a) What are the availability functions of flow and non flow process?

(b) A heat exchanger is designed to cool 10 mol/s of chlorine gas from 1 bar 700 K to 450 K by a stream of air entering at 1 bar and 300 K. The specific heats of chlorine gas and air are 34 J/mol K and 29 J/mol K respectively. The air leaves the heat exchanger at 400 K and 1 bar. Assume the heat exchanger is insulated and the ambient temperature is 27ºC. Calculate the loss in available energy because of energy transfer from chlorine gas to air.

4 + 8 = 12

Group - D

6. (a) For a van der waals gas derive an expression for $C_p – C_v$.

(b) Ethane is held at 351.2K and 58.61 bar in a rigid cylinder. The maximum pressure that the cylinder can withstand is 70 bar. What is the maximum temperature upto which the cylinder can safely be heated? Given P_c = 49 bar and T_c = 305K.

6 + 6 = 12

7. (a) Calculate the theoretical flame temperature of a gas containing 30% CO and 70% N_2 when burned with 100% excess air, both air and gas initially being at 25^{0}C.
Data: Heat capacity C_P = a + bT, Kcal/kmol K
The values of the coefficients for different materials are as follows:

Material	a	b x 10^3
CO_2	6.339	10.14
O_2	6.117	3.167
N_2	6.457	1.389

The standard heat of combustion of CO (ΔH^0_{298K}) = - 67.636 kcal/mol