THERMODYNAMICS I
(CHEN 2104)

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) The point at which both liquid and gas phases are identical is called
(a) critical point (b) triple point
(c) boiling point (d) burnout point

(ii) Which of the following energy properties does not change during the change in phase of pure substance?
(a) Internal energy (b) Enthalpy
(c) Helmholtz free energy (d) Gibbs free energy

(iii) Which of the following is an undesirable property for a good refrigerant?
(a) High thermal conductivity (b) Low freezing point
(c) High latent heat of vaporization (d) High viscosity

(iv) Rankine efficiency of a steam power plant
(a) improves in summer as compared to that in winter
(b) improves in winter as compared to that in summer
(c) improves in dry season as compared to that in wet season of same temperature
(d) is unaffected by climatic condition.

(v) Choose the correct statement:
(a) The Gibbs energy when given as a function of T and P serves as a generating function for the other thermodynamic properties
(b) The work function when given as a function of T and P serves as a generating function for the other thermodynamic properties
(c) Enthalpy when given as a function of T and P serves as a generating function for the other thermodynamic properties
(d) none of the above.

(vi) The ratio of isobaric thermal expansion coefficient to isothermal compressibility coefficient for ideal gas is
(a) proportional to molar volume (b) inversely proportion to molar volume
(c) proportional to temperature (b) inversely proportional to temperature

(vii) Which of the following have the minimum value of COP for a given refrigeration effect?
(a) Reverse Carnot cycle (b) Ordinary vapour compression cycle
(c) Absorption refrigeration cycle (d) Air refrigeration cycle

(viii) Which of the following is an undesirable property for a good refrigerant?
(a) High thermal conductivity (b) Low freezing point
(c) High latent heat of vaporization (d) High viscosity

(ix) The definition for the generic residual property is:
(a) $M = M^R - M^{ig}$ (b) $M^R = M - M^{ig}$
(c) $M^{ig} = M - M^R$ (d) None of the above

(x) For a given gas the virial coefficients are
(a) functions of temperature only
(b) functions of temperature and pressure
(c) functions of temperature and volume
(d) functions of temperature, pressure and volume.

Group- B

2. (a) Explain the difference between reversible and irreversible process. 'A quasi-static process is not necessarily be a reversible process'-Justify the statement. [(CO2)Understand/LOCQ]

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

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

where, P_{in} and P_{out} are the inlet and outlet pressure of the compressor, T_{in} is the inlet temperature of the gas and γ is the heat capacity ratio of the ideal gas. [(CO5) Analyze/IOCQ]

4 + 8 = 12

3. (a) Steam enters a heat exchanger at a pressure of 0.5 MPa and temperature of 250°C, and a mass flow rate of 1 Kg/s, the steam exits as a saturated vapor at 151.8°C. Cooling water enters the heat exchanger at a temperature of 285°K and exits at an increased temperature. What is the temperature in water if its flowrate is 2 kg/s? Specific heat capacity of water is 4.2 kJ/(kg K).
[(CO1) Understand/LOCQ]

(b) Carbon dioxide gas enters a water cooled compressor at 10 psia and 20 C. It is being discharged at 500 psia and 93 C. The mass flow rate of carbon dioxide is 78 gm/s. The gas enters the compressor through a 4 inch pipe and is discharged

through 1 inch pipe. Shaft work supplied to the compressor 127 J/kg and the heat extracted from the compressor is 40000 kJ/kg. If the inlet enthalpy of carbon dioxide is 714 kJ/kg, what is the outlet enthalpy of gas. Specific volume of inlet carbon dioxide is 0.6 m^3/kg and at outlet it is 0.02 m^3/kg.
[(CO1) Analyze/IOCQ]

4 + 8 = 12

Group - C

4. (a) For one mole of a homogeneous fluid of constant composition, prove that :
(i) dU = TdS – PdV
(ii) dH = TdS + VdP
(iii) dA = -PdV – SdT. [(CO1) (Remember/LOCQ)]

(b) Prove that:
$dH = C_P dT + [V - T(\frac{\partial V}{\partial T})_P]dP$ [(CO1) (Analyze/IOCQ)]

(c) Define Simple Fluid. Prove that the acentric factor (ω) is given by:
$\omega = -1.0 - \log(P_r^{sat})_{T_r=0.7}$. [(CO2)(Analyze/IOCQ)]

3 + 4 + 5 = 12

5. (a) Prove that:
$\frac{G^R}{RT} = \int_0^P (Z-1)\frac{dP}{P}$ (at constant T). [(CO2) (Analyze/IOCQ)]

(b) Evaluate the second and third virial coefficients of R.K. equations.
[(CO2) (Analyze/IOCQ)]

(c) Prove that:
$dH = C_P dT + [V - T(\frac{\partial V}{\partial T})_P]dP$ [(CO2)(Analyze/IOCQ)]

4 + 4 + 4 = 12

Group - D

6. (a) It is desired to produce 5000 kg/h of ice at 273 K from water at 273 K, while the ambient temperature is 313 K. It is planned to supply power from a heat engine to run the refrigerator. The heat engine operates between a source at 373 K and the ambient atmosphere. Calculate i) the minimum power required to run the refrigerator, ii) the maximum efficiency of the heat engine and iii) the ratio of heat rejected by both the devices to the ambient atmosphere to the energy absorbed by the refrigerator from the water at 273 K. Data given: the latent heat of fusion of water at 273 K is 6.002 kJ/mol. [(CO5) Apply/IOCQ]

(b) An inventor claims to have designed a flow device which gives equal amounts of cold air at 250 K and hot air at 350 K at 1 bar pressure when the device is fed with air at 30 bar and 300 K. He further claims that the device does not require any energy input to operate. Treat the air is an ideal gas with γ = 1.4. Judge whether such device is thermodynamically possible or not. [(CO4) Evaluate/HOCQ]

6 + 6 = 12

7. (a) Show that, the efficiency of a reversible heat engine only depends on the temperature of thermal reservoir between which it is working. [(CO5) Understand/LOCQ]

(b) A rigid insulated tank of volume $4m^3$ is divided into two compartments by a removable partition. One compartment of volume $2m^3$ contains ideal gas A at 400 K and 5bar while the other compartment contains ideal gas B at 700 K and 15 bar. The partition is removed and the gas is allowed to mix. After mixing, calculate the total change in entropy of the process. Given, specific heat capacity ratio of both ideal gases is 1.4. [(CO4) Evaluate/HOCQ]

6 + 6 = 12

Group - E

8. (a) Derive an expression to estimate the approximate COP of an absorption refrigeration system which is considered as a combination of a heat engine and heat pump that is operated on the principal of Carnot and reverse Carnot cycle respectively. [(CO5) Remember/LOCQ]

(b) The compression ratio of an air standard ideal Otto cycle is 10. The pressure and temperature of air ($\gamma = 1.4$) at the beginning of compression stroke are 1 bar and 300 K respectively. The amount of energy added to the air as a result of combustion is 1600 kJ/kg of air. Determine the pressure and temperature of the air at the end of each process of the cycle. [(CO3) Evaluater/HOCQ]

5 + 7 = 12

9. In a process industry hot gases are delivered by different units. One unit delivers a gas A at 1 bar and 1000 K at a rate of 1 Kmol/s while a second unit delivers a gas B at 1 bar and 500 K at a rate of 3 Kmol/s. The ambient atmosphere is at 290 K. An engineer plans to use the hot gases as source and ambient atmosphere as sink to operate an heat engine and thus obtain power out of it. Calculate the maximum power that can be obtained if

(i) gases A and B are used a separate sources and. [(CO 4,5) Evaluate/HOCQ]

(ii) gases A and B are mixed and the mixture is used as source. [(CO 4,5) Evaluate/HOCQ]

Assume both the gases A nad B are ideal with $\gamma = 1.4$

6 + 6 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	22.92	44.79	32.29

Course Outcome (CO):

After completion of the course students will be able to:

1. Apply mass and energy balances to closed and open systems.
2. Evaluate the properties of non-ideal gases and quantify the deviation from ideal behavior of a real gas at any given state.
3. Solve problems involving liquefaction, refrigeration and different power cycles.

4. Evaluate entropy changes in a wide range of processes and determine the reversibility or irreversibility of a process from such calculations.
5. Calculate thermodynamic efficiency of a process.

*LOCQ: Lower Order Cognitive Question; IOCQ: Intermediate Order Cognitive Question; HOCQ: Higher Order Cognitive Question

Department & Section	Submission Link
CHE	https://classroom.google.com/c/NDA1NjMwNDY1NDYy/a/NDY3Nzg3ODExMzkx/details