Question Bank for Chemical Engineering Thermodynamics

Chapter 1: Introduction and Basic Concepts		Marks	CO	BTL
1	Compare the scope and limitations of thermodynamics.	5	C304.1	L4
2	Explain the concept of heat reservoir, heat engine and heat pump.	5	C304.1	L2
3	Compare heat pump and refrigerator.	5	C304.1	L4
4	If a man circling the earth in a spaceship weighs 300 N, where the local gravitational acceleration is 3.35 m/s^2, what would be the mass of the man and his weight on the earth, where the gravitational acceleration is 9.81 m/s^2?	5	C304.1	L3
5	A mercury manometer is used to measure pressure inside a vessel. One end of the manometer is open to the atmosphere and the manometer reads 400 mm (manometer reading). The atmospheric pressure is 1.01325 bar. Find the absolute pressure prevailing in the vessel. Data: ρ of mercury = 13.56 kg/m^3 and g = 9.81 m/s^2.	5	C304.1	L3
6	A car having a mass of 1200 kg is running at a speed of 60 km/h. Calculate the kinetic energy of the car in kJ. Also calculate the work to be done on the car to bring it to a stop.	5	C304.1	L2
7	A man weighing 700 N takes 2.5 min to climb up a staircase. Find the power developed in the man, if the staircase is made of 20 stairs, each of 0.18 m height.	5	C304.1	L2
8	Steam supplied to an engine liberates 5000 J of heat. The efficiency of the engine is 40%. Find the height to which a body of mass 10 kg can be lifted using the work output from the engine.	5	C304.1	L2
9	Nitrogen gas is confined in a cylinder and its pressure is maintained by a weight placed on the piston. The mass of the piston and the weight together is 100 kg. Assuming frictionless piston, find: (i) the force exerted by the atmosphere, the piston and the weight on the gas, (ii) the pressure of the gas, (iii) the work done by the gas (in kJ) if the gas is allowed to expand pushing up the piston and the weight by 500 mm. Data: Piston diameter = 200 mm, g = 9.81 m/s^2, Atmospheric pressure = 1.01325 bar	10	C304.1	L3
10	A balloon that was originally empty is being filled with hydrogen from a cylinder. The atmospheric pressure is 1.01325 bar. Estimate the work done by the balloon-cylinder system when the balloon attains a spherical shape 6 m in diameter.	5	C304.1	L3
11	A piston encloses a gas within a cylinder. The piston is restrained by a linear spring. The initial volume and pressure are 0.001 m3 and 1.5 bar (150 kPa) respectively. At the initial position/condition, the spring touches the piston, but exerts no force. The gas is heated until the volume becomes three times the original volume and the pressure rises to 10 bar (1000 kPa). (i)	10	C304.1	L3

<table>
<tr><td></td><td>Draw the P-V diagram for the process. (ii) Calculate the work done by the gas. (iii) Calculate the work done against the piston and against the spring. The force relation for a linear spring is: Fspring = ks d where ks is the spring constant and d is the distance displaced from the position of zero force.</td><td></td><td></td><td></td></tr>
<tr><th colspan="2">Chapter 2: First Law of Thermodynamics</th><th>Marks</th><th>CO</th><th>BTL</th></tr>
<tr><td>1</td><td>Derive the expression for first law of thermodynamics for a cyclic process.</td><td>5</td><td>C304.2</td><td>L2</td></tr>
<tr><td>2</td><td>Derive the expression for first law of thermodynamics for a steady state flow process.</td><td>5</td><td>C304.2</td><td>L2</td></tr>
<tr><td>3</td><td>A system undergoes a process 1-2 in which it absorbs 100 kJ energy as heat and does 40 kJ work. Then the system follows the process 2-3 during which 30 kJ is rejected as heat while 50 kJ work is done on it. It is desired to restore the system to the initial state by an adiabatic path. Calculate (i) the work and heat interactions during the adiabatic process and (ii) the net work done and the net heat interaction.</td><td>5</td><td>C304.2</td><td>L3</td></tr>
<tr><td>4</td><td>A system undergoes a series of processes as a result of which it is finally restored to its initial state. The work and heat interactions for processes taking place are as given below:
<table>
<tr><th>Process</th><th>ΔU (kJ)</th><th>Q (kJ)</th><th>W (kJ)</th></tr>
<tr><td>1-2</td><td>–</td><td>200</td><td>100</td></tr>
<tr><td>2-3</td><td>200</td><td>– 150</td><td>–</td></tr>
<tr><td>3-4</td><td>–</td><td>–</td><td>– 250</td></tr>
<tr><td>4-1</td><td>50</td><td>–</td><td>300</td></tr>
</table>
Calculate the unknown quantities in the above table and the net work and heat interactions.</td><td>5</td><td>C304.2</td><td>L3</td></tr>
<tr><td>5</td><td>Liquid water at 100°C (373 K) and 101.3 kPa has an internal energy of 420 kJ/kg. The specific volume of liquid water at these conditions is 1.04 × 10^{-3} m3 /kg. The water is converted to the vapour state at 200°C (473 K) and 700 kPa. At these conditions, its specific volume is 0.30 m^3 /kg and enthalpy is 2844 kJ/kg. Calculate: (ii) The enthalpy of the liquid water and (ii) The changes in internal energy and enthalpy associated with the vaporization process.</td><td>5</td><td>C304.2</td><td>L3</td></tr>
<tr><td>6</td><td>A sample of 10 g of saturated benzene at 1 atm is vaporized using a 12 V, 0.5 A electric supply. The boiling point and latent heat of vaporization of benzene are 353.2 K and 30.8 × 103 kJ/kmol respectively. Calculate: (i) The change in internal energy and (ii) The time required for complete vaporization.</td><td>5</td><td>C304.2</td><td>L3</td></tr>
<tr><td>7</td><td>The following results were obtained by conducting a trial run on steam turbine power plant:
<u>At inlet to boiler:</u>
Mass flow rate = 3600 kg/h</td><td>5</td><td>C304.2</td><td>L3</td></tr>
</table>

	Enthalpy of water = 850 kJ/kg Elevation from datum level = 4.3 m Water velocity = 5 m/s <u>At exit of turbine:</u> Steam velocity = 25 m/s Elevation from datum level = 0 m Enthalpy of steam = 2625 kJ/kg Find the power developed by the turbine if the heat added in the boiler is 2100 kJ/s.			
8	Water at 200 kPa and 82°C (355 K), enters a straight pipe with a velocity of 3 m/s, where it is heated by flue gases from outside. Steam leaves the system at 100 kPa and 150°C (423 K) with a velocity of 200 m/s. Find the heat that must have been supplied per kg of water flowing. Data: H for water = 343.3 kJ/kg, H for steam = 2776.3 kJ/kg	5	C304.2	L3
Chapter 3: P-V-T Behaviour and Heat Effect		**Marks**	**CO**	**BTL**
1	Explain the behaviour of pure fluid on a PV diagram.	5	C304.3	L2
2	Explain the behaviour of pure fluid on a PT diagram.	5	C304.3	L2
3	A certain mass of air, initially at a pressure of 480 kPa and temperature 190°C (463 K) is expanded adiabatically to a pressure of 94 kPa. It is then heated at constant volume until it attains its initial temperature when the pressure is found to be 150 kPa. State the type of compression necessary to bring the system back to its original pressure and volume. Find (i) the index of adiabatic expansion and (ii) the work done per kg of air. Data: Molecular weight of air = 29.	5	C304.2	L3
4	A gas at a pressure of 1.4 MN/m^2 and 360°C (633 K) is expanded adiabatically to a pressure of 100 kN/m^2. The gas is then heated at constant volume until it attains 360°C (633 K) where its pressure is found to be 220 kN/m^2 and finally it is compressed isothermally to the original pressure of 1.4 MN/m^2 . Sketch the process on P-V diagram and for 0.5 kmol of gas, calculate the change in internal energy during the adiabatic expansion. Assume ideal gas behaviour.	5	C304.2	L3
5	A non-flow system executes four different thermodynamic processes in sequence continuously as given below: 1-2 adiabatic compression, 2-3 isobaric heat addition, 3-4 adiabatic expansion and 4-1 constant volume heat rejection. The temperatures of the four points 1, 2, 3 and 4 are respectively 300 K, 700 K, 1500 K and 600 K. The working substance is 1 kg mass of air. Take for air: C_p = 29.14 kJ/(kmol·K) and C_v = 20.82 kJ/(kmol·K), Mol. Wt. = 29 Determine the net work done, the net heat transfer and the change in internal energy for the cycle.	5	C304.2	L3
6	1 kmol of a gas [Cp = 30 kJ/(kmol·K)] that can be approximated by the ideal gas equation PV = nRT [R = 8.31451 kJ/(kmol·K)] is initially at 27°C (300 K) and 1 bar (100 kPa). It is then heated	5	C304.2	L3

	at constant pressure to 127°C (400 K) and compressed isothermally to its initial volume. Find ΔU, ΔH, Q and W.			
7	An ideal gas is compressed adiabatically from 1.5 bar (150 kPa) and 65°C (338 K) to a pressure of 9 bar (900 kPa). The process is reversible and $\gamma = 1.23$. Calculate: (i) the work of compression, (ii) the temperature at the end of compression, (iii) the heat transferred, (iv) the change in internal energy and (v) the change in enthalpy.	5	C304.2	L3
8	One mole of an ideal gas contained in a piston-cylinder assembly is compressed from 100 kPa and 27°C (300 K) till its volume is reduced to 1/15 of the original volume. The process of compression is polytropic with n = 1.2. Determine (i) the final temperature and pressure of the gas, (ii) the work done on the gas, and (iii) the heat interaction.	5	C304.2	L3
9	Find the flow rate of steam required to produce 500 kW from an adiabatic turbine with inlet conditions of 800 kPa and 400°C (673 K) and exit conditions of 10 kPa and x = 0.95 (where x is the quality of steam). Data: For steam at 800 kPa and 673 K: H = 3267.1 kJ/kg For steam at 10 kPa and x = 0.95: HL = 191.83 kJ/kg and HV = 2584.70 kJ/kg	5	C304.2	L3
10	Nitrogen gas is to be compressed at a rate of 5000 kg/h from 100 kPa and 300 K to 1000 kPa and 450 K. Cooling water at 300 K enters the compressor at a rate of 7500 kg/h and leaves at 320 K. Determine the power required by the compressor. Data: Cp for N2 = 1.071 kJ/(kg·K) and Cp for water = 4.1868 kJ/(kg·K)	5	C304.2	L3
11	A pump is used to transfer a solution (ρ = 1200 kg/m^3) from a mixing vessel to a storage tank at a velocity of 1 m/s. The diameter of a pipe is 80 mm and the difference between the level in the mixing vessel and the storage tank is 20 m. Both the vessel and tank are open to the atmosphere. Frictional loss is 300 W. Determine: (i) the power input to the pump and (ii) the pressure increase over the pump.	5	C304.2	L3
12	An adiabatic compressor operating under steady-state conditions receives air at 1 bar and 27°C (300 K). The compressor discharges air at 10 bar. Find the power consumption of the compressor if air flows at a rate of 2 mol/s through it.	5	C304.2	L3
Chapter 4: Second & Third Law of Thermodynamics		**Marks**	**CO**	**BTL**
1	State and explain second law of thermodynamics.	5	C304.1	L1
2	Justify the equivalence of Kelvin-Planck & Clausius statements.	5	C304.1	L2
3	A small metallic object 4 kg in mass at a temperature of 500 K is thrown into the lake which is at 300 K. Calculate the change in entropy of the universe. Data: Cp of object = 0.50 kJ/(kg·K)	5	C304.2	L3
4	One mole of an ideal gas is compressed isothermally at 400 K from 100 kPa to 1000 kPa. The work required for this irreversible process is 20% more than that for a reversible compression. The heat liberated during the process of compression is absorbed by a	5	C304.2	L3

	thermal reservoir at 300 K. Calculate: (i) the entropy change of the gas, (ii) the entropy change of the reservoir and (iii) the total entropy change.			
5	A block of 10 kg ice at 273 K is dumped in an insulated vessel that contains 100 kg water at 303 K. Calculate the entropy change of the mixture. Data: Cp of water = 4.23 kJ/(kg·K) and latent heat of melting of ice at 273 K = 333.5 kJ/kg	5	C304.2	L3
6	35 kg of a steel casting at 725 K is quenched in 150 kg oil at 275 K. If there are no heat losses, calculate the change in entropy. Data: Cp of steel = 0.88 kJ/(kg·K) and Cp of oil = 2.5 kJ/(kg·K)	5	C304.2	L3
7	In a heat exchanger, cold air is heated from 293 K to 353 K by means of hot air which enters the exchanger at 423 K. The molar flow rates of both the streams are equal. The specific heat of air is 29.3 kJ/(kmol·K).	5	C304.2	L3
8	4 kg of water at 300 K are mixed with 1 kg of ice at 273 K. Assume the mixing process to be adiabatic. Determine the final temperature of mixture of ice and water and the net change of entropy. Enthalpy fusion of ice = 335 kJ/kg and Cp of water = 4.187 kJ/(kg·K)	5	C304.2	L3
Chapter 5: Thermodynamic Properties of Pure Fluids		**Marks**	**CO**	**BTL**
1	Compare work function(Helmholtz free energy) and Gibb's free energy.	5	C304.4	L4
2	Derive maxwell's equation and write its significance.	5	C304.4	L2
3	Derive Clapeyron equation.	5	C304.4	L2
4	Explain the concept of activity and its variation with pressure and temperature for a pure liquid.	5	C304.4	L2
5	Discuss the concept of refrigeration and liquefaction process.	5	C304.4	L2
6	Derive Gibb's- Helmholtz equation.	5	C304.4	L2
7	Define fugacity coefficient. Write the effect of temperature and pressure on fugacity.	5	C304.4	L2