BIRLA INSTITUTE OF TECHNOLOGY, MESRA, RANCHI
(END SEMESTER EXAMINATION)

CLASS: B.TECH./BSC. **SEMESTER : IV/II**
BRANCH: BIOTECHNOLOGY/CHEMISTRY **SESSION : SP/2025**

SUBJECT: BE210 THERMODYNAMICS OF CHEMICAL & BIOLOGICAL SYSTEMS

TIME: 3 Hours **FULL MARKS: 50**

INSTRUCTIONS:
1. The question paper contains 5 questions each of 10 marks and total 50 marks.
2. Attempt all questions.
3. The missing data, if any, may be assumed suitably.
***4*. Before attempting the question paper, be sure that you have got the correct question paper.**
5. Tables/Data hand book/Graph paper etc. to be supplied to the candidates in the examination hall.

			CO	BL
Q.1(a)	What is thermodynamic equilibrium? Describe its types.	[5]	1	1
Q.1(b)	A 1.5 kg mass of air is compressed isothermally in a piston-cylinder device from an initial pressure of 100 kPa to a final pressure of 700 kPa. The initial density of air is 1.16 kg/m^3, and the process occurs quasi-statically. Calculate the work done (in kJ) during the compression process.	[5]	2	4
Q.2(a)	Derive the steady-flow energy equation for control volumes (open systems).	[5]	1	2
Q.2(b)	A rigid vessel with a volume of 1.2 m^3 contains 2 kg of steam at a pressure of 3 bar. The steam is in a saturated mixture state. Evaluate the following: i. Dryness fraction, enthalpy, and entropy of the steam. ii. If the vessel is heated, explain how the specific volume and dryness fraction will be affected. How are these two properties related to each other? Provide a brief explanation, assuming no mass is added or removed. Properties at 3 bar: T_{sat} = 150°C; v_f = 0.00113 m^3/kg; v_g = 0.674 m^3/kg; h_f = 630.4 kJ/kg; h_{fg} = 1950.3 kJ/kg; s_f = 2.086 kJ/kg K; s_{fg} = 6.247 kJ/kg K	[5]	3	4
Q.3(a)	Discuss the two corollaries of the Second Law of Thermodynamics. Using the Clausius Inequality, show that entropy is a state function.	[5]	2	1,3
Q.3(b)	A heat engine receives 420 kJ/cycle of heat reversibly from a source at 327°C and rejects heat reversibly to a sink at 27°C. There are no other heat transfers. For each of the three hypothetical amounts of heat rejected, in (a), (b), and (c) below, compute the cyclic integral of dQ/T. From these results, determine which case is irreversible, which is reversible, and which is impossible: I. 210 kJ/cycle rejected II. 105 kJ/cycle rejected III. 315 kJ/cycle rejected	[5]	3	3
Q.4(a)	The efficiency of a Carnot engine is 25%. The efficiency is increased to 30% when the sink temperature is reduced by 20°C. What will be the source temperature?	[5]	5	3
Q.4(b)	Define Raoult's Law and explain its significance in characterizing an ideal solution. A binary solution contains 1.2 mol of component A and 0.8 mol of component B. If the activity of A in the solution is found to be 0.84, calculate the activity coefficient of A. Based on your result, would you classify this solution as ideal or non-ideal? Justify your answer.	[5]	5	3

PTO

Q.5(a)	Explain how enthalpy and entropy govern the helix–coil transition process. A short peptide undergoing this transition exhibits an enthalpy change of –30 kJ/mol and an entropy change of –100 J/mol·K during helix formation. Determine the transition temperature. Additionally, evaluate whether the helix or coil conformation is thermodynamically favored at 50°C, and justify your answer based on thermodynamic principles.	[5]	4	2,4
Q.5(b)	Metabolic pathways like glycolysis or the TCA cycle continue to proceed even though some reactions have a positive standard Gibbs free energy change (ΔG°). Why does this not halt the pathway? Additionally, in a red blood cell at 310 K, the concentration of glucose-6-phosphate is 8×10^{-5} M, and that of fructose-6-phosphate is 1.4×10^{-5} M. Given that $\Delta G^\circ = +1668$ J/mol for the phosphoglucose isomerase reaction, calculate the Gibbs free energy change (ΔG) under these cellular conditions and relate your findings to the explanation above.	[5]	4	2,5

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