Ref. No.: Ex/PE/PE/H/T/414A/2025

B.E. Power Engineering, 4rd Year, 1st Semester Examination, 2025

Design and Analysis of Thermal Systems (Hons.)

Time: Three Hours **Full Marks: 100**

Group A: CO1 (30 Marks)

1. Answer the following questions briefly (any four questions)
   a) Describe the process of thermal system modeling and its significance in design and analysis?
   b) What are the characteristics of a thermal systems?
   c) What are the common methods for analyzing the performance of thermal systems?
   d) What is Modeling in a design?
   e) How is Modeling different from Simulation?

Marks: 4 × 4 = 16

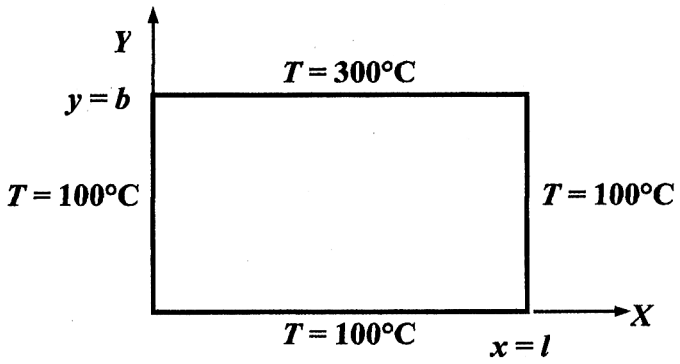
2. In a reheat steam cycle, the initial steam pressure is 150 bar, and the maximum temperature is 550°C. Given that the condenser pressure is 0.1 bar and the moisture content at the condenser inlet is 15%, calculate the following, assuming an ideal process: (a) the reheat pressure, (b) the cycle efficiency, and (c) the steam-to-fuel ratio (SSC). **Marks: 14**

OR

Design a shell-and-tube heat exchanger to cool the condensate from a methanol condenser, lowering its temperature from 95°C to 40°C. The methanol has a flow rate of 100,000 kg/h, while water, acting as the coolant, will experience a temperature increase from 25°C to 40°C. **Marks: 14**

Group B: CO2 (20 Marks)

3. A two-dimensional rectangular plate is subjected to the boundary conditions as shown in the figure below. Derive an expression for the steady-state temperature distribution $T(x, y)$ across the plate and then calculate the final expression.



OR

Considered a fin having a 'Triangular' profile and it ends up to a point. The length of the fin is 'L', the thickness is 't', and the width is 'b'. The fin material has a thermal conductivity k, while the convective heat transfer coefficient at the surface of the fin is h. The fin is attached to a base wall having temperature T_b. From the energy balance across a small element in the fin, develop the governing equation for heat transfer through the fin and write down the boundary conditions.

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If a modified Bessel equation in the form of $\frac{d^2y}{dx^2}+\frac{1}{x}\frac{dy}{dx}-y=0$ has a general solution as, $y=C_1I_0(x)+C_2K_0(x)$, where $I_0(x)$ and $K_0(x)$ are the modified zero-order Bessel functions of the first and second kind, respectively, show that the temperature distribution along the fin can be expressed as,

$\frac{T-T_\infty}{T_b-T_\infty}=\frac{I_0(2B\sqrt{x})}{I_0(2B\sqrt{L})}$; assuming $z=2B\sqrt{x}$ **Marks: = 20**

Group C: CO3 (30 Marks)

4. Answer the following questions briefly
   a) Explain the concept of exergy analysis in the design of a thermal systems.
   b) How the concept of exergy and economics analyses is connected with a thermodynamic system performance?
   c) Briefly describe about the fin effectiveness and fin efficiency. Elaborate on the criteria for optimum design of a finned surface

Marks: 3 × 4 = 12

5. In a Rankine cycle, steam inlet to the turbine is (a) dry saturated steam at 10 bar, (b) superheated steam 200°C of 10 bar. The steam is exhausted from the turbine at 0.5 bar. In each of the above case calculate (i) condition of steam after adiabatic expansion, (ii) Rankine efficiency, (iii) specific steam consumption, (iv) heat rate.

Marks: 18

OR

A steam turbine is supplied with steam at a pressure of 85 bar and 450°C. The steam is reheated at 10 bar to same temperature of 450°C. The exit pressure of the turbine is 0.08 bar. Find the efficiency of the reheat cycle and work output for the flow rate of steam is 1 kg/s. Also, calculate the work done by pump. **Marks: 18**

Group D: CO4 (20 Marks)

6. Answer all the questions (any four questions)
   a) Explain the process of performance optimization in thermal systems using modeling and simulation. Discuss the various methods and tools used to model and simulate thermal systems for performance enhancement.
   b) Define the Log Mean Temperature Difference (LMTD) for a heat exchanger and explain its physical significance. Why is a correction factor applied in heat exchanger analysis?
   c) What are the key factors affecting the performance of a heat exchanger in thermal systems? How can modeling and simulation be used to optimize its design and operation?
   d) State the design aspect for enhancing the performance of a finned heat exchanger. When application of fin is advantageous?
   e) Explain the concept of "energy and exergy analysis" in the context of thermal system optimization. How can these analyses be applied to improve the performance of energy conversion systems such as power plants and refrigeration cycles?
   f) Elaborate on the furnace exit gas temperature control and their impacts on the design of a steam generator.

Marks: 4 × 5 = 20