Ref. No Ex/ME/T/414H/2019

B.M.E. FOURTH YEAR FIRST SEMESTER EXAMINATION, 2019

Elective-II

Design of Thermal Systems

Time: Three hours **Full Marks 100**

All parts of the same question must be answered together. Assume any unfurnished data suitably

Use of Thermodynamic Tables permitted

Group I

Answer any one question

Q:1 Consider a simple vapour power cycle working on Rankine cycle with specified condenser and boiler pressures and turbine inlet temperature. Draw an information flow diagram for determining thermal efficiency and net work output. 10

Q:2 A number of isothermal vertical plates (at temperature T_a) are attached in a electronic board of length W at a very narrow distance z and cold air at temperature T_o is circulated by natural convection. The width of the plates are b. Derive an expression for heat transfer from the plates under close spacing condition. 10

Group II

Answer any one question

Q:3 The flow rate Q in circular pipes is measured as a function of the diameter D and the pressure difference Δp. The data obtained for the flow rate in m^3/s are 20

D (*m*)	**0.3**	**0.5**	**1.0**	**1.4**
Δp (atm)				
0.5	**0.13**	**0.43**	**2.1**	**4.55**
0.9	**0.25**	**0.81**	**4.0**	**8.69**
1.2	**0.34**	**1.12**	**5.5**	**11.92**
1.8	**0.54**	**1.74**	**8.59**	**18.63**

Obtain a best fit to these data, assuming a power-law dependence of Q on the two independent variables D and Δp in the for m of $Q = CD^a (\Delta p)^b$

Q:4 The temperature T of an electrically heated wire is obtained from its energy balance. If the energy input into the wire, per unit surface area, due to the electric current is 1000 W/m^2, the heat transfer coefficient h is 10 $W/(m^2K)$, and the ambient temperature is 300 K, as shown in figure, the resulting equation is obtained as 20

$$1000 = 0.5 \times 5.67 \times 10^{-8} \times [T^4 - (300)^4] + 10 \times (T - 300).$$

Calculate the temperature of the wire by the secant method. Using this numerical simulation, determine the effect of the energy input on the temperature by varying the input by ±200 W/m^2.

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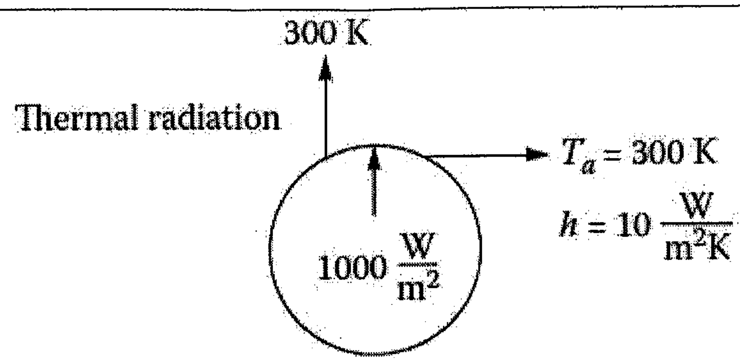


Group III

Answer any two questions

Q:5 Consider the following system of equations $\dot{X}_1 = f_1(X_1, X_2)$ and $\dot{X}_2 = f_2(X_1, X_2)$ .representing the dynamics of a two variable system. Assuming that the dynamics of the system can be represented by $\ddot{x}_1 = (f_{11} + f_{22})\dot{x}_1 - (f_{11}f_{22} - f_{21}f_{12})x_1$ .where $\frac{\partial f_i}{\partial X_j}$ is denoted by f_{ij}

Determine the different dynamical states possible for different values of the trace and determinant of the Jacobian matrix. 20

Q:6 Consider a hot water tank of volume V. Water at a temperature T_i(varies with time t) is entering the tank at a mass flow rate $\dot{m}_i$. Water is heated by an electric heater with constant power Q. A stirrer in the tank ensures uniform temperature. The exit flow rate is equal to inlet flow rate and is kept constant and the exit temperature of water is equal to the water temperature in the tank, given by T.

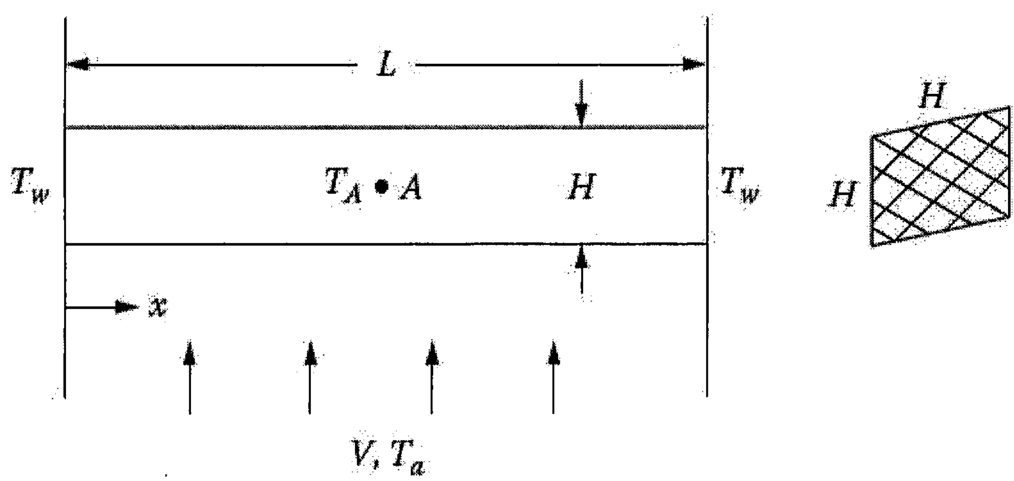
i. Develop a state space model for the dynamics of the process. 5

ii. Convert the state space model into an input-output model in terms of perturbation quantities. 4

iii. Develop a transfer function considering inlet water temperature as input and outlet water temperature as output. 5

iv. Determine the response of the system to unit step function as input perturbation. 6

Q:7	Consider a straight fin of length b, thickness t and width L losing heat by convection to the surrounding air. The base temperature is specified, the tip is insulated and the convective heat transfer co-efficient is h. (a) Find out the optimal condition of maximum heat transfer for a fixed profile area constraint. (b) Also find out the optimal thickness and length of the fin. (c) Determine the expressions for maximum heat transfer and the fin efficiency. (d) Also plot the heat transfer as a function of the thickness.	(5+ 5+ 5+ 5)
Q.8	In an oven, the support for the walls is provided by long horizontal bars, of length L and square in cross-section, attached to two vertical walls, as shown in Figure. A crossflow of ambient air, at velocity V and temperature Ta, cools the bars. The walls may be assumed to be at uniform temperature Tw. We can vary Ta, the material of the supporting bars, and the width H of the bars. The temperature at the midpoint A, T_A, must be less than a given value Tmax due to strength considerations. (a) Develop a suitable mathematical model for this system, giving the governing equations and the relevant boundary conditions. (b) Sketch the expected temperature distribution in the bar. (c) What are the fixed quantities, requirements, and design variables in the problem? (d) Discuss the simulation of the system and obtain an acceptable design for this application.	20



Group IV

Answer any one question

Q:9 Briefly explain the typical design procedure by a simple block diagram. What do you mean by design requirements, design variable, constraint and operating conditions? An annealing furnace is to be designed for a specified temperature and cooling rate. Define the requirements, design variable and operating condition. 10

Q:10 Design a counterflow, concentric-tube heat exchanger to use water for cooling hot engine oil from an industrial power station. The mass flow rate of the oil is given as 0.2 kg/s and its inlet temperature as 90°C. The water is available at 20°C, but its temperature rise is restricted to 12.5°C because of environmental concerns. The outer tube diameter must be less than 5 cm and the inner tube diameter must be greater than 1.5 cm due to constraints arising from space and piping considerations. The engine oil must be cooled to a temperature below 50°C. Even though the fluid properties vary with temperature, take these as constant for simplification, with the specific heat at constant pressure (Cp), viscosity (m), and thermal conductivity (k) as 2100, 0.03, and 0.15 for the oil, and as 4179, 8.55 × 10–4, and 0.613 for water, all in S.I. units. For Di/Do = 0.5, Re_D=140, the Nusselt number for developed annular flow is 5.74. 10

Group V

Answer any one question

Q:11(a) The heat lost by a thermal system is given as hL^2T, where h is the heattransfer coefficient, T is the temperature difference from the ambient,and L is a characteristic dimension. The heat transfer coefficient, inSI units, is given as

$$3\left(\frac{T^{1/3}}{L^{3/2}}\right) + 8.7\left(\frac{T^{1/3}}{L^{1/2}}\right)$$

It is also given that the temperature T must not exceed $7.5L^{-3/4}$.Calculate the dimension L that minimizes the heat loss,using Lagrangianmultiplier.What information does the Langrange multiplier yield? 15

(b) Explain Fibonacci search method for unimodalunivariate functions. 5

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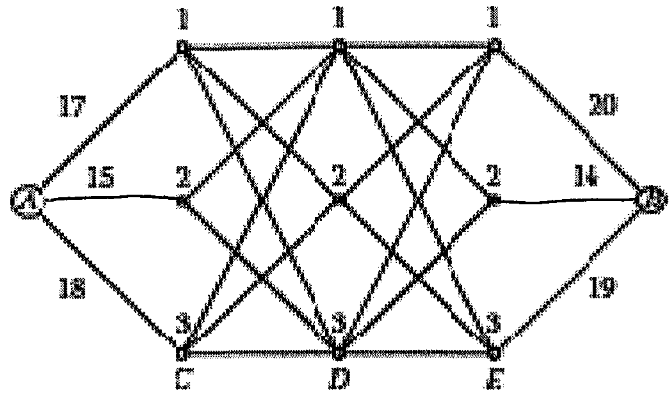
<tr><td>Q:12</td><td>

Use dynamic programming to find the path for minimum cost of transportation from point *A* to *B* in the above figure while passing through one of the three stations of locations *C*, *D*, and *E*. Employ the costs given in the figure and the following costs for going between the other locations:
1 – 1   1 – 2   1 – 3   2 – 1   2 – 2   2 – 3   3 – 1   3 – 2   3 – 3
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