P P SAVANI UNIVERSITY

Fifth Semester of B. Tech. Examination

December 2021

SEME3011 Heat Transfer

02.12.2021, Thursday **Time: 09:00 a.m. To 11:30 a.m.** **Maximum Marks: 60**

Instructions:

1. The question paper comprises of two sections.
2. Section I and II must be attempted in separate answer sheets.
3. Make suitable assumptions and draw neat figures wherever required.
4. Use of scientific calculator is allowed.

SECTION – I

Q - 1 **Answer the Following: (Any five)** **[05]**

(i) How does heat transfer differ from thermodynamics?

(ii) Under what situations does the fin efficiency becomes 100%

(iii) How does transient heat conduction differ from steady state heat conduction?

(iv) State Fourier's law of conduction.

(v) What are Fourier and Biot numbers?

(vi) What are Heisler charts?

(vii) Which factors affect the thermal conductivity of the material?

Q - 2 (a) What is meant by thermal resistance? Explain the electrical analogy for solving heat problems. **[05]**

Q - 2 (b) A steam pipe is covered with two layered of insulation, first layer being 3 cm thick and second 5 cm. The pipe is made of steel (k = 58 W/m.K) having ID of 160 mm and OD of 170 mm. The inside and outside film coefficients are 30 and 5.8 W/m_2K respectively. Calculate the heat loss per meter of pipe if the steam temperature is 300°C and air temperature 50°C. The thermal conductivity of two insulating materials are 0.17 and 0.093 W/m.K respectively. **[05]**

OR

Q - 2 (a) What is the critical thickness of insulation on a small diameter wire and a steam pipe. Explain its physical significance in both the cases & derive an expression for the same. **[05]**

Q - 2 (b) Derive general heat conduction equation in Cartesian coordinates. **[05]**

Q - 3 (a) Derive equations of temperature distribution and heat dissipation for Fin insulated at tip. **[05]**

Q - 3 (b) Explain lumped heat capacity method of heat transfer and state its assumptions. **[05]**

OR

Q - 3 (a) Define and Explain significance of fin effectiveness & fin efficiency. **[05]**

Q - 3 (b) A fin 30 cm long and 10 cm diameter throughout is made of steel alloy of thermal conductivity 43 W/m-K. The fin attached to a plane heated wall at 200 °C temp. extends into surroundings at 25°C and heat transfer coefficient of 120 W/m^2 K. Find fin efficiency and fin effectiveness. Assume that the tip of the fin is insulated and thermal radiation effect is negligible. **[05]**

Q - 4 **Attempt any one.** **[05]**

(i) Explain the situation when the addition of fins to a surface is not useful.

(ii) Explain physical significance of thermal diffusivity and conductivity?

SECTION – II

Q - 1	**Answer the Following: (Any Five)**	
(i)	Define Prandtl Number.	[05]
(ii)	Define Solid Angle.	
(iii)	Define Shape Factor.	
(iv)	State Newton 's law of cooling.	
(v)	State Stefan Boltzman 's Law for radiation.	
(vi)	Define Convection.	
Q - 2 (a)	Derive an expression for LMTD for Counter Flow heat exchanger	[06]
	OR	
Q - 2 (a)	Derive an expression for Effectiveness for parallel flow heat exchanger.	[06]
Q - 2 (b)	In a counter flow heat exchanger, water is heated from 25 ^{0}C to 65 ^{0}C by an oil of specific heat 1.45 kJ/Kg K and the mass flow rate of 0.9 Kg/s. The oil os cooled from 230 ^{0}C to 160 ^{0}C. If the overall heat transfer co-efficient is 420 W/m^2 ^{0}C, Calculate following.	[05]
	1. The rate of heat transfer	
	2. The mass flow rate of water	
	3. The surface area of heat exchanger.	
	4.	
Q - 3 (a)	Using Buckingham $\prod$ Theorem, Derive that Nusselt Number is the function of Reynold and Prandtl Number for Forced Convection.	[06]
	OR	
Q - 3 (a)	Explain the concept of Thermal and Hydrodynamic Boundary Layer.	[06]
Q - 4	**Attempt any one/two.**	[08]
(i)	Derive an expression for Radiation exchange between two infinite parallel plates.	
(ii)	Write a short note on fouling.	
(iii)	State and prove Kirchoff 's law for Radiation.	

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SECTION – I

Q - 1 **Answer the Following: (Any Five)** **[05]**

(i) What do you mean by Critical Radius of Insulation?

(ii) Define Biot Number.

(iii) Define Fourier Number.

(iv) What do you mean by Thermal Diffusivity?

(v) What do you mean by Thermal Resistance?

(vi) State any Five applications of insulation in the Engineering Field?

Q - 2 (a) Write general heat conduction equation for non-homogeneous material, self heat generating and unsteady three-dimensional heat flow in cylindrical coordinates. Name and state the unit of each variable. **[06]**

Case 1: Reduce above equation to one dimensional

Case 2: Reduce Case 1 equation for Steady State Conduction

Case 3: Reduce Case 2 equation for No Internal Heat Generation

Q - 2 (b) A Mild Steel tank of wall thickness 10 mm contains water at 90 ^{0}C. The thermal conductivity of mild steel is 50 W/m ^{0}C and the heat transfer co-efficient for inside and outside are 2800 and 11 W/m^2 ^{0}C respectively. If the atmosphere temperature is 20 ^{0}C, Calculate **[05]**

1. The rate of heat loss per m^2 of the tank surface
2. The Temperature of the outside surface of the tank

OR

Q - 2 (a) Explain Physical significance of critical thickness of insulation in the case of small diameter wire and steam pipe & derive an expression for the same. **[06]**

Q - 2 (b) An insulated steam pipe of 160 mm inner diameter and 180 mm outer diameter is covered with 40 mm thick insulation and carries steam at 200 ^{0}C. Thermal conductivity of pipe material is 29 W/m ^{0}C and of insulation is 0.23 W/m ^{0}C. The inside and outside heat transfer co-efficient are 11.6 and 23.2 W/m^2 ^{0}C respectively. If the temperature of surrounding air is 25 ^{0}C, Calculate the rate of heat loss to surrounding from the pipe of 5 m length. Also fond the interface temperatures. **[05]**

Q - 3 (a) Derive an expression for heat transfer through Rectangular infinitely long fin. **[06]**

Q - 3 (b) Estimate the time required to cook the carrot in boiling water at atmosphere pressure. The carrot is initially at room temperature of 32 ^{0}C and cooking require minimum temperature of 97 ^{0}C at the centre of the carrot. Treat the carrot as a long cylinder of 18 mm diameter and having folloeing properties. **[05]**

Density = 1025 kg/m^3

Specific Heat = 4000 J/Kg K

Thermal Conductivity = 3.45 W/m ^{0}C

Convective heat transfer co-efficient = 60 W/m^2 ^{0}C

OR

Q - 3 (a) Define fin effectiveness and Fin efficiency. Derive their equation for infinitely long fin. [06]

Q - 3 (b) A gas turbine blade made of stainless steel ($k = 32\ W/m\ ^0C$) is 70 mm long, 500 m^2 of cross section area and 120 mm perimeter. The temperature at the root of the blade is 500 ^0C and it is exposed to the combustion product of the fuel passing from the turbine at 830 ^0C. If the film co-efficient between the blade and the combustion gases is 300 $W/m^2\ ^0C$, Determine [05]

1. The temperature at the middle of the blade
2. The rate of heat flow from the blade
3.

Q - 4 State the assumptions made during lumped parameter analysis. [03]

SECTION – II

Q - 1 **Answer the Following: (Any five)** [05]

(i) What do you mean by spectral and total emissivity?

(ii) LMTD in case of counter flow heat exchanger as compared-to parallel flow heat exchanger is (a) higher (b) lower (c) same (d) depends on the area of heat exchanger

(iii) All radiations in a black body are ___
(a) reflected (b) refracted (c) transmitted (d) absorbed

(iv) State: Stefan Boltzman's law

(v) What is Newton's law of cooling?

(vi) What is the difference between natural and forced convection?

(vii) Why do we prefer to wear white cloths in Summer season?

Q - 2 (a) Distinguish between natural and forced convection heat transfer. Also Define velocity & thermal boundary layer thickness. [05]

Q - 2 (b) A long horizontal pipe of 15 cm outside diameter passes through a large room. The surface temp of the pipe is 95 °C and the surrounding air is at 25 °C. Work out the convective coefficient for free convection. Use the correlation: [05]

$Nu = 0.53\ (Gr.\ Pr)^{0.25}$

Take the air properties at mean film temp. of 60 °C as:

$C_p = 1046\ J/kg\text{-}K$ $k = 2.9 \times 10^{-2}\ W/m\text{-}K$

$v = 18.97 \times 10^{-6}\ m^2/s$ $\mu = 1.929 \times 10^{-5}\ kg/m.s$

OR

Q - 2 (a) Write Von-karman integral momentum equation, for the hydrodynamic laminar boundary layer of fluid flowing over stationary plate. Using this equation, derive the expression for hydrodynamic boundary layer thickness considering the cubic velocity profile. [05]

Q - 2 (b) Derive the equation of LMTD for counter flow heat exchangers. [05]

Q - 3 (a) How are the heat exchangers classified? Sketch the temp variations in (i) parallel flow heat exchanger (ii) counter-flow heat exchangers (iii) Boiler (iv) Condensor [05]

Q - 3 (b) In a shell and tube heat exchanger, 6 kg/s of oil flows through the shell side. The oil enters at 105 °C and leaves at 40 °C. Water flows in the tubes, entering at 32 °C and leaving at 50 °C. In addition, $C_{poil} = 2282\ J/kg.K$ and $U = 416\ W/m^2.K$. Determine number of tubes, if outer diameter of tubes is 100 mm, length of each tube is 1.9 m and take correction factor as 0.85. [05]

OR

Q - 3 (a) (1) Explain Wien's displacement law of radiation.
(2) Explain Kirchoff's law of radiation. [05]

Q - 3 (b) A spherical liquid oxygen tank 0.3 m in diameter is enclosed concentrically in a spherical container of 0.4 m diameter and the space in between is evacuated. The tank [05]

surface is at -183°C and has an emissivity 0.2. The container surface is at 15°C and has an emissivity of 0.25. Determine the net radiant heat transfer rate and rate of evaporation of liquid oxygen if its latent heat is 220 kJ/kg.

Q - 4 **Attempt any one.** [05]

(i) What is a black body? What are its properties?

(ii) Define and explain briefly the effectiveness and NTU of heat exchanger.

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