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Sixth Semester B.E. Degree Examination, June/July 2019
Heat and Mass Transfer

Time: 3 hrs. Max. Marks:100

Note: 1. ***Answer any FIVE full questions, selecting at least TWO questions from each part.***
2. ***Use of that transfer data Handbook and steam table are permitted.***

PART – A

1 a. Define the following giving units :
   i) Overall heat transfer coefficient
   ii) Thermal diffusivity
   iii) Radiation heat transfer coefficient. **(05 Marks)**

b. Derive the following expression for loss heat from a lagged pipe per square meter of metal surface per degree temperature difference between the metal and the lagging surface.

$$G'' = \frac{K}{r \log R / r}$$

Where K is thermal conductivity of lagging material, r and R are the radii of metal and lagging surface. Neglect thermal resistance due to metal surface **(07 Marks)**

c. A hot metal slab of thickness L and initial temperature T_0 is removed from a heat treating furnace and placed in a quenching oil bath at temperature T_∞. The convective heat treatment coefficient at each face is h. Write the mathematical formulation of the problem. **(08 Marks)**

2 a. A carbon steel pipe (k = 45 W/mK), 78mm in diameter and 5.5mm thick has eight longitudinal fins 1.5mm thick. Each fin extends 30mm from the pipe wall. If the wall temperature, ambient temperature and surface heat transfer coefficients are 150°C, 28°C and 75W/m^2 K is respectively. Calculate the percentage increase in heat transfer rate for the finned tube over the plain tube. **(10 Marks)**

b. The current carrying capacity of an electrical cable of 1.2cm in diameter is increased to a maximum of 15%by providing an insulation but without increasing its surface temperature of 70°C. The ambient air temperature is of 30°C. Determine the conductivity of the insulating material. Assume heat transfer coefficient on bare cable and insulated cable as 14W/m^{2}K. **(10 Marks)**

3 a. Obtain an expression for the instantaneous heat transfer and total heat transfer for lumped heat analysis treatment of heat conduction problem. **(10 Marks)**

b. A metallic sphere of radius 10mm is initially at a uniform temperature of 400°C. It is heat treated by first cooling it in air (h = 10W/m^{2}K) at 20°C until its central temperature reaches 335°C. It is then quenched in a water bath at 20°C with h = 6000W/m^{2}K, until the centre of the sphere cools from 335°C to 50°C. Compute the time required for cooling in air and water for the following physical properties of the sphere.

$\rho = 3000\,\text{Kg/m}^3$, C = 1000 J/kg K, K = 20W/mK, $\alpha = 6.66 \times 10^{-6}$ m^2/Sec

Also calculate the surface temperature at the end of cooling in water. **(10 Marks)**

4 a. Explain briefly with sketch
   i) Hydrodynamic boundary layer
   ii) Thermal boundary layer **(06 Marks)**

b. Derive Reynolds – Colburn analogy relating the drug coefficient and Stanton number. **(06 Marks)**

c. A square plate 0.5m × 0.5m with one surface insulted and other surface maintained at a uniform temperature of $T_w = 385$ K which is placed in quiescent air at atmospheric pressure and $T_\infty = 315$K. Calculate the average heat transfer coefficient for free convection for the following orientation of the hot surface.

i) The plate is horizontal and the hot surface faces up

ii) The plate is horizontal, and the hot surface faces down

The physical properties of atmospheric air at $T_f = \frac{1}{2}(385+315) = 350\text{K}$ are taken as

$\gamma = 2.076 \times 10^{-5}$ m²/Sec, $P_r = 0.697$, K = 0.03 W/mK. **(08 Marks)**

PART – B

5 a. Explain the physical significance of
(i) Prandtl number (ii) Reynold number (iii) Nusselt number iv) Groshoff number. **(08 Marks)**

b. Air at 16°C and a pressure of 1 bar is flowing over a plate at a velocity of 3m/Sec. If the plate is 30cm wide and at 60°C, find the following quantities using exact method.

i) Hydrodynamic and thermal boundary layer thickness at x = 30cm and at the distance corresponding to the transition point.

ii) Average shear stress and total drag force upto first 30cm of the plate.

iii) Total heat transfer in the laminar portion of the boundary layer properties of air at the bulk mean temperature 16 + 60/2 = 38°C are

$\rho = 1.1374$ Kg/m³, $C_p = 1.005$ kJ/Kg K, $K = 2.372 \times 10^{-2}$ W/m K, $\gamma = 16.768 \times 10^{-6}$ m²/Sec. **(12 Marks)**

6 a. Obtain an expression for the effectiveness of a counter flow heat exchanger in terms of Number of Transfer units and heat capacity ratios (R). **(10 Marks)**

b. A heat exchanger has 17.5m² available for heat transfer. It is used for cooling oil at 200°C by using water available at 20°C. The mass flows rate and specific heat of oil are 10,000 kg/hr and 1.9 kJ/Kg K and mass flow rate and specific heat of water are 3000 kg/hr and 4.187 kJ/kg K. If the overall heat transfer coefficient is 300 W/m² K. Estimate the outlet temperatures of oil and water for parallel flow and counter flow arrangement by using NTU method. **(10 Marks)**

7 a. Clearly explain the regimes of pool boiling with a neat sketch. **(06 Marks)**

b. What do you understand by

i) Mass transfer coefficient

ii) Diffusion coefficient Give their units. **(04 Marks)**

c. Steam at 100°C is condensing on cylindrical drum having a diameter of 20cm and a temperature of 90°C. If the drum is vertical how long must it to be to condense 100kg of steam per hour. The properties of the condensing water at mean temperature are given as $\rho = 965.1$ kg/m³, K = 0.673 W/mK, $\mu = 0.315 \times 10^{-3}$ kg/ms, $\gamma = 0.312 \times 10^{-6}$ m²/Sec, $h_{fg} = 2270$ kJ/kg. **(10 Marks)**

8 a. Define solid angle and intensity of radiation. For a blacks body enclosed in a hemispherical space, prove that emissive power of the black body is π times the intensity of radiation. **(10 Marks)**

b. A spherical tank with diameter of 50cm is filled with a cryogenic fluid at 70K is placed inside a spherical container of diameter 75cm and is maintained at 300K. The emmissivities of inner and outer tanks are 0.1 and 0.2 respectively. Calculate the rate of evaporation of cryogenic fluid. Take $h_{fg} = 2.1 \times 10^5$ J/kg. **(10 Marks)**