KERALA AGRICULTURAL UNIVERSITY
B.Tech.(Food Technology) 2021 Admission
III Semester Final Examination – February 2023

Pafe.2115 **Heat and Mass Transfer in Food Processing (2+1)** **Marks: 50**
Time: 2 hours

I State True or False **(10x1=10)**

1. The thermal conductivity of gases decreases with an increase in temperature.
2. For insulation, a material with lower thermal conductivity should be used for the inner layer and one with higher thermal conductivity for the outer.
3. With an increase in the thickness of insulation around a circular pipe, heat loss to the surroundings due to convection decreases, while due to conduction increases.
4. The heat transfer through a surface always increases with the use of fins.
5. Reynolds Number is the ratio of inertia force to viscous force.
6. Biot number is the ratio of convective resistance to conductive resistance.
7. For Prandtl number greater than 1, the thickness of the thermal boundary layer would be more than the thickness of the hydrodynamic boundary layer.
8. For an opaque body, $\alpha + \rho = 1$.
9. The LMTD of the counter-flow heat exchanger is greater than the LMTD of the parallel-flow heat exchanger.
10. A black body has the maximum wavelength λ_m at 2000 K. Its corresponding wavelength at 3000 K will be $\frac{2}{3}\lambda_m$.

II Write short notes on ANY FIVE of the following **(5x2=10)**

1. Explain the significance of the critical radius of insulation.
2. Define fin efficiency and fin effectiveness.
3. Define absorptivity, transmissivity, and reflectivity.
4. What is Biot number? How is it different from Nusselt number?
5. Define Prandtl number and write its physical significance.
6. What is the fouling factor? How does it affect the performance of a heat exchanger?
7. Air enters a 12 m long, 7 cm diameter pipe at 50°C at the rate of 0.06 kg/s. The air is cooled at an average rate of 400 W per m^2 surface area of the pipe. Find the air temperature at the exit of the pipe.

III Answer ANY FIVE of the following **(5x4=20)**

1. Engine oil at 60°C flows over the upper surface of a 5 m long flat plate whose temperature is 20°C with a velocity of 2 m/s. Determine the rate of heat transfer per unit width of the entire plate. (The properties of engine oil at 40°C are $\rho = 896\ \text{kg/m}^3$, Pr = 2962, $k =$ 0.144 W/m°C $\nu = 2.485\times10^{-4}\ \text{m}^2/\text{s}$)
2. In a food processing plant, a brine solution is heated from 8°C to 14°C in a double pipe heat exchanger by water entering at 55°C and leaving at 40°C at the rate of 0.18 kg/s. If the overall heat transfer coefficient is 800 W/m^2K, determine the area of the heat exchanger required
   (a) for a parallel flow arrangement
   (b) for a counterflow arrangement
   (Take c_p for water = 4.18 kJ/kg-K)

3. Define and explain the physical significance of
   (a) Schmidt number and
   (b) Sherwood number.
4. Explain the velocity boundary layer with neat sketch. Define boundary layer thickness.
5. Derive the three-dimensional general heat conduction equation in cartesian coordinates and reduce them as Poisson's, Fourier and Laplace equation by specifying the required conduction.
6. Write short notes on different boiling regimes.
7. A solid copper sphere of 10 cm diameter ($\rho = 8954\ \text{kg/m}^3$, $c_p = 383\ \text{J/kgK}$, $k = 386\ \text{W/mK}$), initially at a uniform temperature 250°C, is suddenly immersed in a well stirred fluid which is maintained at a uniform temperature 50°C. The heat transfer coefficient between the sphere and the fluid is $h = 200\ \text{W/m}^2\text{K}$. Determine the temperature of the copper block after 5 min of the immersion.

IV Write an essay on ANY ONE of the following **(1x10=10)**

1. Air at 30°C flows with a velocity of 2.8 m/s over a plate 1000 mm (length) x 600 mm (width) x 25 mm (thickness). The top surface of the plate is maintained at 90°C. If the thermal conductivity of the plate material is $25\ \text{W/m°C}$, Calculate
   (a) Heat loss by the plate
   (b) Bottom temperature of the plate for the steady state condition.
   (The thermophysical properties of air at mean film temperature 60°C are $\rho = 1.06\ \text{kg/m}^3$, $c_p = 1.005\ \text{kJ/kgK}$, $k = 0.02894\ \text{W/m°C}$ $\nu = 18.97 \times 10^{-6}\ \text{m}^2/\text{s}$, Pr = 0.696)
2. Determine heat lost by radiation per meter length of 80 mm diameter pipe at 300°C, if
   (a) Located in a large room with red brick walls at a temperature of 27°C,
   (b) Enclosed in a 160 mm diameter red brick conduit at a temperature of 27°C.
   (Take ε (pipe) = 0.79, ε (brick conduit) = 0.93)

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