Name: BITS ID:

BITS Pilani, Pilani campus, First semester 2023-2024

MF F218 Transport phenomena in manufacturing

Comprehensive Examination- Regular

Date: 09/12/2023, 9:00 am to 12:00 noon, Total marks: 70, and Weightage: 35%

Instructions

i. There are 6 questions printed on both sides of this paper. Please answer all of them.
ii. This is an open-book examination. However, the use of Textbook (Welty, Wicks, Wilson, Rorrer, Fundamentals of Momentum, Heat and Mass Transfer, 5th Edition, Wiley, 2010), class slides and handwritten notes are only permitted.
iii. State assumptions if any and assume any missing data.

Questions

1. Answer the following questions below. Each question carries 5 marks.

(a) Explain Newton's law of viscosity, Fourier's law of heat conduction and Fick's Law of Diffusion. Provide a practical example for each of its application.

(b) How does the Reynolds Transport Theorem apply to the conservation of angular momentum in a rotating fluid system? Provide relevant equations and explanations.

(c) Elaborate on the concepts of hydrodynamic and thermal boundary layers in the context of both internal and external forced convection with an example for each.

(d) Discuss the importance of thermal radiation in the Earth's energy balance and its role in the greenhouse effect.

2. Water at 20 ^oC flows through a reducer elbow and exits to the atmosphere. The diameter of the reducer elbow at inlet is D_1= 8 cm, while the diameter at its outlet is D_2= 4 cm. At a mass flow rate of 10 kg/s, the pressure p_1= 0.3 MPa. A flange with bolts arrangement fixes the reducer elbow to a vertical wall such that the direction of flow at inlet is parallel to the horizontal floor and the angle between the velocities at inlet and outlet is 120^o.

(a) Estimate the magnitude and direction of force acts on the flange arrangement. Neglect the weight of water and elbow.

(b) For part (b), if the outlet diameter is increased to 8 cm and the angle between the inlet and outlet velocities is changed to 180^o, find the magnitude and direction of force acts on the flange arrangement.

(10 marks)

3. A thermocouple is formed by soldering end-to-end wires forming a spherical bead of diameter of 0.5 mm. The thermal diffusivity of the material is 5×10^{-6} m²/s, and the thermal conductivity of the material is 20 W/mK. The probe, initially at 30 ^oC, is placed in a fluid at 100 ^oC to measure the temperature of the fluid.

(a) Given a convective heat transfer coefficient of 50 W/m²K between the wire and the fluid, determine the time constant for the probe and the time taken for it to read 98 ^oC.

(b) If the convective heat transfer coefficient is doubled, find again the time constant for the probe and the time taken for it to read 98 ^{o}C.

(10 marks)

4. Air at 30 ^{o}C flows through a tube of 5 cm diameter and 5 m length with a velocity of 1 m/s. The tube wall is at 60 ^{o}C.

(a) Determine the average heat transfer coefficient, heat transfer rate and exit temperature of air.

(b) If the velocity of air changed from 1 m/s to 10 m/s, calculate again, the average convective heat transfer coefficient, convective heat transfer rate and exit temperature of air.

(10 marks)

5. A plate heater of dimension 0.5 × 0.5 m × 0.5 cm, made using electrical elements, has a constant heat flux of 1000 W/m^2. It is placed in room air at 15 ^{o}C horizontally with the hot side facing up. Consider heat transfer from both the surfaces.

(a) Determine the value of average convective heat transfer coefficient and average plate temperature.

(b) If the above given plate heater is mounted vertically with the hot side facing left and right, calculate again the value of average convective heat transfer coefficient and average plate temperature.

(10 marks)

6. Two large parallel planes are at 100 ^{o}C and 400 ^{o}C. Determine the radiative heat exchange per unit area for the following cases.

(a) If surfaces are black

(b) If the hot one has an emissivity of 0.8 and the cooler one 0.5

(c) If a large plate is iserted between these two, the plate having an emissivity of 0.2.

(10 marks)