Ref. No. : Ex/ChE/T/414D/2018

B.E. CHEMICAL ENGINEERING FOURTH YEAR FIRST SEMESTER - 2018

ADVANCED TRANSPORT PHENOMENON

Time : Three hours

Full Marks : 100

Answer any five questions
All questions carry equal marks
Clearly state all assumptions
Notations bear usual significance

1) What is lubrication approximation? Write the assumptions required for analyzing lubrication flow. With a suitable diagram explain why the velocity profile in lubrication flow through a channel may be a combination of coquette flow and Poiseuille flow.

An incompressible fluid flows through a tube of circular cross section, for which the tube radius changes linearly from R_0, at the tube entrance to a slightly smaller value R_L at the tube exit. Assume that the Hagen-Poiseuille equation is approximately valid over a differential length, dz, of the tube so that the mass flow rate is given by,

$$w = \frac{\pi[R(z)]^4\rho}{8\mu}\left(-\frac{d\mathcal{P}}{dz}\right)$$

From the above equation derive an expression for mass flow rate using lubrication approximation.

2) A incompressible Newtonian fluid is in steady laminar motion flows through a vertical tube in upward direction and then flows down over the outside surface of the tube. Find velocity profile and mass flow rate for outside film flow. The Navier Stoke equation in cylindrical co-ordinate is given below. Clearly state all the approximations.

$$\rho\left(\frac{\partial v_z}{\partial t} + v_r\frac{\partial v_z}{\partial r} + \frac{v_\theta}{r}\frac{\partial v_z}{\partial \theta} + v_z\frac{\partial v_z}{\partial z}\right) = -\frac{\partial p}{\partial z} + \mu\left[\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial v_z}{\partial r}\right) + \frac{1}{r^2}\frac{\partial^2 v_z}{\partial \theta^2} + \frac{\partial^2 v_z}{\partial z^2}\right] + \rho g_z$$

3) Consider two horizontal parallel plates through which a highly viscous Newtonian fluid is flowing in steady laminar motion. The above plate is at temperature T_L and bottom plat is at lower temperature T_0. The above plate is moving with a velocity UL and the bottom plate is stationary. Heat is generated in the fluid due to inter layer friction. Find velocity distribution and temperature distribution in the fluid. Explain how heat transfer between fluid and upper plate is influenced by Brinkman Number. Consider parametric values of Brinkman Number as 0, 2, and 4. Use necessary schematics to explain the physics of the problem.

4) Consider Newtonian fluid is flowing through a laminar motion in a horizontal pipe. The pipe wall is subjected to uniform heat flux. Show that Nusselt Number may be given by 48/11.

5) State the assumptions for solving Stefan's problem (Melting-solidification phase change problem). Consider a liquid metal of low melting point is at temperature T_∞. The molten metal is in contact with a colder surface at temperature T_S. The Metal loses heat through the surface and solidifies. The solidification front moves with time and moving boundary problem evolves. Show that the position of the moving front is given by,

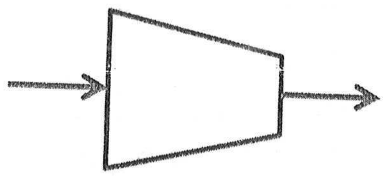
$$x = \sqrt{\frac{2k_s(T_\infty - T_s)t}{\rho_l h_{sf}}}$$

Notations have usual meaning.

6) A Newtonian liquid flows down a vertical flat plate forming a liquid film of thickness Z. The free surface is exposed to a pure sparingly soluble gas A. The gas is absorbed in the liquid. Find concentration distribution of A in liquid for short contact time. Clearly write model equations for this problem and required boundary conditions for long and short contact time.

7) Name the different flow patterns with sketch for vertical two phase flow. Define void fraction and quality related to two phase flow. Derive the relationship between void fraction and quality in gas liquid two phase flow. Write the model equations for gas-liquid separated flow.

8) Consider air flow through a variable area duct. Air enters the larger cross section at a pressure 100 kPa at 283 K with a velocity 150 m/s. the outlet flow area is half of the inlet flow area. Calculate density at the out let assuming incompressible and compressible flow. Comment on your answer.



Explain shock wave in compressible flow. Derive continuity equation and momentum equation for one dimensional compressible flow through a converging diverging nozzle. Explain how these equations differ from continuity equation and momentum equation for incompressible flow.