INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR
Mid-Autumn Semester 2018-19

Date of Examination: 24/09/2018 Session AN Duration 2 hrs Full Marks: 30
Subject No.: CH61011 Subject: Advanced Fluid Dynamics
Department: CHEMICAL ENGINEERING
Specific charts, graph paper, log book etc., required: NO.
Special Instructions (if any):

1. All Questions are compulsory.
2. Clearly write your Name, Roll No., Subject Name, and Subject Number on the Answer Book.
3. **. Also, all sub parts of each question MUST be together.**
4. Be Precise with your answers. Long, redundant answers can potentially fetch zero!
5. **No doubts will be clarified in the examination hall.**

PART A

All parts of question No. 1 must be written sequentially at one place

1. (a) Derive expression of Rate of Angular Deformation of a fluid element at a constant Z plane. Logically argue that τ_{xy} is proportional to $\left(\frac{\partial u}{\partial y}+\frac{\partial v}{\partial x}\right)$. What is a Newtonian Fluid? (1.5+2+0.5=4)

   (b) What is a Stokes Fluid? (1)

   (c) Explain the different components of τ_{ij}. (2)

   (d) Derive an expression for **Substantial Derivative**. (2)

   (e) Write the appropriate suffix of τ_1 and τ_2 in figure 1 with justification. (2)

   Total Marks in Q1: 11 marks

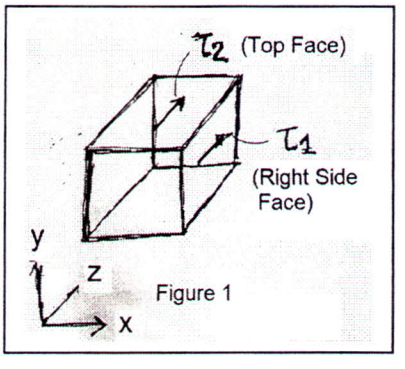

Figure 1

2. Find out the expression for shear stress profile in flow of a ***liquid*** of thickness "H" over an inclined plane making an angle θ to the horizontal. Use the Navier Equations for the Cartesian System. State all the assumptions/ conditions that you have used. **(4 marks)**
   (Note: No Governing Equation will be supplied separately)

PART B

3. Verify, if a set of objects $\tau_{1,1}=x^2$, $\tau_{1,2}=xy$, $\tau_{2,1}=xy$ and $\tau_{2,1}=y^2$ is a tensor or not? **(5 marks)**
4. In a flat but curved surface, where the awareness of a third dimension is an abstract mathematical concept, the rate of strain has to be mathematically formulated. For this, one initially located a system of curvilinear coordinates (U^1, U^2) in the surface and the distance between two adjacent points is given by $(ds)^2 = a_{\alpha,\beta} dU^\alpha dU^\beta$ (α=1,2; β=1,2), where α is the surface metric tensor.
   (a) Clearly tabulate all the steps required before reaching an expression for the rate of strain tensor, starting from the above equation. **(4 marks)**
   (b) Write an expression for the rate of strain tensor **(3 marks)**
   (c) Are the expressions reached the same, when we use moving and fixed coordinate systems? If not, indicate the possible differences in the mathematical terms involved in both these approaches **(3 marks)**