INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR

Mid-Autumn Semester Examination 2023-24

Date of Examination:22.09.2023 **Session: AN** **Duration: 2 Hrs Full Marks:30**

Subject No.: CH61011 **Subject: Advanced Fluid Dynamics**

Department/Center/School: **Chemical Engineering**

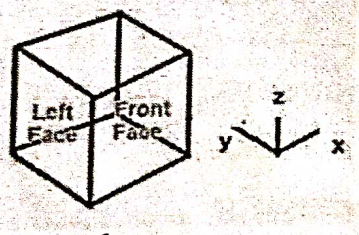
Specific charts, graph paper, log book etc., required Nil

Special Instructions (if any): Make rational assumptions wherever necessary, No doubts will be cleared by the paper setters during the examination

PART A

1. A cone and plate arrangement has been used to evaluate the nature of the flow of a complex fluid. Assuming that "T" is the total torque available by the motor to be applied on the fluid, answer the following (a) suggest the most appropriate coordinate axes (draw a figure of the setup and clearly show the coordinate axes), and write the stress tensor matrix (**without neglecting the pressure elements**). If some of the **tensor components are zero,** clearly mention them (5 marks); (b) From fundamental fluid dynamics equations, derive an expression for the velocity profile of the active component of velocity (6 marks): (c) Identify the component of stress tensor that could give the **shear viscosity of the fluid** and derive an expression for it in terms of the torque (4 marks)

PART B

2. 

For the control Volume shown in the adjoining figure, please discuss:

a) On which faces stress term τ_{yz} will be active and why? (2)

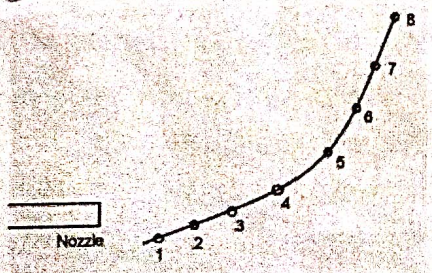
b) What components of momentum enter the CV through the bottom face? (3)

3. (a) Derive expression of Angular Deformation and rotation for a 2D flow. (2+1)

(b) Discuss why it is possible to schematically represent pure rotation but not irrotational flow. (3)

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

(d) What conclusions can you draw from the Streak line shown in the figure below? (3)



All the best ☺

INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR

End-Autumn Semester Examination 2023-24

Date of Examination: 22.11.2023 **Session: AN Duration: 3 Hrs** **Full Marks: 50**
Subject No.: CH61011 **Subject: Advanced Fluid Dynamics** **Department: Chemical Engineering**

Specific charts, graph paper, log book etc., required: Nil

Special Instructions:

- **Make rational assumptions wherever necessary**
- **No doubts will be cleared by paper setters during the examination**
- **All sub-parts of each questions and all questions of each part must be answered together.**

Part A

1. Blood coming out of a capillary vein of a human body is a common event that happens during accidents (such as cuts using a sharp object) or during surgical procedures. A blood collecting device has to be newly designed in a healthcare industry for collecting and sampling blood droplets coming out of a suddenly cut vein during a surgical procedure. The design engineers have identified this to be a capillary jet breakup problem and started solving this by assuming the bloodstream coming out to be a seminifinite cylinder. Complete the design by answering the following; (a) With a neat diagram, show the nature of the bloodstream coming out (and entering into air) from the mouth of the cut vein. Show the coordinate axes and all possible mathematical fixations that are required (***6 marks***) (b) Assuming that the **problem be** considered **as a spatial one** (that is mathematical formulations developed by considering that the jet instabilities grow across the space outside the vein mouth rather than growing over time), **derive an expression for the velocity of the jet** in terms of the **frequency of oscillations** (disturbances on the jet) of the bloodstream. (***10 marks***); (hint: you may want to use a Lagrangian coordinate system that moves with the jet and dimensionless numbers of the correlating parameters although it is not necessary to do so if derivations can be done otherwise); (c) Discuss if there are roots to the above correlation (solution in part (b)) that do not make physical meaning, preventing to materialize the final design of the device. How will you resolve such cases? (***9 marks***)

Part B

2. a) Obtain the **Prandalt Boundary** layer equations for a 1-D Laminar Flow of a Newtonian Fluid flowing over a flat plate, based on scaling analysis. (5)
   b) What is the physical significance of Reynolds Number within a boundary layer? (2)
   c) What is the shape of the Boundary Layer at the leading edge of the Plate and why? (2)
3. (a) Show that both the **mean** as well as **instantaneous fluctuation** components of velocity in a Turbulent flow independently obey the Continuity equation. (3)
   (b) How do additional stress gets augmented in Turbulent Flow? (5)
   (c) What is Homogeneous Turbulence and Stationary Turbulence? Explain with suitable figure. (3)
   (d) Starting from the simplified expression of the x component momentum balance within the boundary layer over a flat plate (no pressure drop and no effect of gravity), derive an expression of the velocity profile within the Turbulent Boundary layer in the wall co-ordinate system. Please show steps and identify the regimes. (4)
   (e) Write down some limitations of the classical description of a Turbulent Boundary Layer in wall coordinate system. (1)

End of the question paper

All the best ☺