**Department of Chemical Engineering, IIT Kharagpur**

**Fluid Mechanics (CH 20001) Mid-Semester Examination, 2013**

## 2nd year B.Tech (H)/M.Tech (Dual) No. of Students 84, Time 2 Hrs., Full Marks 30

## Open Book Examination

## Only the two textbooks by the following sets of authors are allowed

## i) Fox & McDonald and ii) Bird Stewart & Lightfoot

## Any other book(s), photocopies of text books and class notes are not allowed

There may be handwritten notes on the pages of the book but sharing of books is NOT allowed.

**Q1.** Water and oil flow down a vertical plane as shown. The flow is steady, laminar and fully developed. Simplify the Navier-Stokes equations separately for water and oil films with the relevant boundary conditions. Obtain and sketch (qualitatively) the two velocity profiles clearly emphasizing the region near the oil-water interface. **2+2+1=5**

**Q2.** An incompressible isothermal liquid exists in the annular space between two vertical coaxial cylinders, whose inner and outer wetted surfaces have radii of κ*R* and *R*, respectively with either or both cylinders rotating at constant speeds inducing a laminar circulatory motion. The gap is open to the atmosphere at the top. Derive a general expression for the velocity distribution in the liquid assuming both the inner and outer cylinders rotating with constant velocities of Ωi and Ωo respectively.

Determine the shape of the free liquid surface *z*(*r*) at steady state (neglecting end effects, if any) for the following cases: **3+2+2+2+1= 10**

|  |  |
| --- | --- |
| figure : free surface shape for rotating inner cylinder and fixed outer cylinder **Case a)** | figure : free surface shape for rotating cylinder in infinite liquid **Case b)** |
| figure : free surface shape for fixed inner cylinder and rotating outer cylinder **Case c)** | **Case (a)** when the inner cylinder is rotating and the outer cylinder is stationary. Let *zR* be the liquid height at the outer cylinder.  **Case (b)** when a single vertical cylindrical rod of radius *Ri* is rotating at a constant angular velocity Ωi in a large body of liquid. Let *zRo* be the liquid height far away from the rotating rod.  **Case (c)** when the outer cylinder is rotating at a constant angular velocity and the inner cylinder is stationary. Let *zR* be the liquid height at the outer cylinder.  Show that the result in part (c) reduces to the expected parabolic velocity distribution when the liquid is in a vertical cylindrical vessel (one cylinder only) of radius *R*, which is rotating about its own axis at a constant angular velocity Ωo Let *zR* be the liquid height at the vessel wall.  ***Contd.*** |

**Q3.** One tube of a manometer is inclined 30° with the horizontal. The vertical leg of the manometer is connected to an air line, while the inclined tube is left open to atmosphere. Both the legs are of same diameter. Oil of specific gravity 0.8 is the manometric liquid. The scale with the inclined tube is set such that when the liquid in the vertical tube is at same level as in the inclined tube, the reading in the scale is zero. If there is a deflection of 5 cm from the zero reading in the inclined tube, calculate i) the pressure in the air line, ii) the deflection one would have observed while measuring the same pressure with both the legs held vertically. **2+1**

**Q4.** Obtain the equations for the streamline and the acceleration for the following velocity fields.

1. with
2. **2+2**

**Q5.** Two coaxial glass tubes forming an annulus with small gap are immersed in water in a trough. The inner and outer radii of the annulus are ri and r0 respectively. What is the capillary rise if σ is the surface tension and θ is the contact angle? **3 Marks**

**Q6.** A spherical tank of radius 1.5 m is half filled with oil of specific gravity 0.8. If the tank is given a horizontal acceleration of 10 m/s2, calculate the inclination of the oil surface to the horizontal. Repeat the same problem with vertical instead of horizontal acceleration of same magnitude. At which point(s) of the liquid, the pressure is highest in the two cases, and what are their magnitudes? **3 Marks**

**Q7.** Theflue gas (CO2 + N2) from a burner climbs the chimney without the help of exhaust fan or a blower. What is the motive force? The burning logs in the fireplace heat the gases in the chimney to 170°C. Assume that both air and flue gases are ideal and of same molecular weights, the flow is sufficiently small such that laws of fluid statics prevail, and the pressure inside the house is same as outside. Calculate (PA – PB) if the height of the chimney is 6 meters, and the ambient temperature is 10°C. Is this pressure drop measurable by a conventional manometer? **3 Marks**

Air

A

B