BENGAL ENGINEERING AND SCIENCE UNIVERSITY, SHIBPUR
B.E. 3RD SEMESTER (AE) FINAL EXAMINATIONS, 2011
Fundamentals of Fluid Mechanics (AE 301)

Full Marks: 70 **Time: 3 hrs**

(i) Answer any **six** questions taking **three** from **each half**
(ii) All questions carry equal marks
(iii) **Do not** write anything on this question paper

First Half

1. For steady laminar fully-developed flow through a circular pipe, consider a small cylindrical control volume as shown in Fig 1. Indicate the forces acting on the C.V. Applying the momentum equation develop an expression for the velocity distribution. Mention the additional assumptions. Also, determine the radial distance from the pipe axis at which the velocity equals the average velocity.

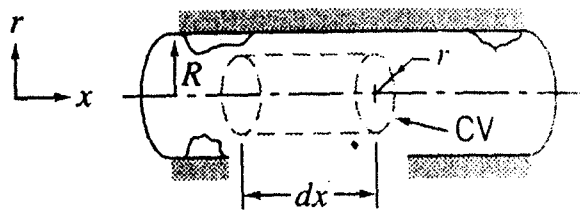

Fig. 1

2. a) Consider two tanks next to each other, separated by a common dividing wall. Water flows from tank-1 to tank-2 through a small submerged orifice (area = A_o, coefficient of discharge = C_d) fitted at the common wall. Cross-sectional areas of tank-1 and tank-2 are A_1 and A_2, respectively. Initial free surface level in tank-1 is H_0 higher than that in tank-2. How long does it take to reduce the water level difference between the tanks to H?

   b) For two-dimensional potential flow, show that stream function satisfies Laplace equation.

3. a) An open tank 3 m long and 2 m deep has a horizontal bottom and contains 1.2 m depth of water. The tank is moved down in a direction inclined to 30° with horizontal with an acceleration of 2 m/s^2. Determine the free surface slope and pressures at the bottom corners of the tank.

   b) Write short notes on (i) Centre of pressure, and (ii) Vena contracta

4. Consider a line sink of strength $-m$ at origin and a uniform stream along positive x-direction having a velocity U. Assuming frictionless and irrotational flow; derive the stream function and velocity potential for the superimposed flow-field. Determine the velocity field in terms of r and θ. Draw the streamline pattern for the superimposed flow. Determine the coordinates of the stagnation point.

Contd... to p.2

5. a) A necked-down section in a pipe flow develops low throat (suction) pressure which can aspirate fluid upward from a reservoir, as in Fig. 2. Neglecting viscous losses derive an expression for the velocity V_1 (in terms of D_1, D_2 and h) which is just sufficient to bring reservoir fluid into throat.

b) A circular disc of radius R is kept at a small height h above a fixed disc. The gap between the discs are filled by an oil of viscosity μ. If the disc is rotated at an angular velocity ω, obtain an expression for the viscous torque on the disc in steady-state. State the assumptions clearly.

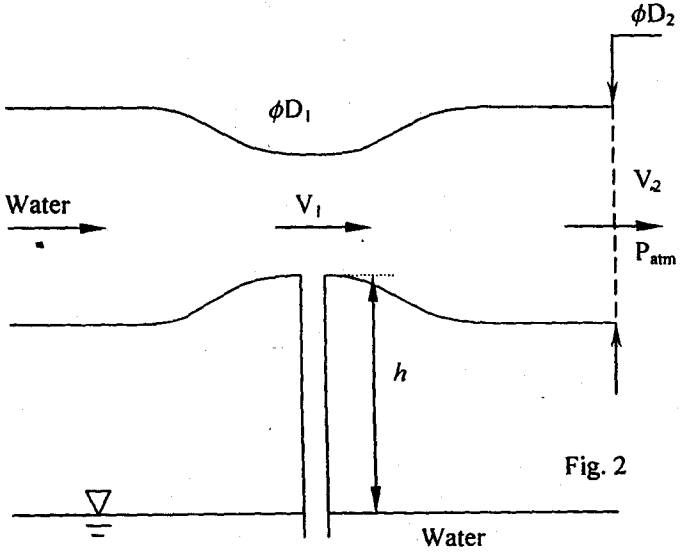

Fig. 2

Fig 2

Second Half

6 (a) What is the basic difference between Lagrangian Method and Eulerian Method of Analyses of behaviour in a continuum.

A two dimensional flow is described in the Lagrangian system as

$$x = x_o e^{-kt} + y_o (1 - e^{-2kt}) \quad \text{and} \quad y = y_o e^{kt}$$

Find (a) the equation of pathline of the particle and (b) the velocity components in Eulerian system.

(b) The velocity vector, **V**, in a three dimensional flow field is given by

$$\mathbf{V} = (4 + xy + 2t)\,\mathbf{i} + 6x^3\,\mathbf{j} + (3xt^2 + z)\,\mathbf{k}$$

Find the acceleration of the fluid element at (2, 4, -4) at t = 3.

7. Deduce 'Reynolds Transport Theorem' relating the concept of control volume to that of a control mass system in terms of a general property of the system.

Hence deduce linear momentum equation for steady flow of a fluid through a closed conduit. What is 'Momentum Correction Factor?

8. Define 'geometric similarity', 'kinematic similarity' and 'dynamic similarity' between a model and a prototype. What is 'Characteristic Length'?

The resistance, R, to the motion of a supersonic aircraft during its flight is found to depend on a characteristic length, L, speed of advancement, U, of the aircraft, viscosity, μ, density, ρ, and bulk modulus of elasticity, K of air. Obtain a functional relationship amongst a complete set of dimensionless parameters involving the above variables, by applying Buckingham's π-theorem and identify the conventional dimensionless numbers involved in the phenonmeneon.

9 a) Starting from fundamentals deduce the continuity equation in cylindrical polar coordinates for three dimensional flow of an incompressible fluid.

b) In a two dimensional flow field the velocity components in r- and in θ- directions are given by $v_r = \text{Cos}\theta/r^2$ and $v_\theta = \text{Sin}\theta/r^2$, respectively. Find the equation of the streamline passing through the point $r = 2$, $\theta = \pi/2$, if such flow exists.

10. An oil of specific gravity 0.8 flows through a 400 mm x 600 mm, 90° expanding bend in a horizontal pipeline. The pressure at inlet to the bend is 130 kPa and losses in the bend is 0.6 times the velocity head at inlet. Find the force required to support the bend if the discharge through the bend is 1 m^3/sec.