BENGAL ENGINEERING AND SCIENCE UNIVERSITY, SHIBPUR
B.E. 3RD SEMESTER (AE, ME) FINAL EXAMINATIONS, 2013
Fundamentals of Fluid Mechanics (AM 309)

Time: 3 hrs Full Marks: 70

(i) Answer any **six** questions taking three from each half
(ii) All questions carry equal marks (4 marks reserved for neatness)
(iii) **Do not** write anything on this question paper

First Half

1. a) Derive the differential equation of mass conservation (continuity) in Cartesian (x-y-z) coordinate system. 5
b) The lift force F on a missile is found to be a function of its length L, velocity V, diameter D, angle of attack α, and density 'ρ', viscosity 'μ' and speed of sound 'a' of the air. Rewrite this function in terms of dimensionless groups and identify the conventional dimensionless numbers. 6

2. a) Derive an expression for the minor head loss when a horizontal pipe of diameter d suddenly expands to a pipe having a larger diameter D. Flow is steady and incompressible; flow rate Q is known. State all other assumptions clearly. 7
b) An experiment is conducted in the Fluid Mechanics Lab of BESU to estimate the minor loss coefficients for sudden enlargement and sudden contraction. Pipe diameter is 19.6 mm and flow rate of water is 0.164 L/s. Diameter of enlargement is 26 mm, which is same as the diameter of the upstream side of contraction. Data obtained from the Piezometers installed at the upstream and downstream sides of each fitting are as follows

Piezometer reading	Enlargement	Contraction
Upstream (mm)	124	131
Downstream (mm)	131	118

Determine the loss coefficients for each fitting 4

3. a) Show that the streamlines and the equipotential lines are mutually orthogonal. 3
b) For two-dimensional potential flow, show that stream function satisfies Laplace equation.
c) Water flows out of a tank through a sharp-edged small orifice on a vertical wall, under a constant head of 2 m. The orifice diameter is 20 mm. If the free jet drops 100mm in a horizontal distance of 850 mm from the *vena contracta*, determine
   i. coefficient of velocity, C_v
   ii. discharge, if $C_c = 0.62$, and
   iii. horizontal thrust on the tank due to the water jet. 6

4. a) Show that the volume flow rate between any two points in a 2D flow field is equal to the change in stream function between those points. 5
b) The stream function for a plane potential flow is given by, $\psi = 9r^2\sin^2\theta$. Determine the velocity potential in Cartesian coordinate frame. What is the discharge between stream surfaces through the points $r = 1$, $\theta = 0$ and $r = 1$, $\theta = \pi/4$? 6

5. a) With illustrative examples distinguish between: i) streamline and streakline, ii) steady and unsteady flow 5

b) A water jet pump has jet area 0.009 m^2 and jet speed of 30.5 m/s. The jet is issued within a secondary stream of water having speed $V_s = 3$ m/s. The total area of the duct (the sum of the jet and secondary stream areas) is 0.07 m^2. The water is thoroughly mixed and leaves the jet pump as a uniform stream (see Fig 1). The pressures of the jet and the secondary stream are the same at the pump inlet. Determine the flow velocity at the pump exit and the pressure rise, $p_2 - p_1$. 6

6. a) 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 a fluid particle occupying point (2, 4, –4) at $t = 3$. 5

b) Distinguish between Lagrangian and Eulerian methods in mechanics. 3

c) Citing illustrative examples distinguish between forced and free vortex. 3

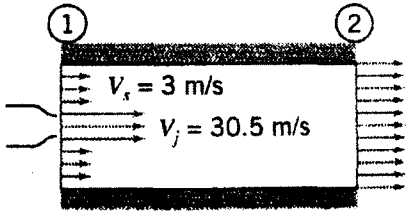

Fig. 1

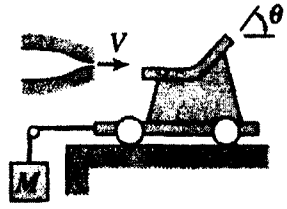

Fig. 2

7. a) Derive the equation of motion for steady, frictionless flow along a streamline. Stating additional assumption(s) derive Bernoulli's equation from the equation of motion. 4+2

b) A jet of water issuing from a stationary nozzle ($A_j = 0.05$ m^2) at 15 m/s strikes a turning vane mounted on a cart as shown in Fig 2. The vane turns the jet through an angle θ. Determine the value of the mass M required to hold the cart stationary when $\theta = 45^\circ$, 90° and 135°. 5

8. a) What is 'centre of pressure'? Show that the 'centre of pressure' on a plane immersed surface (inclined at an angle θ with respect to the free surface) always lies below its centroid. 1+5

b) A circular lamina having 1.35 m diameter is immersed in water so that the distance of its circular edge measured vertically below the free surface varies from 0.6 m to 1.5 m. Determine the total force due to water pressure acting on one side of the lamina and the depth of the 'Centre of Pressure' from the free surface. 5