INDIAN INSTITUTE OF ENGINEERING SCIENCE AND TECHNOLOGY, SHIBPUR
B.E. 4TH SEMESTER (ME) FINAL EXAMINATIONS, 2014
Mechanics of Fluids (AM 407)

Time: 3 hrs Full Marks: 70

(i) Answer any <u>**six**</u> questions by taking three from each half
(ii) The questions are of equal marks (4 marks are reserved for neatness)
(iii) **Do not** write anything on this question paper
(iv) Use separate answer script for each half

First half

1. a) Discuss briefly the techniques of delaying or preventing boundary layer separation.

   b) A supersonic aircraft flies horizontally at 1500 m altitude with a constant speed of 750 m/s. The aircraft passes directly over a stationary observer at ground. How much time elapses after it has passed over the observer before the later hears the aircraft (sonic boom)? Assume average speed of sound in the locality is 335 m/s.

   c) A solid sphere (SG = 7) of diameter 8 mm falls in an oil of density 800 kg/m^3 and attains a terminal velocity of 40 mm/sec. Find viscosity of oil. Also verify if the expression used for determination of drag force is valid.

2. Considering an infinitesimally small control volume derive x-component of Navier-Stokes equation in Cartesian co-ordinate system. State all the necessary assumptions.

3. a) Derive the expression for static pressure ratio across a normal shock in terms of Mach numbers. State the assumptions clearly.

   b) A normal shock sits at the exit of a converging-diverging nozzle (refer to Fig. 1). Mach number upstream of the shock is $M_1 = 2$. Given, $T_0 = 300$ K, $p_{atm} = 10^5$ N/m^2, $\gamma_{air} = 1.4$, and $R = 287$ J/kg.K. Determine (i) mach no. at throat, (ii) throat-to-exit area ratio, (iii) static pressure (p_1) and temperature (T_1) upstream of the shock, and (iv) stagnation pressure p_0.

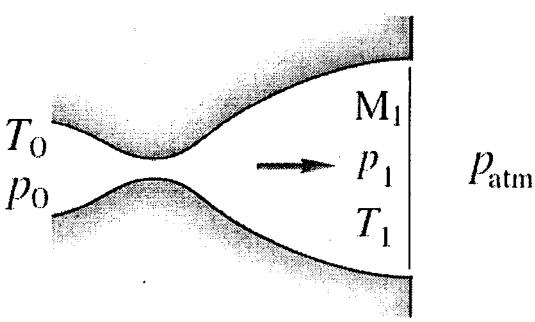

Fig. 1

[*Hint*: for air, $\gamma_{air} = 1.4$,

$$\frac{A}{A^*} = \frac{1}{M}\left[\frac{5+M^2}{6}\right]^3, \text{ and}$$

$$M_2^2 = \frac{5+M_1^2}{7M_1^2-1} \quad \text{(across a normal shock).}$$

Notations have their usual meanings]

4. In a slipper-pad bearing arrangement, a viscous oil (of constant ρ and μ) is forced into the thin gap $h(x)$ between a fixed slipper block and a wall moving at velocity U. Clearly mentioning the assumptions reduce the Navier-Stokes equations to a single differential equation for streamwise velocity. What are the proper boundary conditions? Also, deduce

Contd. to page 2

the expression for pressure distribution in the oil, assuming a linear variation of oil-film thickness, $h(x) = h_0 - (h_0 - h_L)x/L$.

5. a) Consider laminar incompressible flow induced by a two-dimensional plate of infinite extent which is pulled at a constant velocity U, as shown below. The channel is also two-dimensional and is of semi-infinite extent.
   i. Determine the velocity profiles at section 1 and section 2. Assume that the flow is fully-developed in section-2 and ambient air doesn't retard the motion.
   ii. Compute the thickness ratio t/h of the film that flows with the plate

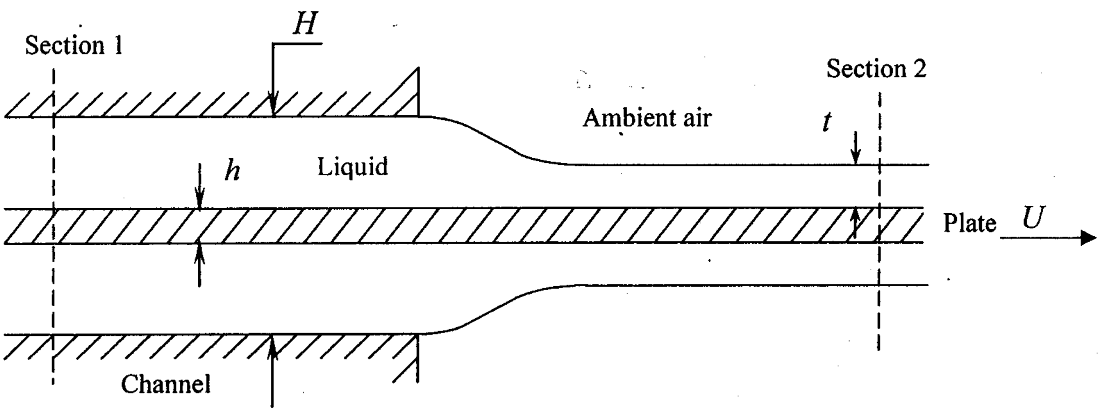

Fig. 2

b) Derive the area-velocity relationship for a quasi one-dimensional compressible flow. State and apply the assumptions involved.

SECOND HALF

6 Applying momentum integral equation and assuming a cubic velocity distribution within the boundary layer, e.g.

$$\frac{u}{U_\infty} = f(\eta) = a + b\eta + c\eta^2 + d\eta^3 , \qquad \text{where } \eta = y/\delta$$

Estimate the boundary layer thickness (δ), displacement thickness (δ^*), and local skin friction coefficient (C_{fx}) in terms of streamwise coordinate (x) and Reynolds number (Re_x) for a two dimensional, incompressible, laminar flow over a flat plate held parallel to the flow.

7.a) Derive momentum and continuity equation when water hammer takes place in a pipeline due to instantaneous closure of a valve fitted at its exit. Hence also deduce an expression for the velocity of pressure wave in the pipe in terms of diameter and wall thickness of the pipe, modulus of elasticity of the pipe material, bulk modulus of elasticity and density of the fluid flowing through the pipe.

b) Show that the time period of oscillation of a frictionless column of liquid of length, L, in a U-tube of constant bore is the same as that of a simple pendulum of length L/2 .

8. Three reservoirs A, B and C are connected by a pipe system having lengths of 700 m, 1200 m and 500m respectively and their diameters are 400 mm, 300 mm and 200 mm respectively. The water levels in reservoir A and B from datum are 50 m and 45 m respectively. The level of water in reservoir C is below that of reservoir B. Find the discharge into or from reservoirs B and C if the rate of flow from reservoir A is 150 lit/sec. Also determine the height of water level in reservoir C from datum. Take f = 0.02 for all pipes.

9.a) An oil flows from an open vessel at the rate of 1.7 cc/sec through a 450 mm long and 2.5 mm bore vertical tube. The oil surface in the vessel is 600 mm above the lower end of the tube. Neglecting the exit velocity and assuming fully developed laminar flow throughout the entire tube, determine the kinematic viscosity of the oil.

b) Two reservoirs, A and C, are connected through a 300 mm diameter pipeline 1 km long. At a point B in the pipeline, 300 mm from reservoir A, a valve is fitted on a short branch pipe, laid in parallel to the main pipe, which discharges in to atmosphere. The valve may be considered as an orifice with C_d = 0.65. If the friction factor f for all pipes is 0.03, calculate the rate of discharge to the reservoir C when the valve on the branch line at B is fully open. Also estimate the flow through the short pipe into atmosphere.

10. Write, with sketches wherever necessary, short notes on any three of the following :

(i) Mach Cone, (ii) Boundary Layer Separation, (iii) Friction velocity, (iv) Economic diameter of Pipe
(v) Strouhal Number