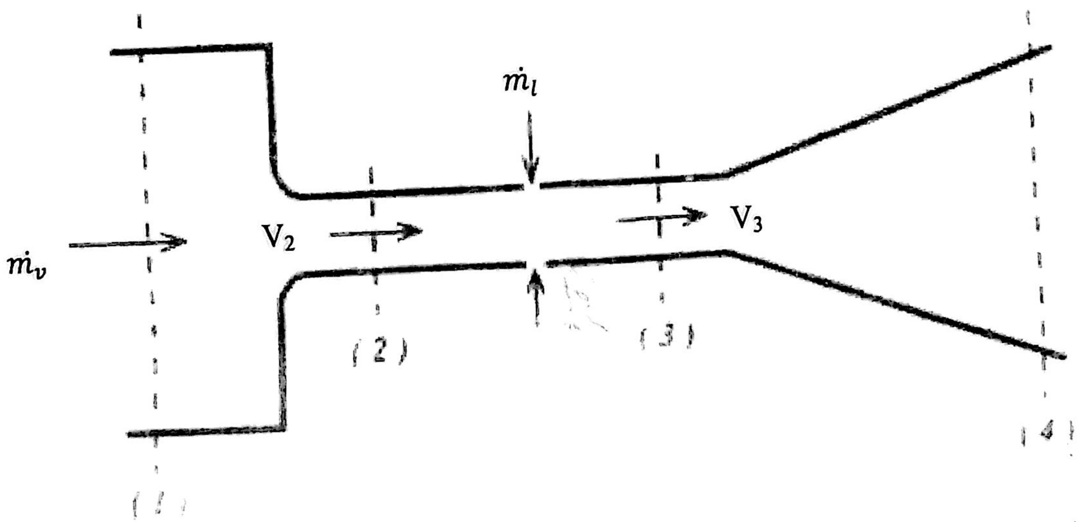
APL105
MECHANICS OF SOLIDS AND FLUIDS
Majors (Part B)

Max. Marks 60 5-5-2016

Please answer all the questions. Bold face indicate vectors.

Q1 Given a velocity field $\vec{V} = x^2\,\mathbf{i} - 2xy\mathbf{j}$ and the temperature field T = 3xyt .
Determine with working:
a) If the flow field is incompressible.
b) The streamfunction ψ (if it exists) for this flow.
c) acceleration of the fluid particle at the point (1,1) at t= 1 sec.
d) The rate of change of temperature with time of a particle moving in the flow at (1,1) at t= 1 sec.
e) The rate of change of temperature with time as measured by a thermometer which is fixed at (1,1) at t= 1 sec.
f) The rate of change of velocity with time as measured by a probe which is fixed at (1,1) at t= 1 sec.
(14 marks)

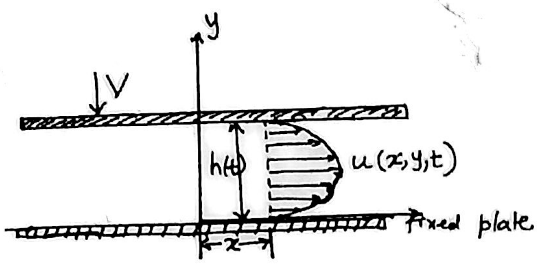
Q2. In the apparatus shown steam at steady mass flow rate $\dot{m}_v$ and density ρ_v accelerates in an inviscid flow from a very large slow speed reservoir (section 1) through a nozzle to the speed V_2 in a duct of constant cross-sectional area A. Spray nozzles surrounding the duct inject liquid water radially at sufficient mass flow rate $\dot{m}_l$ to condense all the steam so that at section 3 only liquid flows at speed V_3 and density ρ_l. The liquid stream is decelerated in an inviscid flow through a diffuser to a very low speed at section 4. The flow is steady and can be treated as incompressible in section from 1 to 2 and in section from 3 to 4 with densities ρ_v and ρ_l respectively. Express the answers in terms of ρ_v, ρ_l, $\dot{m}_v$ and $\dot{m}_l$.
a) Derive an expression for the velocity ratio V_3/V_2 .
b) Derive an expression for the dimensionless pressure change $\dfrac{(p_2-p_3)}{(\frac{\rho_v}{2})V_2^2}$.
c) Find the condition that the downstream pressure p_4 is greater than p_1. (16 marks)



Q3. A viscous incompressible fluid is squeezed out of a gap between two parallel plates with the upper plate moving downwards at a speed V and the lower plate being stationary. Assume 2 dimensional flow. The u component of the velocity is has a distribution given by:

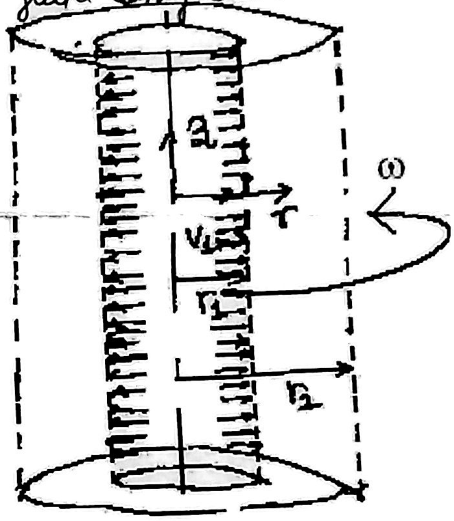
$u(x,y,t) = f(x)\left[\frac{y}{h} - \frac{y^2}{h^2}\right]$, where f(x) is a function of x only. Note the dependence of u on t comes through h which is a function of t. Since the y axis is a plane of symmetry and the flow to the left is a mirror image of flow to the right, u (0,y,t) = 0.

Find f(x) in terms of x, V and h. (10 marks)



Q4. In an industrial process a constant property Newtonian fluid at pressure p_1 is sprayed out of a porous cylinder of radius r_1. There is another concentric porous cylinder of radius r_2 through which the fluid moves out. The inner cylinder is fixed with fluid coming out. radial velocity V_1 where as the outer cylinder rotates with constai angular velo ω following assumptions can be made:

i) Gravity can be neglected.
ii) The flow is axisymmetric.
iii) Since the cylinders are long, the velocity profile does not change with z.
iv) The flow is steady.
v) $p = p_{atm}$ outside the outer cylinder.
vi) $V_z = 0$.



a) State the boundary conditions on V_r, V_θ and p.

Simplify the continuity and Navier Stokes equations and obtain the following:

b) an expression for Vr.
c) an ODE for V_θ.
d) an ODE for p. (20 marks)

Reynolds Transport theorem

$$\frac{dB}{dt} = \frac{\partial}{\partial t}\iiint_{\forall} \beta \rho \, d\forall + \oint_{cs} \beta(\rho \vec{V}\cdot\hat{n})\, dA$$

mass balance: $\beta = 1$, momentum balance: $\beta = \vec{V}$