Fluid Mechanics (ME21101), Mid-semester Examination, September 2010 Time- 2 hours, Full Marks- 60

Q1.

(a) State the assumptions under which the following expressions/ formulae are valid (symbols have usual meaning):

(i) Metacentric height: $GM = \frac{I}{V} - BG$

(ii) $\frac{p_1}{\rho g} + \frac{V_1^2}{2g} + z_1 = \frac{p_2}{\rho g} + \frac{V_2^2}{2g} + z_2$, between any two points 1 and 2 in the flow field.

(iii) $\frac{\partial(\rho u)}{\partial x} + \frac{\partial(\rho v)}{\partial y} = 0$

(b) Explain why:

(i) Incompressible flow may be of variable density

(ii) A time dependent velocity field may be non-accelerating

[10 Marks]

Q2.

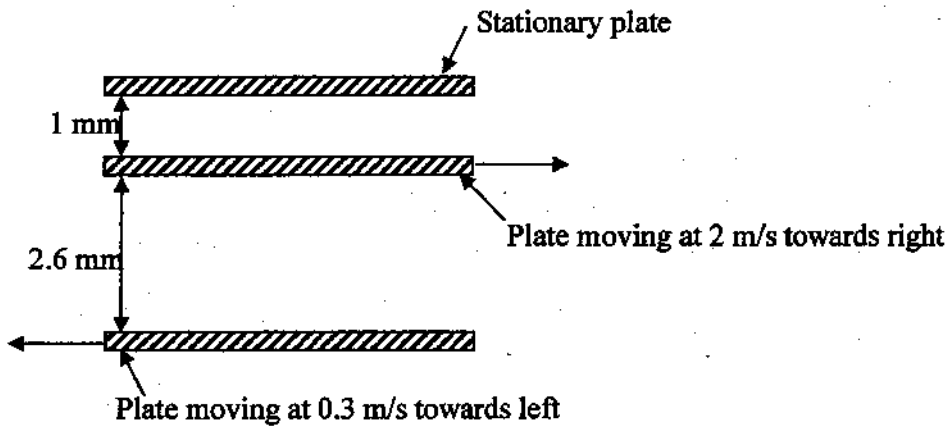
(a) Write the stress tensor components for a fluid at rest.

(b) A soap bubble of radius r has a liquid-vapor surface tension coefficient of σ. What is the pressure difference between the inside and outside of the bubble? Is the pressure greater at inside or outside?

(c) A thin 40 cm×40 cm flat plate is pulled at the rate of 2 m/s horizontally through a 3.6 mm thick oil layer sandwiched between two plates, one stationary and the other moving at a constant velocity of 0.3 m/s. Viscosity of the oil is 0.027 Pa.s. Assuming velocity in each oil layer to vary linearly,

(i) Sketch the velocity profile and find the location where the oil velocity is zero.

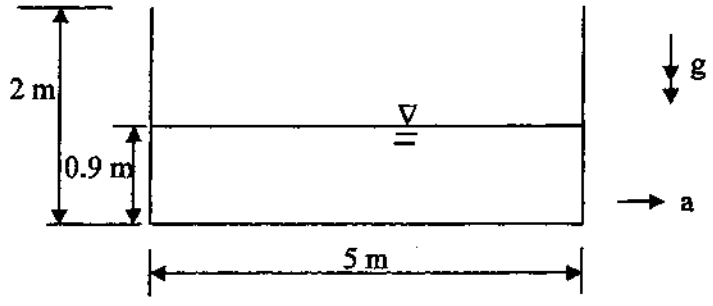
(ii) Determine the force that needs to be applied to the plate moving at 2 m/s to maintain its motion.



[2+3+10 = 15 marks]

Q3.

(a) The tank shown in the figure accelerates towards the right at 4.5 m/s^2. Will the water spill (justify your answer with reasons)? If so, by what amount?



(b) A wooden block in the form of a rectangular prism floats with its shortest axis vertical. The block is 40 cm long, 20 cm wide, and 15 cm deep, with a depth of immersion of 12 cm. Will the block float stably? Given: density of water as 1000 kg/m^3.

[8+7 = 15 marks]

Q4.

(a) A velocity field is described by the following components: $u = ax(1+2t)$, $v = by$, $w = 0$

(i) Can this be a valid description of a physically realizable flow field? Justify.

(ii) A fluorescent die is injected into the flow through the point (x_0, y_0) over a time interval $[t_0, t_f]$. At $t = t_f$, a thin coloured line can be seen in the flow. What is the equation of that line?

(b) A two-dimensional inviscid velocity field is described as $\vec{V} = Ax\hat{i} - Ay\hat{j}$, where A is a time-independent constant.

(i) Derive an equation for pressure difference between two points 1 and 2 in the flow field, given that the body force (per unit mass) is described as $g\hat{i}$. Start your derivations from first principles of force balance over a differential control volume. State any other assumptions you make.

(ii) Sketch the deformed configuration of an originally rectangular fluid element in the above flow field..

[8+12 = 20 marks]