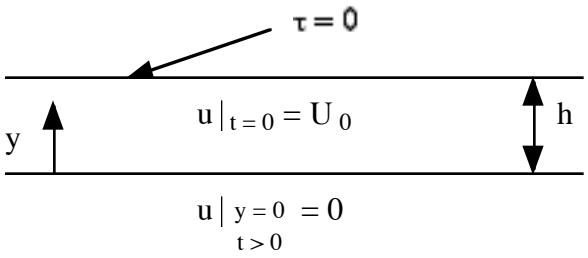
CBE 60544 Transport Phenomena I
First Hour Exam

Closed Books and Notes

1). (20 points) Consider the flow depicted below. A layer of fluid of thickness h is placed on a belt, intially moving with a uniform velocity U_0 (the belt and the fluid both move with this velocity). At time t = 0 the belt stops (e.g., the velocity at y = 0 is zero). We wish to determine how far a spot on the upper surface (y = h) is displaced (relative to the belt, which is no longer moving!) before coming to rest. The upper surface as stress-free.



a). Write down the governing equation and boundary conditions and render them dimensionless. How does the final displacement depend on the parameters of the problem?

b). Solve for the final displacement.

c). The complete solution obtained in part b is an infinite series. Quantitatively, what is the magnitude of the error if we only keep the lead term of the series?

2). (20 points) The belt of problem 1 is now moved back and forth in an oscillatory manner such that its displacement is given by $\Delta x \mid_{y=0} = \Delta x_0 \sin(\omega t)$. **Estimate** the amplitude of the displacement of the upper surface $\Delta x \mid_{y=h}$ **in the limit of high frequencies**. What dimensionless parameter does it depend on?

3). (10 points) Consider a particle fixed at the origin at zero Reynolds number in the pure straining flow $u_j^\infty = E_{jk} x_k$ where E_{jk} is a symmetric, second order, physical tensor. We wish to examine the torque M_i on the particle due to E_{jk}.

a). What is the most general tensorial relationship for an arbitrarily shaped particle between M_i and E_{jk}? What can you say in general about this tensor?

b). Show that if the particle is a body of revolution with fore-and-aft symmetry whose orientation is specified by the director p_i, then the tensor for part (a) may be reduced to a single term (e.g., glop multiplied by one unknown scalar constant).

c). What is this tensor if the particle is a sphere?