

APL361 (2025-2026-I): Quiz-2

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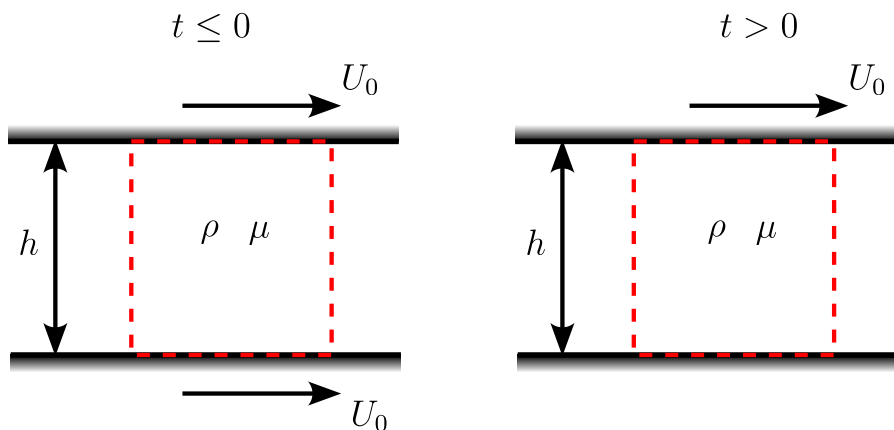
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Maximum score is 40. There are 2 questions in total. Time limit is 60 minutes. Clearly write all your assumptions and steps. No marks will be given for correct answers without any steps.

1. Electrohydrodynamics is the study of electric field driven fluid flow of a dielectric fluid (fluid with bulk charge density). For a steady electric field $\underline{E}$ on a dielectric fluid of permittivity ϵ , the Coulombic force per unit volume is given by $\underline{F}_e = \underline{E} \nabla \cdot (\epsilon \underline{E}) - \frac{1}{2} |\underline{E}|^2 \nabla \epsilon$. Steady electric field implies $\nabla \times \underline{E} = 0$.

For an interface between two dielectric Newtonian isotropic fluids of permittivity, viscosity, and density $\epsilon_1, \mu_1, \rho_1$ and $\epsilon_2, \mu_2, \rho_2$, respectively, with uniform surface tension coefficient σ , derive the dynamic interface condition. **(10)**

2. Two infinitely long plates separated by a gap h are moving with constant speed U_0 as shown. The plates have been moving for a very long time. At an instant (end of time $t = 0$), the bottom plate is stopped and brought to rest impulsively. For $t > 0$, the top plate continues to move with bottom plate at rest. Assume 2D planar flow at all times and that the plates are hard walls.



Problem 2

- (a) Show that the flow is uni-directional. **(1)**
- (b) Since the plates have been moving for a very long time before the bottom plate stops, the flow between them is steady. Compute this steady solution. **(2)**
- (c) Compute the unsteady solution after $t > 0$. **(20)**
- (d) What is the steady solution for $t > 0$? **(1)**
- (e) What is the change in total vorticity ($\underline{\omega} = \nabla \times \underline{u}$) inside the square shown by red dashed lines as the bottom plate stops? Compute this change between the two steady state solutions. Justify this change in vorticity. **(3)**
- (f) Sketch the variation of vorticity in time. Show the initial, final, and atleast two intermediate states. **(3)**