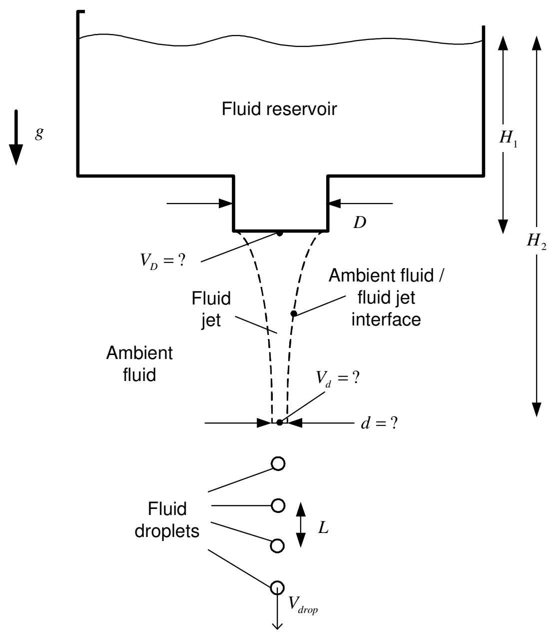
Qualifying Exam- Fluids 1- Fall 2007

Fluids1: Problem A (estimated time 40 minutes, 25 total points)

Given:

- A semi-infinite reservoir possessing a constant fluid height has a gravity driven fluid jet issuing from a circular orifice of diameter D (known) into an ambient fluid (fluid jet and ambient fluid are different materials) as shown below. Assume atmospheric pressure acts everywhere.
- As this liquid jet falls under the force of gravity, it accelerates and decreases in diameter. At some distance, H_2, the jet diameter is d (unknown). At some point beyond H_2, the jet undergoes an instability process and breaks up into spherical droplets that possess a velocity V_{drop} and are separated by a distance L. This problem focuses on the fluid dynamic prior to the break up process.

Schematic:



Find:

a) Assuming that the **<u>ambient fluid is air and the fluid reservoir contains water</u>**, determine the velocity at the center of the orifice exit V_D. List your assumptions in making this calculation. **(5 points)**

b) What is the boundary condition at the ambient fluid / fluid jet interface? Can any approximations be made for an air / water interface? **(5 points)**

c) For the fluid jet in a), determine the velocity at the bottom of the jet V_d. List your assumptions in making this calculation. **(4 points)**

d) For the fluid jet in a), determine the diameter at the bottom of the jet d. List your assumptions in making this calculation. **(5 points)**

e) If the ambient fluid was changed to oil and the fluid reservoir remained water, would the calculation methods and assumptions in a) – d) change? If so, how? **(6 points)**

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Fluids1: Problem B (estimated time 45 minutes, 25 total points)

Given:

- Fully-developed flow between two infinite, parallel plates separated by a distance h and driven by an oscillating pressure gradient $\frac{1}{\rho}\frac{\partial p}{\partial x} = \text{Re}\left\{Ke^{j\omega t}\right\}$.

Find:

a) Reduce the Navier-Stokes equations to the appropriate PDE governing this flow and state the boundary and initial conditions. **(3 points)**
b) Solve this PDE in terms of the axial velocity field for the sinusoidal steady state solution. **(6 points)**
c) Consider the Stokes number for this problem $S = \sqrt{h^2\omega/4\nu}$. Explain the physical meaning. **(3 points)**
d) Physically (NOT MATHEMATICALLY) discuss the limit of the solution for very large frequencies and very small frequencies. Discuss the two classic Navier-Stokes solutions at very high and very low oscillation frequencies **(4 points)**
e) Sketch the magnitude of non-dimensional velocity field for several values of the Stokes number (0,2,10, and 30). **(3 points)**
f) At $S = 30$, the maximum velocity magnitude does not occur at the centerline. Rather, there is a velocity overshoot near the wall. Physically, describe the underlying cause of this phenomenon. **(3 points)**
g) Discuss the generation and decay (destruction) of voriticity generation for both cases in d). **(3 points)**

Schematic: