The Fluid Mechanics Qualifying Examination

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Format: A single examination of 60minutes length. The first 30 minutes are spent on your own developing a written solution to the assigned problem. Followed immediately by a 30minute presentation at the blackboard in front of three or four faculty members outlining the key features of the solution. A single score (out of 10) is assigned; based primarily on the oral presentation together with additional consideration of the written supporting material. The Hydrodynamics and Geophysical Fluid Dynamics exams (from former OE Dept.) follow the same format. A student may take only one of these three exams.

Goal of the examination: the central goal of the fluids qualifying exam is to explore the candidate's knowledge of the fundamental physical principles governing fluid flow and the ability to apply these principles in problems of real engineering interest. Little credit is given for being able to write down mathematical results (e.g. the Navier-Stokes equations) in their full glory. Rather, we seek to see if a candidate is able to understand which contributions to the governing equations, and which physical phenomena, may be important in a given type of problem. The ability to make engineering approximations and estimation is key. Being able to develop scalings to estimate for competing effects and developing non-dimensional forms of appropriate results is also a central feature of many of the problems.

Background. The desired preparation for the qualifying exam is a successful pass (B or higher) of a first level graduate class in fluid mechanics such as 2.25 (or possibly 2.21). Passing the exam having taken only a good undergraduate class in Fluid Mechanics is also possible; however the problems considered in 2.25 and in the Qualifying exam tend to be more involved and focus more on the art of estimation and extracting the essential physics, rather than the 'turn-the-crank' type of problems typically considered at the undergraduate level.

Hints and Guidelines

Successful candidates have a good body of basic fluid mechanics knowledge *at their fingertips.* This enables them to focus on understanding the key features of the assigned problem without having to worry about writing down the equation correctly, missing essential terms or getting units right. The following is a list of *some* of the most important concepts to master:

- Understand the definitions and physical interpretation of the terms in conservation laws for mass, momentum, angular momentum.
- Ability to interconvert from Eulerian/Lagrangian reference frames (Reynolds transport theorem)
- Ability to select and draw control volumes and control surfaces appropriate to the problem.
- Physical units <u>and the magnitudes</u> of essential fluid properties (e.g. density, viscosity, surface tension) for common fluids (water, oil, air…).
- Definitions and physical interpretation of the terms entering definitions of common dimensionless groups (Reynolds number, Prandtl number, Froude number, drag coefficients, etc).
- A knowledge of order of magnitude values for drag coefficients for simple objects (e.g. for blunt bodies such as spheres, flat plates); and an understanding of how drag forces scale with velocity in the limits of high and low Reynolds numbers.
- Ability to make order of magnitude estimates of different terms in the governing equations (continuity, Navier-Stokes equations).
- Limiting forms of the Navier-Stokes equations resulting from such scalings (e.g. the lubrication equation, the Euler equation, boundary layer equations).