409.319A

Aero Thermo Hydro Engineers Nexus Application

Seoul National University
Fall 2018

Midterm Exam

1. Bathyscaphe **20%**

Refer to http://en.wikipedia.org/wiki/Bathyscaphe. The Swiss scientist Auguste Picard developed a navigable diving vessel, the "bathyscaphe," to investigate the ocean at great depths. A bathyscaphe a free-diving self-propelled deep-sea submersible, consisting of a crew cabin similar to a bathysphere, but suspended below a float rather than from a surface cable, as in the classic bathysphere design. In 1960, his son Jacques, accompanied by Lt. Don Walsh of the U.S. Navy, reached a depth of 10, 916 m in the Pacific's Mariana Trench.

A. Sketch the internal arrangement of a representative bathyscaphe of your own finding.
B. Supposing that the ocean is at constant temperature, has a density of 1030 kg/m^3 at sea level, and can be characterized by a constant isothermal bulk compressibility, compute the pressure at a depth of 11 km assuming the density is constant at the sea level value, and taking the water's compressibility into account.
C. What if the ocean temperature varies as in the physically realistic case, the sea water density varies, and its bulk compressibility, or modulus, changes? Discuss as fully quantitatively as you possibly can.
D. Now, should a scientist from nowhere be planning to detonate an atomic bomb inside Mariana Trench, what will it be looking like? Use dimensional analysis to study the propagation of the shock wave from a philosopher's, mathematician's, and engineer's point of view.

2. Earth's Atmosphere **20%**

The pressure distribution in a static, constant temperature planetary atmosphere, modeled as an ideal gas, can be expressed in terms of z the altitude above a reference altitude $z = 0$, P_0 the absolute pressure at $z = 0$, and H a length scale characterizing the atmosphere. Its value may as well be determined by the gravitational acceleration and the parameters appearing in the ideal gas equation of state. For the standard isothermal model of the earth's atmosphere $T = 288$ K, $P_0 = 1.013 \times 10^5$ Pa if $z = 0$ at sea level. Note that the distribution given above is based on the assumption that $H << a$ the earth's radius. Suppose a sounding rocket or balloon equipped with a static pressure sensor is traveling through the atmosphere with given velocity (v_x, v_y, v_z).

A. Derive an expression for the rate of change of pressure recorded by the rocket's sensor.
B. Evaluate this time of change at an altitude z = 20,000 m for a rocket traveling upward through the earth's atmosphere with a direction of 30◦ from the vertical and a speed of 465 m/s.
C. Suppose a rocket carries instruments that measure both the instantaneous atmospheric pressure P and the rate of change of that pressure, dP/dt. Given the value of these two quantities at a particular time and P_0 and H, derive expressions for the rocket's instantaneous altitude and vertical upward velocity.
D. Suppose the Earth's atmosphere is isothermal and radially symmetric around a perfectly spherical earth with radius a = 6400 km. What is the total mass of the Earth's atmosphere? What fraction is this of the solid and liquid parts of the planet's mass?

3. Discharge of Water from a Long Pipe **20%**

In addition to understanding the effects of fluid acceleration in steady flow, we are also interested in impulsively started flows and transient flows. In fact, the unsteady Bernoulli equation is not necessarily a very useful result in general since the temporal term can change dramatically from one point to another. To use this in practice we'd need to be able to draw streamlines at each instant in time. It works for simple cases such as impulsively started confined flows where streamlines have the same shape at each instant and we are interested in time required to start the flow. Now we are interested to study flow out of a long pipe connected to a reservoir (steady and transient starting stages).

A. Sketch discharge of water from a long pipe connected to a reservoir with cross section area $A_1 >> A_2$. The problem approaches steady state when the valve has been open for a long time but is transient in the starting stage.
B. Starting from the Euler equation for such flows, derive the Bernoulli equation, and solve for the exit velocity v_2.
C. Plot velocity in the pipe as a function of time. Note that the characteristic time constant is $\tau \equiv L/(2gh)^{1/2}$.
D. Once a steady state has been attained, you want to attach a valve to control v_2 linearly with its opening. How?

4. Vacuum Cleaner **20%**

Take a vacuum cleaner into your room and clean up using one of the tools attached to the pipe. You vote on whether the flow in the pipe is laminar or turbulent. You may resort to a YouTube video to illustrate 'laminar flow in pipe' and a corresponding video 'turbulent flow in pipe.' Take typical values for the parameters involved in this problem.

A. Sketch the velocity profile development in the pipe, and estimate the Reynolds number of the air flow in the pipe.
B. How will the profile change as the air entering with a uniform velocity across the section moves along the pipe?
C. Estimate the head losses for a plastic tube whose relative roughness can be taken as zero.
D. What are you going to do if we abandon the idea of continuum mechanics and go with a stochastic approach?

5. Your Own Problem **20%**

One morning you wake up to find yourself living on a distant planet whose atmosphere consists of 21% nitrogen and 78% oxygen. Make up an ATHENA problem in four parts and solve it considering differing gravities.