Physics 525 – Homework # 10

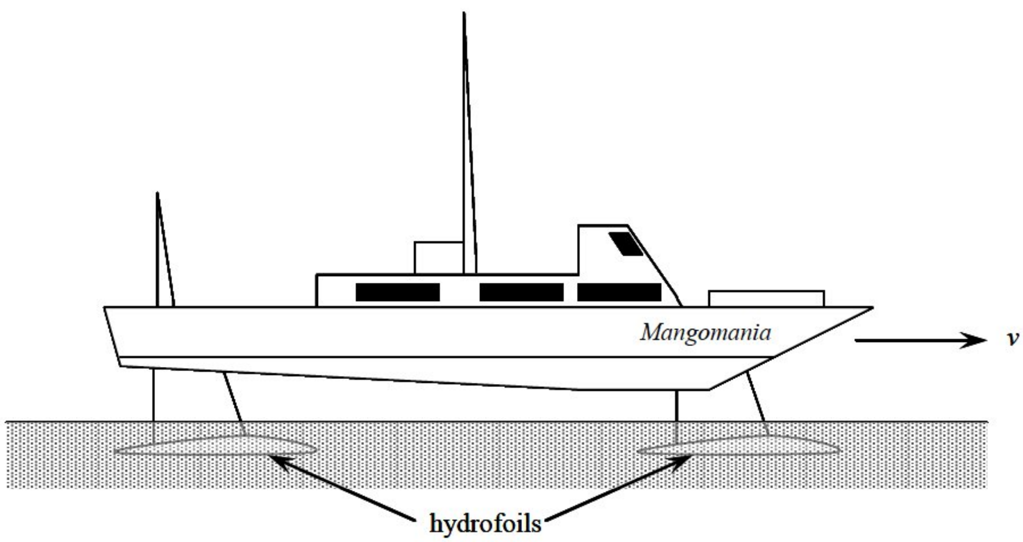
Due May 1, 2024

10.1 (20 points) **Leaks in Space**

A tank of liquid water on an orbiting satellite is pressurized to ten atmospheres: about 10^6 N/m^2. The density of water is 1000 kg/m^3. The tank develops a leak after a small meteor punches a hole in it. Water begins venting into (airless) space. Neglecting viscosity and the sudden drop in the boiling temperature of water at reduced pressure, calculate the speed with which the stream of water is moving as it vents from the tank.

10.2 (20 points) **Fruit running into Idaho**

A pair of criminals scheme to smuggle unripe mangoes into Idaho using a decommissioned Pegasus-class hydrofoil warship. They plan to sprint east on the Spokane River at high speed, crossing into Idaho, then entering Lake Coeur d'Alene where they hope to rendezvous with a waiting submarine. Fully-loaded with mangoes and traveling at speed v, the hull of the ship rises out of the water so that its weight is entirely supported by the lift generated by its thin, wing-like hydrofoils, as shown in the figure. Please assume that the areas of the top and bottom surfaces of a hydrofoil are nearly identical, and that the forward and aft hydrofoils are built to the same specifications. The area of the upper surface of *one* hydrofoil is A.

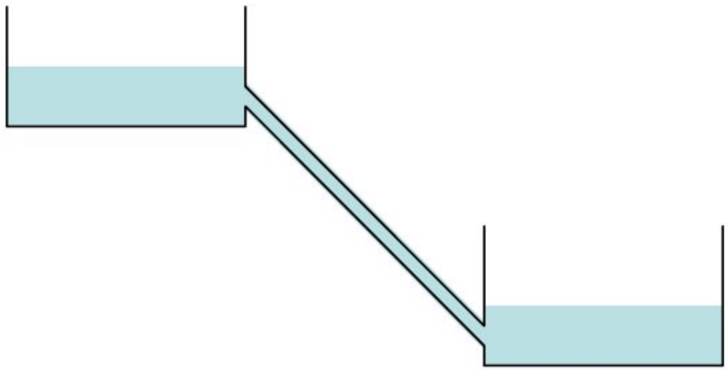


According to the manufacturer, the flow velocities of water passing over the upper and lower surfaces of a hydrofoil for a ship traveling at speed v are $1.1v$ and $1.0v$ respectively. The weight of the mango-laden ship is mg, where m is the combined mass of the ship, cargo, and crew. (For those of you who are highly knowledgeable about these things, you should assume that the angle of attack of a hydrofoil is zero.)

What is the weight of the fully loaded, fully crewed ship and cargo? Please express your answer in terms of A and v. Recall that the density of water is 1000 kg/m^3.

10.3 (20 points) **Downhill pipe**

Water flows through a pipe that descends from one fluid reservoir to another. If we approximate the water as an incompressible, non-viscous fluid and ignore the possibility of turbulence, the velocity of water in the pipe will be constant everywhere as it drains the upper reservoir.



Use Bernoulli's equation to determine the rate of change of pressure inside the pipe, dp/dy, as a function of height above the lower reservoir, assuming that the upper (and lower) reservoir are shallow so that the fluids in them are at atmospheric pressure.

Note that something complicated happens to the pressure of the flowing fluid in the vicinity of the point where the pipe opens into the lower reservoir. Ignore this, and assume you're far enough away from this end that you don't need to do anything particularly sophisticated to discuss the pressure in the tube other than use Bernoulli's equation.

10.4 (30 points) **Plumbing Tarzan's tree house**

Typical urban water pressures for municipal water systems are a few atmospheres. (1 atmosphere $\sim 10^5$ N/m^2.)

Some years ago I installed water manifolds on the outside of my house to feed faucets near the back of my house used for gardening. Since I didn't know much about fluid flow in pipes I took a guess at an appropriate diameter and built the system from 1-inch (inside-diameter) PVC pipe.

Let's see how well this worked, in the approximation that the flow is laminar (non-turbulent). Starting data:

- Inlet pressure: 4×10^5 N/m^2
- Outlet pressure: 10^5 N/m^2 (atmospheric pressure)
- PVC pipe inside diameter: 0.025 m (so the radius is 0.0125 m)
- Length of pipe: 20 m
- Viscosity of water: $\mu = 10^{-3}$ Ns/m^2

(a) What is the average flow speed in the pipe? What is the flow rate?

(b) Calculate the Reynolds number of the flow. Experiments show that turbulence develops in a cylindrical pipe when the Reynolds number is larger than about 2000. Is the laminar assumption valid in this case?