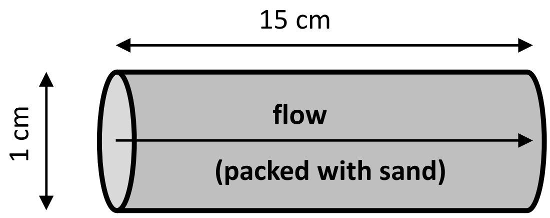
AESB2320, 2018-19
Part 1 Examination - 12 March 2019

Write your solutions *on your answer sheet,* not here. In all cases ***show your work***.
To avoid any possible confusion,
state the equation numbers and figure numbers of equations and figures you use
along with the text you are using (BSL1, BSL2 or BSLK).
Beware of unnecessary information in the problem statement.

1. A colleague wants to see the effect of turbulence on fluids injected to enhance oil recovery. He wants therefore to create turbulence as a Newtonian fluid (density 1000 kg/m^3, viscosity 0.005 Pa s) flows through a packing of sand particles. The grains are roughly spherical, with diameter 0.1 mm. The packing has diameter 1 cm, length 15 cm, and porosity 0.35.
   a. What minimum flow rate Q does he need to impose to get highly turbulent flow? Briefly justify your answer.
   b. What would be the pressure difference Δp across the pack at that flow rate? The pack is horizontal.

   (Note: this is an unrealistic idea. Don't be alarmed if you get unrealistic values. The point is to show that it is unrealistic.)
   (30 points)

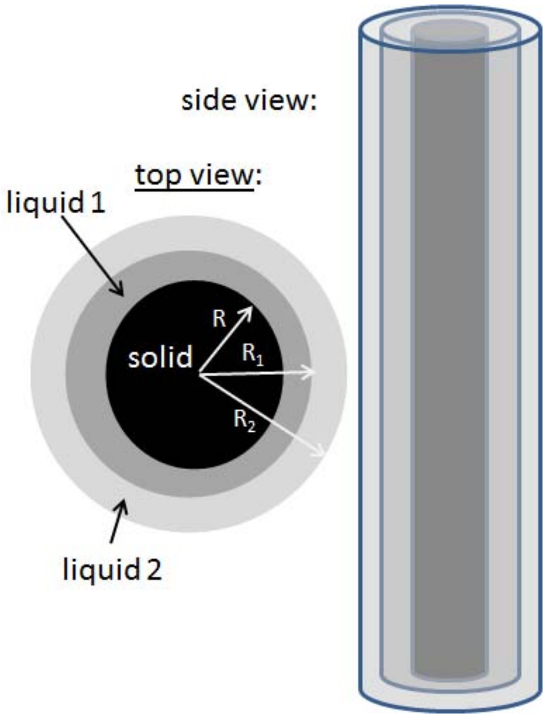


2. In our first lecture, I mentioned the "peanut butter floor" art installation. Suppose the peanut butter is spread with uniform thickness on a flat surface. Suppose the peanut butter is a Bingham plastic with τ_0 = 27 Pa and μ_0 = 17.1 Pa s; its density ρ is 1100 kg/m^3. Suppose the floor is tilted at a 45° angle (not horizontal, as shown at right) and the peanut butter adheres to the floor. How thick could the layer of peanut butter be without starting to flow down the tilted surface?
   (20 points)

3. A vertical cylinder of radius R, very long in the vertical direction, is coated by a layer of liquid out to radius R_1. This liquid has density ρ_1 and viscosity μ_1. Coated on top of that layer is a layer of a second liquid, out to radius R_2. This liquid has density ρ_2 and viscosity μ_2. The outer layer is surrounded by air. The two liquids flow downward under gravity. There is no applied pressure gradient. The cylinder is fixed in place.

   State the boundary conditions that would be needed if one were to solve for velocity $v_z(r)$ in the two liquid layers.

   (15 points)



4. In homework we estimated the width of the crack (represented as a rectangular slit) that sank the ship *Titanic*, assuming first laminar flow, and then using friction factors. Apply now the Macroscopic Mechanical Energy balance to this problem.

   The flow rate through the slit is 0.189 m^3/s. The slit is 2 inches (5.08 cm) long in the flow direction (through the hull of the ship) and 200 ft (60.96 m) wide along the hull of the ship (perpendicular to the page in the diagram at right below). The gap width 2B is to be determined. One side of the slit lies in still water, 3.05 m below the water surface. The other side is open to air at atmospheric pressure. Assume water has density 1037 kg/m^3 and viscosity 0.001 Pa s. Assume that the roughness factor (k/D) is 0.004. Assume that the entrance to the slit is sharp, not rounded

   a. Derive an equation for the gap width would give the initial flow rate through the slit. You do not need to solve this equation, but fill in all the parameter values into this equation based on the problem statement.
   b. What physical factors does this solution include that were left out of both our earlier solutions?

   (35 points)