Fluid Dynamics Problem Set

1. Sedimentation along the Andean Margin in South America.

   The basic question here is how far offshore suspended sediment from the Andes will travel before it falls to the bottom of the ocean. The ocean quickly drops to a depth of about 4000 m (4 km) offshore and there is an ocean current that moves with an average velocity of 0.2 m/s to the west. We will consider 3 different size classes of sediment – clay (radius = 0.001 mm), fine silt (radius = 0.005 mm), and coarse silt (radius = 0.025 mm) – and we will pretend they are all perfectly spherical. Assume a sediment particle density of 2650 kg/m^3 and a water viscosity of 1.5e-3 Pa*s.

   A. Find the settling velocity of each size of sediment giving your answer in m/s. Include the Reynold's number for each case to justify your choice of turbulent or viscous settling velocity. Be wary of your units and remember to write them down within each step of the problem to ensure the correct answer.

   B. Find the time required (in seconds and years) to reach the bottom of the ocean for each sediment size.

   C. How far offshore will the sediments travel through the Pacific Ocean? Is the Pacific Ocean wide enough to accommodate this distance? (Average width of the Pacific is ~11,000 km).

   D. Observations show that the Andean sediment does not extend past 150 kilometers offshore, offer an explanation to this paradox.

2. While visiting your friend's vacation home at the foot of Mt. Rainier in Washington, an eruption begins. An andesitic lava flow has issued forth from the summit crater and is flowing down the 28° flanks – your friend's vacation home is in the expected path just 3 kilometers from the crater! Should you make a run for it, or should you calmly finish your dinner of grilled salmon, wild leeks, and Island Vintage volcano espresso? While your friend panics, you calmly get out a piece of paper and your calculator and get to work recalling your knowledge from fluids class. You also recall from your earth science courses that the viscosity of andesitic lava is 1.5e4 Pa*s, and its density is 2500 kg/m^3. Assume a flow depth of 2 meters.
   a. What is its velocity at the top of the flow? Give the answer in m/s and km/hr.

   b. How much time do you have (in minutes) to finish your dinner before making a run for it? Show your work and explain.

3. You have just been hired by one of the most prestigious, Toret Energy Incorporated, as a staff scientist. The company plans to install several new well pads but needs to bring its "secret" fracking formula up to the DEP code, and you have been tasked with determining the viscosity needed for the formula to efficiently fracture the rock layers. The "breakdown pressure" for hydraulic fracturing is about 7500 psi, which is about 50 MPa, this is the fluid pressure needed to get fractures to propagate. For the fractures to continue to grow, the fluid must be able to advance into the new crack as fast as the crack tip is advancing, about 300 m/s. This means that the viscosity of the fluid has to be low enough to permit the fluid to flow fast enough in the crack. On the other hand, the fluid iscosity needs to be high enough to keep the proppants entrained. You recall from your fluids course that you can model the situation as viscous flow in a channel, where the channel height is the width of these cracks during fracking, typically 6e-5 m. The pressure gradient in this case is the breakdown pressure. Now you know exactly how to solve for the viscosity.