Order-of-Magnitude Physics – Lab 3

Guidelines:

- Break up into groups of 1, 2, or 3 people.
- At any given moment, there should be ≤ 1 "scribe" (person with marker/pen).
- The scribe has complete control over what to write down (and what not to write down).
- Please change scribes when switching to another problem, but not within a given problem.
- When you have an answer, write it down on the "Answer Board" where everyone's answers will be collected.
- If you are done, feel free to leave, or you can observe other groups.

Problem 1. Burn-out

Incandescent light bulb filaments are made of refractory metals (e.g., Tungsten) so that when heated enough to radiate at optical wavelengths, they don't sublimate.

(a) The resistance of a light bulb measured with a 3 V battery tester is about 10 times lower than when measured at 120 V (North American) line voltage. Why?

Relatedly, why do incandescent light bulbs tend to burn out right after you turn them on rather than when they've been on for awhile?

(b) Predict the length and thickness of the filament of a 100 W incandescent light bulb.

Problem 2. Ocean Currents

The satellite TOPEX/Poseidon, the "most successful ocean experiment of all time,"[1] measured the topography[2] of the ocean surface by radar. The radar altimeter measured water height variations on the order of 1 m on oceanwide lengthscales.

The momentum equation for a fluid reads:

$$\frac{\partial \mathbf{v}}{\partial t} + (\mathbf{v} \cdot \nabla)\mathbf{v} = -\frac{\nabla P}{\rho} + \mathbf{g} + \nu \nabla^2 \mathbf{v} + \text{Coriolis} + \text{Lorentz} + ... \tag{1}$$

where the notation is that used in class.[3]

(a) Using the momentum equation, deduce a typical horizontal velocity of ocean currents—at depth, away from any boundaries—on oceanwide lengthscales.

Hint: The momentum equation is a vector equation. That means there are at least two separate equations inside it.

(b) Deduce a typical vertical velocity of ocean currents—at depth, away from any boundaries—on oceanwide lengthscales.

Hint: Think of an oceanwide circulation pattern. Alternatively, recall that ocean water is practically incompressible,[4] and that for incompressible fluids, $\nabla \cdot \mathbf{v} = 0$.

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[1] According to oceanographer Walter Munk.

[2] Topography is not topology, as my geologist friends keep reminding me.

[3] People might be wondering why we included the Coriolis force and not the centrifugal force, since both arise when working in a rotating frame. The reason is that the centrifugal force can often be absorbed into gravity $\mathbf{g}$; the centrifugal force is just another force field that depends only on position, just like gravity. And for the case of the Earth, the centrifugal force is a pretty small addition to gravity (the Earth is not rotating at break-up).

[4] People who did the global warming problem on a previous problem set estimated the degree of compressibility of deep ocean water and saw that it was indeed small.

Problem 3. The Earth Wobbles (But Won't Fall Down)

As reported in the August 2006 issue of Physics Today: Using global positioning system (GPS) data, Lambert et al. (2006, Geophys. Res. Lett.) have measured irregular, day-to-day displacements in the Earth's rotational pole position. In other words, the rotation axis of the Earth doesn't always point toward North — the axis moves around on timescales of days.

Explain why these changes in spin axis orientation occur and estimate an amplitude (in units of length) for the displacements.

Hint: The information given in Problem 2 may be helpful.