Order-of-Magnitude Physics – Problem Set 6

Problem 1. Swimming in Snot[1]

From Gettelfinger and Cussler's research paper, "Will Humans Swim Faster or Slower in Syrup?", published in the American Institute of Chemical Engineers Journal in 2004:

"When one of us was training for the 100-m butterfly in the US Olympic Trials, we began to discuss the fluid mechanics of swimming. We noted that swimmers go faster in salt water than in fresh water because they are more buoyant. We argued about how drag could be minimized coming off a turn. Most of all, we wondered whether swimmers would go faster or slower if the viscosity of the fluid was increased [while keeping the density fixed].

"We discussed this with our colleagues, but found no consensus. Most, including some who were experts in fluid mechanics, felt that the swimmers would go more slowly. Some said the swimmers would go faster, because of increased drag on the hands. A few suggested that there would be no change."

Gettelfinger and Cussler actually performed the experiment by pouring 310 kg of guar gum into 650 m^3 pool.[2] The viscosity of the aqueous guar solution was twice that of water. The density was within 1 part in 10000 of that of water. Sixteen swimmers (10 competitive, 6 recreational) were asked to swim one 25-yard length in a normal pool, two 25-yard lengths in the guar-dosed pool, and finally, after a shower, another 25-yard length in the normal pool. Swimmers rested 3 minutes between each length.

Without looking up the results, predict the outcome of the experiment: faster, slower, or the same in syrup vs. water, and by what fractional amount. Be sure to account for noise in the experiment. E.g., if the answer is faster, estimate the signal-to-noise of the measured fractional difference.

Problem 2. Your Mileage May Vary

Construct, from first principles and order-of-magnitude physics, a plot of mileage (miles travelled per gallon of gas consumed) vs. speed for a typical 4-door sedan. Label your plot quantitatively (numbers and slopes).

Problem 3. Amtrak

Consider a passenger railway in North America travelling at top speed. How many passenger cars could be added to the train before skin friction drag becomes more important than pressure drag?

[1] We are indebted to Isamu Matsuyama for bringing this problem to our attention.
[2] "It looked like snot," said Cussler.

Problem 4. Hail

Hailstones grow from ice particles that repeatedly fall and rise in the circulating flow of a thundercloud.

A golf-ball-sized (2 cm radius) hailstone drops to the ground. Estimate how many times the hailstone has circulated through the parent thundercloud.

Problem 5. Ask Your Own Question

Ask an OOM question of your own. You don't have to answer it.