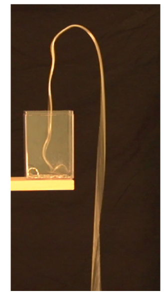
Problems for

The USAYPT Invitational Tournament

North Carolina State University
Winter, 2022



Rope and Chain Fountains

The figure* shows a long chain falling from a jar, which, oddly, rises well above the jar's walls as it falls to the ground. Why would the chain rise up like this without any interaction with the walls or anything above the jar to lift it up? It appears to defy gravity.

Investigate, both experimentally and theoretically, the physics of rope and chain fountains.

A Magnetic Force Law

One of our first experiences with permanent magnets is that *like poles* repel and *opposite poles* attract. Charles-Augustin de Coulomb tried in vain to develop a simple magnetic force law, much like his electrostatic law, but these attempts ultimately failed since there is no magnetic corollary to charge. That said, for the simple case of spherical magnets one would expect a simple attractive force law.

For this problem you are to measure the attractive force between strong spherical magnets, which are free to rotate, as a function of the distance between their centers. Compare your measurements to the force predicted by classical electrodynamics as we now understand it.

Turbulence in a French Press

A French press coffee maker is simply a glass beaker with a mesh piston to filter out the coffee grounds after mixing with the water. Take a French press, fill it about ¾ of the way with boiling water, and then float coffee grounds, or tea leaves, on top of the water. Slowly push the plunger down a short distance, and pull it back quickly. Do the same thing again, but pull it back slowly; repeat it again without pulling it back at all.

Investigate, both experimentally and theoretically, the onset of turbulence and the mixing of fluids, using French press coffee pots.

The Longitude Problem

Ever since Eratosthenes measured the size of the Earth in the third century BC, measuring one's north-south location on the high seas has been easy. However, finding one's east-west location remained an intractable problem for the next two millennia until John Harrison invented the marine chronometer in 1761 AD. The problem is that while one can measure the local time astronomically, one must also know the corresponding time at a known longitude, which was a difficult problem on land and impossible on a rocking boat at sea.

Measure the latitude and longitude of your land-based observatory, using no technology invented after 1760 AD

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* The figure is from: J. Pantaleone, "A quantitative analysis of the chain fountain," American Journal of Physics **85**, 414 (2017).

Notes from the Problem Master

Clarification of the term *investigate*:

All the problems require both a *theoretical* and an *experimental* investigation. To investigate something theoretically, it means that you must start with clearly stated assumptions and derive, or calculate, from those what you expect to measure. This process is called *deductive reasoning.* To investigate something experimentally, it means that you must control variables and test hypotheses. This is the process of *inductive reasoning.* Good science combines inductive and deductive reasoning. Good physics is both theoretically derivable and experimentally testable.

In practice, however, real things are complicated, so we usually start with grossly simplistic assumptions, called *hypotheses*, and use deductive reasoning to build a *toy model* that can predict the results of an experiment. Through the process of inductive reasoning, we compare our toy model to experimental measurements, and evaluate our assumptions. By iterating between deductive and inductive reasoning, we learn which assumptions to keep, and which need to be lifted, until the model's predictions match the experiment.

Academic honesty and sources of information:

When you embark on researching a new topic, often you will refer to a source for information, such as a: book, journal article, patent claim, data archive, or any other source of information. In all of these cases, it is important to be clear about where the information came from, which you do by citing each source in context. You never want to confuse your work with work done by others. Whenever possible, it is good practice to find, read, and cite *primary sources*, which were authored by the scientists who did the actual work. If you took the time to read the literature about a topic, and you make that clear, the jurors will reward you for it.

Understanding where data come from is particularly important in science. For example, it is acceptable to use public scientific data, so long as you analyze them yourselves and clearly cite where they came from. Even fundamental constants are measured (or used to define the SI), and need to be appropriately cited.

Additional hints and resources:

I maintain a blog located at: https://jkeohane.wordpress.com/ that contains advice for both the presenter and the opponent. It also contains two important tutorials about: physical modeling and error analysis. These provide more details and examples of what it means to investigate something theoretically and experimentally respectively.

Good luck working through these problems, and I look forward to seeing you at the next USAYPT invitational physics tournament.

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