Problems for

The USAYPT Invitational Tournament

North Carolina State University, Raleigh, North Carolina

February 3-4, 2024

Inelastic Magnetic Collisions

Magnetic dynamics carts are often used to show both elastic, and inelastic, collisions. While in the inelastic case the abutting magnets collide and stick together, in the elastic case they repel magnetically without touching.

Modify your school's dynamics carts to collide inelastically without actually touching each other in the process. Clearly show that momentum is continuously conserved, and explain how the excess kinetic energy is dissipated.

The Surface of the Moon

Mountain heights, and crater depths, on the moon's near side have been calculated since the 17th century. Now, anyone with a cell phone camera and a small telescope can photograph the moon to resolutions on the scale of kilometers.

Image the moon using standard equipment, and make a three dimensional map of its surface.

Bouncing Drops of Water

When water drops bounce on a flat surface, symmetry suggests that they do not spin, but rather bounce and splash. However, when bouncing on a surface with an asymmetrical pattern, they can both bounce and spin.[*]

Investigate the bouncing of water droplets both experimentally and physically.

Long Jumping with Weights

In Ancient Greece, athletes employed hand-held weights or halteres to extend the range of the standing long jump. In a brief 2002 article in Nature[†], Minetti & Ardigó found that archaeological halteres were in the mass range that optimized one potential benefit of the weights. The halteres may also have been hurled while the athlete was in flight.

Consider all the effects of hand-held weights in the standing long jump, where the goal is to optimize horizontal distance traveled in one leap before striking the (horizontal) ground, from both a theoretical and experimental basis.

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[*] See this video, and the paper referenced therein: https://www.youtube.com/watch?v=nzhjBFhEwvg

[†] See https://www.researchgate.net/publication/11035735_Halteres_used_in_ancient_Olympic_long_jump

Note from the Problem Master

About the Problem Writing Process:

Each year I write, but do not solve, a slate of about a dozen problems on a variety of topics, and send them to the USAYPT President, who reads them over for clarity and makes suggestions. After another revision, the President sends them to the Tournament Director, who in turn sends them to the Board of Directors for ranking and comment. Finally, based on the Board's comments, the Tournament Director chooses four problems that work well together as the official problems for the next year. Therefore, like laws, the problems are as written, and it is up to each team to interpret them from then on.

Each *problem* is designed to be primarily a *research question*, rather than a traditional problem. Nobody already knows the answers, but we do have faith that you, the student, will contribute to our understanding of each question. By presenting your work, and debating the questions with colleagues, you demonstrate that you not only understand the physics involved, but are also an active participant in the scientific community.

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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