Group Project: Newton and Fundamental Constants
Graduate Quantum I
Physics 6572

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Student-run oral examinations Friday September 7

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Resources

There are many amazing physicists who have provided 'dimensional-analysis' style analyses of our world. Alex Alemi pointed out several good references he's found, many from a course he took at Caltech (http://www.its.caltech.edu/~oom/):

Edward Purcell, *Back of the Envelope Problems*,
http://ajp.dickinson.edu/Readers/backEnv.html

Victor Weisskopf, *Search for Simplicity*

P. L. Kapitza, *Problems in Physics*, from the *Collected Papers of P. L. Kapitza*, pp. 327

Goldreich, Mahajan, and Phinney, "Order-of-Magnitude Physics: Understanding the World with Dimensional Analysis, Educated Guesswork, and White Lies",
http://www.inference.phy.cam.ac.uk/sanjoy/.

Many of you have already taken substantive quantum mechanics courses. All of you have developed unusual expertise in taking physics courses and doing homeworks. This semester I'm trying an experiment, to introduce you to new skills (group learning, oral defenses) and to creative thinking. Form groups of four or five students each, and work on these problems collaboratively. In roughly two weeks, we'll have 'mini-Q-exams', where you'll be quizzed on the material by three other students in the class.

You're Isaac Newton, resurrected with all of your knowledge and experience and in full mental and physical health, by a collaboration between the Gates and Howard Hughes foundations. You've spend the past months learning about modern society; as former Master of the Mint for England, you're rather disgusted that modern cryptography has not been utilized to make counterfeiting impossible. Having learned finally that 'natural philosophy' is now called 'physics', you've tracked down a physicist and are asking how your work on gravitation, optics, and motion has developed since 1727.

I.1 **Coulomb.** (Dimensional Analysis) ②

Intrigued to hear that lodestones and static electricity are now rather well understood, you're told that the electrical force between particles follows your law of gravitation, except that the 'mass' is replaced by the charge and G is replaced by a new constant k. You're told that there are tiny particles called electrons, and are told G, k, e, m_e, and the mass of the Earth. *What can you deduce about our world from these constants?*

I.2 **Planck.** (Dimensional Analysis) ②

You've heard that Huygens was right about light–that it behaves as a wave, and that the colors of light are related to the frequency ω of the wave. You're told that actually it sometimes behaves as a particle, lumps of energy of size $\hbar\omega$. You're told $\hbar$. *What now can you deduce about our world?*

I.3 m_P**.** (Dimensional Analysis) ②

Based on your analysis, you complain that the new potential doesn't make sense unless there is something to cancel it, and that in any case there isn't enough mass to explain the density of matter. You're then introduced to the idea of positive and negative charges and the proton, and told the mass of the proton (which you had already estimated). *What now can you deduce about our world?*

I.4 **Speed of Light.** (Dimensional Analysis) ②

Asking about motion, you're told a bunch of confusing stuff about trains and clocks. But you hear that Galileo's attempt to measure the speed of light has now been turned into a good measurement. You're told the speed of light. *What now can you deduce about our world?*