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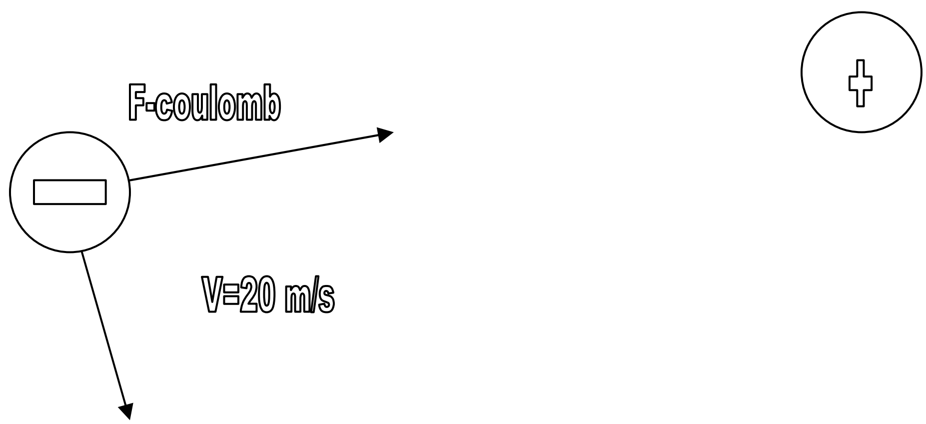
Recitation Quiz from Jan. 26

Section B:
The problem was to draw the free-body diagram for this classical atomic model and calculate the radius at which the electron is orbiting the proton. For extra credit, one could write the quantization condition given the de Broglie relationship:

$$\frac{[?] \quad meters}{\frac{h}{m_e v} \quad meters} = [?] \quad unit-free \ .$$

The electron has a circular orbit around the proton. Assume that the proton is stationary, and assume that gravity can be ignored. Either a symbolic or numeric answer is acceptable. The first part of the problem is to draw the free body diagram on the electron, which has been done on the problem model below.



$$F = m_e a = m_e \frac{v^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{q_e q_p}{r^2}$$

$$r = \frac{1}{4\pi\varepsilon_0}\frac{q_e q_p}{m_e v^2} \qquad r = \left(9\cdot 10^9 \frac{Nm^2}{C^2}\right)\frac{\left(1.6\cdot 10^{-19} C\right)^2}{9\cdot 10^{-31} kg\left(20\frac{m}{s}\right)^2} = .64m$$

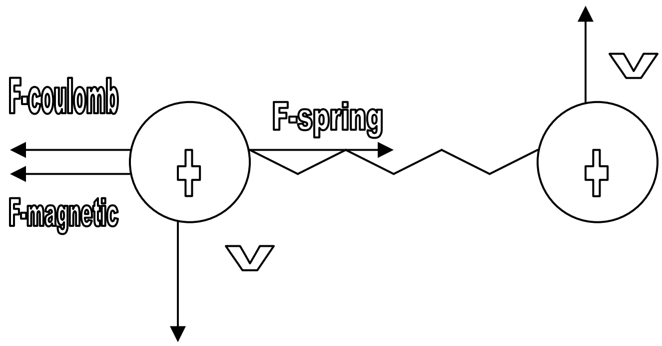
This is an enormous radius, but I chose an arbitrary velocity without carefully considering the ramifications. At this distance, the electron would probably be inclined to go find a new proton. The quantization condition (this duplicates the Bohr model) is just that the electron ends up where it started! This means that:

$$\frac{2\pi r \quad meters}{\frac{h}{m_e v} \quad meters} = [1,2,3,...] \quad unit-free$$

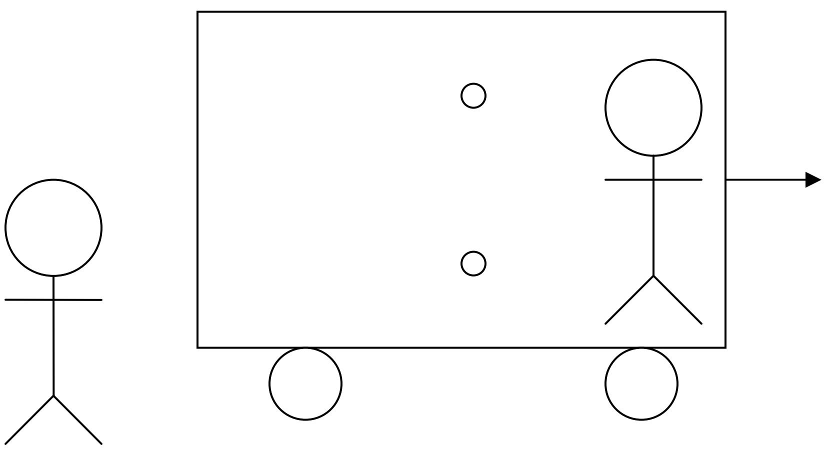
Now by substituting the radius I calculated into this condition, I can solve for allowed velocities and thereby allowed energies of my electron! This model is thus the beginnings of Quantum Physics!

Section C:
The problem was to draw the free-body diagram for this atomic model, ignoring the force of gravity and magnetic force. The magnetic force could be drawn for extra credit. I was looking for the following: The diagram should have all vectors drawn from the body, and the forces must be clearly labeled. I was happy to see that no one included "centripetal force" without qualifying that it was provided by the spring. All labels below are vectors.

Many people labeled the momentum and its derivative: this is not necessary, but I didn't take points off for it.



The extra credit was worth 2 extra points, since it was much easier than the extra credit for the first problem. This led me into a discussion of how relativity is built into these forces. For example, suppose I had two protons on a train as such:



By the person on the train's measurements, there is no magnetic field and the protons repel each other at a standard rate. By the person off the train's measurements, there is a magnetic field created by the moving protons causing them to have a slight, attractive magnetic force in addition to the repulsive force that is given by Coulomb's Law. How do you resolve this apparent difference in forces? The solution is that time must be going more slowly for the observer on the train with respect to the person off the train, so that the observations can be consistent. In fact, when the train is going the speed of light, the protons will neither repel or attract one another according to the observer off the train: as far as he is concerned, time must have stopped inside the train! In fact, it turns out that our electric and magnetic constants are related to the speed of light! $\mu_0 \varepsilon_0 = \frac{1}{c^2}$