15.31: Electromagnetism

These notes are intended to cover only mechanics, and therefore I resist the temptation to cover here special relativity and electromagnetism. I point out only that in many ways this misses many of the most exciting parts of special relativity, and indeed it was some puzzles with electromagnetism that led Einstein to formulate the theory of special relativity. One proceeds as we have done with mechanical quantities; that is, we have to define carefully what is meant by each quantity and how in principle it is possible to measure it, and then see how it transforms between frames in such a manner that the laws of physics – in particular Maxwell's equations - are the same in each. One such transformation that is found, for example, is $\mathbf{E'} = \gamma(\mathbf{E} + \mathbf{u} \times \mathbf{B})$ so that what appears in one frame as an electric field appears in another at least in part as a magnetic field. The Coulomb force transforms to a Lorentz force; Coulomb's law transforms to Ampères law.

Although I do no more than mention this topic here, I owe it to the reader to say just a little bit more about the speedometer that I designed in Section 15.4. It is indeed true that, as the train moves forward, the net repulsive force between the two rods does diminish, although not quite as I have indicated, for one has to make the correct transformations between frames for force, current, electric field, magnetic field, and so on. But it turns out that the weights of the rods – i.e. the downward forces on them – also diminish in exactly the same ratio, and the angle between the strings remains stubbornly the same. Our trip to the patent office will be in vain. The speedometer will not work, and it remains impossible to determine the absolute motion of the train.