Feb 21st, 2012

P340: Homework Assignment No. 2

DUE DATE: Monday, 5th March 2012

Please note that late assignments will not be marked

(1) Space, Time, and Matter: The ideas we have of space and time, and also of what is material mass, were first clearly formulated by Galileo and Newton.

(i) Describe how Galileo measured the way in which balls rolled down inclined planes. What measurements did he make, how did he make them, and what results did he find? In what way did these results contradict the ideas of Aristotle?

- To make these measurements, Galileo had to define both distance and time, and also measure distance and time intervals. Explain how he did this.

(ii) Explain Newton's 2nd and 3rd Laws of motion. Then, using the possibility of experiments involving interacting masses, explain how the concepts of mass and force are defined. To do this you should consider how they would be measured in these experiments.

- The time measurements used by Galileo could be justified using the theory of Newton. Explain how you could show, using Newton's laws, that there will be frictionless periodic systems, such as a frictionless spring, which will set a time standard and thereby keep time. In this sense the existence of regular time intervals is actually a *consequence* of Newton's laws.

- Newton was actually very concerned to find some way of defining time and length independently of the way they were measured. He therefore defined what he called "Absolute Space" and Absolute Time". Explain what he meant by this, and also explain the 'Rotating Bucket' thought experiment he used to demonstrate the existence of absolute space.

- Finally, explain what were the objections to the ideas of absolute space and time, that were given by Leibniz.

(2) Electromagnetic Fields: The first field to have its properties elucidated was the Electromagnetic Field. This required a combination of theory and experiment, and the idea of the field later became central to all of physics.

(i) We begin with a brief look at static EM fields.

- Show the electric field lines near a pair of electric charges, having charges q and $-q$ (an electric dipole). Assume the only fields around are those generated by these 2 charges. Then explain how you would measure these fields using 'test charges', and assuming Newton's laws.

- Then show the magnetic field lines near (a) a straight wire carrying current, and (b) a single loop of wire carrying a current- assume there are no other magnetic fields around apart from that generated by the loop.

- Now show the magnetic field lines in the vicinity of a solenoid, and explain why it is that the field pattern around a long bar magnet looks basically the same.

(ii) Now we look at the dynamic properties of these two fields.

- Describe an experiment that shows that changing an electric field in time causes a magnetic field (the 'magnetic induction' effect). There are a number of different experiments that do this - take your pick.

- Now describe an experiment that shows how if we change a magnetic field in time, we produce an electric field.

(iii) Now let us ask in what sense we consider the EM field to be 'physically real'.

- The electric field $\mathbf{E}(\mathbf{r}, t)$ at some point $\mathbf{r}$ in space, and at some time t, plays the same role for the EM field as the elastic stress in an elastic solid medium like a jelly - it 'stretches' it. On the other hand the Magnetic field $\mathbf{B}(\mathbf{r}, t)$ at some point $\mathbf{r}$ in space, and at some time t, plays the same role as a 'twist' in an elastic medium.

Explain this analogy further, showing in particular how you think an elastic medium like a jelly would be distorted if you (a) inserted a bubble of air into it, and expanded it, and (b) inserted a wire into it, and then twisted this.

- Now explain what you think is the key *difference* between the elastic medium and the EM field. To answer this, it is helpful to ask yourself (i) what do you think is 'physically real' about the elastic medium, and why, and what do you think is physically real about the EM field; and (ii) in what way do we know about these two media, and the stresses and twists in them?