Nov 6th, 2012

P340: Homework Assignment No. 2

DUE DATE: Monday, 19th November 2012

Please note that late assignments will not be marked

(1) Electromagnetism:

(i) Imagine you want to explain to someone who has *not* attended this class, how electromagnetism works. You need to begin by explaining some of the *facts*. We consider first static phenomena.

Explain first what would be seen in an experiment where we have a small metal ball which has been charged up with positive charge using a nylon rod. Explain how it is charged, and then what happens when you bring other "test charges" near to it. Show how one can then find Coulomb's results. Draw a picture of the force field one finds from the metal ball. How do you think you would you measure these forces?

Now explain how you would map out the force field around a current-carrying straight wire. In this case you would need to use a very small test coil. Describe what sort of observations you would make to determine the force field, and illustrate what results you would find.

(ii) Explain what is electromagnetic induction, using an example of your choice. You need to explain first the example in some detail, and then explain what is happening and why.

Now summarize all of what you have found, both for static and inductive phenomena, by explaining what are the basic mechanisms operating in electromagnetic phenomena - you should give your explanation in terms of charges and fields, connecting it to what is observed.

(iii) Light is an example of an electromagnetic wave. Give a brief explanation of why there must be waves in an EM field, and show what they look like.

Finally, if an EM wave has a wavelength of 20 cm (ie., 0.2 m), what will be its frequency? Assume that the velocity of light is $c_o = 3 \times 10^8$m. If I now increase the wavelength by a factor of 5, what will happen to the frequency?

(2) Spacetime, Mass, and Geometry:

(i) We start by considering 2-dimensional geometries, which we can visualize 'from outside' in our 3-dimensional world. Imagine that we compare (a) a triangle, and (b) a circle, in 2 different geometries, viz., in a flat Euclidean plane, and in a sphere of radius R. Explain first of all how a being living only in one or other of these 2-d geometries would try to decide what geometry they were in, using measurements performed on the 2 geometrical objects. How would they define and measure angles and distances in their geometry?

Then show what they would find. You can show this using pictures, but you should also draw graphs of (i) how you think the total internal angle of the triangle (ie.the sum of the 3 internal angles) will vary with the size of the triangle, for both geometries, and (ii) how the area of a circle of radius r will vary as we vary r, for both geometries.

(ii) In General Relativity, it is the geometry of 4-dimensional spacetime that one is interested in. Since we are inside this geometry, we cannot visualize it 'from outside'. However we can still test 'from inside' to see what the geometry is. One way is to look at the path of a ray of light in a vacuum (which defines a straight line in our world). Describe using diagrams how the theory of Einstein was tested using light propagation past the sun. Explain what would have been seen if Newtonian theory were correct, and what was actually seen.

Now suppose we think of light as a wave. Remembering what happens when light passes through a 2-slit experiment, show in a diagram, and explain, what you think would happen if an EM wave were to move past a compact massive object like a neutron star. How do you think you would try to look at this?

(iii) Explain in what sense one can describe the General Theory of Relativity (GR) as a "field theory" like EM theory. You should do this by comparing and contrasting in detail the 2 theories, and at the same time explaining the basics of GR. What are the key differences between the two field theories?

(3) The Relativistic Cosmos:

(i) Explain two key pieces of early evidence we have for the Big Bang and the expansion of the universe, viz., (a) the motion of galaxies as seen from the earth, and (b) the microwave background. You need to explain what is seen, how to describe what is seen in physical terms, and why this is evidence for the Big Bang.

(ii) Two of the most striking pieces of evidence we have for black holes in the universe are (a) supermassive black holes in galactic centres, and (b) the phenomenon of quasars. Explain in each case what is seen, what is the physical explanation of what is seen, and how this provides evidence for black holes.