Reading: Finish Feynman’s QED

1. Consider our particle the huge. Instead of a simple change in the nature of the particle suppose that the fundamental happening is for one huge to turn into two huges, see Figure 1. An event in which one particle turns into two is called a vertex. To maintain microscopic reversibility, we include, with the same strength, the reverse vertex with two huges turning into one. Draw the diagrams that contribute to the case with one huge in and one huge out, the huge propagator. Order the diagrams in terms of the number of g’s present and include all diagrams with up to four g’s. Now consider the class of all diagrams but still ordered in terms of the number of g’s. Using the pattern that emerges from the case of four g’s, reorganize the diagrams so that at least a large group of them can be summed with the trick \( \frac{1}{1-x} = 1 + x^2 + x^3 + x^4 + \ldots \). Using only the diagrams in this class, do you see a property of the ones that are not in that class? Can we extend our class of iterated diagrams to now include these misfits? Is there now a pattern for including all diagrams to assessing the huge propagator? Is there a theme to this construction?

2. Now show all diagrams that have one huge in and two huges out. Draw all diagrams with up to five g’s. Does a similar pattern emerge among these diagrams as occurred in the case of the propagator? Can we sum large classes of diagrams by replacing the bare huge legs with the full huge propagator? This process is called insertions. Are we leaving out any diagrams. Can we develop an extended protocol that will include these diagrams. Can the new summed vertex the dressed vertex. Sum the diagrams to get the expression for the dressed vertex.

3. Now let’s do two huges in and two huges out. This is called huge huge scattering. Again examine all diagrams with up to four g’s. Reorganize the class of all diagrams along the lines of the pattern that emerges
from examining the four g cases. Make insertions of the dressed propagator and the dressed vertex. Calculate the scattering amplitude.

4. Using a one spatial dimensional manifold with equally spaced galaxies give an argument that the Hubble velocity distance relationship or a no expansion relationship are the only two options consistent with Galilean invariance. If the distances get large and the velocities get large does the Hubble relationship have to be changed and how?

5. We developed the rules for the electron photon system. From these rules, show that in any process, if the charges are reversed and the velocities are reversed, this is the same as reversing the time. This is the great CPT Theorem.

6. Suppose a system of test masses are present in an expanding universe.
   
   (a) What kind of change does it measure (extension or compression)?
   (b) What happens if you watch the system of masses for a long time?
   (c) How big should the system of masses be for this description to be appropriate?
   (d) What happens if you use a system of a different size?
   (e) To what extent do your answers depend on the kind of cosmology assumed (positive/negative curvature, finite/infinite volume)?
   (f) What happens to the system of masses in the distant future in a recollapsing cosmology? Why is it called a singularity?
   (g) What quantity is the system of masses measuring?

7. Consider a galaxy that is far away, say 100 Mpc. An atom of hydrogen emits light of wavelength one half that of the visible light. What is the wavelength and frequency of this light as seen by an astronomer on earth?

8. The universe is expanding like a piece of chalk that is throw up and rises against the earth’s attraction. We can infer from what we know about tossed chalk whether the universe will expand forever or fall back on itself. You realize that most of the time when you toss chalk up that it falls back but that, in principle, if you throw it fast enough, it will escape the earth completely. Given what we know about the earth, what is the escape velocity of chalk from the earth. Use dimensional arguments. Using us as a reference frame, (What is wrong and what is right about doing this?) what is the escape velocity for a galaxy at a distance R from us? Again, use dimensional arguments and the mass-energy density of the universe. Thus we see that the current mass-energy density of the universe and the current recession pattern will determine the future fate of the universe. What is the crucial relationship of the mass-energy density and the current value of the Hubble constant the determines the fate of the universe?