Candidacy Exam
Spring 2015

The exam has 6 questions. You must answer 4 of them correctly in order to pass. If you attempt more than 4, your best 4 answers will be kept. This is closed book. You have 4 hours to take the exam.

1. Show all the diagrams that contribute to $e^- q \to e^- q$ in the Standard Model. Calculate the total cross section including only QED contributions. Now lets imagine we have an $e - p$ collider. Explain how to carry the $e^- q$ calculation over to $e^- p$.

2. i.) Explain, using formulae and diagrams, why the photon mass is not quadratically divergent in QED. ii.) Next, explain why the electron mass is not quadratically divergent.

3. What is an anomaly in QFT? Explain the concept from as many angles as you can, and then prove that there are no gauge anomalies in the Standard Model.

4. Assuming neutrinos have Majorana masses, draw the diagrams for neutrinoless double β decay. Derive, using dimensional analysis, the amplitude for this process. How can we make use of this process to test whether neutrinos are Majorana – meaning what would the signal be, what's the background, and what modifications are needed to make the amplitude we estimated useful?

5. Explain how a Higgs boson can decay to photons. In other words, write the effective operator for the decay, give the Feynman diagram(s) which contribute to the operator, explain why the diagrams are finite, and give an estimate for the width of this process. How would this change if there were a 4th generation of heavy quarks? Would the branching ratio to photons increase or decrease?

6. The Fermi theory for the weak interactions is not renormalizable. Why is that so, and what does it imply about the theory? In particular, under what circumstances can the Fermi theory be used, and where does it fail? In what way does it fail?