Phys. 671 Spring 2021 Instructor: Xerxes Tata

This class is the second semester of a two-semester course in non-relativistic QM (follows PHYS 670). Please review the free particle solution in spherical polar coordinates as this will be important for scattering theory (p 346-350 of Shankar). We talked about this a the end of the last term and you will soon get HW asking you to write the plane wave in spherical coordinates. As I had told you last term, I will assume all of you have all solved the Hydrogen atom and are thoroughly familiar with its solutions from baby QM classes.

We will begin with discussing the path integral formulation of quantum mechanics, a topic we would normally have covered in P670 but did not. Please review Gaussian integrals **before you come to class on Tuesday** as these will be crucial for our discussion.

We will then move on to the chapter on combining angular momenta (Shankar, Chap. 15). Make sure you become very good friends with the angular momentum stuff from Chap. 12 and Chap. 14 that we have discussed. The angular momentum algebra will be essential for the material in Chap 15.

During the course we will emphasize the applications of QM to complex systems using approximation methods because the dynamics of these systems cannot be solved exactly. The need for approximations is typical of real life systems we encounter in physics: the Scroedinger equation for these is not exactly solvabe. I urge you to supplement our text with other excellent texts of your choosing. These include: Sakurai, Merzbacher, Schiff, Bethe and Jackiw (especially for Hartee Fock methods) Landau and Lifschitz, Davydov, Messiah, Baym, Dirac, Weinberg and Gottfried and Yan, to name a few. I urge you to look at books beyond our class text as the topics get increasingly sophisticated.

Topics to be covered:

- Path Integral formalism of quantum mechanics (Chap. 8)
- Addition of angular momenta
- Energy degeneracies of 3-D Coulomb and harmonic oscillator potentials
- Approximation Methods (WKBJ, perturbation theory, variational methods) and their applications to real systems.
- Time-dependent Hamiltonians using perturbation theory
- Aharanov-Bohm effect, Berry's phase
- Elements of elastic scattering theory
- Self-consistent fields and Hartree-Fock methods
- Relativistic wave equations and failure of relativistic quantum mechanics for one-particle systems

- Quantizing the electromagnetic field
- Decay rates for atomic transitions
- Einstein-Podolsky-Rosen type correlations

While we will definitely cover the core topics in non-relativistic QM (through scattering theory), and depending on time and interest, we will pick and choose from the other topics.

HW will be assigned regularly (roughly weekly), and will count for 1/3 of your grade. Also, we will have one midterm and a final exam, each counting for a third of your grade. We will decide the format for these exams when the time approaches.

This class will provide you expertise to work on problems for which non-relativistic quantum mechanics provides an adequate framework, and prepare you for courses in Quantum Field Theory, which is the framework used by research physicists working with quantum systems in which relativistic effects are important.