**Syllabus: Quantum Mechanics II**

**Spring 2025**

**Instructor:**  Dan Boyanovsky, 208 Allen Hall, ph: (412)-624-9037, e-mail: [boyan@pitt.edu](mailto:boyan@pitt.edu)

**Objectives:**  The objectives of the class are to obtain a solid, deep and broad knowledge of Quantum Mechanics. The class focuses on the fundamental aspects and discusses various applications from condensed matter, particle physics and astrophysics, emphasizing conceptual and calculational frameworks, discussing in depth the mathematical background and physical principles.

**Prerequisites**: Quantum Mechanics I.

**Content:**  Review of time independent perturbation theory: non-degenerate and degenerate cases, examples: spin-orbit, fine and hyperfine structure of the H-atom: the 21 cm astrophysical line. Zeeman and Paschen-Back effects in magnetic fields. The Van-der-Walls interaction between atoms. Non-perturbative methods: i) WKB: connection formula and bound state quantization conditions (connection with Bohr-Sommerfeld quantization), metastable states. App: Gamow’s theory of alpha decay and thermonuclear fusion processes in stars, ii) Variational method: the origin of the chemical (covalent) bonds. Scattering theory: fluxes and cross sections. Lippman-Schwinger equation, scattering amplitudes, Born approximation. Rutherford scattering: classical and quantum. Partial wave analysis, optical theorem. Phase shifts, examples. Coulomb scattering. Connection between scattering amplitudes and bound states. Coherent vs. incoherent scattering: Bragg scattering. Mean free path and relaxation time. Indistinguishable particles, bosons and fermions, spin statistics connection. Scattering of indistinguishable particles. Many indistinguishable particles: a primer on second quantization: many particle Fock states. Dynamics: two level systems, Larmor presession of spins: classical and quantum, basics of NMR and spin resonance: pi pulses and population inversion. App: the physics of neutrino oscillations. Time dependent perturbation theory: interaction picture and Dyson series, S-matrix, Harmonic perturbations: comparison to exact treatment. Transition rates. Fermi’s Golden rule and exponential decay. App: a model for decay of a two level system. Density matrix: the von-Neumann equation of motion, pure vs. mixed states, two-level systems and the Bloch vector. Quantization of the electromagnetic field: gauge invariance, photons and their polarizations. Coupling of charged particles to electromagnetic fields: minimal coupling and gauge covariance of the Schroedinger equation. Examples: Aharonov-Bohm effect, Landau levels in a constant magnetic field. Interaction of atoms and light: stimulated and spontaneous emission and absorption. Dipole transitions and selection rules. Quadrupole transitions. Higher order processes: Raman scattering. Einstein’s A,B coefficients and approach to thermal equilibrium, black body radiation. Relativistic quantum mechanics: the Klein-Gordon equation and its caveats. The Dirac equation: spinors, main predictions: relativistic corrections, gyromagnetic and Thomas factors.

**Suggested Textbooks**: The material is standard and there are several excellent textbooks:

**Lectures on Quantum Mechanics** by G. Baym,

**Modern Quantum Mechanics** by J. J. Sakurai,

**Principles of Quantum Mechanics** by R.Shankar,

**Quantum Physic**s by M. Le Bellac,

**Quantum Mechanics: Fundamentals** by K. Gottfried, T-M. Yan

and various other good books. I will borrow freely from many books and will not adopt a particular one.

**Class notes will be shared**: I will send by e-mail the lecture notes for the class two days in advance, so you have an opportunity to study the material prior to class which will cover the details in more depth and expand upon the notes. The notes are NO substitute for coming to class, they are a complement to the class. **THE NOTES ARE ONLY FOR YOUR PERSONAL USE, NOT TO BE SHARED OR DISTRIBUTED, THEY ARE PROTECTED BY INTELLECTUAL PROPERTY RIGHTS.**

**OFFICE HOURS: Monday, Wednesday,Friday: ``Express service’’ (quick questions) 9:30 am 🡪 10:15 am, regular office hours 3:30 pm -🡪 4:30 pm in my office: 208 Allen Hall.**

**I will also respond to questions by e-mail within 24 hours. If needed we can meet via zoom at a time of mutual convenience.**

**Suggestion to make the most out of the course: 1) study the notes prior to class, 2) come to class, annotate the questions in the notes that need more explanation, and during class focus on these, THE NOTES ARE NO SUBSTITUTE FOR THE CLASS, THEY COMPLEMENT THE CLASS, 3) go back to the notes and re-study them in view of what I covered in class, 4) do the homework, this is the only way to actually learn!!. Try to do the homework on your own rather than in groups to avoid ``groupthink’’.**

**Homework: every week I will assign a set of 4 problems on the material covered during the week. Doing the homework is an important part of the learning experience, and the only way to actually understand the material.**

**Homeworks will be sent by PDF on Fridays, they are due back in PDF and compressed format (files larger than 5Mb will be returned for compression!) by the following Friday no later than midnight. No grace period is allowed and no late homework will be accepted**.

**Exams: there will be a one week take home midterm and a one-week take-home final exam. THE EXAMS MUST BE INDIVIDUAL, I RESERVE THE RIGHT TO SUMMON TO AN ORAL EXAMINATION IF IN DOUBT.**

**Grade: The final grade is obtained as follows: (1/3)x (average of homework)+ (1/3)xMidterm+(1/3)xFinal**