**Syllabus, PHYS 784, Quantum Mechanics II, Spring 2023**

Time: Tuesday, 4:30-7:10pm
Place: Planetary Hall 220
Instructor: Erhai Zhao
Office Hour: by appointment
Email: ezhao2@gmu.edu

How to reach me: Email is preferred. You can also drop by my office.

**Textbook**
For the sake of continuity, I will stick to the book used in QM I (Phys 684),
*Modern Quantum Mechanics*, 3rd Ed., J. J. Sakurai and J. J. Napolitano

Warning: we only follow the book loosely, and cover chapter 5 to 7. [We will skip chapter 8 on Dirac equation. If you are interested, consider taking Phys 786, Quantum Field Theory, where Dirac equation is discussed *in the modern perspective as a field equation*.] And I will discuss topics beyond the book.

**Grades**
Homework (80%) + Term Paper (20%).

**Lectures**
I will use the whiteboard, and occasionally the projector. Please take notes if needed.

**Homework**
There will be 4 to 5 sets of homework (depending on how much we cover). They will appear in the Assignment folder of Blackboard with due date indicated. The homework will be graded on a coarse scale: Excellent (5), Very Good (4), Fair (3), Absent (0).

**No Exams**
The term paper can be on any topics of your interest, but preferably related to what we have discussed and/or of current research interest. It is free-format, 4 to 10 pages. I will look for your own thinking about a topic or a problem.

**Prerequisite**
This course continues from Phys 684, Quantum Mechanics I (chapter 1 to 4 of Sakurai).

**Course Goals**
Most real-world problems involving Quantum Mechanics cannot be solved exactly. So a main goal of this course is to develop a repertoire of approximation techniques. Each approximation method will be illustrated by working out examples.

The second goal is to introduce modern research topics, e.g. quantum many-body systems, entanglement and decoherence in open quantum systems etc.

**Topics** (subject to change, topics in color: time permitting)

1. Semiclassical expansion: WKB, bound states and Bohr-Sommerfeld quantization rule, tunneling.

2. Time-independent perturbation theory: 1st and 2nd order, level repulsion, projection operators, lift of degeneracy. Examples: perturbed harmonic oscillator, Stark effect, fine structure of H atom.

3. Time-dependent perturbation theory: interaction picture, Dyson series, constant and harmonic perturbation, transition rate and Fermi's golden rule, photoelectric effect.

4. Scattering theory: S and T matrix, Lippmann-Schwinger Eq, Green function, cross section, Born approximation, partial waves, phase shifts, scattering length, resonance and bound states.

5. Second quantization: permutation and identical particles, symmetrization postulate, fermions vs bosons, many-body Hamiltonians in terms of creation and annihilation operators.

6. Interaction between particles: exchange interaction, Helium atom and variational methods, interacting Fermi gas, BCS theory of superconductivity.

7. Entanglement and decoherence: open quantum systems, entanglement, modern view of measurement, decoherence.

8. Light-matter interaction: quantization of electromagnetic field, photon states, cavity QED, superconducting circuits.

9. Geometric phase, quantum Hall effect, topological insulators.

**University Resources**
Learning Services (https://learningservices.gmu.edu/)
Student Support and Advocacy Center (https://ssac.gmu.edu/)
Counseling and Psychological Services (https://caps.gmu.edu/)
Mason's Title IX Coordinator (703-993-8730, titleix@gmu.edu)

**Academic Integrity**
The George Mason University Honor Code can be found at the Office of Academic Integrity website http://oai.gmu.edu. It has clear guidelines regarding cheating, plagiarism, and other academic misconduct.

**Accommodations**
Disability Services at George Mason University is committed to providing equitable access to learning opportunities for all students by upholding the laws that ensure equal treatment of people with disabilities. If you are seeking accommodations for this class, please first visit http://ds.gmu.edu/ for detailed information about the Disability Services registration process. Then please discuss your approved accommodations with me. Disability Services is located in Student Union Building I (SUB I), Suite 2500. Email:ods@gmu.edu — Phone: (703) 993-2474.

**Diversity and Inclusion**
Please refer to Mason's Non-Discrimination Policy,
https://universitypolicy.gmu.edu/policies/non-discrimination-policy/.
and the Mason Diversity Statement,
https://stearnscenter.gmu.edu/knowledge-center/general-teaching-resources/mason-diversity-statement/.