PHYS 173L Applied Physics III: Topics in Modern Physics

Units: 4
Fall 2020
Lectures: Mon-Wed 10-10:50 am
Discussions: Tue-Thu 4-4:50 pm
Lab Sections: Fri 8-10:50 am, 11 am-1:50 pm, 2-4:50 pm

Location: ONLINE—can be accessed via https://blackboard.usc.edu

Instructor: Prof. Paolo Zanardi
Office: SSC 225 (will hold office hours ONLINE this semester)
Office Hours: By appointment
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Instructor: Prof. Todd Brun
Office: EEB 502 (will hold office hours ONLINE this semester)
Office Hours: Monday 2-4 pm, Thursday 9-10 am
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Laboratory Manager: Dr. Gökhan Esirgen
Office: KAP B19 (will meet ONLINE this semester)
Office Hours: By appointment
Contact Info: esirgen@usc.edu

Course Description

This course will give an introductory understanding of quantum mechanics, statistical mechanics, and solid-state physics, with emphasis on applications in the areas of applied physics and engineering. It includes the ideas behind quantum computers and quantum information processing.

Learning Objectives

By the end of this course, you will be able to:

- Explain the postulates of quantum theory and apply them to simple quantum systems;
- Describe quantum states and operators in terms of complex vectors and matrices, and represent them in Dirac notation;
- Find the time evolution of finite-dimensional systems (such as qubits) by solving the Schrödinger equation, and calculate the probabilities of measurement outcomes;
- Express quantum computations by quantum logic circuits, explain how several well-known quantum algorithms work and determine their computational complexity;
- Describe the evolution of particles in space by the Schrödinger equation for continuous variables, and solve this equation for several simple systems;
- Incorporate open-system effects such as decoherence and loss into quantum theory using density operators, and use this to describe quantum systems at nonzero temperatures;
- Carry out experimental demonstrations of basic quantum effects;
- Run simulations of small-scale quantum systems in Mathematica.

Prerequisite(s): PHYS 162L or PHYS 172L

Recommended Preparation: A basic understanding of vectors and matrices and of complex arithmetic is helpful for this course.

Course Notes

Include grading type (e.g., Letter, Credit No/Credit, Numeric). Note any unique characteristics of the course of operating procedure. Is the course Web-Enhanced (i.e. Blackboard), Blended or Online? If copies of lecture slides and other class information will be posted on Blackboard, note that here. If multimedia or technology-enhanced learning strategies will be used, please describe them here.

Technological Proficiency and Hardware/Software Required

This class will use lab demonstrations, as well as computer simulations using Mathematica, which is freely available to USC students at https://software.usc.edu.

Required Readings and Supplementary Materials

Introduction to Quantum Mechanics 3rd Edition, by David J. Griffiths and Darrell F. Schroeter. Course handouts. Instructional videos and other course materials on the Blackboard site.

Description and Assessment of Assignments

This class will include regular problem sets, laboratory assignments, and a midterm and final exam. The problems sets will be assigned roughly a week ahead of when they are due. Laboratory assignments will be a mix of experiments done in the lab sections, and computer simulations using Mathematica. For the experiments, the experimental procedure must be followed, data collected, and a brief write-up describing the procedure and interpreting the results submitted. The computer simulations will be done in a Mathematica notebook, which must be completed and submitted.

Grading Breakdown

Including the above detailed assignments, how will students be graded overall? Participation should not exceed 15% of the total grade. Where it does, the syllabus must provide an added explanation. No portion of the grade may be awarded for class attendance but non-attendance can be the basis for lowering the grade, when clearly stated on the syllabus. The sum of percentages must total 100%.

Assessment Tool (assignments)	**% of Grade**
Problem Sets	30%
Labs	20%
Midterm Exam	20%
Final Exam	30%
TOTAL	100%

Assignment Submission and Grading Policy

Problem sets and laboratory assignments will be given out most weeks, to be completed and handed in by the following week. Late assignments will not be accepted. We will strive to grade and return assignments within a week. All assignments will be handed in electronically via Blackboard.

Additional Policies

Because of the COVID-19 pandemic, this class will be held online in Fall 2020. While this is not what anyone hoped, we will strive to make it an informative and interesting class. Lectures, Discussions, and Labs will all be conducted online. Office hours will also be held online.

Course Schedule:

	Topics/Daily Activities	**Readings/ Preparation**	**Deliverables**
Week 1	**Origins of Quantum Mechanics:** Blackbody radiation, photoelectric effect, double-slit electron interference, de Broglie wavelength, spectroscopy and the Bohr atom.	Class notes	
Week 2	**Finite dimensional systems:** The Stern-Gerlach experiment, spin-1/2 particle as a 2D vector, qubits and the Bloch sphere, qubit states and measurements, Pauli spin matrices, Photon polarization and interferometers.	Class notes, Griffiths 1.3	
Week 3	**Linear algebra:** Complex vectors and matrices, adjoints, vector spaces and linear operators, matrix types, Dirac notation, inner products, outer products, bases and basis change, Eigenvectors and eigenvalues, observables.	Class notes, Griffiths Appendix	HW 1 due Lab 1
Week 4	**Quantum dynamics and measurement:** The Schrödinger equation and Hamiltonians, unitary transformations, stationary states, energy levels, degeneracy, quantum measurements, expectations, incompatible observables, Heisenberg Uncertainty Principle.	Class notes	HW 2 due Lab 2

Week 5	**Joint systems:** Two or more qubits, quantum gates, local observables and joint observables, tensor products for general systems, isolated and interacting subsystems.	Class notes, Griffiths Chapter 3	HW 3 due Lab 3
Week 6	**Entanglement and quantum communication:** Product states and entangled states, correlated measurements, the EPR experiment and Bell inequality violation, quantum teleportation and superdense coding, quantum cryptography/key distribution.	Class notes, Griffiths 12.1-2	HW 4 due Lab 4
Week 7	**Quantum computation I:** Logic gates and circuits, reversible circuits, quantum gates and circuits, Turing machines, circuits, and computational complexity.	Class notes	HW 5 due Lab 5
Week 8	**Quantum computation II:** Quantum circuits and algorithms: Deutsch, Shor and Grover algorithms. **Midterm Exam**.	Class notes	**Midterm Exam**.
Week 9	**Free particle in space:** Continuous variables, states and operators, position and momentum, Heisenberg uncertainty, the Schrödinger equation, plane waves and wave packets.	Griffiths Chapters 1 and 2	HW 6 due Lab 6
Week 10	**Bound states:** Particle in a box, eigenvalues and eigenvectors, square well, bound and free states, harmonic oscillator, raising and lowering operators.	Griffiths Chapter 2, 4.1	HW 7 due Lab 7
Week 11	**Central potentials:** Orbital angular momentum and spin angular momentum, rotations.	Griffiths 4.2-3	HW 8 due Lab 8
Week 12	**Central potentials**: The harmonic oscillator again, the Hydrogen atom.	Griffiths 4.2-3	HW 9 due Lab 9
Week 13	**Quantum computation III:** Realizing quantum bits and gates, resonant driving, the ion trap, superconducting quantum bits, quantum errors.		HW 10 due
FINAL			Refer to the final exam schedule in the USC *Schedule of Classes* at classes.usc.edu.

Statement on Academic Conduct and Support Systems

Academic Conduct:

Plagiarism – presenting someone else's ideas as your own, either verbatim or recast in your own words – is a serious academic offense with serious consequences. Please familiarize yourself with the discussion of plagiarism in SCampus in Part B, Section 11, "Behavior Violating University Standards" policy.usc.edu/scampus-part-b. Other forms of academic dishonesty are equally unacceptable. See additional information in SCampus and university policies on scientific misconduct, policy.usc.edu/scientific-misconduct.

Support Systems:

Counseling and Mental Health - (213) 740-9355 – 24/7 on call
studenthealth.usc.edu/counseling

Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention.

National Suicide Prevention Lifeline - 1 (800) 273-8255 – 24/7 on call
suicidepreventionlifeline.org
Free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week.

Relationship and Sexual Violence Prevention Services (RSVP) - (213) 740-9355(WELL), press "0" after hours – 24/7 on call
studenthealth.usc.edu/sexual-assault
Free and confidential therapy services, workshops, and training for situations related to gender-based harm.

Office of Equity and Diversity (OED) - (213) 740-5086 | Title IX – (213) 821-8298
equity.usc.edu, titleix.usc.edu
Information about how to get help or help someone affected by harassment or discrimination, rights of protected classes, reporting options, and additional resources for students, faculty, staff, visitors, and applicants.

Reporting Incidents of Bias or Harassment - (213) 740-5086 or (213) 821-8298
usc-advocate.symplicity.com/care_report
Avenue to report incidents of bias, hate crimes, and microaggressions to the Office of Equity and Diversity |Title IX for appropriate investigation, supportive measures, and response.

The Office of Disability Services and Programs - (213) 740-0776
dsp.usc.edu
Support and accommodations for students with disabilities. Services include assistance in providing readers/notetakers/interpreters, special accommodations for test taking needs, assistance with architectural barriers, assistive technology, and support for individual needs.

USC Campus Support and Intervention - (213) 821-4710
campussupport.usc.edu
Assists students and families in resolving complex personal, financial, and academic issues adversely affecting their success as a student.

Diversity at USC - (213) 740-2101
diversity.usc.edu
Information on events, programs and training, the Provost's Diversity and Inclusion Council, Diversity Liaisons for each academic school, chronology, participation, and various resources for students.

USC Emergency - UPC: (213) 740-4321, HSC: (323) 442-1000 – 24/7 on call
dps.usc.edu, emergency.usc.edu
Emergency assistance and avenue to report a crime. Latest updates regarding safety, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible.

USC Department of Public Safety - UPC: (213) 740-6000, HSC: (323) 442-120 – 24/7 on call
dps.usc.edu
Non-emergency assistance or information.