Ph. D. program in Physics at SMU
Written core proficiency exam

CURRENT POLICIES – JANUARY 2022

The policies described here were approved in a series of votes by all physics faculty in 2011, 2017, 2018, and 2019.

PURPOSE OF THE CORE PROFICIENCY EXAM (CPE)

Our CPE serves several purposes. First, it ensures that the students that are clearly unprepared to continue to a PhD do not remain in the program for more than two years. Second, the CPE encourages the students to review and consolidate their knowledge of basic physics. Finally, the CPE can serve as a flag for students whose skills in some subjects are marginal and should be remedied. Passing the CPE awards a Masters degree to the student. CPE is a part of the evaluation of the student's preparedness for the Ph. D. research and does not guarantee by itself that a faculty member will agree to supervise the student for a Ph. D.

POLICIES

1. The CPE follows the university policy on Ph. D. qualification exams available in the SMU Graduate Catalog.

2. The CPE consists of four sections testing on the knowledge of classical mechanics, electrodynamics, quantum mechanics, and statistical mechanics. The exam is proctored. (No open-ended exams.) Each section is to be completed within two hours. The proctor has a discretion to add more time on the exam if necessary. The preparers of each subject exam are responsible for proctoring.

3. The test level is advanced undergraduate. We will provide an example of one or two undergrad texts for each subject to the students and preparers in order to identify the exam level and possible topics.

4. Each subject exam will consist of 4 problems. Two of these problems will be shorter (about 15 minutes each) and worth 20 points each. Two of the problems will be longer (about 45 minutes each) and worth 30 points each.

5. You will be allowed one textbook of your choice, one math reference book, and a calculator.

6. Examples of previous questions (but not solutions) are made available on our web site beforehand (several months in advance).

7. All full-time faculty will be requested to submit problems for consideration for inclusion in the subject tests. A single exam committee appointed by the Graduate Committee and consisting of 4 people will assemble the exam from the problem pool, and consult with faculty if additional problems or modifications are needed. Two graders will conduct the final grading, and the final grading will be reviewed by the exam committee before returning results to the students.

8. Each exam with solutions must be prepared at least one week before the test in order to ensure that the test has been timed, and the questions are soluble. We further recommend that each proposed problem be solved by a committee member under conditions approximating the actual exam, but leave the details of preparation and checking of questions to the committee.
9. Preparers grade their exams within a week of the test, and the department announces results shortly (within several days) thereafter.
10. Students must pass all four sections and may retake individual sections once without retaking the entire exam.
11. We will offer all exams on a regular annual schedule at the beginning of winter semester, just as classes begin.
12. The department will save the actual exams, though the students may look at them after they're graded. Grading is in principle pass/fail, though for the sake of the students and accreditation, it is useful for the grading to be somewhat detailed, with a score that reflects the percentage of the material of which the student demonstrated mastery.

SUBJECT GUIDELINES

Classical Mechanics

The qualifying exam on Classical Mechanics will be at the level of SMU's advanced undergraduate course (e.g., Fowles & Cassiday or Marion & Thornton). The exam questions will be on the following topics

1. Special Relativity (kinematics, time dilation, lenght contraction, doppler shifts)
2. Lagrangians (equations of motion and forces of constraint) and Hamiltonians.
3. Coupled oscillators and finding normal modes/eigenfrequencies.
4. Dynamics of multi-particle systems and motions (especially rotations) of a solid body.
5. Motion in non-inertial reference frames (e.g., coriolis force).
6. Central and gravitational force (e.g., Kepler's 3 Laws, Newton's Gravitation Law)

Also, students should know some basic (non-obscure) physical data: the value of Newton's Constant (G), mass and size of Earth, mass and number density of air at standard temperature and pressure (STP), the acceleration due to gravity (g) near Earth, and so on.

Electricity and Magnetism

The exam will be at the advanced undergraduate level. Sample texts that contain problems similar to the type on the exam include Lorrain and Corson ("Electromagnetic Fields and Waves"), Barger and Olsson ("Classical Electricity and Magnetism"), Griffiths ("Introduction to Electrodynamics"), and Pollack and Stump ("Electromagnetism"). The exam questions will be on the following topics

1. Students should know some basic physical data: the value of the electric charge, the electric permittivity of free space, the magnetic permeability of free space and the speed of light in vacuum.
2. Determination of electrostatic potentials and field in vacuum for various charge distributions. Application of bounder conditions for the electric field at the surface of a conductor.
3. Solution of the Laplace equation using the method of images including solutions in spherical coordinates for problems with azimuthal symmetry.
4. Calculation of the potential energy of a distribution of charges and calculation of energy density in a static electric field.
5. Calculation of electrostatic fields in linear and homogeneous dielectric materials and knowledge of boundary conditions at the intersection of two dielectrics. Calculations of the

torque and force on an electric dipole, including the case of a non-homogeneous but static electric field.

6. Calculation of magnetic fields from simple, uniform current distributions. This includes the Biot-Savart law, Ampere's law and magnetic vector potential. Knowledge of the magnetic dipole moment, both its definition and the magnetic field it produces. Student are expected to be able to calculate magnetic forces on simple current distributions and to be able to calculate the torque on a magnetic dipole. Knowledge of magnetic potential energy is also expected.
7. Boundary conditions at the surface of a current-carrying sheet in a vacuum, magnetic fields in matter and magnetostatic boundaries for magnetized media.
8. Analysis of circuits that contain resistors, capacitors and inductors.
9. Magnetic force on a moving charge, electric and magnetic dipole radiation and the power emitted by an accelerated charge, and the Poynting vector.
10. Lenz's law, Faraday's law and Maxwell's equations in vacuum. Propagation of waves in one dimension, reflection and refraction at a boundary.
11. Radiation from a single accelerated charge, electric and magnetic dipole radiation.
12. Relativistic transformation of E and B fields. (Online Feymann Lectures in Physics may be useful to help you remember.)

Quantum Mechanics

The PhD qualifying exam will be at the level of the textbooks by Liboff, Griffiths, Shankar, etc. The exam questions will be on the following topics

1. Principles of Quantum Mechanics like the superposition principle, definition of a quantum state, the probability interpretation, discrete and continuous symmetries, commuting operators and the uncertainty relation, etc.
2. The time-dependent and time-independent Schrödinger equation, bound state and unbound state exact solutions in 1, 2, and 3 dimensions, e.g. Square Well, Rectangular Box, Square Step, Harmonic Oscillator, Hydrogen atom, periodic potentials, delta-function potentials, etc.
3. Solving the Schroedinger equation, approximately
    a. Variational method
    b. WKB approximation
    c. Time-independent perturbation theory (degenerate and nondegenerate)
    d. Time-dependent perturbation theory
4. Angular Momentum
    a. SU(2), spin-1/2
    b. Addition of Angular Momenta and selection rules
5. Scattering
    a. Fermi's golden rule and quantum state transition rates, e.g. ionization of Hydrogen, Rutherford scattering.
    b. Familiarity with the non-relativistic scattering cross sections of half-integer spin particles, e.g. symmetry constraints on the 2x2 scattering matrix, polarization, etc.

Note that some of these topics may or may not be covered in the books mentioned above

Statistical Mechanics

The PhD qualifying exam will be at the level of the textbooks by Schroeder ("An Introduction to Thermal Physics) and Reif (Fundamentals of Statistical and Thermal Physics). The exam questions will be on the following topics

1. CLASSICAL THERMODYNAMICS: the 4 laws of thermodynamics; thermal equilibrium; thermodynamic potentials: internal energy, enthalpy, Helmholtz free energy,

Gibbs free energy; Joule expansion (free expansion); PV and TS diagrams; adiabats, isotherms, isochors, isobars; heat; work; ideal gas; heat capacities of dilute gases; equipartition theorem; heat engines and refrigerators; entropy; the Carnot engine; latent heat; phase changes; van der Waals equation

2. PROBABILITY AND MATHEMATICAL TOOLS: Binomial, Poisson, and Gaussian probability distributions; Stirling's approximation; Gaussian integrals

3. STATISTICAL MECHANICS: partition function; microcanonical, canonical, and grand canonical ensembles; paramagnets; Einstein solids; Boltzmann distribution; Maxwell-Boltzmann speed distribution; chemical potential

4. QUANTUM STATISTICS: blackbody radiation and the Stefan-Boltzmann law; Planck distribution; Bose-Einstein and Fermi-Dirac statistics; heat capacity of a crystal