Physics 390: Final review

The final exam will take place from **1:30pm to 3:30pm** on **Tuesday April 22** in 1230 USB (the usual room). It will be open-book: you may use your copy of Tipler & Llewellyn and the course handouts on relativity, the simple harmonic oscillator, and the liquid-drop model, but not class notes or solutions to homework problems. You will probably need a calculator to complete some of the problems.

Here is a list of the topics you should know about for the exam. You should also make sure you have completed all the reading and that you're familiar with the solutions of the homework problems. If you want extra problems to practice for the exam, take a look at the list of suggested problems handed out in the review session.

Special relativity: There will not be any questions on the exam specifically about relativity, but you may need to know relativistic formulas to answer some questions, particularly the formula for relativistic energy $E^2 = (pc)^2 + (mc^2)^2$. You may bring the course handout on relativity to the exam and use it. If you have lost your copy you can download another one from the course web site.

Basic experimental results: Quantization of charge. Quantization of light and the existence of the photon. Rutherford scattering and the nuclear atom.

Early quantum physics: De Broglie waves, wave packets, phase velocity, group velocity, and the probabilistic interpretation of the wave function. The uncertainty principle.

The Schrödinger equation: The derivation of the Schrödinger equation by replacing classical quantities by operators (particularly the momentum and energy operators), so that $p^2/2m + V(x) = E$ becomes

$$-\frac{\hbar^2}{2m}\frac{\partial^2\Psi}{\partial x^2} + V(x)\Psi(x,t) = i\hbar\frac{\partial\Psi}{\partial t},$$

where $\Psi(x,t)$ is the (complex) wave function. The time-independent solution of this equation:

$$-\frac{\hbar^2}{2m}\frac{\partial^2\psi}{\partial x^2} + V(x)\psi(x) = E\psi(x).$$

Conditions on the wave function: normalization $\int |\Psi|^2 \, dx = 1$, continuity of value and continuity of slope. The Schrödinger equation in three dimensions.

Particular solutions of the Schrödinger equation: The infinite square well, the finite square well, the simple harmonic oscillator, the 3D infinite square well, reflection and transmission at a potential step, tunneling through a potential barrier.

You may bring the course handout on the simple harmonic oscillator to the exam and use it. If you have lost your copy you can download another one from the course web site.

Atomic physics: Solution of the Schrödinger equation for the hydrogen atom. You will not need to know the details of the solution, but you should be familiar with the important conclusions: quantization of angular momentum and energy and the meaning of the three quantum numbers ℓ, m, and n. Orbital dipole moment, its relation to angular momentum, and the Stern-Gerlach experiment. Particle spin and the gyromagnetic ratio (also called the "g-factor").

Quantum mechanics for more than one particle, the generalization of the wave function and the Schrödinger equation. Quantum mechanics for identical particles and the symmetry of the wave function, bosons and fermions and their relation to particle spin (bosons = integer spin, fermions = half-integer spin), the Pauli exclusion principle.

The shell structure of the atom, the periodic table, and spectroscopic notation.

Statistical mechanics: The definition and use of the Boltzmann distribution and the partition function:

$$p(s) = \frac{e^{-E_s/kT}}{Z}, \qquad Z = \sum_s e^{-E_s/kT}.$$

Calculation of averages such as the average energy. Physics of a particle in a box at temperature T, the equipartition theorem ($\frac{1}{2}kT$ per degree of freedom), the ideal gas. Quantum statistics, the Fermi-Dirac and Bose-Einstein distributions, the Fermi sphere and Fermi energy, density of states.

Solid state physics: The structure of crystals, ionic crystals, the Madelung constant, approximate form for the repulsive potential. Metals, metallic bonds, the Drude formula for conductivity, the relaxation time and the mean free path, band structure, conductors, insulators, and semiconductors. Magnetism, paramagnetism and ferromagnetism, the mean-field (Curie) formula for magnetization, the magnetic phase transition.

Nuclear physics: The structure of the nucleus, its density, the approximate formula for the radius of the nucleus ($R = R_0 A^{1/3}$). Nuclear stability, the NZ plot and the stable line, the physics of the stable line (the exclusion principle, electrostatic repulsion between protons, the magic numbers). Nuclear masses, the liquid drop model for binding energies. Nuclear decay, including α, β, and γ decay, half-life and decay rate, α chains, the quantum tunneling explanation of α decay, the three modes of β decay and the existence of the neutrino, calculation of decay energies from atomic masses.

Particle physics: Leptons, quarks, and bosons, antiparticles, baryons and mesons, the three generations of leptons and of quarks, the four fundamental forces and their bosons. Masses and charges of bosons, flavor and color (gluons carry color, the weak force bosons have mass). Symmetry and conservation laws, operators that commute with the Hamiltonian. Conservation of baryon number and stability of the proton, conservation of lepton numbers and its possible violation, strangeness, isospin.