Physics 390: Mid-term review

The mid-term exam will take place at **11am–12pm, Wednesday February 20** 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 and the simple harmonic oscillator, 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 up to the end of Chapter 6 and that you're familiar with the solutions of the homework problems.

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 from the course web site.

Quantization of charge: Thomson's technique for measuring e/m for the electron, Millikan's oil drop experiment.

Quantization of light: The relation between energy and frequency for photons $E = hf$, Planck's theory of the black-body radiation spectrum, Stefan's law, Wien's law. The photoelectric effect, stopping potentials and work functions, the use of Einstein's photoelectric equation $eV_0 = hf - \phi$. X rays, their generation and Bragg scattering, the Compton effect.

The atom: Rutherford scattering and the use of the formula

$$b = \frac{qQ}{4\pi\epsilon_0 m v^2 \tan \frac{1}{2}\theta}$$

relating the impact parameter to the scattering angle. Calculation of the distance of closest approach and measurements of the size of the nucleus.

The Bohr model: Atomic spectra and their explanation using the Bohr orbital model, particularly for hydrogen. Calculation of the energy levels of the hydrogen atom and the derivation of the Rydberg–Ritz equation for the wavelengths of atomic lines:

$$\frac{1}{\lambda} = Z^2 R\left(\frac{1}{m^2} - \frac{1}{n^2}\right),$$

where R is the Rydberg constant. The Balmer, Lyman, and Paschen series in hydrogen. The reduced mass correction and the calculation of the corrected Rydberg constant. X ray spectra and Moseley's approximate formula for X ray frequencies, the meaning and measurement of the screening parameter b in the formula.

De Broglie waves: De Broglie's hypothesis, $f = E/h$, $\lambda = h/p$, Davisson and Germer's scattering experiment. Wave packets, phase velocity, group velocity, and the probabilistic interpretation of de Broglie waves. The uncertainty principle, the energy of a particle in a box.

The Schrödinger equation: The derivation of the Schrödinger equation by replacing classical quantities by operators, particularly the momentum and energy operators

$$\hat{p} = -\mathrm{i}\hbar\frac{\partial}{\partial x}, \qquad \hat{E} = \mathrm{i}\hbar\frac{\partial}{\partial t},$$

so that $p^2/2m + V(x) = E$ becomes

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

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

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

Conditions on the wave function: normalization $\int |\Psi|^2\,\mathrm{d}x = 1$, continuity of value and continuity of slope.

Particular solutions of the Schrödinger equation: The infinite square well, calculation of energy levels and spectrum of transitions. Normalization of the wave function, shape of the probability distribution, calculation of the mean position of the particle, calculation of the mean momentum. The finite square well and the penetration of the wave function into the walls of the well. The simple harmonic oscillator, Schrödinger's solution using raising and lowering operators, the ground state of the simple harmonic oscillator.

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 from the course web site.

Reflection and transmission: Reflection and transmission of a beam of particles at a potential step. Reflection and transmission at a potential barrier, quantum tunneling, application of tunneling to the scanning tunneling microscope and α-decay.