What to expect

The exam will consist of 30 multiple choice questions. Only one submission attempt is allowed. The exam will be graded electronically, and the grade returned to you upon submission. Questions will be based on content covered in class and will be primarily pulled from lecture material and the textbook, although some questions may also come from supplemental material such as class videos, homework, or class quizzes. This is a semi-comprehensive final; questions from throughout the course can and will be asked, but the majority (~ 2/3) will come from the most recent material.

Instructions

The exam will begin at 7:30 A.M. on Friday, December 9th, and you will have 2 hours to complete the exam. The exam must be taken though the Respondus Lockdown browser. You will need to have your camera on during the exam and show your TAMU Student ID before you begin.

The exam will be open notes, open computer (within the limits described below), and open book (allows use of the textbook, notes, and google). Using a secondary electronic device such as a tablet, advanced calculator, or computer is allowed, as long as the screen is turned so that it is visible to the camera.

The exam is **NOT** open friend (i.e. you are not allowed to work with other classmates or receive outside help from tutors, study services, other students, etc.) and any form of external help is not allowed (i.e. the use of answer key services such as Chegg, Quizlet, etc are also explicitly not allowed). Rescheduling finals is difficult, so baring an emergency, you will be required to take the final at the normal time should you fail to notify us of schedule conflicts ahead of time.

Recommendations for studying (material from chapters 8, 12, & 15 are highlighted in yellow)

- Review all chapters covered in class, with emphasis on chapters 8, 12, & 15.
- Review all class lectures, with emphasis on chapters 8, 12, & 15.
- Review the HW assignments.
- Review the previous Exams (I, II, III) on SIBOR.
- Prepare a quick formula sheet for use during the exam. This sheet should include information such as relevant formulas and constants, examples of solved problems, and self-written explanations of the concepts covered. While the exam is open-book, searching for the needed information will whittle away your time; having everything you need in one location will greatly help.
- A calculator is highly recommended

Preparation for Exam

Concepts to know

* This is an overview of items to know, it is not necessarily comprehensive and not all items here may appear on the exam. Use it as a general guideline on what to study. *

- Concept of the inertial reference frame.
- Concept of Galilean Invariance & Transformation
- Ether and the Michaelson & Morley Experiment
- Einstein's Postulates
  - The principle of relativity: The laws of physics are the same in all inertial systems. There is no way to detect absolute motion, and no preferred inertial system exists.
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- Lorentz Transformations
- Time Dilation
- Length Contraction
- Relativistic Doppler Effect
  - $f = \frac{\sqrt{1+\beta}}{\sqrt{1-\beta}} f_0$
- Relativistic Momentum:
  - $p = \gamma m\vec{u}$
- Relativistic Kinetic Energy
  - $K = m_o c^2(\gamma - 1)$
- Rest Mass and Mass-Energy Conversion
- Discovery of x-ray and electron
- Millikan drop experiment and determining the charge of an electron

Preparation for Exam

- Rydberg Equation: $\frac{1}{\lambda} = R_H\left(\frac{1}{n^2} - \frac{1}{k^2}\right)$ $R_H = 1.096776 \times 10^7\ \text{m}^{-1}$
- Light = Electro-Magnetic Radiation
- Blackbody radiation
- Concept of Wien's Displacement Law and Stephan-Boltzmann law
- Ultraviolet Catastrophe and what it meant for classical physics
- Planck's Radiation Law: $\mathcal{I}(\lambda,T) = \frac{2\pi c^2 h}{\lambda^5}\frac{1}{e^{hc/\lambda kT} - 1}$
- Planck's Postulates:
  - The oscillators (of electromagnetic origin) can only have certain discrete energies determined by $E_n = nhf$, where n is an integer, f is the frequencyof the radiation, and h is called Planck's constant.
    $h = 6.6261 \times 10^{-34}$ J·s.
  - The oscillators can absorb or emit energy in discrete multiples of the fundamental quantum of energy given by: $\Delta E = hf$

- Concept and equations of the photo-electric effect.
- Combination of constants
- Compton Effect
- Pair Production and Annihilation
- The various Atom models, their strengths, their weaknesses, and what lead to their conception.
- Bohr radius: $a_0 = 0.529$Å
- How to calculate changes in electron states
- The Correspondence Principle
- Electron shells and Mosely Plot

Preparation for Exam

- Braggs Law and Bragg Planes
  - $n\lambda = 2d \sin\theta$
    (n = integer)
- De Broglie waves
  - $\lambda = \frac{h}{p}$
- Ideas of wave motion
  - See slides 15-18, Lecture 9
- Phase and Group Velocity
  - Phase Velocity: $v_{\text{ph}} = \frac{\lambda}{T} = \frac{\omega}{k}$
  - Group Velocity: $u_{\text{gr}} = \frac{dE}{dp} = \frac{pc^2}{E}$
- Uncertainty Principle
  - Position-Momentum: $\Delta p_x \, \Delta x \geq \frac{\hbar}{2}$
  - Energy-Time: $\Delta E \, \Delta t \geq \frac{\hbar}{2}$
- The Copenhagen Interpretation
  - The uncertainty principle of Heisenberg
  - The complementarity principle of Bohr
  - The statistical interpretation of Born, based on probabilities determined by the wave function
- All aspects of a particle in a box
  - Energy of n-th level: $E_n = n^2 \frac{\hbar^2 \pi^2}{2ml^2}$
- General form of the Schrodinger Wave Equation
  - $\Psi(x,t) = Ae^{i(kx-\omega t)} = A[\cos(kx-\omega t) + i\sin(kx-\omega t)]$
- What is Normalization why it is needed

Preparation for Exam

- How to Normalize an equation.
- Boundary Conditions for Wave Equations
    - In order to avoid infinite probabilities, the wave function must be finite everywhere.
    - In order to avoid multiple values of the probability, the wave function must be single valued.
    - For finite potentials, the wave function and its derivative must be continuous. This is required because the second-order derivative term in the wave equation must be single valued. (There are exceptions to this rule when *V* is infinite.)
    - In order to normalize the wave functions, they must approach zero as *x* approaches infinity.
- Time-Independent Schrodinger Equation
    - $-\frac{\hbar^2}{2m}\frac{d^2\psi(x)}{dx^2}+V(x)\psi(x)=E\psi(x)$
- What is an expectation value and how to find it
- The various Operators
- Solutions to 1D Infinite and Finite Square Wells
- Degeneracy
    - Degeneracy is when multiple wave functions have the same energy.
- Simple Harmonic Oscillator
- Purpose of Radial and Angular Equations
- Quantum Numbers, what they represent, and their Boundary Conditions
    - $n = 1, 2, 3, 4, \ldots$ Integer

- $\ell = 0, 1, 2, 3, \ldots, n - 1$ Integer
- $m_\ell = -\ell, -\ell + 1, \ldots, 0, 1, \ldots, \ell - 1, \ell$ Integer

- What is the Zeeman Effect
- Intrinsic Spin
    - $m_s = \pm\frac{1}{2}$
- Selection Rules
    - Δn = anything
    - $\Delta\ell = \pm 1$
    - $\Delta m_L = \pm 1, 0$
- Principle of equivalence
    - There is no experiment that can be done in a small confined space that can detect the difference between a uniform gravitational field and an equivalent uniform acceleration.
- Inverse Photoelectric effect
- Electron Filling & Pauli Exclusion Principle
- Total Angular Momentum
    - **J = L + S**
    - $$L = \sqrt{\ell(\ell+1)}\hbar$$
      $$S = \sqrt{s(s+1)}\hbar$$
      $$J = \sqrt{j(j+1)}\hbar$$
- Spin Orbit Coupling
- Hund's rules

  - The total spin angular momentum S should be maximized to the extent possible without violating the Pauli exclusion principle.
  - Insofar as rule 1 is not violated, L should also be maximized.
  - For atoms having subshells less than half full, J should be minimized.
- Anomalous Zeeman Effect
- Applications of Hund's rules (aka, how to find the state of a valance electron)
- What an isotope is
- Fermi Distribution
  - $\rho(r) = \frac{\rho_0}{1 + e^{(r-R)/a}}$
- Intrinsic Magnetic Moment
- Nuclear Forces
- Liquid Drop Model
- Nuclear Shell Model
- Radioactive Decay
  - Alpha
  - Beta
  - Gamma
- Determining Ages
- Stellar Evolution

Preparation for Exam

- General Relativity
  - The principle of Equivalence in General relativity: There is no experiment that can be done in a small confined space that can detect the difference between a uniform gravitational field and an equivalent uniform acceleration.
- Gravitational Time dilation
- Gravitational Waves
- Black Holes
- Conservation Laws
- Schwarzschild Radius
  - $r_S = \frac{2GM}{c^2}$
- Equivalence of Mass and Energy
  - $E = mc^2$
- Hawking Radiation
  - $T = \frac{\hbar c^3}{8\pi kGM}$