Physics 112

Study Notes for Final Exam 2009

This document lists only topics covered since Exam III. For notes on the remaining material, consult the previous study notes documents (linked to the Reading and Workbook Assignments web page).

Chapter 28 Quantum Physics

1. Bragg Diffraction of X Rays
   Figure 28.5 (b) shows why the path-length difference between rays hitting adjacent layer of atoms in the crystal is $2d\cos\theta$. Eq. 28.1 gives the condition for constructive interference. Looking ahead, anticipate being able to apply this very geometry to the constructive interference of de Broglie matter waves reflected from a crystal. (This is essentially how the de Broglie postulate was originally verified.)
2. Photoelectric Effect
   Authors' discussion is quite detailed and focused on describing how our understanding of this phenomenon confirmed the particle nature of light. Understand the physical significance of both intercepts and the slope of the plotted V_{stop} vs. frequency.
3. Photons

   This section compliments §25.7.
4. Matter Waves
   De Broglie relation $\lambda = h/p$ postulated for particles.
   Be able to determine this λ from potential difference through which a particle is accelerated (find momentum from kinetic energy caused by change in potential energy).
   A de Broglie wave represents a probability amplitude. The square of this amplitude is a probability density (e.g. probability per unit length in the 1-dimensional box). As is the case for waves more familiar to you, matter wave amplitudes obey superposition (interference, diffraction). The 'intensity' of a matter wave is its probability density.
5. Quantized Energy
   Quantized (discrete) energy levels exist for all *bound* quantum systems.
   Understand the particle-in-a-box both conceptually and quantitatively. It exhibits features common to all bound systems in quantum mechanics.
6. Energy Levels and Transitions
   Remember that energies of photons absorbed or emitted by a quantum system must have energies corresponding to *differences* between energies of allowed levels.

7. Heisenberg Uncertainty Principle

   Read authors' note on p. 956. On this exam you will not be asked to make any precise calculation with the uncertainty principle, but you may need to estimate something, in which case you must state clearly how you are defining Δx and Δp.
8. You may ignore this section.
9. Be familiar with the Compton Effect (barely mentioned in book). The class equation $\lambda' - \lambda = \frac{h}{m_e c}(1 - \cos\theta)$ is derived from conservation of energy and momentum in the elastic scattering of photons by free particles. The term $\frac{h}{m_e c}$ is called the Compton wavelength of the electron. In very high energy interactions, we could just as well have Compton scattering with a particle of any mass. At the end of this document is a practice problem for you to work on this topic. The final exam may include a multiple choice question on Compton scattering, but no worked problem.

Chapter 30 Nuclear Physics

1. Nuclear Structure

   Be very fluent with the isotope notation ${}^{A}_{Z}E$ where Z is the atomic number, A is the nucleon number and E is the element symbol. Know the concept of the atomic mass unit, but do not memorize conversion factors. These will be provided as needed.

   Nuclei all have very similar density. Thus the volume of a (spherical) nucleus $V = \frac{4}{3}\pi r^3$ is directly proportional to the nucleon number A and the radius then scales as $A^{1/3}$. A useful formula for the radius of a nucleus that appeared in Mastering Physics, but not in your book is $R = R_0 A^{1/3}$, where R_0 is empirically found to be about 1.2fm.
2. Nuclear Stability

   Be able to calculate total binding energy and binding energy per nucleon for any isotope (mass data will be provided as needed).

   Understand the graph of Fig. 30.5.

3. Forces and Energy in the Nucleus

   Shell Model

   Pauli Principle applies separately to protons and neutrons

   Two major differences between nuclear and atomic shells:

   Nuclei have no restriction that $l < n$. Hence states such as $1s$, $1p$, $1d$ etc. are found in nuclei

Nuclear energy levels have much stronger dependence on l than atoms

Just as certain atomic numbers provide high atomic stability (noble gases), there are certain numbers of protons or neutrons that give high nuclear stability. The actual numbers are different because of differences in the particle interactions involved, but the fundamental explanations are similar. The first few 'magic numbers' for nuclear stability are 2, 8, 20 and 28.

Low-Z Nuclei

Generally like to have equal or nearly equal numbers of protons and neutrons.

High-Z Nuclei

Need more neutrons to offset the increased Coulomb repulsion of many protons.

4. Radiation and Radioactivity

   Nuclear Decay and Half Lives

   Understand the probabilistic underpinnings of the decay-rate equation

   Note that eqs. 30.9 and 30.12 are identical (with Eq. 30.11 giving the needed relationship between half life $t_{1/2}$ and decay probability r per unit time.

   Activity

   Be familiar with the activity unit Bequerel (*Bq*)

   Dating Techniques

   Be familiar with the theory of ^{14}C dating. Don't memorize specific numbers such as equilibrium concentration or half life, but be able to infer age from pertinent data.

5. Nuclear Decay Mechanisms

   Know what α, β^-, β^+ and γ decays imply.

   Be able to 'balance' decay equations

   Be able to calculate energy released from mass defect information.

   Also be able to balance and compute energy absorbed or released in a nuclear collision (discussed in class but not in book). This is nearly identical to a decay problem, but involves two interacting nuclei on the left side as opposed to just one thing that spontaneously flies apart.

6. Subatomic Particles

   Skip this section. It's really interesting, but we just didn't have time to cover it.

7. Medical Applications of Nuclear Physics

   No questions from this section either… Out of semester time.

Practice Problem: A photon of energy 250*MeV* has a Compton interaction with a particle initially at rest. The scattered photon exits the collision at an angle 69° from the incident photon's direction and has energy 100*MeV*. Find the particle's

a) rest energy in *MeV*,

b) total relativistic energy after the collision,

Try making clever use of the hybrid constant $hc = 1240 eV\ nm = 1240 MeV\ fm$