King Fahd University of Petroleum and Minerals
Physics Department
Phys-212: Modern Physics
Spring 2002

FINAL EXAM

Please Answer all the problems. Use the formula sheets attached

Part I.

Q1. (15 points)

A. Write briefly about

I. The different types of solids, and their properties
II. Isotopes in nuclear physics
III. Magic Numbers in nuclear physics
IV. Half-Live of radioactive materials

B. Discuss briefly the types of decay processes in radioactivity giving reaction equations if possible and discussing the changes occurring in the nuclei.

C. What are the fundamental processes in nature? What are their relative strengths? What is the field particle (mediator) associated with each force?

Q2. (20 points)

A. Assume that the nucleus of an atom can be regarded as a three dimensional box of length $2x10^{-14}$ m. If a proton moves as a particle in this box, find
   a. The ground state, the first and the second excited states energies of the proton
   b. The degeneracy of each state?
   c. Repeat (a) and (b) for the case of a two-dimensional box.

B. A hydrogen atom is in the 6g state,
   a. What is the principal and the orbital quantum numbers?
   b. What is the energy of the atom?
   c. What is magnitude of the electron's orbital angular momentum?

C. Consider an electron in the l=3 state.
   a. What are the possible values of the magnetic quantum numbers
   b. For each m_l, find the angle θ that the orbital quantum number makes with the z-axis.

Q3. (20 points)

A. I. Calculate the magnetic energy and the Larmor frequency for an electron in the n=2 state of hydrogen (neglect spin) assuming the atom is in a magnetic filed of strength 1.0 T.

II. What are the possible energies of the electron after splitting.

B. An electron in an atom is in the $4F_{5/2}$.

a. Find the values of the quantum numbers n, *l*, and j
b. The magnitude of the electron's total angular momentum
c. The possible values for the z-component of the electron's total angular momentum

C. I. Write out the electronic configuration for oxygen ${}^{16}_{8}O$

II. Write out the values for the set of quantum numbers n, *l*, m_l, m_s for each electron in oxygen.

D. According to the selection rules, which one of the following transitions: is allowed?

I. 3p to 2p
II. 5s to 6s
III. 4d to 3p
IV. 3s to 3d
V. 1p to 1d

Q4. (15 points)

Consider the HCl molecule, which consists of a hydrogen atom of mass 1 u and bound to a chlorine atom of mass 35 u. The equilibrium separation between the atoms is 0.128 nm.

I. Calculate the three lowest rotational energy states

II. What is the frequency associated with the l =3 to l =4 transition?

III. If the frequency associated with the ν=0 to ν=1 vibrational states is 8.66×10^{13} Hz, then calculate the three lowest vibrational energy sates**.**

Part II.

Q5. (5 points)

Imagine that in the year 2025 scientists will be able to build a supersonic jet (Aerospace students should be happy) of length 5 meters, that moves with a speed 0.6c relative to you (stationary). Find the length of this jet measured by you.

Q6. (5 points)

Calculate the energy released per fission in the following reaction

$${}^{236}_{92}U \rightarrow {}^{90}_{37}Rb + {}^{143}_{55}Cs + 3{}^{1}_{0}n$$

Q7. (5 points)

A photon of initial energy 0.1 MeV undergoes Compton scattering at an angle of 60^{o}. Find

a. The energy of the scattered photon
b. The recoil kinetic energy of the electron

Q8. (5 points)

A hydrogen atom initially at rest in the n = 4 state decays to the ground state with the emission of a photon. Calculate

a. The wavelength of the emitted photon
b. The recoil momentum of the atom

Q9. (5 points)

We wish to measure simultaneously the wavelength and the position of a photon. Assume the wavelength measurement give $\lambda = 6000\,\text{Å}$ with an accuracy of $\Delta\lambda/\lambda = 10^{-6}$. What is the minimum uncertainty in the position of the photon?

Q10. (5 points)

Find the normalization constant for the harmonic oscillator ground state wave-function

$$\psi = C_o \exp(-m\omega x^2 / 2\hbar)$$