**22.101 Applied Nuclear Physics  (Fall 2006)**

**Problem Set No. 1**                                                                              **Due:  Sept. 13, 2006**

## Problem 1

Before getting into the concepts of nuclear physics, every student should have some feeling for the numerical values of properties of nuclear radiations, such as energy and speed, wavelength, and frequency, etc.  This involves some back of the envelope calculations using appropriate universal constants.

(i)      A thermal neutron in a nuclear reactor is a neutron with kinetic energy equal to $k_B T$, where $k_B$ is the Boltzmann's constant and T is the temperature of the reactor.  Explain briefly the physical basis of this statement.  Taking T to be the room temperature, 20C, calculate the energy of the thermal neutron (in units of ev), and then find its speed v (in cm/sec), the de Broglie wavelength $\lambda$ (in A) and circular frequency $\omega$ (radian/sec).  Compare these values with the energy, speed, and interatomic distance of atoms that make up the materials in the reactor.  What is the point of comparing the neutron wavelength with typical atomic separations in a solid?

(ii)     Consider a 2 Kev x-ray, calculate the frequency and wavelength of this photon. What would be the point of comparing the x-ray wavelength with that of the thermal neutron?  For an electron with wavelength equal to that of the thermal neutron, what energy would it have?

(iii)    The classical radius of the electron, defined as $e^2 / m_e c^2$, with $e$ being the electron charge, $m_e$ the electron rest mass, and c the speed of light, has the value of 2.818 x $10^{-13}$ cm.  Use this fact to calculate the Coulomb repulsion energy between two protons at a distance of 1 F.  On the basis of this result what can you conclude about the energy that is holding together a nucleus of  several protons and neutrons?

## Problem 2

Use the Table of Nuclides (kaeri) website, http://atom.kaeri.re.kr/  to find the necessary data on the lightest chemical element, hydrogen (Z = 1), to answer the following questions.

(1)  How many isotopes of hydrogen are there?

(2)  Is each isotope stable?  If not, describe fully the decay scheme (half life, what particle is given off at what energy).

(3)  State the spin, electric and magnetic moments of each isotope.

Comment briefly on what special interest hydrogen might hold in the three main application areas in the department, fission, fusion, and nuclear science and technology.

Repeat the questions (1) and (2) for the element uranium (Z=92) considering only the long-lived isotopes $U^{233}$, $U^{235}$, and, $U^{238}$.

## Problem 3

Use the Table of Nuclides (kaeri) to find the thermal neutron absorption cross section of two hydrogen isotopes, $H^1$ and $H^2$, and the thermal neutron fission cross section of two uranium isotopes, $U^{235}$ and $U^{238}$. Combine this information with the natural abundance of these four isotopes. Write a paragraph discussing the connections between the nuclear properties dictated by nature and the historical developments of nuclear power reactors in the US and in Canada.