UCSD Physics 130b $\qquad$ *Quantum Mechanics* $\qquad$ Assignment 7

Prof. B. Keating $\qquad$ Assigned: December 1 $\qquad$ Due: December 8, 2014: in Class

NO LATE HOMEWORK ACCEPTED FOR THIS ASSIGNMENT ONLY

You must staple all of your sheets together. All handwritten work must be neatly written.

$\boxed{1}$ Particle Data Group (PDG): Particle Physics Booklet (PPB)

This problem requires that you have a PPB. If you do not have a physical copy, then **it is probably too late to order one, so go to the website and print out the PDF version**. In the meantime, you can look up these answers on the web at *http://pdg.lbl.gov/2012/download/rpp-2012-booklet.pdf*. You'll need to print out the entire booklet for the Final Exam.

(a) What is the mass of the proton in kg and where is it found in the PPB?

(b) What are the spherical harmonics Y_ℓ^m for all values of m for $\ell \le 2$, and where are they found in the PPB?

(c) Does the PPB give you the functional form of the Hydrogen atom's radial wave functions for ground state ($n = 1$) and first excited state ($n = 2$)? If so, where in the PPB are they found?

(d) Write down the functional form of the Hydrogen atom's wave functions for $n = 1$ and $n = 2$ for all possible values of m for $\ell \le 2$.

(e) Many cosmologists believe that there is a particle responsible for Dark Matter called the WIMP (Weakly Interacting Massive Particle). This particle has a very low cross-section for interacting. Estimates of the weak interaction coupling strength come from upper limits from experimental searches for Dark Matter. Use the PPB to determine what is the current best estimate for the WIMP's cross-section?

$\boxed{2}$ Griffiths Problem 9.17

$\boxed{3}$ Luminosity and Neutrino Scattering (Read Chapter 11 first)

Estimates of the neutrino's cross-section yield $\sigma_\nu = 10^{-47} m^2$ in the beta decay range of energy. This is $\simeq 20$ *orders of magnitude* less than the scattering cross-section for two protons at low energy!

Using this cross-section, and the answers to Problem 1, part a and part e, estimate the mean free path λ_{MFP} for neutrinos and WIMPS for the following target materials:

(a) For water with a density of 1000 kg/m^3

(b) For lead with a density of 11400 kg/m^3

(c) By examining Figure 8 of the following paper: *http://arxiv.org/pdf/1006.0972v2.pdf*, determine which of the following three experimental searches for WIMPs has the best constraints (upper limits) on the WIMP mass and cross-section: XENON-10/100 vs. CoGeNT vs. DAMA.