6.728 Applied Quantum and Statistical Physics

Department of Electrical Engineering and Computer Science
Massachusetts Institute of Technology

PROBLEM SET 11

Issued: 12-06-02 Due: 12-11-02, in-class

Problem 11.1 Some Hydrogen Facts

(a) Are there continuum states for the hydrogen atom?

(b) How loarge is the $1s$ orbital for a hydrogenic atom with $Z = 8$?

(c) An electon is in a $3d$ orbital ($n = 3$ and $\ell = 2$). What values can m take on?

(b) If an electron is removed from the $1s$ state from silicon, then thte electon in the $2p$ state can radiatively decay to the vacant $1s$ state. A hydrogenic model can be used for the lower lying states. What is the wavelength of the radiation if the $2p$ electron makes a transition to the $1s$ state.

Problem 11.2 A Different Central Potential (this is a former final problem)

A particle is in the ground state of a spherical box. The relevant time-independent Schrödinger equation is

$$E\psi(\mathbf{r}) = \left[-\frac{\hbar^2\nabla^2}{2M} + V(|\mathbf{r}|)\right]\psi(\mathbf{r})$$

The potential $V(r)$ is given by

$$V(r) = \begin{cases} 0 & 0 \le r \le a \\ \infty & r > a \end{cases}$$

The eigenstates of the system can be written as

$$\Psi(r,\theta,\phi) = \frac{P(r)}{r}Y_{\ell,m}(\theta,\phi)$$

where

$$|\mathbf{L}|^2 Y_{\ell,m}(\theta,\phi) = \hbar^2\ell(\ell+1)Y_{\ell,m}(\theta,\phi)$$

and

$$\left\{-\frac{\hbar^2}{2M}\frac{d^2}{dr^2} + V(r) + \frac{\hbar^2\ell(\ell+1)}{2Mr}\right\}P(r) = EP(r)$$

(a) Determine the energies and wavefunctions for the ground state and the first excited state for s-states ($\ell = 0$), that is, for the $1s$ and $2s$ states.

(b) In the H-atom problem, all the $2p$ states have the same energy. Would you expect the p states of this well all to have the same energy ? Explain.

Problem 11.3 Problem 28.1 parts (a) through (c) on page 642 of the notes.

Problem 11.4 Problem 29.1 on page 666 of the notes.