5.74 Introductory Quantum Mechanics II
Spring 2009

5.74, Problem Set #0
Spring 2009
Not graded

These are some problems to make sure that you are up to speed on the basics of solving numerical problems.

1. **Numerically solving for eigenstates and eigenvalues of an arbitrary 1D potential.** Obtain the energy eigenvalues E_n and wavefunctions $\psi_n(r)$ for the anharmonic Morse potential below. (Values of the parameters correspond to HF). Tabulate E_n for n = 0 to 5, and plot the corresponding $\psi_n(r)$.

   $$V = D_e\left[1-e^{-\alpha x}\right]^2$$

   Equilibrium bond energy: $D_e = 6.091\times10^{-19}$ J

   Equilibrium bond length: $r_0 = 9.109\times10^{-11}$ m $\quad x = r - r_0$

   Force constant: $k = 1.039\times10^{3}$ J m^{-2} $\quad \alpha = \sqrt{k/2D_e}$

   (If you aren't familiar with these problems, study the notes and worksheets on the Discrete Value Representation).

2. **Resonant driving of two level system.** If two states k and l are coupled with a sinusoidal potential, the differential equations that describe their probability amplitude are

   $$\dot{b}_k = \frac{-i}{2\hbar} b_\ell \, V_{k\ell} \, e^{i(\omega_{k\ell}-\omega)t}$$

   $$\dot{b}_\ell = \frac{-i}{2\hbar} b_k \, V_{\ell k} \, e^{-i(\omega_{k\ell}-\omega)t}$$

   Numerically solve for the probability of being in state k and l for times t = 0 to t =1 ps given that the system is in state k at t = 0. You can take the coupling to be $V_{\ell k}/hc = 100\,cm^{-1}$. Compare the behavior for detuning from resonance of $(\omega_{k\ell}-\omega)/2\pi c = 0\,cm^{-1}$ and $100\,cm^{-1}$.

   (If you aren't familiar with numerically solving differential equations, study your software's implementation of the Runga-Kutta method).