1) BD 14.1
2) BD 14.2
3) Show that application of a “pi” rotation of any two-level system results in multiplication of the initial wavefunction by -1.
4) Show how the blockade concept results in the controlled-phase gate.
5) By sandwiching a controlled-phase gate between $\pi/2$ pulses on the target qubit, show that a CNOT gate is produced.
6) PRL 104, 010503 (2010) describes a second type of CNOT gate, the amplitude-swap gate. Show that the blockade mechanism with the amplitude-swap sequence gives a CNOT gate.
7) (worth double) The interaction between two identical atoms whose wavefunctions do not overlap is $V_{dd} = \frac{e^2}{R^3}(x_1x_2 + y_1y_2 - 2z_1z_2)$, where $(x_1, y_1, z_1)$ is the position of the electron on the first atom measured with respect to the nucleus of that atom, and $R = R^2$ is the internuclear separation. The atoms have the following structure: an s-state with energy $E_s$ and a p-state with energy $E_p$. Ignore spin. Find the energy levels of the atom pair as a function of $R$ when $E_p = E_s$. Express your answer in terms of the radial matrix element $\langle r \rangle = \int dr P_s(r)rP_p(r)$ where the $P$s are the radial wavefunctions for the atom. You can approach the problem one of two ways: construct the 16X16 matrix in Mathematica and find the energies that way, or use $[V_{dd}, L_{1z} + L_{2z}] = 0$ and the fact that $V_{dd}$ is symmetric on interchange of the two atoms to simplify the problem to a much smaller set of problems. Note: because of parity, $\langle s|x|s \rangle = \langle p|x|p \rangle = 0$.
8) Ditto, but instead use second-order perturbation theory to find the shift of the $|ss\rangle$ state, for $E_p \gg V_{dd}$.
9) Show that the Bell state $|00 + 11\rangle$ has a parity oscillation of amplitude 1.