NST - Oral Exam 2015

Second question

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Problem 1:

Consider two spins-1/2, A and B, in a large magnetic field. The two spins are initially in eigenstates of the Hamiltonians H_a and H_b, which describe the interaction of each spin with the magnetic field. The two spins interact via a (small) Hamiltonian H_{ab} and we retain only the part of H_{ab} that conserves the spins total energy (as set by $H_a + H_b$).

a) Do the two spins become entangled during their joint evolution? Consider two cases: spins A and B are the same type of spins (example: two nuclear spins of the same isotope) or they are different (example: one nuclear spin and one electronic spin).

b) Suppose that we want to follow the dynamics of spin A and we have no information about spin B (i.e. we can only measure the state of spin A or observables of spin A). Will the reduced evolution of system A be unitary?

Problem 2:

a) Consider a spin 1 such the NV center in diamond where the states $|\pm 1\rangle$ are not degenerate (e.g. because of an applied field). Can you drive with an electromagnetic field the transition $m_s = +1 \leftrightarrow -1$? Why? Propose alternative methods to go from the state $|+1\rangle$ to the state $|-1\rangle$.

b) Assume we still want to transfer the state $|+1\rangle$ to the state $|-1\rangle$, but now we want to try to avoid to ever populate the state $|0\rangle$. What strategy would you suggest? What is a similar technique in atomic physics called?
Describe the technique and when it is applied.