Problem statement: Many-body quantum systems can exhibit strange, interesting, and potentially useful phenomena. A time crystal is an example of such a phenomenon, where a system exhibits periodic behavior that lasts indefinitely. The goal of this project is for students to learn how to simulate quantum systems by exploring time crystals.

Lab techniques: Computer simulation.

Biohazards: none

Goal: Create code to create Fig. 2c in <https://www.nature.com/articles/s41467-021-22415-6>

Evaluation: Progress toward the goal.

Background reading:

1. Paper on time-crystal physics in quantum dots: <https://www.nature.com/articles/s41467-021-22415-6>
2. General introduction to quantum-dot spin qubits: <https://arxiv.org/abs/2112.08863>
3. General introduction to time crystals: <https://arxiv.org/abs/1704.03735>, https://journals.aps.org/rmp/abstract/10.1103/RevModPhys.95.031001

Steps.

1. Refresh your memory of the matrix formulation of quantum mechanics for two-level systems. If you are not familiar with this, Introduction to Quantum Mechanics by Griffiths or A Modern Approach to Quantum Mechanics by Townsend is a good place to start.
2. Create some code to simulate a single spin undergoing Rabi oscillations. If you don’t have a preferred coding language, use Matlab.
   1. Consider a spin-1/2 particle with Hamiltonian Suppose that the particle is initially prepared in an eigenstate of Plot the probability that at measurement of the system will yield the same eigenvalue as a function of time and
3. Create some code to explore two qubits interacting via exchange, and observe the quantum states swapping back and forth.
   1. Consider two spin-1/2 particles interacting with Hamiltonian Suppose that one spin is initially prepared as spin up and the other is prepared as spin down. Plot the probability that the first particle will yield a measurement of spin up as a function of time.
4. Read the paper referenced above in the Goal section. Use what you have learned above to recreate Fig. 2c.