Quantitative Physiology I / Molecular and Cellular Systems; BMEN E4001x
HW3: Modeling and membrane transport
Due Oct. 29, 2025, 11:00PM

1) Oscillations (20 points)

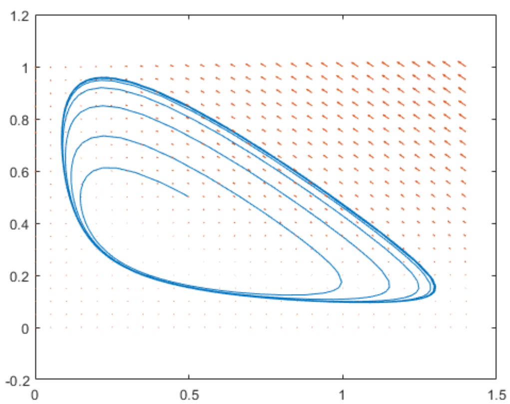
1.1) Using MATLAB, simulate the Sel'kov glycolysis system presented in K&S section 1.3. Specifically, generate the two figures below describing concentrations as a function of time. The quiver plots (arrows) are not needed. (10 pts.)

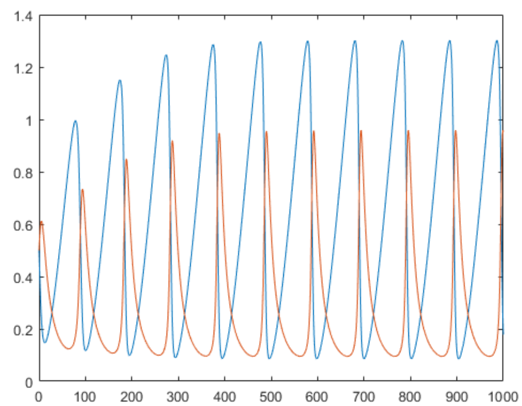
Use the following parameters:

γ (gamma) =2 α (alpha) = 1.0 ν (nu) = 0.0285 η(eta) = 0.1

Simulate over a period of $\tau = 0 \dots 1000$; $\sigma_1(t=0) = 0.5$; $\sigma_2(t=0) = 0.5$

Include your code along with these graphs.





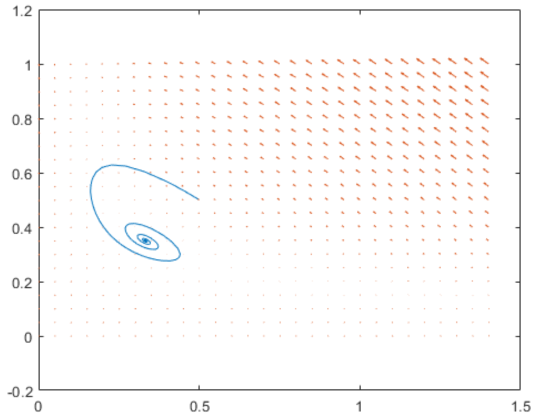
1.2) Now, simulate with $\nu = 0.035$, representing a higher rate of ATP introduction into the system. Include graphs of σ_1 vs. σ_2 and σ_1,σ_2 vs. time for this new value of ν. (7 pts)

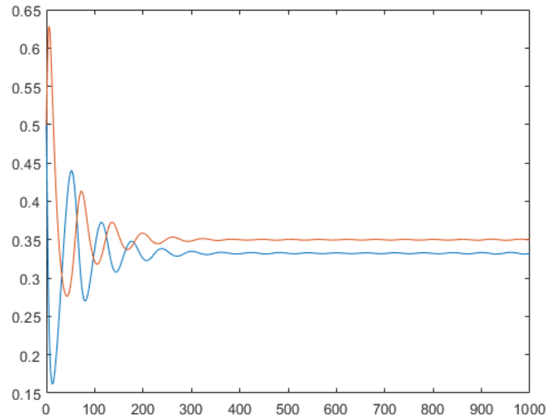
1.3) Interpret qualitatively why the behavior at $\nu = 0.035$ is different than that at 0.0285. (3 pts) The text describes a Hopf bifurcation, which is of mathematical importance, but we are looking for a descriptive explanation based on the chemical reaction. While not required as an answer for this question, plotting u1 and u2 as a function of τ may help in understanding what is going on.

For your reflection (not graded):

- In part 1.2, increasing ν models increasing the rate at which ATP is added to the system. Can you identify a change in a different parameter that will restore the oscillatory nature of the original ($\nu = 0.0285$) system?

ν = 0.035





Start with the condition of ν = 0.0285, at a point in a cycle where the ATP concentration is at a minimum. With little ATP around to act as substrate, the overall reaction rate goes slowly. With a slow reaction rate, ATP accumulates, since it isn't being used in the reaction. This rise in ATP causes the reaction rate to increase, producing more ADP. The ADP concentration consequently rises, making more active enzyme and increasing the reaction speed. This faster reaction speed uses up ATP, causing the concentration of ATP to decrease, leading to a decrease in reaction rate and ADP formation, thus the concentration of active enzyme also drops.

At ν = 0.035, the higher rate of ATP addition avoids significant depletion of ATP at the beginning of the cycle described above.

2) Membrane transport (10 points)

For your 3 favorite membrane pumps, active carriers, exchangers, or cotransporters, describe:

- The target molecules(s) that is (are) being transported,
- The physiological role of the target molecule(s), and
- The driving force for this transport (such as ATP or concentration gradient of a molecule)

No more than 4 sentences for each protein. For example (but don't count this as one of your three):

> The Na/glucose cotransporter proteins promote uptake of glucose into cells, using a gradient of Na^+ ions to drive this process. ATP is not needed for this transport.