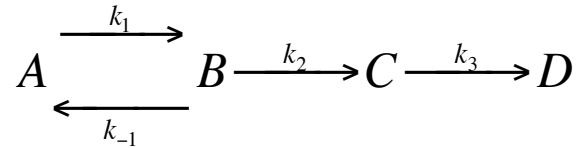


YOU ARE NOT PERMITTED TO HAVE ANY EMAIL OR MESSAGING PROGRAM OPEN AT ANY TIME DURING THE EXAM. ANY VIOLATION OF THIS PROHIBITION WILL RESULT IN A FAILING GRADE FOR THE COURSE.

1. You are given the following reaction mechanism.



a) (8 points) Write the differential equations.

b) (4 points) Make an estimate of the timescale of the system.

c) (10 points) Describe how you would make a model of this system using either Excel or Maple.

2. The general form of a first-order compartmental model is $\mathbf{X}' = \mathbf{A}\mathbf{X} + \mathbf{f}$.

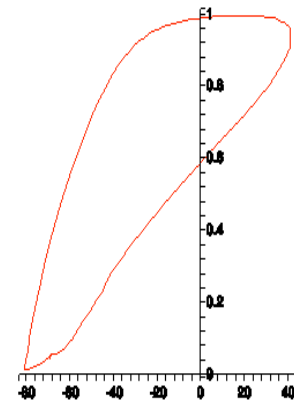
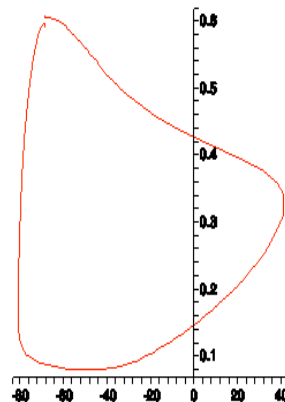
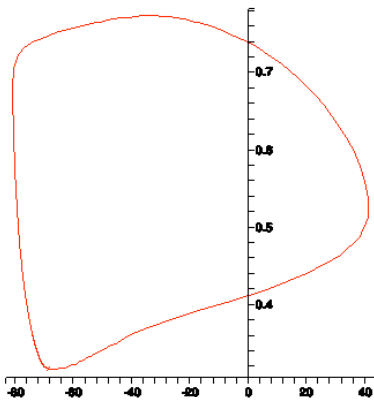
a) (8 points) Give definitions of each of the variables (include dimensions).

b) (8 points) Under what condition(s) does the following analytical solution apply to this model:

$$\mathbf{X} = e^{\mathbf{A}t} [\mathbf{X}_0 + \mathbf{A}^{-1}\mathbf{f}] - \mathbf{A}^{-1}\mathbf{f}.$$

3. The following graphs were generated using the Hodgkin-Huxley model.

a) (5 points) What is the name of this type of graph?



(5 points each) From your knowledge of the model, what variables are graphed in each of these?

b)

c)

d)

4. You are given a system consisting of the recursion relation $y(i+1)=y(i)^2-a*y(i)$.

a) (8 points) What are the possible steady state values of y ?

b) (8 points) Assuming you are given an initial value of y and a value for the parameter a , how would you empirically determine whether any of the steady state values will be reached?

c) (6 points) Sketch a parameter line for the system.

5. Give a brief definition of the following methods for numerical integration

a) (5 points) Euler's method

b) (5 points) Midpoint method

c. (4 points) What is another name for the midpoint method?

d. (6 points) Under what conditions does the midpoint method provide better accuracy than Euler's method?

6. a) (8 points) You are given a three channel fluorescence microscope image in which the first channel contains an image of a total DNA probe, the second contains an image of a total protein probe, and the third channel contains an image of a tagged Golgi protein. Describe how you would create an image to use as a geometry map for Virtual Cell that would enable you to build a compartmental model with three compartments (cytoplasm, Golgi and nucleus). Be as specific as you can about the methods you would use.

b) (4 points) Would your answer change if you needed to do the same task for thousands of such images? If so, how?

c) (8 points) Imagine that each image (field) can contain more than one cell. Also imagine that you are given images for 50 fields each for 100,000 different tagged proteins in a given cell type (the different tagged proteins are visualized in the third channel). Describe how you would find out how many statistically distinct subcellular patterns are present in that cell type. Be as specific as you can about the methods you would use.

7. (3 points each) Which of the following methods can be used to reconstruct a 2D digital image to numerical accuracy:

- a) Haralick Texture Features _____ yes _____ no
- b) 2D Fast Fourier Transform _____ yes _____ no
- c) Daubechies 4 Wavelet Transform _____ yes _____ no

8. (4 points each) Fill in the blanks (with one **or more** words).

- a) If a system does not reach a steady-state but rather continuously moves among a set of finite values it is said to reach a _____.
- b) A _____ matrix shows the frequencies with which a classifier correctly and incorrectly recognizes various input patterns.
- c) Collecting a 3D image of a very small (diameter < 0.1 micron) fluorescent microsphere is a way of determining the _____ of a fluorescence microscope.
- d) The numerical integration of a system of differential equations requires values for the parameters of the system and specification of the _____ conditions.
- e) A formula that describes how the next value of a discrete function may be calculated from the previous value is a _____ relation.
- f) Biological images that cannot be directly compared on a pixel-by-pixel basis can be indirectly compared by first calculating _____.

9. Write pseudo-code, C++, or Java fragments for the following tasks:

(a) (15 points) Calculate a gray-level co-occurrence matrix for the horizontal (width) adjacency of an 8-bit image I with height h and width w

(b) (15 points) Finding the best alignment between two sequences using a similarity matrix S , a gap opening penalty G , and a gap extension penalty E