**IBEHS-4QZ3**

**Modeling of Biological Systems**

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DURATION OF EXAMINATION: **1 week**, estimated time 3 hours

MCMASTER UNIVERSITY FINAL EXAMINATION

DECEMBER 2021

THIS EXAMINATION PAPER INCLUDES 3 PARTS (A, B, C). YOU

ARE RESPONSIBLE FOR ENSURING THAT YOUR COPY OF THE PAPER IS COMPLETE. BRING ANY DISCREPANCY TO THE ATTENTION OF YOUR INVIGILATOR.

Special Instructions:

This is an open book examination. Any code used to solve questions should be included in an appendix. However, this is just supplementary. All work should be explained in the actual question response.

The exam paper has **110 marks total**.

Please answer questions on the exam paper provided.

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**Part A: Math Questions. Each are worth 10 marks (total 30)**

1. In this problem ***Pt*** represents the fraction of neurons of a large neural network that fire at time ***t***. As a simple model of epilepsy, the dynamics of the network can be described by the finite-difference equation

A picture containing text

Description automatically generated

where C is a positive number, and 0 ≤ ***Pt*** ≤ 1

(a) Compute the fixed points.

(b) Determine the stability at each fixed point and describe the dynamics in the neighborhood of the fixed points as a function of C.

(c) Plot **Pt+1** as a function of **Pt** for C = 5. Show all maxima, minima, and inflection points.

(d) On the basis of the preceding work plot and discuss the dynamics as t 🡪∞ starting from an initial condition of **Po** = 0.55 with C = 5.

2. A cardiovascular researcher wants to assess heart rate variability in a new way, immediately prior to exercise stress. The following data were taken at rest immediately before the activity. Consider the time (in seconds) of occurrence of the QRS peak of the following 9 consecutive heart beats measured in a healthy volunteer:

Calculate HRV, based on the average of all N-N intervals (AVNN). Then using the relative

dispersion (RD) approach, determine the temporal fractal dimension (FD) of heart rate *variability* in this individual, over this time scale.

0.17, 1.45, 1.96, 2.11, 3.65, 4.28, 5.43, 6.14, 7.91, 8.56, 9.1, 9.99, 11.14, 12.56 ,13.12, 13.78, 15, 15.98

3. In a circadian cosinor analysis problem of 279 measures of salivary cortisol a student calculates the b-hat vector as [27.3 3.4 7.7] T. What is the mesor, amplitude and acrophase? The student wasn’t pleased with the result and was wondering whether their results would best be represented by a single cosinor or double cosinor. What would happen to the calculated F-statistic when switching from single to double cosinor? Given all the same data would single or double cosinor analysis lead more or less likely to model significance (i.e., greater than a calculated critical F-value)? Show your calculations to back up your decision.

**Part B: Code Questions. Each are worth 20 marks (total 40)**

1. Consider the EMG data in **dataB1.mat** Using what we

have learned so far create a program in MATLAB that can show differences in the patients (neuropathy and myopathy) from the healthy control. Can a MATLAB script be devised that shows a clear difference in neuropathy from myopathy?

2. The Van Der Pol Oscillator is a nonlinear oscillator similar to the linear oscillator, except it has

a non-linear damping term that is positive for large oscillations but negative (i.e., adds energy) for

small oscillations. This mathematical construct has utility in both the physical and biological

sciences. For example, Fitzhugh and Nagumo extended the equation over a planar field in use as a model for neuronal action potentials. The Van Der Pol Oscillator develops stable but nonlinear

oscillations and can be described as a first order system with the following equations:

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Solve the Van Der Pol equations using a time span from 0 to 200 and initial conditions of ***x0*=0.05**, ***y0*=0**. Solve the equations for ***u***=0, 0.1, 1.0, 5.0 and 10.0. For each value of ***u*** plot the trajectories in phase space as well as ***x(t)*** vs. ***t***. Hint: For this problem use the ode45 solver in MATLAB to solve the ordinary differential equations.

**Part C: Long Answer. Worth 10, 20, 10 marks respectively. Total 40**

1. Describe 3 systems within the body that could be considered fractaled. What is the benefit for each having this configuration?
2. You are tasked with measuring EEG signals (32 channels set in 10-20 coordinates, sampling rate = 6kHz, 24bit dynamic range) in hockey players who are healthy and those suffering a recent traumatic brain injury. Your goal is to be able to differentiate the two groups. Describe in detail how you could analyze these signals, given what you have learned in this course.
3. Describe the similarities and differences, as well as pros and cons of using Fourier analysis, Short Time Fourier transform, and wavelet transform.

**-- THE END --**