

# Spring 2015 Course Syllabus: **Math 430 & Math 635**

|                |   |
|----------------|---|
| Course Title:  | <b>Analytical and Computational Neuroscience</b>  |
| Textbook:      | <b>"Dynamical Systems in Neuroscience: The Geometry of Excitability and Bursting" by E.M. Izhikevich, MIT Press (2007), 1st Ed., ISBN-10: 0262514206</b>    |
| Prerequisites: | <b>Math 211 or Math 213 with a grade of C or better, and Math 222 with a grade of C or better, and 100-level CS or Math 340 with a grade of C or better</b> |
| Website:       | <b><a href="https://web.njit.edu/~matveev/Courses/M430_635_F15/">https://web.njit.edu/~matveev/Courses/M430_635_F15/</a></b>                                |

## **Recommended Books:**

- "Mathematical Foundations of Neuroscience" by G.B. Ermentrout & D.H. Terman – Springer (2010), 1st edition - ISBN: 978-0-387-87707-5.
- "Foundations of Cellular Neurophysiology" by D. Johnston & S. Wu – The MIT Press (1995) - ISBN: 0-262-100053-3.
- "Biophysics of Computation - Information processing in single neurons", by Christof Koch. Oxford University Press, 1999. ISBN 0-19-510491-9.
- "Theoretical Neuroscience: Computational and Mathematical Modeling of Neural Systems", by Peter Dayan and Larry F. Abbott. The MIT Press, 2001. ISBN 0-262-04199-5.

## **Course Objectives**

- Students will gain understanding of cell physiology underlying neuronal excitability.
- Students will learn the Hodgkin-Huxley model of action potential generation and propagation.
- Students will learn models of neuronal spiking and bursting of different levels of complexity.
- Students will learn how to qualitatively analyze the behavior of solutions of ordinary differential equations using phase-plane analysis.
- Students will understand the concept of bifurcation of a dynamical system, and use it to analyze models of neuronal excitability.
- Students will learn how to use MATLAB to graphically analyze and numerically solve ordinary differential equations arising in neuronal modeling.

## **Course Outcomes**

- Students can describe physiological mechanisms underlying an action potential in an excitable cell.
- Students are able to analyze the behavior of a non-linear ordinary differential equation using phase-plane analysis.
- Students are able to build and analyze models of spiking and bursting neurons.
- Students are able to write a MATLAB program to numerically solve ordinary differential equations arising in the modeling of neural excitability.
- Students will be able to find bifurcations of models of neural excitability and other ordinary differential equations.

## Course Assessment

- The assessment of objectives is achieved through homework assignments and one class project, and the in-class midterm and final examinations.

| <b>Course Outline</b> |       |  |                     |
|-----------------------|-------|--|---------------------|
| Lecture               | Date  | Topic  | Assignment          |
| 1                     | 9/3   | Introduction: cell excitability and the nervous system                       | Emailed after class |
| 2                     | 9/8   | Physiology of cell excitability: the equivalent circuit and Nernst potential |                     |
| 3                     | 9/10  | Equation of the passive membrane and separation of variables                 | Emailed after class |
| 4                     | 9/14  | Passive membrane dynamics and derivation of the Nernst potential             |                     |
| 5                     | 9/17  | ODEs in 1D: inhomogeneous equations; linear stability analysis               | Emailed after class |
| 6                     | 9/21  | Introduction to MATLAB   |                     |
| 7                     | 9/24  | Numerical methods: the forward Euler method                                  | Emailed after class |
| 8                     | 9/28  | 1D models: bifurcations and integrate-and-fire models                        |                     |
| 9                     | 10/1  | 1D models: more bifurcations; introduction to 2D models                      | Emailed after class |
| 10                    | 10/5  | 2D models: vector fields and phase-plane analysis                            |                     |
| 11                    | 10/8  | 2D models: linear systems  | Emailed after class |
| 12                    | 10/12 | 2D models: Jacobian, equilibria classification, limit cycles and oscillators |                     |
| 13                    | 10/15 | 2D models: Fitzhugh-Nagumo model   | Emailed after class |
| 14                    | 10/19 | 2D models: Hopf bifurcation  |                     |
| 15                    | 10/22 | Review for the midterm exam  |                     |
| 16                    | 10/26 | Midterm Exam   |                     |
| 17                    | 10/29 | Physiology of cell excitability: ionic current activation and inactivation   | Emailed after class |
| 18                    | 11/2  | Biophysical 4D model: Hodgkin-Huxley equations I                             |                     |
| 19                    | 11/5  | Biophysical 4D model: Hodgkin-Huxley equations II                            | Emailed after class |
| 20                    | 11/9  | Biophysical 2D reductions of Hodgkin-Huxley model                            |                     |
| 21                    | 11/12 | Biophysical 2D reductions of Hodgkin-Huxley model: continued                 | Emailed after class |
| 22                    | 11/16 | Biophysical 3D models: time-scale separation and neuronal "bursting"         |                     |
| 23                    | 11/19 | Neuronal Bursting: Geometry and Classification                               | Emailed after class |
| 24                    | 11/23 | Neuronal Bursting: Classification and Models                                 | Emailed after class |
| 25                    | 11/30 | Propagation of action potential: the cable equation 1                        |                     |
| 26                    | 12/3  | Propagation of action potential: the cable equation 2                        | Emailed after class |
| 27                    | 12/7  | Neuronal networks: two coupled cells   |                     |
| 28                    | 12/10 | Neuronal networks: two coupled cells   | Project due         |

| <b>IMPORTANT DATES</b> |                      |
|------------------------|----------------------|
| FIRST DAY OF SEMESTER  | September 1, 2015    |
| Midterm Exam           | October 26, 2015     |
| LAST DAY TO WITHDRAW   | November 2, 2015     |
| LAST DAY OF CLASSES    | December 10, 2015    |
| FINAL EXAM PERIOD      | December 15-21, 2015 |

## Grading Policy

| <b>Assignment Weighting</b> |      |
|-----------------------------|------|
| Homework & Quiz             | 22 % |
| Course Project              | 16 % |
| Midterm Exam                | 28 % |
| Final Exam                  | 34 % |
|                             |      |
|                             |      |

| <b>Tentative Grading Scale</b> |          |
|--------------------------------|----------|
| A                              | 86 – 100 |
| B+                             | 80 – 85  |
| B                              | 74 – 80  |
| C+                             | 68 – 74  |
| C                              | 62 – 68  |
| D                              | 56 – 60  |

## **Homework, Quiz and Project Requirements**

- Homework will be emailed by the instructor by the end of each week, and will be due Thursday the following week; in-class quizzes may also be given, and will be announced in advance. A single individual course project will be assigned by the middle of the semester, and will be due at the last class of the semester.

## **Academic Integrity Honor Code**

- Honor code is taken very seriously at NJIT, ensuring fair treatment and fairness in grading for all students. All submitted course work should represent your individual effort, unless instructions for group work are explicitly given in the assignment. Instances of assignment copying or plagiarism are extremely easy to spot and will automatically lead to the referral of the case to the NJIT Dean of Students. See NJIT policy documents for more details:

[http://www.njit.edu/provost/docs/Best\\_Practices\\_related\\_to\\_Academic\\_Integrity.pdf](http://www.njit.edu/provost/docs/Best_Practices_related_to_Academic_Integrity.pdf)

<http://www.njit.edu/education/pdf/academic-integrity-code.pdf>

**Prepared by Prof. Victor Matveev, August 25, 2015**