Math in Biomedical Research  
Math 596  
Course Summary

The following is a summary of Math 596: Math in Biomedical Research, supported by the Initiative for Maximizing Student Development (IMSD), and being taught by Jarod Hart. The purpose of this summary is to inform student advisors about the class so that they are aware of the course and can advise on student enrollment in the course. For more information, questions, or comments pertaining to Math 596, please contact Dr. Jarod Hart, jvhart@ku.edu.

Course format

The Math in Biomedical Research course is a three-credit, project-based class limited to 18 students per semester. The purpose of the course is to develop students’ independent research abilities, specifically those pertaining to mathematics, in the context of biomedical research problems. The course is intended for students in biomedical related fields who have completed or nearly completed the math requirements for their degree, but want to further develop their mathematical abilities in a research setting. The only prerequisite is a second semester calculus course. The desired students for the course are those who intend to participate in a graduate program in a biomedical-related field. Students from underrepresented groups in these programs are encouraged to participate.

Goals of Math in Biomedical Research

- Develop information-seeking, problem-solving, written/oral communication, and research methodology skills
- Shorten the time and coursework needed to mathematically prepare students for research in biomedical fields
- Channel students towards opportunities for research experiences

Content of Math in Biomedical Research

In this course, students work on research projects that have a substantial math component, and likely a computer programming component, as motivated by biomedical research topics. Students complete research proposals, short-term modules, semester-long research projects, and research plans that connect all of these components. The main purpose of the module assignments is for students to master the mathematical and computer programming techniques necessary to complete various aspects of their research project. Initially, modules are pre-defined for students, but by the end of the semester students are expected to formulate and complete their own modules based on the needs of their research project. Each student will create a portfolio made up of their research proposals, research plan, modules, and final research paper. Students will also make oral presentation throughout the semester communicating various aspects of their research projects. The following are three typical student descriptions for which this class would be appropriate: (1) a transfer student majoring in biomedical-related field with previous coursework that is somewhat incompatible with their current coursework, (2) a student majoring in a biomedical-related field that is interested in participating in scientific research in the future, or (3) beginning graduate students that want to strengthen their mathematical background in the context of their area of research.
The following are technical descriptions for a few previous Math 596 student projects. The purpose of these descriptions is to provide some examples of the type of subject matter and mathematical content in the course.

- **Stochastic disease dynamic models for assessing the effects of vaccination and herd immunity:** This project takes a discrete stochastic modeling approach to SIR (Susceptible–Infected–Recovered) disease dynamic modeling. Typical SIR models make a simplifying assumption that any infected member of a population is equally likely to infect any susceptible member of the population, but this assumption is not a realistic one. This project takes a novel approach to modeling disease interactions that accounts for differing transmission probabilities among individual susceptible–infected interactions. Based on this underlying stochastic SIR model, the effects of vaccination, initial infected population profile, and herd immunity will be explored. This project has the potential to contribute a new stochastic model for simulating disease dynamics, vaccination effects, and herd immunity for infectious disease modeling theory. This project includes a study of discrete probability, an in-depth development of discrete-time Markov processes, and a significant Matlab programming component.

- **Numerical models of pendulums to model human gait:** In this project, systems of ordinary differential equations and control theory are used to model single and double pendulums related to a person’s movement and balance while walking. Runge-Kutta methods will be used to create numerical solutions to a pendulum swinging. This models a person’s leg swinging back to front in their stride. Simulation and control of an inverted pendulum will be used to model balance of a person’s upper body while walking. Using these pendulum models to analyze human gait is standard practice in biomechanics, and the use of numerical methods and control theory are common techniques for such models. This project includes a review of pertinent ODE theory, a study of numerical differential equation solvers, an introduction to control theory, and programming in Matlab.

- **Fast-slow differential equation model of the onset and dynamics of diabetes:** This project uses ordinary differential equations theory to model diabetes in the human body, taking into account glucose, insulin, and β-cell mass. All of these factors have been understood clinically to impact well-being of people with diabetes. However, insulin and glucose levels vary on a short time scale (on the order of minutes), whereas β-cell mass levels vary at a much longer times scale (on the order of days). The challenge of this project is to account for, and take advantage of, the disparity in the time scales on which these variables change to provide a more accurate glucose/insulin model than one with a fixed β-cell mass level. Fast-slow ordinary differential equations theory will be used to analyze the β-cell mass-glucose-insulin model. The analysis of this model and much of its description here is based heavily on the article where this model was introduced, *A Model of β-Cell Mass, Insulin, and Glucose Kinetics: Pathways to Diabetes* by B. Topp et al., J. Theor. Biol. (2000) 206, 605-619. This project is largely devoted to developing the mathematical background to understand this model, and to reproduce the results of the cited paper. This project will include solving linear systems of ODEs, linearization and stability analysis of nonlinear systems of ODEs, and fast-slow analysis techniques for ODEs.