CALCULUS FOR BIOMEDICINE

MATH 1940

Course Description:

Introductory calculus with an emphasis on dynamical systems analysis applied to biological systems. Topics include differential and integral calculus, elementary chaos theory, discrete modeling, neural networks, and elementary differential equations, population dynamics, and biochemical signal transduction. **5 credits**

Prerequisites:

ACT Math sub score at least 25, Math SAT at least 570, or Math SAT2016 at least 590 within last 2 years; or Accuplacer or COMPASS score at least 6 within last 2 years; or MATH 1320 with at least C- within last 2 years; or permission of instructor

Overview of content and purpose of the course:

Calculus for Biomedicine will cover all of the calculus topics included in MATH 1930 (Calculus for the Managerial, Life, and Social Sciences) as well as all of the material from BIOL 1950. MATH 1940 will focus exclusively on application of calculus to the life sciences. In order to achieve this goal, MATH 1940 will cover dynamical systems analysis from BIOL 1950 which will allow the calculus methods to be applied in a highly advanced way to understanding the fundamental essence of life at a mathematical level. This experience provides the life sciences student a much richer math experience than any of the current offerings.

Anticipated audience/demand:

Students in the life and social sciences make up a large percentage of the College of Arts & Sciences, and a significant percentage of them have a mathematics requirement beyond algebra. This course is an excellent option for these students to get exposure to calculus in such a way as to actually gain real insights into the living systems they study. There is no other (single) course that provides this type of opportunity, making Calculus for Biomedicine an attractive option for these students.

Major topics:

I. Intro to Calculus-based Chaos Theory-- Periodicity, stability, and chaos in nonlinear finite-difference equations

1) Linear Functions

2) Linear Finite-Difference Equations

3) Nonlinear Functions
- a. Quadratic
- b. Polynomial
- c. Exponential
- d. Logarithmic

4) Nonlinear Finite-Difference Equations

5) Fixed Points, Periodic Cycles, and Chaos in Nonlinear Finite-Difference Equations

6) Limits, Continuity

7) The Derivative
- a. Product/Quotient Rules
- b. Chain Rule
- c. Derivatives of Exponential and Logarithmic Functions

8) Graphs of Derivatives
- a. Increasing/Decreasing Functions
- b. Higher Derivatives, Concavity, and the Second Derivative Test
- c. Curve Sketching

9) Classical Applications of the Derivative
- a. Relative/Absolute Extrema
- b. Implicit Differentiation
- c. Related Rates

10) Application of the Derivative to Nonlinear Dynamics
- a. Existence and Stability of Fixed Points in Nonlinear Finite-Difference Equations
- b. Existence and Stability of Period-2 (and higher) Cycles in Nonlinear Finite-Difference Equations

11) Application of Nonlinear Dynamics to Biological Systems: *Population Dynamics of the Flour Beetle* Tribolium

II. Intro to Complexity Theory-- Order, Chaos, and Complexity in Discrete Model Systems

1) Intro to Discrete Modeling (Discrete vs. Continuous)

2) Boolean Functions

3) Attractors in Boolean Networks
- a. Networks with One Input/Node
- b. Networks with Two or More Inputs/Node

4) Application: *Locomotion in Salamanders*

5) Binary Numbering and Cellular Automata

6) Random (Kauffman) Networks

7) Order/Chaos/Complexity in Boolean Networks/Cellular Automata

8) Stability of Fixed and Periodic Points (States) in Boolean Networks

9) Parameters of Stability in Boolean Networks: *N*, *K*, and *P*

III. Order, Chaos, Complexity and the Essence of Life

1) Self similarity, Dimension, and Fractal Geometry
- a. Hausdorf Dimension
- b. Box Counting Dimension
- c. Convergence of Infinite Series
- d. Fractals and Dynamics

2) Nonlinearity, Complexity, and Nontrivial Emergent Dynamics

3) Emergent Properties in Networks
- a. Neural Networks/Artificial Intelligence
- b. Algorithms to "Teach" Artificial Neural Networks

4) Linear and Nonlinear Biochemical Pathways
- a. Emergent Properties of Nonlinear Biochemical Pathways

5) An Irreducible Biochemical Network
- a. Intracellular Signal Transduction
- b. Emergent Information Processing in Signal Transduction

IV. Continuous Models

1) The Integral

2) Intro to Differential Equations

3) Solving First-Order Ordinary Differential Equations of a Single Variable

4) Growth, Decay, Fixed points

5) Nonlinear Dynamics in Continuous Models.

Textbook:

Lial, Margaret L., and Raymond N. Greenwell, and Nathan P. Ritchey. *Calculus with Applications, 9th ed*. London: Pearson, 2007.

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