COURSE SYLLABUS

Course Title: **Honors Calculus I+II for Data Science**

Abbreviated Title As Appears on Transcript: `Honors Calc BC for Data Sci`

Course Number: DMAT 255

Credit Hours: 5 credits [semester credit hours]

Course Description: An honors-level single course introduction to differential and integral calculus for data science students, with emphasis on a modern, empirical exposition of the classical subject, condensing the essential topics from first year calculus. Topics include a study of the algebraic, numerical, and graphical aspects of polynomial, exponential, logarithmic, and trigonometric functions, limits, function growth, derivative analysis and optimization, introduction to differential equations, methods and applications of integration, the Fundamental Theorem of Calculus, calculus of data sets, numerical issues of derivative and integral computations, Monte-Carlo method, Taylor's Theorem and spline approximations, and methods of integration. Honors courses will include greater breadth and depth of topics, and develop technical writing skills, culminating in a combination programming project and mathematical term paper on an approved topic.

Prerequisite: Successful completion with B grade or higher in Precalculus with Trigonometry or equivalent, or consent of instructor; experience with a computer programming language.

Course Workload: 5 semester credit hours • 3 student work hours per credit hour • 14 week Carnegie semester = 210 hours student course workload average

Examination Requirements: Proctored written final examination must be passed at 60% or higher to earn passing grade in course. "B" and "A" grade paths have additional examinations.
See https://www.distancecalculus.com/grades/ for more information.

Course Professor: Robert R. Curtis, Ph.D.<rcurtis@rwu.edu>, <robert@distancecalculus.com>

University Information: Roger Williams University, University College, 1 Empire Plaza, Providence, RI, USA 02903. Roger Williams University, 1 Old Ferry Road, Bristol, RI 02809. Accredited by New England Commission of Higher Education (NECHE).
See https://www.rwu.edu/academics/accreditation/ for more information.

E-Textbook: *Calculus&Mathematica* by Davis/Porta/Uhl

Mathematical Software: Mathematica™ Computer Algebra & Graphing System

ADA ACCOMMODATIONS

Roger Williams University has a continuing commitment to providing reasonable accommodations for students with documented disabilities. Students with disabilities who need accommodations in order to fully participate in this class are urged to contact Student Accessibility Services, as soon as possible, to explore the arrangements needed to be made to assure access. Student Accessibility Services is open Monday through Friday from 8:00AM to 5:00PM Eastern Time; Email: sas@rwu.edu or Voice: 401-254-3841. For more information about SAS, visit https://www.rwu.edu/undergraduate/academics/student-academic-success/student-accessibility-services-sas

Learning Outcomes for DMAT 255 - Honors Calculus I+II for Data Science

1. To understand and compute algebraic, numerical, and graphical limits at finite and infinite values;
2. To understand and compute the fundamental concept of the derivative;
3. To understand and compute various measurements of growth of a function
4. To algebraically compute derivatives of common functions using summation, product, quotient, and chain rules for derivatives;
5. To understand and compute optimization of functions using derivatives, finding critical values;
6. To understand and compute the second derivative;
7. To understand and compute first order differential equations;
8. To understand and compute parametric equations, including projectile motion;
9. To understand and calculate numerically and graphically the core concepts of the integral for applications to signed area measurements;
10. To compute numerically, algebraically, and graphically integrals of a variety of functions;
11. To algebraically compute integrals of basic polynomial, exponential, and trigonometric functions, with an introduction to the algebraic substitution technique;
12. To use of tools of differential and integral calculus in various applications
13. To understand and compute the Fundamental Theorem of Calculus
14. To understand and compute an integral functions, including inverse trigonometric and logarithmic integrals that do not algebraically resolve;
15. To utilize computer algebra and graphing software to amplify traditional manual computation techniques.
16. To understand spline interpolation with polynomial functions; points of contact
17. To understand Taylor's Theorem, error analysis
18. To understand convergences and divergence concepts of sequences, series, polynomial approximations
19. To understand and compute double integrals
20. To understand and compute 3D vector analysis, dot product, planes, and cross products
21. To understand and compute partial derivatives and tangent planes to a surface

Honors Additional Topics:

22. *To investigate data interpolation and algebraic modeling of data sets using polynomial and trigonometric functions
23. *To investigate numerical limits error analysis, the need for Lagrange, Newton, L'Hopital, Extrapolation, more advanced polynomial and rational polynomial approximation methods.

24.*To understand the concept of algebraic integration in Finite Terms
25.*To understand and compute integrals using complex integration techniques
26.*To understand and compute numerical integration techniques of Newton, Midpoint, and Runge-Kutta, and higher RK approximations.
27.*To understand and explore higher integral functions, such as those defined by elliptical and hyperbolic integrals
28.*To explore and analyze Preditor-Prey systems of differential equations
29.*To develop mathematical technical writing skills, culminating in a term paper on an approved topic
30.*To utilize programming-based computer algebra software to make investigations for a programming term project in application to data science

* = Additional topics for Honors course

Syllabus Topics Outline for DMAT 255 - Honors Calculus I+II for Data Science

1. Getting Started
   - 1.1 Email and Chat
   - 1.2 Learning About the Course
   - 1.3 Required Hardware
   - 1.4 Software Fundamentals

2. Growth: Preparing for the Derivative
   - 2.1 Growth of Linear Functions
   - 2.2 Growth of Power Functions
   - 2.3 Growth of Exponential Functions
   - 2.4 Dominance of Growth of Functions
   - 2.5 Percentage Growth of Functions
   - 2.6 Global Scale: Infinite Limits
   - 2.7 Data Functions and Interpolation
   - 2.8 Approximation of Functions by Linear Functions

3. Continuity
   - 3.1 Limits
   - 3.2 Continuous Functions
   - 3.3 Jump Discontinuities
   - 3.4 Piecewise Functions and Continuity
   - 3.5 Limit Rules

4. Exponential Functions and Natural Logarithms
   - 4.1 e = Euler's Number
   - 4.2 Natural Logarithm
   - 4.3 Growth Analysis
   - 4.4 Applications: Carbon Dating
   - 4.5 Percentage Growth and Steady Growth of Exponential Functions
   - 4.6 Data Functions and Logarithmic Analysis

- 4.7 Inverse Functions
- 4.8 Applications: Compound Growth Rates
- 4.9 Applications: World Population

5. The Derivative of Polynomial, Exponential, Logarithmic, and Fractional Powers
   - 5.1 Instantaneous Growth Rates
   - 5.2 Definition of the Derivative
   - 5.3 Computing the Derivative Graphically
   - 5.4 Computing the Derivative Algebraically
   - 5.5 Computing the Derivative Numerically
   - 5.6 Average Growth Rate vs. Instantaneous Growth Rate
   - 5.7 Applications of the Derivative: Spread of Disease
   - 5.8 Finding Maxima and Minima of Functions
   - 5.9 Relating a Function and Its Derivative

6. Computing Derivatives
   - 6.1 Sum, Difference, Product, Quotient Rule
   - 6.2 Chain Rule
   - 6.3 Instantaneous Percentage Growth
   - 6.4 Growth Dominance

7. Using Derivatives
   - 7.1 Finding Maxima and Minima
   - 7.2 Finding Good Representative Plots
   - 7.3 Applications: Maximizing Volume
   - 7.4 The Second Derivative
   - 7.5 Applications: The Space Shuttle Challenger

8. Integration
   - 8.1 Measuring Area Under a Curve
   - 8.2 Definition of the Integral
   - 8.3 Properties of Integrals, Symmetry
   - 8.4 Integrals of Data Functions
   - 8.5 Numerical Methods: Rectangles, Trapezoids
   - 8.6 Undefined Integrals
   - 8.7 Numerical Calculation of Integrals
   - 8.8* Monte-Carlo Method of Integration

9. Fundamental Theorem of Calculus
   - 9.1 Derivative of an Integral
   - 9.2 Integral of a Derivative
   - 9.3 Fundamental Formula
   - 9.4 Distance, Velocity, and Acceleration
   - 9.5 Improper Integrals
   - 9.6 More Properties of Integrals

- 9.7 Applications: Measure Accumulation Totals
- 9.8 Indefinite Integrals and Antiderivatives
- 9.9 u-Substitution
- 9.10 Inverse Circular and Hyperbolic Trigonometric Functions

10.* Limits Revisited
- 10.1* Limitations of Numerics with Limits
- 10.2* Lagrange, Newton, Extrapolation Numerical Methods
- 10.3* L'Hopital's Rule for Limits

11.* Preditor-Prey Systems
- 11.1* Parametric Solutions of Differential Equations
- 11.2* Preditor-Prey Models
- 11.3* Applications

12.* Data Interpolation
- 12.1* Linear and Quadratic Approximations
- 12.2* Polynomial Approximations and Interpolation
- 12.3* Trigonometric Function Interpolation

13.* Algebraic Integration Theory
- 13.1* Machine Integration Engines
- 13.2* Integration in Finite Terms
- 13.3* Integratability and Limitations
- 13.4* Defining advanced special functions using integrals or series

14. Taylor's Expansion of a Function
- 14.1 Splines and Smooth Splines
- 14.2 Points of Contact
- 14.3 Application: Landing an Airplane
- 14.4 Taylor Expansion
- 14.5 Recognizing Familiar Expansions
- 14.6 Using Expansions for Approximations
- 14.7 Derivatives and Integrals of Expansions
- 14.8 Expansions At Other Points
- 14.9 Newton's Method
- 14.10 Convergence Intervals and Barriers
- 14.11 Calculating Limits: L'Hopital's Rule
- 14.12* Expansions and Solving Differential Equations
- 14.13* Complex Exponentials
- 14.14* Euler, Midpoint, Runge-Kutta Integral Estimates

15.* Differential Equations
- 15.1* Types of Differential Equations
- 15.2* Linkage to Algebraic and Numerical Integration Theory

15.3* Power Series Solutions to Differential Equations
15.4* Elliptical and Hyperbolic Integration Functions
15.5* Exploring Special Named Functions

16. Polar Coordinates
16.1 Basic Graphing
16.2 Recognizable Curves
16.3 Differentiation and Integration in Polar Coordinates

17. Vector Analysis
17.1 Vector Arithmetic
17.2 Dot Product, Cross Product
17.3 Planes
17.4 Partial Derivatives
17.5 Tangent Planes

18.* Mathematical Writing
18.1* Cogent writing
18.2* Mathematical Presentation
18.3* Term Paper Topic and Research