Course Description	
COURSE NUMBER and NAME	**Numerical Methods**
UNITS	3
LENGTH OF CLASS	8 Weeks
COURSE DESCRIPTION	This course introduces the basic techniques of efficient computational methods for numerical solutions to problems in science and engineering. Topics include root finding, interpolation, approximation of functions, integration, differential equations, and direct and iterative methods in linear algebra. Programming assignments are an integral part of the coursework. Prerequisite/s: Calculus
REQUIRED TEXT	Chapra, S. C., & Canale, R. P. (2021). *Numerical Methods for Engineers* (8th ed.). McGraw Hill **ISBN: 978-1-260-23207**
INSTRUCTIONAL METHOD	Online / On-Campus

Summary of Graded Work and Assessments

Graded work and assessments offer students the opportunity to show the degree of mastery for each CLO. The following table shows how assessments and CLOs align (link).

Assignments	Totals	Weight	CLOs
Engagement and Professionalism - Live Class Activities	160	16%	1, 2,3,4,5,6,7
Week 1 Discussion	20	2%	1
Week 1 Assignment	60	6%	1
Week 2 Assignment	60	6%	1,,3
Week 2 Lab Assignment	30	3%	1,3
Week 3 Assignment	60	6%	1,4
Week 3 Lab Assignment	30	3%	1,4
Week 4 Assignment I	60	6%	1,2
Week 4 Assignment II	80	8%	1,2
Week 4 Lab Assignment	30	3%	1,2
Week 5 Assignment	60	6%	5
Week 5 Lab Assignment	30	3%	5
Week 6 Assignment	60	6%	1,5,6
Week 6 Lab Assignment	30	3%	1,5,6
Week 7 Assignment	60	6%	1,6
Week 7 Lab Assignment	30	3%	1,6
Week 8 Assignment	60	6%	1,7
Week 8 Assignment	80	8%	1,2
Total Points/Percentage	**1000 Points**	**100%**	

Course Policies

For Westcliff's course policies, please see the Course Policies document.

Discussion Requirements

For all discussions, the primary response is due by Wednesday at 11:59 p.m. Pacific Time. The primary response must be at least 200 words in length and fully address the topic, demonstrating critical thinking and understanding. Each student must then also post a minimum of two responses to other students in the discussion by Saturday at 11:59 p.m. Pacific Time. Each peer response must be at least 50 words in length and substantively engage with the other student's original post, continuing the discussion professionally. If at any time information or material is brought in from an outside source or website, it must be properly cited following APA 7th edition guidelines, and a full reference must be provided.

Assignment Requirements

Each assignment deliverable is specifically defined in the assignment instructions, such as page length, citations, references, audio or video, presentations, tables, etc. For all written assignments, the required page length does not include the cover or reference pages. Refer to the specific requirements as stated in each assignment, and reach out to your instructor for additional information as needed. All graded submissions are due by Sunday at 11:59 p.m. Pacific Time.

Participation Requirements

Students are required to attend each live class session either in person or virtually as stipulated in the course policies. Participation in the live class session is determined by actively engaging, answering or asking questions, providing comments, interacting in group activities, etc., as required by the instructor. Students who are unable to attend the live in-class or virtual sessions must follow the Virtual Class Session (VCS) submission requirements as stated in the Course Policies document.

Writing Center

The Westcliff University Writing Center is dedicated to providing quality support to students and faculty. From assignment reviews to in-class workshops to dissertation support, to publication help, the Writing Center is committed to empowering individuals to use the written language to articulate and disseminate knowledge.

Course Learning Outcomes (CLOs)

Learning outcomes are statements that describe significant and essential scholarship that students have achieved and can reliably demonstrate at the end of the course. Learning outcomes identify what the learner will know and be able to do by the end of a course – the essential and enduring knowledge, abilities (skills), and attitudes (values, dispositions) that constitute the integrated learning needed for the successful completion of this course. The learning outcomes for this course summarize what students can expect to learn, and how this course is tied directly to the educational outcomes of the degree.

Course Learning Outcomes (CLOs)	PLOs
1. Explain the concept of errors in numerical calculations, identify sources of errors, analyze the propagation of errors in numerical methods, and partial differential equations, classify them, derive difference equations, and solve specific examples including Laplacian and Poisson's equations in engineering contexts.	1,5,6
2. Differentiate between interpolation and extrapolation, regression and interpolation, and apply Lagrange's Interpolation, Newton's Interpolation using divided differences, and Cubic spline interpolation.	1, 4
3. Apply the Trial and Error method, Half-Interval method, Newton's method, Secant method, Fixed-point iteration, and Newton's method for multiple roots to solve nonlinear equations.	1,4
4. Analyze the existence of solutions and properties of matrices, and apply the Gaussian elimination method, pivoting, Gauss-Jordan method and matrix inversion using the Gauss-Jordan method, eigenvalue, and eigenvector problems and apply the power method to solve eigenvalue problems.	1,4,6
5. Apply Two-Point and Three-Point formulas for differentiating continuous functions, use Newton's Differences for differentiating tabulated functions, and apply various numerical integration methods including the Trapezoidal rule, Simpson's rules, Gaussian integration algorithm, and Romberg integration, and analyze their accuracy.	1,4,6
6. Apply matrix factorization techniques and solve systems of linear equations using Dolittle and Cholesky's algorithms, apply iterative methods such as Jacobi Iteration, and the Gauss-Seidel method to solve systems of linear equations, Taylor series method, Picard's method, Euler's method, Heun's method, and Runge-Kutta method to solve ordinary differential equations.	1,4,6
7. Solve systems of ordinary differential equations, handle higher-order equations, and address boundary value problems using numerical techniques such as the Shooting method.	1,6

Detailed Course Outline

The following outline provides important assignment details for this course, unit by unit. Students are responsible for all of the assignments given. Please refer to the Detailed Description of Each Grading Criterion in the syllabus for specific information about each assignment.

Week 1

Assignments to complete this week:

- Reading:
    - **Introduction**
        - Chapter 1: Mathematical Modeling and Engineering Problem Solving
        - Chapter 3: Approximations and Round-Off Errors
        - Chapter 4: Truncation Errors and the Taylor Series

Week 1 Assignment

Complete the following problem and upload it in GAP for grading

- Problems (Page 110): 4.1, 4.5, 4.13 (a,b,d)

Week 1 Discussion (Rubric)

It is crucial to identify and quantify errors in numerical calculations as errors impact the reliability of numerical results. Justify this statement with examples from the internet source where numerical errors have led to the disaster.

<u>Week 2</u>
Assignments to complete this week:

- Reading:
  - **Roots of Equations**
    - Chapter 5: Bracketing Methods
    - Chapter 6: Open Methods

Week 2 Assignment

Complete the following problem and upload it in GAP for grading

- Problems (Page 143): 5.3, 5.12
- Problems (Page 174): 6.1, 6.5, 6.14

Week 2 Assignment ([Rubric])

- Develop, debug, and test a program in C/Python to implement the Newton Raphson Method, Two equations of Newton Raphson Method, and Secant Method.

Week 3

Assignments to complete this week:

- Reading:
  - **Linear Algebraic Equations**
    - Chapter 9: Gauss Elimination
    - Chapter 10: LU Decomposition and Matrix Inversion
    - Chapter 11: Special Matrices and Gauss-Seidel

Week 3 Assignment

Complete the following problem and upload it in GAP for grading

- Problems (Page 281): 9.10, 9.13
- Problems (Page 303): 10.10, 10.20, 10.21
- Problems (Page 322): 11.12

Week 3 Lab Assignment

- Develop, debug, and test a program in C/Python to implement the Gauss-Seidel method.

Week 4

Assignments to complete this week:

- Reading:
  - **Curve Fitting**
    - Chapter 17: Least-Squares Regression
    - Chapter 18: Interpolation

Week 4 Assignment I

Complete the following problem and upload it in GAP for grading

- Problems (Page 495): 17.33
- Problems (Page 531): 18.7, 18.13, 18.14

Week 4 Assignment II

Research and demonstrate the application of interpolation and regression techniques in analyzing real-world data.

- Find a dataset related to a topic of interest (e.g., stock prices, climate data, or consumer trends). This dataset should contain a series of data points.
- Apply interpolation (e.g., polynomial or spline) to estimate missing data points within your dataset. Also, apply regression techniques to model and predict future trends.

Prepare 3-5 APA formatted reports to explain your findings and conclusions.

Week 4 Lab Assignment

- Develop, debug, and test a program in C/Python to implement cubic spline interpolation.

Week 5

Assignments to complete this week:

- Reading:
  - **Numerical Differentiation and Integration**
    - Chapter 21: Newton-Cotes Integration Formulas
    - Chapter 22: Integration of Equations

Week 5 Assignment

Complete the following problem and upload it in GAP for grading

- Problems (Page 639): 21.3, 21.6, 21.11, 21.14

Week 5 Lab Assignment

- Develop a user-friendly computer program in C/Python for the multiple-application trapezoidal rule based on Fig. 21.9 (pg. no. 622) and the multiple-application version of Simpson's rule based on Fig. 21.13*c* **(pg. no. 632)**. Test the program using any examples.

Week 6

Assignments to complete this week:

- Reading:
  - **Numerical Differentiation and Integration**
    - Chapter 22: Integration of Equations
    - Chapter 23: Numerical Differentiation

Week 6 Assignment

Complete the following problem and upload it in GAP for grading

- Problems (Page 665): 22.9 (a, c), 22.16, 22.20
- Problems (Page 682): 23.8 (a, d), 23.9

Week 6 Lab Assignment

- Develop a computer program in C/Python for dartboard Monte Carlo integration for cases where the function can be positive, negative, or zero across the integration interval. Use your code to estimate the derivative of the integral from Prob. 22.20 **(pg. no. 666).**
- Develop a user-friendly computer program in C/Python to apply a Romberg algorithm to estimate the derivative of a given function.

<u>Week 7</u>

Assignments to complete this week:

- Reading:
  - **Ordinary Differential Equations**
    - Chapter 25: Runge-Kutta Methods
    - Chapter 27: Boundary-Value and Eigenvalue Problems

Week 7 Assignment

Complete the following problem and upload it in GAP for grading

- Problems (Page 764): 25.1
- Problems (Page 820): 27.1, 27.4
- Problems (Page 820): 27.11, 27.12, 27.23

Week 7 Lab Assignment

- Develop a user-friendly computer program in C/Python for systems of equations using the fourth-order RK method. Use this program to duplicate the computation in Example 25.10 **(pg. no. 753)**.
- Develop a user-friendly computer program in C/Python to solve for the smallest eigenvalue with the power method. Test it by duplicating Example 27.8 (**pg. no. 811**).

Week 8

Assignments to complete this week:

- Reading:
  - **Partial Differential Equations**
    - Chapter 29: Finite Differences: Elliptic Equations
    - Chapter 30: Finite Differences: Parabolic Equations

Week 8 Assignment

Complete the following problem and upload it in GAP for grading

- Problems (Page 883): 29.2
- Problems (Page 884): 29.8

Week 8 Assignment

Solving systems of linear and non-linear equations is vital in the field of computer science like machine learning, data analysis, cybersecurity, and data privacy. Research and select a real-world case from data science or analytics and explain how linear equation solving plays a pivotal role in model training or data analysis, leading to valuable insights or predictions.