Numerical Methods

Numerical methods are techniques to approximate mathematical procedures (e.g., integrals). Approximations are needed because we either cannot solve the procedure analytically (e.g., the standard normal cumulative distribution function) or because the analytical method is intractable (e.g., solving a set of a thousand simultaneous linear equations for a thousand unknowns). By end of this course, participants will be able to apply the numerical methods for the following mathematical procedures and topics: differentiation, nonlinear equations, and simultaneous linear equations, interpolation, regression, integration, and ordinary differential equations. Additionally, they will be able to calculate errors and implement their relationship to the accuracy of the numerical solutions. To be prepared for this course, students should have a passing grade in introductory physics, integral calculus, differential calculus, and ordinary differential equations.

1. *Nonlinear Equations*

a) **Quadratic Equations**
Cubic Equations
b) **Bisection Method**
c) **Newton-Raphson Method**
d) **Secant Method**
e) **False-Position Method**

2. *Simultaneous Linear Equations*

   a) **Intro to Matrix Algebra**
   Gaussian Elimination
   b) **Gauss-Seidel Method**
   c) **LU Decomposition**
   d) **Cholesky and LDL Decomposition**

3. *Interpolation*

a) **Background of Interpolation**
Direct Method
b) **Newton's Dif Method**
c) **Lagrange Method**
d) **Spline Method**

4. *Integration*

   a) **Primer on Integral Calculus**
   Trapezoidal Rule
   b) **Simpson's 1/3rd Rule**
   c) **Romberg Integration**
   d) **Gauss-Quad Rule**
   e) **Discrete Data Integration**
   f) **Improper Integration**
   g) **Simpson's 3/8 Rule**

5. *Ordinary Differential Equations*

a) **Primer on Ordinary Differential Equations**
Euler's Method
b) **Runge-Kutta 2nd**

c) **Runge-Kutta 4th**
d) **Finite Diff Method**
e) **Shooting Method**
f) **Higher Order/Coupled**

6. Partial Differential Equations

a) Introduction to Partial Differential Equations
b) Parabolic Partial Differential Equations
Elliptic Partial Differential Equations
c) Finite Element Methods