# Science 2 (PART 1)

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**Requirements:**

- Newtonian Mechanics
- Lagrangian formulation /Classical Mechanics
- Basics of Matrix
- Statistical Mechanics
- Matlab/Python/C++
- Graphical Plot (Must)
- Computational Complexity, Error calculation

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**Module -1 a,b (prerequisite):**

- Basics of matrix
- Computational Knowledge
- Solving Linear Equations (Class 10 mode)

**Module -1 a (Tools you will learn /or revisit):**

- Algebra of matrices
- Singularity, condition of singularity, Symmetric, diagonal, Identity, upper triangular, zero, Hermitian, Vector Norm, Matrix norm, Matrix condition number, Error bounds,
- Operation: Addition, Multiplication, Trace,
- Naïve Gaussian elimination: Forward and backward elimination, pseudo code, computational complexity
- Tridiagonal Systems, Diagonal Dominance, Tridiagonal Algorithm-importance, Examples, Gauss-Jordan Algorithm, LU decomposition in any linear equations, Cholesky decompositions , pseudo code

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**Module -1b (prerequisite):**

- Basics of matrix
- Module 1a
- Algebra of matrices

**Module -1 b (Tools you will learn /or revisit):**

- Linear Least square Problems : $Ax \approx b$; data fitting, Existence and uniqueness, Normal Equations,
- Orthogonality, Sensitivity, Normal Equations, QR factorization: Orthogonal transformation to triangular form,
- Householder transformation, Gram-Schimdt Orthogonalization, Computational complexity

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**Overall Target:**

- Know how systems of linear equations can be compactly represented in terms of matrix-vector multiplication
- Give examples of overdetermined and underdetermined systems, and systems with a unique solution
- Application

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**Module -2 (prerequisite):**

- Basics of matrix
- Module 1
- Ordinary Differential Equations
- Newtonian Mechanics

**Module -2 (Tools you will learn):**

- Algebra of matrices

- Singular Value decomposition (used to solve linear least square problems in any rank)
- Eigen Value Problems, Algortihm
- Spring-mass systems, ecology

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**Overall Targets:**

- Complete Idea about eigen value and eigen vector
- Singular Value Decompostion
- Application of eigen value and eigne vectors in real
    - spring-mass systems
    - Rabit vs Sheep or Rabit vs Lynx
    - Eigen value determines the stability of large eco systems

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**Module -3 (prerequisite):**

- Module 1,2
- Ordinary Differential Equations
- Newtonian Mechanics

**Module -3 (Learning outcome):**

- Learning of Non-linear Differential Equations
- Predator-Prey interactions and SIR model
- Numerical Methods-Euler, Runge-Kutta 4
- Double Pendulum, Lorenz Oscillator
- Chaos theory : A brief and general idea (sensitivity to IC)
- Fractal

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**Overall Target:**

- Numerical solution of nonlinear ordinary differential equations
- Modelling disease, emergence of chaos, chaos in physical systems

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**Module -4 (prerequisite):**

- Random Numbers
- Numerical Integration
- Probability and Statistics (knowledge on distribution)

**Module -4 (Learning outcome):**

- Monte Carlo Method
- Importance sampling
- Random number generation techniques
- Non-uniformly distributed Random Number Generator
- Metropolis-Hastings algorithm
- Application to numerical integration

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**Overall Targets:**

- Calculation of Pi
- Random Walk
- Multidimensional Integration

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**Module -5 (prerequisite):**

- Numerical techniques for ODE (Module 3)
- Module 4
- Brownian Motion

**Module -5 (Learning outcome):**

- SDE –Numerical solver
- Brownian motion simulation/Langevin equation

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**Module -6 (prerequisite):**

- Differential Equation

**Module -6 (Learning outcome):**

- PDE –Numerical solver
- Reaction-diffusion systems
- Spiral/stripe pattern in reality

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## Reference Material


1. Introduction to Computational Physics, Lecture of Prof. H. J. Herrmann Swiss Federal Institute of Technology ETH, Zürich, Switzerland Script by Dr. H. M. Singer, Lorenz Müller and Marco - Andrea Buchmann Computational Physics, IfB, ETH Zürich **(Module 3, 4, and 6)**

2. Nonlinear Dynamics –Steven Strogatz **(Module 2 and 3)**

3. Scientific Computing, An Introductory Survey, Second Edition by Michael T. Heath **(Module 1-4,6)**

4. Numerical Solution of Stochastic Differential Equations in Finance Timothy Sauer, Department of Mathematics, George Mason University, Fairfax, VA 22030, tsauer@gmu.edu **(Module 5)**

5. Books: Gilbert Strang **(Module 1 and 2)**


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