Course Code: **JF305**
Course Title: **Advanced Computational Science**
Instructors: **Santosh Ansumali**
Credits: **3.0**

1. **Introduction to High Performance Computing (6 Hours)**
   I. Introduction to distributed computing
   II. Amdahl's law and Gustafson's law
   III. MPI parallelization and SIMD vectorization
   IV. Memory Bandwidth optimizations and Roofline Model

2. **Ordinary Differential Equations (6 Hours)**
   I. One-step methods
   II. Forward and Backward Error Analysis
   III. Runga Kutta and Multi-step methods
   IV. Symplectic Integrators
   V. Stiff Equations
3. **Particle Based Methods – (9 Hours)**
   I. Molecular Dynamics, Hard Sphere Dynamics,
   II. Discrete simulation Monte Carlo
   III. Multi-Particle Collision Dynamics,
   IV. Brownian Dynamics Method

4. **Finite Difference Method (6 hours)**
   I. Introduction to Finite difference
   II. Von Neumannn Analysis
   III. Discrete Differntial Operators
   IV. Modified Equation and Artificial viscosity Methods
   V. Lax-Wandroff Method
   VI. Crank-Nicholson Method
   VII. Mac-Cormack Method for Advection equation
   VIII. Fractional Step Methods
5. **Introduction to Kinetic Theory of Gases (8 Hours)**
   I. Distribution function, Mean Free path, Maxwell-Boltzmann Distribution,
   II. Transport Properties,
   III. Models of Boltzmann Equation and moment Chain
   IV. Methods of Reduced Description and Hydrodynamic Limit, Chapman-Enskog Method, Grad's Moment Method, Maximum Entropy's Method
6. **Introduction to Lattice Boltzmann Models (9 Hours)**
   I. Discrete Velocity Models for Hydrodynamics,
   II. Basic 2D and 3D implementations, Boundary Conditions,
   III. Entropic Lattice Boltzmann
   IV. Multiphase Flow
   V. LBM as PDE solver
7. **Introduction to Computational Fluid Dynamics (4 hours)**
   I. Pseudo-compressibility Method
   II. Pressure Projection Method
   III. Pseudo-Spectral Method