Numerical methods in marine sciences – 2 credits

Course Number: 224.4012

Lecturer: Dr. Regina Katsman

Office Hours: Monday, 12:00-14:00, Multipurpose Building – Room 261, tel. 048288979, email: katsman@univ.haifa.ac.il

Course Type: Lecture

Course Level: MSc/ PhD

Prerequisites: Advanced mathematic and scientific programming with MATLAB for Marine Sciences (224.4092).

Course Description:

Physics of continuum is the basis for energy and matter motion, starting with seismic waves, ocean currents, sediment transfer, to compaction of marine sediments. The objective of the course is to gain an experience in numerical solutions of scientific problems in area of Marine Sciences. The course begins with mathematical background of physics of continuum. The course discusses derivation of mass, momentum, and energy conservation equations for liquids and solids. Finite-difference numerical approximations of derivatives and methods of numerical solutions of ordinary differential equations are presented. Numerical solutions of parabolic, hyperbolic, and elliptic partial differential equations in 1D and 2D are studied, applicable for various processes within the scope of Marine Sciences.

Topics:

1. Numerical vs. analytical solutions. Law of mass conservation.
2. Laws of momentum and energy conservation.
3. Basics of matrix theory - matrix addition, multiplication, zero matrix, identity matrix, special matrices: triangular, symmetric, diagonal.
4. Basics of matrix theory - elementary operations on matrices: Gauss-Jordan elimination, transposition.
5. Basics of matrix theory - introduction to determinants, solutions of systems of linear equations.
6. Physical and mathematical concepts of derivatives. Finite-difference approximation to derivatives - Central-, Forward-, Backward differences, schemes with arbitrary number of points, accuracy of approximation.
7. Ordinary differential equations - one-step methods : Euler explicit/implicit methods, Runge-Kutta methods.
8. Ordinary differential equations - linear multistep methods: Adams-Bashforth (explicit) method, Adams-Moulton (implicit) method, Predictor-corrector method.
9. Consistency, Stability, and Convergence of the numerical schemes. Initial and boundary conditions.
10. Partial differential equation in 1D - parabolic (diffusion, heat transfer) equations: explicit scheme, Cranc-Nicolson implicit scheme.

11. Partial differential equation in 1D - hyperbolic (advection, wave) equations: FTCS, Lax-Friedrichs schemes.
12. Partial differential equation in 1D - hyperbolic (advection, wave) equations: Lax-Wendroff, up-wind schemes.
13. Partial differential equation in 2D - elliptic (Poisson and Laplace) equations: 5 and 9-Points approximations.
14. Solution of Large Linear Systems, Direct vs. iterative methods. Iterative methods - Jacobi, Gauss-Seidel, relaxation methods.

Learning Outcomes:

At the end of the course, students will be able to:
1. Design the numerical solutions for various physical problems.
2. Run simulations and analyze the results.

Requirements: Attendance, Final project, Homework assignments, Test on matrices.

Grading:

Passed – 65% (test on matrices 10%, homeworks 50%, final project 40%), with grade.

Reading List:

1. G.D.Smith (1986) Numerical solution of partial differential equations: Finite difference methods, Clarendon Press, Oxford.
2. C.Hirsch (1988) Numerical computation of internal and external flows, v.1, John Willet & Sons.