OPTI 403A/503A: Mathematical Methods for Optics & Photonics

3 Credit Hours, 45 Contact Hours

Categorization of credits in Table 5-1 (math and basic science, engineering topic, and/or other).

1. **Instructor Name:** Masud Mansuripur

2. **Text book, title, author, and year**
   a. **Required Materials:**
      i. None
   b. **Recommended Materials:**
      i. G. B. Arfken and H. J. Weber, *"Mathematical Methods for Physicists,"* 6th edition, 2005.
      ii. 2. F. B. Hildebrand, *"Advanced Calculus for Applications,"* 2nd edition, 1976.
      iii. 3. R. Bracewell, *"Fourier Transform and its Applications,"* 3rd edition, 1999.
      iv. 4. M. Mansuripur, *"Introduction to Information Theory,"*, 1987.
      v. 5. J. Mathews and R. L. Walker, *"Mathematical Methods of Physics,"* 2nd edition, 1970.
      vi. 6. G. Stephenson and P. M. Radmore, "*Advanced Mathematical Methods for Engineering and Science Students,*", 1990

3. **Specific course information**
   a. **Course Description:** This course covers the basic mathematics needed for an in-depth understanding of the science and technology of fiber-optical communication systems. Every mathematical tool/technique developed in this course will first be motivated by the relevant application. The students are not expected to have a broad-based prior knowledge of the topics covered in this course, but they should generally be familiar with the basics of algebra, Euclidean geometry, trigonometry, integral and differential calculus, simple differential equations, and the rudiments of complex number analysis. The course will cover Complex Analysis, Fourier transform theory, and method of stationary phase (in the context of optical diffraction), vector algebra, linear algebra, ordinary and partial differential equations (e.g., Maxwell¿s electrodynamics, wave equation, diffusion equation), special functions (e.g., Bessel functions needed to study the guided modes of optical fibers), and probability theory (needed for understanding various sources of noise in communication systems, photodetection theory, digital communication via noisy channels, Information theory, etc.).
   b. **Prerequisites or Co-Requisites**
      i. **Major:** OSE
      ii. **Adv Stdg:** Engineering
      iii. **Prerequisites:** MATH 322
         1. students should have familiarity with basic calculus, Euclidean geometry, algebra, trigonometry, and the complex number system
   c. **Course Type:** Elective

4. **Specific goals for the course**
    a. **Outcomes of Instruction:**
        i. To learn the tools and techniques of scientific analysis in the context of their applications in optics and photonics
    b. explicitly indicate which of the student outcomes listed in Criterion 3 or any other outcomes are addressed by the course.

5. **Brief list of topics to be covered**
    - Elementary calculus, exponential and logarithmic functions, Taylor series expansion
    - Approximation methods
    - Complex number theory, complex integration and differentiation, simple functions in the complex domain
    - Special functions: Rectangular and triangular functions, delta-function and its derivatives, sinc function, etc.
    - The convolution operation
    - Linear, shift-invariant systems
    - Fourier transform theory, theorems, useful Fourier transform pairs
    - The method of stationary phase
    - Applications of Fourier theory to optical diffraction
    - Linear algebra, operations with matrices, matrix inversion
    - Eigen-values and eigen-vectors, matrix diagonalization
    - Vector algebra, vector identities
    - Divergence, curl, gradient, and Laplacian operators
    - Ordinary differential equations; elementary methods of solution
    - Partial differential equations, method of separation of variables,diffusion equation
    - Maxwell’s equations; the wave equation
    - Solutions of the wave equation in Cartesian, cylindrical, and spherical coordinate systems
    - Special functions: Bessel functions of the 1st, 2nd, and 3rd kind; modes of an optical fiber
    - Probability theory
    - Statistical properties of thermal noise, shot noise, and modal noise in fiber optics systems
    - Introduction to Information Theory and Coding
    - Communication via noisy channels; Shannon’s noisy channel capacity
    - Compression codes, error-correction codes, modulation coding

6. Assignments

Graduate students must solve all the assigned problems.
For undergraduates, the problems marked with an asterisk (*) are optional.

Assignment 1: Chapter 1, Problems 3, 4, 5, 8*, 11, 16, 17. Due: Wednesday, January 16.

Assignment 2: Chapter 2, Problems 2, 4, 5, 6*, 8, 9, 12*, 13. Due: Monday, January 28.

Assignment 3: Chapter 3, Problems 2, 5, 8*, 9, 10*, 11, 12, 13. Due: Monday, February 11.

Assignment 4: Chapter 4, Problems 1, 3, 4, 7, 9, 12*, 16, 18*. Due: Wednesday, February 20.

Assignment 5: Chapter 5, Problems 1, 5, 7, 9*, 10, 11, 13. Due: Monday, March 11.

Assignment 6: Chapter 6, Problems 2, 5, 6*, 7, 11, 13*, 14. Due: Wednesday, March 20.

Assignment 7: Chapter 6, Problems 24, 27, 30*, 32, 33, 35*. Due: Monday, March 25.

Assignment 8: Chapter 7, Problems 2, 6*, 17, 18, 25*, 30, 39. Due: Wednesday, April 3.

Assignment 9: Chapter 8, Problems 2, 5, 7, 8, 13*, 20. Due: Monday, April 15.

Assignment 10: Chapter 9, Problems 1, 4, 6, 7, 10, 17*. Due: Monday, April 29.

Grading Criteria

Midterm (counting for 35% of total grade), final exam (counting for 50%); homework assignments (counting for 15%).

Note: Each homework assignment contains one or more problems marked with an asterisk (*). These problems are required for graduate students, but are optional for undergraduates.