OPTI 512R: Linear Systems and Fourier Transforms
Fall 2024 (3 credits)

Instructor: Prof. Meredith Kupinski
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Office Hours: Wednesday 12:30pm, in-person/Zoom
Lecture: Monday & Wednesday 11am-12:15pm, Meinel 307
Course Website: d2l.arizona.edu

Teaching Assistants (TAs): Chuan Luo and Clarissa DeLeon
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TA Office Hours: Clarissa (in-person) Thursdays 2pm MST, Meinel 747
Chuan (Zoom) Fridays 11 am MST.
TA support also available by appointment

Welcome!

This course is an introduction to linear operators and Fourier analysis. Our emphasis is on applications in imaging, diffraction, and optical sciences and engineering.

Course Description: OPTI512R. Linear Systems and Fourier Transform (3 credits). Linear system theory, Fourier optics, Interference and diffraction, Image formation, Optical transfer function. Pre-requisites: undergraduate courses on complex analysis, vector calculus, and linear algebra.

Expected Learning Outcomes

- Assumptions of linear system theory, impulse response function, eigenanalysis.
- Understand discrete representation of continuous functions and linear decomposition using basis sets.
- Properties and theorems of Fourier transforms.
- Quantify diffraction and image formation using relevant approximations and Fourier transforms.
- Proficiency analyzing optical imaging systems using linear system theory.
- Operational definitions for important Fourier concepts in optics: Huygens wavelets, Gibbs phenomenon, stationary phase approximation, Kramers–Kronig relations, Nyquist–Shannon sampling, Talbot effect, zero-padding DFT and Abbe sine condition.

Communications: D2L will be the main form of communication for all course announcements. D2L discussion posts will be used for weekly course questions. For direct communication with the instructor or TA, use D2L email with the subject line OPTI 512R, and expect a response time of 24-48 hours.

Course Materials

A desktop or laptop computer is required. Laptops can be checked out from the university libraries https://lib.arizona.edu/borrow/tech.

Required Textbooks:

Foundations of Image Science, H.H. Barrett, K.J. Myers Availability: https://wp.optics.arizona.edu/kupinski/resources/
The Fourier Transform and Its Applications, R.N. Bracewell Availability: Select chapters on D2L. Amazon and other vendors.
Linear Systems, Fourier Transforms, and Optics, Jack D. Gaskill Availability: Select chapters on D2L. Amazon and other vendors

Recommended Resources:

Introduction to Fourier Optics, J.W. Goodman Availability: Amazon and other vendors
Field Guide to Linear Systems in Optics, J. S. Tyo and A. Alenin Availability: UA Library Search https://lib.arizona.edu/find/books, https://doi.org/10.1117/3.1002932
Prof. Schwiegerling OPTI 512R Archive Availability: https://wp.optics.arizona.edu/visualopticslab/opti-512r-linear-systems-fourier-transforms/#top
Ubiquity of Fourier Transformation in Optical Sciences, Masud Mansuripur https://doi.org/10.1364/AO.390342

Course Assessments

Homeworks: Problem sets and solutions will be available through D2L. All homework must be submitted via D2L. Homework is assigned about once per week on a Monday and due the following Monday (or Tuesday in the case of UA holiday) at 11:59 PM-MST. In order to publish solutions within a week of the due date, the late policy is as follows:

- Within 24 hours of due date: -10%
- Within 1 week of due date: - 20%
- More than 1 week late: -50%

i.e. the maximum score attainable for submissions more than one week late is 50%. All students will receive a one time late submission allowance of one week without any grade reduction. On time homework will be graded and returned within a week of submission, late assignments will be graded within 2 weeks of submission.
Please put the problem number and your name on every page to facilitate grading. Only D2L homework submissions will be accepted.
Exams:

Grading

Item	Grade Percentage
12 Homeworks	50%
Midterm Exams	25%
Final Exam	25%

Course Schedule

Lectures	Topics	Assessment
8/26 8/28	Course Introduction Vector Spaces and Operators	None
9/2 9/4	No Class - Labor Day Eigenanalysis	HW 1 Due (9/3)
9/9 9/11	Singular-Value Decomposition Fourier Series	HW 2 Due
9/16 9/18	Fourier Transforms Special Functions and Relations	HW 3 Due
9/23 9/25	Sampling Theory Discrete Fourier Transform (DFT)	HW 4 Due
9/30 10/2	LSIV Systems Convolution Properties	HW 5 Due
10/7 10/9	CC, CD, and DD Operators Special Functions	HW 6 Due
10/14 10/16	Gibbs Phenomena Aliasing	HW 7 Due
10/21 10/23	Space Limited and Band Limited Functions Stationary Phase Approximation	HW 8 Due
10/28 10/30	Fourier Analysis in Imaging Midterm Exam	HW 9 Due Midterm Exam
11/4 11/6	Transfer Functions Impluse Response	None
11/11 11/13	No Class - Veteran's Day Maxwell's Equations in Fourier Domain	HW 10 Due (11/12)
11/18 11/20	Review Midterm Solutions Abbe Sine Condition	HW 11 Due
11/25 11/27	1-1 Student Meetings, 5 min/each No Class - Thanksgiving	None
12/2 12/4	Zero-padding DFT Talbot effect and Poisson/Argo spot	None
12/9 12/11	Kramers–Kronig relations Course Review	HW 12 Due
12/16	FINAL EXAM	

Recommended Reading

Barrett and Myers

Chapter 1: Vectors and Operators

1.1: Linear Vector Spaces

1.2: Types of Operators

1.3: Hilbert-Space Operators

1.4: Eigenanalysis

1.5: Singular-Value Decomposition

Chapter 3: Fourier Analysis

3.1: Sines, Cosine, Complex Exponentials

3.2: Fourier Series

3.3: 1D Fourier Transform

3.4: Multi-Dimensional Fourier Transforms

3.5: Sampling Theory

3.6: Discrete Fourier Transform

Chapter 7: Deterministic Descriptions of Imaging Systems

7.2: Linear Continuous-to-Continuous

7.3: Linear Continuous-to-Discrete

7.4: Linear Discrete-to-Discrete

Bracewell

Chapter 2: Groundwork

Chapter 3: Convolution

Gaskill

Chapter 8: Characteristics and Applications of Linear Filters

Chapter 9: Two-Dimensional Convolution and Fourier Transform

Chapter 10: Diffraction in the Fresnel Region

Class Policies

Students with a Learning Challenge: If a student is registered with the Disability Resource Center, https://drc.arizona.edu/,they must submit appropriate documentation to the instructor if they are requesting reasonable accommodations.
Makeup Policy for Students Who Register Late: Students who register after the start of the class will have the opportunity to makeup any assignments, before the first exam.
Incomplete (I) or Withdrawal (W): Requests for incomplete (I) or withdrawal (W) must be made in accordance with University policies, which are available at https://registrar.arizona.edu/faculty-staff-resources/grading/grading-policies.

University Policies

All university policies related to a syllabus are available at: https://catalog.arizona.edu/syllabus-policies.

Graduate Student Resources

University of Arizona's Basic Needs Resources page: http://basicneeds.arizona.edu/index.html

Subject to Change Statement

Information contained in the course syllabus, other than the grading policy, may be subject to change with advance notice, as deemed appropriate by the instructor.