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Spring 2022

PHYS 114-002: Introduction to Data Reduction with Applications

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Course Outline: Phys 114, Spring 2022
Introduction to Data Reduction with Applications (3-0-3)
Co-requisites: Math 111

Instructor: Dr. John Federici, Office: 474T, 596-8482; email: federici@njit.edu

Office Hours: Tuesdays and Thursdays 10:30-11:30pm or by appointment

Synopsis: An introduction to both the theory and application of error analysis and data reduction methodology. Topics include the binomial distribution and its simplification to Gaussian and Poisson probability distribution functions, estimation of moments, and propagation of uncertainty. Forward modeling, including least-squares fitting of linear and polynomial functions, is discussed. The course enables students to apply the concepts of data reduction and error analysis using data analysis software applied to real data sets found in the physical sciences.

COURSE MATERIAL:

- **Textbooks:** *Data Reduction and Error Analysis for the Physical Science* (3rd Edition), by Philip R. Bevington and D. Keith Robinson. This book is in the bookstore. You should be able to find a FREE PDF copy online. If you have problems, please let your instructor know.

  As a supplemental textbooks, the following FREE online textbooks will be used
  https://phys.libretexts.org/Core/Data_Analysis/Error_Analysis
  https://openstax.org/details/books/introductory-statistics
- **MATLAB** (available for download from NJIT web page) or similar analysis and plotting software. **NOTE: The course has standardized on MATLAB, but if you wish to use another software package (eg. Mathcad, Mathematica, etc.) PLEASE DISCUSS with your instructor... Quizzes and exams may contain MATLAB questions.**
- **Note:** The homework assignments will be distributed via the world wide web. The course webpage can be accessed through the following web address: https://sites.google.com/njit.edu/federici/phys-114-matlab

ATTENDANCE: It is expected that students will attend all lectures, recitations, etc. If you anticipate an absence, please let your instructor know immediately. If you miss any in-class exercises, unless it is an 'excused absence', the in-class exercise (if it is graded) will count as a zero in your grade. Absence from class DOES NOT alter the deadlines for turning in assignments or taking exams.

HELP: Visit or email your instructor if you are having trouble with the course; do not simply hope for a miracle and fall further behind.

GRADING: Your final letter grade in Phys 114 will be based on a composite score for term's work that includes the mid-term, final exam, and homework.

- Homework - Homework is given every week and is considered an important part of the class. The homework usually consists of reading the text, short answer questions, and numerous mathematical calculations. Homework assignments are given in the syllabus below and are due weekly. Late homework will NOT be accepted.
- Exams – The purpose of the exams is to test the *individual* student's progress in the class. Exams are closed book/notes. Exams will be announced ahead of time. In the event of a student missing an exam, the physics department policy for 'make up' exams will be followed.
- In-class quizzes and class participation - There will be short, in-class quizzes at random times roughly every 2-3 weeks. In addition, attendance at lecture is expected and will be rewarded through online or in-person responses.

Final Letter Grades : Here are the approximate weights to be used for calculating the composite score:

- **18%** for first exam
- **18%** for 2nd Exam
- **19%** for Final Exam
- **25%** for Homework
- **10%** for In-Class quizzes and class Participation
- **10%** for Final In-class Project

The cutoff percentages for various letter grades will be in the range of 85% for A, 80 % for B+, 75% for B, 70% for C+, 60% for C, 55% for D, and F below 55 %.

HONOR CODE STATEMENT: NJIT has a zero-tolerance policy for cheating of any kind and for student behavior that disrupts learning by others. Violations will be reported to the Dean of Students. The penalties range from a minimum of failure in the course plus disciplinary probation up to expulsion from NJIT. Avoid situations where your own behavior could be misinterpreted as dishonorable. **Students are required to agree to the NJIT Honor Code on each exam, assignment, quiz, etc. for the course.**

The mode of class delivery will normally be in-person on NJIT campus. Due to mandated format changes by NJIT (for example, due to COVID), class will be live online using WEBEX. The WEBEX link is https://njit.webex.com/meet/federici . Turn off all cellular phones, wireless devices, and messaging devices of all kinds during exams and lecture portion of class. For in-class assignments, the instructor will let you know when to utilize your computer for calculations.

Assignments: You are responsible for all weekly reading and homework assignments listed in this outline. The reading should be completed BEFORE class each week. Homework assignments MUST be turned in ON TIME. Homework assignments are due just about EVERY WEEK. Check syllabus weekly to see what is due. ALL ASSIGNMENTS not turned in by the assigned date will be scored as a zero. **Each student must turn in individual Homework assignments. No group submissions will be accepted.**

Course Policy on Submitting Matlab Code:
If for any homework problem or class project that requires you to submit Matlab code please use one of the following options:
(a) Make sure that the location of any input files is included in the file path in which Matlab searches (use PATHTOOL command in Matlab).
(b) The submitted code via must be 'stand-alone'. This means that if your instructor copies and pastes your code into Matlab it should run WITHOUT any errors. To ensure that this is true, when you download any data files from the course web page which will be imported into Matlab, DO NOT change the name(s) of any input files.
(c) If you define any Matlab functions which are required for your code to run, you must include the functions as a Matlab file as an attachment to your homework.
(d) Prior to submitting your HW assignment or other Matlab assignments, you should VERIFY that your Matlab code will run WITHOUT any execution errors.

EMail/ Alternative Methods of Delivery Policy: When the class is 'in-person', you may turn in your homework assignments either on paper in class, or via email. You may find that since the course utilizes Matlab a lot, that is more convenient to submit all assignments must be delivered by email. The email must be date stamped BEFORE the due date/ time. THE INSTRUCTOR IS NOT RESPONSIBLE FOR LOST EMAILS, COMPUTER CRASHES, ETC.

Groups and Working Together: With regards to homework assignments, you are encouraged to work together if that method helps you learn the material. However, each student must submit an individual homework assignment with their own analysis, graphs, and discussion. Remember that you must understand the homework assignment well enough that you can do it BY YOURSELF on the exams. DO NOT CUT AND PASTE your homework from other students' work.

LEARNING OUTCOMES: For this course, you can expect to be assessed on the following learning outcomes:

1. Be able to address the pros and cons of various methods of measurement
2. Be conversant with the data reduction and error analysis concepts mentioned above,
3. Be able to analyze 1D and 2D data sets to find computational estimates of PDFs, moments, and to address the appropriateness of various forward models,
4. Be familiar with various measurement techniques so as to best experimentally determine PDFs, moments, and the appropriateness of various forward models,
5. Be able to devise an experiment capable of making a measurement to a pre-determined level of precision,
6. Be able to create figures that are journal-quality,

7. Be extremely familiar with the Matlab software package so as to utilize it in subsequent classes and research endeavors.

Week	Topic/ Text Assignment (with Lecture Note Links)	HW Problems
1	**INTRODUCTION TO CLASS** **MatLAB** Review of MatLAB: capabilities and programming environment Forms of data (vectors, arrays, images as numbers) APPLICATION: Write a basic MatLAB program Lecture01 Making plots Lecture02 Using HELP Defining Functions – Homework Submissions of MATLAB CODE APPLICATION: Write a basic MatLAB program to plot generated data	Download MatLab from NJIT Website
2	Info on finding Summer Research **More MatLAB** Basic matrix/array operations for reading in data and for graphical output. Lecture03 Do's and Don'ts of Journal Quality Figures Lecture3_Sample_data Navigating filenames, writing a function to import picotd files, basics of THz time-domain measurements Lecture04 APPLICATION: Write a basic MatLAB program to read in real data and make a plot	HW #2 Reference.picotd Amber.picotd
3	**Uncertainties in Measurement:** Bevington Book, Chapter 1 – PRIMARY TEXTBOOK for course https://phys.libretexts.org/Core/Data_Analysis/Error_Analysis - Sections 1, 4-8. https://openstax.org/details/books/introductory-statistics - Sections 1.1-1.2, 2.5, 2.7 https://phys.libretexts.org/Core/Data_Analysis/Uncertainty_in_Physical_Measurements - Sections 0, 1 Accuracy, Precision, Systematic/ Statistical Errors, Parent/Sample Distributions Mean, Median, Mode, Variance, Standard Deviation Lecture05 Percent error, SNR—reduction of noise through repeated measurements APPLICATION: Random Noise and Systematic Noise in THz Time-Domain Transmission measurements. Lecture06	HW #3 noise_1, noise_5, noise_10, noise_50, noise_100, noise_500, noise_1000, noise_5000, noise_10000
4	**Discrete Probability Distribution Functions:** Bevington Book, Chapter 2, Binomial and Poisson Distributions. https://phys.libretexts.org/Core/Data_Analysis/Error_Analysis - Sections 3 https://faraday.physics.utoronto.ca/PVB/Harrison/GUM/01_ExcelVersion/Backgammon101.pdf https://openstax.org/details/books/introductory-statistics - Sections 4.1,4.2,4.3, 4.6, also read KEY TERMS and CHAPTER REVIEW for Chapter 4. Binomial Lecture07 and Poisson PDFs Lecture08	HW #4
5	**Continuous Probability Distribution Functions:**	HW #5

	Bevington Book, Chapter 2, Gaussian and Lorentzian Distributions https://openstax.org/details/books/introductory-statistics - Sections 5.1, 6.1, 6.2 https://phys.libretexts.org/Core/Data_Analysis/Error_Analysis - Sections 4,5. Gaussian PDF, and other noise: White Noise and 1/f noise. Lecture09 https://phys.libretexts.org/Core/Data_Analysis/Error_Analysis - Section 9 Statistical Uncertainty and Propagation of Errors, Bevington Book, Chapter 3 Lecture10, Lecture 11 Lecture11_example matlab code	
6	**Exam 1: In class**	
7	**Error Analysis** Averages of averages, Central Limit Theorem, 'Bad' data points Bevington Book, Section 4.1 only https://openstax.org/details/books/introductory-statistics - Sections 7.1-7.3 https://phys.libretexts.org/Core/Data_Analysis/Error_Analysis Section 11. Lecture12 APPLICATION: Effects of averaging in an experiment	HW #7
8	**Confidence Intervals, Student's t-Test, Chi-Squared test, Goodness of Fit** Bevington Book, Chapter 4, Chapter 11.1-11 https://openstax.org/details/books/introductory-statistics - Sections 8.1-8.2 https://openstax.org/details/books/introductory-statistics - Sections 11.1-11.2 Lecture 13	HW #8 HW8 Problem 3 Data
9	**Fitting of Data to Linear Functions** Bevington Book, Chapter 6 https://phys.libretexts.org/Core/Data_Analysis/Least-Squares_Fitting https://phys.libretexts.org/Core/Data_Analysis/Fitting_Techniques https://openstax.org/details/books/introductory-statistics - Chapter 12 Linear least squares fitting. Lecture 14, Lecture 14a Chi-Square and R-square fitting. Uncertainty in fitting parameters. Data set For Class Exercise Lecture 14	HW #9
10	**EXAM 2: In-class**	
11	Linear Fits for Polynomial, Linearization of Fitting Equation Lecture 15 Bevington Book, Chapter 8 Nonlinear fitting - Custom and 'arbitrary' fitting, Generalized least-squares fitting. **https://phys.libretexts.org/Core/Data_Analysis/Fitting_Techniques** 'culling' of data in matlab. Lecture 16 CLASS EXERCISE DATA APPLICATION: Fitting of THz Spectra of fossilized amber to various theoretical models.	HW#11
12	lecture17.ppt Fourier Transforms, Prepare for Final Project	final_project_data
13	In-Class Project: Final project hints final_project_data	

	Final Project Instructions Journal Paper Template	
14	Final Project, REVIEW for FINAL	

Spring Break March 14-18
April 15 – Good Friday – No Classes
Tuesday May 3rd follows a FRIDAY schedule
READING DAYs – May 4-5
FINAL EXAM PERIOD – May 6-12