New Jersey Institute of Technology- Spring 2025

PHYS 114 – INTRODUCTION TO DATA REDUCTION WITH APPLICATIONS (3-0-3)

Topics: An introduction to both the theory and application of data processing, error analysis, and data reduction methodologies, for use in scientific research. Topics include probability distribution functions, specifically 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 are discussed. Topics in digital signal processing, including Fourier transforms, windowing, filtering, and power spectral density estimation is reviewed. The course enables students to apply the concepts of the data reduction and error analysis using a commonly available data analysis software suite to real data sets often found in the physical sciences.

Objectives: By the end of the course, students should

a) Be able to address the pros and cons of various methods of measurement

b) Be conversant with the data reduction and error analysis concepts mentioned above,

c) 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,

d) Be familiar with various measurement techniques so as to best experimentally determine PDFs, moments, and the appropriateness of various forward models,

e) Be able to create figures that are journal-quality,

f) Be extremely familiar with the agreed upon software package so as to utilize it in subsequent classes and research endeavors.

Instructor:

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Office Hours: TBD

Co-requisite: MATH 111

Course Materials: Bevington, P.R. and D. K. Robinson, *Data reduction and error analysis for the physical sciences, 3rd ed.*, McGraw-Hill, Boston, 2003.

Python, using the Anaconda package (https://www.anaconda.com)

Course Requirements and Grading Policy:

Homework: 30%

Homework is given every other week and is considered an important part of the class. The homework usually consists of reading the text, short answer questions, and mathematical calculations; often requiring Python. An assignment is given on the first lecture of the week [when theoretical material is covered] and may require measurements to be performed during that week either at the second lecture or outside of class. Students *are encouraged to work together* on the homework problems, though each student is responsible for handing in an *individual* homework set.

3 Exams (2 during the semester worth 15% each, and 1 final worth 25%): 55%

The purpose of the exams is to test the *individual* student's progress in the class. Exams are closed book/notes, but the student is allowed to bring in one 8.5x11 inch sheet of notes for each exam. Later exams can make use of previous note sheets (i.e., the note sheets are cumulative). Exams will be announced ahead of time.

Class participation 15%

Attendance at lecture is expected.

AI Statement: Use of AI technologies have become part of our lives in the past 2-3 years, and their exponential+ growth will likely continue. Like the invention of the calculator to replace the slide rule, then the desktop [computer] to replace the calculator, then the laptop to replace the desktop, etc., we as a society need to both appreciate these developments as TOOLS, which have strengths and weaknesses. Always remember, we still need to learn “long division” before blindly trusting the calculator.

For PHYS 114 Exams, you will not need such technologies. That is, you will not need any AI platform, your phone, your laptop, your tablet, smart glasses, smart watches, or even your calculator. So such technologies should be closed, shutdown, put away, and not in sight at any time during such assessments. ***If you are found with such technologies, if even to “check a text”, you will be suspected of suspicious activity and reported to the Dean of Students.*** This rule will be strictly enforced, so please do not get yourselves in trouble.

For PHYS 114 Homework, you should feel open to using these technologies. However, plagiarism is a real thing, and applies to AI technologies such as ChatGPT. As such, site what you utilize from such platforms. More so, make sure “what AI is telling you is correct.” I have seen too many students tell me things on ChatGPT are just plain wrong.

THE NJIT HONOR CODE WILL BE STRICTLY ENFORCED AND ANY VIOLATIONS WILL BE BROUGHT TO THE IMMEDIATE ATTENTION OF THE DEAN OF STUDENTS.

Week	Date	Topic
1	Jan 19	INTRODUCTION TO CLASS Data files, types, conversion, importance (e.g., *header*, *metadata*, *EOF*) Review of *Python*: reasons for use, range of capabilities, and alternatives APPLICATION: Writing a basic Python program
2	Jan 26	*Undergraduate Research 101* *Funding agencies and mission*, *proposals* (purpose, submission, review), *budgets*, *tasks* Things To Do and Things To Not Do: Strongly Encouraged Suggestions Basic Python operations for reading in data, analysis, and professional graphical output APPLICATION: Write a basic Python program to read in real data and make a plot
3	Feb 2	Uncertainties in Measurement: Chap 1 *Probability Distribution Functions (PDFs)* *Sample mean* + *sample standard deviation* *Percent error, SNR, dB/dBi* APPLICATION: Given a counting experiment [e.g., PMT] find various quantities
4	Feb 9	Explicitly defined *PDFs*: Chap 2 *Binomial* *Gaussian*, *Poisson*, Others [*Lorentzian*, *Cauchy*, etc.] *PDF Moments* and *Moment Generating Function*, focus on the *first and second moments* APPLICATION: Determine the PDF for 3-4 different random variables [temperature, PMT photon count from previous week]
5	Feb 16	**CATCH UP + REVIEW + EXAM 1**
6	Feb 23	An Aside: Uncertainty Analysis: Chap 3 *Statistical Uncertainty* and *Bias* *Propagation of Uncertainty* APPLICATION: Propagation of uncertainty in a "complex" measurement: Measurements from a CCD
7	Mar 2	*Estimators and Estimation Theory*: Chap 4 Best estimates of the moments: Mean, standard deviation of the mean, standard deviation of the standard deviation of the mean, etc. Variance, standard deviation of the variance, standard deviation of the standard … The *Forward Model* Concept APPLICATION: Expected photon counts from "*The Lidar Equation*"
8	Mar 9	*Curve Fitting*: Chap 6-8 Linear fits to data Least-squares fitting to a linear data set Polynomial forward model Least-squares fitting to a polynomial data set *Generalized Least-Squares Fitting*
-	Mar 16	**SPRING BREAK**
9	Mar 23	Testing the Fit: Chap 11 [and some Chap 5] *Correlation Analysis* *Chi-square* *Monte-Carlo Techniques/Methods*
10	Mar 30	**CATCH UP + REVIEW + EXAM 2**
11	Apr 6	*Generalized Random Variables and Stochastic Processes* Continuous realm to discrete realm Introduction to *Digital Signal Processing (DSP)* *Common DSP functions: delta, step, step down, top-hat (square), sinc, Gaussian*
12	Apr 13	Into the *Spectral Domain* Limitations and assumptions, *data windows* *FT vs. DFTs vs. FFTs* FTs of common functions
13	Apr 20	*Power Spectral Density (PSD)* estimation, from *periodograms*
14	Apr 27	*DSP Filtering* concepts, *low-pass, high-pass, bandpass, and stopband filters* When all heck breaks loose: *Lomb-Scargle, parametric vs. non-parametric*, etc.
15	May 4	**LAST WEEK OF CLASSES + CATCH UP-REVIEW**