Physics 231: Introduction to Statistics and Applications to Experimental Physics

As taught by Henry Lubatti

Overview

The goal of this course is to introduce you to statistics applied to analysis of experimental data. The course consists of lectures describing various statistical distributions that are widely used in physics and a weekly laboratory where the goal is to measure fundamental constants such acceleration of gravity, e/m, h/e and determine the lifetime of a radioactive substance. All of the labs require setting up the experiment and, collecting data and performing a fit to the data to obtain the physical quantity of interest an dits uncertainty. Three important distributions are covered in lecture: Gaussian, binomial, Poisson and Chi square. The maximum likelihood approach to obtaining the best value and uncertainty of the parameters describing the data of the data and the Chi squared goodness of fit that is reported when discussing the fit parameters.

Evaluation

Detailed lab reports covering methodology, data acquisition, data analysis, results and their uncertainty (85%). Take home final (15%)

Texts

1. **Required:** J. R. Taylor 'An Introduction to Error Analysis' second edition, ISBN 0-935702-42-3

Topics by week

1. Concept of distributions with examples of discrete and continuous distributions, normalized and un-normalized distributions, moments of distributions with emphasis on first and second moments especially variance. Use of standard deviation in reporting uncertainty of measurements. Use of fractional uncertainties and introduction to combining uncertainties.
2. Random and systematic uncertainties and more on standard deviations and standard deviation of the mean. Introduce the Gaussian distribution and discuss its importance and widespread use by discussing the central limit theorem (assign problem to do an empirical proof of central limit theorem by generation values from a uniform distribution, calculating mean of each distribution and mean of the means and plotting the obtained distribution of means.
3. Continue Gaussian distribution and go through mean, mode and most probable value emphasizing symmetry about mean. Go through probability of falling with in n-sigma of mean.. Introduce concept of joint probability and show that most probable value of Gaussian is the mean.

4. More on combining uncertainties and develop the general case for parameter that is function of many uncorrelated variables. Discuss presenting results in terms of number of standard deviations away from previous measurements. Begin linear regression following Taylor's development.
5. Linear regression continued. Solution of equations to yield the slop and intercept and respective uncertainties. Chi square distribution and Chi square probability. Do a simple fit to a set of data.
6. More examples of fits to data. Begin binomial distribution and give examples.
7. Show that in for large number of trials the binomial distribution goes to the Poisson distribution and discuss applications fo Poisson distribution to counting experiments with examples.
8. Review of the three distributions and summary of major items to take from this course.
9. No lecture **holiday.**
10. Assign take home final
11. Distribute course evaluation forms