Physics 650, Section 75 – Spring Semester 2017
Research Methods in Physics & Astronomy

Instructors

This course is being taught sequentially this semester by three faculty members of the Department of Physics & Astronomy –

Professor John Kielkopf
Natural Science Building LL06
University Email: kielkopf@louisville.edu
Google Mail: jkielkopf@gmail.com
Telephone: 502.852.5990

Assistant Professor Byron Freelon
Natural Science Building 211
Email: bkfree02@louisville.edu
Telephone: 502.852.0912

Assistant Professor Swagato Banerjee
Natural Science Building 210
Email: swagato.banerjee@louisville.edu
Telephone: 502.852.0915

Where and When

The class will meet Tuesday and Thursday from 5:30 to 6:45 PM in Natural Science 312, in the TEAL facility, Natural Science 134.

Objectives

This course is a survey of research methodologies that in this term are drawn primarily from computing and data analysis, and are broadly applicable for graduate students who are engaged in doctoral level research. With the objective of providing useful tools and a perspective on how advanced scientific research is conducted, we will cover three topics this semester:

1. Essentials of Python, Javascript, and HTML5 with WebGL (Kielkopf)
2. Advanced topics in Python (Freelon)
3. ROOT, a language for data mining and machine learning (Banerjee)

This is a required course for students in the doctoral program in Physics & Astronomy.

Requirements

Students should be enrolled in the graduate program in Physics & Astronomy or have comparable experience.

You are expected to

1. Attend and participate in all classes
2. Study the in-class and on-line material for the topics
3. Respond in a timely way to homework assignments

Blackboard and other websites

The gateway for this course is the University's Blackboard system,

`http://blackboard.louisville.edu/`

which offers access to announcements and to grades. Your University *User ID* and *Password* are required to log into Blackboard.

An instructional site for the section on Python with other useful links is

`http://prancer.physics.louisville.edu/classes/650/`

There may be other websites used in this class to support the topics covered, and they will be linked on Blackboard, the class site above, and described in class meetings.

Textbooks, software, and computer access

There are no required textbooks. They will be material offered in class and on the websites.

The TEAL classroom has computing facilities at the desk that we may use during class. You will also need access to a computer connected to the Internet on which you can load and run software. Most laptop computers running OSX, Windows, or Linux will fill this need. Current tablet computers may not, because of operating system limitations. For those who prefer desktop access, the department's computing resources are available, including consoles in the astronomy lab, the computational physics cluster, and graduate student labs and offices. We do not require proprietary software, but we may ask that you install Open Source or free software.

Topic 1 – Essential Python, Javascript, and WebGL – Kielkopf

In this topic we will introduce you to writing your own programs using Python with examples drawn from astronomy, astrophysics, and optics. We will discuss the merits (and pitfalls) of programming in contrast to using commercial or community-based programs, and compare commonly used languages and tools. Python was chosen because it is free, flexible, and now widely used in physics, astronomy, space science, and engineering. We will use the time available to help you develop core skills that you can turn to in your own research.

Prior experience with programming is not required, but the skills developed here may be useful if you want to explore other languages or programming systems. We will also introduce Javascript, the browser-based programming language that is extremely powerful for graphic user applications and for website development. Javascript provides an introduction to graphical language programming, and to graphical processing unit (GPU) computing. Each student will have an individual culminating project in Python or Javascript relevant to their research interests that they develop and present to the class during the last week of this topical period.

Topic 2 – Advanced topics in Python – Freelon

The goal of this section of the course is to further familiarize participants with Python as a tool for data analysis, data handling and code extension. Physical and graphical user interfaces will be covered. Students will be exposed to Python's features for implementation with 3rd generation programming languages (3GPL) and understand why this is attractive. Learners will appreciate why Python adoption continues to rapidly grow [20+ years after its genesis] among physical and data scientists. It is expected that students will understand various deployment strategies for the major Python distributions, have a rough sense of how Python packages are created, be cognizant of packages available for Python development and be aware of tools that convert code from 3GPL to Python and *vice versa* . Python has many implementation strategies; the course will include a discussion of how Python can be utilized with other programming languages and popular scientific data analysis packages. This will cover, if time allows, discussions of important non-Python data analysis tools, new computation-specific languages and new 4th generation programming languages (all of which can be coupled to Python). Simple Python projects will be expected of class participants. Most projects will be delivered as group work with some oral component. Projects will be assigned from the following areas: a) file and data handling (b) numerical computation and (c) simple visualization or interfacing.

Topic 3 – ROOT, a language for data mining – Banerjee

The last topic of the course will be an introduction to ROOT and its use in data analysis. ROOT is a modular scientific software framework, available for free usage from `https://root.cern.ch`. It provides all the functionalities needed to deal with big data processing, statistical analysis, visualisation and storage. It is mainly written in C++ but integrated with other languages such as Python and R. Makefiles provide powerful methods for standalone compilation using ROOT libraries in UNIX-like platforms. We will learn graphical methods to visualize data with multi-variate atributes, and machine learning techniques for signal over background separation. The principle of maximum likelihood ratio can be demonstrated as basis of all modern artificial neural network classifiers. It is imperative that students demonstrate that their projects actually work during the oral presentation at the end of the semester.

Grades

This is a Pass/Fail course and it will be graded as an average of the 3 grades for each topic, assigned by the faculty teaching that topic.

Caveats

We reserve the right to make changes in the syllabus when necessary to meet learning objectives, or when there is a technical or software issue that requires a change in content or methodology. Any changes will be announced in class, by email, and posted in the current on-line syllabus and schedule.

Syllabus version of December 23, 2016

Schedule and Content

Python and Javascript Programming

10 January and 12 January Simple Python.
Data types, lists, tables, and statements

17 January and 19 January Assignments, flow control and functions

24 January and 26 January Scientific computing with Numpy and Scipy,
Fourier Transforms, and simple graphics

31 January and 2 February HTML5, Javascript, and Three.js

7 February and 9 February Student projects.

Advanced Python

14 February and 16 February

21 February and 23 February

28 February and 2 March

3 March and 5 March

7 March and 9 March

14 March and 16 March *Spring break*

ROOT and data mining

21 March to 23 March ROOT: Introduction and Graphs

28 March to 30 March Histograms and Ntuples

4 April to 6 April Standalone Makefiles

11 April to 13 April Multi-variate discriminators

18 April to 20 April Student Projects

Class schedule version of December 23, 2016 May be subject to change to meet the learning objectives.

Title IX/Clery Act Notification

Sexual misconduct (including sexual harassment, sexual assault, and any other nonconsensual behavior of a sexual nature) and sex discrimination violate University policies. Students experiencing such behavior may obtain confidential support fromthe PEACC Program (502.852.2663), Counseling Center (502.852.6585), and Campus Health Services (502.852.6479). To report sexual misconduct or sex discrimination, contact the Dean of Students (502-852-5787) or University of Louisville Police (502.852.6111).

Disclosure to University faculty or instructors of sexual misconduct, domestic violence, dating violence, or sex discrimination occurring on campus, in a University-sponsored program, or involving a campus visitor or University student or employee (whether current or former) is not confidential under Title IX. Faculty and instructors must forward such reports, including names and circumstances, to the University's Title IX officer.

For more information, see the Sexual Misconduct Resource Guide here `http://louisville.edu/hr/employeerelations/sexual-misconduct-brochure`.