# PHY 6750: Applied Computational Methods

Course Syllabus: **Fall 2019**

**Instructor: Prof. Alex Matos Abiague**
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**Meeting times**
MW, 10:30 am - 11:55 pm

**Office Hours**
MW 12:25 pm – 1.25 pm. If you can't make it during regular office hours, please feel free to email me to schedule an appointment at some other day/time.

**Course Synopsis**
This course will cover mathematical and computer applications to Physics, Biology, and other related sciences. Students will learn a variety of numerical techniques and computational methods and will employ them to model and solve interesting problems.
Many thanks to Prof. Peter Hoffmann and Prof. Christopher V. Kelly, who respectively assembled and modified much of the course content. Further course adjustments have been made by your instructor.

**Learning Objectives**
By the end of the course students will be able to:

1. Demonstrate a conceptual understanding of computer programming
2. Use Python programming to solve scientific problems and visualize the results
3. Demonstrate the capability to learn new programming skills through independent use of help menus and online resources
4. Develop computer models and simulations of real-world processes and physical systems
5. Interpret and present the results generated by computer models

**Recommended Texts**
*A Student's Guide to Python for Physical Modeling* (PPM), by Jesse M. Kinder & Philip Nelson
https://press.princeton.edu/titles/11349.html
Note that this book is NOT required. You will be able to find all the help you need with online resources. However, you may find convenient to have a textbook with the basics. If this is your case, this book is a fine one.

**Online Resources**
Canvas: https://canvas.wayne.edu/
Online tutorials: www.learnpython.org/; www.datacamp.com; www.tutorialspoint.com/python/ ; etc.
Software: https://www.anaconda.com/download/ (Python, Spyder, Jupyter)

**Software**
We will use Python throughout the course. All software is available to you in the Physics Computer Lab (377 Physics) from 8:30 am to 5 pm on work days via a key from the Physics Department office. Python is free and you can easily install it in your own computer if you would like to practice at home.

**Pre-requisites**
PHY 3750 and PHY 3700, or consent of the instructor.

**Add/Drop Dates**
Please, refer to WSU's Academic and Registration Calendar (http://reg.wayne.edu/students) for the University add and drop dates. Note: Failing to drop a class by a deadline may hurt your GPA, financial aid status, and/or your tuition bill.

**Exams**
There will be no exams in this course. Projects and presentations represent the largest contribution to the final grade.

**Homework Assignments**
Homework will be assigned and submitted every week. It will usually require the writing and submission of working Python code. Code should be properly commented and submitted as an easy-to-read HTML or PDF file that shows all your computations completed successfully. In addition, there will be reading assignments and short at-home quizzes to complete in Canvas.
Students are encouraged to work together on the homework via small study groups. However, each student is required to write their own code and answers without copying or plagiarizing others. Any copying or plagiarizing will be considered cheating, resulting in no credit and, possibly, university-level disciplinary actions (https://doso.wayne.edu/pdf/student-code-of-conduct.pdf). Your homework and project submissions may be checked for plagiarism with SafeAssign.

**Type of Class Activities**
There will be three types of class activities: Exercises, Projects, and Final Project

- **Exercises**: Are composed of a series of tasks designed to learn and practice programming skills. Each Exercise-type week students will complete the tasks in class and submit their solutions (as explained in Homework Assignments).
- **Projects**: Projects challenge students to develop a computational model of a scientific problem, program the model, and interpret the results. Students will work on projects during class and in extra-time, if needed. Students should submit their solutions as explained in Homework Assignments. Before the beginning of each project there will be a related reading assignment and a short in-class quiz to evaluate student readiness.
- **Final Project**: All students will be required to participate in a final project and present it to the rest of the class. Students will work on the final project individually or in a small group of no more than 3 students. Students are encouraged to propose their own topics for their final projects. However, each project must require a sophisticated use of Python to achieve something that would be nearly impossible to do without computer programming.

**Grading**
The course grade has the following components:

- **Quizzes & Reading Assignments: 10%** - Short quizzes on topics covered in class and reading materials for project preparation.
- **Exercises: 20%**
- **Projects: 40%** - Grade based on completion and ability to explain project details
- **Final Project: 30%** - Grade based on project completion, final presentation, and ability to answer detailed questions about the project

The course grade will be assigned according to the total number of percentage points with the following cutoffs:

| A | A- | B+ | B | B- | C+ | C | C- | D+ | D | D- | F |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 90 | 86 | 82 | 78 | 74 | 70 | 66 | 62 | 58 | 54 | 50 | < 50 |

**Undergraduate vs. Graduate Students**

University regulations require that course work and grading be independent for undergraduate and graduate students. Graduate students will complete exercises, homework, and projects that require a higher proficiency in Mathematics and Physics. As there are no grades lower than C for graduate students, graduate students will receive a fail grade if they garner less than 66% of the total score of the course

**Policy on Missed Work**

There will be no make-up quizzes. We will drop the lowest quiz grade from the grade calculations. The same applies to exercises and projects, except the final project and its presentation. The final project and its presentation are mandatory for the course and failing to complete them will result in a fail grade for the course.

**Incompletes**

The mark of 'I' for Incomplete is given to either an undergraduate or a graduate student when he/she has not completed all of the course work as planned for the term and when there is, in the judgment of the instructor, a reasonable probability that the student can complete the course successfully without again attending regular class sessions. A grade of incomplete 'I' will be given only in exceptional cases (to accommodate illness or emergency) after consultation with the instructor **before** the end of term. The student should be passing at the time the grade of 'I' is given. A written contract specifying the work to be completed should be signed by the student and instructor. Responsibility for completing all course work rests with the student (see WSU Undergraduate Bulletin).

**Student Disability Services**

If you have a documented disability that requires accommodations, you will need to register with Student Disability Services for coordination of your academic accommodations. The Student Disability Services (SDS) office is located at 1600 David Adamany Undergraduate Library in the Student Academic Success Services department. The SDS telephone number is 313-577-1851 or 313-202-4216 for videophone use. Once you have met with your disability specialist, I will be glad to meet with you privately during my office hours to discuss your accommodations. Student Disability Services' mission is to assist the university in creating an accessible community where students with disabilities have an equal opportunity to fully participate in their educational experience at Wayne State University. You can learn more about the disability office at www.studentdisability.wayne.edu.

To register with Student Disability Services, complete the online registration form at:
https://wayne-accommodate.symplicity.com/public_accommodation/

**Syllabus Modifications**

I will be trying a number of teaching techniques throughout this semester. As I learn what is working and what is not, I will be modifying the policies of this course. The schedule and topics of projects may also be modified if needed. Hence, this syllabus is a dynamic document that may be updated as the semester progresses.

**Academic Misconduct**

Academic misbehavior means any activity that tends to compromise the academic integrity of the institution or subvert the education process. All forms of academic misbehavior are prohibited at WSU, as outlined in the Student Code of Conduct (https://doso.wayne.edu/pdf/student-code-of-conduct.pdf). Students who commit or assist in committing dishonest acts are subject to downgrading (to a failing grade for the test, paper, or other course-related activity in question, or for the entire course) and/or additional sanctions as described in the Student Code of Conduct. Cheating: Intentionally using or attempting to use, or intentionally providing or attempting to provide, unauthorized materials, information or assistance in any academic exercise. Examples include: (a) copying from another student's test paper; (b) allowing another student to copy from a test paper; (c) using unauthorized material such as a "cheat sheet" during an exam. (d) unauthorized access to a test from a previous semester also constitutes cheating. Fabrication: Intentional and unauthorized falsification of any information or citation. Examples include: (a) citation of information not taken from the source indicated; (b) listing sources in a bibliography not used in a research paper. Plagiarism: To take and use another's words or ideas as one's own. Examples include: (a) failure to use appropriate referencing when using the words or ideas of other persons. (b) altering the language, paraphrasing, omitting, rearranging, or forming new combinations of words in an attempt to make the thoughts of another appear as your own. Other forms of academic misbehavior include, but are not limited to: (a) unauthorized use of resources, or any attempt to limit another student's access to educational resources, or any attempt to alter equipment so as to lead to an incorrect answer for subsequent users; (b) enlisting the assistance of a substitute in the taking of examinations; (c) violating course rules as defined in the course syllabus or other written information provided to the student; (d) selling, buying or stealing all or part of an un-administered test or answers to the test; (e) changing or altering a grade on a test or other academic grade records.

**WSU Resources for Students**

- Student Disability Services (SDS) http://studentdisability.wayne.edu/
- Academic Success Center http://www.success.wayne.edu/
- Counseling and Psychological Services (CAPS) http://www.caps.wayne.edu
- Dean of Students' Office http://www.doso.wayne.edu
- College of Liberal Arts & Sciences: https://clas.wayne.edu/students
- Departmental Website: http://physics.clas.wayne.edu//

## Class Schedule & Projects

(It may be adjusted as needed throughout the semester)

- Project 1: Fractals
- Project 2: Roots Finder
- Project 3: Interpolation & Derivatives
- Project 4: Curve Fitting & Systems of Linear Equations
- Project 5: Numerical Integration
- Project 6: Monte Carlo Simulations
- Project 7: Solving Differential Equations

**Note:** This is a preliminary list of possible projects. If needed, the topics of the projects will be readjusted.

| Date | Class Activity |
|---|---|
| W 08/28 | Course ABC, Spyder & Jupyter: Exercise 1 |
| M 09/02 | NO CLASS (Labor Day) |
| W 09/04 | Exercise 2 |
| M 09/9 | Exercise 3 |
| W 09/11 | Exercise 4 |
| M 09/16 | Project 1 |
| W 09/18 | Project 1 |
| M 09/23 | Project 2 + Grading of Project 1 |
| W 09/25 | Project 2 |
| M 10/30 | Project 3 |
| W 10/02 | Project 3 + Grading of Project 2 |
| M 10/07 | Project 4 |
| W 10/9 | Project 4 + Grading of Project 3 |
| M 10/14 | Project 5 |
| W 10/16 | Project 5 + Grading of Project 4 |
| M 10/21 | Exercise 5 |
| W 10/23 | Exercise 6 + Grading of Project 5 |
| M 10/28 | Project 6 |
| W 10/30 | Project 6 + Grading of Project 5 |
| M 11/04 | Exercise 7 |
| W 11/06 | Exercise 8 + Grading of Project 6 |
| M 11/11 | Project 7 |
| W 11/13 | Project 7 |
| M 11/18 | Exercise 9 |
| W 11/20 | Exercise 10 |
| M 11/25 | Final Project Proposals |
| W 11/27 | NO CLASS (Holiday) |
| M 12/02 | Work on Final Project |
| W 12/04 | Work on Final Project |
| M 12/09 | Presentation of Final Project I |
| W 12/11 | Presentation of Final Project II |

# PHY 6750 Learning Outcomes

Week 1- (August 28 only):

- Use the Python environment, including Spyder and Jupyter
- Save Python notebooks as html
- Perform calculations in Python

Week 2 - (September 4 only):

- Define, manipulate and use data sequence structures, such as lists, arrays and strings
- Load and use Python modules, such as numpy and matplotlib

Week 3 - (September 9, 11):

- Work with lists, arrays, strings, and dictionaries
- Write simple programs in Python
- Define functions in python
- Create 2D data plots

Week 4 - (September 16, 18):

- Use programming structures such as loops and conditionals
- Plan a programming task and subdivide into modules, subroutines or functions
- Write multipart programs with submodules
- Calculate with complex numbers
- Use multiple decision trees
- Create mathematically defined drawings
- Define fractals and calculate the fractal dimension of an object

Week 5 - (September 23, 25):

- Read and write data in Python
- Calculate roots of nonlinear functions by a variety of methods
- Explain advantages and disadvantages of different root finding methods
- Define functions recursively

Week 6 - (September 30, October 2):

- Interpolate data
- Calculate the $1^{st}$ and $2^{nd}$ derivative of data
- Estimate errors and use strategies to minimize errors in calculations
- Use Euler′s method to solve simple $1^{st}$ order differential equations

Week 7 - (October 7, 9):

- Perform matrix calculations
- Perform linear curve fitting
- Convert nonlinear equations into linear ones (if possible) to perform curve fitting
- Solve systems of linear equations
- Perform nonlinear curve fitting

Week 8 - (October 14, 16):

- Perform 1D numerical integration
- Estimate integration errors and employ methods to reduce errors
- Calculate multidimensional integration and articulate possible limits in terms of computing time

Week 9 - (October 21, 23):

- Define and manipulate statistical distributions, including uniform, normal, binomial and Poisson distributions.
- Calculate random numbers taken from different statistical distributions

Week 10 – (October 28, 30):

- Perform Monte Carlo integration
- Write a program to simulate a random walk
- Write a simple Monte Carlo simulation

Week 11 – (November 4, 6):

- Solve 1$^{st}$ order differential equations
- Build different kinds of plots (bar graphs, surface plots, density plots, 2D histograms, and 3D plots) to represent calculated and imported numerical data

Week 12 - (November 11, 13):

- Solve 2$^{nd}$ order ordinary differential equations
- Estimate integration errors and employ different integration methods to reduce error
- Discuss the need to use the correct integration method when calculating physical systems to maintain energy conservation

Week 13 - (November 18, 20):

- Creating mathematical animations
- Exporting animations as MP4 video and animated GIF files
- Perform image analysis and manipulation, including image filtering, rotation and Fourier analysis

Week 14 - (November 25 only):

- Formulation of final projects

Week 15 - (December 2, 4):

- Work on final projects

Week 16 - (December 9, 11):

- Final project presentations