Physics 3181 — Spring 2018

Computational Physics

Physics 3181 Lectures: Mon/Wed 2:20-3:35 pm, Corcoran Hall, Room 413
Instructor: Prof. Oleg Kargaltsev
Office: Corcoran Hall 407; Office hours: Monday 4-5 pm, or by appointment
Email: kargaltsev@gwu.edu

Prerequisites: MATH 2233 and PHYS 3161, programming experience

Short description: The purpose of this course is to *discuss and practice* a number of numerical methods that are useful in solving Physics, Astrophysics, and Applied Mathematics problems. The course will cover a good fraction of methods that are frequently encountered in these fields. These methods are well established and have a solid theoretical foundation. Our focus will be less on the theoretical underpinnings and more on *practical use of these methods to solve concrete problems*.

Details: The course is project driven and a new topic will be discussed every week. To help you understand the material and to provide an assessment of your progress, you will have to solve a homework each week. The homework will be motivated by physics problems and to solve then you will rely on the numerical methods covered in class. Required physics background will be reviewed in class.

The programming tools we plan to use in this course are *C and Wolfram Mathematica*. We will use C to practice low-level programming and solve some basic computational problems. Mathematica will be used for higher-level problems, to assist with debugging the codes and verifying C-code results, to further analyze and visualize the results of computations, to create plots and animations, etc. For each homework set, you will be asked to submit the documented code and, in some cases, write a report (preferably in Latex, a tool that will allow you to typeset equations, include graphs to support your presentation, and create a bibliography). An effective workflow depends on your ability to use these tools. Although some introduction will be provided, this course is not meant to teach you programming language or Latex, so you will need to work on it outside the class. Students must bring their own laptops and configure them appropriately. The use of Unix (the one in Mac OS or other flavor) is preferred (your instructor will have laptop with Mac OS).

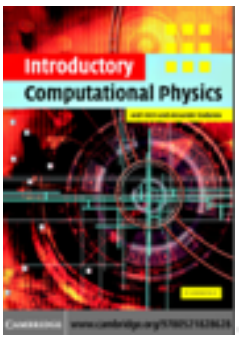
Learning Outcomes: Upon completion of this course you will be able to write programs in C and Mathematica and apply programming skills in conjunction with the laws of physics to solve a wide range of physics and astrophysics problems .

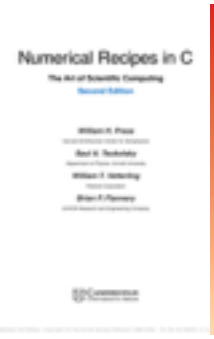
Students will acquire the following *specific skills* that will be verified via specially designed, graded homework assignments:

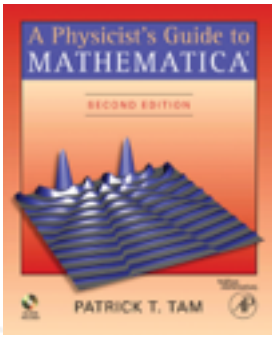
- Numerical Integration
- Integration of differential equations
- Optimization
- Hypothesis testing and fitting

- Chaos/N-body dynamics
- Machine Learning
- Monte Carlo methods
- Root finding
- Fourier transforms

Textbook: No textbook is required. If you still want to have one, I can recommend:







Klein, Cambridge University Press 2006, "Introductory Computational Physics"

Tam, Cambridge University Press 2006 "A Physicist's Guide to Mathematica"

Numerical Recipes in C available free at http://www.nrbook.com/a/bookcpdf.html

The notes and printouts will be provided by the instructor as needed. They will be accessible in GW Blackboard.

Assignments: Coding homework projects will be posted regularly at the class web site on Blackboard http://blackboard.gwu.edu. Homework must be turned in as a printed report. The report must contain statement of the problem, algorithm/method description, code, results of calculations in numerical and/or graphical form, physical interpretation of the results by student. The assignments will be graded by the instructor using rubric assessment for each of these components. Assignments may also require turning is a documented code in C or Mathematica (uploaded to Blackboard or sent by e-mail). Students must visit the class Blackboard site regularly.

Expected Time Investment: Over 14 weeks students will spend 3 hours per week in classroom activities (lectures, quizzes, problem-solving and programming projects). Minimum amount of independent, out-of-class, learning expected per week is 8 hrs.

Outline of the course for Spring 2018

Week	Dates	Topic
1	Jan 17	Introduction and setup. Basics of programming (in C).
2	Jan 22,24	Basics of Mathematica. Graphing in Mathematica. Data visualization. Intro to statistics. Predator and prey problem.

Week	Dates	Topic
3	Jan 29,31	Roots of nonlinear equations. Interpolation, cross-correlation, numerical derivative. KS-test. Sums. Multiple collision accelerator. Resistor networks.
4	Feb 5,7	Numerical integration. Random number generation.
5	Feb 12,14	Ordinary differential equations I. Euler method and advanced difference schemes for ODEs. Nonlinear pendulum. Intro to Chaos. Motion in central field.
6	Feb 21	Ordinary differential equations II. Boundary value problems for ODEs. Linear algebra. Quantum particle in a box.
7	Feb 26,28	Basics of fitting and minimization. Chi-square fitting (X-ray spectrum example).
8	Mar 5,7	Bootstrap and Monte Carlo methods. Applications to fitting and image analysis. Mid semester review.
9	Mar 12,14	**Spring break!**
Spring break	Mar 19,21	N-body simulations (star cluster, gas dynamics). Increasing computational efficiency and power. High-performance computing.
10	Mar 26, 28	TBD
11	Apr 2, 4	Unsupervised Machine Learning. Clustering (k-NN algorithm and its relatives)
12	Apr 9,11	Supervised Machine Learning. Information Gain. Entropy. Decision Trees.
13	Apr 16,18	Review. Time variable signals. Detecting variability.
14	Apr 23,25	Periodicity detection and search for periodic signal. Fourier and its applications to signal processing.
15	Apr 30	Data visualization.
16	May 2	Term project presentations

Attendance: The students are *expected to attend every class*. If you have to miss >2 classes, you should discuss this with the instructor. Note that if you miss a class, your grade for the in-class quiz/participation will be zero. All requests to have an absence excused must be substantiated with appropriate documentation. Valid excuses include personal illness (with a doctor's note), family emergency, GW sanctioned travel for a team sport, or religious holiday.

Course Grade: The final grade will be based on the homework (50%), term project (20%), and attendance, in-class participation, and quizzes (30%). There is no final exam in this course.

ONLINE RESOURCES

The course webpage will be on Blackboard (http://blackboard.gwu.edu/). Course announcements will be posted on this site. Any distributed reading materials and any PowerPoint slides shown in class will be made available online *after* each class. After entering *Blackboard*, it is necessary for you to click on the course name (PHYS 3181). You are *automatically* subscribed within the *Blackboard* system to the courses for which you are registered (but you also must have a valid GW e-mail address to login).

University Policies

Academic Integrity:

Any acts of academic dishonesty will be dealt with according to the GW Code of Academic Integrity. Cheating compromises the integrity of our course and is unfair to those students who earn their grade through honest hard work. We have a zero-tolerance policy regarding cheating. For the full Academic Integrity code, see: https://studentconduct.gwu.edu/code-academic-integrity

Accommodations for Students with Disabilities:

Any student who feels that an accommodation may be needed based on the impact of a disability should contact the instructor privately to discuss specific needs. Please also contact the Disability Support Services office at 202-994-8250 in Rome Hall, Suite 102, to establish eligibility and to coordinate reasonable accommodations. For additional information, refer to: https://disabilitysupport.gwu.edu/.

Mental Health Services (202-994-5300):

The University's Mental Health Services offers 24/7 assistance and referral to address students' personal, social, career, and study skills problems. Services for students include: crisis and emergency mental health consultations confidential assessment, counseling services (individual and small group), and referrals.

counselingcenter.gwu.edu/

University Policy on Religious Holidays:

1. Students should notify faculty during the first week of the semester of their intention to be absent from class on their day(s) of religious observance.

2. Faculty should extend to these students the courtesy of absence without penalty on such occasions, including permission to make up examinations.

3. Faculty who intend to observe a religious holiday should arrange at the beginning of the semester to reschedule missed classes or to make other provisions for their course-related activities.

The full University policy regarding religious holidays can be found at https://provost.gwu.edu/files/downloads/Resources/Religious-Holiday-Calendar-2015-2016.pdf

Classroom Emergency Preparedness and Response Information

To Report an Emergency or Suspicious Activity
Call the University Police Department at 202-994-6111 (Foggy Bottom) or 202-242-6111 (Mount Vernon). If the line is unavailable or you are calling from another University location, dial 911.

Shelter in Place – General Guidance
Although it is unlikely that we will ever need to shelter in place, it is helpful to know what to do just in case. No matter where you are on campus, the basic steps of shelter in place will generally remain the same:

* If you are inside, stay where you are unless the building you are in is affected. If it is affected, you should evacuate. If you are outdoors, proceed into the closest GW building or follow instructions from emergency personnel on scene.
* Shelter-in-place in an interior room, above ground level, and with the fewest windows. If sheltering in a room with windows, keep away from the windows. If there is a large group of people inside a particular building, several rooms maybe necessary.
* Shut and lock all windows (locking will form a tighter seal) and close exterior doors.
* Turn off air conditioners, heaters, and fans. Close vents to ventilation systems as you are able. (Facilities staff will turn off ventilation systems as quickly as possible).
* Make a list of the people with you and call the list in to UPD so they know where you are sheltering.
* Visit GW Campus Advisories for incident updates http://campusadvisories.gwu.edu or call the GW Information Line 202-994-5050. If possible, turn on a radio or television and listen for further instructions. If your e-mail address or mobile device is registered with Alert DC, check for alert notifications.
* Be comfortable and look after one other. You will get word as soon as it is safe to come out.

An **evacuation** will be considered if the building we are in is affected or we must move to a location of greater safety. We will always evacuate if the fire alarm sounds. In the event of an evacuation, please gather your personal

belongings quickly (purse, keys, cell phone, GWorld card, etc.) and proceed to one of the nearest exits. Do not use the elevator. Once we have evacuated the building, proceed to meet in front of the building.

Alert DC provides free notification by e-mail or text message during an emergency. Visit GW Campus Advisories for a link and instructions on how to sign up for alerts pertaining to GW. If you receive an Alert DC notification during class, please share the information immediately.

GW Alert provides popup notification to desktop and laptop computers during an emergency. In the event that we receive an alert to the computer in our classroom, we will follow the instructions given. You are also encouraged to download this application to your personal computer. Visit GW Campus Advisories to learn how.

Additional information about emergency preparedness and response at GW as well as the University's operating status can be found on GW Campus Advisories http://campusadvisories.gwu.edu or by calling the GW Information Line at 202-994-5050.