Term Information

Effective Term	Spring 2024
Previous Value	*Summer 2012*

Course Change Information

What change is being proposed? (If more than one, what changes are being proposed?)

1. Change to prerequisites

2. Course number

What is the rationale for the proposed change(s)?

1. We want to add an introductory programming course as a prerequisite to make sure students have the introductory programming knowledge necessary for the course. A programming course is already required for the major (and is a prerequisite for Physics 3700, a required course), so this won't add a burden to our students. We also want to reduce the physics prerequisite from Physics 5501 (Quantum Mechanics II) to Physics 5500 (Quantum Mechanics I) for two reason: One - because Physics 5501 is not a required course and fewer than half of our students take it. And two - because this will allow students to take Physics 6810/5810 during spring of their junior year instead of only having the option to take it spring of senior year.

2. I've attached a separate document that discusses the rationale for changing the course number.

What are the programmatic implications of the proposed change(s)?

(e.g. program requirements to be added or removed, changes to be made in available resources, effect on other programs that use the course)?

More flexibility with scheduling. Additionally, these changes will allow us to move forward with creating a computational physics certificate.

Is approval of the requrest contingent upon the approval of other course or curricular program request? No

Is this a request to withdraw the course? No

General Information

Course Bulletin Listing/Subject Area	Physics
Fiscal Unit/Academic Org	Physics - D0684
College/Academic Group	Arts and Sciences
Level/Career	Graduate, Undergraduate
Previous Value	*Graduate*
Course Number/Catalog	5810
Previous Value	*6810*
Course Title	Topics in Computational Physics
Transcript Abbreviation	Computational Phys
Course Description	Experimental and theoretical aspects of areas of current interest in Computational Physics.
Semester Credit Hours/Units	Fixed: 4

Offering Information

Length Of Course	14 Week, 12 Week
Flexibly Scheduled Course	Never
Does any section of this course have a distance education component?	No
Grading Basis	Letter Grade

Repeatable	No
Course Components	Lecture
Grade Roster Component	Lecture
Credit Available by Exam	No
Admission Condition Course	No
Off Campus	Never
Campus of Offering	Columbus

Prerequisites and Exclusions

Prerequisites/Corequisites	CSE 1222, CSE 1223, CSE 1224, Astronomy 1221, Engineering 1221, or Engineering 1281H; and Physics 5500 or 5500H; or permission of instructor.
Previous Value	*Prereq: 5501 or grad standing or permission of instructor.*
Exclusions	
Electronically Enforced	Yes
Previous Value	**No**

Cross-Listings

Cross-Listings

Subject/CIP Code

Subject/CIP Code	40.0899
Subsidy Level	Doctoral Course
Intended Rank	Junior, Senior, Masters, Doctoral
Previous Value	*Senior, Masters, Doctoral*

Requirement/Elective Designation

The course is an elective (for this or other units) or is a service course for other units

Course Details

Course goals or learning objectives/outcomes

- Write correct, clear, and well-documented computer code.
- Know some of the tools (algorithms) of computational Physics.
- Understand the limitations of computational solutions to Physics problems.
- Understand where computational solutions to Physics problems are better than analytical solutions.
- Have a better understanding of Physics through having to put Physics concepts into code.
- Have a better understanding of Physics through playing with numerical solutions to Physics problems.

Previous Value

Content Topic List

- Unix environment and how to write a computer program
- Rounding errors in floating point arithmetic
- Using scientific computing libraries
- Numerical differentiation and integration
- Parallel processing
- Solving Linear algebra, differential equations, and quantum mechanics problems with programming
- Oscillations, pendulums, and chaos
- Debugging, optimizing, and profiling
- Random numbers and Monte Carlo methods
- Ising model

Previous Value

- *Computational Physics: Topics to be announced each semester*

Sought Concurrence

No

Attachments

- physics6810syllabus.pdf: Physics 6810 Syllabus (for comparison)

  (Syllabus. Owner: Thaler,Lindsey Nicole)
- Request.pdf: Explanation for course request

  (Cover Letter. Owner: Thaler,Lindsey Nicole)
- Sample_Plan.pdf: Sample Academic Plan

  (Other Supporting Documentation. Owner: Thaler,Lindsey Nicole)
- Curriculum_Map.pdf: Curriculum Map

  (Other Supporting Documentation. Owner: Thaler,Lindsey Nicole)
- Phy5810Syllabus_V2.pdf

  (Syllabus. Owner: Thaler,Lindsey Nicole)
- Physics6810FinalProjectRubric (1).pdf

  (Other Supporting Documentation. Owner: Thaler,Lindsey Nicole)
- Physics6810Modules.pdf

  (Other Supporting Documentation. Owner: Thaler,Lindsey Nicole)
- Response_to_Feedback.pdf

  (Other Supporting Documentation. Owner: Thaler,Lindsey Nicole)

Comments

- We've attached a syllabus that has been updated in response to the panel's feedback. We've also attached a grading rubric for the final project, a screenshot of the Carmen Module page, and responses to the feedback that was not addressed in the updated syllabus. Thank you. *(by Thaler,Lindsey Nicole on 02/13/2023 07:53 AM)*
- Please see Panel feedback e-mail sent 09/20/22. *(by Cody,Emily Kathryn on 09/20/2022 02:08 PM)*
- A curriculum map has been requested, so we request to put this on hold until we generate one. *(by Humanic,Thomas John on 05/10/2022 09:31 AM)*
- If this course will count in your major, could you please provide an updated curriculum map indicating which major goal(s) are fulfilled by this class and at what level? *(by Vankeerbergen,Bernadette Chantal on 03/21/2022 04:24 PM)*

Workflow Information

Status	User(s)	Date/Time	Step
Submitted	Thaler,Lindsey Nicole	03/10/2022 11:52 AM	Submitted for Approval
Approved	Humanic,Thomas John	03/10/2022 01:46 PM	Unit Approval
Revision Requested	Vankeerbergen,Bernadette Chantal	03/21/2022 04:25 PM	College Approval
Submitted	Humanic,Thomas John	03/21/2022 04:35 PM	Submitted for Approval
Revision Requested	Humanic,Thomas John	05/10/2022 09:31 AM	Unit Approval
Submitted	Thaler,Lindsey Nicole	06/06/2022 11:00 AM	Submitted for Approval
Approved	Humanic,Thomas John	06/06/2022 11:34 AM	Unit Approval
Approved	Vankeerbergen,Bernadette Chantal	08/31/2022 12:52 PM	College Approval
Revision Requested	Cody,Emily Kathryn	09/20/2022 02:08 PM	ASCCAO Approval
Submitted	Thaler,Lindsey Nicole	02/13/2023 07:54 AM	Submitted for Approval
Approved	Humanic,Thomas John	02/13/2023 08:11 AM	Unit Approval
Approved	Vankeerbergen,Bernadette Chantal	02/15/2023 02:40 PM	College Approval
Pending Approval	Jenkins,Mary Ellen Bigler Hanlin,Deborah Kay Hilty,Michael Vankeerbergen,Bernadette Chantal Steele,Rachel Lea	02/15/2023 02:40 PM	ASCCAO Approval

Feedback: In the syllabus, please include a course schedule that approximates what topics the instructor anticipates covering weekly (if not daily, as applicable) so students have a stronger sense of the pacing of the class material for the term. This course schedule should also feature titles, author names, and/or links to downloads for reading assignments, as well as any important benchmarks.

Response: We've updated the syllabus to include a course schedule that also includes the timing of the homework assignments and the final project.

We respectfully disagree with the suggestion of listing and linking to all the material for each topic; this would have been appropriate before the advent of electronic learning systems, but now it would just lead to a very cluttered syllabus. This information is much better structured in Carmen; We have attached a pdf of the Carmen Modules page for the course for the committee's information.

Feedback: Also, the Panel would like clarification on how any and/or all assignments will be impacted by the fact that the course is being adjusted from a 6000-level to a 5000-level with an eye toward including prospective upper-level undergraduates, who are however perhaps less familiar with certain specialized, discipline-specific aspects of the class than their graduate student colleagues.

Response: This request is a result of a misunderstanding. This class has always been taken by about ⅔ upper-level undergraduate students and ⅓ graduate students (in fact, during registration the department often reserves some slots for graduate students in order for them to have a chance to take the class since it otherwise would be completely filled up by undergraduate students). The class has thus always been taught in a way that is accessible to upper level undergraduates. The request to renumber it from a 6000-level to a 5000-level class is simply a request to align the numbering, which was done at the incorrect level during semester conversion, with the reality of how this class is taught.

Feedback: As the Panel understands the present grading structure of the course — which members recognize was originally conceived with only graduate students in mind, when it was previously numbered at the 6000-level and thus exclusive to graduate students — it appears that an undergraduate student could, in effect, do the absolute bare minimum required for each assignment, and yet still end up with some kind of a B in the class at minimum. There are many possible solutions to address this issue of course rigor and grading in a class that enrolls both undergraduate and graduate students. One option he Panel recommends would be to create separate grading scales for undergraduate vs. graduate students, along with statements indicating the overall expectations for each group.

Response: As indicated above, it is not true that this class was conceived with only graduate students in mind or was ever exclusive to graduate students. On the contrary, this renumbering request is solely an attempt to rectify the numbering done at the wrong level at semester conversion. Yes, it is true that bare minimum submissions for every assignment would result in a B. Surprisingly, there are still Cs, Ds, and even Es every year.

This request is to renumber a course from Physics 6810 (Computational Physics) to Physics 5810.

the course was designed during the quarter to semester transition for advanced undergraduates and first year graduate students. It was wrongly assumed at the time that 6,000 was the appropriate numbering for this. We have lived with this situation for a number of years, but recently it has surfaced as a problem as we are trying to create a computational physics certificate aimed at undergraduate students. The problem is that most of the physics courses required for this certificate are taught as 6000-level courses, that we have learned are not allowed to be used in an undergraduate certificate.

Both the Physics Graduate Studies Office and the Physics Undergraduate Studies Office approve of this change.

Syllabus:
Physics 5810
Computational Physics

Spring 2023

Course Information

- **Course times:**
  Lecture: Wednesdays & Fridays 12:40-2:45pm
- **Credit hours:** 4
- **Mode of delivery:** In person

Instructor

- **Name:** Ralf Bundschuh
- **Email:** bundschuh.2@osu.edu
- **Office location:** 2064 Physics Research Building
- **Office hours:** After class and any time I am in my office

Computer Consultant

- **Name:** Terry Bradley
- **Email:** Bradley.77@osu.edu
- **Office location:** 1199 Physics Research Building

Course Prerequisites

Prerequisites: CSE 1222, CSE 1223, CSE 1224, Astronomy 1221, Engineering 1221, or Engineering 1281H; and Physics 5500 or 5500H; or permission of instructor.

It will be expected that you have some experience with one or more of: Mathematica, MATLAB, Python, C, fortran, or C++. The teaching strategy is to give you computer programs and have you run and then modify (or debug) them as you follow along through worksheets. Let me know if you are concerned about your preparation (e.g., if you have very limited experience).

Course Description

Experimental and theoretical aspects of areas of current interest in Computational Physics.

The goal of the course is to make every student comfortable in addressing physics problems using computational methods. Given that in contrast to the physics textbook's end-of-chapter problems, hardly any real life problems can be solved using pencil and paper, being comfortable using computational methods is a very important skill for every physicist. Being comfortable addressing physics problems with computers means knowing how to write good code, but also understanding the shortfalls of computational algorithms, and how to evaluate a computation's results for plausibility rather than just believing that everything that comes out of a computer must be correct. The course will address all these issues. In addition, we will hopefully also learn a bit of interesting physics that can only be addressed computationally; it is a physics course after all! Since the only way to learn computation is by doing, lecturing will be minimal and most of the class time will be spent hands on working through worksheets on the computers in the classroom (or your own).

The course will cover the following topics:

- Unix environment and how to write a computer program
- Rounding errors in floating point arithmetic
- Using scientific computing libraries
- Numerical differentiation and integration
- Solving Linear algebra, differential equations, and quantum mechanics problems with programming
- Parallel processing
- Oscillations, pendulums, and chaos
- Debugging, optimizing, and profiling
- Random numbers and Monte Carlo methods
- Ising model

Learning Outcomes

1. Write correct, clear, and well-documented computer code.
2. Know some of the tools (algorithms) of computational Physics.
3. Understand the limitations of computational solutions to Physics problems.
4. Understand where computational solutions to Physics problems are better than analytical solutions.
5. Have a better understanding of Physics through having to put Physics concepts into code.
6. Have a better understanding of Physics through playing with numerical solutions to Physics problems.

Course Schedule

The following shows the tentative activities for each week of the semester:

Week	Topics
1	Writing first programs and floating point precision More on floating point precision
2	Differentiation and Integration More derivatives, pointers, and linear algebra
3	Simple quantum mechanical systems
4	Parallel computing and differential equations Homework 1 due
5	Driven non-linear oscillations and chaos
6	More on input and output (optional - catch-up for students who need more time)
7	Damped pendulum and installing your own packages Homework 2 due
8	Debugging, profiling, and backups
9	Interpolation and more differential equations Homework 3 due
10	Fitting and Optimization
11	Fun with random numbers
12	Ising model Homework 4 due
13	More on Monte Carlo simulations
14	Simulated annealing and partial differential equations (optional - catch-up for students who need more time) Final project due

How This Course Works

Mode of delivery: This course expected to be delivered in person.

Credit hours and work expectations: This is a 4 credit-hour course. According to Ohio State bylaws on instruction (go.osu.edu/credit hours), students should expect around 4 hours per week of time spent on direct instruction in addition to 8 hours outside of class to receive a grade of [C] average.

Attendance, grading, and participation requirements:

Pre-class readings (10%)

For most class periods, you will be expected to complete a reading assignment before class. These will be announced in class and on Carmen. On days with reading assignments you have to answer some questions about the reading using the "Quizzes" feature of Carmen by 3:59am the day of class. Your answers will not be graded; the only requirement is that you submit the questionnaires on time. Your credit for this section of the course is the fraction of the reading assignment feedbacks that you have submitted on time.

Worksheets (30%)

The class sessions will only have a short lecture content at the beginning of class time. The majority of the class time will be spent working on computational problems with the instructors going around to help out and discuss findings. Ideally, two students will work together. As you are doing so, you will be filling out worksheets, which are submitted electronically at the end of every section of the course. Each student will submit their own worksheet and will be graded independently. Collaboration is actively encouraged but simply copying and pasting answers is not allowed. These worksheets will be graded using categories of outstanding (12 points), adequate (11 points), or needs improvement (10 points). We reserve the right to give 0 points for essentially empty worksheets not showing a credible effort. In addition to the grade for a worksheet, comments will be provided to indicate any shortcomings. The worksheets can be submitted for unlimited re-grading until four weeks after they were first handed out or April 26 whichever comes first. The four week due date will be announced on the worksheet and in Carmen. It is firm in order to avoid procrastination.

Problem Sets (30%)

Problem sets will be due roughly every other week. They serve to ensure a thorough understanding of the material worked on in class. Since we all have many other commitments, they will be rather limited in length. The problem sets will also be graded using the categories of outstanding (12 points), adequate (11 points), or needs improvement (10 points). As long as you hand something showing credible effort in by the due date, you are allowed to make improvements based on grading comments until four weeks after the due date or April 24, whichever comes first.

Final project (30%)

At the end of the course, you will be asked to develop a final project. The goal of the final project is for you to demonstrate that you are able to synthesize the material learned in the course. The project is scaffolded throughout the second half of the semester. On the third homework set, which is due right before spring break, you will be asked to come up with a project of your own choice.

There will be examples but you are also welcome to choose something from your own research as long as it involves computation. The fourth homework assignment consists exclusively of writing a few paragraphs to plan out the final project (there are no other homeworks during the second half of the semester to allow you time to focus on the final project). The project itself is due on the last day of class, Friday, April 22, in Carmen, and can be submitted for regrades until Thursday, April 28. It will be graded using the same categories as the in-class worksheets and the homework. A detailed rubric available on Carmen shows expectations for "outstanding", "adequate", and "needs improvement" ratings.

In order to obtain an "adequate" rating, your project needs to be at least "adequate" in all categories. Similarly, to obtain an "outstanding" rating, your project needs to reach the "outstanding" markers in all categories. How much effort this final project will be largely depends on what you choose to do with it as all the rubric categories can be fulfilled with small projects just as much as with complex and large projects. You are encouraged to discuss your projects with me as you are working on them and I will try my best to steer you toward a reasonably scoped project. The grading rubric for the final project is on Carmen.

<u>Attendance (0%)</u>
I will not specifically take attendance in this class. All worksheets are available on Carmen and are submitted there as well and thus could in principle be worked through independently outside of the classroom as well. However, the real value of this class is the interaction with your peers and the instructors. Thus you are highly advised taking optimal advantage of these interactions by attending.

<u>Late or missing submissions</u>
Late submissions of pre-class reading assignments will not be accepted. If you are sick or at a conference let me know and I will credit you the points for missed submissions of pre-class reading assignments. All other course components have two submission dates: a due date and a closing date. A first submission should be done by the due date. Repeatedly missing the due date will result in me reaching out to you to discuss time management. Submissions for regrading can be done until the closing date, which is four weeks after the due date or April 26, whichever comes first. The closing date is *firm*, i.e., no submission will be accepted beyond the closing date (zero points for the assignment if nothing or nothing showing credible effort was submitted by that time) unless there are previously approved extenuating circumstances such as long periods of illness.

Academic integrity and collaboration: Your submitted assignments should be your own original work. We do encourage students to help each other understand the material. However, the bulk of each assignment should be - unambiguously - each student's own work. Science is a collaborative field and so working together is important, but one must be careful to distinguish one's own contributions from those of others.

Course Materials, Fees and Technologies

Required Materials and/or Technologies

There is no required text to buy but there will be readings for each class session from handouts passed out in class and background notes posted online. We will supplement these with readings from the 2015 lecture notes by Morten Hjorth-Jensen from the University of Oslo. Prof. Hjorth-Jensen's course in computational physics covers similar topics. (His course web pages: FYS3150 (Links to an external site.) and FYS4411 (Links to an external site.).) These will be posted on Carmen. For a long list of other interesting books look at the "Textbooks" page in the "Useful information" Module on Carmen.

CarmenCanvas Access

You will need to use BuckeyePass (buckeyepass.osu.edu) multi-factor authentication to access your courses in Carmen. To ensure that you are able to connect to Carmen at all times, it is recommended that you do each of the following:

- Register multiple devices in case something happens to your primary device. Visit the BuckeyePass - Adding a Device (go.osu.edu/add-device) help article for step-by-step instructions.
- Request passcodes to keep as a backup authentication option. When you see the Duo login screen on your computer, click **Enter a Passcode** and then click the **Text me new codes** button that appears. This will text you ten passcodes good for 365 days that can each be used once.
- Install the Duo Mobile application (go.osu.edu/install-duo) on all of your registered devices for the ability to generate one-time codes in the event that you lose cell, data, or Wi-Fi service.

If none of these options will meet the needs of your situation, you can contact the IT Service Desk at 614-688-4357 (HELP) and IT support staff will work out a solution with you.

Technology Skills Needed for This Course

- Navigating CarmenCanvas (go.osu.edu/canvasstudent)
- CarmenZoom virtual meetings (go.osu.edu/zoom-meetings)

The bulk of the work in this class will be done within a virtual desktop environment at the Ohio Supercomputer Center (OSC). If you do not yet have an OSC account instructions will be provided on how to obtain one in the beginning of the semester. OSC accounts are available to OSU students free of charge.

In order to participate in the hands on activities in class and to work on homework and the final project you need a device that can access the OSC OnDemand portal. There are no class policies that restrict what device you use. Access to the OSC OnDemand portal is completely browser based. The official OSC guidance is to use newer versions of Chrome (87+), Firefox (87+), or Internet Explorer (11+). Tablets (such as iPads) are not officially supported by OSC OnDemand but likely work as long as they have an external keyboard. There are two desktop computers in the classroom for students who do not have access to a portable device. You will also need to use Mathematica in this class. Every OSU student has access to Mathematica licenses through OSU's site license program. Mathematica is available for newer Windows, Mac, and Linux versions. It has fairly substantial hardware requirements. However, you can also use the web version of Mathematica, which only requires a web browser and should thus run on nearly any device.

You agree to using the computational resources provided to you by this class *exclusively* for class related activities and to not make excessive use of these resources in your final project. If in doubt about your final project, please consult with me.

Technology Support

For help with your password, university email, CarmenCanvas, or any other technology issues, questions or requests, contact the IT Service Desk, which offers 24-hour support, seven days a week.

- **Self Service and Chat**: go.osu.edu/it
- **Phone:** 614-688-4357 (HELP)
- **Email:** servicedesk@osu.edu

Digital Flagship

Digital Flagship is a student success initiative aimed at helping you build digital skills for both college and career. This includes offering an engaging collection of digital tools and supportive learning experiences, university-wide opportunities to learn to code, and a Design Lab to explore digital design and app development. Digital Flagship resources available to help Ohio State students include on-demand tutorials, The Digital Flagship Handbook (your guide for all things tech-related), workshops and events, one-on-one tech consultations with a peer or Digital Flagship staff member, and more. To learn more about how Digital Flagship can help you use technology in your courses and grow your digital skills, visit go.osu.edu/dfresources.

What to do if you feel like you are falling behind

Reach out! Contact an instructor or TA, and we can help you develop strategies to help. We also strongly recommend that you form study groups--interacting with other humans helps solidify concepts. Everyone in the group brings a different perspective and skillset to the table.

Other Accommodations

If any of the class requirements as laid out in this syllabus are causing an issue for you, e.g., because you have technology issues accessing components of the class, an exam falls on one of your religious holidays, you are ill, or any other reason, please contact me as early as possible so that we can work out a solution.

Grading Scale

The grade for this class is determined by a weighted average of pre-class readings, in-class worksheets, homework assignments, and a final project. There will be no curve grading and I hope that everybody will get an A. The final grades will be determined according to the standard OSU scheme:

93–100: A
90–92.9: A-
87–89.9: B+
83–86.9: B
80–82.9: B-
77–79.9: C+
73–76.9: C
70–72.9: C-
67–69.9: D+
60–66.9: D
Below 60: E

Other Course Policies

Discussion and Communication Guidelines

The following are my expectations for how we should communicate as a class. Above all, please remember to be respectful and thoughtful.

- **Writing style**: While there is no need to participate in class discussions as if you were writing a research paper, you should remember to write using good grammar, spelling, and punctuation. A more conversational tone is fine for non-academic topics.
- **Tone and civility**: Let's maintain a supportive learning community where everyone feels safe and where people can disagree amicably. Remember that sarcasm doesn't always come across to others.

Academic Integrity Policy

See Descriptions of Major Course Assignments for specific guidelines about collaboration and academic integrity in the context of this online class.

Ohio State's Academic Integrity Policy

Academic integrity is essential to maintaining an environment that fosters excellence in teaching, research, and other educational and scholarly activities. Thus, The Ohio State University and the Committee on Academic Misconduct (COAM) expect that all students have read and understand the university's Code of Student Conduct (studentconduct.osu.edu), and that all students will complete all academic and scholarly assignments with fairness and honesty. Students must recognize that failure to follow the rules and guidelines established in the university's *Code of Student Conduct* and this syllabus may constitute "Academic Misconduct."

The Ohio State University's *Code of Student Conduct* (Section 3335-23-04) defines academic misconduct as: "Any activity that tends to compromise the academic integrity of the university or subvert the educational process." Examples of academic misconduct include (but are not limited to) plagiarism, collusion (unauthorized collaboration), copying the work of another student, and possession of unauthorized materials during an examination. Ignorance of the university's *Code of Student Conduct* is never considered an excuse for academic misconduct, so I recommend that you review the *Code of Student Conduct* and, specifically, the sections dealing with academic misconduct.

If I suspect that a student has committed academic misconduct in this course, I am obligated by university rules to report my suspicions to the Committee on Academic Misconduct. If COAM determines that you have violated the university's Code of Student Conduct (i.e., committed academic misconduct), the sanctions for the misconduct could include a failing grade in this course and suspension or dismissal from the university.
If you have any questions about the above policy or what constitutes academic misconduct in this course, please contact me.

Other sources of information on academic misconduct (integrity) to which you can refer include:

- Committee on Academic Misconduct (go.osu.edu/coam)
- Ten Suggestions for Preserving Academic Integrity (go.osu.edu/ten-suggestions)
- Eight Cardinal Rules of Academic Integrity (go.osu.edu/cardinal-rules)

Copyright for Instructional Materials

The materials used in connection with this course may be subject to copyright protection and are only for the use of students officially enrolled in the course for the educational purposes associated with the course. Copyright law must be considered before copying, retaining, or disseminating materials outside of the course.

Statement on Title IX

All students and employees at Ohio State have the right to work and learn in an environment free from harassment and discrimination based on sex or gender, and the university can arrange interim measures, provide support resources, and explain investigation options, including referral to confidential resources.

If you or someone you know has been harassed or discriminated against based on your sex or gender, including sexual harassment, sexual assault, relationship violence, stalking, or sexual exploitation, you may find information about your rights and options on Ohio State's Title IX website (titleix.osu.edu) or by contacting the Ohio State Title IX Coordinator at titleix@osu.edu. Title IX is part of the Office of Institutional Equity (OIE) at Ohio State, which responds to all bias-motivated incidents of harassment and discrimination, such as race, religion, national origin and disability. For more information, visit the OIE website (equity.osu.edu) or email equity@osu.edu.

Commitment to a Diverse and Inclusive Learning Environment

The Ohio State University affirms the importance and value of diversity in the student body. Our programs and curricula reflect our multicultural society and global economy and seek to provide opportunities for students to learn more about persons who are different from them. We are committed to maintaining a community that recognizes and values the inherent worth and dignity of every person; fosters sensitivity, understanding, and mutual respect among each member of our community; and encourages each individual to strive to reach his or her own potential. Discrimination against any individual based upon protected status, which is defined as age, color, disability, gender identity or expression, national origin, race, religion, sex, sexual orientation, or veteran status, is prohibited.

Your Mental Health

As a student you may experience a range of issues that can cause barriers to learning, such as strained relationships, increased anxiety, alcohol/drug problems, feeling down, difficulty concentrating and/or lack of motivation. These mental health concerns or stressful events may lead to diminished academic performance or reduce a student's ability to participate in daily activities. No matter where you are engaged in distance learning, The Ohio State University's Student Life Counseling and Consultation Service (CCS) is here to support you. If you find yourself feeling isolated, anxious or overwhelmed, ondemand mental health resources (go.osu.edu/ccsondemand) are available. You can reach an on-call counselor when CCS is closed at 614- 292-5766**. 24-hour emergency help** is available through the National Suicide Prevention Lifeline website (suicidepreventionlifeline.org) or by calling 1-800-273-8255(TALK). The Ohio State Wellness app (go.osu.edu/wellnessapp) is also a great resource.

Disability Services

The University strives to make all learning experiences as accessible as possible. In light of the current pandemic, students seeking to request COVID-related accommodations may do so through the university's request process, managed by Student Life Disability Services. If you anticipate or experience academic barriers based on your disability (including mental health, chronic or temporary medical conditions), please let me know immediately so that we can privately discuss options. To establish reasonable accommodations, I may request that you register with Student Life Disability Services. After registration, make arrangements with me as soon as possible to discuss your accommodations so that they may be implemented in a timely fashion. SLDS contact information: slds@osu.edu; 614-292-3307; slds.osu.edu; 098 Baker Hall, 113 W. 12th Avenue.

Final project grading rubric

	needs improvement (10)	adequate (11)	outstanding (12)
	Fundamentals		
Compiling (if applicable)	code does not compile	code compiles possibly with warnings	code compiles without warnings
Execution	code does not run	code runs	code runs
Physics	code does not implement the appropriate physics for the problem	code implements the appropriate physics for the problem	code implements the appropriate physics for the problem
Validation	no validation provided	no validation provided	provides validation through error analysis, comparison of multiple methods, and/or comparison to known solutions/limiting cases
	Coding		
Commenting	No comments in code	Variables and main steps of logic documented through comments	Thorough documentation through comments
Version/author comments	No version or author comments	Version and author comments in most files	Version and author comments in every file
Names	Cryptic variable and function names	Most variable and function names are self-explanatory	All variable and function names are self-explanatory
Code structure	Entire code in one function	Code is broken into logical units	Code is broken into logical units
Indentation	Code is not systematically indented	Indentation follows control statements	Indentation follows control statements

Code components			
Makefile (if applicable)	No makefile provided	Makefile provided	Makefile provided
Plot files	No plot files provided	Plot files provided	Plot files provided
Output			
Data files (if applicable)	Raw data files	Data files have explanatory headers	Data files have explanatory headers
Axes labels	Figures do not have axes labels	Figures have appropriate axes labels	Figures have appropriate axes labels
Legends	Figures do not have legends or have generic legends	Figures have appropriate legends	Figures have appropriate legends

Collapse All View Progress

Useful resources

Textbooks

Acess to compute resources

OnDemand portal at OSC (https://ondemand.osc.edu/)

Classroom portal at OSC for jupyter notebooks (https://class.osc.edu/)

Mathematica on the web (https://www.wolframcloud.com)

Connecting to a desktop session on OSC

Getting ready to use python on OSC

Starting a jupyter notebook session on OSC

Using an interactive shell on OSC

Starting a jupyter notebook session on OSC - non-class jupyter applications

What to do if OSC OnDemand misbehaves?

One time setup instructions to prepare for the class

Obtaining an OSC account for the class

New user guide from OSC (https://www.osc.edu/resources/getting_started/new_user_resource_guide)

Way more extensive getting started page from OSC (https://www.osc.edu/book/export/html/4509)

Obtaining access to Mathematica

Only for Mac users

Installation instructions for Macs (gnuplot, gsl, and openmp)

------------ The items below are for the ASC virtual machine version of the course ----------------

Instruction for setting up CarmenZoom (https://teaching.resources.osu.edu/toolsets/carmenzoom/guides/getting-started-carmenzoom)

BuckeyePass registration (https://osuitsm.service-now.com/selfservice/kb_view.do?sysparm_article=kb05024)

Instructions to connect to the virtual machine

Fixing access issues after dropped connections

Connecting to an Arts&Sciences machine via RDP (https://osuasc.teamdynamix.com/TDClient/1929/Portal/KB/ArticleDet?ID=105618)

Connecting to an Arts&Sciences machine via ssh and jump host (https://osuasc.teamdynamix.com/TDClient/1929/Portal/KB/ArticleDet?ID=29849)

Using Mathematica on the virtual machine

Setup instructions for XRDP (from Terry Bradley)

Connecting to the ASC VPN (https://osuasc.teamdynamix.com/TDClient/KB/ArticleDet?ID=14542)

Session 1 - Writing first programs and floating point precision

Notes for session 1 to read ahead of class

Session 1 Reading Quiz
Jan 12 | 2 pts

Slides for session 1

Recording of 1/12/22 class (course overview and session 1) (https://osu.zoom.us/rec/share/6wB-8MJ2HUiO-o-W0NdWMb-hPCPoBVjJH_0LLFBR1V-IpT4mENHeH-PbYVKXk48w.YGUTae78VbsB327s)

Session 1 activities worksheet (word file)

Session 1 activities worksheet

zip archive with session 1 source codes

Session 1 activities upload
Jan 14 | 12 pts

Useful background material

Useful Unix commands

recommended C++ options

Introduction to GSL

Full GSL documentation (https://www.gnu.org/software/gsl/doc/html/index.html)

Listings of example codes

Listings of various "area" source codes

Listing of make_area makefile

Listings of various other source codes

Relevant Hjorth-Jensen lecture notes

Hjorth-Jensen lecture notes preface

Hjorth-Jensen lecture notes table of contents

Hjorth-Jensen lecture notes chapter 1

Hjorth-Jensen lecture notes chapter 2

Hjorth-Jensen lecture notes references

Session 2 - more on floating point precision

Notes for session 2 to read ahead of class

Session 2 Reading Quiz
Jan 14 | 2 pts

Slides for session 2

Recording of 1/14 class (session 2) (https://osu.zoom.us/rec/share/AvO9zvhXIK2dpKoDKctH884zWotvB-IOIvWnwYa5uaa407T-Pp-QHyAsxb_fP-S3.9uhHuI5cYp3YVTq5)

Session 2 activities worksheet (word file)

Session 2 activities worksheet

zip archive with session 2 source codes

Session 2 activities upload
Jan 19 | 12 pts

Useful background material

Plotting data from a file with Gnuplot

Using a plot file with Gnuplot

Gnuplot 4.2 tutorial (http://people.duke.edu/~hpgavin/gnuplot.html)

Gnuplot 5 documentation (http://gnuplot.sourceforge.net/docs_5.0/gnuplot.pdf)

Listings of example codes

Listings of quadratic equation source codes

Listing of order of summation source code

Listing of Bessel function source code

First homework set

First problem set - due 1/31/2021

Hints and suggestions for problem set 1

First homework set (upload)
Jan 31 | 12 pts

Session 3 - Differentiation and Integration

Notes for session 3 to read ahead of class

Session 3 Reading Quiz
Jan 19 | 2 pts

Slides for session 3

Recording of 1/19 class (session 3) (https://osu.zoom.us/rec/share/bNrn4ogLWdK5SZQH0gaWbB8PuismkuI9Zha9EJAGZSo6Iz7H2iyhPjWApufyqoTV.cspmoezgM1LKMUMr)

Session 3 activities worksheet (word file)

Session 3 activities worksheet

zip archive with session 3 source codes

Session 3 activities upload
Multiple Due Dates | 12 pts

Useful background material

Fitting with gnuplot

Formatting with C++ manipulators (UIC notes)

Listings of example codes

Listing of derivative source code

Listings of integration source codes

Relevant Hjorth-Jensen lecture notes

Hjorth-Jensen lecture notes chapter 3

Hjorth-Jensen lecture notes chapter 5

Session 4 - more derivatives, pointers, and linear algebra

Notes for session 4 to read ahead of class

Session 4 Reading Quiz
Jan 21 | 2 pts

Slides for session 4

Recording of 1/21 class (session 4) (https://osu.zoom.us/rec/share/moa5TdBx-qcvnkNFboXpXFgdjnj1z9KD-XOBeNI-8_8nZSPwE4SkFoO9JHSRAOYV.CFs2H8Ts8wzAu1DG)

Recording of 1/26 class (comments on session 3 material) (https://osu.zoom.us/rec/share/PHQ36AFH-R3S466UuQwGIZVrI9TG0G_vCcpPIVrnpXaTWV77bvWmXsLIc3AHegCq.077MYydnD9akgGt_)

Session 4 activities wordsheet (word file)

Session 4 activities worksheet

zip archive with session 4 source codes

Session 4 activities upload
Jan 26 | 12 pts

Useful background material

Calculating integrals with singularities

cplusplus.com tutorial on pointers

Listings of example codes

Listing of pointer test source code

Listing of derivative test source code

Listing of integration with singularities source code

Listing of eigenvalue test source code

Session 5 - Simple quantum mechanical systems

Notes for session 5 to read ahead of class

Session 5 Reading Quiz
Jan 28 | 2 pts

Slides for session 5

Recording of 1/28 class (session 5 intro) (https://osu.zoom.us/rec/share

/wCZcey7ZSnkgW5bMw55udsO4urA0d0npWu0JmZt2mjtIG_nB9yGaL_-i5geY7e-U.fGSU-QIndZBYoXEA)

Recording of 2/2 class (session 5 issues) (https://osu.zoom.us/rec/share/1LxeQp6Enm_HZ15qfwLweJcYXuZjW0vPgzCuhYmykq5UkmQXZhDkLAaZz0-R9ghW.SJR3uFMIMg9t5mB3)

Session 5 activities worksheet

Session 5 activities worksheet (word file)

zip archive with session 5 source codes

Session 5 activities upload
Feb 2 | 12 pts

Useful background material

Are round-off errors really random?

Listings of example codes

Listing of NaN test source code

Listing of source code to diagonalize a Hamiltonian in coordinate representation

Listing of source code to diagonalize a Hamiltonian in a harmonic oscillator basis

Listing of source code to calculate harmonic oscillator eigenfunctions

Relevant Hjorth-Jensen lecture notes

- Hjorth-Jensen lecture notes chapter 6
- Hjorth-Jensen lecture notes chapter 7

Second homework set

- Second problem set - due 2/21/2021
- Hints and suggestions for problem set 2
- Second homework set (upload)
  Feb 21 | 12 pts

Session 6 - Parallel computing and differential equations

- Notes for session 6 to read ahead of class
- Session 6 Reading Quiz
  Feb 4 | 2 pts

Slides for session 6

Recording of 2/4 class (session 6 intro) (https://osu.zoom.us/rec/share/Uis49TqjWQz9DVp_pxISiQxSCB0PPJh9kIIl2JtKUnDoDbTrjVjhgWZhsE69tX0m.I0cUVzNHmu2m7Pde)

Recording of 2/9 class (comments on session 6 and earlier) (https://osu.zoom.us/rec/share/bxjqnoJKK-IhsMgcm890EPPgvz3qsxnMInXdBdNr6KX62nkT2p4XJmpmVGdHR9Q2.vhHfxYG4wb9KgX48)

Session 6 activities worksheet (word file)

Session 6 activities worksheet

zip archive with session 6 source codes

Session 6 activities upload
Feb 9 | 12 pts

Listings of example codes

Listing of source code for eigenvalue calculation using classes

Listing of source code for integration using OpenMP

Listing of source codes for two differential equation solvers

Listing of source code for differential equation solver test program

Relevant Hjorth-Jensen lecture notes

- Hjorth-Jensen lecture notes chapter 8

Session 7 - Driven non-linear oscillations and chaos

- Notes for session 7 to read ahead of class
- Session 7 Reading Quiz
  Feb 11 | 2 pts
- Slides for session 7
- recording of 2/11 class (intro to session 7) (https://osu.zoom.us/rec/share/0B6LDq-5c77n7gJOum_RtPJCj_UCZ6VWhlwd7ZbgKvRXbOW9zCVfD5koObIm2CIZ.XnPbi0qFv3QW_w94)
- recording of 2/16 class (thoughts about session 7 and classes) (https://osu.zoom.us/rec/share/Kg1kyzYAf1jL93ifiKgA20RpFEpe_S5mNxO1AMafK7kwn9a8pmLWsUvPkDAE53Be.ikoR-2F_HmszT0Rc)
- Session 7 activities worksheet (word file)
- Session 7 activities worksheet
- Chaos parameters - for instructors only

zip archive with session 7 source codes

Session 7 activities upload
Feb 16 | 12 pts

Listings of example codes

Listing of source code to diagonalize a Hamiltonian using classes

Listing of source code to solve the non-linear oscillator

Session 8 - more on input and output - not graded, thus no upload provided

Notes for session 8 to read ahead of class

Session 8 Reading Quiz
Feb 18 | 2 pts

Slides for session 8

recording of 2/18 class (session 8 intro) (https://osu.zoom.us/rec/share/3QotjJ_kItrY31xmuCFflDyceGoBboj7S-zv3ZjiccqKcJpNMhRARWc4TIWNcLxn.fC6GFm18e5v_W9nI)

Session 8 activities worksheet (word file)

Session 8 activities worksheet

zip archive with session 8 source codes

Useful background material

cplusplus article on parsing command line arguments (http://www.cplusplus.com/articles/DEN36Up4/)

Full documentation of XML parser library libxml2 (http://xmlsoft.org/)

Listings of example codes

Listing of source code for simulating oscillator using command line arguments

Listings of source codes for simulating oscillator using XML files

Third homework set

Third problem set - due 3/11/2021

Updated version of derivative_test.cpp

Hints and suggestions for problem set 3

Third homework set (upload)
Mar 11 | 12 pts

Session 9 - damped pendulum and installing your own packages

Notes for session 9 to read ahead of class

Session 9 Reading Quiz
Feb 23 | 2 pts

Slides for session 9

recording of 2/23 class (session 9 intro) (https://osu.zoom.us/rec/share/9BQnjIf4GKz7wHfv31fqa5nwiFTzv3kqR04w8sZ903KX5AdkLu12b33ck40UDBVe.oEHtXLC1899-YJgk)

Session 9 activities worksheet (word file)

Session 9 activities worksheet

E.2 solution (limit cycles) - for instructors only

zip archive with session 9 source codes

Session 9 activities upload
Feb 25 | 12 pts

armadillo-10.8.0.tar.xz - Armadillo package just in case SourceForge is down

Useful background material

Plots of damped oscillations

Mathematica notebook to solve nonlinear differential equations

Listings of example codes

Listing of source code to create file names on the fly

Listings of source codes for a class to interactively plot from a program using gnuplot

Listing of source code to solve a damped driven pendulum

Session 10 - debugging, profiling, and backups

Notes for session 10 to read ahead of class

Session 10 Reading Quiz
Mar 2 | 2 pts

Slides for session 10

recording of 3/2 class (session 10 intro) (https://osu.zoom.us/rec/share/0uw8bV-C24M0FRKgM3ByV-b_d989Fj3pctC3ZEds3Pj1-cWAIVm516iSrY0ndJXR.yzuBQIfjnMWuLuwA)

recording of 3/4 class (hints on HW3) (https://osu.zoom.us/rec/share/W6M9YKEPdY2HNpZI7wh1Zz5q-IhFb7FJCI7fFTK09Ry923cT48Cc5sOnz4pLA6y4.027tQal1oFboVbzJ)

Session10 activities worksheet (word file)

Session 10 activities worksheet

zip archive with session 10 source codes

Session 10 activities upload
Mar 4 | 12 pts

Useful background material

Visualization of the Pendulum's dynamics (from Baker&Gollub, "Chaotic Dynamics")

gdb debugger quick reference

Using the gdb debugger

Wikipedia page for rsync

Listings of example codes

- Listings of source codes for Circle class and testing it
- Listing of source code to compare private and public class members
- Listing of source code to compare different ways of squaring a number

Session 11 - interpolation and more differential equations

- Notes for session 11 to read ahead of class
- Session 11 Reading Quiz
  Mar 9 | 2 pts
- Slides for session 11
- recording of 3/9 class (session 11 intro) (https://osu.zoom.us/rec/share/4kZnsTmo5L1NLgbO7eu5eFMy-bftZbSIM3IYSMXapDyTAkvFsmxopqtbHxje6L-S.ILN8qFGPTokgzJrw)
- Session 11 activities worksheet (word file)
- Session 11 activities worksheet

Zip archive with session 11 source codes

Session 11 activities upload
Mar 11 | 12 pts

Command line mystery material

Instructions for command line mystery

Zip archive for command line mystery

Useful background material

Overview over interpolation with GSL

Power spectra of a driven pendulum

Listings of example codes

Listings of source codes to perform spline interpolation with GSL

Listing of source code to solve an ordinary differential equation with GSL

Relevant Hjorth-Jensen lecture notes

Hjorth-Jensen lecture notes chapter 3

Fourth homework set

Fourth problem set - due 4/4/2021

Fourth homework set (upload)
Apr 4 | 12 pts

Session 12 - Fitting and optimization

Notes for session 12 to read ahead of class

Session 12 Reading Quiz
Mar 23 | 2 pts

Slides for session 12

Recording of 3/23 class (session 12 intro) (https://osu.zoom.us/rec/share/v6h6UXwSzyxpJMhmqNcNG_pAKKo3BC2p2APjELR4v97VULHa0yOpzASp97v1GMHp.6Z2OTrLzQMJzGlyM)

Recording of 3/25 class (convergence criterion for GSL minimization) (https://osu.zoom.us/rec/share/A8FbG_ni5LgBWEg9Fr0A4aVf_aZIQY9O1uP1dEirLhmzFgpB_u4POS8eQgeWhvb0.YuEzsATJuUdnRjLo)

Session 12 activities worksheet (word file)

Session 12 activities worksheet

Zip archive with session 12 source codes

Session 12 activities upload
Mar 25 | 12 pts

Useful background material

Power spectra of a driven pendulum

GSL documentation on multidimensional minimization (https://www.gnu.org/software/gsl/manual/html_node/Multidimensional-Minimization.html)

GSL documentation on non-linear least squares fitting (https://www.gnu.org/software/gsl/manual/html_node/Nonlinear-Least_002dSquares-Fitting.html)

Problems with solver_ptr->J in multifit_test.cpp?

Listings of example codes

Listing of source code to perform multidimensional minimization with GSL

Listing of source code to perform non-linear least square fitting with GSL

Listings of souce codes to solve ODEs with GSL

Session 13 - fun with random numbers

Notes for session 13 to read ahead of class

Session 13 Reading Quiz
Mar 30 | 2 pts

Slides for session 13

Recording of 3/30 class (session 13 intro) (https://osu.zoom.us/rec/share/LgLsD9Dv2NHU57rrYHtV7FcqBKKIgwRnKsq0phc6a5EKx6dPxyHFBEuJSiEwKLdr.T-IhzwpB5XgXMs-7)

Recording of 4/1 session (more on random numbers) (https://osu.zoom.us/rec/share/1NvpYApSxAyDAqRKxsZ1qaWgljGpM9J96LzSdk3Znns_tMeUgSZQp7ADctLIMNM.ARMWeLONM8Jd8CLI)

Session 13 activities worksheet (word file)

Session 13 activities worksheet

Zip archive with session 13 source codes

Session 13 activities upload
Apr 1 | 12 pts

Useful background material

- Unix man page for random and urandom

Listings of example codes

- Listing of source code to generate Gaussian random variables
- Listing of source code to simulate a random walk
- Listings of source codes to simulate a random walk using classes
- Listing of (buggy) source code to calculate factorials

Relevant Hjorth-Jensen lecture notes

- Hjorth-Jensen lecture notes chapter 11
- Hjorth-Jensen lecture notes chapter 12

Session 14 - Ising model

- Notes for session 14 to read ahead of class

Session 14 Reading Quiz
Apr 6 | 2 pts

Slides for session 14

Recording of 4/6 class (session 14 intro) (https://osu.zoom.us/rec/share/U2dnscJj8qem4zKT5ufgUeZRL-OLvjHUhcC-IBCVIdUva2hxDFnWvKZi46S1l1RA.KnyP5Pju1etJnJR3)

Recording of 4/8 class (more thoughts on sessions 13 and 14) (https://osu.zoom.us/rec/share/obYqbPDQ7BFRy87I7v1uwuM63tW0UqhgBeQpRmPjU6wyk09VERugND-QpAed72T6.cE_1R0GutjyIVagt)

Session 14 activities worksheet (word file)

Session 14 activities worksheet

Zip archive with session 14 source codes

Session 14 activities upload
Apr 8 | 12 pts

Useful background material

HTML 5 Ising Model simulation

Binder/Heerman excerpt on Monte Carlo Simulations

Listings of example codes

- Listing of source code to sample energy distributions of the 1D Ising model
- Listing of source code for Monte Carlo simulation of Ising model
- Listing of optimized source code for Monte Carlo simulation of Ising model

Relevant Hjorth-Jensen lecture notes

- Hjorth-Jensen lecture notes chapter 13

Session 15 - more on Monte Carlo simulations

- Notes for session 15 to read ahead of class
- Session 15 Reading Quiz
  Apr 13 | 2 pts
- Slides for session 15
- Recording of 4/13 class (Session 15 intro) (https://osu.zoom.us/rec/share/1eGrh--ywPO_D1losEC6kN0AJyGt5PNslidqVlsXMoAA9Ja7SGnt9XDwLhouVc41.be6t0eBd2Is_VpRn)
- Recording of 4/15 class (comments on the Ising model) (https://osu.zoom.us/rec/share/-MW6CDaXIY_EiNeuc3o0_q0iTuYLCrInUW2_6GOdHaswRLzQ9fccAFIRkntbQiz0.uCCUaz_ArtUb6ly-)

Session 15 activities worksheet (word file)

Session 15 activities worksheet

Zip archive with session 15 source codes

Session 15 activities upload
Apr 15 | 12 pts

Listings of example codes

Listing of source code to calculate autocorrelation functions

Listings of source codes for variational Monte Carlo

Relevant Hjorth-Jensen lecture notes

Hjorth-Jensen lecture notes chapter 14

Session 16 - Simulated annealing and partial differential equations

Notes for session 16 to read ahead of class

Session 16 Reading Quiz

Apr 20 | 2 pts

Slides for session 16

Recording of 4/20 class (session 16 intro) (https://osu.zoom.us/rec/share/lET6MrWeP69QKhGkv-0GVLenpqkfoKr5dbs7LINhmdR9KeI-4DDde3TlmguvjZAZ.-ckpu2abTNaZB43Z)

Recording of 4/22 class (learning goals revisited) (https://osu.zoom.us/rec/share/SxGEI8NziDWhfCrepximH75DsDZD8_2kJ5OHFUCktD1Y4iptZoPZBwOfYq5u2OM_.VxMsfwOd9URR0xC9)

Session 16 activities worksheet (word file)

Session 16 activities worksheet

Zip archive with session 16 source codes

Useful background material

NaCl structure problem from Tao Pang: An Introduction to Computational Physics

Three-Dimensional Plots with Gnuplot

Chapter 17 from Landau and Paez on solving PDEs

Listings of example codes

Listing of source codes to find minimum of test function with simulated annealing

Listing of source code to solve Laplace's equation

Relevant Hjorth-Jensen lecture notes

Hjorth-Jensen lecture notes chapter 10

Final project

Previous years' projects

Final project (upload)
Apr 22 | 12 pts

Final project grading rubric

Computational Physics humor

Labeling your axes (https://xkcd.com/833/)

Pointers (https://xkcd.com/138/)

- How great new discoveries may not be so new (https://fliptomato.wordpress.com/2007/03/19/medical-researcher-discovers-integration-gets-75-citations/)
- Software Engineering (http://justins-fat-tire.blogspot.com/2008/06/best-programming-cartoon-ever.html)
- A guide to writing good code (https://xkcd.com/844/)
- Python (https://xkcd.com/353/)
- Editors (https://xkcd.com/378/)
- Compiling (https://xkcd.com/303/)
- Goto (https://xkcd.com/292/)
- Idiosyncrasies of compilers (https://xkcd.com/371/)

		Physics Major Program Outcomes				
		Undergraduate Physics majors aquire a basic mastery of fundamental areas of physics, from classical mechanics, though electromagnetism, and finally to modern physics including quantum mechanics and relativity.	Undergraduate Physics majors develop powerful analytical and problem solving skills in areas involving both physics and mathematics.	Undergraduate Physics majors aquire a basic mastery of experimental physics.	Undergraduate Physics majors acquire a basic mastery of data reduction and error analysis.	Undergraduate Physics majors effectively communicate their physical understanding both professionally and colloquially (orally and in writing).
required courses	Physics 2095: Physics Seminar					
	Physics 2300: Mechanics I	3	3	1		
	Physics 2301: Mechanics II	3	3	1		
	Physics 3700: Data Analysis Lab	1	3	3	3	3
	Physics 5400: Electromagnetism	3	3			
	Physics 5500: Quantum Mechanics	3	3			
	Physics 5700: Physics Senior Lab	2	3	3	3	3
required 3rd lab (choose 1)	Physics 3201: Holography	2	3	3		2
	Physics 4700: Electronics Lab	2	3	3	2	3
	Physics 5680: Big Data Analytics	1	3	2	3	1
	Physics 5810: Computational Physics	1	3	2	2	2

Relationship: 1 light, 2 intermediate, 3 high

Undergraduate Physics majors are apprised of and encouraged to participate in academic research, industrial research, and/or outreach activities which are consistent with their interest, ability, and post-graduation plans.
3
1
2
2
2
2