

**MATH/CS 335, Fall 2014**  
**Optimization**

**Professor:** Carl Toews

**Office:** Thompson 390H

**Phone:** x3839

**Email:** [ctoews@pugetsound.edu](mailto:ctoews@pugetsound.edu)

**Office Hours:** MWF: 10:30-11:30 and by  
appointment

**Class Website:** [math.pugetsound.edu/~ctoews/teaching/fall14/opt/](http://math.pugetsound.edu/~ctoews/teaching/fall14/opt/)

**Schedule:** MWF 3:00-3:50pm, Thompson 374; Th 3:30-4:20pm, Thompson 374

Welcome to Optimization! This broad subject lies at the intersection of pure mathematics, computational methods, and applied science. Generally speaking, the subject of Optimization deals with methods for finding the minimum of a function of one or more variables, usually called a cost function. While there are many ways to classify such functions, in practice one of the most important features is whether or not the function is convex: broadly speaking, convex functions are tractable while non-convex functions are not.

The purpose of this course is threefold. First, it is to supply you with a toolkit of theoretical techniques for finding minimizers to convex cost functions. Implicit in this goal is the development of the capacity to recognize which functions are convex and which are not. Second, the course will expose you to a broad range of real-world applied problems, thus helping to develop a sense of how this subject unifies the worlds of theory and practice. Lastly, the course will focus on how to actually solve these optimization problems on a computer, thus building programming and modeling skills.

This is a math course. As such, it will focus on proofs and logical arguments. But it is important to remember that the purpose of the mathematical results is to provide rigorous performance guarantees for the solution of real world problems, and that real world processes often proceed without theorems (admittedly a scandalous notion.) Which is to say that the field also has an empirical dimension, and that the role of the computer can be both to validate and motivate theorems. Expect to both prove and program in this course.

**Course Catalog Description:**

*This course is about how to find the best—or at least good—solutions to large problems frequently arising in business, industry, and scientific settings. Students learn how to model these problems mathematically, algorithms for finding solutions to them, and the theory behind why the algorithms work. Topics include the simplex method, duality theory, sensitivity analysis, and network models. The focus is on linear models and models with combinatorial structure, but some nonlinear models are considered as well. Optimization software is used frequently.*

### **Specific Learning Goals:**

After successfully completing this course, you should be able to:

1. cast real-world optimization problems in the language of mathematics;
2. use pre-existing software to solve formal optimization problems;
3. code your own algorithms to solve formal optimization problems;
4. analyze the strengths and weakness of optimization routines;
5. express that analysis effectively in both oral and written form.

More broadly, this class should improve your capacity to think critically about where, how, and why optimization routines are used, to become a deft problem solver, and to become an effective technical communicator.

### **Required Text:**

- “The Basics of Practical Optimization”, by Adam Levy.

### **Other Requirements:**

- Laptop capable of running iPython. (I will ask you to bring this class.)
- A laboratory notebook (marble covered, 9.75x7.50in, available from the bookstore.)

### **Grade Distribution:**

Weekly homework	10%
Labs	10%
Participation	10%
Project	10%
Exams	40%
Final Exam	20%

The final grading scale is as follows:

> 93.3	A	73.3 – 76.6	C
90.0 - 93.3	A-	70.0 – 73.3	C-
86.6 - 89.9	B+	66.6 – 69.9	D+
83.3 - 86.6	B	63.3 – 66.6	D
80.0 - 83.3	B-	60.0 – 63.3	D-
76.6 - 79.9	C+	< 59.9	F

### **Class Expectations:**

I try to structure a classroom that revolves around the twin pillars of *discovery* and *discussion*. I believe that learning is an active process, and that class works best when it functions as an

opportunity for guided inquiry, where the “guides” are both the professor and the peer group. In the wider educational community, my approach is labeled “Inquiry Based Learning”, or IBL.

There are a number of ways to structure an IBL class, but salient features of this class will include the following:

- Lectures punctuated by hands-on activities
- An emphasis on group work
- Lots of dialogue and discussion
- Student presentations
- A supportive environment in which to take “risks”
- An emphasis on communication, both oral and written
- A need for trust and confidence, both student-student and student-professor

*Productive failure* is an idea that lies at the root of our approach. When you’re trying to learn something, never making a mistake is generally a sign that you’re not pushing yourself hard enough. This class should be a safe and supportive space in which to get things wrong. When talking or presenting, you are challenged to work slightly outside of your comfort zone, to volunteer answers when you have a pretty good idea but aren’t 100% certain, to risk a conjecture that might turn out to be off the mark. And when you are listening to fellow students talk, you are challenged to pay strict attention, to flag small errors of language or comprehension, and to politely and respectfully help guide one another towards a clearer and truer picture of the matter at hand. Failure is part of the design spec for this class, and it can be hard, but you will not be struggling alone.

Although the spirit of what I’m shooting for with this IBL style class is probably clear, here is a minimalist list of concrete expectations:

- attend class daily
- do all assigned homework
- do all assigned reading, in a timely fashion
- participate actively in class discussions and class group work activities
- volunteer to present solutions on the board
- volunteer answers to questions I pose, and to ask your own questions when you are confused, uncertain, or simply thinking outside the box
- be courteous and supportive of your fellow learners
- help create a classroom that is a supportive, energetic, respectful place to learn.

More broadly, my basic hope and expectation is that you will engage the spirit of Inquiry Based Learning with enthusiasm, openness, and joy (*it is fun*), and help make this class a fun and supportive place in which to learn.

Lastly, a word about goals and outcomes: the goal in IBL is to produce critical thinkers who have a strong, creative command of the subject material. There is ample research evidence to support the IBL model, and I’m happy to share it with you if you’d care to see it. For me, one of the strongest element of IBL is the host of secondary skills you develop almost “for free”, including skills in abstract thinking, working from first principles, working with other people, and communicating your ideas. As my colleague Dana Ernst has noted, “All of the secondary skills you will develop in this course are highly valued by society. Whether you become a teacher, a lawyer, an engineer, or an artist, what differentiates you from your competition is your ability to think critically at a high level, collaborate professionally, and communicate effectively.”

## **Details About Class Activities:**

### ***Homework:***

I will assign and collect homework weekly, generally assigning on Wednesdays and collecting on Mondays. On collection days, we will cover solutions to at least a subset of the problems you turn in. I expect student volunteers to present the solutions, and non-presenters to compare these solutions against their own. New or missing material may be added to your own solutions at this point, but I'll ask that you use special "felt-tipped pens" that I provide so as to distinguish between material that you brought to class and material that you picked up during discussion. I'll collect your homework, and grade it for both style and content according to the following scale:

3	All problems attempted; correct answers, strong effort to articulate thought process
2	Most problems attempted; correct solutions, but not a great articulation of thought process
1	Half or fewer of the problems attempted; incorrect and ill-articulated answers
0	Nothing submitted

You are welcome (indeed, encouraged) to work on your homework in groups. You should, however, turn in your own copy of your work, written up in your own words. As with any mathematical writing, homework solutions are to be written out in complete sentences, and you need to make an effort to articulate your thought process, not merely provide "an answer." The lowest homework score will be dropped at the end of the term.

### ***Computational Labs:***

In optimization, computers are more than just tools for finding an answer; they are also powerful agents of exploration and understanding. Using a computer as an "experimental laboratory" will be a key idea in this course, and one that we will leverage through regular class computing sessions.

I'll use Python as the main computer language for this class. Most of the class computing sessions will be in the form of iPython Notebooks, a particular Python interface that is well suited to interactive and exploratory work. Part of the computational lab will consist of working through the exercises and coming up with correct code, but another part will consist of thinking, discussing, and writing about the "bigger picture." When you submit a computational lab, you will submit both a code file (generally an iPython Notebook file) and a physical notebook that has your responses to these big picture questions. You should think of this physical notebook as a tool for recording and organizing what you learn via your computer—it is directly analogous to a scientist's laboratory notebook, and serves the same purpose.

Computational labs will generally be done with a partner. You and your partner can turn in one iPython Notebook file, but each of you should submit your own lab notebooks. I will grade each lab on a 0-10 scale, assessing style, correctness, creativity, and attention to expression. The lowest lab score will be dropped at the end of the term.

### ***Participation:***

Since active participation by each member of the class is a critical element in the success of the IBL classroom, participation counts as 10% of your total grade in this course. This grade will be evenly apportioned along the following two axes:

- *Presentations of homework solutions*

Solutions to homework problems will be discussed in detail on Mondays, the day you turn the homework in. I will ask for student volunteers to present these solutions. **At a minimum, you should plan on presenting at least four times over the course of the semester, and at least once between each exam.**

Some notes on style: though the environment in this class should be informal and friendly, what we're doing is serious business. The presentations made by students are a foundational part of this class, and they should be taken with great seriousness. I ask that the following points be kept in mind during students presentations:

- The point of the presentation is not to convince me that you've done the problem, but rather to make the problem and its solution clear to your peers.
- When possible, presenters are to write in complete sentences, using proper English grammar.
- Presenters should explain their reasoning, not simply show techniques.
- Fellow students can ask questions at any point, and should pay attention both to what is written on the board and what is said by the speaker. Anything that is unclear or incorrect should be noted and addressed.
- Since the presentation is directed at students, the presenter should make appropriate eye contact and try to gauge how well students are following the argument.

- *Other forms of in-class participation*

Aside from presenting homework solutions, there are a variety of other ways to participate in this class.

- Ask questions! Anytime, anywhere, and on any topic. Good options include during student presentations, during my "lectures", within your working groups, before and after class, during office hours, etc.
- Answer questions! Sometime I or a student will ask questions, and we'll need answers. If you have ideas, share them!
- Come to class having read the text. I generally assign the week's reading on Monday, and you should have it done by Wednesday. Showing up to class having read and thought about the text is a good way to ensure that you can participate.
- Bring in optimization tidbits to share with the class. (Factoids, newspaper articles, a summary of how optimization played a role in a science seminar, whatever.)

***Project:***

There will be one project assigned during the last couple of weeks of class. The project will involve independent research, analysis, coding, and a polished, professional looking report. The purpose of the project is not just to expand your exposure to novel optimization topics, but also to give you some research practice and the opportunity to hone your scientific writing. A portion of your project grade will be tied to an in-class presentation that you give the final week of class.

***Exams:***

I will give two tests during the semester. Each test will have two parts, a take-home part and an in-class part. The take home parts will involve some use of the computer, and you'll generally have a couple of days to complete them. The in-class part will be administered during a regular class session (generally Thursdays), and neither notes nor technology will be allowed. Material for each test will generally be chosen from the material we have most recently studied, but each test is theoretically "cumulative" in the sense that any material we have covered is fair game for any test.

***Final Exam:***

There will be a cumulative, "mastery-based" final exam administered during our allotted exam slot in finals week, i.e. Monday, December 15<sup>th</sup>, 4:00-6:00pm. All students must take the final exam to pass the class. The exam will have two parts. Part 1 of the final contains basic problems that all students should be able to do to demonstrate a basic knowledge of Math 335. Completing Part 1 successfully (i.e. getting all problems correct except maybe a couple of minor errors) allows a student to keep his/her preliminary grade, or get at least a C- in the course. Part 2 contains more challenging problems.

**Policies:*****Attendance:***

Built into the philosophy of inquiry-based learning is the idea that we help one another to learn. As a consequence, your daily attendance in class is very important, not just for your own benefit, but for that of your peers.

I will take roll every day and verify attendance. You are allowed to miss up to three days with no penalty. After three missed classes, two things happen: 1) every additional absence causes you to lose 10% of your final participation grade, and 2) I reserve the right to drop you from the class.

***Late work:***

Late homework will be docked at the rate of one point per day (note that since homework is graded on a 0-3 scale, one point is a lot.) Late computer labs will be also be docked at one point per day (since computer labs are graded on a 0-10 scale, this is less grave.) Late exams lose one letter grade per day late (eg. an A becomes a B, a B becomes a C, etc.) Late projects are also docked one letter grade per day. The final exam cannot be turned in late.

***Absences:***

When I form grades, I will drop your lowest homework and laboratory scores. The idea behind this policy is that you might get sick once in a while and miss an assignment—if that

happens, simply think of the missed work as “dropped” and carry on. If you miss more than one homework or computer lab for legitimate reasons (e.g. death in the family, medical emergency, etc.) talk to me and we’ll work out something equitable.

If you need to be absent for some planned family or medical reason, you should contact me in advance. If an emergency arises, contact me as soon as possible after the emergency has passed. Student athletes who need to miss class for games should let me know of this as early as possible.

### ***Classroom policies:***

You are welcome to bring a cup of coffee or a bottle of water to class, but please eat your meals outside of class. Please turn off your phones and keep your laptops closed, unless we happen to be doing a computer exercise. You can take a bathroom break if necessary, but please make this the exception, not the rule—in general, I don’t want people entering and leaving the room during class.

### ***Academic integrity:***

It is your responsibility to understand the academic integrity policy of the university. You can find this policy in the Academic Handbook, and it is also available online at:

<http://www.pugetsound.edu/student-life/student-resources/student-handbook/academic-handbook/academic-integrity/>.

Not citing other people’s work, turning in the same work to satisfy two different classes, citing false information, or plagiarism are all violations of the academic integrity policy. Such violations are taken very seriously, and will be reported if discovered.

### ***Disabilities:***

If you have a physical, psychological, medical or learning disability that may impact your course work, please contact Peggy Perno, Director of Student Accessibility and Accommodation, 105 Howarth Hall, 253-879-3395. She will determine with you what accommodations are necessary and appropriate. All information and documentation is confidential.

### **Getting Help:**

Optimization is an advanced class, and there are probably no tutors available to help you. But I’m around: I have regular office hours, and if you can’t make those, then try just dropping by or setting up an appointment (I am generally in my office if I’m not teaching, eating, or working out.) Make a habit of coming to see me to discuss any questions you might have. I imagine that one of the reasons you chose to go to a liberal arts college was to gain access to your professors, and I am very much on board with that vision. You should leverage me as a resource.

### **Classroom Emergency Response Guidance**

Please review university emergency preparedness and response procedures posted at [www.pugetsound.edu/emergency/](http://www.pugetsound.edu/emergency/). There is a link on the university home page. Familiarize yourself with hall exit doors and the designated gathering area for your class and laboratory buildings.

If building evacuation becomes necessary (e.g. earthquake), meet your instructor at the designated gathering area so she/he can account for your presence. Then wait for further instructions. Do not return to the building or classroom until advised by a university emergency response representative.

If confronted by an act of violence, be prepared to make quick decisions to protect your safety. Flee the area by running away from the source of danger if you can safely do so. If this is not possible, shelter in place by securing classroom or lab doors and windows, closing blinds, and turning off room lights. Lie on the floor out of sight and away from windows and doors. Place cell phones or pagers on vibrate so that you can receive messages quietly. Wait for further instructions.