



Instructor Contact Information

- Ben Delaware
- **Email:** bendy at purdue.edu
- **Office:** LWSN 2166M
- **Office Hours:** Tuesday, 10:30a-12:00n, Zoom
- I will respond to all emails within 24-48 hours. For my own work-life-balance, I will not be checking or responding to email before 9am EST or after 9pm EST.

TA Contact Information

- Qianchuan Ye
- Email: ye202 at purdue.edu
- Office Hours: TBD

Course description

This course will examine the design and implementation of programming languages from a foundational perspective. Our goal will be to develop tools that will enable us to both design and specify new language features, to precisely understand the rationale for existing features in modern languages, and to understand how design decisions can impact implementations. The course will be divided into roughly three parts:

- principles (e.g., semantics, type systems, specifications)
- proof techniques and formal reasoning
- interactive theorem proving using the Coq proof assistant

Our discussion of principles will be crafted in the context of definitions and theorems that capture salient properties of modern languages. The validation of these theorems will be undertaken using Coq, a powerful theorem prover and mechanized proof assistant.

Course-Level Learning Outcomes:

At the end of this course, students will be able to:

- Compare and contrast different approaches to specifying a programming language's behaviors (and how they effect reasoning about programs).
- Specify different categories of program errors and apply language-based techniques to ensure their absence.
 - Program logics
 - Type Systems
- Rigorously formalize and reason about systems in the [Coq](#) proof assistant. In particular, students will be able to:
 - define mathematical representations of systems,
 - state their properties in logic,
 - and formally prove those properties hold.

How to Succeed in this Course

In order to be successful, students should be familiar with:

- Programming in an imperative language, e.g. Java / C / Python, etc.
- Basic logic and proofs techniques found in an undergraduate discrete math course like CS182: sets, relations, functions, proof by induction, proof by case analysis; recursion; and propositional logic.
- The sorts of basic data structures and algorithms encountered in an undergraduate course like CS 251, e.g. lists, trees, heaps, graphs, sorting, graph traversals, and search.

We'll briefly review important concepts as needed, but this will be a refresher and not an introduction.

In this course, we will be using the Coq proof assistant as a sort of 'personal TA' to check our work. As you work through homework assignments, Coq will identify any gaps in your reasoning and provide immediate feedback. Once Coq gives the thumbs up on a homework problem, you can be reasonably confident that you have finished it correctly. This tight feedback loop can lead to an unfortunate anti-pattern, however, in which students [blindly push buttons](#) until they happen upon something that works. This approach will waste a lot of your time and will not help you learn the material. Students should resist the temptation to immediately start hacking on a problem in Coq, and instead work out a solution on pen and paper. Only once you have found a solution should you code it up in Coq, relying on the proof assistant to check your reasoning.

Learning Resources, Technology, and Texts

Course Text:

We will be using [Software Foundations](#) as the course textbook. [Types and Programming Languages](#) has a more in-depth treatment of semantics and type systems, while [Certified Programming with Dependent Types](#) is an excellent resource for applied programming and proving in Coq.

Discussion Forum:

The course piazza site will serve as the discussion board; all course announcements will also be posted there. In lieu of emailing the instructor or the TA with any general questions about using Coq or assignments, please post them to piazza so that any other students with the same question can see the answer.

Software:

The official project page of the Coq proof assistant has plenty of documentation. The latest version of Coq is 8.8.1, which should be used for all assignments.

There are a couple of [editors](#) with good Coq integration:

- **CoqIDE** comes bundled with Coq, and has all of the features you need to develop Coq.
- [ProofGeneral](#) is an Emacs mode that includes an excellent Coq mode (this is the instructor's preferred editor).
- [Cogtail](#) is a Vim/NeoVim extension which is similar to CoqIDE and ProofGeneral.

Assessment

Your learning will be assessed through a combination of biweekly homeworks, a midterm, and a final exam. Due to the pandemic, both the midterm and the final will be take home. Details on the assignments and exams, including a schedule of due dates, will be posted to the course website.

Grading Structure

Final grades in this course will reflect the sum of your achievement throughout the semester. Homework assignments are worth 50% of your final grade, and each assignment will contribute equally to your final homework grade. Both the midterm and final will be cumulative, although the final focusing more on material from the second half of the semester. The midterm and the final will be worth 20% and 30% of your final grade, respectively. To summarize how each kind of assessment will be weighted:

- Homework Assignments: 50%
- Midterm (10/16): 20%
- Final (12/14): 30%

At the end of the semester, final grades will be calculated by summing up your weighted homework and test grades and translating the truncated result into letter grades using the following buckets as an upper bound:

- A+: 96 - 100
- A: 93 - 95
- A-: 90 - 92
- B+: 86 - 89
- B: 83 - 85
- B-: 80 - 82
- C+: 76 - 79
- C: 73 - 75
- C-: 70 - 72
- D+: 66- 69
- D: 63 - 65
- D-: 60 - 62
- F: 59 and below

The instructor may opt to use a lower minimum for the A- bucket, e.g. 88-90, but will never adjust the ranges upward. In other words, a final total of 86 is **guaranteed** to translate to **at least** a B+.

Course Logistics

Reflecting the unfortunate realities of the ongoing COVID-19 pandemic, this fall's offering of CS565 is structured so that it can be taken entirely online:

- There will be no in-person instruction this semester. Each Monday, recorded **lectures** will be posted on Brightspace. Students are expected to watch these lectures during the week they are posted and post any questions they have to the course discussion board.
- Each Thursday from 10:30-12:00, there will be a **live lab session** in which the professor will answer student questions (including those posted to piazza), and interactively work through example problems. These sessions will be recorded and will be posted the following day.
- Each Tuesday from 10:30-12:00, the instructor will have **virtual office hours**. In the event that students cannot attend these virtual office hours, they should contact the instructor via email to schedule a time to meet individually.
- **Homeworks** will be posted every other week according to the course schedule. These assignments will require students to fill in missing definitions and proofs in an incomplete Coq file. Homeworks are to be submitted via BlackBoard by 6PM on their assigned due date. Make sure that Coq accepts your file in its entirety. If it does not, it will not be graded. You can use Admitted to force Coq to accept incomplete proofs. Everyone will receive three courtesy late days for the semester. Once all these days have been used, students will need to notify the instructor or the TA ahead of time with an explanation and plan for completion. These requests will be accepted at my discretion and may include a point penalty of 5% per day late. Asking for an extension does not guarantee it will be granted.

Academic Honesty

Academic integrity is one of the highest values that Purdue University holds, and students are expected to adhere to the university's policies regarding academic dishonesty. Students are permitted and encouraged to discuss homeworks at a high level, and to ask clarifying questions on the course discussion board. At the end of the day, each student is expected to produce the solutions they submit on their own. The midterm and final are cumulative assessments of individual students' learning over the course of the semester, and thus students should not discuss the exams with their classmates.

Incidents of academic misconduct in this course will be addressed by the course instructor and referred to the Office of Student Rights and Responsibilities (OSRR) for review at the university level. Any violation of course policies as it relates to academic integrity will result minimally in a failing or zero grade for that particular assignment, and at the instructor's discretion may result in a failing grade for the course. In addition, all incidents of academic misconduct will be forwarded to OSRR, where university penalties, including removal from the university, may be considered."

Nondiscrimination Statement

Purdue University is committed to maintaining a community which recognizes and values the inherent worth and dignity of every person; fosters tolerance, sensitivity, understanding, and mutual respect among its members; and encourages each individual to strive to reach his or her own potential. In pursuit of its goal of academic excellence, the University seeks to develop and nurture diversity. The University believes that diversity among its many members strengthens the institution, stimulates creativity, promotes the exchange of ideas, and enriches campus life. More details are available on our course Brightspace table of contents, under University Policies.

Mental Health Statement

- If you find yourself beginning to feel some stress, anxiety and/or feeling slightly overwhelmed, try WellTrack. Sign in and find information and tools at your fingertips, available to you at any time.
- If you need support and information about options and resources, please contact or see the Office of the Dean of Students. Call 765-494-1747. Hours of operation are M-F, 8 am- 5 pm.
- If you find yourself struggling to find a healthy balance between academics, social life, stress, etc. sign up for free one-on-one virtual or in-person sessions with a Purdue Wellness Coach at RecWell. Student coaches can help you navigate through barriers and challenges toward your goals throughout the semester. Sign up is completely free and can be done on BoilerConnect. If you have any questions, please contact Purdue Wellness at evans240@purdue.edu.
- If you're struggling and need mental health services: Purdue University is committed to advancing the mental health and well-being of its students. If you or someone you know is feeling overwhelmed, depressed, and/or in need of mental health support, services are available. For help, such individuals should contact Counseling and Psychological Services (CAPS) at 765-494-6995 during and after hours, on weekends and holidays, or by going to the CAPS office of the second floor of the Purdue University Student Health Center (PUSH) during business hours.

Classroom Guidance Regarding Protect Purdue

The Protect Purdue Plan, which includes the Protect Purdue Pledge, is campus policy and as such all members of the Purdue community must comply with the required health and safety guidelines. Required behaviors in this class include: staying home and contacting the Protect Purdue Health Center (496-INFO) if you feel ill or know you have been exposed to the virus, properly wearing a mask in classrooms and campus building, at all times (e.g., mask covers nose and mouth, no eating/drinking in the classroom), disinfecting desk/workspace prior to and after use, maintaining appropriate social distancing with peers and instructors (including when entering/exiting classrooms), refraining from moving furniture, avoiding shared use of personal items, maintaining robust hygiene (e.g., handwashing, disposal of tissues) prior to, during and after class, and following all safety directions from the instructor.

Students who are not engaging in these behaviors (e.g., wearing a mask) will be offered the opportunity to comply. If non-compliance continues, possible results include instructors asking the student to leave class and instructors dismissing the whole class. Students who do not comply with the required health behaviors are violating the University Code of Conduct and will be reported to the Dean of Students Office with sanctions ranging from educational requirements to dismissal from the university.

Any student who has substantial reason to believe that another person in a campus room (e.g., classroom) is threatening the safety of others by not complying (e.g., not wearing a mask) may leave the room without consequence. The student is encouraged to report the behavior to and discuss next steps with their instructor. Students also have the option of reporting the behavior to the Office of the Student Rights and Responsibilities. See also Purdue University Bill of Student Rights.

Academic Guidance in the Event a Student is Quarantined/Isolated

If you become quarantined or isolated at any point in time during the semester, in addition to support from the Protect Purdue Health Center, you will also have access to an Academic Case Manager who can provide you academic support during this time. Your Academic Case Manager can be reached at acmq@purdue.edu and will provide you with general guidelines/resources around communicating with your instructors, be available for academic support, and offer suggestions for how to be successful when learning remotely. Importantly, if you find yourself too sick to progress in the course, notify your academic case manager and notify me via email or Brightspace. We will make arrangements based on your particular situation. The Office of the Dean of Students (odos@purdue.edu) is also available to support you should this situation occur.

Tentative Course Schedule

- W1: Functional Programming in Coq
- W2: Polymorphism + Basic Reasoning
- W3: Inductive Evidence + PL Foundations
- W4: Operational Semantics
- W5: Operational Semantics of other Language Features
- W6: The Lambda Calculus
- W7: Denotational Semantics
- W8: Axiomatic Semantics (Program Logics)
- W9: Advanced Program Logics
- W10: Basics of Type Systems
- W11: Type Inference / Reconstruction
- W12: Substructural Type Systems
- W13: Flex Time (Polymorphism / System F / Lambda Cube / Rust / Recap)

Emergency Preparation

In the event of a major campus emergency, course requirements, deadlines and grading percentages are subject to changes that may be necessitated by a revised semester calendar or other circumstances beyond the instructor's control. Relevant changes to this course will be posted onto the course website or can be obtained by contacting the instructors or TAs via email or phone. You are expected to read your @purdue.edu email on a frequent basis.