# Symbolic Logic

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| Instructor: | Eric Pacuit (pacuit.org) |
| Semester: | Spring 2023 |
| Email: | epacuit@umd.edu |
| Course Website: | https://umd.instructure.com/courses/1340799 |
| Class Times: | TuTh 11:00am - 12:15pm |
| Location: | SQH 1123 |
| Office Hours: | Mondays 3pm - 4pm, Skinner 1103A |
| | Fridays 11am - noon, Zoom |
| Office: | Skinner 1103A |

## Course Description

This course is intended as a first course in logic for students with no previous exposure to the subject. The course is focused on two logical systems: propositional logic and first order logic. For each logical system, we will discuss the syntax (what it means to construct a well formed sentence in the logic), the semantics (how one decides whether or not a sentence in the logic is true), and a proof theory (how, if you know some true things, you can figure out what else is true). The main objective is to become proficient at "elementary" formal reasoning involving propositional and first-order logic. By the end of the semester students will be able to analyze arguments using propositional or first-order logic; interpret formulas and proofs in propositional/first-order logic; and will be proficient with basic logical concepts.

Along the way, we will study some of the concepts from set theory (sets, functions, relations) used in the definition of semantic models for logical systems. We may also introduce some alternative, or non-classical logics. Although the subject of symbolic logic was developed by mathematicians and philosophers for their own special purposes (which we will discuss), logical concepts and techniques have found applications in a variety of disciplines, including computer science, economics, law, linguistics, and psychology. We may also consider some of these applications.

**Prerequisites**: There are no prerequisites for this course.

## Required Resources

- Course Website: `https://umd.instructure.com/courses/1340799`

- This term we will be using Campuswire (`https://campuswire.com/c/G9F83A3B3/feed`) for class discussion. The system is highly catered to getting you help fast and efficiently from both me and your classmates. Rather than emailing questions to me, I encourage you to post your questions on Campuswire. You can join the class using the link `https://campuswire.com/p/G9F83A3B3` with the join code is **9822**.
- We will be using `https://carnap.io/` for many of the tutorial questions. The registration link to enroll in the course is `https://carnap.io/enroll/PHIL%20271`. You will need a Google account to register for the course (you can use your umd email to register).
- Readings: The main textbook for the course is:
  - a version of ***Forall*** $x$, originally written by P.D. Magnus and Tim Button, available on the course website: `https://umd.instructure.com/courses/1340799/modules/items/11880313`.

  In addition, the following books and online notes may be helpful.
  - `https://logic-probability.pacuit.org`: Online notes about logic and probability.
  - `https://carnap.io/book`: Online book covering much of the material discussed this semester.
  - V. Halbach, *The Logic Manual*, Oxford University Press, 2010.
  - I. Chiswell and W. Hodges, *Mathematical Logic*, Oxford Texts in Logic, 2007.

# Grading Policy

The course requirements are:

- **Tutorials** (25% of your final grade): There will be 10-12 tutorials containing questions that will be discussed during the lectures. These are low-stakes problems designed to give students a chance to practice with the concepts introduced in the lectures. Many of the questions and answers will be discussed during the lectures, and students are encouraged to discuss the questions with fellow students. Most of the tutorials will be automatically graded and students will have multiple chances to correct their answers to these problems.
- **Problem sets** (25% of your final grade). There will be 3-5 problem sets assigned this semester. Problem sets will be submitted through Gradescope (accessible through the course website). You can use your notes, the readings, and the online textbook, but you should not discuss your answers with your classmates or use any AI tools, such as ChatGPT, to answer these questions. The tentative due date for the Problem Sets are (consult the course website for the due dates):

| | Tentative Due Date |
|---|---|
| Problem Set 1 | 2/17 |
| Problem Set 2 | 3/3 |
| Problem Set 3 | 4/7 |
| Problem Set 4 | 4/21 |
| Problem Set 5 | 5/12 |

- **Exams** There will be 3 in-person exams given during the semester:

  **Exam 1** (15% of your final grade) on propositional logic.

  **Exam 2** (15% of your final grade) on first order logic.

  **Final exam** (20% of your final grade): The final will be cumulative and given as an in-class exam given during finals week. A study guide will be provided during the last week of the semester. Consult Testudo for the date, time and location of the final exam.

See undergraduate catalogue for description of grades, e.g., A+, A, A-, etc.: `http://www.umd.edu/catalog/index.cfm/show/content.section/c/27/ss/1584/s/1534`. Your final grade may be curved.

# Topics

Below is a tentative list of topics that will be covered. Consult the website for the final list of topics discussed this semester.

1. Propositional logic: syntax, basic proof theory
   (a) The Boolean connectives and language of propositional logic
   (b) Fitch-style natural deduction
2. Propositional logic: Semantics
   (a) Valuations (truth-tables)
   (b) Satisfaction and satisfiability
   (c) Semantic implication and validity
3. Meta-theorems about propositional logic (time permitting)
   (a) Deduction Theorem
   (b) Functional Completeness
4. First-order logic: Syntax and basic proof theory

(a) Syntax: Predicates, terms and atomic formulas
(b) Syntax: Quantifiers
(c) Natural deduction

5. First-order logic: Semantics
   (a) Semantics for first-order logic
   (b) Substitutions
   (c) Truth in a model
   (d) Satisfiability
   (e) Semantic implication and validity
   (f) Adding identity
6. Elementary set theory (time permitting)
   (a) Sets, relations, functions
   (b) Properties of relations and functions
   (c) Introduction to mathematical induction
   (d) Size of sets
7. Some nonclassical logics (time permitting)
   (a) Many-valued logics
   (b) Intuitionistic logic
   (c) Some modal logics

**Schedule**

A more detailed schedule, including links to the reading material, can be found on the course website. The reading refers to the Forall$x$ textbook available on the course website.

| Date | Topic | Readings |
|---|---|---|
| 1/26 | Introduction | Syllabus, Ch. 1 - 3, pp. 1 - 25 |
| **Part 1 - Propositional Logic** | | |
| 1/31 | PL: Language and translations | Ch. 4 - 8, pp. 26 - 67 |
| 2/2 | PL: Language and translations | Ch. 4 - 8, pp. 26 - 67 |
| 2/7 | PL: Semantics I | Ch. 9 - 12, pp. 68 - 95 |
| 2/9 | PL: Semantics II | Ch. 9 - 12, pp. 68 - 95 |

| Date | Topic | Readings |
|---|---|---|
| 2/14 | PL: Semantics III | Ch. 9 - 12, pp. 68 - 95 |
| 2/16 | PL: Semantics III | Ch. 9 - 12, pp. 68 - 95 |
| 2/17 | **Problem Set 2 Due** | |
| 2/21 | PL: Natural Deduction I | Ch. 15 - 21, pp. 108 - 189 |
| 2/23 | PL: Natural Deduction II | Ch. 15 - 21, pp. 108 - 189 |
| 2/28 | PL: Natural Deduction III | Ch. 15 - 21, pp. 108 - 189 |
| 3/2 | PL: Natural Deduction IV | Ch. 15 - 21, pp. 108 - 189 |
| 3/3 | **Problem Set 2 Due** | |
| 3/7 | Review and practice | Ch. 1 - 12, 15 - 21 |
| 3/9 | **Exam 1** | |
| 3/14 | FOL: Language and translations I | Ch. 22 - 28, pp. 190 - 257 |
| 3/16 | FOL: Language and translations II | Ch. 22 - 28, pp. 190 - 257 |
| 3/21 | **No Class - Spring Break** | |
| 3/23 | **No Class - Spring Break** | |
| 3/28 | FOL: Semantics I | Ch. 29 - 33, pp. 258 - 291 |
| 3/30 | FOL: Semantics II | Ch. 29 - 33, pp. 258 - 291 |
| 4/4 | FOL: Semantics III | Ch. 29 - 33, pp. 258 - 291 |
| 4/6 | FOL: Semantics IV | Ch. 29 - 33, pp. 258 - 291 |
| 4/7 | **Problem Set 3 Due** | |
| 4/11 | FOL: Natural Deduction I | Ch. 34 - 39, pp. 292 - 321 |
| 4/13 | FOL: Natural Deduction II | Ch. 34 - 39, pp. 292 - 321 |
| 4/18 | FOL: Natural Deduction III | Ch. 34 - 39, pp. 292 - 321 |
| 4/20 | FOL: Natural Deduction IV | Ch. 34 - 39, pp. 292 - 321 |
| 4/21 | **Problem Set 4 Due** | |

| Date | Topic | Readings |
|---|---|---|
| 4/25 | Review and practice | Ch. 22 - 39 |
| 4/27 | **Exam 2** | |
| **Part 3 - Introduction to Discrete Mathematics** | | |
| 5/2 | Reasoning about Sets I | TBA |
| 5/4 | Reasoning about Sets II | TBA |
| 5/9 | Relations and Functions I | TBA |
| 5/11 | Relations and Functions II | TBA |
| 5/12 | **Problem Set 5 Due** | |
| 5/?? | **Final Exam** | |

# Learning Outcomes

This course satisfies the GenEd Analytic Reasoning requirement. Courses in Analytic Reasoning will foster a student's ability to use mathematical or formal methods or structured protocols and patterns of reasoning to examine problems or issues by evaluating evidence, examining proofs, analyzing relationships between variables, developing arguments, and drawing conclusions appropriately. The learning outcomes for this course are:

- *Demonstrate proficient application of the skills required by the Mathematics Fundamental Studies requirement, including the ability to communicate using formal or mathematical tools.*

  Students will be introduced to basic topics in logic. In addition to providing written solutions to problems testing their understanding of logic, students will be required to discuss their solutions with other students and to present their solutions during class discussions.

- *Distinguish between premises and conclusions, or between data and inferences from data.*

  One of the main objectives of the course is the formal study of arguments. The first step in a logical analysis of arguments is to distinguish between premises and conclusions. The problems from the online tutorials and the exams will assess the student's ability to distinguish between premises and conclusions.

- *Apply appropriate analytical methods to evaluate inferences and to reason about complex information.*

An important objective of the course is to demonstrate how logical tools can enhance student's basic mathematical reasoning. The lectures and problem sets will highlight how logic justifies and enhances mathematical arguments.

- *Use formal, analytical, or computational techniques to address real-world problems.*

  The lectures and problem sets will highlight important patterns of reasoning used throughout mathematics, computer science, and economics. The readings and class discussions will focus on the the use of logic to evaluate the use of mathematical reasoning in many disciplines, including philosophy, computer science, and economics.

# Course Policies

A full list of course-related policies and relevant links to resources may be found at:

`http://www.ugst.umd.edu/courserelatedpolicies.html`.

## Communication about this Course

I will use email and Campuswire.com to convey important information, and students are responsible for keeping their email address up to date, and must ensure that forwarding to another address functions properly. Failure to check email, errors in forwarding, and returned email are the responsibility of the student, and do not constitute an excuse for missing announcements or deadlines.

## Class Cancelations

The University may be closed in the event of an emergency, in which case class will be cancelled. To find out if the University is closed you can check its main site (`http://www.umd.edu`), its emergency preparedness site (`http://www.umd.edu/emergencypreparedness/`), or call the "snow phone line" at 301-405-7669 (which covers more than just snow caused closings). If class is cancelled while the University remains open, then there will be an announcement posted on the course ELMS page.

**Emergency protocol**: In the case of an extended closure to the University (e.g., because of inclement weather), consult the ELMS course page for announcements and changes to any due dates.

## Attendance and Absences

Students are expected to attend classes regularly. Consistent attendance offers students the most effective opportunity to gain command of course concepts and materials. Events that justify an excused absence include: religious observances; mandatory military obligation; illness of the student or illness of an immediate family member; participation in university

activities at the request of university authorities; and compelling circumstances beyond the student's control (e.g., death in the family, required court appearance). Absences stemming from work duties other than military obligation (e.g., unexpected changes in shift assignments) and traffic/transit problems do not typically qualify for excused absence. Students claiming an excused absence must notify the course instructor in a timely manner and provide appropriate documentation. The notification should be provided either prior to the absence or as soon afterwards as possible. In the case of religious observances, athletic events, and planned absences known at the beginning of the semester, the student must inform the instructor during the schedule adjustment period. All other absences must be reported as soon as is practical. The student must provide appropriate documentation of the absence. The documentation must be provided in writing to the instructor by the means specified in this syllabus. The full university attendance/absence policy can be found here: `http://www.ugst.umd.edu/courserelatedpolicies.html`.

## Academic Integrity

The UMD Honor Code prohibits students from cheating on exams, plagiarizing papers, submitting the same paper for credit in two courses without authorization, buying papers, submitting fraudulent documents and forging signatures. On every examination, paper or other academic exercise not exempted by the instructor, students must write by hand and sign the following pledge:

> *I pledge on my honor that I have not given or received any unauthorized assistance on this examination (or assignment).*

Allegations of academic dishonesty will be reported directly to the Student Honor Council: `http://www.shc.umd.edu`

## Disability Support

Students with a documented disability should inform the instructors within the add-drop period if academic accommodations will be needed. NB: You are expected to meet with your instructor in person to provide them with a copy of the Accommodations Letter and to obtain your instructor?s signature on the Acknowledgement of Student Request form. You and your instructor will plan together how accommodations will be implemented throughout the semester. To obtain the required Accommodation Letter, please contact Disability Support Service (DSS) at 301-314-7682 or dissup@umd.edu

## Copyright Notice

Class lectures and other materials are copyrighted. They are the property of the instructor - do not sell them, do not post them on a website. They may not be reproduced for anything other than personal use without written permission from the instructor. Copyright infringements may be referred to the Office of Student Conduct.

## Academic Accommodations for Students who Experience Sexual Misconduct

The University of Maryland is committed to providing support and resources, including academic accommodations, for students who experience sexual or relationship violence as defined by the University's Sexual Misconduct Policy. To report an incident and/or obtain an academic accommodation, contact the Office of Civil Rights and Sexual Misconduct at 301-405-1142. If you wish to speak confidentially, contact Campus Advocates Respond and Educate (CARE) to Stop Violence at 301-741-3555. As 'responsible university employees' faculty are required to report any disclosure of sexual misconduct, i.e., they may not hold such disclosures in confidence. For more information: `http://www.umd.edu/ocrsm/`

## Diversity

The University of Maryland values the diversity of its student body. Along with the University, I am committed to providing a classroom atmosphere that encourages the equitable participation of all students regardless of age, disability, ethnicity, gender, national origin, race, religion, or sexual orientation. Potential devaluation of students in the classroom that can occur by reference to demeaning stereotypes of any group and/or overlooking the contributions of a particular group to the topic under discussion is inappropriate.

For information on elms, counseling, health, learning workshops, tutoring, writing help, student rights in undergrad courses, questions about graduation or add/drop/withdraw, please see `http://www.ugst.umd.edu/courserelatedpolicies.html`.