PHIL 370: Logic, Sets and Computation

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Semester:	Fall 2016
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Course Website:	myelms.umd.edu/courses/1205095
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Office Hours:	Tuesdays, 2:15pm - 4:15pm
Class Times:	MW 2:00pm- 3:15pm
Class Location:	JMZ 0103

Course Description

This course is an introduction to meta-logic. "Meta-logic" is so-called because it is the discipline that studies logic itself. Logic proper is concerned with canons of valid inference, and its symbolic or formal version presents these canons using formal languages, such as those of propositional and predicate, a.k.a., first-order logic. Meta-logic investigates the properties of these language, and of the canons of correct inference that use them. It studies topics such as how to give precise meaning to the expressions of these formal languages, how to justify the canons of valid inference, what the properties of various proof systems are, including their computational properties. These questions are important and interesting in their own right, because the languages and proof systems investigated are applied in many different areas—in mathematics, philosophy, computer science, and linguistics, especially—but they also serve as examples of how to study formal systems in general.

Like any discipline, meta-logic both has a set of results or facts, and a store of methods and techniques, and this course covers both. Some students won't need to know some of the results we discuss outside of this course, but they will need and use the methods we use to establish them. The Löwenheim-Skolem theorem, say, does not often make an appearance in computer science, but the methods we use to prove it do. On the other hand, many of the results we discuss do have relevance for certain debates, say, in the philosophy of science and in metaphysics. Philosophy students may not need to be able to prove these results outside this course, but they do need to understand what the results are—and you really only *understand* these results if you have thought through the definitions and proofs needed to establish them.

The course format consists of weekly lectures (Mondays and Wednesdays, 2:00pm - 3:15pm). All readings for this course are available on ELMS. ***Students are strongly encouraged to put their laptops and other devices away during the lecture.***

> **WARNING**: Although this course builds on material from PHIL 170, it is very different in character. In this course, we prove theorems *about* logical systems (and not *in* logical systems, e.g., there will be be almost no formal proofs). Doing well in PHIL 170 is no guarantee that this will come easy to you.

Course Goals

By the end of the semester students will be able to define well known logical systems (propositional logic, first order logic and modal logic); be proficient with basic set-theoretic reasoning and mathematical induction; understand the proofs of important meta-logical theorems (completeness, compactness and decidability); explain the similarities and differences between propositional logic, first order logic and modal logic; and explain the basic mathematical model of computation (Turing Machines).

Textbook

We will not follow a particular textbook for this course. All the required reading for this course will be available on ELMS. Much of the primary text is based on the open logic textbook (an open source logic text): openlogicproject.org

About the Open Logic Project: The *Open Logic Text* is an open-source, collaborative textbook of formal meta-logic and formal methods, starting at an intermediate level (i.e., after an introductory formal logic course). Though aimed at a non-mathematical audience (in particular, students of philosophy and computer science), it is rigorous.

The *Open Logic Text* is a collaborative project and is under active development. Coverage of some topics currently included may not yet be complete, and many sections still require substantial revision. We plan to expand the text to cover more topics in the future. We also plan to add features to the text, such as a glossary, a list of further reading, historical notes, pictures, better explanations, sections explaining the relevance of results to philosophy, computer science, and mathematics, and more problems and examples. If you find an error, or have a suggestion, please let the project team know.

The project operates in the spirit of open source. Not only is the text freely available, we provide the LaTeX source under the Creative Commons Attribution license, which gives anyone the right to download, use, modify, re-arrange, convert, and re-distribute our work, as long as they give appropriate credit.

Please see the Open Logic Project website at openlogicproject.org for additional information.

Additional Readings.

Consult the following texts for additional readings about topics that will be discussed in the course. The additional readings are provided for people that would like to explore different perspectives on the topics discussed in the course.

- `http://www.logicinaction.org`: A free online textbook providing a general introduction to logic.
- H. Enderton, *A Mathematical Introduction to Logic* (second edition), Academic Press, 2002.
- G. Boolos, J. Burgess and R. Jeffrey, *Computability and Logic*, Cambridge University Press, 2007.

Communication about this course

I will use email 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.

All announcements (e.g., changes to the schedule, hints about the problem sets) about the course will be posted on the ELMS announcement page.

`https://myelms.umd.edu/courses/1205095/announcements`

Please make sure that you check this page regularly and/or receive the email notifications from ELMS when the page is updated.

Grading Policy

The course requirements are:

- participation (25%),
- problem sets (25%),
- Exam 1 (10%), and
- Exam 2 (20%), and
- final exam (20%).

I will grade on a curve (this means that, for example, a final average of 90% may turn out to be an A rather than an $A-$). See the undergraduate catalogue for the official 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`.

Participation: Throughout the semester, I will give short in-class quizzes. These in-class quizzes will generally not be announced and could take place at any time during the lecture. There will be approximately 10-12 in-class quizzes this semester. The purpose of these in-class quizzes is to encourage participation and to test basic comprehension of the material. ***I will drop the 2 lowest grades***.

Although I will not take attendance, students are *strongly encouraged to attend all lectures*. This is a fast-paced course, so you will quickly fall behind if you miss lectures. Students are responsible for any announcement made during the lectures.

Problem Sets: There will be approximately 5 problem sets. Each will consist of 2-3 problems, and students will submit their answers via ELMS. Late problem sets will be accepted and points will be deducted according to the following scheme:

1 day late:	lose 2% of the total points
2 days late:	lose 5% of the total points
3 days late:	lose 10% of the total points
4+ days late:	0 points

Exams: There will be two exams:

- Exam 1: Wednesday, September 14 during class.
- Exam 2: Wednesday, October 26 during class.

Make-up exams will not be scheduled after the exam date (except for emergencies such as illness or death in the family).

Final Exam: The final will be an in-class exam given during finals week. It will be a cumulative exam covering all the topics discussed throughout the semester (a review sheet will be provided towards the end of the semester).

Final exam week is **December 14 - 20**. The official final exam schedule is not available until mid-semester. Consult

`https://ntst.umd.edu/soc/exam/search?courseId=&sectionId=&termId=201608`

for the Fall 2016 exam schedule.

A student may seek to reschedule final examinations so that he or she has no more than three (3) examinations on any given day. It is the responsibility of the student to initiate the rescheduling or be responsible for taking the examination as originally scheduled. If requesting to reschedule the exam, please notify the instructor at least 2 weeks before the scheduled exam date (**December 2, 2016**).

Course Schedule

Below is a tentative schedule for the semester (consult the ELMS course site for the most up-to-date information about due dates for the assignments). This is an ambitious syllabus, which may change given the students background and interests.

Background: Sets, Functions, Relations, and Induction

Readings: Mathematical background: readings from the OpenLogic project.

Description: The first part of the course provides the necessary mathematical background: elementary reasoning about sets, relations and functions. In addition, I will introduce mathematical induction.

Important Date: The first exam will be on Wednesday, September 14 during class. The exam will cover the material from Chapters 1 - 5 of the online text book (Mathematical Background). A review sheet with sample problems will be available by Friday, September 9.

Monday	Tuesday	Wednesday	Thursday	Friday
Aug 29th **Lecture** Introduction	30th	31st **Lecture** Sets, Relations, Functions Readings: Chapters 1, 2, 3	Sep 1st	2nd
5th No Class	6th	7th **Lecture** Size of Sets and Induction Readings: Chapters 4, 5	8th	9th
12th **In-Class Problem Session** Sets, Relations, Functions and Induction Readings: Chapters 1 - 5	13th	14th **Exam 1** Online Textbook, Chapters 1 - 5	15th	16th

The Logic of "All" and "Some"

Readings: Notes on natural logic available on ELMS.

Description: The first logical system that we will discuss is a syllogistic logic: the logic of "All" and "Some". The main motivation for studying this logic is that it provides a very simple example of a soundness and completeness result.

Important Dates: The first problem set is due on Friday, September 30 at 11:59pm (submitted via ELMS).

Monday	Tuesday	Wednesday	Thursday	Friday
Sep 19th **Lecture** Notes on Natural Logic	20th	21st **Lecture** Notes on Natural Logic	22nd	23rd

Monday	Tuesday	Wednesday	Thursday	Friday
26th **In-Class Problem Session** Notes on Natural Logic	27th	28th	29th	30th **Problem Set 1** Due: 11:59pm

Propositional Logic

Readings: Notes on propositional logic by Melvin Fitting (available on ELMS).

Description: I assume that most people will already be familiar with propositional logic (also called sentential logic). We will discuss a number of results about propositional logic (truth-functional completeness, deduction theorem and compactness).

Monday	Tuesday	Wednesday	Thursday	Friday
Sep 26th	27th	28th **Lecture** Notes on Propositional Logic	29th	30th
Oct 3rd **Lecture** Notes on Propositional Logic	4th	5th **Lecture** Notes on Propositional Logic	6th	7th **Problem Set 2** Due: 11:59pm

Modal Logic

Readings: Notes on Modal Logic (by E. Pacuit), Chapters from *Modal Logic for Open Minds* by Johan van Benthem.

Description: I will introduce a modal logic (syntax, semantics and a proof theory). We will discuss the key properties of propositional modal logics (decidability and axiomatic completeness). We will also introduce some basic model theory, discussing notions of invariance of the propositional modal language, and results about what can be expressed in the propositional modal language.

Important Dates: I will be away at a conference October 10 - 14. The lectures for that week will be online. I can set up times to chat/Skype, if necessary.

Monday	Tuesday	Wednesday	Thursday	Friday
Oct 10th **Online Lecture** Notes on Modal Logic *Away at conference*	11th	12th **Online Lecture** Notes on Modal Logic *Away at conference*	13th	14th
17th **Lecture** Notes on Modal Logic	18th	19th **Lecture** Notes on Modal Logic	20th	21st **Problem Set 3** Due: 11:59pm
24th **In-Class Problem Session** Modal Logic	25th	26th **Exam 2**	27th	28th

First Order Logic

Readings: First Order Logic: readings from the OpenLogic project.

Description: The main part of the course is a rigorous introduction to first order logic. I will introduce the syntax, semantics, and a natural deduction system. We will discuss the main results (axiomatic completeness, expressivity results, compactness and the Löwenheim-Skolem Theorem).

Important Dates: The second exam is Monday, November 21 during class. A review sheet will be made available about a week before the exam.

Monday	Tuesday	Wednesday	Thursday	Friday
Oct 31st **Lecture** Introduction to First-Order Logic Reading: First Order Logic, Chapter 1	Nov 1st	2nd **Lecture** First Order Theories Reading: First Order Logic, Chapter 2	3rd	4th

Monday	Tuesday	Wednesday	Thursday	Friday
7th **Lecture** Natural Deduction Reading: First Order Logic, Chapter 3	8th	9th **Lecture** Natural Deduction Reading: First Order Logic, Chapter 3	10th	11th
14th **Lecture** Completeness Reading: First Order Logic, Chapter 4	15th	16th **Lecture** Completeness Reading: First Order Logic, Chapter 4	17th	18th **Problem Set 4** Due: 11:59pm
21st **Lecture** Completeness Reading: First Order Logic, Chapter 4	22nd	23rd No Class Thanksgiving	24th	25th

Computability Theory

Readings: Turing Machines: readings from the OpenLogic project.

Description: We conclude the course by discussing computability theory. I will introduce Turing machines and undecidability.

Monday	Tuesday	Wednesday	Thursday	Friday
Nov 28th **Lecture** Turing Machines Reading: Computability, Chapter 1	29th	30th **Lecture** Turing Machines Reading: Computability, Chapter 1	Dec 1st	2nd
5th **Lecture** Undecidability Reading: Computability, Chapter 2	6th	7th **Lecture** Undecidability	8th	9th **Problem Set 5** Due: 11:59pm

Monday	Tuesday	Wednesday	Thursday	Friday
12th **Concluding Remarks**	13th	14th	15th **Review Session (tentative)**	16th

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.

Academic Support

You should make sure you are familiar with the rules regarding proper academic conduct as outlined at `http://www.shc.umd.edu/`.

Accommodations. Students who require special accommodations should inform the instructor at the beginning of the course, and must provide the appropriate documentation from the DSS office (see `http://www.counseling.umd.edu/DSS/`).

Course Procedures and Policies

Consult the following webpage for the official procedures and policies for this course:

www.ugst.umd.edu/courserelatedpolicies.html