

Symbolic Logic

Course Info: Phil 441, Sec. 01, Spring 2019

Location: College Hall 314

Days/Time: Tues & Thurs 12:25-1:40

Instructor: Charles Lassiter **Office:** Campion 205

Office hours: Mon and Fri 10-11, Tues 8-9, Thurs 1:45-2:45, and by appt

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“...doing philosophy ought to be *fun*.” — Paul Grice, “Reply to Richards” in *Philosophical Grounds of Rationality*

“Philosophy is thinking really hard about the most important questions and trying to bring analytic clarity to both the questions and the answers.” — Marilyn McCord Adams in *Philosophy Bites*

Course Description

Logic has been a staple of philosophy for thousands of years. While there are many interesting twists and turns in its development, we will focus on *first-order* logic as it was developed by luminaries like Peirce, Frege, and Boole. Very broadly speaking, this combines the logic of Aristotle’s syllogisms (e.g. All A’s are B’s; all B’s are C’s; therefore all A’s are C’s) and Stoic propositional logic (e.g. if the first, then the second; the first; therefore, the second) by utilizing tools from mathematics. We will also be looking at metalogical issues of completeness and consistency, and we’ll close out the term by looking at Godel’s famous incompleteness proofs from 30,000 feet.

Learning Outcomes

By the end of the course, students will be able to:

1. Complete proofs/test for consistency in first-order logic
2. Use truth-tables
3. Sketch proofs of soundness and completeness for fragments of first-order logic
4. Describe mathematical beauty and find analogues in their own majors.

Course Texts

1. Richard Jeffrey, *Formal Logic: Its Scope and Limits*, 4th edition. Indianapolis: Hackett Publishing. Other materials will be made available on Blackboard.

Course Work

1. Elegance Project: Mathematicians and logicians will frequently talk about *elegance* (also: *beauty*). What is elegance? A proof is described as elegant when something deep is proven by relatively austere means. There's a sense of awe and that typically accompanies elegant proofs. An elegant proof often startles us; it's something unexpected.

This project is a multi-part project, the parts of which you will submit over the course of the term. The primary aim of the project is for students to come away with a sense of what mathematicians and logicians mean when they say a proof or idea is 'elegant' or 'beautiful' and to see if there's an analogous notion in their own fields.

- a. **Part 1:** Finding an example of elegance/beauty in math or logic. Write up 3 pages (1) summarizing the idea/proof and (2) trying to explain why you find it beautiful/elegant (maybe consider why you're drawn to it; is there something surprising or startling about it?) Here are a few very popular ones. These are good cases because their proofs are understandable by people whose background is no greater than high school math, but please don't feel constrained by these suggestions.
 - i. There is no largest prime number (first proven by Euclid)
 - ii. $\sqrt{2}$ is irrational (first proven by Pythagoras)
 - iii. The Pythagorean Theorem (many different proofs)
 - iv. The set of fractions is denumerable, i.e. can be put into a 1-1 correspondence with the cardinal numbers (first proven by Cantor)
 - v. There is no way to exhaustively enumerate the list of real numbers — i.e. that there are more real numbers than rational numbers, i.e. that there are *grades of infinity* (first proven by Cantor)
 - vi. The number of people you need in a room in order to have a better-than-chance likelihood of two people sharing a birthday is 23 (aka the Birthday Problem).
 - vii. In playing the Monty Hall game, changing the door maximizes your chances of winning (aka the Monty Hall Problem)

I have a couple of requests. First, whatever you pick, please choose something that you feel you understand. For example, the Banach-Tarski paradox is very cool, but a grasp of its proof requires understanding quite a bit of advanced mathematics. If you feel comfortable with such math, then please by all means tackle it! But if you don't, then find something you feel like you could explain to a friend or classmate. Second, please don't pick the insolvability of the halting problem or the undecidability of 1st order logic. We'll be doing these together in class.

- b. **Part 2:** Describing mathematical elegance/beauty. Look online for articles in which mathematicians talk about mathematical beauty. Write up 3 pages reporting what they say and why your proof from Part 1 is elegant/beautiful according to what you have found.

- c. **Part 3:** Finding an example in your own field. Find an idea or argument or proof in your major field of study that is elegant or beautiful. Explain it. Is the sense of awe for that idea or argument or proof the same as or different than what the mathematicians and logicians said from part 2? Explain. Please remember that the notion of elegance is essentially tied to a *formal system*. That is: the kinds of things that are elegant are formal things. (For a reminder about formal systems, reread the pages from *Metalogic*, assigned for the 2nd day of class.) So when you're thinking about an idea or argument or proof in your field, pick something that approximates a formal system. E.g. in psychology, you might pick the Rescorla-Wagner model of conditioning.
- d. **Part 4:** An element of mathematical/logical beauty is that the logician finds something beautiful in a rigorously defined system. ([Ludwig Wittgenstein in the Philosophical Investigations describes this with some disdain as the "crystalline purity of logic"](#) in section 107.) Are findings/developments in your major field of study amenable to description in terms of a rigorously defined system? (Wittgenstein says that we need to give up the idea of a precisely describable world— "Back to the rough ground!" is his rallying cry.) Another way of thinking of this question: are findings/developments in your major able to be reduced to mathematics, as in [this XKCD cartoon](#)? (If your major isn't pictured, e.g. history, think of how findings/developments in your major could be translated into the terms of a discipline that is pictured. E.g. history is translatable into sociology or maybe psychology.) Yet another way to think of this question: is existence, the universe, you, me, everyone you know and love--is it mathematically describable all the way down? Why or why not? Yet *another* way to think about the question: is your field of study open to being translated into a formal system in the way that Hunter describes them?

It's worth separating two questions here. One is an *ontological* question: is everything in reality mathematically (or formally) describable all the way down? Another is an *epistemological* question: can we *know* everything there is to know about the world by means of mathematical description? Why are these questions worth separating? A common attitude is that a field like history can't be described as a formal system. This is an answer to the epistemological question but not the ontological one: even if there's no way to formalize history like there is math, that doesn't entail that math isn't in some essential way a formalizable discipline. That is, there really is something like "mathematical history" even if we don't have the conceptual resources to develop it now or ever. Be clear which issue you're interested in.

2. Take-home midterm and final exams/problem-sets: The purpose of these exams/problem-sets is to give you further opportunities to refine your technical abilities in

doing logic. I will make the midterm questions available to you by the end of the 2nd full week of the semester. The final questions will be available by the end of the week after spring break. (Why “exams/problem-sets” as opposed to “exams” or “problem-sets”? Exams tend to focus only on technical stuff; problem-sets on technical and creative stuff. I’m taking both kinds of assignments and mashing them into one.)

3. Quizzes: Sometimes faculty think about assignments as carrots and sticks: carrots are attractors and rewards for completing an assignment. Sticks are more punitive and unpleasant measures for making sure students keep up with work. Quizzes are sticks. They are short 15-20 minute tests of how well you’re keeping up — particularly with the non-technical material.

Here’s how each of the above contributes to your grade:

Elegance Project: 25%

Quizzes: 15%

Midterm exam/problem-set: 30%

Final exam/problem-set: 30%

Grading Scale

Numerical Value	Letter/GPA point value	Rough idea of what the grade means
94-100	A/4.0	Outstanding. Student goes above and beyond what is required. (E.g. offers an insight/analysis that appears elsewhere in the philosophical literature; does extensive research for papers/presentations.) Concepts elucidated clearly and with novel examples.
90-93	A-/3.7	
86-89	B+/3.3	Very good. Student does more high-quality research than is required for the assignment.
82-85	B/3.0	
78-81	B-/2.7	Average. Doing what is assigned. Note that following the instructions will put you in the orbit of this grade.
74-77	C+/2.3	

70-73	C/2.0	
65-69	C-/1.7	Below average. Doing less than what is assigned. Missing some component(s) of an assignment.
60-64	D/1.0	
<60	F/0.0	Plagiarism. Failure to show anything learned.

Attendance

Students are allowed to miss **twice** the number of weekly meetings. If you exceed the number of absences permitted, your grade will go down one letter for each additional day missed. Exceptions include: documented illness (undocumented illness isn't exempted), religious holidays, military commitments, travelling for sports events (or comparable extracurricular activity, e.g. debate team).

Also, if a student is so tired that they need to put their head on their desk, then that student will be asked to leave and take a nap. It will count as a missed meeting, however.

Late Work

Papers are penalized by one letter grade for each class it is late. If students know ahead of time that they will have some difficulty meeting a deadline, please contact me. I'll be more than happy to take other commitments you might have into consideration when assigning due dates.

Technology in Class

I do not allow students to use laptops, tablets, smartphones, etc. during class. My experience has been that the temptation to stray from the task at hand proves too strong. If you need to use such a machine in class, please come speak with me; I make exceptions on a case-by-case basis.

Please note that if I see a student using a smartphone in class, I will ask that student to gather their things and leave. It is highly disrespectful to everyone in the class to be occupied with a phone while we're creating a learning environment.

Plagiarism and Cheating

Plagiarism, or taking someone else's work without giving credit to the original author, can and must be avoided at all costs. It violates the integrity of scholarship and academic honesty. It is certainly fine to build on or explain the work of others, and in fact, such communal work is necessary to expand our knowledge. But, to claim the other's work as your own is dishonest, and honesty is essential to the life of a student.

Plagiarism and cheating are not tolerated. Academic dishonesty includes, but is not limited to cheating, plagiarism, and theft. Any student found guilty of academic dishonesty is subject to disciplinary action, which may include, but is not limited to, (1) a failing grade for the test or assignment in question, (2) a failing grade for the course, or (3) a recommendation for dismissal from the University. If you have any questions about what does or does not count as plagiarism or

cheating, please feel free to ask me. (See also “Academic Honesty” on page 72 of the [University’s online catalogue](#).)

Statement Concerning Sexual Misconduct

Gonzaga University recognizes the inherent dignity of all individuals and promotes respect for all people. Sexual misconduct is not tolerated at Gonzaga. This includes unwanted physical/sexual contact, sexual assault, and unwanted and harassing sexual comments. (Clearly, this list isn’t exhaustive.) If you have been the victim of sexual misconduct, I want you to know that I am a first point of contact for getting you in touch with mental health services, campus police, and (if you should choose to pursue legal action) city police. As a faculty member, I am interested in promoting a safe and healthy environment. But you should also know that if you tell me anything that incriminates a student, I am legally bound to report that information. The technical terminology here is that I (and all other faculty and administrators) am a *mandatory reporter*. This rule might seem a little draconian, but it prevents faculty and administrators from being passive bystanders: if you tell me something, I’m breaking the law if I don’t tell the relevant people, e.g. Gonzaga University’s title IX coordinator. But I understand that you might not want to begin going down the road of an investigation. Perhaps you just want to talk with someone about what happened. That’s ok. If you would feel more comfortable talking with someone other than me or any other mandatory reporter, here are some phone numbers that will connect you with people to whom you can talk.

- **Gonzaga Health Center** | [509.313.4052](tel:509.313.4052) | 704 E Sharp Avenue
- **Gonzaga Counseling Center** | [509.313.4054](tel:509.313.4054) | 324 E Sharp Avenue
- **Any priest serving as a sacramental confessor or any ordained religious leader serving in the sacred confidence role.** | [509.313.4242](tel:509.313.4242)
- **Lutheran Community Services and SAFeT** | [509.624.7273](tel:509.624.7273)

The people you would talk to at these numbers are either (1) bound to keep the information to themselves (e.g. a priest serving in the role of confessor) or (2) are not affiliated with the university in a such capacity that makes them mandatory reporters (e.g. Lutheran Community Services). But no matter whether you talk to me, another faculty member/administrator, or someone at one of the above numbers, there are lots of people in the Gonzaga community who want — and are able — to help.

If you have questions or concerns or need to file a report, please contact:

Stephanie N. Whaley
Title IX Director
509-313-6910
whaleys@gonzaga.edu
Business Services Building 018

Or by filling out [an online form](#).

Notice to Students with Disabilities or Medical Conditions:

The Americans with Disabilities Act (ADA) is a federal anti-discrimination statute that provides

comprehensive civil rights protection for persons with disabilities. Among other things, this legislation requires that all students with disabilities be guaranteed a learning environment that provides reasonable accommodation for their disabilities. If you believe you have a disability/medical condition requiring an accommodation, please call or visit the Disability Access office (room 209 Foley Library, 509-313-4134).

Course Evaluation:

At Gonzaga, we take teaching seriously, and we ask our students to evaluate their courses and instructors so that we can provide the best possible learning experience. In that spirit, we ask students to give us feedback on their classroom experience near the end of the semester. I will ask you to take a few minutes then to carry out course/instructor evaluation online. Please know that I appreciate your participation in this process. This is a vital part of our efforts at Gonzaga to improve continually our teaching, our academic programs, and our entire educational effort.

Expectations:

Here is what you have a right to expect of me:

1. Be on time for class
2. Respond to communications in a timely fashion (usually, within 24 to 36 hours)
3. Return your work with feedback and to explain feedback when needed
4. Return your work in a timely fashion (usually, 7-10 days)
5. Be available for office hours (with exceptions for illness or other unexpected events)
6. Answer your questions to the best of my abilities as a professional philosopher
7. Assess your work in a critical and unbiased manner
8. Listen to and address your concerns.

Here is what I have a right to expect of you:

1. Be on time for class
2. Ask questions when you do not understand
3. Accept that some questions do not have clear answers and be willing to entertain various possibilities of answers
4. Submit your assignments in a timely fashion (with exceptions for unexpected events); all due dates are in the syllabus and I will not remind you of them
5. Come to office hours if you need additional help
6. Use class time effectively: attend to what we're talking about. If you don't understand, ask a question. If you don't see the point of what we're doing, say so.
7. Listen to and address my concerns regarding the class.
8. Arrive at class with all necessary texts for the day

Course Schedule

Note: This is a projected reading schedule. We may get a little behind if some concepts require further fleshing out or generate discussion. That's ok. We'll compensate accordingly. On the other hand if students want to move faster, I can *definitely* find more material and will adjust the schedule as needed.

Date	Reading	Big Ideas	Assignments
1/15	“The Webpage That Cannot Exist”	What is symbolic logic? A <i>very</i> brief history and apology for study	
1/17	from <i>Metalogic: an Introduction to the Metatheory of Standard First Order Logic</i> , p. 1-15	What are formal languages? What is the difference between logic and metalogic?	
1/22	from Shapiro, <i>Thinking About Mathematics</i>	Structuralism in the philosophy of mathematics	Quiz
1/24	Jeffrey, 1.1-1.11	propositional constants, operators, truth-tables	
1/29	Jeffrey, 1.1-1.11	propositional constants, operators, truth-tables	
1/31	Jeffrey, 1.12 - 1.17	formation rules, validity, consistency, a Deduction Theorem (kinda sorta) for our system	Elegance project part 1
2/5	Jeffrey, 2.1 - 2.5	tableaux	
2/7	Jeffrey, 2.1 - 2.5		
2/12	SNOW DAY	NO CLASSES	DO YOU WANNA BUILD A SNOWMAN?
2/14	Jeffrey, 2.7 - 2.10	soundness, completeness, decidability proofs	
2/19	Smullyan, pp. 30-38 (BB). Note that pp. 30-35 are optional reading.	Compactness and Maximally Consistent Sets	Quiz

2/21	Jeffrey, 3.1 - 3.3	quantifiers	
2/26	Jeffrey, 3.5 - 3.7	formation rules	
2/28	Jeffrey, 3.9 - 3.11	semantics	Elegance project part 2
3/5	Jeffrey, 3.13 - 3.15	soundness, completeness, decidability proofs	
3/7	Jeffrey, 4.1 - 4.9	overlapping quantifiers	Take-home midterm/problem set
3/12	Spring Break!	Spring Break!	
3/14	Spring Break!	Spring Break!	
3/19	Jeffrey, 4.11 - 4.15	soundness, completeness proofs, and <i>undecidability</i>	
3/21	from <i>Metalogic: an Introduction to the Metatheory of Standard First Order Logic</i> , p. 16-30	Denumerable and non-denumerable sets, effective enumeration	Quiz
3/26	Jeffrey, 5.1 - 5.4	Identity, definite descriptions, number	
3/28	Jeffrey, 5.6 - 5.9	Soundness and completeness	Elegance project part 3
4/2	Jeffrey, 6.1 - 6.5	Functions	
4/4	Jeffrey 6.9	Robinson arithmetic	
4/9	Jeffrey 6.9	Robinson arithmetic	
4/11	Jeffrey, 7.1 - 7.2	Register machines	
4/16	Jeffrey, 7.3 - 7.4	Church-Turing Thesis	Quiz — new date!
4/18	TBD	Paradoxes of self-reference	
4/23	Jeffrey, 7.5, 7.7	Unsolvability of the halting	Elegance project part

		problem	4
4/25	Jeffrey, 8.1-8.3	Proof of undecidability	
4/30	Jeffrey, 8.4 - 8.7	Focusing undecidability results	
5/2	TBD	Looking beyond: Godel and incompleteness	
TBA			Final Exam/Problem-set, TBA