

PH340-15 Logic III: Incompleteness & Undecidability

21/22

Department

Philosophy

Level

Undergraduate Level 3

Module leader

Benedict Eastaugh

Credit value

15

Module duration

10 weeks

Assessment

100% exam

Study location

University of Warwick main campus, Coventry

Description

Introductory description

Developments in formal logic in the late 19th and early 20th century opened up the prospect of an entirely formalised mathematics, in which all mathematical statements could be expressed by sentences of a formal language, all proofs could be transformed into deductions in a logical system, and all basic mathematical principles could be codified as axioms. This naturally raised a question of completeness: given such a formal language, and an axiomatic theory T expressed in that language, could T either prove or refute every sentence in the formal language, and thus provide a solution (at least in principle) to every mathematical question expressible in that language? Gödel's incompleteness theorems showed that in general the answer is no: for any consistent axiomatic theory T containing a sufficient amount of arithmetic, there will be sentences in the language of T which T can neither prove nor refute (the first incompleteness theorem). Moreover, such a theory T cannot even prove its own consistency (the second incompleteness theorem). This demonstrates the limits of formalisation in mathematics: there can be no universal formal theory capable of answering all mathematical questions, and we can only prove the consistency of our theories by appealing to strictly stronger theories. In this module we will explore the incompleteness theorems: precisely what they say, and how they are proved. Along the way we will develop an understanding of formal theories of arithmetic and elementary computability theory.

Module aims

To expose students to Gödel's First and Second Incompleteness Theorems and their significance for the foundations of mathematics. Related material about formal arithmetic and elementary computability theory will also be developed.

Outline syllabus

This is an indicative module outline only to give an indication of the sort of topics that may be covered. Actual sessions held may differ.

Week 1: review of first-order logic, the language of arithmetic, the standard model

Week 2: crash course in computability, representing numerical properties

Week 3: formal arithmetic theories

Week 4: primitive recursive functions and relations

Week 5: arithmetization of syntax, Gödel numbering

Week 7: the first incompleteness theorem

Week 8: the diagonal lemma, generalizations of the first theorem

Week 9: the second incompleteness theorem, the derivability conditions, Löb's theorem

Week 10: non-standard models of PA, provability logic

Learning outcomes

By the end of the module, students should be able to:

- demonstrate knowledge of Gödel's First and Second incompleteness Theorems and related technical results and definitions (arithmetic representability, proof predicates, self-referential statements, decidable and undecidable theories)
- understand the significance these concepts and results have for logic and mathematics

Indicative reading list

Our primary text will be a version of the Open Logic text customised for PH340.

The same material is also covered in a number of other sources including:

Computability and Logic, 5th ed. by George Boolos, John Burgess, and Richard Jeffrey, Cambridge University Press, 2007

Subject specific skills

write precise mathematical proofs

Transferable skills

use and define concepts with precision, both within formal and discursive contexts

Study

Study time

Type	Required
Lectures	9 sessions of 3 hours (18%)
Seminars	9 sessions of 1 hour (6%)
Private study	114 hours (76%)
Total	150 hours

Private study description

Private study and preparation for classes.

Costs

No further costs have been identified for this module.

Assessment

You do not need to pass all assessment components to pass the module.

Students can register for this module without taking any assessment.

Assessment group B

	Weighting	Study time
In-person Examination	100%	
<ul style="list-style-type: none">Answerbook Pink (12 page)		

Feedback on assessment

Discussion and feedback on exercises during seminar.

[Past exam papers for PH340](#)

Availability

Pre-requisites

Students are advised to take the module PH210 Logic II: Metatheory before taking the module. This module can be taken in the same academic year as PH210.

Courses

This module is Core optional for:

- Year 3 of UMAA-GV19 Undergraduate Mathematics and Philosophy with Specialism in Logic and Foundations

This module is Optional for:

- Year 2 of UMAA-GV19 Undergraduate Mathematics and Philosophy with Specialism in Logic and Foundations
- UPHA-V700 Undergraduate Philosophy
 - Year 2 of V700 Philosophy
 - Year 2 of V700 Philosophy
 - Year 3 of V700 Philosophy
 - Year 3 of V700 Philosophy
- Year 4 of UPHA-V701 Undergraduate Philosophy (with Intercalated year)
- Year 4 of UPHA-V702 Undergraduate Philosophy (with Work Placement)
- UPHA-VQ72 Undergraduate Philosophy and Literature
 - Year 2 of VQ72 Philosophy and Literature
 - Year 3 of VQ72 Philosophy and Literature

This module is Core option list A for:

- UMAA-GV17 Undergraduate Mathematics and Philosophy
 - Year 3 of GV17 Mathematics and Philosophy
 - Year 3 of GV17 Mathematics and Philosophy
 - Year 3 of GV17 Mathematics and Philosophy
- Year 3 of UMAA-GV19 Undergraduate Mathematics and Philosophy with Specialism in Logic and Foundations

This module is Core option list B for:

- UMAA-GV17 Undergraduate Mathematics and Philosophy
 - Year 2 of GV17 Mathematics and Philosophy
 - Year 2 of GV17 Mathematics and Philosophy
 - Year 2 of GV17 Mathematics and Philosophy
- UMAA-GV19 Undergraduate Mathematics and Philosophy with Specialism in Logic and Foundations
 - Year 2 of GV19 Mathematics and Philosophy with Specialism in Logic and Foundations
 - Year 4 of GV19 Mathematics and Philosophy with Specialism in Logic and Foundations

This module is Core option list C for:

- Year 4 of UMAA-GV19 Undergraduate Mathematics and Philosophy with Specialism in Logic and Foundations

This module is Option list A for:

- UPHA-VL78 BA in Philosophy with Psychology
 - Year 2 of VL78 Philosophy with Psychology
 - Year 3 of VL78 Philosophy with Psychology
- UMAA-GV17 Undergraduate Mathematics and Philosophy
 - Year 3 of GV17 Mathematics and Philosophy
 - Year 3 of GV17 Mathematics and Philosophy
 - Year 3 of GV17 Mathematics and Philosophy
- UMAA-GV19 Undergraduate Mathematics and Philosophy with Specialism in Logic and Foundations
 - Year 3 of GV19 Mathematics and Philosophy with Specialism in Logic and Foundations
 - Year 4 of GV19 Mathematics and Philosophy with Specialism in Logic and Foundations

This module is Option list B for:

- Year 2 of UHIA-V1V5 Undergraduate History and Philosophy
- UMAA-G105 Undergraduate Master of Mathematics (with Intercalated Year)
 - Year 2 of G105 Mathematics (MMath) with Intercalated Year
 - Year 3 of G105 Mathematics (MMath) with Intercalated Year
 - Year 5 of G105 Mathematics (MMath) with Intercalated Year
- UMAA-G100 Undergraduate Mathematics (BSc)
 - Year 2 of G100 Mathematics
 - Year 2 of G100 Mathematics
 - Year 2 of G100 Mathematics
 - Year 3 of G100 Mathematics
 - Year 3 of G100 Mathematics
 - Year 3 of G100 Mathematics
- UMAA-G103 Undergraduate Mathematics (MMath)
 - Year 2 of G100 Mathematics
 - Year 2 of G103 Mathematics (MMath)
 - Year 2 of G103 Mathematics (MMath)
 - Year 3 of G100 Mathematics
 - Year 3 of G103 Mathematics (MMath)
 - Year 3 of G103 Mathematics (MMath)
 - Year 4 of G103 Mathematics (MMath)
 - Year 4 of G103 Mathematics (MMath)
- UMAA-G106 Undergraduate Mathematics (MMath) with Study in Europe
 - Year 2 of G106 Mathematics (MMath) with Study in Europe
 - Year 3 of G106 Mathematics (MMath) with Study in Europe
 - Year 4 of G106 Mathematics (MMath) with Study in Europe
- Year 2 of UMAA-G1NC Undergraduate Mathematics and Business Studies
- Year 2 of UMAA-GL11 Undergraduate Mathematics and Economics
- Year 2 of UECA-GL12 Undergraduate Mathematics and Economics (with Intercalated Year)
- UMAA-GV17 Undergraduate Mathematics and Philosophy
 - Year 2 of GV17 Mathematics and Philosophy
 - Year 2 of GV17 Mathematics and Philosophy
 - Year 2 of GV17 Mathematics and Philosophy

- UMAA-GV18 Undergraduate Mathematics and Philosophy with Intercolated Year
 - Year 2 of GV18 Mathematics and Philosophy with Intercolated Year
 - Year 2 of GV18 Mathematics and Philosophy with Intercolated Year
- UMAA-G101 Undergraduate Mathematics with Intercolated Year
 - Year 2 of G101 Mathematics with Intercolated Year
 - Year 4 of G101 Mathematics with Intercolated Year
- UPHA-VQ72 Undergraduate Philosophy and Literature
 - Year 2 of VQ72 Philosophy and Literature
 - Year 3 of VQ72 Philosophy and Literature