The University of Iowa
The College of Liberal Arts and Sciences
Spring, 2024

Title of Course: Abstract algebra II (MATH:5010:0001)
Course meeting time and place: 11:30am-12:20pm /MWF, 205 MLH
Department of Mathematics: https://math.uiowa.edu/

Course ICON site: To access the course site, log into Iowa Courses Online (ICON) https://icon.uiowa.edu/index.shtml using your Hawk ID and password.

Course Home
The College of Liberal Arts and Sciences (CLAS) is the home of this course, and CLAS governs the policies and procedures for its courses. Graduate students, however, must adhere to the academic deadlines set by the Graduate College.

Instructor: Ionut Chifan (yo-nüts key-fun)
Office location: 1B MLH
Student drop-in hours: MWF 10:30pm-11:20pm, and by appointment.

Discussion section: There will be a 1-hour weekly discussion section for problem solving that will be held on the Zoom platform. The time for this as well as the other relevant information (Zoom coordinates, etc) will be communicated later.

Phone: 319-335-0777
E-mail: ionut-chifan@uiowa.edu
DEO Contact information: Professor Ryan Kinser, 14 MLH, ryan-kinser@uiowa.edu

Prerequisite: MATH: 5000

Description of Course
This two-semester course is designed as a comprehensive introduction to abstract algebra. It covers in detail many fundamental concepts in algebra such as groups and homomorphisms, Sylow Theorems, rings, finitely generated modules over a PID, Galois theory, vector spaces, linear transformations and matrices, canonical forms, etc. Due to the wide variety of intrinsic connections with other fundamental areas of mathematics and beyond such as number theory, topology, geometry, aspects in ergodic theory, functional analysis, operator algebras, various chapters in applied mathematics, DNA structure, etc, this is mandatory background for every student pursuing a PhD in Mathematics, Computer Science, etc.

Learning Objectives
The course is intended to familiarize the student with many of the aforementioned fundamental concepts in algebra. In his lectures the instructor will encourage students to

develop the much-needed algebraic thinking---a skill which should not be missing from the background of any mathematician. To do this his will promote a more conceptual understanding of this theory by exposing students to detailed proofs of many important classical theorems in algebra. This is part of instructor's efforts to teach students how to write rigorous proofs, one of the main goals of this class. In addition, the three hours lectures the instructor will be complemented by a one-hour discussion session intended to develop extensively students' ability to apply the theory in solving various complex problems pertaining this theory. This is expected to provide all students with a solid preparation for the upcoming PhD Qualifying exam in Algebra.

Textbook/Materials

For my lectures and homework problems I will use the following book:

David S. Dummit and Richard M. Foote: Abstract Algebra, 3rd Edition, John Wiley and Sons.

This will be complemented with my personal notes and other relevant resources, which will be shared with the students as the class progresses.

First semester covered chapters 1-9 as follows:

Groups (Chapters 1-6) and include the following topics as a minimum:

1. Basics: groups, subgroups, integers mod n, symmetric groups, alternating groups, matrix groups, dihedral groups, cyclic groups, generators and relations, subgroup lattice, cosets, Lagrange's theorem, normal subgroups, quotient groups
2. Four isomorphism theorems
3. Towers of subgroups/subnormal series, composition series, solvable groups
4. Group actions and permutation representations, normalizers, centralizers, groups acting on themselves by multiplication and by conjugation, Cayley's theorem, class equation, automorphisms
5. Sylow's theorems plus applications for groups of small order
6. Direct products, semidirect products
7. Commutator subgroups, derived series, connection to solvable groups, S_n is not solvable for n>4.

Rings (Chapters 7-9) and include the following topics as a minimum:

8. Basics: rings, subrings, matrix rings, polynomial rings, integral domains, ring homomorphisms, ideals, quotient rings
9. Isomorphism theorems for rings
10. Properties of ideals, maximal ideals, Zorn's lemma, prime ideals
11. Chinese remainder theorem
12. Rings of fractions
13. Euclidean domains, principal ideal domains, unique factorization domains, prime elements and irreducible elements

14. More on polynomial rings: Gauss' Lemma, irreducibility criteria for polynomials (reduction modulo an ideal; Eisenstein; etc)

Second semester will cover chapters 10-14 as follows:

Modules and Vector Spaces (Chapters 10-12) and include the following topics as a minimum:

15. Basics: modules vs. vector spaces, submodules, Z-modules, F[x]-modules, algebras, module homomorphisms, quotient modules, isomorphism theorems for modules
16. Generation of modules, direct sums and direct products, free modules (universal mapping property)
17. Exact sequences of modules, Short Five Lemma, split exact sequences, short exact sequences ending in a free module split
18. Vector space basics (finite and infinite dimensional), matrices, change of basis, dual vector spaces
19. Multilinear functions and determinants
20. Introduction to Noetherian rings and modules (left and right)
21. Fundamental theorem of finitely generated modules over PIDs: invariant factor and elementary divisor decomposition
22. Smith normal form, Cayley-Hamilton Theorem, rational canonical form, Jordan canonical form

Fields and Galois Theory (Chapters 13-14 PLUS supplement with Lang's Algebra book as needed) and include the following topics as a minimum:

23. Basics: fields, extension fields, multiplicativity of degrees, algebraic vs. transcendental extensions, minimal/irreducible polynomials of algebraic elements, finitely generated extensions, finite extensions
24. Embeddings, extensions of embeddings, composites
25. Existence of algebraically closed fields and algebraic closures, uniqueness of algebraic closure
26. Splitting fields (existence and uniqueness), normal extensions
27. Separable and inseparable polynomials, finite fields, perfect fields
28. Separable extensions, primitive element theorem
29. Galois extensions as separable and normal extensions, fundamental theorem of finite Galois theory (state it so that most of it goes through for infinite Galois extensions), Artin's theorem
30. Abelian/cyclic extensions: Galois groups of cyclotomic extensions, Galois groups of finite fields
31. Galois groups of composite extensions
32. Linear independence of characters, cyclic extensions, root extensions, solvability by radicals (may assume characteristic 0, i.e., may avoid Artin-Schreier extensions), connection to solvable Galois groups
33. Insolvability of the general quintic, discussion of the general polynomial of degree n
34. Classical straightedge and compass constructions

Academic Honesty and Misconduct
All students in CLAS courses are expected to abide by the CLAS Code of Academic Honesty. Undergraduate academic misconduct must be reported by instructors to CLAS according to these procedures. Graduate academic misconduct must be reported to the Graduate College according to Section F of the Graduate College Manual.

Student Collaboration:

The homework for this course is designed to help you master your knowledge related to the topics covered during lecture. As such, you may work on the homework problems and other assignments with others or use online resources. However, please be aware that to master the skills needed for this class, practice is required and that to do well on the final exam you will need to work many of these problems multiple times without help. Be sure to test your knowledge by doing much of the homework on your own. Even if you collaborate with your colleagues when solving the homework problems, I strongly encourage you not to copy, mot-a-mot, the solutions from others but instead try to write them in your own understanding. This is an excellent exercise proven to help students with their material comprehension.

Student Complaints
Students with a complaint about a grade or a related matter should first discuss the situation with the instructor and/or the course supervisor (if applicable), and finally with the Director or Chair of the school, department, or program offering the course.

Drop Deadline for this Course
You may drop an individual course before the deadline; after this deadline you will need collegiate approval. You can look up the drop deadline for this course here. When you drop a course, a "W" will appear on your transcript. The mark of "W" is a neutral mark that does not affect your GPA. Directions for adding or dropping a course and other registration changes can be found on the Registrar's website. Undergraduate students can find policies on dropping and withdrawing here. Graduate students should adhere to the academic deadlines and policies set by the Graduate College.

Grading System and the Use of +/-
Final course grade will be assessed based on your performance in the following activities:

Homework: 20% - on 10 assignments

Midterm I: 25% - on 2/14, 6:30-8:30pm (location TBD)

Midterm II: 25% - on 3/27, 6:30-8:30pm (location TBD)

Final: 30% - TBD

As the class progresses, all grades will be recorded on ICON.

I will use the +/- grading system. Cutoffs for the letter grade are expected to follow the recommended scale given by CLAS below, and cutoffs for +/- are at the discretion of the instructor. You should not view this as a predetermined grade scale for assigning the final grade, but rather as a guaranteed minimum grading scale.

A [100,93); A- [90,93)

B+ [87,90); B [83,87); B- [80,83)

C+ [77,80); C [73,77); C- [70,73)

D+ [67,70); D [63,67); D- [40,63)

F [0, 40)

Next, I will briefly explain what this means. Let's say you finished the course with a 89%. This guarantees a B+. However, based on various factors such as material difficulty, the performance of the entire class in the course, etc, the grades may be curved in a way that the 89% corresponds to a grade of A-. But 89% will never be lower than a B+. In other words, any type of curving in this class is designed to only help you. If you are curious about your standing in the class, or your potential grade, please do not hesitate to reach out to me!

The grade of A+ will be awarded in extremely rare circumstances only for truly exceptional performance in the class.

Course attendance: Attendance is expected for each class meeting, as it will help you better understand the concepts covered in lectures. If you miss a class, you are responsible for any assignments/announcements made/material covered.

Participation in class discussions: I strongly encourage you to actively participate in class discussions; ask questions or ask for more explanations whenever you feel confused; in this class there is NO stupid question! Also, as a general rule, for each lecture you should spend at least two hours on reading/homework/repeating the material, etc. You should start working over the homework problems right after the relevant sections are covered. If you encounter any difficulties, I strongly recommend you seek help immediately! Don't postpone it until one day before the exam! Also remember this: small deficiencies at the beginning tend to rapidly grow into big ones.

Assignments: There will be weekly homework assigned primarily of problems from the book and other problems of my choosing. As the semester progresses, the assignments and their due

dates will be announced during the lecture time and will be also posted on ICON. The lowest homework score will be dropped. Solutions for the homework problems will be posted on the ICON. No late homework will be accepted unless extraordinary circumstances are encountered. The HW must be submitted typed in Latex (or similar). For example, you could use Overleaf to generate it---is fairly easy to use and there is a pretty good option free of charge. Keep in mind that learning Latex as early as possible is an excellent skill which will serve you well throughout your career as a mathematician (or any other type of scientist). In any case, the HW you turn in should look neat and professional. The following guidelines should be followed:

- It must be typed on an 8.5x11 inch white paper using black ink.
- It should be stapled. (There is no stapler in the classroom.)
- The problems must be answered linearly in the order they are assigned.
- It should look need with, with space left between margins and in the margins.
- It should not have scratch work or scribbles on it.
- Your solutions should clearly indicate your reasoning, credit will not be given if you do not show your work.
- The problems statements must appear on your HW directly before your solutions. You do not need to write the problems word by word, but it should be clear enough so someone can understand the problems without having to consult the book.

Date and Time of the Final Exam TBD

Calendar of Course Assignments and Exams

Week	Beg-End	No lectures	Chapters covered	Activities
1	1/16 - 1/19	2	15	
2	1/22 - 1/26	3	15,16	Hw
3	1/29 - 2/2	3	17,18	Hw
4	2/5 - 2/9	3	19,20	Hw
5	2/12 - 2/16	3	20,21	Exam
6	2/19 - 2/23	3	22	Hw
7	2/26 - 3/1	3	23	Hw
8	3/4 - 3/8	3	24,25	Hw
9	3/18 - 3/22	3	26,27	Hw
10	3/25 - 3/29	3	27,28	Exam
11	4/1 - 4/5	3	29,30	Hw
12	4/8 - 4/12	3	30,31	Hw
13	4/15 - 4/19	3	31,32	Hw
14	4/22- 4/26	3	32,33	Hw
15	4/29 - 5/3	3	34	Hw

College of Liberal Arts and Sciences (CLAS) Course Policies
Attendance and Absences

Course attendance: Attendance is expected for each class meeting, as it will help you better understand the concepts covered in lectures. If you miss a class, you are responsible for any assignments/announcements made/material covered.
University regulations require that students be allowed to make up examinations which have been missed due to illness or other unavoidable circumstances (eg involvement in other UI authorized activities or sports, etc). So, students that missed an exam or assignment due to any of these reasons must notify the instructor immediately. They are also strongly encouraged to use the CLAS absence form on ICON under the Student Tools.
Students with mandatory religious obligations or UI authorized activities must discuss their absences with me as soon as possible. Religious obligations must be communicated within the first three weeks of classes.
Exam Policies

Communication: UI Email
Students are responsible for all official correspondences sent to their UI email address (uiowa.edu) and must use this address for any communication with instructors or staff in the UI community.

Other Expectations of Student Performance

Cell phones policy: I am expecting you to NOT use your cell phones, i-pads, or computers during the lecture time for other purposes than class related.

Changing grade policy: If I change your grade on a homework or exam you should always remind me in the same day by e-mail that I have changed your grade.

Where to Get Help

Students will find the following resources useful for this course:

Writing Center: http://www.uiowa.edu/~writingc/

Speaking Center: http://clas.uiowa.edu/rhetoric/for-students/speaking-center

Math Tutorial Lab: 125 MLH http://www.math.uiowa.edu/math-tutorial-lab

Tutor Iowa: https://tutor.uiowa.edu/

University Policies

Accommodations for Students with Disabilities
Basic Needs and Support for Students
Classroom Expectations
Exam Make-up Owing to Absence
Free Speech and Expression
Mental Health
Military Service Obligations
Non-discrimination
Religious Holy Days
Sexual Harassment/Misconduct and Supportive Measures
Sharing of Class Recordings