Syllabus and General Information

MTH 327H: Honors Intro to Analysis *(Fall 2020)* **Willie Wong**
MWF 10:20a-11:10a (see below) wongwwy@math.msu.edu

COVID/Remote-learning Info

Instructional Modality.— Remote, flipped w/ both synchronous and asynchronous activities

Synchronous course activities.— Zoom Meeting ID XXXX, passcode XXXX

Mon 10:20a-11:10a Office hours*, attendance optional.

Wed/Fri 10:20a-11:10a Group discussion and small-group work, attendance required.

**Additional office hours available by appointment.*

Communication/tools.— (see D2L site for links)

D2L site Announcements, links to assignments, submission of written work, grades.

Eli Review Peer review of written work.

Perusall Collaborative reading/annotation of lecture notes.

Email Expect response within two working days; emails sent after Friday 4pm will receive a response by Tuesday morning.

Zoom Synchronous course activities on MWF.

Microsoft Team One-on-one office hour appointments; final oral interview.

Course Description.— A fast-paced first introduction to single variable real analysis, this course provides the rigorous underpinnings of the mathematical techniques taught in Calculus 1 and 2.

The first half of the course consists of an axiomatic discussion of the real number line and its properties, with strong emphasis on its completeness relative to the order structure. This leads to a rigorous discussion of limits and convergence of directed sets of real numbers, with sequences and series being particular applications.

The second half of the course deals with properties and operations on real valued functions of one variable. The notion of limits is used to define continuity and differentiability of functions. The Intermediate Value and Mean Value Theorems are highlights. Riemann(-Henstock-Stieltjes) integrability of functions is introduced to illustrate convergence in more general sense. Time permitting sequence and series of functions and their convergence properties will be discussed.

Course Pre-requisites.— Students are expected to be . . .

. . . familiar with the *how* (but not necessarily the *why*) of single-variable calculus (MTH132, MTH133, or their equivalents);

. . . comfortable reading and writing mathematical proofs (MTH299, MTH309, or MTH317H).

Components to Your Grade.— (See §4 and §6 for more details.)

4% Attendance and in-class participation

20% Out-of-classroom reading, annotation, and discussion

12% Written Work: Peer review participation

50% Written Work: Content and style of submission

14% Final oral interview*

**Students who do not participate in the oral interview cannot earn a final grade higher than 2.0 on the MSU scale.*

Contents

§1 Welcome to MTH 327H: Honors Intro to Analysis!

This is a fast-paced course in single variable real analysis. Our goal is to understand properties of the real number line $\mathbb{R}$ and properties of functions whose domain and range are both (subsets of) $\mathbb{R}$.

"Why study real analysis?" you ask.—

- *Real analysis provides the rigorous underpinnings behind differential and integral calculus, the subjects covered in Calculus I and II at this university.*
- *The central idea of real analysis, that of limits and convergence, not only pervades all analytic branches of mathematics, but is isolated, distilled, and vastly generalized by the entire branch of topology.*

Calculus, as originally construed by Newton and Leibniz, was based the idea of *infinitesimals* (Newton called them *fluxions* and Leibniz *differentials*). In the modern calculus classroom, many operations are described also via an appeal to an "intuitive grasp" of how these infinitesimals behave. However, there are reasons to be wary of the use of infinitesimals: the fact that infinitesimals are supposed to square to zero indicate that they do not belong to what we would normally called "numbers". And if they are not numbers, is it really kosher for us to pretend they are numbers and perform computations with them?

This worry was alleviated in the 19th and early 20th century by, among others, Cauchy, Bolzano, Weierstrass, and Dedekind, who showed that a rigorous understand of the idea of a *limit* can justify calculus using only real numbers, and previous appeal to the infinitesimals can be regarded as a short-hand for limiting operations that do not in fact require such mysterious quantities.[1] The content of this course is designed based on this theme.

This rigorous understanding of limits is (at least in part) the foundation of many modern branches of mathematics.

- The notion that a variable x approaches a value x_0 when the absolute value of their difference $|x-x_0|$ gets ever smaller can be abstracted into the concept of *metric spaces*, which is indispensable in the development of modern *functional analysis*.
- The different behaviors contrasting open and closed intervals can be codified into the basis for the field of *topology*; in this the Intermediate Value Theorem, one of the highlights of this course, is transformed in the notion of "connectedness" of a set.
- The infinitesimals of Newton and Leibniz survive, in an altered form, as the concept of a *tangent space* around which modern *geometry*, both *differential* and *algebraic*, is built.

What this course is about.— The starting point of this course is an understanding of the *real number line*. Our emphasis will be on its *completeness*: specifically, our mental picture of the real number line being a continuous line with *no holes*. "Having no holes" turns out to require some precise definition. Naïvely one may start by saying that the number line has no holes because "between any two numbers one can always find a third number", and hence there cannot be any sizable gaps between the numbers. However, this property of "between any two one can always find another" is also satisfied by the set of *rational numbers* (that is, numbers that can be formed as the ratio of two integers). Yet even since the ancient Greeks one understands that there are numbers beyond the rationals (for example, starting with a isosceles right triangle with legs of length 1, the length of the hypotenuse, which is $\sqrt{2}$, is known to not be a rational number). So somehow this property of "between any two one can always find another" is not sufficient to describe "having no holes". In fact, one can easily ask whether there could be still *hidden* holes within the familiar real number line, which consists of the usual rational

[1] It is worth noting that in the mid 20th century mathematicians also discovered ways to augment the real numbers with infinitesimals in a completely rigorous manner that allows one to actualize these short-hands as "numbers" in an extended number system. In modern parlance these are studied by the fields of "non-standard analysis" (which is not a pejorative term) and "synthetic differential geometry".

and irrational numbers. The first three weeks of this course will be dedicated to answering versions of this question: we will begin with an *axiomatic* description of the real numbers. In fact, one can *build* the real number line from the rational numbers (through a sophisticated version of the "decimal expansion" process), and demonstrate that not only does the real number line not have any holes, one can in fact not squeeze any more numbers into the line without breaking things.

It turns out that this notion of having no holes—*Dedekind completeness*—and the ability to sensibly take limits of sequences are two sides of the same coin. In the second three weeks we will explore the mathematical implications of the ability to take limits, and discuss some theorems that guarantee the convergence of sequences (and more generally, nets). That rational numbers are insufficient for a full development of mathematics, yet the irrational (real) numbers can always be obtained as limits of rational numbers is a recurring theme of modern analysis: that certain *nice family* of objects is insufficient for problem solving (the solutions belong to the "holes"), yet to actually get any traction in understanding what elements of the *completed family* look like, the only hope is to approach it with ever improving approximations by elements of the original nice family.

Having fully developed our understanding of the real numbers, in the remaining 5 weeks we will focus on properties of functions that map real numbers to other real numbers. Specifically we will be concerned with properties in relation to the process of taking limits, i.e. the properties of *continuity*, *differentiability*, and *integrability*. In addition to forming the basis of the theory of differential and integral calculus, these three topics are the germs of the modern mathematical fields of *topology*, *geometry*, and *measure/probability theory* respectively. Some of the highlighted applications in this course captures fundamental ideas in those more advanced fields. For example, the Intermediate Value Theorem for continuous functions can be rephrased as a statement in topology about continuous functions preserving "connectedness" of a set. The hope is that real analysis is not only useful for you as a topic in its own right, but also a connection to other modern mathematical ideas which you may pursue in the future.

§1.1 Teaching Philosophy.— As you read through this syllabus, I wish you keep in mind some of the philosophy that underlies the design decision for how this course is built.

Degree of generality.— While it is the case that a lot of what we will discuss can be generalized to more advanced contexts, I will make a concious decision *not* to make such generalizations, and frame all discussions entirely within the context of the real number line and functions on the reals. On the other hand, whenever a choice presents itself I will prefer the proof of a statement that leans more heavily on methods that generalize easily to more advanced contexts, as opposed to proofs that rely on extremely special properties of the real numbers. I make these choices because many of the main theorems presented in this course are either "intuitively obvious" (the main exception being perhaps Borel's Covering Lemma), or something already presented in Calculus 1 and 2, or both. The novelty of this course for you does not lie so much in the "mathematical facts" discussed, but in the "mathematical structures" that enables us to proceed axiomatically and verify these intuitions and facts. By deliberately limiting the scope to the real numbers and functions on the real, we better focus the attention on the methods of proof and the logical reasoning underlying these verifications.[2] By choosing generalizable proofs I am not expecting you to perform the generalizations yourselves; rather, I do so with the hope that when you do encounter the similar statements and proofs in more general contexts in your future studies, this experience will offer you a comforting degree of familiarity.

Skills you will practice.— At MSU, you should've taken at least *two* proof-based mathematics classes prior to this one. In this honors course we expect you to start coming into your own in *reading and writing* mathematics. In the professional, academic practice of mathematics, very little of the

[2] However, you should absolutely feel free to ask about generalizations in in-class discussions or office hours.

communication of mathematical idea take place in the form of *lectures*. Most of the time seminars and lecture presentations serve little more purpose than as an advertisement of one's work, with the actual transference of knowledge happening through small group (or one-on-one) discussions and the reading and writing of journal articles. To promote these skills, I will be running this course in a flipped format, with emphasis on

- *active reading* of the lecture notes, with collaborative annotation and commentary;
- *small group discussion* of the course material, guided by exercises;
- *anonymous peer criticism* of each other's writings.

Additionally, you will practice the preparation of electronic documents with mathematical content. Therefore:

- *All written work* for this course are to be typed, and submitted in PDF format.

In professional practice the most common way to prepare documents with mathematical notation is using the LaTeX system; I will highly recommend you doing so, and support you by providing a basic LaTeX template file for typing up your answers to the problem sets. You may use other word processing systems if you wish, provided you meet certain formatting guidelines.

§1.2 Tentative Schedule of Topics.— The intended topic for each week of the course is listed below in order; new course material will be introduced until Thanksgiving. Only ten weeks are included: this gives us one week of flexibility if we need to devote more time on some topics. (If not, we can discuss topics related to sequences and series of functions.) The two weeks after Thanksgiving will be used to conduct oral interviews. Needless to say, the schedule is subject to change.

1. Review of sets of integers $\mathbb{Z}$, the rationals $\mathbb{Q}$, and the reals $\mathbb{R}$, and their algebraic properties; review of notations and notions from elementary set theory: sets, functions, relations, cardinality
2. Partial orders, maximum/al, mininum/al, supremum, infimum; total order; closed versus open intervals
3. Order completeness; $\mathbb{R}$ versus $\mathbb{Q}$ and the Dedekind construction; Archimedean property; Borel Covering Lemma
4. Monotonicity, directed sets, and nets in $\mathbb{R}$; convergence in $\mathbb{R}$; Cauchy's criterion, limit superior and limit inferior.
5. Sequences and series, some convergence theorems
6. Monotone Convergence Theorem; Bolzano-Weierstrass Theorem
7. Continuity and uniform continuity of functions; the Intermediate Value Theorem; the Extremal Value Theorem
8. Differentiability of functions; Cauchy's Mean Value Theorem; L'Hospital's Rule; Taylor's Theorem
9. Riemann Integration and its properties
10. The Henstock and Stieltjes Integrals

§2 Course Materials

There are no *required textbooks* for this course; lecture notes will be offered. We will be using heavy amounts of technology facilitated discussion in this course, however, and so there will be some required hardware/software to enable your participation.

§2.1 Required technology.—

Computer For access of websites, reading of electronic documents, and preparation of written assignments.

Internet Access

Webcam *(Can be via smart phone)* for participation in synchronous class activities on Zoom, and

for participation in one-on-one meetings (especially the final oral interview).

Zoom We will conduct synchronous class activities on Zoom.

Microsoft Teams One-on-one meetings (including the final oral interview) with the instructor will be conducted using Microsoft Teams.

LaTeX software Students are expected to submit written assignments in PDF format with line numbering enabled to facilitate peer review. A LaTeX template file will be provided by the instructor; this file can be used both with a personal installation of a TeX distribution on the student's personal computer, or via the Overleaf cloud service. Overleaf can be used at no cost to the student.

(Students may alternatively compose their written work in another document preparation system such as Microsoft Word. The only hard formatting requirement that must be followed is that the submitted work be (a) typed, with one file per question, (b) in PDF format, and (c) has line numbering.)

Perusall Web service for collaborative annotation and commenting of lecture notes. No cost to students.

For help using Perusall, visit Perusall's user support page.

Eli Review Web service to facilitate peer review of student work. Students submit their work online and receive that of another student to critique. No cost to MSU students.

For help using Eli Review, visit Eli Reivew's user support page.

D2L Learning management system, where we keep the grade book, post announcements, and where you submit your final write-up for each problem set to be graded.

For help using D2L, visit the MSU D2L help site, or e-mail ITHelp@msu.edu.

§2.2 **Suggested Reference Textbooks.—** If you feel the need to consult additional reference beyond the provided lecture notes, the following two books are recommended.

1. **Title** Principles of Mathematical Analysis
   Author Walter Rudin
   ISBN 007054235X
   Publisher McGraw-Hill
   Comment A copy (3rd edition) is available on reserve in the MSU Library.
   Comment Most of the course topics are covered within chapters 1-6 of this book but not necessarily in the order given; our discussion will be very light on topology, meaning very little of chapter 2 will be covered. However, the topics of *nets* and *Henstock integrals* are more fashionable in modern presentations of the subject and are not part of this book.
2. **Title** Handbook of Analysis and its Foundations
   Author Eric Schechter
   ISBN 0126227608
   Publisher Academic Press
   Comment This book is available electronically through the MSU Library. Click link to access its catalog entry.
   Comment This is an excellent and exhaustive general reference for mathematical analysis; those who wish to go significantly further than what we can discuss in one semester are welcome to use it for self-study (that's the author's original intent for this Handbook). I include this book mostly for its extensive discussion of *nets* (and its dual concept, *filters*), as well as its comprehensive modern perspective on *integration theory* (Chapter 24). Be warned! This book is self-contained with extensive cross referencing, and so is not easy to

read if you start from the middle.

§2.3 Other Optional Course Material.— To facilitate group discussion of mathematics in a Zoom break out room, here are some ideas.

- A decidedly low-tech and low cost method is to point a webcam at a writing pad. To hold up your WebCam or smart phone, you can use one of the stands mentioned in this article, or potentially just pile up a stack of books.
- Another method is to get large easel pads which you can draw on using a thick marker, or a medium-sized white board. In this case you do not need a camera stand.
- If you have a touch-screen enabled device, consider using a stylus to write on a drawing app, and share screen via Zoom.
- An alternative to touch-screen enabled device is a pen tablet device such as a Wacom Intuos or a Boogie Board Jot which allows you to capture drawing and writing on your computer screen.

§2.4 Policy on WebCam use.— The use of WebCams to show your face is *not required* for the synchronous online activities. You should turn on your WebCam only if you feel comfortable doing so. For the Friday small group discussion you may choose to only use your WebCam to facilitate showing your work: it is perfectly acceptable to have your WebCam turned on and pointed at a writing pad or a white board. Alternatively, you may choose not to use your WebCam at all and just use a digital writing implement and share your screen.

The only time the use of WebCam is required is for the **final oral interview**. This is for two purposes: to a lesser degree I use this to verify your identity, since the oral interview is a graded component of this course; to a greater extent I use this so that I can see any non-verbal behavioral signals that may allow me to more effectively guide the discussion.

§3 Learning Objectives

In each of the bulleted items below, the "…" is to be replaced by "You will, at the end of this course, be able to".

§3.1 Content Knowledge Objectives.—

Structure of the real numbers.—

- …*explain* what it means for the real numbers to be a **complete ordered field**.
- …*invoke* the **Archimedean property** suitably for constructing counterexamples.
- …*devise mathematical arguments* that take advantage of the completeness property, specifically the **least upper bound** and **greatest lower bound** property.
- …rigorously *define* what it means for a set of real numbers, indexed by a directed set, to **converge**.
- …*verify* the convergence of a set of real numbers, indexed by a directed set, using **Cauchy's criterion**.
- …*articulate* the relation between the **Bolzano-Weierstrass Theorem**, the **Monotone Convergence Theorem**.
- …*illustrate, by way of examples and counterexamples* the different analytical properties of open and closed intervals, such as the **Borel Covering Lemma** and **continuity properties of functions**.

Continuity and differentiability of functions.—

- …*state* the definitions of continuity and differentiability of functions both in terms of **the** $\epsilon - \delta$ **definition** and in terms of **nets**.
- …*apply* the definitions to prove or disprove the continuity/differentiability of explicitly defined

functions.
- . . . *determine* whether statements abut all continuous/differentiable functions is true or false, and provide a rigorous proof or a counterexample.
- . . . *justify* the necessity of each hypothesis in the statements of the **Intermediate/Extremal/Mean Value theorems** by way of counterexamples.

Integrability of functions.—
- . . . *state* the definition of **Riemann and Henstock integrability** of functions both in terms of **the $\epsilon - \delta$ definition** and in term of **nets**.
- . . . *apply* the definitions to prove or disprove the integrability of explicitly defined functions.
- . . . *apply* the definitions to prove or disprove the integrability of classes of functions satisfying given conditions.
- . . . *relate* integration to differentiation through the **Fundamental Theorem of Calculus**.

§3.2 Skills Objectives.—
- . . . correctly *use* mathematical terminology in their appropriate context within a mathematical argument.
- . . . *articulate orally* a mathematical concept or argument.
- . . . *read critically* a piece of mathematical writing and identify gaps and weaknesses in the argument; *fill-in* and *remedy* said gaps and weaknesses.
- . . . *compose* extended arguments with style and organization that does not detract from the presentation of the content.
- . . . *hold a mathematical dialogue* both orally and in writing.
- . . . *prepare* typed electronic documents with mathematical content.

§4 Assessments and Due Dates

§4.1 Reading Assignments.— When reading research articles, frequently a paragraph or two of arguments can take several days to digest. The lecture notes that I will be preparing will not be as dense, but it will still require *active*, *engaged reading*. To promote this we will be making use of **Perusall**, a collaborative annotation software designed for active reading and conversation between many participants.

What is Perusall and how to use it.— Perusall is a *free* software platform designed for flipped classrooms, where students are expect to complete the *knowledge transfer* portion of the learning process at home, asynchronously, with the classroom time dedicated to *knowledge consolidation* practice through discussion and group work. The platform provides, among other features, **annotation tools** where you, as students, can comment on the assigned readings, highlight important concepts, ask questions of each other and respond to them, and more. Please visit their website to find out more.

To gain access to this course on the Perusall platform:
1. Visit `https://perusall.com`, click *Login*, and then **Log in using your MSU Google Account**.
   - You can learn more about your MSU Google Account at `https://googleapps.msu.edu`.
   - Please make sure to use your MSU account and not a personal account; I will use the NetID to verify your identity and assign participation credit.
2. Select *I am a student* and enter the course code [REDACTED, SEE D2L POST].

Design decisions.— I will upload lecture notes at least one week in advance of their due dates. Please expect approximately 12—15 pages of reading per week (depending on the topic it may be a bit longer or shorter). I highly recommend breaking the reading into chunks, split between at least three

different sittings.

To promote engagement with the material, you will find:

- Sometimes the argument/proof given in the lecture notes are deliberately *incomplete*. These could either be explicitly pointed out within the notes, or it could be a hidden omission to see if you are paying attention. If you see things like this, please try to point them out and try to provide the missing details.
- The lecture notes will have many *exercises* or *food for thought* listed. Try your best (collaboratively) to answer as many of them as possible before the due date. Your contributions will help guide the synchronous discussions on Wednesdays and Fridays.

Your participation will be graded; see §6 for details.

§4.2 In-class Discussion.— On Wednesdays and Fridays, during the synchronous hour, we will discuss your readings. On Wednesdays I will try to answer any lingering questions you may have, and draw your attention to important points that I noticed after reading your contributions to Perusall. On Fridays we will split up into breakout rooms, with groups of 3–4 students. An exercise sheet will be provided which you should collaboratively work through. The weekly written assignments will draw upon the content of the exercise sheet; the in-class discussion will help bring everyone up to speed, ready for the written work. Additionally, this activity specifically targets your ability to converse orally about mathematics, a skill that will also be assessed in the Final Oral Interview for this class. Please use this opportunity to develop your chops.

Your participation on the Friday small group discussions will be graded; see §6 for details.

§4.3 Written Work.— The main method of assessing your understanding of course content material is through weekly written assignments. Each written assignment will have **four problems** of differing difficulty, on the topics of discussion that week. You are encouraged to work together with other students, provided you follow the guidelines listed in §8 when preparing your submission.

You will find provided on D2L a LaTeX-template file which you can use with any TeX installation. If you have not installed any TeX distribution on your computer, you may also use the (free) Overleaf service to compile your TeX files online. (Those of you who have taken MTH299 should already be familiar with LaTeX.) You may choose not to use LaTeX for the preparation of your submissions, as long as you type up your responses following the guidelines:

- **Each problem should be its own file**. Therefore there should be 4 files you need to prepare each week.
- The title of each document should clearly indicate the Problem Set number and the Problem number the submission is addressing.
- **Do NOT include your name or identifying info anywhere in the text**. To prevent implicit bias, both peer evaluation and grading by instructor will be done *double blind*.
- **You must turn on line numbering**. This is for the ease of your peers when they critique your work. (This is automatically handled by the LaTeX template provided.)

When preparing your write-up, you may make use of any **numbered theorems** (including propositions, lemmas, corollaries, etc.) or **equations** that appear in **any lecture note to date** or displayed in the statements of **any previous problem sets**. (The numbering will be unique so there will be no ambiguity.)

You will be assessed on both mathematical correctness and writing style; see §6 for details.

Peer evaluation.— To promote your skills at critically evaluating written mathematics, and to give you an opportunity to obtain peer feedback on your work prior to turning them in to grading, we will be using **Eli Review** to perform peer review of each other's work.

Every week you will upload your solutions to the problem sets to Eli Review. For each file/problem that you upload, you will be randomly paired with another classmate[3]. You should provide anonymous *constructive criticism* on the work of your classmate(s). At the conclusion of the exercise, you are expected to make use of the feedback you received, as well as anything you may have learned from reading the work of your classmates, to improve your write-up prior to turning it in for grading.

To set-up Eli Review, please:

1. Log-in to D2L.
2. Follow the link in *Announcement* box to get to the corresponding D2L page.
3. Follow the on-screen instructions to create an Eli Review account (if you don't have one already); you will be automatically added to the Eli Review course for this class.

Please be civil to each other when providing feedback. If you feel that another student has been abusive toward you on the platform, please send me an e-mail.

Submission for grading.— Submissions must be typed, in PDF format, and follow the formatting guidelines listed above. Failure to do so will result in a zero on the assignment. To submit your assignment for grading:

1. Go to the course D2L page.
2. Click on "Assigned Work and Submission" in the Navigation Bar, and select "Assignments".
3. Navigate to the appropriate problem set.
4. You will be asked to upload the files for your assignment. *Make sure to attach all four files.*
    - If you made a mistake, you can re-upload your files as long as it is before the due date.
    - Note: you cannot replace just a single file. D2L will only keep the files uploaded in the most recent submission. If you wish to edit any of the files, you have to re-upload all of them.

§4.4 Oral Interview.— At the end of the semester each student is required to conduct an oral interview of no more than 40 minutes with me; the interviews will be scheduled individually. Procedure and rules:

1. I will have enough openings in my schedule to fit every student; it is however your responsibility to make sure you schedule an appointment in a timely manner to ensure a convenient time-slot for you.
2. Do not be late or miss your interview spot. Except in the cases of medical emergencies or loss of internet access, I will not reschedule missed interviews.
3. Thirty minutes prior to the start of the interview, you will receive by e-mail a short list of questions drawn from in-class exercises and from assigned problem sets (possibly slightly modified).
4. I will ask you to turn on your WebCam so I can see you. Please factor this in when selecting the locale where you will conduct this interview.
5. During the interview you will first be asked to spend 5 minutes presenting the solution to the question of your choice from the list emailed. Then you will be asked to spend 5 minutes presenting the solution to the question of my choice from the list emailed. The interview will grow organically from there, and may touch on problems you may not have previously seen (but within the content-knowledge objectives described in §3.1).

§4.5 Due dates.— All times below are listed in US Eastern time; this is UTC-4 in September and October due to Daylight Saving Time, and UTC-5 in November and December.

[3] In the case of only *odd* number of students submitting an assignment, you may on occasion be placed in a group of three.

Reading Assignments Readings (including any comments and annotations) are due on **Perusall** on **Wednesdays** at **10am**. Replies to existing comments can continue to be submitted (and be factored into your grade) until **Fridays** at **10am**. (See §D.)

One reading assignment will be due each Wednesday between September 9 through November 18 (eleven assignments total).

In-class Participation Participation grade will be awarded for attendance and engagement on each **Friday** between September 11 and November 20 (eleven classes in total).

Written Work There will be 11 problem sets, corresponding to the reading assignments.

- Problem sets will become available on D2L on **Fridays** at **noon**. The first on September 11 and the final one on November 20.
- Submission of written work to **Eli Review** in preparation for peer critique are due the following **Monday** at **8pm**. *(Those who do not submit work on time cannot participate in peer critique, and will earn no points for peer review that week.)*
- You will receive your peer critique assignments on Tuesday morning. Your reviews will be due on Eli Review on **Wednesdays** at **10am**. *(For the final assignment, due to Thanksgiving, the peer critique will be due on Friday, November 27, at 11pm.)*
- You will submit your final copy of written work for grading on the D2L assignments page on **Thursdays** at **midnight**. *(For the final assignment, due to Thanksgiving, the final submission will be due on Monday, November 30, at noon.)*

Oral Interview The scheduling website for oral interview will open on or around **November 9**. Scheduling is first-come-first-serve, with availability between **December 1—11**. Scheduling website will close on **December 4**, or when all available slots are filled, whichever occurs first.

§5 A Week in MTH 327H: Honors Intro to Analysis

At any given time in this course you should be simultaneously *doing the reading on new material* while *applying your knowledge on exercises on old material*. To illustrate this, you are expected to, during the week of September 13–19:

	Module 2	Module 3	Module 4
Sep 13–14	Solve problem set assigned on Sep 11, prepare to submit to Eli Review.	Read and annotate on Perusall the lecture notes due on Sep 16.	
Sep 15	Review peer work on Eli Review for Sep 11 Problem Set	—"—	
Sep 16–17	Revise work for Sep 11 Problem Set, turn in on D2L	Work on exercises related to lecture notes due on Sep 16	
Sep 18		Participate in group work during synchronous class time on topics covered in lecture notes of Sep 16. Solve problem set assigned on Sep 18.	Read and annotate on Perusall the lecture notes due on Sep 23.
Sep 19		Solve Sep 18 Problem Set.	—"—

§6 Grading Policy

§6.1 Reading assignments.— The weekly reading assignments (11 in total) will be posted on Perusall; prior to the due-date you are expected to read and annotate (collaboratively with your classmates) the posted material using the Perusall platform. The Perusall platform uses a mixture of artificial intelligence natural language processing and statistical analysis to assign a reading score based on your reading and annotation activities. See §D for a quick discussion on how this works.

For each assignment you will receive a score of 0, 1, 2, or 3, therefore you may earn up to a maximum cumulative total of 33 points. For the purpose of computing your final grade, we will cap the total at **20** points. This means that if you average a 2 out of 3 for 10 out of the 11 weeks, you will receive a perfect score on this portion of your grade.

This portion of your grade is worth 20% of the total course grade.

§6.2 In class participation.— Attendance will be taken for each of the Friday classes between September 11 and November 20 (eleven meetings in total). During the Friday classes students will be divided into breakout rooms to discuss course material. For showing up and participating you earn 1 point. Partial credits may be deducted for tardiness, leaving early, or failure to participate in the small-group discussions (I will bounce around the various breakout rooms to eavesdrop and observe the proceedings).

You may therefore earn a maximum cumulative total of 11 points. For the purpose of computing your final grade, we will cap the total at **8**. This means that if you miss three of the Fridays it is still possible to earn a perfect score on this portion of the course.

This portion of your grade is worth 4% of the total course grade.

§6.3 Written Work: Peer Review.— Prior to submitting your responses to the problem sets for grading by your instructor, you are asked to participate in one round of peer review using the Eli Review platform. There will be 11 written assignments total, with 4 problems on each problem set. For each problem you submit on Eli Review, and for each corresponding peer response that you review,

you get 1 point.[4] Partial credit maybe deducted for bad-faith submissions (for example, if you submit a blank page, or just the sentence "I don't know how to do this problem") and for bad-faith reviews.

With this you may earn up to 4 points per problem set, or 44 points cumulatively in all. For the purpose of computing your final grade, we will cap the total at **30**. This means that if you earn 3 out of 4 available points on 10 of the problem sets you earn a perfect score on this portion of the course.

This portion of your grade is worth 12% of the total course grade.

§6.4 Written Work: Final Submission.— After peer-review you are encouraged to update your responses factoring the comments of your peers. The updated final copy will be graded both for correctness and style. Each question you turn in will be graded out of 4 points, making 16 point maximum per problem set. Of the 4 points per question:

Correctness is worth 3 points. You earn 3 points for a flawless argument, 2 points for argument with minor flaw, 1 point for being on the right track but with major flaws, and 0 point for everything else.

Style is worth 1 point. This refers to the general organization of your argument and the fluency of your mathematical writing. You will earn 1 point unless how you organized/presented your work actually hindered the reader's ability to understand your argument.

The problem sets are not all worth the same: to reward you for improving over the semester, the earlier problem sets are worth less than the later ones. The first problem set is worth 2% of your final grade, while the last one is worth 6%. The table below contains the full details.

PS no.	1	2	3	4	5	6	7	8	9	10	11	Total
% of final grade	2%	3%	3%	4%	4%	5%	5%	6%	6%	6%	6%	50%

§6.5 Final Oral Interview.— The interview will be graded *generously*. It will count toward 14% of your final grade.

§6.6 A Note on the D2L Gradebook.— To work around certain limitations of D2L, the Eli Review portion is shown as being graded out of 3 instead of 4 per problem set, and the Perusall portion is shown as being graded out of 2 instead of 3. *This is entirely due to certain technical limitations of the D2L gradebook.* The numerical score you will see on the grade book corresponds to the description given above.

Additionally, D2L grade book will show, throughout the semester, a calculated final grade. This number is prorated to incorporate only graded assignments. The gradebook also displays the prorated contribution of each individual grade item to the current calculated final grade.

To illustrate the two points above, if after the first 4 weeks, a student has earned the grades of "3, 3, 0, and 0" on the first four Perusall reading assignments, the gradebook display will display as in Figure 1. The first column shows that raw numerical score: note that it displays "3/2" instead of "3/3", as described above. The second column is the prorated weighted contribution. Since only four readings have been assigned and graded so far, the 20% reading score is divided among those assignments yielding 5% each, with the score on the first two assignments earning 7.5% each, yielding a total of 15% to date. This can be used as a fair estimate of your final grade in this portion of the course *if your subsequent performance is similar*. In particular, if you score 3/3 on half the assignments and 0/3 on the other half, you will have earned between 15 and 18 points total on the Perusall portion of your grade.

[4] At times you may be assigned to a group of three students for the review task (this happens for example when we have an odd number of students turning in the work for one problem). In this case you will be expected to provide *two* reviews, one for each of the other students in your group. You may earn an extra 0.5 points for completing the extra review.

Perusall Reading Every week you will be assigned reading assignments, which you must read **actively** on Perusall. Your annotation will be graded out of 3 points each week (11 weeks total). A total of 20 points earned will get you full credit on this category. (For convenience of setting up the gradebook, the baseline max grade is shown as 2pts per week, so in effect you have a chance to earn 1 pt extra credit for within this category per week.)		15 / 20
Week1	3 / 2	7.5 / 5
Week2	3 / 2	7.5 / 5
Week 3	0 / 2	0 / 5
Week 4	0 / 2	0 / 5
Week 5	- / 2	- / -

Figure 1: Illustration of D2L gradebook display.

§6.7 Computation of final grade.— Your final grade is computed in accordance to the percentages listed above. If you have participated in the final oral interview, your final numerical grade is converted to grades on the MSU 4.0 scale via the following table.

To earn a …	1.0	1.5	2.0	2.5	3.0	3.5	4.0
You need at least …	54%	60%	65%	70%	76%	83%	90%

If you did *not* participate in the final oral interview, your grade on the MSU scale is capped at 2.0.

§7 Expectations of Civility

MSU welcomes a full spectrum of experiences, viewpoints, and intellectual approaches because they enrich the conversation, even as they challenge us to think differently and grow. However, we believe that expressions and actions that demean individuals or groups compromise the environment for intellectual growth and undermine the social fabric on which the community is based.

In this course you will frequently interact with other students to provide mutual critique. By providing feedback on each other's ideas and contributions, we grow together to enhance everyone's learning. The expectation and requirement for you to provide constructive criticism should not be taken as an invitation to belittle other students' intellectual contributions. During the small group discussions, within your postings on Perusall, and when performing peer review on Eli Review, please keep in mind the following basic rules of engagement.

Make it about the ideas Criticism should be directed at ideas, not the individual.[5]

Be constructive Instead of just pointing out shortcomings, share how you would make it better.

[5]To help enforce this, peer review on Eli Review will be double blind; you will not know who reviewed your work, and you will not know whose work you are reviewing. Please do not take this to imply you may be mean or impolite to others in your reviews; *I still know who you are*.

Acknowledge your fellow students When engaging in a discussion, do not talk over or ignore others. Every idea that is shared deserves evaluation and consideration.

§8 Course Specific Policy on Academic Integrity

Here are specific policies concerning academic integrity for the graded aspects of this course. Unless otherwise noted in the policy here, the University Policy described in §A applies.

Weekly written assignments You are *allowed* to make use of the following resources, *provided you properly acknowledge their use* as indicated below.

- You may consult other students. No acknowledgement is necessary as students are expected to work together in this class.
- You may incorporate details that you learned from the peer-review process (both suggestions provided to you or content you learned from another student's work during the course of review). No acknowledgement is necessary.
- You may consult other scholarly texts and publications (online or in print). Include in your write up full bibliographic information of the item consulted. *For help on deciding what bibliographic information should be included, and how to format the items, please consult any of the citation guides listed on the MSU Library Website.*
- You may use the `https://math.stackexchange.com` Q+A website. Provide link to your question in your write-up.

While you may use external resources or consult with other students, you *must* write/type your responses in your own words. Copying-and-pasting is not allowed; students found to have copied work from other sources will be assigned a penalty grade.

Eli Review You *may not* share the work assigned to you for review with any other individual.

Reading assignments on Perusall You *may not* share the student and instructor comments and annotations on the reading assignments with individuals outside of this course. You *may* share the underlying reading itself with other people. You *may not* present comments or annotations due to other individuals as your own work.

Final oral interview The oral interview will run over the course of two weeks. You *may not* discuss with other students the content of your final oral interview until December 20, 2020.

§9 Attendance Policy

§9.1 Attendance to Synchronous Elements.— The synchronous elements of this course delivered every **Monday, Wednesday, Friday** between **September 2** and **November 30, 2020** (except for university holidays) at **10:20am–11:10am**. A list of the important dates can be found in §10. The synchronous elements are delivered through Zoom

- Meeting ID: 979 4598 3550
- Passcode: 549813
- *To call in by phone, dial +1 312 626 6799 and enter the meeting ID and passcode above.*

Attendance is *required* for the **Wednesday** and **Friday** meetings. A portion of your grade will be determined by attendance and participation in the activities.

Attendance is *not required* for the **Monday** meetings, which will be run as general Q+A on course material.

§9.2 Grading: Missed Work, Absences, Extensions.— The grading for the attendance/participation portion of the course is, by design, flexible.

Friday in-class participation Students may miss up to 3 of the 11 Friday classes and still receive perfect attendance grade.

Eli Review participation Students may miss, in their entirety, the peer-review portion of the written homework for up to 3 of the 11 assignments and still receive perfect participation grade.

Perusall annotation Students may miss up to 4 of the 11 reading assignments and still receive perfect participation grade.

This built-in flexibility is intended to account for any emergencies (health, family, or internet connectivity), religious observances, and participation in University sanctioned events. Students who miss any synchronous discussions due to such reasons are encouraged to reach out to me to catch up on any material missed.

For **written homework assignments**, it is the students' responsibility to be aware of the course schedule and complete the work in a timely manner. In the case of emergencies or exceptional circumstances, extensions to the due dates may be granted on a case-by-case basis.

§9.3 Final Oral Interview.— Attendance and participation in the individual final oral interview is required. Non-participation will result in final course grade capped at 2.0 on the MSU scale.

§9.4 Internet Connectivity Issues.— Many of the participatory components of this course will be conducted synchronously over the internet through Zoom meetings and Microsoft Team meetings. If you suffer a sudden loss of internet connectivity, you can still join the Zoom meetings via the phone number listed above. If you join a meeting by phone, I may ask you to identify yourself, since Zoom's participant listing will not show your name if you join the meeting by phone.

The grading scheme for in class participation factors in the possibility of emergencies such as loss of internet connection. If internet connectivity is expected to be a persistent or recurring issue for you, please reach out to me at the beginning of term and we can discuss possible arrangements.

If you miss any one-on-one meetings (either office hour appointments or the final oral interview) due to connectivity issues, please contact me as soon as possible so we can reschedule if necessary.

§9.5 Administrative Drop for Non-attendance.— In compliance with federal regulations governing financial aid and veterans education benefits, instructors are required to report students who stop attending or who have never attended class. After the first week of classes, through the middle of the term of instruction, instructors who identify a non-attending student should notify their departmental office. Students may be dropped from a course for non-attendance by a departmental administrative drop after the fourth class period, or the fifth class day of the term of instruction, whichever occurs first. (See §10 for relevant dates.)

§9.6 Religious Observation.— University policy requires

> The faculty and staff should be sensitive to the observance of these holidays so that students who absent themselves from classes on these days are not seriously disadvantaged. It is the responsibility of those students who wish to be absent to make arrangements in advance with their instructors.

Students who are absent from synchronous activities should reach out to me to find out what they missed. With very few exceptions, any impact of religious observances on graded work is already factored into the general grading policy (see §9.2) and no additional accommodations will be made.

§9.7 University Sanctioned Events.— If additional accommodation is needed beyond those provided already in §9.2 for participation in University-sanctioned events, students must contact the instructor in advance of the date of the event and the requested accommodation.

§9.8 Grief Absence.— In the unfortunate case you suffered a familial loss, the University has codified the following procedure for reporting and requesting accommodation. It will be **your responsibility** to

1. notify the Associate Dean of your college of the need for a grief absence in a timely manner, but no later than one week from your initial knowledge of the situation,
2. provide appropriate verification of the grief absence as specified by the Associate Dean, and
3. complete all missed work as determined in consultation with the instructor.

For the initial notification, you may use the Grief Absence Request Form from the MSU registrar's office. It is the *responsibility of the Associate Dean or a designee of your college* to

1. determine with you the expected period of absence — it is expected that some bereavement processes may be more extensive than others depending on individual circumstances,
2. notify the faculty that you will be absent, and
3. receive verification of the authenticity of a grief absence request upon your return.

§10 Important Dates

Sept 2 First day of classes
Sept 7 Labor day, no class
Sept 11 Fourth class period
Sept 28 End of Tuition Refund
Oct 21 Middle of Semester
Nov 9 Begin taking reservations for oral interview slots; first come first serve
Nov 26, 27 Thanksgiving, no class
Nov 30 Last synchronous meeting
Dec 1–11 Oral interviews

§A University Policies on Academic Integrity

§A.1 University Policy.— Article 2.III.B.2 of the *Student Rights and Responsibilities* states: "The student shares with the faculty the responsibility for maintaining the integrity of scholarship, grades, and professional standards." In addition, the Math Department adheres to the policies on academic honesty specified in General Student Regulation 1.0, Protection of Scholarship and Grades; the all-University Policy on Integrity of Scholarship and Grades; and Ordinance 17.00, Examinations.

Therefore, unless authorized by your instructor, you are expected to complete all course assignments, including homework, lab work, quizzes, tests and exams, without assistance from any source. You are expected to develop original work for this course; therefore, you may not submit course work you completed for another course to satisfy the requirements for this course. Also, you are not authorized to use the www.allmsu.com or other "tutoring" Web sites to complete any course work in this course. Students who violate MSU regulations on Protection of Scholarship and Grades will receive a failing grade in the course or on the assignment.

Faculty are required to report all instances in which a penalty grade is given for academic dishonesty. Students reported for academic dishonesty are required to take an online course about the integrity of scholarship and grades. A hold will be placed on the student's account until such time as the student completes the course. This course is overseen by the Associate Provost for Undergraduate Education.

§A.2 Spartan Honor Pledge.— Student leaders have recognized the challenging task of discouraging plagiarism from the academic community. The Associated Students of Michigan State University (ASMSU) introduced the Spartan Code of Honor academic pledge, focused on valuing academic integrity and honest work ethics at Michigan State University. The pledge reads as follows:

> *As a Spartan, I will strive to uphold values of the highest ethical standard. I will practice honesty in my work, foster honesty in my peers, and take pride in knowing that honor is worth more than grades. I will carry these values beyond my time as a student at Michigan State University, continuing the endeavor to build personal integrity in all that I do.*

§B Accessibility

§B.1 RCPD Statement.— Michigan State University is committed to providing equal opportunity for participation in all programs, services and activities. Requests for accommodations by persons with disabilities may be made by contacting the Resource Center for Persons with Disabilities at 517-884-RCPD or on the web at `https://rcpd.msu.edu`. Once your eligibility for an accommodation has been determined, you will be issued a verified individual services accommodation ("VISA") form. Please present this form to me at the start of the term and/or two weeks prior to the accommodation date (test, project, etc). Requests received after this date will be honored whenever possible.

§B.2 Accessibility of course material.— Most of the asynchronous components of the course will be conducted through reading and writing using various technology platforms. Thus of particular concern are support for low-vision users.

D2L has robust support for screen readers. See D2L documentation.

Eli Review conforms with Section 508 standards, and strives to ensure accessibility for low-vision users and those using screen-readers. See `https://elireview.com/support/tech/`.

Perusall has built-in read-aloud function for course documents, in additional to other accessibility features. See Perusall support article on accessibility.

Unfortunately, displayed equations in PDF documents are known to be problematic for screen readers. Please reach out to me if you need accommodation in this regard.

Student works are expected to be prepared using the LaTeX document preparation system. Some resources for low-vision users can be found on the Blind Science website.

This course does not utilize pre-recorded course videos. This course however does involve group work and face-to-face discussion using various video conferencing software. Please let me know as soon as possible if this creates a barrier for you and we can try to work toward a solution with RCPD.

§C Limits to Confidentiality

Essays, journals, and other materials submitted for this class are generally considered confidential pursuant to the University's student record policies. However, students should be aware that University employees, including instructors, may not be able to maintain confidentiality when it conflicts with their responsibility to report certain issues to protect the health and safety of MSU community members and others. As the instructor, I must report the following information to other University offices (including the Department of Police and Public Safety) if you share it with me:

- Suspected child abuse/neglect, even if this maltreatment happened when you were a child;
- Allegations of sexual assault, relationship violence, stalking, or sexual harassment; and
- Credible threats of harm to oneself or to others.

These reports may trigger contact from a campus official who will want to talk with you about the incident that you have shared. In almost all cases, it will be your decision whether you wish to speak with that individual. If you would like to talk about these events in a more confidential setting, you are encouraged to make an appointment with the MSU Counseling and Psychiatric Services.

§D How Perusall Works

(The rubric below is provided by the Perusall website, with some additional minimal editing and formatting applied.)

Perusall helps you master readings faster, understand the material better, and get more out of your classes. To achieve this goal, you will be collaboratively annotating the textbook with others in your class. The help you'll get and provide your classmates (even if you don't know anyone personally) will get you past confusions quickly and will make the process more fun. While you read, you'll receive rapid answers to your questions, help others resolve their questions (which also helps you learn), and advise the instructor how to make class time most productive. You can start a new annotation thread in Perusall by highlighting text, asking a question, or posting a comment; you can also add a reply or comment to an existing thread. Each thread is like a chat with one or more members of your class, and it happens in real time. Your goals in annotating each reading assignment are to stimulate discussion by posting good questions or comments and to help others by answering their questions.

Research shows that by annotating thoughtfully, you'll learn more and get better grades, so here's what "annotating thoughtfully" means: *Effective annotations deeply engage points in the readings, stimulate discussion, offer informative questions or comments, and help others by addressing their questions or confusions*. To help you connect with classmates, you can "mention" a classmate in a comment or question to have them notified by email (they'll also see a notification immediately if online), and you'll also be notified when your classmates respond to your questions.

For each assignment we will evaluate the annotations you submit on time (see below). Based on the overall body of your annotations, you will receive a score for each assignment as follows

3 = demonstrates exceptionally thoughtful and thorough reading of the entire assignment

2 = demonstrates thoughtful and thorough reading of the entire assignment

1 = demonstrates superficial reading of the entire assignment OR thoughtful reading of only part of the assignment

0 = demonstrates superficial reading of only part of the assignment

§D.1 How many annotations do I need to enter?.— When we look at your annotations we want them to reflect the effort you put in your study of the text. It is unlikely that that effort will be reflected by just a few thoughtful annotations per assignment. On the other extreme, 30 per assignment is probably too many, unless a number of them are superficial or short comments or questions (which is fine, because it is OK to engage in chat with your peers). Somewhere in between these two extremes is about right and, thoughtful questions or comments that stimulate discussion or thoughtful and helpful answers to other students' questions will earn you a higher score for the assignment. Note, also, that to lay the foundation for understanding the in-class activities, you must familiarize yourself with each assignment in its entirety. Failing to annotate the entire assignment will result in a lower score.

§D.2 What does "on time" mean?.— The work done in class depends on you having done the reading in advance, so it is necessary to complete the reading and post your annotations before the deadline to receive credit. Your instructor may choose to allow a late annotation period during which the credit for your annotations linearly decreases from 100% at the deadline to 0% at the end of the late annotation period. *[N.B. we will not use a late annotation period for this course; annotations are due on Wednesday before start of class.]*

To encourage discourse, your instructor may provide a reply window after each deadline during which you can continue to reply, for full credit, to questions posted by others. However, the number of additional points you can earn after the deadline is capped at the credit you receive for annotations made on that assignment before the deadline. *[N.B. we will have a late reply window; you may continue to earn credit for replies to other students for up to two days after the due date (so until Friday before class).]*