STA261: Probability and Statistics II (Summer 2024)

Course Instructor:	Rob Zimmerman	**Lectures:**	T,Th 13:00 - 16:00 (EDT)
Course Email:	sta261@course.utoronto.ca	**Spillover:**	T,Th 16:00 - 17:00 (EDT)
Course Website:	q.utoronto.ca/courses/345693	**Location:**	PB B250

Course Description: This course is a mathematically rigorous introduction to statistical inference using the theory built up in STA257, split into six weekly modules. In Module 1, we will learn what a statistic actually is, and discuss certain properties of statistics as they relate to data reduction. In Module 2, we will focus on point estimation, and understand how certain point estimators can be "best". In Module 3, we will move onto hypothesis testing, studying its theory and uses (and misuses). In Module 4, we will start by using our previous theory to construct confidence intervals, and then assess whether our assumptions about the data have been correct from the start. In Module 5, we will extend our notions of point estimation, hypothesis tests, and confidence intervals to "large" samples, and see how useful it can be to consider limiting cases. In Module 6, we will switch focus to the Bayesian paradigm, first discussing priors and prior selection, and then studying Bayesian analogues of point estimation, hypothesis tests, and confidence intervals.

Learning Outcomes: After finishing STA261, you should be able to understand the concepts taught in lecture, explain them in non-technical language, and use them to solve problems and prove results similar to those presented the course. You should also be able to use the theory you learned in STA261 as a basis to critically assess the uses, misuses and abuses of statistics that you will encounter in everyday life.

Prerequisites: The official prerequisites are STA257H1/STAB52H3/STA256H5, which will be strictly enforced. Please don't email me (the course instructor) about waiving prerequisites; these matters are beyond my jurisdiction and can be addressed by contacting the department at ug.statistics@utoronto.ca. Unofficially, you should have a strong calculus background, and you should come into the course with a good amount of *mathematical maturity*, since you will be expected to write and understand mathematical proofs.

Lectures and Tutorials: Lectures will be used to go through theory and examples; see the lecture schedule below for a list of topics. Lectures will be held from 13:00-16:00 *except* on Tuesday July 16 and Tuesday July 30, when lectures will be held from 15:00-17:00 (following the midterms). Generally, the extra hour from 16:00-17:00 will be used to cover any material missed in the prior lectures (if necessary). Your regular attendance in lectures is essential and expected. Lectures will not be recorded, but annotated slides will be posted on Quercus following each lecture.

Office Hours: Instructor office hours will take place in person, while TA office hours will take place online via Zoom; the exact weekly schedule of office hours will be posted on Quercus towards the start of the course.

Piazza: We have a Piazza page for the course: https://piazza.com/utoronto.ca/summer2024/sta261h1s. This resource is meant only to provide help with course concepts and clarify brief administrative questions, so off-topic posts may be removed. While the teaching team will try to monitor the page, it is no substitute for office hours and there is no guarantee that every post will be responded to. You are strongly encouraged to participate and answer the questions of your fellow students (correct and helpful answers will be endorsed). If you do opt to use this service, make sure you're comfortable with the implications for your

privacy; the ways that Piazza shares your personal information are outlined in the Privacy Policy and Terms of Service.

Marking Scheme: Final grades will be calculated according to the following scheme:

Midterms	$2 \times 20\% = 40\%$
Participation	10%
Final Exam	50%

Midterms: Midterms consist of problems similar to those in lecture and on the assignments (see below); the focus will be on material not covered on prior assessments. Each midterm is be 80 minutes long and will be held in EX 310. They will be held according to the following schedule:

Midterm #1	July 16, 13:00 - 14:20 (EDT)
Midterm #2	July 30, 13:00 - 14:20 (EDT)

Participation: There will be two types of participation: participation during lectures (Lecture), and asynchronous participation in weekly topic threads on Quercus' discussion boards (Discussion).

- **Lecture:** Each lecture will include a number of multiple choice questions (MCQs) administered in-lecture through Quercus. These will typically be short conceptual questions intended to test your basic understanding of a certain topic, but they may also include poll-type questions. You will receive full credit for submitting a response, regardless the correctness of your answer. Your Lecture mark (as a percentage) will be calculated as

$$\text{Lecture} = \frac{\text{Number of in-lecture MCQs answered throughout the term}}{\text{Total number of in-lecture MCQs asked throughout the term}}.$$

- **Discussion:** Starting from the second week of classes, there will be weekly topic threads on the Quercus discussion board as a space for you and your fellow students to discuss assignment problems, course topics, and optional readings, and to exchange peer support. The teaching team will be monitoring and contributing regularly to keep the discussions going. We expect you to contribute by working collaboratively with each other, and to build your understanding of concepts by answering each others' questions. Contributions will be graded using a point system, with a maximum of one point available in each of the five weeks; a basic rubric will be posted separately. Your Discussion mark (as a percentage) will be calculated as

$$\text{Discussion} = \frac{\text{Number of points earned for discussion posts}}{5}.$$

Your total Participation mark (as a percentage) will then be calculated as

$$\text{Participation} = \min\left\{0.2 \times \text{Lecture} + \text{Discussion}, 1\right\}.$$

Final Exam: The Final Exam will consist of a cumulative 180-minute written test administered by FAS. It will be scheduled to take place sometime during the final exam period.

Assignments: There will be seven assignments, which are not to be handed in. Assignment 0 will be an initial "warmup" assignment testing your prerequisite knowledge, while Assignments 1–6 will correspond to each of the six course modules. Solutions to Assignments 1–6 will not provided; however, you are welcome to discuss the assignment problems during office hours and on the discussion boards.

Tentative Lecture Schedule:

Module	Lecture	Date	Main Topics
1: Statistics	1	July 2	• Random variables, data, and statistics • Statistical models, parametric families, and inference • Sufficiency and minimality
	2	July 4	• Ancillarity and completeness • The likelihood function and the likelihood principle
2: Point Estimation	3	July 9	• The method of moments • Maximum likelihood • Mean-squared error and the bias-variance tradeoff
	4	July 11	• Best unbiasedness and the Cramér-Rao lower bound • Rao-Blackwellization • The Lehmann-Scheffé theorem
3: Hypothesis Testing	5	July 16	• Test statistics • Size, power, errors, and sample size calculations • p-values and misconceptions
	6	July 18	• The likelihood ratio and likelihood ratio tests • Uniformly most powerful tests
4: Intervals and Model Checking	7	July 23	• Random sets and confidence regions • Confidence intervals via test statistics and pivots
	8	July 25	• The empirical distribution function • Visual diagnostics • Goodness-of-fit tests
5: Asymptotic Extensions	9	July 30	• Consistency and limiting distributions • Asymptotic normality and the delta method • Asymptotic efficiency
	10	August 1	• Approximate variance and the information functions • The trinity of tests • Confidence intervals based on approximate tests
6: Bayesian Statistics	11	August 6	• The Bayesian philosophy • Prior and posterior distributions • Choosing priors
	12	August 8	• Estimation, Bayes factors, and credible intervals • Bayes rules • Asymptotic normality of the posterior

Additional References: There is *no* course textbook – the course is self-contained. However, if you'd like some additional references, *very* roughly speaking, most of the course material corresponds to Chapters 5–9 of the first textbook below, but in the order taken by Chapters 6–10 of the second textbook, and with additional examples selected from the third textbook:

- Michael J. Evans and Jeffrey S. Rosenthal. *Probability and Statistics: the Science of Uncertainty.* Freeman, 2nd ed., 2010.
- George Casella and Roger L. Berger. *Statistical Inference.* Brooks/Cole Cengage, 2nd ed., 2002.
- John A. Rice. *Mathematical Statistics and Data Analysis.* Duxbury Press, 3rd ed., 2006.

Note that the first textbook is (officially) available for free on Mike Evans' website. Buyer beware: there is no guarantee that what you find in these textbooks will be perfectly consistent with our presentation of

the course, and you should not expect me or the TAs to be completely familiar with their contents. These textbooks are *not* a substitute for lecture attendance.

Missed Assessments: See the following policies for each component of the course grade:

- **Missed Midterms:** Missed midterms will receive a mark of 0; there will be no extensions or make-ups for midterms. If you need to miss a midterm for a *legitimate* reason (such as an illness), you must inform us at `sta261@utoronto.ca` within one week of the missed midterm, and the weight of that midterm will be evenly distributed among the other midterm and final exam. You must also forward us one of the following recognized forms of documentation:
  - An Absence Declaration via ACORN (you *must* direct ACORN to forward a copy of your completed form to `sta261@utoronto.ca`); note that students may submit one absence declaration per academic term
  - A UofT Verification of Illness or Injury (VOI) form
  - A letter from your College Registrar's Office
  - A letter of Academic Accommodation from Accessibility Services
- **Missed Participation:** No accommodations will be provided for missed lecture or discussion participation, as the grading scheme already allows you to miss a week of participation and still earn full credit.
- **Missed Final Exam:** If you miss the final exam for a *legitimate* reason (such as an illness), you must submit a petition to request to write the exam at a later time, which will occur sometime after the August final exam period. Note that this make-up exam may have a different format from the original (for example, it may be an oral exam) and *may be prepared by a different instructor*. Note that as per departmental policy, if you do not write the August final exam, your course grade on ACORN will be calculated as if you had obtained a 0 on that exam; if you write a make-up exam in the future, the grade will be adjusted then.

Marking Concerns: Any requests to have marked work re-evaluated must be made in writing within *one week* of the date the work was returned. You must write to `sta261@utoronto.ca` with any re-marking requests. Requests must include a detailed reason for the change that references *objective fact*, and must be made for *legitimate perceived errors only*. The following are examples of unacceptable reasons for requesting a re-mark:

- "I feel my mark was unfair"
- "My friend got a better mark but they wrote the same thing as me"
- "I need a bump to get my GPA over some threshold"

If you find a legitimate marking error, then I'll happily change your mark. However, in the case of any ambiguity over the legitimacy of an error, I'll side with the TAs over you. *By submitting a re-mark request, you are agreeing to have me (the course instructor) re-mark your entire work, and change the grade up, down, or not at all. You are also agreeing that the outcome represents your final mark on the work and will not be contested further.*

Course Communication: If you feel the need to contact the course team, write to `sta261@utoronto.ca`; do *not* email your course instructor or any of the TAs at their UofT email addresses or through Quercus Mail, unless specifically instructed to do so. Emails regarding course concepts you're having trouble with will likely go unanswered, as you should be using office hours, Piazza, or the discussion boards for that.

Etiquette: When communicating with *anyone* in any way – but especially via email – make sure you courteous and respectful. This means using full sentences, not slang like "yo prof, I wanna get the lecture

notes" (a real quote received by a fellow instructor). This is good practice for your eventual transition into industry or grad school. Importantly, *we reserve the right to simply ignore any emails that don't follow these guidelines*. If you need to email us, follow these steps:

- Put "STA261" somewhere in the subject line.
- Start the email with "Hi Rob, ..." or "Dear STA261 Teaching Team, ..." as appropriate, followed by the purpose of your email.
- End the email with a "Thank you", "Sincerely", or something similar that indicates that the email is over, and sign it with your full name and student number.

This policy may seem rigid, but it is not meant to discourage student communication; rather, it is designed to encourage *productive and professional* student communication. It's hard to overstate how much this will help you in your future career. Here's an example of a good email to me:

> Hi Rob,
>
> My name is Bob, and I'm a student in your STA261 class. I would like to follow up on our conversation after yesterday's lecture. Since then, I've determined with complete certainty that $|\log(\text{lcm}(1, 2, \ldots, n)) - n| < \sqrt{n} \cdot \log^2(n)$ for all $n \geq 3$.
>
> Thank you,
> Bob Knobb
> 1005551234

Accessibility Services: Students with diverse learning styles and needs are welcome in this course. If you have a disability/health consideration that may require accommodations, please contact Accessibility Services at (416) 978-8060 or `http://studentlife.utoronto.ca/as`.

Academic Integrity: The University of Toronto's Code of Behaviour on Academic Matters outlines the behaviours that constitute academic misconduct, the processes for addressing academic offences, and the penalties that may be imposed. You are expected to be familiar with the contents of this document. Potential offences on tests include — but are not limited to — the following:

- Using unauthorized aids (internet resources, etc.)
- Communicating with fellow students during a written assessment
- Misrepresenting your identity and/or using any kind of exam writing service
- Submitting altered tests for regrading
- Sending or receiving aid to/from anyone else

Academic offenses will be taken very seriously and dealt with accordingly. If you have any questions about what is or is not permitted in this course, please do not hesitate to contact the STA261 teaching team during office hours or via email at `sta261@utoronto.ca`.