

Department of Statistical Sciences
University of Toronto

STA457H1 /STA2202H F
Time Series Analysis
Syllabus – Fall 2023

Land Acknowledgement

We wish to acknowledge the land on which the University of Toronto operates. For thousandsof years, it has been the traditional land of the Huron-Wendat, the Seneca, and most recently, the Mississaugas of the Credit River. Today, this meeting place is still the home to many Indigenous people from across Turtle Island and we are grateful to have the opportunity to work on this land.

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Course Formats Highlights

This course is an in-person course. Any deviations from this document will be announced on the Quercus course pages. Please keep regularly visited the website link [FAS student FAQs](#) and the course pages at the Quercus.

1. Course and Sections

STA457H1 F /STA2202H F: Time Series Analysis
Section for STA457H1 F/ STA2202H F: L5101

2. Instructor and Team

Professor: Murari Singh
murarii.singh@utoronto.ca (mailto:murarii.singh@utoronto.ca)
Office hours (via zoom meeting): **2 – 3 pm** Friday (The link will be posted on the Quercus.)

TAs and their office hours will also be announced on Quercus.

3. Class Time

Tuesday – PB B2 50, 6:00 PM – 9:00 PM
First lecture: Tuesday, September 12, 2023

4. Course Content

This course will introduce the key concepts, methods, and computing toolboxes for the analysis of time series data. Topics include descriptive methods; filtering and smoothing time series; theory of stationary processes; identification and estimation of time series models; forecasting; seasonal adjustment; spectral estimation, SARIMA, ARCH(1) and GARCH models, bivariate time series.

The learning objectives of this course are:

Course Objectives/Learning Outcomes

By the end of this course, all students should have a sound understanding of theory, methods and problems in analyzing time series data with a primary application in Economics, Business, Finance, Physical and Environmental Sciences. The course will cover theoretical and practical aspects of time series analysis, making extensive use of the ITSM and R statistical software.

- Understand and reason with the basic time series concepts.
- Interpret and compare different time series models.
- Identify and model different types of time series data.
- Perform time series modelling/forecasting and present the results.
- Use ITSM and R to construct time series models and conduct analysis.

5. Course Books

5.1 Required

Introduction to Time Series and Forecasting, 3rd Edition, by Peter J. Brockwell and Richard A. Davis, Springer, 2016.

5.2 Recommended

Time Series Analysis and Its Applications, With R Examples, Springer Texts in Statistics, 4th Ed. (2017), by Robert H. Shumway, David S. Stoffer.

5.3 Optional

Time Series Analysis with Applications in R, Springer Texts in Statistics, 2nd Ed., (2008) by Jonathan D. Cryer and Kung-Sik Chan.

6. Course Materials, including lecture notes

All course materials are copyrighted. If they are from the textbook, the copyright belongs to the textbook publisher. If they are provided by an instructor (for example, lecture notes, computer code, assignments, tests, solutions) the copyright belongs to the instructor. Distributing materials online or sharing them in any way is a copyright violation and, in some situations, an academic offence. Course materials are provided for the exclusive use of enrolled students. Do not share them with others. I do not want to discover that a student has put any of my materials into the public domain, has sold my materials, or has given my materials to a person or company that is using them to earn money. The University will support me in asserting and pursuing my rights, and my copyrights, in such matters.

7. Assessments

7.1 Grading scheme and Assessment Environment

Students will be evaluated according to the following marking scheme.

Assessment	Weight (Undergraduates)	Weight (Graduates)	Section 5101 Date/Time/Day	Assessment Formats/platform
1 Homework (HW) (4 × 5%)	20%	24%	HW1 (Sept 29), HW2 (Oct 27), HW3 (Nov 24), HW4 (Dec 5) Fridays/Tuesday (due dates)	SA questions on Crowdmark
2 Mid-term Test [§]	30% ^a (40%) ^b	31% ^a (36%) ^b	Oct 31, Tuesday (7:20 pm – 8:50 pm)	In-person (in classroom)
3 Final Exam [§]	50% ^a (40%) ^b	45% ^a (40%) ^b	Scheduled by the Faculty	In-person (by FAS)

[§]The marking scheme will use the higher of the combined marks for course resulting from the options (a) and (b) in the above.

Minimum passing requirement

In addition to the U of T grading policy, students must complete the final assessment to pass the course.

7.2 Assessment Formats/Platforms, Missed Assessments and Marking Concerns

7.2.1 Homework assignments

The homework assignments are short-answer questions distributed to the students via Crowdmark. Students will upload their answer on the Crowdmark platform. You are expected to handwrite the proofs and use ITSM and R software for computations.

Late Penalty for Homework Assignments

A **25% per day** penalty will be applied to assignments that are submitted late. For example, this means that if an assignment is due at 17:00 ET, and is submitted at 17:01 ET, then it will incur a 25% late penalty. If it is submitted at 17:01 ET the following day, then it will incur a 50% late penalty.

Missed Homework Assignments (due to valid reasons)

If a homework is missed for a valid reason (e.g., illness or personal emergency), then within one week following the assessment you must, clearly indicating the assessment (e.g., HW1 due 29Sept2023), declare your absence using one of the following recognized forms of documentation for student absence:

1. Absence declaration via the Absence Declaration Tool in ACORN with verification email sent to sta457@utoronto.ca.
2. UofT Verification of Illness or Injury Form
3. College Registrar's letter
4. Letter of Academic Accommodation from Accessibility Services

For more information, see the link: <https://www.artsci.utoronto.ca/current/academics/student-absences>.

Students who properly follow all the steps outlined above will have the weight of the assignment transferred to another assessment. For each such missed assignment, for undergraduates, 50% of the total weight (5%) for that homework assignment will be shifted to the other homework assignments (i.e., 2.5% weight will be shifted to other homework assignments) and the remaining to the final assessment (i.e., 2.5% weight shifted to the final). Otherwise, missed homework will be assigned a grade of zero.

7.2.2 Midterm test

The midterm test will be **in-person** test during class time on the test day. The test will have short-answer questions including computations and proofs. Short answers may require you to interpret R output and use them to answer. You will need to know R syntax to complete for homework but will not be tested for R syntax on the test and exam. However, you will need to know how to interpret output from R and ITSM software.

The **in-person** exams cannot be submitted **late**.

Missed Midterm Test

If the midterm test is missed for a valid reason (e.g., illness or personal emergency), then within one week following the assessment you must, clearly indicating the assessment (e.g., Midterm held 31 Oct 2023), declare your absence using one of the following recognized forms of documentation for student absence:

1. Absence declaration via the Absence Declaration Tool in ACORN with verification email sent to sta457@utoronto.ca.
2. UofT Verification of Illness or Injury Form
3. College Registrar's letter
4. Letter of Academic Accommodation from Accessibility Services

For more information, see the link: <https://www.artsci.utoronto.ca/current/academics/student-absences>.

Students who properly follow all the steps outlined above will have the weight of the assignment transferred to another assessment. If the midterm test is missed for a valid reason, then the full weight of the midterm test will be shifted to the final exam.

7.2.3 Final Exam

The final exam will be **in-person** during the time, date, and place decided by the Faculty of Arts and Science (FAS). The exam will have short-answer questions including computations and proofs. Short answers may require you to interpret R output and use them to answer. You will not be tested for R syntax on the exam, but you will need to know how to interpret output from R and ITSM software.

The **in-person** exams cannot be submitted **late**.

Students who are eligible for **special test accommodations** will be facilitated through the university's **Accommodated Testing Services (ATS)**.

Final Exam Absences or Exemptions

If a student misses the final exam for any reason, then they should contact their College Registrar's office or work through Accessibility Services if it is a matter of accommodation.

7.3 Marking concerns

- Any requests to have marked work re-evaluated must be made in writing to the instructor within one week of the date the work was returned. The request must contain a justification for consideration.

8. Computing

The ITSM and ITSM-R packages are freely available from the websites mentioned in the textbook.

R

We will use ITSM, ITSM-R, and a few other R packages for all examples. R is freely available for download at <http://cran.r-project.org> (<http://cran.r-project.org>) for Windows, Mac, and Linux operating systems. For the tests and exam, you will need to know how to interpret output from R.

RStudio

RStudio is a fantastic integrated development environment (IDE) for R. It is freely available at <https://www.rstudio.com/products/rstudio/> (<https://www.rstudio.com/products/rstudio/>)

I am assuming that students have never used R before. I will provide you with the R syntax for all examples in lecture, which should be sufficient for you to complete the practice problems.

Jupyter Notebook

The Jupyter Notebook is an open-source web application that allows you to create and share documents that contain live code, equations, visualizations, and narrative text (<https://jupyter.org>)

R can be run in a Jupyter notebook in any web browser by logging into <https://utoronto.syzygy.ca> (<https://utoronto.syzygy.ca>) with your UTORid.

To get started using R in a Jupyter notebook, see this page ([jupyterstarter.html](#)). Additionally, you can also use R Studio through the U of T Jupyterhub, by selecting the RStudio option and logging in with your utoriD and password, available here: <https://jupyter.utoronto.ca>.

Calculators

You will need a calculator in this course. Any calculator that has logarithmic functions will be sufficient. Calculators on phones or other devices equipped to communicate with the outside world (for example, through the internet or cellular or satellite phone networks) will not be permitted during the term tests or final exam.

9. Getting Help

9.1 Online Discussion Board

This term you will have the option to use Piazza for class discussion. If you decide not to use Piazza, it will not disadvantage you in any way, and will not affect official University outcomes (e.g., grades and learning opportunities). If you choose not to opt-into Piazza, then you can ask questions or discuss course material with the instructor or

Teaching Assistants (TAs) during office hours. Piazza and office hours are not to expect a re-run of the missed lectures.

Be sure to read Piazza's Privacy Policy (<https://piazza.com/legal/privacy>) and Terms of Use (<https://piazza.com/legal/terms>) carefully. Take time to understand and be comfortable with what they say. They provide for substantial sharing and disclosure of your personal information held by Piazza, which affects your privacy. If you decide to participate in Piazza, only provide content that you are comfortable sharing under the terms of the Privacy Policy and Terms of Use.

The Piazza system is highly catered to getting you help fast and efficiently from classmates, the TA, and the lecturers. Rather than emailing questions to the teaching staff, we encourage you to post your questions on Piazza. To sign up for the discussion forum click on the link for your section:

<https://piazza.com/utoronto.ca/fall2023/sta457h1flec5101>

9.2 Additional help

Need extra help with the coursework? Here are some options:

- For continued class discussion and questions outside of class, try posting on the discussion forums. The instructor and TAs will be monitoring them regularly.
- You can visit your instructor or the teaching assistants during their office hours.

E-mail should only be used for personal emergencies or personal matters.

9.3 How to communicate with your instructor

Questions about course material such as:

- How do I do Question 3.7 in the textbook?
- What is standard deviation?
- When is the midterm?

Should be posted on the discussion forums. Questions can be posted anonymously (so that the author is anonymous to other students but not to the instructors), if desired.

Before emailing your instructor, please:

1. re-read **this syllabus** to see if the answer is here,
2. check [FAS student FAQs](#)
3. check the discussion posts on Quercus,
4. ask your TA,
5. post your question to the appropriate discussion board on Quercus.
6. go to office hours

If your question is not answered after looking through these resources, or for private communication, such as: I missed the test because I was ill, then e-mail your instructor. If you refer to the contents of other emails, then be sure to provide the contents being referred to altogether in a single email message. **When emailing your instructor, please use the subject line, e.g., for STA457 – LEC5101.** Here, STA457 is your course code and LEC5101 is your section (same as on ACORN). **If this subject is not included, we may miss your email.**

Use your utoronto.ca e-mail account to ensure that your message does not automatically go to a Junk folder and include your full name and student number.

10. Accommodations

10.1 Religious Accommodation

As a student at the University of Toronto, you are part of a diverse community that welcomes and includes students and faculty from a wide range of cultural and religious traditions. For my part, I will make every reasonable effort to avoid scheduling tests, examinations, or other compulsory activities on religious holy days not captured by statutory holidays. Further to University Policy, if you anticipate being absent from class or missing a major course activity (such as a test or in-class assignment) due to a religious observance, please let me know as early in the course as possible, and with sufficient notice (at least two to three weeks), so that we can work together to make alternate arrangements. More information: <https://www.viceprovoststudents.utoronto.ca/policies-guidelines/accommodation-religious/>.

10.2 Students with Disabilities or Accommodation Requirements

Students with diverse learning styles and needs are welcome in this course. If you have an acute or ongoing disability issue or accommodation need, you should register with Accessibility Services (AS) at the beginning of the academic year by visiting <http://www.studentlife.utoronto.ca/as/new-registration> (<http://www.studentlife.utoronto.ca/as/new-registration>). Without registration, you will not be able to verify your situation with your instructors, and instructors will not be advised about your accommodation needs. AS will assess your situation, develop an accommodation plan with you, and support you in requesting accommodation for your course work. Remember that the process of accommodation is private: AS will not share details of your needs or condition with any instructor, and your instructors will not reveal that you are registered with AS.

10.3 Specific Medical Circumstances

If you become ill and it affects your ability to do your academic work, consult me right away. Normally, I will ask you for medical documentation in support of your specific medical circumstances. The University's Verification of Student Illness or Injury (VOI) form is recommended because it indicates the impact and severity of the illness, while protecting your privacy about the details of the nature of the illness. You can submit a different form (like a letter from a doctor), as long as it is an original document, and it contains the same information as the VOI. For more information, please see <http://www.illnessverification.utoronto.ca> (<http://www.illnessverification.utoronto.ca>). If you get a concussion, break your hand, or suffer some other acute injury, you should register with Accessibility Services as soon as possible.

10.4 Accommodation for Personal Reasons

There may be times when you are unable to complete course work on time due to non-medical reasons. If you have concerns, speak to me or to an advisor in your College Registrar's office; they can help you to decide if you want to request an extension or accommodation. They may be able to provide you with a College Registrar's letter of support to give to your instructors, and importantly, connect you with other resources on campus for help with your situation.

11. Academic Integrity

All students, faculty and staff are expected to follow the University's guidelines and policies on academic integrity. For students, this means following the standards of academic honesty when writing assignments, collaborating with fellow students, and writing tests and exams. Ensure that the work you submit for grading represents your own honest efforts. Plagiarism—representing someone else's work as your own or submitting work that you have previously submitted for marks in another class or program—is a serious offence that can result in sanctions. Speak to me or your TA for advice on anything that you find unclear. To learn more about how to cite and use source material appropriately and for other writing support, see the U of T writing support website at <http://www.writing.utoronto.ca> (<http://www.writing.utoronto.ca>). Consult the Code of Behaviour on Academic Matters for a complete outline of the University's policy and expectations. For more information, please see

<https://www.artsci.utoronto.ca/current/academic-advising-and-support/student-academic-integrity> (<https://www.artsci.utoronto.ca/current/academic-advising-and-support/student-academic-integrity>) and <http://academicintegrity.utoronto.ca> (<http://academicintegrity.utoronto.ca>)

AI tools such as ChatGPT

Students may use an AI tool such as ChatGPT for enhancing their learning objectives, however, they must not share the course materials and assessments as all content entered may become part of the tool's dataset and may inadvertently resurface in response to other prompts.

The use of generative artificial intelligence tools or apps for assignments in this course, including tools like ChatGPT and other AI writing or coding assistants, is prohibited. Students may not copy or paraphrase from any generative artificial intelligence applications, including ChatGPT and other AI writing and coding assistants, for the purpose of completing assignments in this course.

12. Your responsibilities

The classroom sessions for this class are designed to actively engage you in the course material. We hope you will find them interesting, challenging, and fun, and an excellent opportunity to truly learn the material.



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13. Weekly Lecture Schedule

For the exact dates of homework, term tests and the final, please keep visiting the Course page on the Quercus. A homework assigned in advance; if topics related to some questions are not covered by one day before the due date, an announcement will be made to withdraw such questions.

STA457H1 /STA2202H F Section L5101: Tuesday (T), 6-9 PM, Room: PB B2 50

Week	Topics
Weeks 1 & 2 Sept 12 Tu	Welcome and Course Design and implementation overview. The chapters referred are from the textbook by Brockwell and Davis, 3 rd Ed, 2016.
Sept 19 Tu	Chapter 1: Introduction Examples of Time Series. Objective of Time Series Analysis. Simple Time Series Models. Stationary Models & Autocorrelation function. Estimation & Elimination of Trend and Seasonal components. Testing the Estimated Noise Sequences
Weeks 3, 4 and 5 Sept 26 Tu	Chapter 2: Stationary Processes Basic Properties Linear Processes
Oct 3 Tu	Introduction to ARMA Processes Sample mean & Autocorrelation Function Forecasting Stationary Time Series

Oct 10 Tu	The Wold Decomposition Thanksgiving holiday (October 9) Homework 1. Due Friday <u>Sept 29</u>, 2023 (Coverage: Chapter 1/ Sept 12 - 19)
Weeks 6 & 7	Chapter 3: ARMA Models ARMA (p, q) Processes
Oct 17 Tu	ACF & PACF of an ARMA (p, q) Process
Oct 24 Th	Forecasting ARMA Processes Homework 2. Due Friday Oct 27, 2023 (Coverage: Chapter 2/ Sept 26 – Oct 10) (Solutions for Homework type questions from Chapter 3 will be posted for review on 18 October 2023)
Week 8	Chapter 4: Spectral Analysis
Oct 31 Tu	Spectral Densities, The Periodogram, Time-Invariant Linear Filters, Spectral Density of an ARMA Process <ul style="list-style-type: none"> • Tuesday 31 Oct, lecture 6-7 pm • Tuesday 31 Oct, Mid-term Test: 7:20 pm -8:50 pm; Weeks 1 to 7 (Topics covered up to ARMA models)
Nov 6 -10	Fall Reading Week, no classes
Weeks 9 & 10	Continued... Chapter 4: Spectral Analysis
Nov 14 Tu	Spectral Densities
Nov 21 Tu	The Periodogram Time-Invariant Linear Filters Spectral Density of an ARMA Process Homework 3. Due Friday, Nov 24, 2023 (Coverage: Chapter 4/ Oct 31 – Nov 21)
Weeks 11 & 12	Chapter 5: Modeling & Forecasting with ARMA Processes
Nov 21 Tu	Preliminary Estimation
Nov 28 Tu	Maximum Likelihood Estimation Diagnostic Checking Forecasting Order Selection
Week 13	Chapters 6, 7, 8 and 10: Selected Topics
Dec 5 Tu	SARIMA, ARCH(1) and GARCH models, bivariate time series <ul style="list-style-type: none"> • Review Homework 4. Due Tuesday, Dec 5, 2023 (Coverage: Chapter 5/Nov 21 – Nov 28)

Academic dates Fall 2023

<https://www.artsci.utoronto.ca/current/dates-deadlines/academic-dates#academic-dates-deadlines-accordion-3>

Date	Activity
September 4, 2023	No classes - Labour Day
September 7, 2023	Classes begin in F and Y courses
September 8, 2023	Last day to request November 2023 graduation
September 15, 2023	Waitlists for F and Y courses close at end of day
September 20, 2023	Last day to enrol in F and Y courses
September 20, 2023	Last day to enrol or accept invitation to a program for Fall/Winter <ul style="list-style-type: none"> Find important dates related to program enrolment in the Program Toolkit
September 20, 2023	Program/course fee freeze date (F and Y courses)
September 20, 2023	First day to select a Credit/No-Credit (CR/NCR) option for F and Y courses
October 9, 2023	No classes - Thanksgiving holiday
November 6, 2023	Last day to drop F courses <ul style="list-style-type: none"> Note that some courses cannot be dropped using ACORN and students must contact their College or Department to do so; refer to the Course Enrolment Instructions
November 6 - 10, 2023	No classes - Fall Reading Week
TBD	First day to request June 2023 graduation
TBD	Last day to submit a petition for the November 2023 deferred exam period
December 6, 2023	Classes end in F courses and in Y courses (for Fall term)
December 7, 2023	Last day to add or remove a CR/NCR option in Fall F courses
December 7, 2023	Deadline to request Late Withdrawal (LWD) from Fall F courses
December 7, 2023	At the instructor's discretion, classes scheduled on Mondays will hold their last class on this day to make up for class missed due to the Thanksgiving holiday.
December 8, 2023	Study Day
December 9 - 20, 2023	Final assessments in F courses Term tests in Y courses
December 21, 2023 - January 2, 2024	University closed for Winter Holidays from December 21, 2023 to January 2, 2024 inclusive <ul style="list-style-type: none"> Winter classes for S and Y courses resume in January 2024