Undergraduate Supplemental Calendar

Department of Mathematics and Statistics

2019–2020

· Actuarial Science · Applied Mathematics · Mathematical Biology ·
Mathematics for Education · Financial Mathematics · Pure Mathematics · Statistics ·
International Dual Degree Mathematics and Statistics

Undergraduate Program Office

ugmath@mathstat.yorku.ca

N519 Ross Building

416-736-5902

http://mathstats.info.yorku.ca/

Monday – Friday

9:00a.m. – 12:00p.m. and 1:00p.m. – 3:00p.m.

Administrative Offices: N520 Ross Building
416-736-5250 (main office)
mathstat@yorku.ca (general enquiries)

Office Hours: Monday – Friday
8:30a.m. to 4:30p.m.
(Closed at 3:30p.m. on Fridays only from May until Labour Day)

science | YORK UNIVERSITÉ UNIVERSITY

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The calendar maintained by the Registrar's Office contains a complete listing of courses, not all of which are offered every year. Moreover, some older prerequisites will be found there for the benefit of students who are returning to their studies after taking some time off. Since this supplementary calendar provides a more streamlined listing of courses and prerequisites that are relevant to a particular academic year, students are encouraged to consult it first when selecting their courses.

Guide for Returning Students

The Department has new requirements for all of its programs. However, if you began your studies at York in Summer 2018, or earlier, you may complete your program under the old requirements which were in effect at the time you began your studies at York. Please see https://calendars.students.yorku.ca for academic calendars for previous years.

If a degree program requirement is not being currently offered, you must see the Undergraduate Program Director in N505 Ross to discuss a degree requirement equivalent to replace it. Feel free to bring your questions to the Undergraduate Office.

Guide for New Students

The Department has new requirements for all of its programs. Since you are beginning your studies at York in September 2019, you must meet these new requirements. In particular, you do not have the option of completing your program by meeting the old requirements.

The first three terms of study of all our Honours programs is the Mathematics/Statistics Core. It consists of three semesters of calculus, (MATH 1300, MATH 1310 and MATH 2310), an introduction to mathematical thinking (MATH 1200), probability (MATH 2030), statistics (MATH 1131) and two semesters of linear algebra (MATH 1021 and 2022). In addition, the computing course EECS 1560 is required for all math and statistics programs. For Actuarial Science studies, ECON 1000 and ECON 1010 are required in the first year of studies, and ECON 2300, ECON 2350 are required in the second year of studies. Please see program tables towards the back of this publication for the recommended schedule for your program.

In your second year you will begin taking specialized courses in the area of your selected program. At that point, you will have a familiarity with various types of mathematics and statistics so that you can make an educated choice of a specific program. Note that it is an easy procedure to change from one specific program to another.
Feel free to bring your questions to the Undergraduate Office.

Guide for New Transfer Students

The Department has new requirements for all of its programs. Since you are beginning your studies at York in September 2019, you must see the Undergraduate Program Director in N505 Ross to discuss and clarify your situation.

Guide for Mathematics for Commerce BA and BA (Hons) Programs

These programs were closed as of Fall 2017. If you began one of these programs prior to FW 2017/18, please see the York Academic Calendar of the year you began your program for the program requirements.

Guide for New Three Year Degree Program

The six three-year BSc and BA degrees in Applied Mathematics, Mathematics, and Statistics, and the three year BSc degree in International Dual Degree Mathematics have been retired and replaced with a single three year program offering two degrees, a BSc and a BA in Applied Mathematics, designed to provide students with a set of skills demanded by employers in finance, government and health services. Along with the common core of courses taken by all students in the Department of Mathematics and Statistics, students finishing either of the two new three-year degrees will be able to claim the following on their resumes:

- programming skills in MatLab, the language used in engineering, the sciences and finance;
- knowledge of statistics, data analytics and regression analysis required in many industrial settings;
- basic knowledge of financial mathematics;
- familiarity with differential equations;
- familiarity with the basics of linear programming used in scheduling and transport applications.

The new three-year degree program will accomplish this by requiring students to select from a short list of courses whose focus is on these five learning outcomes. If you began any other Bachelor BSc or BA Program prior to FW 2018/19, please see the York Academic Calendar of the year you began your program for the program requirements.

If you wish to switch to the new three-year degree program in Applied Mathematics, you must see the Undergraduate Program Director in N505 Ross to discuss the matter.

Message from the Departmental Chair

Welcome to the Department of Mathematics and Statistics. Whether you are majoring in one of our programs, taking a course required by another program, or taking a course for general interest, we want to help you learn and enjoy mathematics and/or statistics. The faculty members in this Department value both the beauty and the utility of their discipline. They are dedicated to exploring and developing new ideas in mathematics and statistics, and to helping you to explore, understand, appreciate and make use of those ideas. Ideas are much more than facts. They are harder to acquire, but infinitely more valuable.

This supplemental calendar is intended to help you choose the programs and courses best suited to your needs and interests. Much effort has gone into making it accurate, and it contains much information not available elsewhere. The program tables towards the back of this publication lay out our Department's program requirements, perhaps more clearly than any other York document. Please also consult the "official, legally binding" regulations in the York Academic Calendar, at https://calendars.students.yorku.ca/.

Programs

The Department is especially happy to welcome students choosing to major in one of our many excellent programs, through the Faculty of Science. I urge you to stay in touch with your professors and to ask about, as well as get involved, in student clubs. We offer a diverse set of degree programs, designed to respond to the many differing interests and career aspirations of our students. The current programs are outlined throughout this supplemental calendar. We would like to hear from you if you are unsure as to which program best suits you, if you are contemplating a change, or simply if you feel some advice would be helpful.

Where to go for help

The Department's faculty and staff members are pleased to offer you their assistance. Questions concerning your program, or enrolment in courses, are best handled by the Undergraduate Program Offices (**ugmath@mathstat.yorku.ca**). Students may contact Madeline Salzarulo, Undergraduate Program Secretary, in N519 Ross (**416-736-5902**), Monday–Friday, 9:00a.m.–noon and 1:00p.m.–3:00p.m. Should you need further information on academic matters, please make an appointment with one of the Undergraduate Program Directors: A.I. Weiss (Pure Mathematics); E. Furman (Actuarial Science); S. Moghadas (Applied Mathematics and Computational Mathematics); Y. Fu (Statistics); and J. Heffernan (Mathematics for Education). Some introductory courses will have quite large enrolments, and we urge you to take advantage of the Math/Stat Lab (S525 Ross) and your tutorials, if available, as these will provide some of the individual attention you may require. Other courses may provide help through the Bethune College PASS peer assistance program and students are encouraged to take advantage of this as well. You will find that your teaching assistants, instructors, and course coordinators are eager to help if you encounter difficulties in a course. Don't wait until the end of a course to deal with a problem; contact your instructor for help or advice sooner, not later. Faculty members' office hours can be found through the Department's Main Office in N520 Ross (416-736-5250). Appointments to see the Chair can be made with Susan Rainey, Secretary to the Chair, in N522 Ross (ext. 22555). Most Department members are quite happy to correspond with you by e-mail. The Department also has general Undergraduate and Graduate information available on-line at http://mathstats.info.yorku.ca/. In addition, the course descriptions in this supplemental calendar will be available on the web.

Our goals

You may find that a variety of teaching methods are used in your mathematics and statistics courses. But whatever methods may be used, faculty members have certain goals in common. They want to help you to learn the basic material of the course, to understand how and why this material was developed, and to know how to apply it. Through problem-solving, you will acquire skills in critical thinking and logical analysis that will serve you well in many careers, particularly those that demand a sound understanding of mathematics or statistics. It is important to develop the ability and desire to pursue knowledge independently, to understand the power and elegance of abstract reasoning, and to appreciate the role of mathematics in human culture and the sciences.

Prizes and awards

Each year the Department offers several prizes and awards for outstanding achievements in mathematics and statistics courses. Department members have contributed substantially to some of these. Students receiving any of these will be honoured at the annual Department Awards Ceremony, and their names will be displayed in the halls of the Department and on the Departmental web page. Other prizes (e.g. the **Allen S. Berg Award** in Applied Mathematics) are awarded at the Faculty level.

Students are listed on the **Chair's Honour Roll** for having achieved a high grade point average over all Departmental courses (at least two full course equivalents without second digit 5). An outstanding student in each of the year-levels 2, 3, and 4 in a Departmental program is chosen for the **Irvine R. Pounder Award**. Professor Pounder was one of the two founding members

of the Department, and the award was established by the Department in 1990–91 on the occasion of the hundredth anniversary of his birth. The other founder of the Department is commemorated in the **Alice Turner Awards**, which are awarded to outstanding MATH Majors in a Departmental degree program, one to a three-year and one to a four-year degree graduate. The **Moshe Shimrat Prize Fund** rewards York students (or secondary school students) selected by the department for their interest and demonstrated ability in mathematical problem-solving. The **George R. and Mary L. Wallace Award** was established by the family and friends of G.R. Wallace, the late Senior Vice-President and Chief Actuary of the Zurich Life Insurance Company. It is awarded annually to outstanding Department Honours students in Applied Mathematics, and in the Actuarial and Operations Research streams of the Mathematics for Commerce program. The **George & Frances Denzel Award** is awarded for excellence in Statistics. The **Linda Herskowitz Award** is awarded to a (preferably female) department major who, through her achievements, best honours the memory of this long-time former staff member. The **Abe Karrass/Donald Solitar Bursary** honours the memory of Professor Abe Karrass, and is awarded to an outstanding student in a Department Honours program with an interest in Mathematics Education. The **Ray and Joe Abramson Award in Mathematics and Statistics** is given to an academically strong student who demonstrates involvement in a math-related club or extracurricular activity. In addition, some awards are partially based on demonstrated financial need. Students should also inquire in January with their Math/Stat instructors about the possibility of summer employment through the NSERC Undergraduate Summer Research Program.

For all awards except the Linda Herskowitz Award, recipients are chosen by the Department on the basis of student records. No applications are needed or accepted for these awards.

Applications for the Linda Herskowitz Award may be submitted to the Chair by September 15. To be eligible for this bursary, the student must be a Canadian citizen or permanent resident. Applications must include a Bursary Application form (available from N520 Ross) as well as a statement from the student, with supporting material as appropriate, explaining how the student meets the criteria of the award (e.g. involvement in departmental or university activities outside the classroom, or community service outside the university).

Mathematics contests

There are two international mathematics contests open to undergraduate students. One, **The William Lowell Putnam Mathematical Competition**, has students working on a number of challenging mathematics problems during an all-day examination late in the fall term (see page 8 of this supplemental calendar). The other, **The Mathematical Contest in Modelling**, involves one or more teams of students who are given a weekend to develop a mathematical model for a challenging applied problem (see page 8). In both cases, practice sessions will be held under the guidance of a member of the faculty. Announcements about these contests will be made in classes and posted in the Math/Stat Student Common Room (N537 Ross) at the appropriate times. We invite you to test your skills.

We wish you success in your studies.

P. Szeptycki, Department Chair

Problems?
Where to go for help

Information

See the next section of this supplemental calendar for sources of information, and elsewhere in the supplemental calendar as well. The *York Academic Calendar* will answer many questions that are not addressed here. Please remember in particular that the main Calendar contains the "official, legally binding" statements of all university and faculty regulations. (York's website, www.yorku.ca, has the Calendar on-line, as well as a wealth of other information about the university.)

Course-related Problems

The first person to speak with is **your instructor.** Do not wait until the end of a course to try to resolve problems; deal with them as soon as you see them coming. If for any reason your instructor's answers do not satisfy you, and the course is a multi-section one, seek out the **"Coordinator"** (the professor responsible for all sections of the course). It is part of his/her job to try to resolve problems with a course. If your problem remains unresolved or you feel uncomfortable regarding some issue, visit the **Undergraduate Program Director**, Professor H. Ku (416-736-5250).
If you feel you need personal attention outside class time, one resource is **your instructor**. Faculty members have regular office hours when they are available to their students for contact outside class. Another source of academic help is **the tutorial session (if there is one) in your course**, which must be announced in class by your instructor within the first week or two of classes.

The Math Lab and Stats Lab

This year, these labs, collectively called the Math/Stats Lab, housed in S525 Ross (fifth floor of the south wing of the Ross Building), provide tutorial help for the following first and second year courses: MATH 1013/1014, 1025, 1131, 1190, 1200, 1300/1310, 1505, 1510, 1520, 1530/1540, 1532, 1550, 1021/2022, 2030, 2565.

Note: MATH 1019/1090 have their own tutorial sessions.

See also "Where to go for help" on page 4.

General Information
Choice of Courses

Students should take care to enrol in the mathematics courses most appropriate to their interests, needs and background. In many cases, courses with similar titles may be intended for very different audiences. Students should be guided by the information given in this publication and should consult an advisor in case of doubt.

When selecting courses, please note the following:

1. A student choosing university-level mathematics courses for the first time should consider speaking to a staff member in the Undergraduate Office (see "Where to go for help", page 4 of this supplemental calendar).

2. With the exception of courses which are core requirements for degrees in the Department, students should not necessarily expect courses (especially some upper-level courses) offered in a given calendar year to be offered also the following year. This applies to both Fall/Winter and Summer courses. The Department tries to offer some courses in alternate years, partly to allow variety in choice of topic. In some cases, information about the year a course is expected to be offered next can be found in the **Course Offerings** section later in this supplemental calendar.

3. In Summer 2019, this department is planning to offer the following courses:
   MATH 1013, 1014, 1019, 1021, 1025, 1090, 1131, 1190, 1200, 1300, 1310, 1505, 1510, 1520, 1581, 2015, 2022, 2030, 2131, 2565, 2930, 3131 and 3330.

4. Note that instructors for some courses may change after publication of this supplemental calendar.

5. MATH 1510 6.00 is intended for students who have a weak mathematical background, even those who may have one or more 12Us in mathematics or OACs or equivalents. It can serve as preparation for MATH 1520 3.00, which provides an entrance to further calculus courses.

6. Calculus options for first-year students:
   (a) Science students (particularly those majoring in Biology, Geography, Kinesiology and Health Science, or Psychology) who do not require other specific calculus courses to satisfy degree requirements, or as prerequisites for higher-level courses, may take MATH 1505 6.00 to satisfy the Faculty of Science 1000-level mathematics requirement. Other students should be guided by paragraphs (b) and (c) below.
   (b) A student with at least one 12U or OAC in mathematics or equivalent, but without previous calculus, must begin the study of calculus with MATH 1510 6.00 and/or MATH 1520 3.00; a student with 12U Advanced Functions can begin without MATH 1510 6.00.
   (c) A student with 12U Calculus and Vectors or equivalent can begin with MATH 1013 3.00 or MATH 1300 3.00, and then take MATH 1014 3.00 or MATH 1310 3.00.

Course Credit Exclusions

Specific regulations concerning "course credit exclusions" (CCE) appear in the York Academic Calendar. These were formally called degree credit exclusions. An exclusion occurs when two courses have overlapping material. As a general rule, you may not take both for degree credit. The concept of

"equivalent" course or "course substitution" is different; see the York Academic Calendar for explanations of both these concepts.

Student Ombuds Service

The Student Ombuds Service (SOS) is a peer-advising service designed to help York students, especially those in Bethune College and the Faculty of Science, find information they need. The SOS office is staffed with knowledgeable upper-year students and serves as a referral network and a resource centre. SOS members try to answer any questions about York University policies and procedures, and give general academic help and advice about University life. SOS resources include departmental supplemental calendars, graduate and professional school information, a tutor registry, and a study-group registry. We encourage you to drop by the SOS office at 208 Bethune College between 10 a.m. and 4 p.m. Monday through Friday. No appointment is necessary. You can also find information on the web at http://bethune.yorku.ca/sos/, or e-mail them at bethune@yorku.ca. The SOS is here for you, so do not hesitate to contact it if you need help.

Study Groups

We encourage students, especially those in 1000- and 2000-level courses, to form study groups early in the term, and to use them as a help in learning their course material. Your study group can help you, as a participant, in all sorts of ways (and you will help the group as well). Many people benefit from working together to solve problems, or just by having people around to help them get motivated to study.

Club Infinity

Club Infinity is York University's Mathematics Club. It is a small and informal group of students who have some interest in math. They meet on an irregular basis to work on club events or just party. There is no membership fee.

Each year they organize a number of events of interest to students involved in math, including: talks of a mathematical nature, given by professors, or graduate or undergraduate students, annual Pi Day celebrations, held on March 14, and their Semi-Annual Past Math Exam Sales, where copies of old math exams are sold.

The club operates out of N537 Ross, the Math/Stat Student Common Room. This is a place where students can go to eat, work on assignments, play cards, discuss math problems, or just socialize. You don't have to be a member of the club; the room is open to all. The room is generally open on weekdays. Visit the website: www.math.yorku.ca/infinity.

ASAYU: Actuarial Students' Association

The ASAYU, Actuarial Students' Association at York University is designed to help students who are interested in actuarial science matters on multiple levels. Those levels consist of study groups, peer advising, exam preparation, and most importantly, the Actuarial Convention held in early January. The convention is created in partnership with the Actuarial Students' National Association and its other member universities. The convention is a three-day event consisting of a career fair for students, followed by workshops, seminars, and networking opportunities with other future actuaries.

The Association will focus on growing the network of both alumni and current students. Also, with a new year brings new opportunities for students to get involved in the actuarial community. The ASAYU has a constant outreach for new members, ideas, and fresh faces to join! If you are interested in joining the club or have any questions on anything, simply e-mail the club at Asayu@yorku.ca.

To get more information, visit the ASAYU Facebook page https://www.facebook.com/ActuarialStudentAssociationYorkUniversity/.

Guidelines for Ethical Research Involving Humans

All students who conduct research that involves interviews have a duty to comply with the Senate policies on ethical conduct for research involving humans. This means, for example, that those conducting interviews normally have a duty to inform the persons being interviewed about the nature and purpose of the research, and about whether the results of the interview will remain confidential. Student research procedures involving human participants must be approved by the student's course director. See http://secretariat-policies.info.yorku.ca/policies/ethics-review-process-for-research-involving-human-participants-policy/.

Information for Majors

The Department of Mathematics and Statistics offers degree programs in six major subjects:

- **Actuarial Science (BA)**
- **Applied Mathematics (BA or BSc)**
- **Mathematics (BA or BSc)**
- **Statistics (BA or BSc)**
- **Mathematics for Education (BA or BSc)**
- **Mathematical Biology (BSc)**

The three-year (BA or BSc) and four-year (BA Hons, BSc Hons) Applied Mathematics programs and the four-year (BA Hons, BSc Hons) programs for the other five major subjects above are described in the next section. Detailed lists of course requirements for each program appear on pages towards the back of this publication. A student should choose one of these majors based on interest and employment goals; one can change their major later, if the requirements of the new major can be met.

Course Numbering

MATH courses with second digit 5 cannot be used to satisfy major or minor degree requirements in this Department, except in a few cases as specifically noted in program

descriptions. With the exception of MATH 1530, MATH courses with third digit **3** involve probability and statistics.

"In-department" Credits, "In-Faculty" Credits

These topics are rather technical; if you are in any doubt about them in particular cases, consult an advisor.

Upper-level courses

In choosing courses, students should bear in mind the prerequisites for courses which they may wish to take in later years. Also, students are cautioned that some courses may be given only in alternate years. The "Special Topics" and "Topics in" courses (MATH 4100 3.00, MATH 4130 3.00, MATH 4930 3.00) may be offered in both terms and may be repeated with different topics. The prerequisites for each course are usually certain 3000-level courses in the appropriate subject area. When registering for these courses, note any letter immediately following the four-digit course number. It indicates the version of the course being given; the same version may not be taken again later for credit.

Math Modeling Competition

The 35th annual Mathematical Contest in Modeling (MCM) was held from January 24-28, 2019. This year, 14,108 teams representing institutions from 17 countries/regions participated in the contest.

Team 1: **Babatunde Adegbesan, Yaniv Khaslavsky and Tien Phan**
Problem A: The Ecological Ramifications of Fiction Dragons

Team 2: **Xiaoyu Bai, The Cong Toan Cao and Fan Zhu**
Problem C: Human Use of Opioids and Narcotic Analgesics

Both Teams received Successful Participants.
Coach: Professor Hongmei Zhu

Putnam Competition

Two York students wrote the Putnam Exam on December 1, 2018: **Sina Adineh** and **Wei Dong**.

Our top student this year was **Sina Adineh** who obtained the good score of **14** points (out of 120) and ranked **804.5** over 4,623 contestants. **Wei Dong** (a first-year student) obtained a score of **8** points and ranked **1275**.

The top five scores in the competition were 114, 114, 109, 109, and 100 (out of 120), and the top five teams were Harvard, MIT, UCLA, Columbia and Stanford.

Coach: Professor Paul Skoufranis

Programs

Applied Mathematics

The Applied Mathematics Program aims to give students a solid base of knowledge of mathematics which has important applications in computer science, psychology, economics, business, and other fields. Our graduates have pursued a variety of careers including business, industry and government as well as teaching. Many have found jobs in various fields related to computing. Some of our students have continued on to graduate studies in mathematics and other areas. Students can obtain qualifications in operations research or the actuarial profession (see the section below entitled Career Information). There are potential jobs for our students wherever mathematics is employed.

Students in Applied Mathematics in the Faculty of Science may pursue a course of study leading to either a BSc (usually three years) or a BSc (Hons) (usually four years). Students may combine the study of Applied Mathematics with that of another subject such as Physics, Earth and Space Science and Engineering, Biology, or Computer Science and thereby graduate with a BSc (Hons) Double Major or, in some cases, a BSc (Hons) Major/Minor in two subjects. Applied Mathematics students interested in Economics, Psychology, or another subject may pursue a combined Program by selecting a BA (Hons) Double Major or Major/Minor Program. For example, an Economics-Applied Mathematics Major/Minor BA (Hons) would be a natural combination. Our students are given the opportunity to take electives in other areas of interest, such as business administration.

All students take a common core of courses in Calculus, Differential Equations, Linear Algebra, Symbolic Computing (MAPLE), and Numerical Analysis. The core of required courses is larger for Honours students. There is a wide choice of elective courses in Applied Mathematics, including Mathematical Modelling, Graph Theory, Operations Research, Partial Differential Equations, Advanced Numerical Analysis, and Complex Variables. In addition, students can select a number of optional courses from outside the Program. Courses in the Program stress applications of mathematics and computing to the solution of problems arising in many facets of science, engineering and commerce.

Some possible areas of concentration and corresponding recommended courses are:

Numerical Analysis: MATH 3242, MATH 4141, MATH 4143.

Discrete Applied Math/Operations Research: MATH 3090, MATH 3171, MATH 3172, MATH 3260, MATH 4090, MATH 4141, MATH 4160, MATH 4161, MATH 4171, MATH 4172, MATH 4430, MATH 4431.

Applied Math in Physical Sciences/Differential Equations: MATH 3090, MATH 3271, MATH 3410, MATH 4090, MATH 4141, MATH 4830, EATS 2470.

Statistical Applied Math: MATH 3131, MATH 3132, MATH 3330, MATH 3430, MATH 4230, MATH 4430, MATH 4431, MATH 4630, MATH 4730, MATH 4830, MATH 4930.

Financial Mathematics Stream

The Applied Mathematics program at York offers a specialized Honours stream in Financial Mathematics. The main objective of this program of study is to prepare students for a career as quantitative analysts (or ''quants'', as they are known in the finance industry). Quants typically use mathematical and statistical tools to analyze various financial instruments and financial markets. This analysis usually involves developing mathematical models, fitting models to market data, performing numerical computations, analyzing the results of these computations and providing insight and information for decision making. The specialized honours stream in Financial Mathematics will provide students with an excellent preparation for either an entry-level position in the finance industry or for further studies at the Master's level.

(In all cases, you should make sure that you satisfy all your degree requirements, given in the program tables towards the back of this supplemental calendar.)

All students entering Applied Mathematics are carefully advised concerning their course of study by a member of the Program. The instructors in Applied Mathematics courses are available throughout the year for additional advice and help with specific course-related problems.

If you would like further information, please contact the Applied Mathematics Program Director, Professor Seyed Moghadas (moghadas@yorku.ca).

Mathematics

The Honours Programs in Mathematics (BA and BSc) are suitable for students who enjoy the intellectual challenge of pure mathematics. These Programs provide an excellent background for many occupations demanding skills in mathematical reasoning and techniques. They are ideal for students who intend to pursue graduate study in mathematics. An Honours Program in mathematics emphasizes the understanding of concepts, abstraction and reasoning; these then become the tools for problem-solving, as well as the language and environment in which problems are solved (for many problems the solutions are called “proofs”). Many students who creditably complete a York Honours degree in mathematics are routinely accepted (with financial support included!) into graduate schools across North America. Taking mathematics in combination with Computer Science, Statistics, or Economics makes a very impressive curriculum vitae for a graduate seeking a career in Industry, Government, or Business.

Mathematics is one of the oldest academic disciplines. A mathematician is known as one who has exceptional reasoning, critical thinking, and problem-solving skills. While the public knows of the *utility* of mathematics, less well known is the fact that most mathematicians do math *because they love it*. The Honours Programs are designed to help you cultivate this same passion. You will meet like-minded classmates and you will find that your studies are a rewarding and exciting adventure bringing you to the frontier of scientific discovery.

Students can also choose a liberal arts education with a moderate emphasis on mathematics, for example, with Mathematics as a Minor in an Honours Major/Minor degree.

If you would like further information, please contact the Mathematics Program Director, Professor Asia Weiss (weiss@mathstat.yorku.ca).

Statistics

Statistics is an interdisciplinary field providing the foundations and techniques required to collect, analyze and present information in an effective and efficient manner. Through its applications in almost every branch of modern professional life and research, statistics is a fast-growing discipline which provides a statistician with a variety of career opportunities. A Program in statistics is an exploration of the nature of measurement, relationships amongst measured variables, chance variation, probability, uncertainty, inductive logic and inference. The Honours BA and BSc Programs in Statistics provide both the mathematical foundations and the methods needed in applications. They also provide exposure to a variety of computing environments, an essential asset for nearly all careers today. Statistics combines naturally with studies in the health sciences, life, physical and social sciences, economics, administrative studies and environmental studies. The Honours Programs also provide excellent preparation for subsequent graduate studies in statistics.

Students in first year who wish to pursue an Honours program with a major in Statistics must plan to complete the Mathematics/Statistics Core (see page 2) and MATH 2131 3.00 prior to entering their third year of study.

If you would like further information, please contact the Statistics Program Director, Professor Cindy Fu (yuejiao@mathstat.yorku.ca).

Actuarial Science

Actuarial Science is the area of mathematics that applies quantitative methods to assess, price and mitigate financial risks. It became a formal discipline in the late 17th century, when the increased demand for such long-term insurance coverages as life insurances, annuities, and burial expense coverages emerged. Since then and for a long time, actuaries have been interested in studying the value of future financial obligations as well as the associated risk in the contexts of life and health insurance, property and casualty insurance, pension funds and social wealth-fare programs. Today actuaries are also being increasingly employed in the areas of enterprise risk management, and even in general finance and investment.

The standard way to qualify as an Actuary (Associate and/or Fellow) is to pass a series of examinations set by professional organizations, for instance, the Society of Actuaries (SOA), or the Casualty Actuarial Society (CAS). University courses cannot be used to substitute for the aforementioned professional exams, yet they can provide you with the knowledge that is necessary to succeed in passing these exams, and so in attaining the Associate/Fellow designations. Our Honours Programs and the Professional Certificate in Actuarial Science do exactly that. Namely, by offering courses in, for instance,

cash flow mathematics, financial mathematics and economics, mathematics of life contingencies, financial risk measurement and risk theory, we provide you with a feasible option to pass all Associate-level professional exams by the time of graduation. Furthermore, as our courses in Economics, Corporate Finance, and Applied Statistics Methods have been approved by the SOA, good Actuarial Science students are granted exemptions from the corresponding Validation by Educational Experience requirements. Last, but not least, ample internship opportunities with, for instance, Sun Life Financial, Aviva Canada, Mercer, RBC Insurance, TD Insurance, etc, exist annually.

We offer a Specialized Honours BA in Actuarial Science, an Honours BA in Actuarial Science, and a Professional Certificate in Actuarial Science. The two Honours degrees (typically four years of full-time studies plus internship terms) are a great option for students who are willing to have comprehensive undergraduate training in mathematics with specialization in Actuarial Science. The Professional Certificate option (typically two years of studies) is for York students who major in other than Mathematics disciplines, and are interested in an insurance-related career; the certificate is also a good choice for 'career changers' who hold a University degree with a strong quantitative basis and seek employment in the insurance industry.

When in the program:

1. Review the Actuarial Science at York U website (http://actsci.math.yorku.ca/);

2. Make an appointment with the Actuarial Science Program Coordinator, Professor Ed Furman (efurman@mathstat.yorku.ca) as soon as you enrol;

3. Join the Actuarial Science Students Association (https://www.facebook.com/ActuarialStudentAssociationYorkUniversity/) and be active;

4. Add your email to the Undergrads_news group (http://mathstat.yorku.ca/mailman/listinfo/undergrad_news), follow events and internships announcements, and never miss events and opportunities;

5. In your resume strike a balance in terms of good academic standing, number of professional exams passed, and relevant internship experience.

If you would like further information, please contact the Actuarial Science Coordinator, Professor Ed Furman (efurman@mathstat.yorku.ca).

Mathematical Biology

The combination of mathematics and biology has become an essential discipline in the understanding of life processes. Mathematical skills are seen as being increasingly important in the fields of Biology, Chemistry, Environmental Science, Engineering and Health. A degree in Mathematical Biology will provide you with knowledge and skills in biology and/or health, chemistry, mathematics, statistics, computing and computer science. Specific skills include experimental methods, data analysis, mathematical modelling, writing computer programs, using specific software applications, and the ability to translate mathematics to a biological question.

Mathematical Biology has a long history, but recently this field has experienced an explosion of interest. Reasons for this include: the availability of large and rich datasets (genomics, cell biology, etc.), the development of robust mathematical tools that can be used to understand complex nonlinear systems, an increase in computing power, and increasing interest in the computer simulation of biological mechanisms so that complications incurred in human and animal research (i.e. ethics, cost, risk, unreliability, etc) are reduced. This will be the first Bachelor of Science program in Mathematical Biology in Ontario.

The Department of Mathematics and Statistics has many faculty members with active research in Mathematical Biology and related areas. These areas include: disease modelling, image processing, mathematical ecology, climate change, bird migration, and geometric structures and rigidity.

Program requirements:

The program will offer Specialized Honours Major, Honours Major, Double Major, and Major in a Major/Minor. The program requirements include courses in mathematics, statistics, biology, chemistry, and/or health. Additional courses in physics and environmental science are recommended. A 3000-level course and a 4000-level project course will provide you with the background and experience in applying mathematics to interesting questions in biology. Students will gain practical experience working with scientists on projects generated by collaborations with real-world researchers.

If you would like further information, please contact the Mathematical Biology Program Coordinator, Professor Jane Heffernan (jmheffer@yorku.ca).

Mathematics for Education

This is a mathematics program that is focused on the needs of students interested in a teaching career with mathematics as a teaching subject. This program ensures a broad background in mathematics and encourages students to develop a wide perspective on mathematics and on the teaching and learning of mathematics. The program also provides a solid background in core mathematics, as well as a range of upper level mathematics, similar to that provided in many liberal arts colleges. As such, it will leave a number of options open within mathematics or in interdisciplinary work at all stages during the program or on graduation, in addition to the B.Ed. pathway. This program is designed to support students who wish to pursue an education degree concurrently or apply to a consecutive education program with mathematics as a teachable subject.

Any students planning to teach at the Intermediate/Senior level will need to select general education, electives and other courses to develop a second teachable subject, and room has been left for that. For clarity, we emphasize that this program

does not replace the B.Ed. program required for certification as a teacher in Ontario.

With an appropriate choice in their fourth semester, students will be able to transfer to, or from an Honours major in each of the other Mathematics programs. Conversely, students from all these math programs will be able to transfer into Mathematics for Education. Similar options to transfer are open even during 3rd year, depending on the elective courses chosen.

If you would like further information, please contact the Mathematics for Education Coordinator, Professor Jane Heffernan (jmheffer@yorku.ca).

Requirements for mathematics as a teaching subject in a B.Ed.:

The mathematics for education major or minor programs satisfies York University's Faculty of Education requirements for mathematics as first teaching subject (six full-year or equivalent university courses). These courses are to span all of the following key areas of mathematics: Calculus, Linear Algebra, Probability and Statistics, and proof-based/modeling-based Mathematics. Students can meet the requirements for a teachable with less than a Minor in Mathematics. Statistics courses taken in other subject areas (e.g. Psychology or Sociology) will only account for a maximum of one half course towards the teaching subject requirement.

*Note that there is no agreement amongst universities about the requirements for mathematics as a teaching subject. However, the major or minor are designed to meet the minimum requirements for all Ontario university requirements.

Please contact Professor Jane Heffernan (jmheffer@mathstat.yorku.ca) or Professor Tina Rapke (trapke@edu.yorku.ca) for more information.

International Dual Degree Program in Mathematics and Statistics

In cooperation with the University of L'Aquila (Italy) an intensive and rigorous Bachelor of Science program in Mathematics and Statistics has been established. The program provides York students with the opportunity to gain international experience and earn, in addition to their Honours BSc degree at York, the Italian *Laurea di primo livello* at the University of L'Aquila within the normal four-year time frame. The program enables students to acquire the necessary background in Mathematics and Statistics, suitable especially for those who wish to pursue a career in international business or academia. Because of its large body of mandatory courses in Mathematics and Statistics the program is particularly demanding and will be of interest to students with academic performance of B average and higher. After two years of study at York, but before the completion of the York degree program requirements, students will be eligible to study as York international exchange students for up to one year at the University of L'Aquila, earn York credits for specified courses taken at L'Aquila towards their York degree program, and at the same time fulfill the degree program requirements for the *Laurea di primo liveloo* at L'Aquila, the Italian equivalent of a 90-credit BSc. All exchanges under this program are administered by York International in collaboration the *Ufficio Internazionale* at the University of L'Aquila. The Program Coordinator at York is Professor Walter Tholen (416-736-2100, ext. 33918).

Glendon College Mathematics Courses

The following is a selection of courses offered in 2019-2020 by the Department of Mathematics at Glendon College, that are equivalent to courses offered at "Mathstat" (Mathematics and Statistics, Keele Campus). "Equivalent courses" are acceptable for degree program credit both at the Glendon campus and at the Keele campus. For further information, contact the Glendon Mathematics Department, 327 York Hall, Glendon College, at 416-487-6731.

We list the equivalent courses offered at "Mathstat" and Glendon:

- MATH 2565: GL/MATH 1610 3.0 Introduction to Statistical Methods I
- MATH 2570: GL/MATH 1620 3.0 Introduction to Statistical Methods II
- MATH 1190: GL/MATH 1650 3.0 Modes of Mathematical Reasoning
- MATH 1021:GL/MATH 1660 3.0 Linear Algebra I
- MATH 1510: GL/MATH 1670 6.0 Fundamentals of Mathematics
- MATH 1300: GL/MATH 1930 3.0 Calculus I
- MATH 1310: GL/MATH 1940 3.0 Calculus II
- MATH 2022: GL/MATH 2660 3.0 Linear Algebra II
- MATH 2310: GL/MATH 2670 6.0 Calcul des fonctions de plusieurs variables
- MATH 1581 and MATH 2581: GL/MATH 2860 6.0 Mathematics of Investment and Actuarial Science
- MATH 3021: GL/MATH 3510 3.0 Modern Algebra I
- MATH 3022: GL/MATH 3515 3.0 Modern Algebra II
- MATH 4011 and MATH 4012: GL/MATH 4240 6.00 Analyse réelle

Career Information

Mathematics Teaching and Co-registration in Education

The Department places great importance on encouraging and helping students interested in Mathematics Education, in both its undergraduate and its graduate programs. Students may pursue a B.Ed. degree concurrently with their BA or BSc degree, or consecutively, following graduation. To be admitted to a faculty of education, you will need to have documentation showing volunteer or paid experience with tutoring, working in a school, etc. as well as a background of appropriate mathematics courses. A number of school boards offer paid positions as "tutors in the classroom" in mathematics and science, and there are also volunteer opportunities in Ontario.

Students seeking a Concurrent B.Ed. degree normally apply to the Faculty of Education for admission on admission or in their

third year. For further information, contact the Faculty of Education in Winters College (416-736-5002). Students seeking a Consecutive B.Ed. degree are advised that intermediate/senior certification requires two teaching subjects—four full courses or equivalent are recommended in the second subject. There are Consecutive Education programs at a number of Ontario universities, including several programs at York University. Not all programs have the same admission criteria, so students should get a range of advice when preparing their applications. For further information on the York Programs, contact the Faculty of Education.

Students working towards an Honours specialist in Mathematics (54 credits plus additional Ministry of Education requirements), may major not only in the Mathematics for Education program but in any of the other programs within Mathematics and Statistics, i.e., Mathematics, Applied Mathematics, Statistics, Actuarial Science, Mathematical Biology, and Computational Mathematics. With appropriate course selection, each of these programs offers good opportunities for preparation in mathematics.

Graduate Studies

York offers several graduate Programs in mathematics and statistics http://mathstats.info.yorku.ca/gradprogram/ ; for details enquire at the Graduate Program Office in N519 Ross (416-736-2100 ext. 33974, or, to leave a message, 416-736-5250). Students who may wish to pursue graduate work at York or elsewhere should choose upper-level undergraduate courses with care. Advice on this can be sought from faculty members. A ring binder of information on applying to graduate schools is available in N537 and S525 Ross.

Actuarial Science

An actuary is a business professional who analyzes the financial consequences of risk. Out of the public eye, actuary was ranked 1st in 2010/2013/2015, as well as 2nd and 4th in 2009/2012 and 2014, respectively, according to the CNBC list of best jobs in North America. One of the reasons is perhaps that the unemployment rates for actuaries have been traditionally very low, and the job prospects are good with the number of actuaries expected to grow significantly. Indeed, the U.S. Bureau of Labor Statistics projects a growth of 18% during 2014–2024, which is much faster than average for all occupations. Another reason is probably the importance of the profession to Society. In fact, numerous empirical studies conclude that a sound national insurance market is an essential characteristic of the macro-economic growth. Yet one more reason is the paystub. Namely, actuaries have been consistently very well-paid; for instance, due to CNN Money, the job is one of the ten best-paying jobs of 2017. However, with the high income comes responsibility, and during the subprime mortgage crisis of 2007–2009, an actuary was accused of inventing the formula that 'killed Wall-Street'.

Actuarial Science is very interdisciplinary in its nature, and not surprisingly, therefore, actuaries often have diverse educational backgrounds, e.g., Mathematics, Statistics, Computer Science, Engineering, Physics, Economics, Business, Biology, and even Medicine. In line with this, at York University we have observed ample of interest in Actuarial Science that comes from outside of the Department of Mathematics and Statistics, and even beyond the Faculty of Science. In addition, we have met many career changers, which looked for joining the field of insurance and finance.

For the aforementioned groups, the Specialized Honours and Honours B.A. programs are as a rule too long. Indeed, these programs are very intense subject-wise - required courses span all of Mathematics, Statistics, and Economics, and time-wise - four years of full-time studies are necessary. For this reason, a Professional Undergraduate Certificate in Actuarial Science (36 credits in total) can serve as an ideal way to go. The Certificate can be completed in one or two years, depending on the student's background.

Admission Requirements:

All students who have successfully completed calculus, statistics and linear algebra courses equivalent to the ones in the list below are admissible.

1. Calculus - similar to SC/MATH 1013 3.00; SC/MATH 1014 3.00;
2. Statistics - similar to SC/MATH 1131 3.00; and
3. Linear Algebra - similar to SC/MATH 1025 3.00.

Note: Students lacking the admission requirements listed above, may choose to enrol in the required courses at York. This would be in addition to the 36 credits required by the Certificate.

Requirements:

To qualify for the Certificate in Actuarial Science, students must complete 36 credits from the list of approved courses including:

YEAR 1:

- AP/ECON 1000 3.00; AP/ECON1010 3.00 - this requirement can be waived if the assessment of student's past academic credentials reveals that the topics were covered at a satisfactory level, which is of particular relevance to Degree Holders in Economics*;
- SC/MATH 2015 3.00 (or SC/MATH 2310 3.00) - this requirement can be waived if the assessment of student's past academic credentials reveals that the topics were covered at a satisfactory level, which is of particular relevance to Degree Holders in Mathematics/Statistics*;
- SC/MATH 2030 3.00; SC/MATH 2131 3.00 - this requirement can be waived if the assessment of student's past academic credentials reveals that the topics were covered at a satisfactory level, which is of particular relevance to Degree Holders in Statistics*;
- SC/MATH 2280 3.00; SC/MATH 2281 3.00.

YEAR 2:
SC/MATH 3280 3.00; SC/MATH 3281 3.00; SC/MATH 3330 3.00; SC/MATH 4280 3.00; SC/MATH 4281 3.00.

Graduating with a certificate:

Minimum cumulative grade point average of 4.00 is required to satisfy certificate requirements.

If you would like further information, contact Professor E. Furman (efurman@mathstat.yorku.ca).

Science and Technology Studies

Science and Technology Studies (STS) is an interdisciplinary program that offers courses of study leading to either a BA or BSc degree. Its purpose is to expand our understanding of science and technology by exploring their social, cultural, philosophical and material dimensions. To achieve that purpose, the program draws upon the disciplines of both the humanities and social sciences to offer courses treating specific scientific ideas, as well as courses addressing broader topics such as science and gender, science and religion, and technology and cultural values. Students are encouraged to draw connections across traditional boundaries as they seek an intellectual appreciation for the sciences and technology as powerful means for understanding, embodying and shaping the world and ourselves. You will learn to analyze complex ideas about science and technology, and to discover how to trace the origins and implications of events and patterns of thought in the past and present. For more information, please consult the Science and Technology Studies supplemental calendar available at http://sts.info.yorku.ca/mini-calendars/.

CORS Diploma in Operational Research

Operations Research or Operational Research (OR) deals with making the "best" decision when confronted with many choices plus a variety of constraints in a large-scale problem. Examples of typical problems are: minimizing operating costs in a large hospital while maintaining quality service to patients, finding the shortest route for a delivery truck which must make many stops, and scheduling jobs on a large construction project to finish in the shortest possible time. The problems are represented by mathematical models and various algorithms are used to find the optimal solution. Because of the magnitude of these problems, computers are usually needed to execute the algorithms.

Employment opportunities in OR usually occur with large organizations with complex operations such as transportation, manufacturing, utilities or government agencies (including the military). Other employers include management consulting firms which offer OR expertise to other companies. Some current areas in which OR practitioners are employed are: organizational design, industrial engineering, supply chain management, decision technology, enterprise resource planning and expert systems. To encourage students to study OR and seek employment in this field, the Canadian Operational Research Society (CORS) offers a Diploma in Operational Research to students who complete a prescribed set of courses.

In the Department of Mathematics and Statistics one can satisfy the requirements for the CORS Diploma while completing an Honours degree. This is simplest in Applied Mathematics since many of the courses required for the Diploma are part of the degree requirements. In other programs, careful planning in choosing courses may be required. The courses required for the Diploma are listed below. Students are also encouraged to become student members of CORS and participate in its meetings. This is a very good way in which to meet practitioners in the field of OR and find out more about potential job opportunities. A membership in CORS listed on your resume will indicate to future employers your seriousness about a career in this field. You can find out more about CORS from its web page (www.cors.ca).

The Faculty Liaison for the CORS Diploma is Professor Michael Chen, chensy@mathstat.yorku.ca, DB 2034, (416) 736-2100 x 66677.

Course Requirements for the CORS Diploma:

To obtain the CORS Diploma, a student must have graduated from an Honours program, must be a member of CORS, and must have completed the following courses with at least a B average.

1. MATH 3171, MATH 3172, MATH 4171 and MATH 4172 - OR courses
2. MATH 2131 and MATH 3330 - statistics courses
3. EECS/1020/1030 or EECS/1520/1530 or EECS/1540 or EECS/1560 - computer languages
4. one of OMIS/MGTS 4000, OMIS/MGTS 4550, OMIS/MGTS 4560. These courses are offered by the Schulich School of Business. All these courses have MATH 2131 and MATH 3170 or 3171/3172 as pre-requisites.

Students are strongly encouraged to select additional courses from the following list in preparation for a career in OR:

- MATH 3260 - graph theory
- MATH 4130B, MATH 4280, MATH 4430, MATH 4830, MATH 4930A - additional statistics courses
- MATH 3280 - actuarial science
- ECON 3580, ECON 3590—accounting
- OMIS/MGTS 4670, OMIS/MGTS 4710, OMIS/MGTS 4720 - information systems
- additional OMIS/MGTS course from item 4 in the list of required courses above.
- EECS 2031 - Software Tools
- OMIS/MGTS 3670 - Spreadsheet-Based Decision Support
- OMIS/MGTS 3730 - Database Management with Microsoft Access

Note that these courses may have additional prerequisites.

Mathematical Biology

Questions in Mathematical Biology:

- How do tumors grow?
- Why do some infectious diseases persist even though there are effective vaccines against them?
- How do proteins fold into their correct biologically active shape?
- How are certain animal species affected by climate change?
- Can we provide sustainable environments for animals living in areas of industrial growth?
- How do plants spread?
- Why do fireflies blink in sync?
- Can we better understand migration and movement of birds and animals?
- Can we model how different animals get thier spots or stripes?

Careers for Mathematical Biology graduates:

- University researchers in Engineering, Medicine, Science, Environmental Studies
- Medicine, Epidemiology, Immunology, etc
- Research laboratories in hospitals
- Business and government research labs, i.e. Environment Canada, Public Health Agency of Canada, World Health Organization
- Museums
- Finance — modelling experience is an asset
- Teaching
- City planning
- Drug companies
- Forestry industry
- Oil and Gas industry

Examples of specialized areas of application

- Biochemistry
- Molecular Biology
- Cell Biology
- Ecology
- Population Biology
- Animals
- Genetics
- Immunobiology and Virology
- Plant Science

Statistics

Statistics has become increasingly essential to discoveries and innovations of every advance of science and society. With the advent of high dimensional data arising from different fields, statistics has undergone dramatic advancement and developments. Statistician is projected to be one of the fast growing jobs according to the Bureau of Labor Statistics in U.S. According to Devan Mehrotra, executive director of the biostatistics department at Merck Research Laboratories, “any real-world problem almost always is going to require some data to be analyzed and interpreted, generating value-added solutions by using statistics. There’s now more exciting opportunities. It has never been a better time to be a statistician”. Students with statistics degree have been employed in pharmaceutical companies, research institutes and government agencies. Statistics Canada has an annual recruitment campaign for statistician with an undergraduate degree in statistics. With the increasing application of statistical techniques in business, statisticians have also been working in financial institutions such as banks and credit card companies. With the advent of big data analytics, more and more statisticians have been working in high technology companies to analyze big data collected from online sources and social media. Other areas of employment include medicine, environmental science, industry statistics, and market research, etc. Upon graduation, students are encouraged to apply for accreditation of the Associate Statistician (A. Stat.) from the Statistical Society of Canada, which has accredited certain courses given below as partially satisfying the requirements for the Associate Statistician (A. Stat.). Further information on the Professional Statistician (P. Stat.) and Associate Statistician (A. Stat.) designation is available at http://www.ssc.ca or contact Professor Cindy Fu, Director of Statistics (yuejiao@mathstat.yorku.ca).

Accredited courses that may be used towards the Associate Statistician designation

Module	Course
Mathematics Modules	
1. Calculus I	MATH 1300 Differential Calculus with Applications, AND MATH 1310 Integral Calculus with Applications
2. Calculus II	MATH 2310 Calculus of Several Variables with Applications
3. Linear Algebra	MATH 1021 Linear Algebra I, AND MATH 2022 Linear Algebra II
Statistics and probability modules	
4. Mathematical Statistics	MATH 3131 Mathematical Statistics I, AND MATH 3132 Mathematical Statistics II

5. Linear Regression	MATH 3330 Regression Analysis	
6. Design of Experiments	MATH 4730 Experimental Design	If only one of these courses is taken, the other must be replaced by a course from the list below.
7. Survey Sampling	MATH 3430 Sample Survey Design OR MATH 4731 Sampling: Design and Analysis	
8. Electives	Select three from • MATH 3280 Actuarial Mathematics • MATH 4330 Applied Categorical Data Analysis • MATH 4830 Time Series and Spectral Analysis OR LE / ESSE 4020 Time Series and Spectral Analysis • MATH 4931 Simulation and the Monte Carlo Method • MATH 4034 Data Mining • MATH 4130K Survival Analysis • MATH 4130B Topics in Probability and Statistics: Introduction to the Theory and Methods of Time Series Analysis • MATH 4230 Nonparametric Methods in Statistics • MATH 4280 Risk Theory — Loss Models and Risk Measures • MATH 4281 Risk Theory — Ruin and Credibility • MATH 4330 Applied Categorical Data Analysis • MATH 4630 Applied Multivariate Statistical Analysis • MATH 4430 Stochastic Processes • MATH 4930A Topics in Applied Statistics: Statistical Quality Control	If MATH 4931 is chosen as one of the three courses required to satisfy module 8, it MAY NOT be used to satisfy module 10.
Computer Skills		
9. Computer Skills I	EECS 1560 Introduction to Computing for Mathematics and Statistics	
10. Computer Skills II	MATH 4931 Simulation and the Monte Carlo Method OR MATH 4939 Statistical Data Analysis Using SAS and R	MATH 4931 may be used in EITHER module 8 or module 10, but not both
Design of Experiments		
11. Communication Skills	WRIT 1702 OR MATH 4000 Individual Project	
Substantive Area		
12. Course 1	A minor in an area other than Statistics following the York University calendar OR three courses at the 3000+ level in an area other than Statistics (e.g. economics, biology, pure mathematics, sociology, psychology ...). At York, MATH courses with a third digit of 3 are classified as Statistics courses.	
13. Course 2		
14. Course 3		

Expiry Date: 17 February 2022

COURSE OFFERINGS
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Note that instructors for some courses may change after publication of this supplemental calendar.

1000-level Courses

MATH 1013 3.00 FW
Applied Calculus I

Calendar copy: Introduction to the theory and applications of both differential and integral calculus. Limits. Derivatives of algebraic and trigonometric functions. Riemann sums, definite integrals and the Fundamental Theorem of Calculus. Logarithms and exponentials, Extreme value problems, Related rates, Areas and Volumes. Prerequisite: SC/MATH 1515 3.00 or SC/MATH 1520 3.00, or a high school calculus course. Course credit exclusions: SC/MATH 1000 3.00, SC/MATH 1300 3.00, SC/MATH 1505 6.00, SC/MATH 1530 3.00, SC/MATH 1550 6.00, SC/ISCI 1401 3.00, GL/MATH/MODR 1930 3.00, AP/ECON 1530 3.00.

Note: MATH 1013 3.00 is a prerequisite for MATH 1014 3.00 and MATH 1310 3.00.

BIOLOGY AND KINESIOLOGY STUDENTS ARE ADVISED TO CONSIDER CAREFULLY WHETHER THEY SHOULD BE TAKING MATH 1013/1014 OR MATH 1505. SEEK ADVICE BEFORE ENROLLING IF YOU ARE UNCERTAIN.

Anyone majoring in a Mathematics and Statistics program should take MATH 1300 3.00 instead of MATH 1013 3.00.

The text will be J. Stewart, Calculus: Early Transcendentals, 8th ed.

Coordinator: A. Skelton (askelton@yorku.ca)

MATH 1014 3.00 FW
Applied Calculus II

Calendar copy: Calculus in Polar Coordinates. Techniques of Integration. Indeterminate Forms. Improper Integrals. Sequences, infinite series and power series. Approximations. Introduction to ordinary differential equations. Prerequisite(s): One of SC/MATH 1013 3.00; SC/MATH 1300 3.00, for non-science students only, six credits from SC/MATH 1530 3.00 and SC/MATH 1540 3.00, SC/MAT 1550 6.00, AP/ECON 1540 3.00. Course credit exclusions: SC/MATH 1310 3.00, SC/MATH 1505 6.00, SC/ISCI 1402 3.00, GL/MATH/MODR 1940 3.00.

Note: MATH 1014 3.00 is a prerequisite for MATH 2015 3.00, MATH 2030 3.00, MATH 2041 3.00, MATH 2280 3.00, MATH 2310 3.00, MATH 2930 3.00 and MATH 3241 3.00.

This course is a sequel to MATH 1013, and will use the same textbook.

Coordinator: A. Skelton (askelton@yorku.ca)

EECS/MATH 1019 3.00 FW
Discrete Mathematics for Computer Science

Calendar copy: Introduction to abstraction. Use and development of precise formulations of mathematical ideas. Informal introduction to logic; introduction to naïve set theory; induction; relations and functions; big O-notation; recursive definitions, recurrence relations and their solutions; graphs and trees. Three lecture hours per week. Plus drop-in optional problem sessions as well as instructor office hours, as these are announced in each term. Prerequisites: SC/MATH 1190 3.00, or two 4U Math courses, including MHF4U (Advanced Function). Course credit exclusion: SC/MATH 2320 3.00, SC/EECS/MATH 1028 3.00.

Note: MATH 1019 3.00 is a prerequisite for MATH 1090 3.00 and MATH 3021 3.00.

The curriculum is an introduction to basic ideas and methods in Discrete Mathematics. There will be a short review of concepts from formal logic and the idea of a mathematical proof (including mathematical induction). Sets and functions will be covered, including the growth of functions and Big-Oh notation. The second half of the course will be devoted to recursion and introductory methods in counting, including the pigeonhole principle, and the solution of linear recurrences.

Coordinators: Fall: TBA
Winter: TBA

MATH 1021 3.00 FW
Linear Algebra I

Calendar copy: Linear equations, matrices, Gaussian elimination, determinants and vector spaces. This course covers material similar to that in SC/MATH 2221 3.00 but at a more advanced level. Required in Specialized Honours statistics and in all applied mathematics, mathematics and mathematics for commerce programs except the BA Program in Mathematics for Commerce. Prerequisite: One 12U or OAC mathematics course or equivalent. Course credit exclusions: SC/MATH 1025 3.00, SC/MATH 2021 3.00, SC/MATH 2221 3.00, GL/MATH/MODR 2650 3.00.

Note: MATH 1021 3.00 is a prerequisite for MATH 2022 3.00, MATH 2200 3.00, MATH 2270 3.00, MATH 3141 3.00, MATH 3171 3.00, MATH 3172 3.00, MATH 3241 3.00, MATH 3330 3.00 and MATH 4171 3.00.

Note: MATH 1540 3.00 may not be taken for credit by anyone taking, or anyone who has passed, MATH 1021.

After the concepts in logic and set theory, the most fundamental idea in all of mathematics is that of a function. The simplest type of function is a linear function, and linear functions (also called linear transformations) are what linear algebra is about. Thus, linear algebra is mathematically more basic than, for instance, differential calculus, where more complicated functions are approximated locally by linear ones. Apart from underpinning much of mathematics, linear algebra has a vast range of applications — from quantum mechanics to computer graphics to business and industry (via statistics and linear programming).

Additional topics: Euclidean *n*-space, lines and planes, linear transformations from R^n to R^m, abstract vector spaces, basis and dimension, rank and nullity of a matrix.

The text has not been chosen yet.

Coordinators: Fall: Hm. Zhu (hmzhu@mathstat.yorku.ca)
Winter: A. Weiss (weiss@mathstat.yorku.ca)

MATH 1025 3.00 FW
Applied Linear Algebra

Calendar copy: Topics include spherical and cylindrical coordinates in Euclidean 3-space, general matrix algebra, determinants, vector space concepts for Euclidean n-space (e.g. linear dependence and independence, basis, dimension, linear transformations etc.), an introduction to eigenvalues and eigenvectors. Prerequisites: One 12U or OAC mathematics course or equivalent. Course credit exclusions: SC/MATH 1021 3.00, SC/MATH 2021 3.00, SC/MATH 2221 3.00, GL/MATH/MODR 2650 3.00.

Note: MATH 1025 3.00 is a prerequisite for MATH 2270 3.00, MATH 2271 3000, MATH 2930 3.00, MATH 3141 3.00, MATH 3171 3.00, MATH 3241 3.00, MATH 3330 3.00 and MATH 4171 3.00.

Note: MATH 1540 3.00 may not be taken for credit by anyone taking, or anyone who has passed, MATH 1025.

MATH 1025 3.00 gives a one-term intensive introduction to linear algebra, with emphasis on its applications. This course is particularly appropriate for students taking Science or Engineering programs which require one term's worth of linear algebra.

The text will be K. Kuttler, *A First Course in Linear Algebra* (available as a free download).

Coordinator: Y. Gao (ygao@yorku.ca)

MATH 1028 3.00 W
Discrete Math for Engineering

Calendar Copy: Introduction to discrete mathematics for engineering disciplines, including an introduction to propositional logic and application to switching circuits; sets, relations and functions; predicate logic and proof techniques; induction with applications to program correctness; basic counting techniques with applications; graphs and trees with applications in circuit analysis, information storage and retrieval, Huffman coding; automata and applications in software engineering. Three lecture hours and two hours of mandatory tutorials per week. Prerequisites: MHF4U and MCV4U. Course Credit Exclusions: LE/SC/EECS 1019 3.0, SC/MATH 1019 3.00, SC/MATH 2320 3.00.

Coordinator: TBA (Computer Science)

MATH 1090 3.00 FW
Introduction to Logic for Computer Science

Calendar copy: The syntax and semantics of propositional and predicate logic. Applications to program specification and verification. Optional topics include set theory and induction using the formal logical language of the first part of the course. Prerequisite: SC/MATH 1190 3.00 or SC/MATH 1019 3.00. Note: This course may not be taken for degree credit by any student who has passed SC/MATH 4290 3.00.

Note: MATH 1090 3.00 is a prerequisite for MATH 2320 3.00.

By taking this course, students will be able to master the syntax and proof techniques of propositional and predicate logic, as well as their informal semantics. The proper understanding of propositional logic is fundamental to all levels of computer programming, even the most basic, while the ability to correctly use variables, scope and quantifiers is crucial in the use of loops, subroutines, and modules, and in software design. Logic is used in many areas of computer science, including digital design, program verification, databases, artificial intelligence, computability and complexity, algorithm analysis, and software specification. Every program implicitly asserts a theorem to the effect that the program will do what its documentation says it will. Proving that theorem is not merely a matter of luck or patient debugging. Making a correct program can be greatly aided by a logical analysis of what it is supposed to do, and, for small pieces of code, a proof that the code works can be produced hand-in-hand with the construction of the code itself.

The main objective of the course is to enable the student to write and annotate correct formal proofs of "theorems", especially in predicate logic. A big secondary goal is to help the student to tell the difference between a theorem and a nontheorem, and to "DISprove" nontheorems. The student will be immersed in proof methodologies of propositional, and, much more extensively, of predicate, logic, via well-annotated and well-structured proofs in both the "equational" and the "Hilbert" style of structuring proofs. Semantics will be introduced (informally, in the predicate case), partly to breathe "meaning" into the formal syntax of logic, and partly as an indispensable tool for producing the "disproofs" mentioned above.

The text will be G. Tourlakis, *Mathematical Logic* (Wiley, 2008).

Coordinator: TBA

MATH 1131 3.00 FW
Introduction to Statistics I

Calendar copy: Displaying and describing distributions; relations in categorical data; Simpson's paradox and the need for design; experimental design and sampling design; randomization; probability laws and models; central limit theorem; statistical inference including confidence intervals and tests of significance; matched pairs; simulation. Prerequisite: At least one 12U mathematics course or OAC in mathematics is recommended. Course credit exclusion: SC/MATH 2560 3.00, SC/MATH 2930 3.00, GL/MATH/MODR 1610 3.00, SC/BIOL 2060 3.00.

Note: MATH 1131 3.00 is a prerequisite for MATH 2131 3.00, MATH 3330 3.00 and MATH 4143 3.00.

Statistics is the science of data, and this course will introduce you to some of the basic, yet incredibly useful, statistical techniques.

Topics include collection and analysis of data, graphical methods to represent data, numerical methods for describing univariate data both for samples and population, summarizing bivariate data, random variables and probability distributions, sampling variability and sampling distributions, estimation and testing using a single sample, comparison of two populations.

It is recommended that students have at least one OAC in mathematics or a 12U mathematics course, but the mathematical level of the course will be quite elementary. Although students might be making use of the computer to calculate statistics, no previous experience in computing is required. Students will receive all the necessary instruction about how to use the statistical computer package chosen by the instructor.

Although this course is recommended for students who wish to major in statistics, the concepts are broadly applicable and it should be interesting to students who do not plan to specialize in statistics.

Coordinator: H. Jankowski (hkj@mathstat.yorku.ca)

MATH 1190 3.00 FW
Introduction to Sets and Logic
(formerly: MATH 1120 3.00, MATH 1090 3.00)

Calendar copy: Topics include logic, sets, functions, relations, modular arithmetic and applications of elementary number theory, proof techniques, induction. Prerequisite: One 12U or OAC mathematics course or equivalent. NCR Note: This course may not be taken for degree credit by any student who has passed any 3000- or higher-level mathematics course. Course credit exclusion: GL/CSLA/MATH/MODR 1650 3.00.

Note: MATH 1190 3.00 is a prerequisite for MATH 1019 3.00, MATH 1090 3.00, MATH 2320 3.00 and MATH 3021 3.00.

It is also intended for math majors and other students wanting an introduction to discrete mathematics. The topics covered are widely used throughout mathematics; many will crop up again in other mathematics courses. The purpose of this course is to give these topics a thorough treatment early in a student's mathematical studies, with the intention of enhancing his or her understanding of future courses, irrespective of whether those courses have MATH 1190 as a prerequisite. The emphasis will be on understanding the basic ideas, and developing an appreciation for mathematical reasoning, proofs and problem solving.

There is considerable overlap between the topics of MATH 1190 and those of the course MATH 1019 (see the MATH 1019 entry earlier in this supplemental calendar). Math majors can choose to take either of these two courses (see the Mathematics BA, BSc program tables at the back of this supplemental calendar), but, before choosing, they should note that:

The coverage of topics in MATH 1019 should be at a higher "level" and perhaps at a faster pace than in

MATH 1190. Moreover, MATH 1190 cannot be taken for degree credit by any student who has already passed MATH 1019. Note also that MATH 1019 is a program requirement in Computer Science.

The text will be K.H. Rosen, *Discrete Mathematics and its Applications*, 7th ed. (McGraw-Hill).

Coordinators: Fall: TBA
Winter: A. Montero

MATH 1200 3.00 FW
Problems, Conjectures and Proofs

Calendar copy: Extended exploration of elementary problems leading to conjectures, partial solutions, revisions, and convincing reasoning, and hence to proofs. Emphasis on problem solving, reasoning, and proving. Regular participation is required. Prerequisite: 12U Advanced Functions (MHF4U) or Advanced Functions and Introductory Calculus (MCB4U). Course credit exclusion: SC/MATH 2200 3.00.
NCR note: Not open to any student who is taking or has passed a MATH course at the 3000 level or higher.

Note: MATH 1200 3.00 is a prerequisite for MATH 2001 3.00, MATH 3021 3.00 and MATH 3141 3.00.

Most high school mathematics problems are solved using algorithmic methods or by reference to model solutions. One purpose of this course is to enable students to develop the confidence and ability to attack richer and more demanding problems. The attempt to check one's work leads to the need to explain one's work to others. Learning how to present convincing reasoning as proof is a major goal of this course.

With this emphasis on communication of convincing argument, much of the class time will be devoted to reading and discussing the proofs proposed by the students in the class. Students will learn that theorems can often be correctly proved by many different approaches, and that some approaches may offer advantages over others. Students will also learn that some proposed proofs have gaps that can be fixed using additional argument.

Class and tutorial attendance is mandatory and active participation is expected of all students.

Coordinator: M. Zabrocki (zabrocki@mathstat.yorku.ca)

MATH 1300 3.00 FW
Differential Calculus with Applications

Calendar copy: Limits, derivatives with applications, antiderivatives, fundamental theorem of calculus, beginnings of integral calculus. Prerequisite: SC/MATH 1520 3.00 or a high school calculus course. Course credit exclusions: SC/MATH 1000 3.00, SC/MATH 1013 3.00, SC/MATH 1505 6.00, SC/MATH 1513 6.00, SC/MATH 1530 3.00, SC/MATH 1550 6.00, SC/ISCI 1401 3.00, GL/MATH/MODR 1930 3.00, AP/ECON 1530 3.00.

Note: MATH 1300 3.00 is a prerequisite for MATH 1014 3.00, MATH 1310 3.00, MATH 2001 3.00 and MATH 2200 3.00.

Differential calculus is the study of rates of change of real valued functions. This notion will be precisely defined and key facts about it will be proved. The examination of these concepts will entail a close study of limits and continuity and will culminate with the proof of a remarkable theorem about the rate of change of the area bounded by the graph of a function.

This is a theoretical course emphasizing precise definitions and featuring proofs of some important results. Students successfully completing this course should be well prepared to continue their studies of more advanced courses such as MATH 2001. The final grade will be based on three midterm examinations as well as a final examination. The material of the course will be presented in three lecture hours and one tutorial hour each week.

The text will be Calculus (8th edition) by J. Stewart. This is not the same text as that used in MATH 1013.

Coordinator: J. Steprāns (steprans@yorku.ca)

MATH 1310 3.00 FW
Integral Calculus with Applications

Calendar copy: Transcendental functions, differential equations, techniques of integration, improper integrals, infinite series. Prerequisite(s): One of SC/MATH 1013 3.00, SC/MATH 1300 3.00; or, for non-science students only, six credits from SC/MATH 1530 3.00 and SC/MATH 1540 3.00, SC/MATH 1550 6.00, AP/ECON 1530 3.00 and AP/ECON 1540 3.00. Course credit exclusions: SC/MATH 1014 3.00, SC/MATH 1505 6.00, SC/ISCI 1402 3.00, GL/MATH/MODR 1940 3.00.

Note: MATH 1310 3.00 is a prerequisite for MATH 2015 3.00, MATH 2030 3.00, MATH 2041 3.00, MATH 2200 3.00, MATH 2280 3.00, MATH 2310 3.00, MATH 3001 3.00 and MATH 3241 3.00.

This is the second in a series of introductory calculus courses designed to follow MATH 1300. The study of integral calculus begun in MATH 1300 is continued. The first half of the course emphasizes methods of integration. Exponential and logarithmic functions are properly defined using integrals. Improper integrals are used to study unbounded areas. Applications are made to compute volumes, approximate areas and compute distance traveled. Simple differential equations are solved with applications to exponential growth and mixing problems. Infinite sequences and series are studied. Functions are represented by Taylor series and power series are used to compute limits and approximate integrals.

This is a theoretical course emphasizing precise definitions and featuring proofs of some important results. Students successfully completing this course should be well prepared to continue their studies of more advanced courses such as MATH 2001. The final grade will be based on three midterm examinations as well as a final examination. The material of the course will be presented in three lecture hours and one tutorial hour each week.

The text will be Calculus (8th edition) by J. Stewart. This is not the same text as that used in MATH 1014.

Coordinator: **J. Steprāns** (steprans@yorku.ca)

MATH 1505 6.00 Y
Mathematics for the Life and Social Sciences

Calendar copy: A presentation of the elements of single-variable differential and integral calculus, elementary linear algebra and introductory probability and statistics. This course is designed to provide a comprehensive mathematical background for students of the biological and social sciences. Emphasis is placed on basic mathematical skills and their applications. Prerequisite: 12U Advanced Functions (MHF4U) or equivalent, or SC/MATH 1510 6.00. Course credit exclusions: SC/MATH 1013 3.00, SC/MATH 1014 3.00, SC/MATH 1300 3.00, SC/MATH 1310 3.00, SC/MATH 1530 3.00, SC/MATH 1540 3.00, SC/MATH 1550 6.00, GL/MATH/MODR 1930 3.00, GL/MATH/MODR 1940 3.00, AP/ECON 1530 3.00, AP/ECON 1540, SC/ISCI 1401 3.00, SC/ISCI 1402 3.00, SC/ISCI 1410 6.00.

The course content emphasizes the following topics in an introductory but mathematically rigorous way: functions, differentiation, integration, vectors, matrices and probability. Applications are discussed throughout the course and calculators are not allowed in this course. It is imperative students taking this course have the appropriate prerequisite mathematical knowledge in order to excel in this course. Students who feel that they do not, are strongly encouraged to enrol in Math 1510 first to build their foundational mathematics. Upon successful completion of Math 1510 (i.e., B or higher), students will then be prepared for Math 1505.

For students enrolled in Math 1505 and who are unsure if they have sufficient prerequisite mathematical knowledge, they should speak with their Math 1505 professor before the add/drop deadline, and there may be an assessment quiz at the beginning of the course to assess mathematical preparedness for Math 1505.

Math 1505 is designed for students enrolled in programs that only require 6 credits of mathematics, and should be taken in the first year of academic studies. Typically, students in a Biology, Psychology and/or Health program enrol in Math 1505. Students who are looking for a comprehensive study of the topics listed above should not be taking Math 1505. The mathematics learned in Math 1505 will not be sufficient for students furthering a pursuit of mathematics at an intermediate or advance level.

The text is J. Stewart and T. Day, *Biocalculus: Calculus, Probability, and Statistics for the Life Sciences*.
Coordinator: A. Chow (amchow@yorku.ca)

MATH 1510 6.00 Y
Fundamentals of Mathematics

Calendar copy: Designed for the student whose mathematical background is weak and who wishes to take further courses in mathematics. Topics include algebraic equations and inequalities; simple sequences and series; analytic geometry; trigonometry; functions, including algebraic, exponential, logarithmic and trigonometric functions. Prerequisites: Ontario Grade 11 Functions or Functions & Relations (new curriculum) or Grade 12 Advanced Mathematics (old curriculum). NCR Note: May not be taken by any student who has taken or is currently taking another university course in mathematics or statistics except for SC/MATH 1520 3.00. Course credit exclusion: GL/ITEC/MATH/MODR 1670 6.00.

Note: MATH 1510 6.00 is a prerequisite for MATH 1505 6.00.

This course prepares students for additional courses in mathematics.

Students in the Faculty of Health (or biology majors) who wish to be better prepared for MATH 1505 should take this course first. If you complete MATH 1510 successfully, you will be well prepared to take MATH 1505.

Students in the Faculty of Liberal Arts and Professional Studies who wish to be better prepared for courses like MATH 1520 should take this course. If you succeed (or are succeeding) in MATH 1510, you will be better prepared for MATH 1520.
Coordinator: A. Pietrowski (pietrows@mathstat.yorku.ca)

MATH 1520 3.00 FW
Introduction to Calculus, with Vectors

Calendar Copy: Elements of vectors in 2- and 3-space including dot products, cross products, lines, and planes; elements of differential calculus including limits and derivatives. Designed for student who have not taken (or who have performed inadequately in) Ontario high school calculus. Prerequisite: One of: MATH 1510 6.00, an OAC mathematics course, 12U Advanced Functions (MHF4U), or equivalent; or permission of the department. This course may be taken at the same time as the second half of MATH 1510 6.00. NCR Note: May not be taken by any student who has passed or is currently taking another university course in calculus, with the exception of students taking SC/MATH 1550 6.00 concurrently.

Note: MATH 1520 3.00 is a prerequisite for MATH 1013 3.00, MATH 1300 3.00 and MATH 1550 6.00.

This course covers the elements of differential calculus including limits, rates of changes, derivatives, methods of differentiation, applications of derivatives, related rates, extreme values, maximum and minimum problems and curve sketching. The course also covers elements of vector in 2- and 3-space including dot products, cross products, lines, and planes.

Supplemental material for vectors will be announced.
Coordinator: A. Weiss (weiss@mathstat.yorku.ca)

MATH 1530 3.00 FW
Introductory Mathematics for Economists I

Calendar Copy: Introduces and develops topics in differential calculus and integral calculus with applications to marginal analysis and profit maximization. Prerequisite: Grade 12U Advanced Functions or equivalent. Prerequisites/Co-requisites: AP/ECON 1000 3.00 or AP/ECON 1010 3.00, or equivalent. Recommended completion: high-school calculus or equivalent. Course credit exclusions: SC/MATH 1013 3.00, SC/MATH 1300 3.00, SC/MATH 1505 6.00, SC/MATH 1513 6.00,

SC/MATH 1550 6.00, GL/MATH/MODR 1930 3.00. Note: Acceptable course substitutes are available in the Calendar.

Note: MATH 1530 3.00 is a prerequisite for MATH 1310 3.00.

Note: This course is not currently offered by the Mathematics and Statistics Department. The Department of Economics is now responsible for all sections.

The pair MATH 1530 3.00 and MATH 1540 3.00 is designed to give the student an introduction to mathematics sufficient for a thorough understanding of modern textbooks in economic theory. The emphasis is on the acquisition of tools for later use and on an understanding of both concepts and techniques for applications, rather than on theoretical proofs or a rigorous development of the mathematics involved. The pair is similar to MATH 1550 6.00.

Topics will include single-variable differentiation, limits, continuity, series, exponential and logarithmic functions, single-variable optimization, and integration. Applications to problems in economics involving supply and demand functions, maximization of profits, elasticity of demand and consumers' surplus will be considered.

Course material will be announced in class.

The final grade may be based on term tests and/or assignments and a final examination. Instructors will announce details in class.

MATH 1532 3.00 FW
Statistics for Business and Society

Calendar Copy: An introduction to statistics with an emphasis on concepts and applications relevant in the Business and Society program. Students learn basic and practical statistical techniques to explore and analyze data. Emphasis is placed on statistical reasoning and the critical interpretation of statistical information such as that seen in the media and journals. NCR note: SC/MATH 1532 3.00 may not be taken for credit by any student who has successfully completed or is concurrently enrolled in SC/MATH 1131 3.00, SC/MATH 2560 3.00, SC/MATH 2570 3.00, SC/MATH 2930 3.00, SC/BIOL 2060 3.00 or equivalents. Course credit exclusion: SC/NATS 1500 3.00.

This course is an introduction to statistics specifically designed for students in the Business and Society program in the Division of Social Science. Students learn basic and practical statistical techniques to explore and analyze data. Emphasis is placed on statistical reasoning and the critical interpretation of statistical information such as that seen in the media and in journals.

There is also a strong emphasis on acquiring practical skills in data exploration with spreadsheet software such as Excel or Calc. The course includes weekly tutorials in a computer lab.

Grading is based on

1. Assignments including lab exercises: 30%
2. Structured project based on the analysis of real data: 25%
3. Mid-term test: 20%
4. Final exam: 25%

The text is to be announced.

Coordinator: Y. Wu (wuyh@mathstat.yorku.ca)

MATH 1540 3.00 FW
Introductory Mathematics for Economists II

Calendar Copy: Introduces and develops topics in comparative statics of general function models and matrix algebra with applications to input-output models, unconstrained and constrained optimization with applications to microeconomic and macroeconomic models, and elements of linear programming with applications to decision-making in economics. Prerequisite: AP/ECON 1530 3.00 or equivalent. Prerequisites/Co-requisites: AP/ECON 1000 3.00 or AP/ECON 1010 3.00, or equivalent. Note: No credit will be retained for this course for students who have successfully completed or who are currently enrolled in SC/MATH 1021 3.00, SC/MATH 1025 3.00, or SC/MATH 2221 3.00. Course credit exclusions: SC/MATH 1505 6.00, SC/MATH 1550 6.00, GL/MATH/MODR 2650 3.00. Note: Acceptable course substitutes are available in the Calendar.

Note: MATH 1540 3.00 is a prerequisite for MATH 1014 3.00 and MATH 1310 3.00.

Note: This course is not currently offered by the Mathematics and Statistics Department. The Department of Economics is now responsible for all sections.

This course is normally taken by students who have completed MATH 1530 3.00 and are in the Bachelor Mathematics for Commerce Program.

The material that is covered in the course is mainly matrix algebra and functions of many variables. The material will be covered in a way that will be of interest to students in economics and business. The emphasis will be on the acquisition and use of tools rather than on a rigorous development of the tools. Applications will include the solution of linear equations, and maxima and minima of functions of several variables, with and without constraints.

The text and grading scheme are anticipated to be the same as those for MATH 1530 3.00.

MATH 1550 6.00 Y
Mathematics with Management Applications

Calendar copy: This course is designed to provide a mathematical background for students in the BBA Honours program. It is also suitable for the bachelor program in mathematics for commerce, but should not be taken by those who intend to major in any other program in mathematics or statistics or in computer science. It includes calculus, basic mathematics of finance and linear algebra, elementary probability and statistics, and elements of optimization with applications to management. Prerequisite: SC/MATH 1520 3.00 (may also be taken as a first-term corequisite), or a high school calculus course. Course credit exclusions: SC/MATH 1013 3.00, SC/MATH 1300 3.00, SC/MATH 1505 6.00, SC/MATH 1513 6.00, SC/MATH 1530 3.00, SC/MATH 1540 3.00, GL/MATH/MODR 1930 3.00, AP/ECON 1530 3.00, AP/ECON 1540 3.00. NCR Note: No credit will be retained for this course for students who have successfully completed or who are

currently taking SC/MATH 1021 3.00, SC/MATH 1025 3.00, SC/MATH 2021 3.00, SC/MATH 2221 3.00, GL/MATH/MODR 2650 3.00 or equivalent.

Note: MATH 1550 3.00 is a prerequisite for MATH 1014 3.00, MATH 1310 3.00 and MATH 3330 3.00.

This course is designed primarily for students interested in business programs. It satisfies a requirement for entry to the delayed entry BBA (Hons) Programs in the Schulich School of Business. One theme of the course is optimization - how to maximize or minimize a linear functions of several variables subject to linear constraints. Most of the course is a discussion of calculus and its applications to management; matrix theory and its applications including elementary Markov chains are also discussed. The emphasis will be on techniques and on applications to business and management problems. The content of this course is mostly similar but is not coinciding with that of the two courses MATH 1530 3.00 and MATH 1540 3.00. These courses will satisfy the requirements for the programs mentioned above, and they are suitable for those who plan to major in economics. Those who wish a stronger foundation in calculus, or who wish to major in any Mathematics program other than those mentioned above, should avoid calculus courses with second digit 5.

The textbook is Ernest F. Haeussler Jr., Richard S. Paul and Richard J. Wood, *Introductory Mathematical Analysis for Business and Economics,* 14th ed. by Pearson Canada Inc., 2019. The grading scheme has not been determined as this supplemental calendar goes to press.

Coordinator: I. Raguimov (raguimov@mathstat.yorku.ca)

MATH 1581 3.00 FW
Business Mathematics I

Calendar copy: This course is an introduction to interest rates (simple, compound), annuities (ordinary, due, deferred), amortization (mortgages, other debts), sinking funds, bonds (face value, bond rate, price, yield rate) and depreciation (straight line, constant percentage). Prerequisite: Ontario Grade 11 mathematics or equivalent. Course credit exclusion: SC/MATH 2580 6.00, GL/MATH 2680 6.00.

Note: MATH 1581 3.00 is a prerequisite for MATH 2581 3.00.

A different title for this course might be "The Mathematics of Money". As money moves through time, the force of interest must be taken into account. Doing so requires mathematical calculations, and this course introduces some of those calculations. While the background required is only (the equivalent of) Ontario Grade 11 mathematics, the course will be a university-level mathematics course that requires problem-solving skills.

This course will be offered in both Fall term and Winter term. It should be particularly attractive to students in the Business and Society Program, and also to students in economics and business-related areas. The course emphasizes problem-solving rather than theory. Computers (spreadsheets) will not be used; student will need a hand-held calculator which can at least calculate exponents and logarithms.

Tentatively, the text will be R.L. Brown, S. Kopp and P. Zima, *Mathematics of Finance*, latest edition (McGraw-Hill Ryerson Limited), but only about half the text (and not exactly the first half) will be covered.

The grading scheme for the course has not been determined, but it will likely involve one or two tests and a final examination.

Coordinators: Fall: TBA
Winter: TBA

2000-level Courses

MATH 2001 3.00 F
Real Analysis I

Calendar copy: Axioms for, and properties of, the real numbers; sequences; functions of a real variable, continuity, and differentiation. Rigorous definitions of convergence and limit underpin a proof-based treatment of the subject material. Intended for Honours students in Mathematics. Prerequisites: SC/MATH 1200 3.00, SC/MATH 1310 3.00. Course credit exclusion: SC/MATH 3110 3.00, GL/MATH 3320 3.00. NCR note: MATH 2001 3.00 is not open to any student who has passed MATH 1010 3.00

Note: MATH 2001 3.00 is a prerequisite for MATH 3001 3.00.

This is the first in a three-course sequence in Analysis (to be followed by MATH 3001 and MATH 4010) for Honours stream Mathematics majors. The course proves that the real numbers, seen as infinite sequences of digits, satisfy various compactness properties. This is followed by a study of limits of sequences. The convergence of sequences is then used to define the continuity of functions on the real line. Differentiation and Riemann integration are then developed, filling in the details of proofs that are not usually provided in first year calculus courses.

The text will be Steven R. Lay, *Analysis with an Introduction to Proof*. MATH 2001 will cover most of Chapters 3 to 8.

Coordinator: P. Szeptycki (szeptyck@yorku.ca)

MATH 2015 3.00 FW
Applied Multivariate and Vector Calculus

Calendar copy: Topics covered include partial derivatives; grad, div, curl and Laplacian operators; line and surface integrals; theorems of Gauss and Stokes; double and triple integrals in various coordinate systems; extrema and Taylor series for multivariate functions. Prerequisite: One of SC/MATH 1014 3.00, SC/MATH 1310 3.00; or SC/MATH 1505 6.00 plus permission of the course coordinator. Course credit exclusions: SC/MATH 2010 3.00, SC/MATH 2310 3.00, GL/MATH/MODR 2670 3.00, GL/MATH 3200 3.00.

Note: MATH 2015 3.00 is a prerequisite for MATH 2131 3.00, MATH 2270 3.00, MATH 2271 3.00, MATH 3271 3.00, MATH 3410 3.00, MATH 4120 3.00, MATH 4143 3.00, MATH 4171 3.00, MATH 4172 3.00, MATH 4271 3.00 and MATH 4830 3.00.

Topics covered include partial derivatives; grad, div, curl and Laplacian operators; extrema and Taylor series for multivariate functions; double and triple integrals in various coordinate systems; line and surface integrals; theorems of Green, Gauss and Stokes.

The textbook is J. Stewart, *Calculus: Early Transcendentals, 8th ed.* Cengage Learning 2016. (Selected topics from Chapters 13 to 16 will be covered.)

Grades: The final grade will depend on WebAssign (20%), two tests (20% each) and a final exam (40%)

Coordinators: Fall: M.W. Wong (mwwong@mathstat.yorku.ca)
Winter: I. Moyles (imoyles@yorku.ca)

MATH 2022 3.00 W
Linear Algebra II

Calendar copy: Inner product spaces, linear transformations, eigenvalues, diagonalization, least squares, quadratic forms and Markov chains. Similar to MATH 2222 3.00 but at a more advanced level. Required in Specialized Honours applied mathematics, Specialized Honours statistics and in all mathematics and mathematics for commerce programs except the BA program in mathematics for commerce. Prerequisite: one of SC/MATH 1021 3.00, SC/MATH 2021 3.00, GL/MATH/MODR 2650 3.00 or permission of the course coordinator. Course credit exclusions: SC/MATH 2222 3.00, GL/MATH/MODR 2660 3.00.

Note: MATH 2022 3.00 is a prerequisite for MATH 2271 3.00, MATH 3010 3.00, MATH 3021 3.00, MATH 3050 6.00, MATH 3052 6.00, MATH 3090 3.00, MATH 4160 3.00 and MATH 4630 3.00.

Math 2022 is the continuation of Math 1021 (Linear Algebra I) and will pursue linear algebra from a more abstract point-of-view. In this course, students will learn about general vector spaces, linear transformations, inner product spaces, orthogonality, spectral theory, and canonical forms of matrices. Time permitting additional topics and applications will be discussed.

Coordinator: P. Skoufranis (pskoufra@yorku.ca)

MATH 2030 3.00 FW
Elementary Probability

Calendar copy: Introduction to the theory of probability as preparation for further study in either mathematical or applied probability and statistics. Topics include probability spaces, conditional probability, independence, random variables, distribution functions, expectation, Chebyshev's inequality, common distributions, moment-generating functions and limit theorems. Prerequisite: One of SC/MATH 1014 3.00, SC/MATH 1310 3.00.

Note: MATH 2030 3.00 is a prerequisite for MATH 2131 3.00, MATH 2281 3.00, MATH 3090 3.00, MATH 4143 3.00, MATH 4172 3.00, MATH 4430 3.00, MATH 4431 3.00 and MATH 4931 3.00.

This course provides an introduction to the theory of probability. It covers the mathematics used to calculate probabilities and expectations, and discusses how random variables can be used to pose and answer interesting problems arising in nature. It is required for most programs in Mathematics and Statistics, or in Computer Science. Subsequent courses that use the material covered include mathematical statistics, operations research, mathematical finance, stochastic processes, as well as more advanced courses in probability.

The text has not yet been chosen.

Coordinators: Fall: J. Grigull (jgrigull@mathstat.yorku.ca)
Winter: T. Salisbury (salt@mathstat.yorku.ca)

MATH 2041 3.00 F
Symbolic Computation Laboratory I

Calendar copy: An introduction to symbolic computing in the Maple environment. Topics from single-variable differential and integral calculus, including simple ordinary differential equations, are covered. Both mathematical understanding and applications are emphasized. Three lecture hours, open laboratory hours. One term. Three credits. Prerequisites: LE/EECS 1560 3.00 (formerly COSC) or equivalent computing experience; SC/MATH 1010 3.00 or SC/MATH 1014 3.00 or SC/MATH 1310 3.00.

Note: MATH 2041 3.00 is a prerequisite for MATH 3090 3.00 and MATH 4143 3.00.

Many of the technological advances that come from scientific innovation depend on efficient means of computation and analysis of large amounts of data. Before digital computers became widely available, these sorts of computations were largely done by hand or with the aid of mechanical calculation tools or tables. However, for every computation tool that we have available, there are always mathematical problems that are beyond the limits of our computational power. For example, the ability to factor an 800 digit integer which is the product of two primes or find the determinant of a large matrix is out of the reach of our current computational tools.

This course will use the program Maple to answer numerical and discrete computation questions which would

otherwise be too difficult to do by hand or the use of a simple calculator. Maple is an example of a Computer Algebra System (CAS) but other examples such as sage, Mathematica and Matlab are similarly capable of doing a wide range of computations and other many specialized programs (such as R, GAP and Macaulay) are particularly efficient at certain types of computations.

Your assignments will be to complete worksheets and computation tasks and the grade for the class will also include the results of in class tests and quizzes.

Coordinator: S. Xu

MATH 2131 3.00 W
Introduction to Statistics II

Calendar copy: This course is a continuation of MATH 2030 3.00. It provides students with an introduction to statistical methods with an emphasis on applications using continuous probability models. Prerequisites: SC/MATH 1131 3.00; SC/MATH 2030 3.00; SC/MATH 2015 3.00 or SC/MATH 2310 3.00.

Note: MATH 2131 3.00 is a prerequisite for MATH 3131 3.00, MATH 3280 3.00, MATH 3430 3.00, MATH 4280 3.00 and MATH 4281 3.00.

This course serves as an introduction to mathematical statistics, and is devoted to the study of the basic probability tools needed in the theory of statistical inference. Topics include joint distributions, multivariate change of variables formula, conditional and marginal distributions, conditional expectation, covariance and correlation, and moment generating functions. Distributional results including those associated with normally distributed observations are examined. The course ends with a look at some statistical applications such as ANOVA or linear regression (time permitting).

The topics considered in this course require a solid knowledge of univariate and multivariate calculus.

Coordinator: S. Wang (stevenw@mathstat.yorku.ca)

MATH 2200 3.00 Y
Extended Problems Conjectures and Proofs

Calendar Copy: Extended exploration of problems leading to conjectures, partial solutions, and proofs. Problems build on reasoning which may be applied to fields such as analysis, algebra or number theory. Regular participation is required. Prerequisites: SC/MATH 1300 3.00, SC/MATH 1310 3.00, SC/MATH 1021 3.00 or equivalents; taking or has taken a math course at the 3000 level or higher. Course credit exclusion: SC/MATH 1200 3.00.

Note: MATH 2200 3.00 is a prerequisite for MATH 3141 3.00.

This class will be offered for students did not take Math 1200 in their first two years of study. The main purpose of the course is to develop communication and analytic skills that will allow students to attack problems where there is no obvious method of solution. To present a convincing argument in mathematics, we try to use clearly defined language, logic, and symbolic manipulation in a way that conveys to the reader that a mathematical statement is true. Students who take this course will develop the skills necessary to present a convincing argument by engaging challenging problems and reasoning. Topics may include definitions, theorems and examples from subjects such as algebra, analysis or number theory.

Coordinator: A. McEachern

MATH 2270 3.00 W
Differential Equations

Calendar copy: Introduction to differential equations, including a discussion of the formation of mathematical models for real phenomena; solution by special techniques; applications; linear equations; solutions in series; other topics if time permits. Prerequisites: One of SC/MATH 2015 3.00 or SC/MATH 2310 3.00; one of SC/MATH 1021 3.00, SC/MATH 1025 3.00, or SC/MATH 2221 3.00. Course credit exclusion: SC/MATH 2271 3.00, GL/MATH 3400 3.00

Note: MATH 2270 3.00 is a prerequisite for MATH 3271 3.00, MATH 4141 3.00 and MATH 4271 3.00.

Differential equations have played a central role in mathematics and its applications for the past three hundred years. Their importance in applications stems from the interpretation of the derivative as a rate of change, a familiar example being velocity. Many of the fundamental laws of physical science are best formulated as differential equations. In other areas, too, such as biology and economics, which involve the study of growth and change, such equations are of fundamental importance.

In this course we will study some important types of linear differential equations and their solutions. Topics will include first-order (differential) equations; homogeneous second and higher order equations with constant coefficients; the particular solution of inhomogeneous second-order equations; first-order linear systems, solutions and phase plane; series-form solutions of equations with variable coefficients; solutions by use of Laplace transforms. Some nonlinear systems will be explored using linearization and phase portrait analysis.

Coordinator: I. Moyles (imoyles@mathstat.yorku.ca)

MATH 2271 3.00 FW
Differential Equations for Scientists and Engineers

Calendar Copy: Introduction to ordinary and partial differential equations, including their classification, boundary conditions, and methods of solution. Equations, methods, and solutions relevant to science and engineering are emphasized, and exploration is encouraged with the aid of software. Three lecture hours per week. One term. Three credits. Prerequisites: One of SC/MATH 2015 3.00, SC/MATH 2310 3.00 or equivalent; one of SC/MATH 1025 3.00, SC/MATH 2022 3.00,

SC/MATH 2222 3.00 or equivalent. Course Credit Exclusions: SC/MATH 2270 3.00, GL/MATH 3400 3.00

Note: MATH 2271 3.00 is a prerequisite for MATH 4120 3.00, MATH 4271 3.00 and MATH 4830 3.00.

This course gives an overview of differential equations for students in science and engineering. The emphasis is on ordinary differential equations, and the classical methods of solutions for a variety of types of equations are covered. General first order equations, as well as linear second order equations, are discussed, both in terms of general theory and particular solution techniques. Series solutions for second order equations are presented. Methods of solution for second order linear equations are extended to higher order equations. Boundary value problems for partial differential equations are presented, with the main solution technique being separation of variables and Fourier series.

The text is D. Zill, *Differential Equations with Boundary-Values Problems*, 9th edition (Nelson).

Coordinator: Hp. Zhu (huaiping@mathstat.yorku.ca)

MATH 2280 3.00 F
The Mathematical Theory of Interest

Calendar copy: Topics include measurement of interest, annuities, amortization of loans, bonds, sinking funds and depreciation. The course is at a level which will prepare students for the Financial Mathematics (FM) exam of the Society of Actuaries. Prerequisite: One of SC/MATH 1014 3.00 or SC/MATH 1310 3.00. Course credit exclusions: SC/MATH 2580 6.00, SC/MATH 2581 3.00, GL/MATH 2680 6.00.

Note: MATH 2280 3.00 is a prerequisite for MATH 2281 3.00 and MATH 3280 3.00.

Actuarial science is the branch of mathematics dealing with insurance and financial risk. This course focuses on interest-only financial calculations (e.g. bonds, loans, mortgages). Topics include: measurement of interest, annuities, amortization of loans, net present value, internal rate of return, bonds, duration, immunization, etc. The course is designed to prepare students for the interest theory portion of the FM actuarial exam. This course is at a level aimed at students in the Actuarial Stream, Mathematics for Commerce Honours Program, and requires knowledge of calculus.

The text will be S.A. Broverman, *Mathematics of Investment Credit*, 5th ed. This course also requires that students have a BA II Plus calculator from Texas Instruments.

Coordinator: Y. Shen (yangshen@mathstat.yorku.ca)

MATH 2281 3.00 W
Models for Financial Economics

Calendar Copy: A quantitative introduction to financial economics. The topics include arbitrage pricing theory, forwards and futures, American and European options, interest rate derivatives, yield curves, arbitrage hedging and pricing, put-call parity, arbitrage bounds, binomial model, Black-Scholes formula, risk-neutral valuation, trinomial model. This course, in conjuction with ECON 4400 and ECON 4410, ensures an adequate preparation for the Investment and Finanical Markets (IFM) exam of the Society of Actuaries. Prerequisites: SC/MATH 2280 3.00; SC/MATH 2030 3.00.

This course is designed to follow MATH 2280, which treats the mathematics of cash flow and bonds. Building on that material, MATH 2281 goes on to consider other types of financial contracts. Its focus is the mathematical valuation of derivative securities and arbitrage pricing theory in discrete time and continuous time. This course, along with the Corporate Finance courses ECON 4400 and ECON 4410, should provide an adequate preparation for exam IFM of the Society of Actuaries. The course is a requirement for all Actuarial Science programs, and is recommended for students preparing to study financial mathematics.

Coordinator: T. Salisbury (salt@mathstat.yorku.ca)

MATH 2310 3.00 F
Calculus of Several Variables with Applications

Calendar copy: Vector functions, partial derivatives, gradient, multiple integrals, line integrals, optimization, applications. Prerequisite: SC/MATH 1010 3.00 or SC/MATH1014 3.00 or SC/MATH 1310 3.00. Students should have a knowledge of vector algebra in two and three dimensions. Course credit exclusions: SC/MATH 2015 3.00, GL/MATH/MODR 2670 3.00, GL/MATH 3200 3.00.

Note: MATH 2310 3.00 is a prerequisite for MATH 2131 3.00, MATH 2270 3.00, MATH 2271 3.00, MATH 3271 3.00, MATH 3410 3.00, MATH 4001 6.00, MATH 4143 3.00, MATH 4171 3.00, MATH 4172 3.00 and MATH 4271 3.00.

This course is designed to follow MATH 1300/1310. It studies the calculus of functions in two and three dimensions, just as those earlier courses examined functions of one variable. In addition to the topics listed above, it covers lines, planes, curves, surfaces, polar coordinates, arc length, Lagrange multipliers, and change of coordinates in multiple integrals. Students may opt to follow it with MATH 3010, which covers further topics in the calculus of vector functions.

The text will be J. Stewart, *Calculus: Multivariable Calculus*, 8th ed. (Cengage Learning, 2016).

Coordinator: T. Salisbury (salt@mathstat.yorku.ca)

MATH 2565 3.00 FW
Introduction to Applied Statistics

Calendar copy: The aim of this course is to give students in various disciplines some fundamental tools in statistical inference. Through a mixture of theory given in lecture hours and practice acquired during lab time, the student will understand when and how to use statistical tools such as the z, t or chi-squared tests, regression analysis, analysis of variance and various other techniques. Students will learn how to use the statistical software R for data analysis. Prerequisites: High school MATH 11U or MATH 11U/C.
Course credit exclusions: SC/BIOL 2060 3.00, AP/ECON 2500 3.00, AP/SC/GEOG 2420 3.00, HH/KINE 2050 3.00, SC/MATH 2560 3.00, SC/MATH 2570 3.00, HH/PSYC 2020 6.00, SB/OMIS 1000 3.00.

Note: Students who have passed SC/MATH 1131 3.00 may not take SC/MATH 2565 3.00.

Three lecture hours per week. Statistics plays a key role in almost all areas of human inquiry. Its importance has grown considerably with the availability of large amounts of data gathered electronically. This course presents an introduction to the concepts and methods of statistics including confidence intervals, tests of significance, regression, analysis of variance and other methods. Students will learn how to use the statistical software R for data analysis.
Coordinators: Fall: Y. Fu (yuejiao@mathstat.yorku.ca)
Winter: W. Liu (liuwei@mathstat.yorku.ca)

MATH 2581 3.00 W

Business Mathematics II

Calendar copy: Spreadsheets and their application to business mathematics; deepening of topics in Business Mathematics I, including continuous compound interest, perpetuities, annuities where payments vary, callable bonds, bond yield rate, capital budgeting; mortality tables, life annuities, life insurance. Prerequisites: SC/MATH 1581 3.00; SC/EECS 1520 3.00 or permission of the instructor. Course credit exclusions: S C/M A T H 2280 3.00; S C/M A T H 2580 6.00, GL/MATH 2680 6.00.

Note: This course will not be offered in FW 2019.

MATH 2590 3.00 F

Thinking Mathematically I
(same as ED/MATH 2591 3.00)

Calendar copy: The main objectives of this course include providing opportunities for students to achieve success in thinking mathematically and to reflect on the learning and practice of mathematics. Intended primarily, but not exclusively, for Education students in the PJ and JI streams. Prerequisite: Successful completion of at least 24 credits or permission of the course director. Note: This course is not open to any student who has taken or is taking another university mathematics course unless permission of the course coordinator is obtained. NCR Note: This course may not be taken for credit by any student who has taken SC/MATH 1580 3.00.

Note: This course will not be offered in FW 2019.

MATH 2930 3.00 FW

Introductory Probability and Statistics
(for engineering students)

Calendar copy: This is an applied probability and statistics course for engineering students. The aim is to provide an application oriented introduction to probability and statistics. The examples will be from a wide selection of engineering disciplines. The probability component is about 30% of the lectures. About 40% of the time, the lectures and tutorials focus on solving practical statistical problems that emerge from engineering problems. Three lecture hours per week. One mandatory tutorial per week. Prerequisites: SC/MATH 1014 3.00 or equivalent; SC/MATH 1025 3.00 or equivalent; LE/EECS 1011 3.00 or equivalent. Course credit exclusions: SC/MATH 1131 3.00; SC/MATH 2560 3.00; SC/MATH 2565 3.00; SC/MATH 2570 3.00.

Coordinators: Fall: P. Peskun (peskun@mathstat.yorku.ca)
Winter: A. Chow (amchow@yorku.ca)

3000-level Courses

MATH 3001 3.00 W
Real Analysis II

Calendar Copy: *Numerical series, Riemann integration, Taylor polynomials, sequences and series of functions, uniform convergence, power series, introduction to metric spaces including compactness and completeness, Weierstrass Approximation Theorem. Continues MATH 2001. Proof-based, intended for Honours students in Mathematics. Prerequisites: SC/ MATH 2001 3.00 and SC/MATH 1310 3.00. Course credit exclusions: SC/MATH 3210 3.00, GL/MATH 3320 3.00, GL/MATH 4240 6.00.*

Note: MATH 3001 3.00 is a prerequisite for MATH 4001 6.00 and MATH 4081 3.00.

The course will cover the basics of Fourier analysis. The first few lectures will examine some of the problems motivating the development of the subject. This will be followed by the definition of the Fourier coefficients of an integrable function and the development of basic properties of Fourier series. The question of when a Fourier series converges pointwise will then be examined. This will include an examination of kernels and Cesaro summability. This will be followed by the proof of mean square convergence of Fourier series and Parseval's formula. The final part of the course will look at three applications of these ideas: the isoperimetric inequality, Weyl's equidistribution theorem and the existence of a continuous nowhere differentiable function.

The text used in the course will be Elias M. Stein and Rami Shakarchi, *Fourier Analysis: Introduction*.

MATH 3001 will cover most of the material in Chapters 1 to 4.

Prerequisites: SC/MATH 2001 3.00, SC/MATH 2310 3.00. Students will also need to be familiar with elementary facts about the complex numbers such as those covered in MATH 1200 or similar courses. Familiarity with linear algebra will also be useful.

Coordinator: P. Gibson (pcgibson@yorku.ca)

MATH 3010 3.00 F
Vector Integral Calculus

Calendar copy: Integrability of continuous functions over suitable domains, iterated integrals and Fubini's theorem, counterexamples, change of variables, Jacobian determinants, polar and spherical coordinates, volumes, vector fields, divergence, curl, line and surface integrals, Green's and Stokes's theorems, differential forms, general Stokes's theorem. Prerequisite: SC/MATH 2310 3.00; or SC/MATH 2015 3.00 and written permission of the mathematics undergraduate director (normally granted only to students proceeding in Honours programs in mathematics or in the Specialized Honours program in statistics). Prerequisite or corequisite: SC/MATH 2022 3.00 or SC/MATH 2222 3.00.

Note: MATH 3010 3.00 is a prerequisite for MATH 3410 3.00.

This course will be a rigorous study of the functions of several variables. The topics included are limits, continuity, differentiation, Implicit Function Theorem, Inverse Function Theorem, integration, line integrals, surface integrals, and elementary differential forms.

Coordinator: A. Skelton (askelton@yorku.ca)

MATH 3021 3.00 F
Algebra I

Calendar copy: Introduction to the basic concepts of abstract algebra, with applications: groups (cyclic, symmetric, Lagrange's theorem, quotients, homomorphism theorems). Prerequisites: SC/MATH 1019 3.00 or SC/MATH 1190 3.00 or SC/MATH 1200 3.00; SC/MATH 2022 3.00 or SC/MATH 2222 3.00. Course credit exclusions: SC/MATH 3020 6.00, GL/MATH 3650 6.00 or GL/MODR 3650 6.00, GL/MATH 3510 3.0

Note: MATH 3021 3.00 is a prerequisite for MATH 3022 3.00.

Algebra I is a relatively simple but exciting subject which very often allows us to solve rather difficult problems in other disciplines of mathematics and of applied mathematics. In other words, it is very fruitful to express properties of other disciplines in terms of some algebraic structures. This gives not only a deeper understanding of a problem but often leads to its solution. This course is a first but necessary step in such direction. It introduces basic notions of the language of the Algebra.

The text will be T.W. Judson, *Abstract Algebra, Theory and Applications*.

Coordinator: Y. Gao (ygao@yorku.ca)

MATH 3022 3.00 W
Algebra II

Calendar copy: Continuation of Algebra I with the introduction of rings (congruences, quotients, polynomials, integral domains, PIDs and UFDs) and fields (field extensions, constructions with ruler and compass, coding theory). Prerequisites: SC/MATH 3021 3.00 or permission of the course coordinator. Course credit exclusions: SC/MATH 3020 6.00, GL/MATH 3650 6.00 or GL/MODR 3650 6.00, GL/MATH 3515 3.00.

Note: MATH 3022 3.00 is a prerequisite for MATH 4021 6.00.

This is a continuation of Math 3021. Algebra is one of the core parts of mathematics. It is concerned with properties of mathematical objects that can be expressed symbolically and it is used in almost every branch of mathematics. Algebraic methods provide not only solutions to problems in other areas of mathematics, but they also provide proofs that certain problems do not have solution. This is the case with some familiar problems such as trisection of an angle and solution of quintic equation in radicals. This course also supports students in learning how to write clear and concise proofs and how to communicate mathematical ideas effectively.

The text will be T.W. Judson, *Abstract Algebra, Theory and Applications*.
Coordinator: Y. Gao (ygao@yorku.ca)

MATH 3050 6.00
Introduction to Geometries

Calendar copy: Analytic geometry over a field with vector and barycentric coordinate methods, affine and projective transformations, inversive geometry, foundations of Euclidean and non-Euclidean geometry, applications throughout to Euclidean geometry. Prerequisite: SC/MATH 2022 3.00 or SC/MATH 2222 3.00 or permission of the course coordinator. Course credit exclusion: SC/MATH 3052 6.00.

Note: This course will not be offered in FW 2019.

MATH 3052 6.00 Y
Exploring Geometries

Calendar Copy: Exploration of various geometries, focusing on symmetry. Geometric reasoning and multiple representations. Learning with hands-on materials, dynamic software, group work, reflection, communication. Prerequisite: SC/MATH 2022 3.00 or 2222 3.00 or permission of the instructor. Course credit exclusion: SC/MATH 3050 6.00.

In this course, students will explore a variety of topics in the field of geometry, with a focus on geometric reasoning and multiple representations. The course will explore geometric questions through investigation, hands-on materials and dynamic geometry software, while also focusing on the development of skills such as communication, collaboration and the use of technology. This course is designed to prepare students for further studies in applications of geometry and geometry education. Graded work will include regular individual and group assignments. There is no text for this course.
Coordinator: A. Skelton (askelton@yorku.ca)

MATH 3090 3.00 F
Computational Mathematics

Calendar copy: Modelling (discrete and continuous, deterministic and stochastic) and practical solutions to general categories of applied problems. Case studies of solutions through modelling and representation of data. Implementation, numerical considerations, efficiency, and application of numerical algorithms. Three lecture hours per week. Prerequisites: SC/MATH 2022 3.00; SC/MATH 2030 3.00; SC/EECS 1560 3.00, or SC/EECS 2031 3.00 and SC/MATH 2041 3.00, or SC/EECS 1540 3.00 and SC/MATH 2041 3.00.

Modelling (discrete and continuous, deterministic and stochastic) and practical solutions to general categories of applied problems from the sciences and/or business applications. Case studies and simulations through modelling and representation of data. Implementation, efficiency and application of numerical and stochastic algorithms.
Coordinator: S. Moghadas (moghadas@yorku.ca)

MATH 3131 3.00 F
Mathematical Statistics I

Calendar copy: Topics include common density functions, probability functions, principle of likelihood, the likelihood function, the method of maximum likelihood, likelihood regions, tests of hypotheses, likelihood ratio tests, goodness of fit tests, conditional tests and confidence sets with a view towards applications. Prerequisite: SC/MATH 2131 3.00 or permission of the course coordinator.

Note: MATH 3131 3.00 is a prerequisite for MATH 3132 3.00, MATH 4130B 3.00, MATH 4230 3.00, MATH 4630 3.00 and MATH 4939 3.00.

After a review of the basic concepts introduced in MATH 2131, we will cover the following topics: some standard multivariate distributions, some special distributions related to the normal distribution, convergence in probability and convergence in distribution, order statistics, maximum likelihood methods, sufficiency and the basis of hypothesis testing. If time permits, we will look at the distribution of special quadratic forms.
Coordinator: D. Wilburne

MATH 3132 3.00 W
Mathematical Statistics II

Calendar copy: Important examples and methods of statistical estimation and hypothesis testing are discussed in terms of their mathematical and statistical properties. Topics include sufficiency, Bayesian statistics, decision theory, most powerful tests, likelihood ratio tests. Prerequisite: SC/MATH 3131 3.00.

Note: MATH 3132 3.00 is a prerequisite for MATH 4230 3.00 and MATH 4939 3.00.

This course is a continuation of Math 3131 3.00. The basic nature of statistical inference will be studied. Topics include sufficiency, exponential family, decision theory, most powerful tests, likelihood ratio tests, Bayesian statistics, linear models, etc.

The final grade will be based on assignments, a presentation, a midterm exam, and a final exam.
Coordinator: Y. Fu (yuejiao@mathstat.yorku.ca)

MATH 3141 3.00 F
Number Theory

Calendar Copy: Basic topics in number theory. Divisibility, primes and factorization, congruences, quadratic residues and the law of quadratic reciprocity, arithmetic functions and the Mobius inversion formula, Diophantine equations, primitive roots, continued fractions, partitions, the distribution of prime numbers, and applications to primality testing and cryptography. Prerequisites: MATH 1200 (or MATH 2200), and one of MATH 1021 or MATH 1025.

This course is an introduction to number theory, the branch of mathematics that deals with the properties of

numbers in general and integers in particular. It is also one of the oldest branches of mathematics, and one of the largest. This course is a rigorous mathematical course, so there will be a certain amount of definitions, theorems, and proofs. However, there will also be a good deal of concrete, hands-on computations, and many interesting and fun applications. Topics include divisibility and congruences, quadratic residues and the law of quadratic reciprocity, arithmetic functions and the Mobius inversion formula, continued fractions, Diophantine equations, primitive roots ,and the distribution of prime numbers.
Coordinator: TBA

MATH 3171 3.00 F
Linear Optimization

Calendar copy: This course introduces students to linear optimization (linear programming), including the problem formulation, simplex method, LP-duality theory, sensitivity analysis, and its business and industrial applications. Three lecture hours per week. Prerequisites: SC/MATH 1021 3.00 or SC/MATH 1025 3.00 or SC/MATH 2221 3.00. Course credit exclusions: SC/MATH 2751 3.00, AP/ECON 3120 3.00, AP/ADMS 3331 3.00, AP/ADMS 3351 3.00, GL/MATH 3660 6.00, SC/MATH 3170 6.00.

Note: MATH 3171 3.00 is a prerequisite for MATH 3172 3.00.

Coordinator: D. Tanny (tanny@mathstat.yorku.ca)

MATH 3172 3.0 W
Combinatorial Optimization
Calendar copy: This course introduces students to combinatorial optimization (integer programming), including problem formulation, branch-and-bound method, cutting-plane method, implicit enumeration, and its business and industrial applications, including transportation problem, network flow optimization etc. Three lecture hours per week. Prerequisites: SC/MATH 3171 3.00, SC/MATH 1021 3.00 or SC/MATH 1025 3.00 or SC/MATH 2221 3.00. Course credit exclusions: AP/ECON 3120 3.00, AP/ADMS 3331 3.00, AP/ADMS 3351 3.00, GL/MATH 3660 6.00, SC/MATH 3170 6.00.
Coordinator: M. Chen (chensy@mathstat.yorku.ca)

MATH 3241 3.00 F
Numerical Methods I
(same as EECS 3121 3.00)

Calendar copy: An introductory course in computational linear algebra. Topics include simple error analysis, linear systems of equations, non-linear equations, linear least squares and interpolation. Prerequisites: One of SC/MATH 1014 3.00, SC/MATH 1310 3.00; one of SC/MATH 1021 3.00, SC/MATH 1025 3.00, SC/MATH 2221 3.00; one of LE/EECS 1560 3.00, SC/EECS 2031 3.00, or SC/EECS 2501 1.00. Course credit exclusion: LE/EECS 3121 3.00.

Note: MATH 3241 3.00 is a prerequisite for MATH 3242 3.00 and MATH 3243 1.00.

The course begins with a discussion of computer arithmetic and computational errors. Examples of ill-conditioned problems and unstable algorithms will be given. The first class of numerical methods introduced are those for nonlinear equations, i.e., the solution of a single equation in one variable. We then discuss the most basic problem of numerical linear algebra: the solution of a linear system of n equations in n unknowns. We discuss the Gauss algorithm and the concepts of error analysis, condition number and iterative refinement. We then use least squares to solve over determined systems of linear equations. The course emphasizes the development of numerical algorithms, the use of mathematical software, and interpretation of results obtained on some assigned problems.
Coordinator: D. Liang (dliang@mathstat.yorku.ca)

MATH 3242 3.00 W
Numerical Methods II
(same as EECS 3122 3.00)

Calendar copy: Algorithms and computer methods for solving problems of differentiation, integration, systems of non-linear equations and matrix eigenvalues. Prerequisite: SC/MATH 3241 3.00 or LE/EECS 3121 3.00. Course credit exclusion: LE/EECS 3122 3.00.

Note: MATH 3242 3.00 is a prerequisite for MATH 4141 3.00.

The course is a continuation of MATH 3241 3.00/EECS 3121 3.00. The main topics include numerical differentiation, Richardson's extrapolation, elements of numerical integration, composite numerical integration, Romberg integration, adaptive quadrature methods, Gaussian quadrature, numerical improper integrals; fixed points for functions of several variables, Newton's method, quasi-Newton methods, steepest descent techniques, and homotopy methods; power method, Householder method and QR algorithms.

The final grade will be based on assignments, tests and a final examination.
Coordinator: D. Liang (dliang@mathstat.yorku.ca)

MATH 3250 3.00 W
Mathematical Biology

Calendar Copy: This course introduces the student to mathematical modelling with applications in biology in related fields such as chemistry, ecology and health. There is an emphasis on case studies and problem solving skills. Topics include discrete and continuous models describing population dynamics, population health, chemical reactions and biological structures.

Prerequisites: Registration in an Honours Program in Mathematics and Statistics, completion of the mathematics/statistics core and LE/EECS 1560, or permission of the instructor.
Coordinator: J. Heffernan (jmheffer@mathstat.yorku.ca)

MATH 3260 3.00 W
Introduction to Graph Theory

Calendar copy: Introductory graph theory with applications. Graphs, digraphs. Eulerian and Hamiltonian graphs. The travelling salesman. Path algorithms; connectivity; trees; planarity; colourings; scheduling; minimal cost networks. Tree searches and sortings, minimal connectors and applications from physical and biological sciences. Prerequisite: At least six credits from 2000-level mathematics courses without second digit 5.

Introductory graph theory with applications. Graphs, digraphs. Eulerian and Hamiltonian graphs. The travelling salesman. Path algorithms; connectivity; trees; planarity; colourings; scheduling; minimal cost networks. Tree searches and sortings, minimal connectors and applications. Matchings, marriages, Menger's theorem, matroids.

The text has not been chosen yet.

Coordinator: I. Farah (ifarah@mathstat.yorku.ca)

MATH 3271 3.00 F
Partial Differential Equations

Calendar copy: Partial differential equations of mathematical physics and their solutions in various coordinates, separation of variables in Cartesian coordinates, application of boundary conditions; Fourier series and eigenfunction expansions; generalized curvilinear coordinates; separation of variables in spherical and polar coordinates. Prerequisites: SC/MATH 2270 3.00 or SC/MATH 2271 3.00; SC/MATH 2015 3.00 or SC/MATH 2310 3.00; SC/MATH 3010 3.00 is also desirable, though not essential, as a prerequisite for students presenting SC/MATH 2310 3.00.

This is the first serious course in partial differential equations. The aim is to use Fourier tranforms and distribution theory to construct explicit solutions and study their properties of the standard partial differential equations in the whole Euclidean space. Among the most important equations to be studied are the heat equation, the Laplace equation, the wave equation, and the Hermite equation.

Grades: The final grade is based on assignments (20%), two class tests (20% each) and a final exam (40%).

The text is M.W. Wong, Partial Differential Equations: Topics in Fourier Analysis, CRC Press, 2014.

Coordinator: M.W. Wong (mwwong@mathstat.yorku.ca)

MATH 3280 3.00 F
Mathematics of Life Contingencies I

Calendar Copy: Probabilistic introduction to the mathematics of life contingencies. The course develops a theoretical basis for modeling the future lifetime of certain financial objects with an emphasis on insurance. Topics include international actuarial notation, life tables, life statuses, (multivariate) survival distributions, dependence, multiple decrement theory. The course, in conjunction with MATH 4430 and MATH 3281, ensures an adequate preparation for the Long Term Actuarial Models (LTAM) exam of the Society of Actuaries. Prerequisites : SC/ MATH 2131 3.00, SC/MATH 2280 3.00. Course credit exclusion SC/MATH 3280 6.00

Note: MATH 3280 3.00 is a prerequisite for MATH 3281 3.00.

Probabilistic introduction to the mathematics of life contingencies. The course develops a theoretical basis for modeling the future lifetime of certain financial objects with an emphasis on insurance. Topics include international actuarial notation, life tables, life statuses, (multivariate) survival distributions, dependence, multiple decrement theory, multiple state models. The course ensures an adequate preparation for the MLC exam of the Society of Actuaries. Three lecture hours per week plus one hour of faculty led tutorials per week.

Coordinator: E. Furman (efurman@mathstat.yorku.ca)

MATH 3281 3.00 W
Mathematics of Life Contingencies II

Calendar Copy: Intermediate level course on the mathematics of life contingencies. The course builds on SC/MATH 3280 3.00 and develops theoretical basis for pricing and supporting life-contingent products. Topics include economics of insurance, general insurances and annuities, (benefit) premiums and reserves, analysis of reserves, Hattendorf's theorem. The course, in conjunction with MATH 4430 and MATH 3280, ensures an adequate preparation for the Long Term Actuarial Models (LTAM) exam of the Society of Actuaries. Prerequisite: SC/MATH 3280 3.00. Course credit exclusion: SC/MATH 3280 6.00.

Intermediate level course on the mathematics of life contingencies. The course builds on SC/MATH 3280 3.00 and develops theoretical basis for pricing and supporting life-contingent products. Topics include economics of insurance, general insurances and annuities, (benefit) premiums and reserves, analysis of reserves, Hattendorf's theorem. The course, in conjunction with MATH 4430 and MATH 3281, ensures an adequate preparation for the Long Term Actuarial Models (LTAM) exam of the Society of Actuaries. Three lecture hours per week plus one hour of faculty led tutorials per week.

Coordinator: E. Furman (efurman@mathstat.yorku.ca)

MATH 3330 3.00 F
Regression Analysis

Calendar copy: Simple regression analysis, multiple regression analysis, matrix form of the multiple regression model, estimation, tests (t- and F-tests), multicollinearity and other problems encountered in regression, diagnostics, model building and variable selection, remedies for violations of regression assumptions. Prerequisites: One of SC/MATH 1131 3.00, SC/MATH 2570 3.00, HH/PSYC 2020 6.00, or equivalent; some acquaintance with matrix algebra (such as is provided in SC/MATH 1021 3.00, SC/MATH 1025 3.00, SC/MATH 1505 6.00, SC/MATH 1550 6.00, or SC/MATH 2221 3.00). Course credit exclusions: SC/MATH 3033 3.00, AP/ECON 4210 3.00, HH/PSYC 3030 6.00.

Note: MATH 3330 3.00 is a prerequisite for MATH 3430 3.00, MATH 4130B 3.00, MATH 4330 3.00, MATH 4630 3.00, MATH 4730 3.00, MATH 4930A 3.00, MATH 4931 3.00 and MATH 4939 3.00.

The course explores linear regression models for the analysis of data involving a single quantitative response variable and one or more explanatory variables. The focus is on understanding the different models, statistical concepts, and their application. The approach will require the use of matrix representations of data and the geometry of vector spaces, which will be reviewed in the course. Topics include simple linear regression, inference assumptions, matrix algebra, multiple linear regression, multicollinearity, diagnostic statistics, model building, indicator variables, and variable selections.
Coordinator: S. Wang (stevenw@mathstat.yorku.ca)

MATH 3333 3.00 W
Data Analytics: A Hands-on Approach

Calendar copy: This is an applied statistics course for all math or science major students. The aim is to provide an application oriented training on data analytics in industrial or business setting. The course will cover a wide selection of data analytic techniques to equip students with appropriate computing skills and required statistical methodologies to conduct machine learning and data mining. The lectures will cover various methodologies and algorithms; as well as teach students to use data analytics related software (R or others) to solve real life problems. The students are expected to analyze data with the proposed software. Prerequisites: SC/MATH 1131 or equivalent; LE/EECS 1560 or LE/EESC 1541 or equivalent.

The lectures will spend 60% of time on various methodologies and algorithms; whereas 40% of the lectures will teach students to use data analytics related software R to solve real life problems. The lecturers will provide students with business case studies to practice their analytical skills. The course will cover dimension reduction methods, logistic regression, Naïve Bayes Estimation and Bayesian Networks, K-nearest neighbor algorithm and hierarchical and k-means clustering, classification and decision Trees, neural networks and application of neural network modeling.
Coordinator: X. Gao (xingao@mathstat.yorku.ca)

MATH 3410 3.00 W
Complex Variables

Calendar copy: Analytic functions, the Cauchy-Riemann equations, complex integrals, the Cauchy integral theorem, maximum modulus theorem. Calculations of residues and applications to definite integrals, two-dimensional potential problems and conformal mappings. Prerequisite: SC/MATH 2010 3.00 or SC/MATH 2015 3.00 or SC/MATH 2310 3.00. (SC/MATH 3010 3.00 is also recommended as a prerequisite for students who have taken SC/MATH 2010 3.00.) Course credit exclusion: GL/MATH 4230 3.00.

Some polynomials, such as $x^2+1= 0$, have no roots if we confine ourselves to the real number system, but do have roots if we extend the number system to complex numbers, which can be defined as the set of all numbers of the form $x+iy$,where x and y are real and $i^2=-1$, with basic arithmetic operations having the same structure as those of the real number system. The complex numbers defined so, include the reals (as a case y=0), and the extended system has the desirable property that not only $x^2+1=0$ but every polynomial equation has a root. In the system of complex numbers certain connections are seen between otherwise apparently unconnected real numbers. A striking example is one of the most beautiful identities in mathematics; namely Euler's formula $\exp(2\pi i)=1$ which is a simple consequence of the extension to complex variables of familiar exponential and trigonometric functions. The concepts and operations of calculus (differentiation, integration, power series, etc.) find their most natural setting in complex (rather than real) variables. The present course is intended to give the student a basic knowledge of complex numbers and functions and a basic facility in their use.
Coordinator: TBA

MATH 3430 3.00 W
Sample Survey Design

Calendar copy: Principal steps in planning and conducting a sample survey. Sampling techniques including simple random sampling, stratified random sampling, cluster sampling and sampling with probabilities proportional to size. Estimation techniques including difference, ratio, and regression estimation. Prerequisite: SC/MATH 2131 3.00 or SC/MATH 3330 3.00.

Note: MATH 3430 3.00 is a prerequisite for MATH 4034 3.00, MATH 4731 3.00 and MATH 4939 3.00.

This course deals with the peculiarities of sampling and inference commonly encountered in sample surveys in medicine, business, the social sciences, political science, natural resource management and market research. Attention will be focused on the economics of purchasing a specific quantity of information.

That is, methods for designing surveys that capitalize on characteristics of the population under study will be presented, along with associated estimators to reduce the cost of acquiring an estimate of specified accuracy. (The emphasis will be on the practical applications of theoretical results.)

The text will be R.L. Schaeffer, W. Mendenhall, L. Ott, and K.G. Gerow, *Elementary Survey Sampling*, 7th ed. (Brooks/Cole).

The final grade may be based on assignments (10%), class tests (30%) and a final examination (60%).
Coordinator: P. Peskun (peskun@mathstat.yorku.ca)

4000-level Courses

MATH 4000 3.00 FW and 6.00 Y
Individual Project

Calendar copy: A project of a pure or applied nature in mathematics or statistics under the supervision of a faculty member. The project allows the student to apply mathematical or statistical knowledge to problems of current interest. A report is required at the conclusion of the project. Prerequisites: Open to all students in Honours programs in the Department of Mathematics and Statistics. Permission of the program director is required. Applied mathematics students can enrol only after they have completed the core program in applied mathematics.

The student works under the supervision of a faculty member, who is selected by the course coordinator and the student. The project allows the student to apply mathematical or statistical knowledge to problems of current interest. A report is required at the conclusion of the project.

The student and the faculty member must agree on a written description of the course, its content, and its method of evaluation at the time of enrolment in the course, and submit this description for approval according to the requirements of the unit teaching the course. Copies must be deposited with that unit, and the student and faculty member should each retain a copy.

The amount of work expected of the student is approximately ten hours per week, that is, the equivalent of a standard full-year (for 4000 6.00) or half-year (for 4000 3.00) course. The supervisor is expected to spend about one or two hours per week with the student averaged over the duration of the project. In addition to the final report, regular short written progress reports will be expected from the student at definite times during the course. The final grade will be based upon the final report as well as the interim progress reports.

- Actuarial Science Coordinator: E. Furman
- Applied Mathematics Coordinator: S. Moghadas
- Mathematics for Education Coordinator: J. Heffernan
- Pure Mathematics Coordinator: A. Weiss
- Statistics Coordinator: Y. Fu

MATH 4011 3.00 F
Analysis III

Calendar copy: Cardinality, metric spaces, the Cantor set, metrics and norms, metric topology, continuity, connectedness, completeness and compactness of metric spaces. Functions and function spaces, including the Inverse and Implicit Function Theorems, the Stone-Weierstrass Theorem, the Riesz Representation Theorem and Fourier series. Prerequisites: SC/MATH 3001 3.00, SC/MATH 2310 3.00. Course credit exclusions: GL/MATH 4240 6.00, SC/MATH 4010 6.00, SC/MATH 4001 6.00.

MATH 4011 is a continuation of the undergraduate analysis stream (MATH 2001 and MATH 3001). In this course, the analytic notions observed in previous courses will be extended to metric spaces; that is, any set with a well-defined distance function. Consequently, the notions of topology, convergence, continuity, connectedness, completeness, and compactness all have generalizations to metric spaces. In addition, several important results will be demonstrated such as the Banach Contractive Mapping Theorem, the Baire Category Theorem, the Principle of Uniform Boundedness, the Borel-Lebesgue Theorem, the Arzela-Ascoli Theorem, and the Stone-Weierstrass Theorem. Consequently, as many of these results apply to function spaces, this course is highly recommended to those students interested in Functional Analysis or obtaining a deeper understanding of theory used throughout applied mathematics.

Coordinator: P. Skoufranis (pskoufra@yorku.ca)

Math 4012 3.00
Analysis IV

Calendar copy: Lebesgue measure and integration on the real line, Hibert space, Lp spaces, Fourier analysis. Intended for Honours Mathematics Students. Prerequisites: SC/MATH 4011 3.00. Course credit exclusions: GL/MATH 4240 6.00, SC/MATH 4010 6.00, SC/MATH 4001 6.00.

Note: This course will not be offered in FW 2019.

MATH 4021 3.00 F
Algebra III

Calendar copy: Continuation of Algebra II, with applications: groups (finitely generated abelian groups, solvable groups, simplicity of alternating groups, generators and relations, group actions, Sylow's theorems); field extensions, splitting fields, finite fields. Prerequisite: SC/MATH 3020 6.00 or SC/MATH 30223.00 or permission of the course coordinator. Course credit exclusions: SC/MATH 4020 6.00, SC/MATH 4241 3.00.

Note: MATH 4021 3.00 is a prerequisite for MATH 4022 3.00.

The course will cover: groups, subgroups, cosets and direct products, homomorphisms and factor groups, permutations, the fundamental theorem of finitely generated abelian groups, Sylow theorems, and group representations.

The text will be T.W. Judson, *Abstract Algebra, Theory and Applications*.

Coordinator: N. Bergeron (bergeron@mathstat.yorku.ca)

MATH 4022 3.00
Algebra IV

Calendar copy: Continuation of Algebra III, with applications: Galois theory, solvability of equations by radicals, additional topics (cyclotomic extensions, lattices, Boolean algebras, module theory, category theory). Intended for Honours Mathematics students. Prerequisite: SC/MATH 4021 3.00 or permission of the course coordinator. Course credit exclusion: SC/MATH 4020 6.00.

Note: This course will not be offered in FW 2019.

MATH 4034 3.00
Data Mining

Calendar Copy: This course will review some of the principal methods used for data mining, with the goal of placing them in common perspective and providing a unifying overview. Prerequisites: SC/MATH 3034 3.00 and SC/MATH 3430 3.00 or permission of the course director. Corequisites: SC/MATH 4630 3.00 or SC/MATH 4730 3.00 or SC/MATH 4230 3.00.

Note: SAS and Splus computing environments will be used to facilitate course work.

Note: This course will not be offered in FW 2019.

MATH 4060 3.00 F
Time Series and Spectral Analysis
(same as LE/ESSE 4020 3.00, SC/PHYS 4060 3.00)

Calendar copy: Treatment of discrete sampled data involving correlation, convolution, spectral density estimation, frequency, domain filtering, and Fast Fourier Transforms. Three lecture hours. One term. Three credits. Prerequisites: LE/EECS 1011 3.00 or equivalent programming experience; SC/MATH 2015 3.00; SC/MATH 2271 3.00. Prior to Summer 2014: Prerequisites: LE/SC/CSE 1540 3.00 or equivalent programming experience; SC/MATH 2015 3.00; SC/MATH 2271 3.00. Course credit exclusions: LE/SC/CSE 3451 4.00, LE/SC/CSE 3451 3.00, SC/MATH 4130B 3.00, SC/MATH 4930C 3.00.
Coordinator: TBA (Physics)

MATH 4080 6.00
Topology

Calendar copy: Topological spaces, continuity, connectedness, compactness, nets, filters, metrization theorems, complete metric spaces, function spaces, fundamental group, covering spaces.

Note: This course will not be offered in FW 2019.

MATH 4081 3.00
Topology I

Calendar copy: An introduction to general topology: topological spaces, continuity, connectedness, compactness, topology of metric spaces, countability axioms, and separation axioms. Prerequisites: SC/MATH 3210 3.00 or SC/MATH 3001 3.00 or permission of the course coordinator. Course credit exclusion: SC/MATH 4080 6.00.

This course is an introduction to the theory of general topological spaces. We begin with a review of the topology of Euclidean space and of metric spaces to motivate the notion of a general topological space. Basic properties and examples are introduced: continuous function between topological spaces, open sets, closed sets, limit points, closure, interior, basis for a topology and others. Equivalent formulations of continuity are considered as well as equivalent definitions for continuous functions on metric spaces and the more familiar notion of continuity of functions on the real line. Basic constructions and the operations of taking sums, products and quotients are introduced.

Basic properties of topological spaces constitute the remainder of the course: separable, first countable and second countable spaces; connectedness and path connectedness especially for Euclidean space. The Intermediate Value Theorem is obtained as direct corollary to the theory of connected spaces; compactness; the most important notion in topology, will be given particular emphasis for the remainder of the course, including countable compactness and other equivalent formulations for metric spaces are studied; the Tychonoff Theorem for finite products is proven; finally the separation axioms T1, T2, T3, T4 and the classes of regular and normal spaces are studied.

The text has not been chosen.

Note: This course will not be offered in FW 2019.

MATH 4090 3.00 W
Mathematical Modelling

Calendar copy: Discrete, continuous and probabilistic modelling of problems from physical and life sciences, engineering and business. The ability to identify and a suitable mathematical framework and apply it in analytical study and simulation will be stressed. Three lecture hours. One term. Three credits. Required: Registration in an Honours Program in Mathematics and Statistics and completion of all specified core courses in that program as well as SC/MATH 3241 3.00, SC/MATH 3271 3.00 and SC/MATH 3243 1.00.

This course will introduce the student to traditional and newer methods of mathematical modelling. The topics include kinetic modeling, statistical model selection, heuristic algorithms and game theory. These subjects will be studied analytically and computationally.
Coordinator: J. Grigull (jgrigull@yorku.ca)

MATH 4100A 3.00 W
Topics in Mathematical Education

Calendar copy: This course provides opportunities for students to examine topics in mathematics, and themes in mathematics education. The main focus will be on developing students' ability to unpack and communicate concepts in mathematics, and to think critically about what mathematicians do and what students do when they are learning mathematics. Prerequisites: A minimum of 21 credits in MATH courses without second digit "5"; permission of the course coordinator.

Note: Computer/Internet use is essential for course work.

This course provides opportunities for students to examine in-depth specific ideas in mathematics as well as themes and theories in mathematics education. The main focus will be on exploring different ways to unpack, repack and communicate concepts in mathematics, and to think critically and reflectively about how mathematics can be learnt, taught, and understood. Students will be encouraged to work with multiple representations and approaches and reflect on how peers also do the mathematics. We will look at sample concepts from a wide area of mathematics including both pure mathematics and applied mathematics, as well as concepts which are central to the Ontario curriculum. The course is designed as a 'capstone' course for students preparing to become teachers, but is relevant to anyone interested in reflecting on the learning of mathematics. We recommend you take the course in your final semester.
Coordinator: A. Skelton (askelton@yorku.ca)

MATH 4120 3.00 F
Gas and Fluid Dynamics

Calendar copy: Fundamental laws: conservation of mass, momentum and energy; ideal flows and potential theory; viscous flows, boundary layer theory and dimensional analysis; compressible flows and gas dynamics. Prerequisites: SC/MATH 2015 3.00 or SC/MATH 2310 3.00; SC/MATH 2270 3.00 or SC/MATH 2271 3.00; SC/PHYS 2010 3.00 or LE/ESSE 2470 3.00 or SC/MATH 3271 3.00. Cross-listed with PHYS 4120.

This course treats basic continuum mechanics and the fundamental laws of fluid motion; inviscid incompressible flows and potential theory; free surface flows, water waves and perturbation methods; dimensional analysis, Navier-Stokes equations, viscous flow and boundary layer theory; gas dynamics, compressible flows and shock waves. Applications from aerodynamics, geophysics and atmospheric science are discussed.
Coordinator: I. Moyles (imoyles@yorku.ca)

MATH 4130B 3.00 F
Topics in Probability and Statistics:
(same as GS/MATH 6633 3.00)
Introduction to the Theory and Methods of Time Series Analysis

Calendar copy: A systematic presentation of many statistical techniques for the analysis of time series data. The core topics include time dependence and randomness, trend, seasonality and error, stationary processes, ARMA and ARIMA processes, multivariate time series models and state-space models. Prerequisites: either SC/MATH 3033 3.00 or SC/MATH 3330 3.00; SC/MATH 3131 3.00; or permission of the course coordinator. Course credit exclusions: SC/EECS 3451 4.00, SC/EATS 4020 3.00, SC/MATH 4830 3.00, SC/MATH 4930C 3.00, SC/PHYS 4060 3.00, SC/PHYS 4250 3.00.

In this course, we will study many statistical techniques for the analysis of time series data. The core topics include time dependence and randomness, trend, seasonality and error, stationary processes, ARMA and ARIMA processes, multivariate time series models and state-space models.
Coordinator: A Wong (august@mathstat.yorku.ca)

MATH 4130K 3.00
Survival Analysis
(same as GS/MATH 6641 3.00)

Calendar copy: This course provides students with an introduction to the statistical methods for analyzing censored data which are common in medical research, industrial life-testing and related fields. Topics include accelerated life models, proportional hazards model, time dependent covariates.

Prerequisite: SC/MATH 3131 3.00; SC/MATH 3330 3.00.

Note: Computer/Internet use is essential for course work.

Note: This course will not be offered in FW 2019.

MATH 4141 3.00 F
Advanced Numerical Methods
(same as GS/MATH 6651 3.00, GS/PHYS 5070A 3.00)

Calendar copy: Numerical methods for solving ordinary differential equations; optimization problems: steepest descents, conjugate gradient methods; approximation theory: least squares, orthogonal polynomials, Chebyshev and Fourier approximation, Padé approximation. Prerequisite: SC/MATH 2270 3.00; SC/MATH 3242 3.00 or SC/EECS 3122 3.00.

The final grade will be based on assignments, tests and a final examination.
Coordinator: D. Liang (dliang@mathstat.yorku.ca)

MATH 4143 3.00 F
Scientific Computation for Financial Applications

Calendar copy: This course covers the basics numerical analysis/computational methods related to portfolio optimization, risk management and option pricing. It provides background material for computations in finance for two streams in the Computational Mathematics program and other interested students. Prerequisites: One of SC/MATH 2015 3.00 or SC/MATH 2310 3.00; SC/MATH 1131 3.00; SC/MATH 2030 3.00; One of LE/EECS 1530 3.00, LE/EECS 1560 3.00 or SC/MATH 2041 3.00.

This course introduces the basic concepts and numerical methods in computational finance. The topics include an introduction to mathematical finance, basics in numerical computations; option pricing and risk management by lattice methods and Monte-Carlo simulations.

We will use MATLAB to carry out the numerical computations and illustrations in the class.

The final grade will be based on assignments, a mid-term, a group term project and a final exam.

Our main textbook is John C. Hull, *Options, Futures, and Other Derivatives*, 10th ed. (Pearson, 2017). However, you may find its student solution manual quite useful for the course and for future references: (optional) John C. Hull, *Student Solutions Manual for Options, Futures, and Other Derivatives*, 2017.

Coordinator: Hm. Zhu (hmzhu@mathstat.yorku.ca)

MATH 4160 3.00 F
Combinatorial Mathematics

Calendar copy: Topics from algebra of sets, permutations, combinations, occupancy problems, partitions of integers, generating functions, combinatorial identities, recurrence relations, inclusion-exclusion principle, Polya's theory of counting, permanents, systems of distinct representatives, Latin rectangles, block designs, finite projective planes, Steiner triple systems. Prerequisites: SC/MATH 2022 3.00 or SC/MATH 2222 3.00; six credits from 3000-level mathematics courses without second digit 5; or permission of the course coordinator.

We learn how to count in this course. Methods used to enumerate finite sets include bijections, the principle of inclusion-exclusion, generating functions, recurrence relations and Polya's theory. We will apply these methods to study the occupancy problem, derangements, partitions of integers, Catalan numbers, and simple graphs.

The text is to be announced.

Coordinator: M. Zabrocki (zabrocki@mathstat.yorku.ca)

MATH 4161 3.00 W
Mathematics of Cryptography
(same as EECS/4161 3.00)

Calendar copy: Probability, information theory and number theory and applications to cryptography. Classical codes such as Caesar shift, Vigenere, ADFGVX, rectangular substitution, and others. Other topics: comma free codes, perfect secrecy, index of coincidence, public key systems, primality testing and factorization algorithms. Prerequisites: At least 12 credits from 2000-level (or higher) MATH courses (without second digit 5, or second digit 7); or SC/EECS 3101 3.00 or permission of the instructor.

In cryptography, our objective is to keep information secret from everyone except for those who are authorized to see it. We will start with classical codes such as Caesar shift and Vigenere. We will introduce symmetric key encryption and public key encryption, with examples like DES and RSA, respectively. We will learn the background in probability theory, information theory and number theory needed for the analysis of these cryptographic systems. Other topics include digital signature, message authentication and hash function.

Coordinator: P. Ingram (pingram@yorku.ca)

MATH 4171 3.00 F
Nonlinear Optimization

Calendar copy: Nonlinear optimization (nonlinear programming); AMPL programming; practical modelling of optimization problems from science, engineering and business. Prerequisites: SC/MATH 2015 or SC/MATH 2310; SC/MATH 1021 3.0 or SC/MATH 1025 3.0 or SC/MATH 2221. Course credit exclusions: AS/MATH 4570 6.00, SC/MATH 4170 6.00.

Selected algorithms for nonlinear optimization or nonlinear programming: Nelder and Mead Polytope method, Shor Ellipsoid method, steepest descent method, trust region, conjugate gradient, and quasi-Newton. Prerequisites: SC/MATH 2015 or SC/MATH 2310; SC/MATH 1021 3.00 or SC/MATH 1025 3.00 or SC/MATH 2221. We will use Python programming language for computing. Course credit exclusions: AS/MATH 4570 6.00; SC/MATH 4170 6.00.

The course introduces the fundamentals of convex analysis and its roles in modern optimization. We study the KKT theorem and LICQ constraint qualification in depth. Iterative optimization algorithms, including Lagrangian method, are introduced.

AMPL is a user friendly programming language, which makes optimization modelling much easier, and is used widely in industries and research institutes. We will learn and use AMPL extensively in the course. Selected optimization models, including the financial portfolio optimization, renewable energy power optimization, transportation scheduling, etc., will be used as examples and assignments throughout the course. Previous programming experience is not required.

The text will be: (1) R. Fourier, D.M. Gay and B.W. Kernighan, *AMPL: A modelling Language for Mathematical Programming*. The free PDF version is available at: http://ampl.com/resources/the-ampl-book/;
(2) W.L. Winston *Operations Research: Applications and Algorithms*.

The final grade is based on homework, midterm and final.

Coordinator: M. Chen (chensy@mathstat.yorku.ca)

MATH 4172 3.00 W
Applied Decision Models

Calendar copy: This course introduces the theory and applications of the following operations research decision models: Decision Tree Analysis, Game Theory, Inventory Models, and Dynamic Programming. Prerequisites: SC/MATH 2015 or SC/MATH 2310; SC/MATH 2030; SC/EECS 1560 or equivalent. Course credit exclusions: AS/MATH 4570 6.00, SC/MATH 4170 6.00.

Note: This course will not be offered in FW 2019.

MATH 4230 3.00
Nonparametric Methods in Statistics
(same as GS/MATH 6634 3.00)

Calendar copy: Order statistics; general rank statistics; one-sample, two-sample and k-sample problems; Kolmogorov-Smirnov statistics; tests of independence and relative efficiencies. Prerequisite: SC/MATH 3131 3.00; SC/MATH 3132 3.00 is recommended but not required.

Note: This course will not be offered in FW 2019.

MATH 4271 3.00 F
Applied Dynamical Systems

Calendar Copy: The objective of this course is to develop skills in analyzing continuous and discrete dynamical systems using analytical, qualitative and numerical techniques widely applicable in biology, physics and engineering. Topics to be covered include fixed points of one-dimensional maps; linear operators and linear approximations; stability and bifurcation; logistic maps, Cantor sets, fractal sets, symbolic dynamics, conjugacy of maps. Introduction to dynamics in two dimensions. Introduction for students with little preparation to the recent discovery that, in certain regimes, fully deterministic mechanics can produce chaotic behavior. Prerequisites: SC/MATH 2015 or SC/MATH 2310; SC/MATH 2270 or SC/MATH 2271.

The course offers an introduction to dynamical systems at an advanced undergraduate level. Upon completing the course material, students will be prepared to use analytical and qualitative techniques of dynamical systems and bi-furcations widely applicable in analysis and in applications.
Coordinator: TBA

MATH 4280 3.00 W
Risk Theory — Loss Models and Risk Measures

Calendar copy: A comprehensive introduction to the single-period mathematical risk theory. The course explores approaches to modeling and measuring (insurance) risks. Topics include (univariate) distribution theory: exponential dispersion models, elliptical distributions, (a,b,k,) class, heavy-tailness; risk measurement: Value-at-Risk, Expected Shortfall, coherency; policy modifications: deductibles. The course, in conjunction with MATH 3131, MATH 3132 and MATH 4281, ensures an adequate preparation for the Short Term Actuarial Models (STAM) exam of the Society of Actuaries. Three lecture hours per week plus one hour of faculty led tutorials per week. Prerequisite: SC/MATH 2131 3.00

This course, together with MATH 4281 3.00, is part of the risk theory sequence of the BA Honours Math for Commerce Actuarial Stream Program. Students who complete this course, along with the sequence MATH 4281 3.00, MATH 3131 3.00, MATH 3132 3.00 and MATH 4430 3.00 (or MATH 4431 3.00) should be adequately prepared to pass the Society of Actuaries Exam C.

This course focuses on mathematical modelling and analysis of the way that funds flow out of an insurance system due to the payment of insurance benefits. The main topics of the course include (a) loss models: severity, frequency, and aggregate models of loss, and (b) risk measures: Value-at-Risk and Tail-Value at Risk, deductibles, coinsurance, limits.
Coordinator: Y. Shen (yangshen@mathstat.yorku.ca)

MATH 4281 3.00 F
Risk Theory — Ruin and Credibility

Calendar copy: A comprehensive introduction to intermediate - level mathematical risk theory. The course on the one hand introduces a dynamic approach to risk measurement, and on the other develops the notion of prospective experience rating. Topics include probability of ruin, adjustment coefficient, Lunberg's inequality, credibility theory, simulation. The course, in conjunction with MATH 3131, MATH 3132 and MATH 4280, ensures an adequate preparation for the Short Term Actuarial Models (STAM) exam C of the Society of Actuaries. Prerequisite: SC/MATH 2131 3.00.

This course, together with MATH 4280 3.00, is part of the risk theory sequence of the BA Specialized Honours Math for Commerce Actuarial Stream Program. Students who complete this course, along with the sequence MATH 4280 3.00, MATH 3131 3.00, MATH 3132 3.00 and MATH 4430 3.00 (or MATH 4431 3.00) should be adequately prepared to pass the Society of Actuaries Exam C.

The course focuses on the mathematical analysis of models for the probability that an insurer's claims will be so severe as to cause ruin (ie insolvency), as well as on measuring the credibility of the data on which prices and forecasts for insurance are based. The main topics of the course include (a) Ruin Theory: probability of ruin at finite and infinite horizons, adjustment coefficient, Lundberg's inequality, Cramer's asymptotic ruin; (b) Credibility Theory: limited fluctuation credibility theory, greatest accuracy credibility theory, Buhlmann and Buhlmann-Straub models.
Coordinator: Y. Shen (yangshen@mathstat.yorku.ca)

MATH 4300 3.00 FW and 6.00 Y
Directed Readings

Calendar copy: A student may arrange to do independent study with a member of the Mathematics and Statistics Department. Such an arrangement must have prior approval of the department Chair. One term: 3 credits. Two terms: 6 credits.

- Students may wish to pursue intensive work with a particular faculty member **on a topic of study not offered in a particular academic session**.
- Students may take independent reading courses only after having successfully completed 24 credits.
- The student and the faculty member must agree on a written description of the course, its content, and its method of evaluation at the time of enrolment in the course, and submit this description for approval according to the requirements of the unit teaching the course. Copies must be deposited with that unit, and the student and faculty member should each retain a copy.

MATH 4330 3.00 F
Applied Categorical Data Analysis

Calendar copy: Categorical response data, two-way and three-way contingency tables, odds ratios, tests of independence, partial association. Generalized linear models. Logistic regression. Poisson regression. Count regression for Rate Data. Multicategory Logit Models. Prerequisite: SC/MATH 3131 3.00; SC/MATH 3330 3.00. Course credit exclusion: SC/MATH 3034 3.00.

Note: MATH 4330 3.00 is a prerequisite for MATH 4939 3.00.

One of the major goals of this course is to study the important extensions of the ideas of linear regression, as seen in MATH 3330, to cases in which the response variable is categorical or integer valued. We also consider models for multivariate categorical responses.
Coordinator: A. Wong (august@mathstat.yorku.ca)

MATH 4400 6.00 Y
The History of Mathematics

Calendar copy: Selected topics in the history of mathematics, discussed in full technical detail but with stress on the underlying ideas, their evolution and their context. Note: 36 credits required from mathematics courses without second digit 5, including at least 12 credits at or above the 3000 level. (12 of the 36 credits may be taken as corequisites.).

The course covers selected mathematical topics from ancient times up to the 20th century. The relationship of mathematical work to historical context and institutional structures will be explored, as will the impact of mathematical discovery on society and culture at various points in history. In addition to lectures on particular mathematical results and methods, students will be guided in research methods, and in oral and written presentation skills.

The grade will be determined by a combination of assignments, tests, written projects and oral presentations.
Coordinator: P. Gibson (pcgibson@mathstat.yorku.ca)

MATH 4430 3.00 W
Stochastic Processes
(same as: FS/MATH 6602 3.00)

Calendar copy: Basic Markov processes, Poisson processes, Diffusion processes, Stochastic Simulation and programming. Prerequisite: SC/MATH 2030 3.00.

This course begins by reviewing conditional expectations and other key topics from probability theory. We then discuss counting processes and discrete time Markov chains. We consider the classification of states, first step analysis, invariant measures, first passage times, as well as applications in science and business. Moving to continuous time, we consider diffusion processes and Brownian motion. We will treat both analytical results and stochastic simulation, the latter using the R programming language.

Note: This course will not be offered in FW 2019.

MATH 4431 3.00 F
Probability Models
(same as GS/MATH 6604 3.00)

Calendar copy: Introduces the theory and applications of several kinds of probabilistic models, including renewal theory, branching processes and martingales. Additional topics may include stationary processes, large deviations or models from the sciences. Prerequisite: SC/MATH 2030 3.00.

Probability theory has been used to describe and analyze many kinds of real-world phenomena. This course will focus on three classes of probability models.

1. Branching processes are a class of simple population growth models. One important question is how the distribution of the number of offspring of one parent can be used to predict the probability that the population eventually dies out. Generating functions will be introduced and used to derive results.

2. Renewal processes are used to model an event that occurs repeatedly at random times, such as the failure of a machine component. The focus of study is on the long-run average behaviour of such processes.

3. The third class of models will be either martingales (models of fair games, important for stock market analysis and decision problems) or random networks (used to model large complex systems and social networks).

The text has not been chosen yet.

The final grade will be probably be based on homework assignments (20%), two class tests (40%), and a final exam (40%).
Coordinator: N. Madras (madras@mathstat.yorku.ca)

MATH 4630 3.00 F
Applied Multivariate Statistical Analysis
(same as: GS/MATH 6632 3.00)

Calendar copy: The course covers the basic theory of the multivariate normal distribution and its application to multivariate inference about a single mean, comparison of several means and multivariate linear regression. As time and interest permit, further related topics may also be covered. Prerequisites: SC/MATH 3131 3.00; SC/MATH 3330 3.00; SC/MATH 2022 3.00 or SC/MATH 2222 3.00.

We will study methods of analysis for data which consist of observations on a number of variables. The primary aim will be interpretation of the data, starting with the multivariate normal distribution and proceeding to the standard multivariate inference theory. Sufficient theory will be developed to facilitate an understanding of the main ideas. This will necessitate a good background in matrix algebra, and some knowledge of vector spaces as well.

Computers will be used extensively, and familiarity with elementary use of SAS will be assumed. Topics covered will include multivariate normal population, inference about means and linear models, principal component analysis, canonical correlation analysis, and some discussion of discriminate analysis, and factor analysis and cluster analysis, if term permits.

The text will be A.C. Rencher and W.F. Christensen, *Methods of Multivariate Analysis*, 3rd ed. (Wiley).
Coordinator: Y. Wu (wuyh@mathstat.yorku.ca)

MATH 4650 3.00 W
Feedback Control Systems
(same as ENG 4650 3.00)

Calendar copy: This course teaches the fundamentals of control design and analysis using state-space methods. This includes both the practical and theoretical aspects of the topic. The students are expected to design controllers using the state-space methods and evaluate the control performance and validate if the controllers are robust to system uncertainties and external disturbances. Prerequisites: LE/ENG 4550 or the following combination of courses: SC/MATH 3410 3.00; SC/MATH 2270 3.00 or SC/MATH 2271 3.00; SC/MATH 2022 3.00.

Control theory stems from the fundamental idea of modifying a dynamical system to achieve a desired goal. From this, many questions arise such as modeling a tractable control system, designing an appropriate control objective, finding an optimal control, and testing the performance and robustness of the controlled system, which lends to a rich course in control theory. This course is an introduction to control theory from a mathematical and engineering perspective. In fact, this course is cross-listed with Lassonde/ESSE so the class demographic will consist of a mixture of math students and engineering students. Topics include representation and solutions of control systems, defining controllability, stability analysis of a controlled system, controller design and optimal control. Applications are addressed throughout the course including time spent in a laboratory setting. Knowledge of complex analysis, ordinary differential equations and linear algebra is needed. Knowledge of MATLAB is an asset.
Coordinator: R. Orszulik (ryan.orszulik@lassonde.yorku.ca)

MATH 4730 3.00 W
Experimental Design

Calendar copy: An examination of the statistical issues involved in ensuring that an experiment yields relevant information. Topics include randomized block, factorial, fractional factorial, nested, Latin square and related designs. Further topics as time permits. The emphasis is on applications. Prerequisite: SC/MATH 3330 3.00, or permission of the course coordinator.

Note: MATH 4730 3.00 is a prerequisite for MATH 4939 3.00.

Experimental design is the process of planning an experiment so that appropriate data will be collected which may be analysed by statistical methods, resulting in valid and meaningful conclusions. This includes the choice of treatments, the required sample size, the random allocation of experimental units to treatments, the method of estimation, and a consideration of how the data will be analyzed once collected.

We will study various experimental situations in this course, considering how the principles of design can be applied to each to create a design that is appropriate to the objectives of the experiment. We will examine appropriate procedures for the analysis of the resulting data, including the underlying assumptions and limitations of the procedures.

Students will use the statistical software SAS for data analysis.

The final grade will be based on two midterm exams, a final exam, and a presentation.
Coordinator: Y. Wu (wuyh@mathstat.yorku.ca)

MATH 4731 3.00 W
Sampling: Design and Analysis

Calendar copy: Topics include: sampling weights and design effects in complex surveys; imputation and weighting methods for nonresponse; variance estimation in complex surveys; effects of complex sampling design on categorical data analysis and on regression analysis. Prerequisites: SC/MATH 3430 3.00 or permission of the course director.

This course concentrates on the statistical aspects of analyzing complex sample surveys obtained by using the basic sampling designs of simple random sampling, stratification, and cluster sampling with equal and unequal probabilities of selection. The use of sampling weights and design effects will be discussed as well as what to do if there is nonresponse. Several methods for estimating variances of various statistics will be described as well as how to perform chi-squared tests and regression analyses using data from complex surveys.

The text will be S.L. Lohr, *Sampling: Design and Analysis*, 2nd ed. (Brooks/Cole).

The final grade will be based on assignments (10%), a class test (30%), and a final exam (60%).
Coordinator: P. Peskun (peskun@mathstat.yorku.ca)

MATH 4930A 3.00
Topics in Applied Statistics:
Statistical Quality Control

Calendar copy: This course provides a comprehensive coverage of the modern practice of statistical quality control from basic principles to state-of-the-art concepts and applications. Prerequisite: SC/MATH 3330 3.00. Corequisite: SC/MATH 4730 3.00.

Note: This course will not be offered in FW 2019.

MATH 4931 3.00 W
Simulation and the Monte Carlo Method

Calendar copy: Introduction to systems, models, simulation and Monte Carlo methods. Random number generation. Random variate generation. Monte Carlo integration and variance reduction techniques. Applications to queuing systems and networks. Prerequisite: SC/MATH 3330 3.00 and LE/EECS 1560 3.00 and SC/MATH 2030. Course credit exclusion: LE/SC/EECS 3408 3.00, SC/MATH 4930B 3.00.

The term "Monte Carlo" refers to a broad class of numerical algorithms which rely on repeated random sampling. Since its beginnings in the late 1940s at the Los Alamos National Laboratory, Monte Carlo has continued to gain in importance in scientific use. The continued growth of computing power coupled with a drastic decrease in price in the last decade, means that Monte Carlo methods are now more practical than ever.

In this course, we will discuss what Monte Carlo methods are, and we will look at their varied applications. The three main topics we will cover are (a) random number generation, (b) "basic" Monte Carlo integration, and (c) bootstrap methodology. Markov chain Monte Carlo will be covered if time permits. Applications will be taken from various sciences including statistics, operations research, and actuarial science.

A significant portion of this course will be spent in the computer lab, using the statistical software R to perform Monte Carlo simulations. Previous experience with computing will be an asset, but is not required.

The text will be C.P. Robert and G. Gasella, *Introducing Monte Carlo Methods with R* (available in electronic form from York's library system).

Coordinator: H. Jankowski (hkj@mathstat.yorku.ca)

MATH 4939 3.00 W
Statistical Data Analysis Using SAS and R

Calendar copy: Case-studies and data analysis representing in-depth investigations into the day-to-day practice of statistics. Hands-on approach with regular data-analysis laboratories and oral/written presentation of results by students. Hypothesis testing, estimation, power, regression, categorical data in practice using both SAS and R. Prerequisite: MATH 3131 3.00, MATH 3330 3.00, MATH 4330 3.00.

Note: The prerequisites of MATH 3131 3.00, MATH 3330 3.00 and MATH 4330 3.00 are strictly enforced.

This is a capstone course in statistics, the course where everything comes together. You will use all the concepts and skills you have learned in previous courses to solve real problems using real data — where the solution can't be found in the previous chapter of the text but uses everything you have learned — and more.

We will learn:

- a lot of R and some SAS and how to combine R and SAS to wrangle real data that always come in more complex forms than simple data sets,
- how the real meaning of statistical results depends on so many factors beyond the analysis and the data itself and we will learn principles we use to find accurate and meaningful interpretations of our results,
- how all the assumptions that underlie statistical methods are never satisfied with real data but understanding those assumptions and developing good judgment about the degree to which they may be violated and the implications for interpretations is vital,
- in addition to basic R and SAS, we will learn about additional essential tools, like regular expressions, SQL, and packages like 'dplyr'.

Team projects and assignments are an important component of this course. Attendance and punctuality are required.

Coordinator: G. Monette (georges+4939@yorku.ca)

Specialized Honours B.A. Program in Actuarial Science (120 credits)

Math/Stats Core: MATH 1200 3.00; MATH 1300 3.00; MATH 1310 3.00; MATH 2310 3.00; MATH 1021 3.00; MATH 2022 3.00; MATH 1131 3.00; MATH 2030 3.00;

Major requirements: EECS 1560 3.00; MATH 2001 3.00; MATH 2131 3.00; MATH 2270 3.00; MATH 2280 3.00; MATH 2281 3.00; MATH 3131 3.00; MATH 3132 3.00; MATH 3280 3.00; MATH 3281 3.00; MATH 3330 3.00; MATH 4280 3.00; MATH 4281 3.00; MATH 4130B 3.00; MATH 4143 3.00; MATH 4430 3.00 (or MATH 4431 3.00); 6 additional credits in Math/Stats that are at least at the 3000 level and at least 3 of these credits must be at the 4000 level (*).

Suggested electives: ECON 1000 3.00; ECON 1010 3.00; ECON 2300 3.00; ECON 2350 3.00; ECON 4400 3.00; ECON 4410 3.00 – total 18 credits.

Gen. Ed.: WRIT 1702 6.00 (HUMA) or both ESL 1010 3.00 and ESL 1015 3.00 (HUMA), MODR 1770 6.00 (MODR); 12 additional credits with at least six credits from Social Science (no more than 9 credits in each subject counting towards the general education requirement)– total 24 credits.

	Fall Term	**Winter Term**
Year 1	MATH 1021 3.00 (core) MATH 1131 3.00 (core, Exam P of the SoA) MATH 1300 3.00 (core)	MATH 1200 3.00 (core) MATH 1310 3.00 (core) MATH 2022 3.00 (core)
	WRIT 1702 6.00 (Gen. Ed. – HUMA)	
	ECON 1000 3.00 (suggested elective – VEE Economics of the SoA)	ECON 1010 3.00 (suggested elective - VEE Economics of the SoA)
Year 2	MATH 2001 3.00 MATH 2030 3.00 (core, Exam P of the SoA) MATH 2280 3.00 (Exam FM of the SoA) MATH 2310 3.00 (core) ECON 2300 3.00 (suggested elective, prerequisite to ECON 4400 3.00)	MATH 2131 3.00 (Exam P of the SoA) MATH 2270 3.00 MATH 2281 3.00 (Exam IFM of the SoA) EECS 1560 3.00 ECON 2350 3.00 (suggested elective, prerequisite)
Year 3	MATH 3131 3.00 (Exam STAM of the SoA) MATH 3280 3.00 (Exam LTAM of the SoA) MATH 3330 3.00 MATH 4430 3.00 or MATH 4431 3.00 (Exam LTAM of the SoA) ECON 4400 3.00 (suggested elective, VEE Corporate Finance of the SoA)	MATH 3132 3.00 (Exam STAM of the SoA) MATH 3281 3.00 (Exam LTAM of the SoA) ECON 4410 3.00 (suggested elective, VEE Corporate Finance of the SoA)
	MODR 1770 6.00 (Gen. Ed. – MODR) or MODR 1790 6.00 (Gen. Ed.– MODR, ESL)	
Year 4	MATH 4130B 3.00 MATH 4143 3.00 MATH 4280 3.00 (Exam STAM of the SoA)	MATH 4281 3.00 Exam STAM of the SoA)
	Six MATH credits at 3000 level or higher, at least three of which are at 4000 level Twelve additional credits in Gen. Ed. courses	

- SoA means the Society of Actuaries.
- VEE refers to the Validation by Educational Experience requirements of the SoA.
- After completion of the 2nd year, students are advised to sit the Exams P and FM of the SoA and also to approach the program coordinator to enquire about the existing internship opportunities.
- After completion of the 3rd year, students are advised to sit the Exam LTAM of the SoA and also to approach the program coordinator to enquire about the existing internship
- Upon graduation the students are advised to sit the Exams IFM and C of the SoA and also to apply for exemptions from the VEE requirements given that their marks are at least B in all relevant courses.

Honours B.A. Program in Actuarial Science (120 credits)

Math/Stats Core: MATH 1200 3.00; MATH 1300 3.00; MATH 1310 3.00; MATH 2310 3.00; MATH 1021 3.00; MATH 2022 3.00; MATH 1131 3.00; MATH 2030 3.00;

Major requirements: EECS 1560 3.00; MATH 2131 3.00; MATH 2280 3.00; MATH 2281 3.00; MATH 3131 3.00; MATH 3132 3.00; MATH 3280 3.00; MATH 3281 3.00; MATH 3330 3.00; MATH 4280 3.00; MATH 4281 3.00; MATH 4130B 3.00; MATH 4430 3.00 (or MATH 4431 3.00).

Suggested electives: ECON 1000 3.00; ECON 1010 3.00; ECON 2300 3.00; ECON 2350 3.00; ECON 4400 3.00; ECON 4410 3.00 – total 18 credits.

Gen. Ed.: WRIT 1702 6.00 (HUMA), MODR 1770 6.00 (MODR), 12 additional credits with at least six credits from Social Science (no more than 9 credits in each subject counting towards the general education requirement)– total 24 credits.

	Fall Term	**Winter Term**
Year 1	MATH 1021 3.00 (core) MATH 1131 3.00 (core, Exam P of the SoA) MATH 1300 3.00 (core)	MATH 1200 3.00 (core) MATH 1310 3.00 (core) MATH 2022 3.00 (core)
	WRIT 1702 6.00 (Gen. Ed. – HUMA)	
	ECON 1000 3.00 (suggested elective – VEE Economics of the SoA)	ECON 1010 3.00 (suggested elective - VEE Economics of the SoA)
Year 2	MATH 2030 3.00 (core, Exam P of the SoA) MATH 2280 3.00 (Exam FM of the SoA) MATH 2310 3.00 (core) ECON 2310 3.00 (suggested elective, prerequisite)	MATH 2131 3.00 (Exam P of the SoA) MATH 2281 3.00 (Exam IFM of the SoA) EECS 1560 3.00 ECON 2350 3.00 (suggested elective, prerequisite)
	Six additional credits in Gen. Ed. courses	
Year 3	MATH 3131 3.00 (Exam C of the SoA) MATH 3280 3.00(Exam LTAM of the SoA) MATH 3330 3.00 MATH 4430 3.00 or MATH 4431 3.00 (Exam LTAM of the SoA) ECON 4400 3.00 (suggested elective, VEE of the SoA)	MATH 3132 3.00 (Exam STAM of the SoA) MATH 3281 3.00 (Exam LTAM of the SoA) ECON 4410 3.00 (suggested elective, VEE of the SoA) MATH 3XYZ 3.00 or MATH 4XYZ 3.00
	Three additional credits in Gen. Ed., elective or MATH courses without the second digit 5	
Year 4	MATH 4130B 3.00 MATH 4280 3.00 (Exam STAM of the SoA)	MATH 4281 3.00 (Exam STAM of the SoA)
	Twenty-one additional credits in Gen. Ed., elective or MATH courses at 3000 level or higher with a total of 24 Gen. Ed. credits and 36 credits at 3000 level or higher	

- SoA means the Society of Actuaries.
- VEE refers to the Validation by Educational Experience requirements of the SoA.
- After completion of the 2nd year, students are advised to sit the Exams P and FM of the SoA and also to approach the program coordinator to enquire about the existing internship opportunities.
- After completion of the 3rd year, students are advised to sit the Exam LTAM of the SoA and also to approach the program coordinator to enquire about the existing internship
- Substantial parts of the topics required for Exams IFM and C of the SoA are covered, yet self-studies are generally required to be able to tackle this exam successfully.
- Upon graduation the students are advised to apply for exemptions from the VEE requirements given that they took the suggested elective courses and their marks are at least B in all relevant courses.

Certificate in Actuarial Science (offered within a 120 Honours degree)

Required courses: MATH 1300 3.00 (or MATH 1013 3.00), MATH 1310 3.00 (or MATH 1014 3.00), MATH 2310 3.00 (or MATH 2015 3.00), MATH 1025 3.00; MATH 1131 3.00; MATH 2030 3.00; MATH 2131 3.00; MATH 2280 3.00; MATH 2281 3.00; MATH 3280 3.00; MATH 3281 3.00; MATH 4280 3.00; MATH 4281 3.00 – total 39 credits.

	Fall Term	**Winter Term**
Year 1	MATH 1131 3.00 (core, Exam P of the SoA) MATH 1300 3.00 (or MATH 1013 3.00)	MATH 1025 3.00 MATH 1310 3.00 (or MATH 1014 3.00)
	Plus additional courses per the students' Honours degree	
Year 2	MATH 2030 3.00 (Exam P of the SoA) MATH 2280 3.00 (Exam FM of the SoA) MATH 2310 3.00 (or MATH 2015 3.00)	MATH 2131 3.00 (Exam P of the SoA) MATH 2281 3.00 (Exam FM of the SoA)
	Plus additional courses per the students' Honours degree	
Year 3	MATH 3280 3.00 (Exam MLC of the SoA)	MATH 3281 3.00 (Exam MLC of the SoA)
	Plus additional courses per the students' Honours degree	
Year 4	MATH 4280 3.00 (Exam C of the SoA)	MATH 4281 3.00 (Exam C of the SoA)
	Plus additional courses per the students' Honours degree	

- SoA means the Society of Actuaries.
- After completion of the 2nd year the students are advised to sit the Exams P and FM of the SoA and also to approach the program coordinator to enquire about the existing internship opportunities.
- After completion of the 3rd year the students are advised to sit the Exam MFE of the SoA and also to approach the program coordinator to enquire about the existing internship opportunities.
- Substantial parts of the topics required for Exams MLC and C of the SoA are covered, yet self-studies are generally required to be able to tackle these exams successfully.

Specialized Honours B.A. Program in Applied Mathematics (120 credits)

Math/Stats Core: MATH 1200 3.0; MATH 1300 3.0; MATH 1310 3.0; MATH 2310 3.0; MATH 1021 3.0; MATH 2022 3.0; MATH 1131 3.0; MATH 2030 3.0;

Major requirement:

- EECS 1560 3.0;
- MATH 2001 3.0; MATH 2041 3.0; MATH 2270 3.0; MATH 3001 3.0; MATH 3241 3.0; MATH 3242 3.0; MATH 3271 3.0; MATH 3410 3.0; MATH 4090 3.0;
- MATH 3260 3.0 or both MATH 3171 3.0 and MATH 3172 3.0;
- 9 additional credits selected from mathematics courses at the 4000 level;

	Fall Term	**Winter Term**
Year 1	MATH 1021 3.0 (core) MATH 1200 3.0 (core) MATH 1300 3.0 (core)	MATH 1131 3.0 (core) MATH 1310 3.0 (core) MATH 2022 3.0 (core) EECS 1560 3.0
	Nine additional credits in Gen. Ed. or elective courses	
Year 2	MATH 2001 3.0 MATH 2041 3.0 MATH 2310 3.0 (core)	MATH 2030 3.0 (core) MATH 2270 3.0
	Fifteen additional credits in Gen. Ed., elective courses, or Math courses without the second digit 5	
Year 3	MATH 3241 3.0 MATH 3271 3.0	MATH 3001 3.0 MATH 3242 3.0 MATH 3410 3.0
	MATH 3260 3.0, or both MATH 3171 3.0 and MATH 3172 3.0; 9-12 additional credits in Gen. Ed., elective courses, or Math courses without the second digit 5	
Year 4		MATH 4090 3.0
	Nine credits in MATH 4XYZ Eighteen additional credits in Gen. Ed., elective courses, or Math courses without the second digit 5	

Gen. Ed.: 24 credits from the following areas: Humanities, Models of Reasoning, Natural Science, Social Science. Of these 24 credits, students must complete the following minimum requirements: at least six credits from Humanities, Natural Science and Social Science (with no more than 9 credits in each counting towards the general education requirement).

Outside-major: At least 18 credits must be non-MATH courses nor EECS 1560 – fulfilled by Gen. Ed. courses.

At least 120 credits must be completed with at least 51 credits from the Major.

At least 36 credits must be at the 3000 level or higher, 18 of these 36 credits must at 4000 level.

MATH courses with second digit 5 do not count towards the Applied Mathematics program requirements.

Honours B.A. Program in Applied Mathematics (120 credits)

Math/Stats Core: MATH 1200 3.0; MATH 1300 3.0; MATH 1310 3.0; MATH 2310 3.0; MATH 1021 3.0; MATH 2022 3.0; MATH 1131 3.0; MATH 2030 3.0;

Major requirements:

- EECS 1560 3.0;
- MATH 2041 3.0; MATH 2270 3.0; MATH 3241 3.0; MATH 3271 3.0; MATH 4090 3.0;
- MATH 3242 3.0 or MATH 3260 3.0 or both MATH 3171 3.0 and MATH 3172 3.0;
- 9 additional credits selected from mathematics courses at the 4000 level;

	Fall Term	**Winter Term**
Year 1	MATH 1021 3.0 (core) MATH 1200 3.0 (core) MATH 1300 3.0 (core)	MATH 1131 3.0 (core) MATH 1310 3.0 (core) MATH 2022 3.0 (core) EECS 1560 3.0
	Nine additional credits in Gen. Ed. or elective courses	
Year 2	MATH 2041 3.0 MATH 2310 3.0 (core)	MATH 2030 3.0 (core) MATH 2270 3.0
	Eighteen additional credits in Gen. Ed., elective courses, or Math courses without the second digit 5	
Year 3	MATH 3241 3.0 MATH 3271 3.0	
	MATH 3242 3.0 or MATH 3260 3.0 or both MATH 3171 3.0 and MATH 3172 3.0 18-21 additional credits in Gen. Ed., elective courses, or Math courses without the second digit 5	
Year 4		MATH 4090 3.0
	Nine credits in MATH 4XYZ Eighteen additional credits in Gen. Ed., elective courses, or Math courses without the second digit 5	

Gen. Ed.: 24 credits from the following areas: Humanities, Models of Reasoning, Natural Science, Social Science. Of these 24 credits, students must complete the following minimum requirements: at least six credits from Humanities, Natural Science and Social Science (with no more than 9 credits in each counting towards the general education requirement).

Outside-major: At least 18 credits must be non-MATH courses nor EECS 1560 – fulfilled by Gen. Ed. courses.

At least 120 credits must be completed with at least 51 credits from the Major.

At least 36 credits must be at the 3000 level or higher, 18 of these 36 credits must at 4000 level.

MATH courses with second digit 5 do not count towards the Applied Mathematics program requirements.

Specialized Honours B.Sc. Program in Applied Mathematics (120 credits)

Math/Stats Core: MATH 1200 3.0; MATH 1300 3.0; MATH 1310 3.0; MATH 2310 3.0; MATH 1021 3.0; MATH 2022 3.0; MATH 1131 3.0; MATH 2030 3.0;

Major requirements:

- EECS 1560 3.0;
- MATH 2001 3.0; MATH 2041 3.0; MATH 2270 3.0; MATH 3001 3.0; MATH 3241 3.0; MATH 3242 3.0; MATH 3271 3.0; MATH 3410 3.0; MATH 4090 3.0;
- MATH 3260 3.0, or both MATH 3171 3.0 and MATH 3172 3.0;
- nine additional credits selected from mathematics courses at the 4000 level.

	Fall Term	Winter Term
Year 1	MATH 1021 3.0 (core) MATH 1200 3.0 (core) MATH 1300 3.0 (core)	MATH 1131 3.0 (core) MATH 1310 3.0 (core) MATH 2022 3.0 (core) EECS 1560 3.0
	Nine additional credits in Foundational Science, Science-outside-major, Non-science or elective courses	
Year 2	MATH 2001 3.0 MATH 2041 3.0 MATH 2310 3.0 (core)	MATH 2030 3.0 (core) MATH 2270 3.0
	Fifteen additional credits in Foundational Science, Science-outside-major, Non-science or elective courses, or Math courses without the second digit 5	
Year 3	MATH 3241 3.0 MATH 3271 3.0	MATH 3001 3.0 MATH 3242 3.0 MATH 3410 3.0
	MATH 3260 3.0, or both MATH 3171 3.0 and MATH 3172 3.0; 9-12 additional credits in Foundational Science, Science-outside-major, Non-science or elective courses, or Math courses without the second digit 5	
Year 4		MATH 4090 3.0
	Nine credits in MATH 4XYZ Eighteen additional credits in Foundational Science, Science-outside-major, Non-science or elective courses, or Math courses without the second digit 5	

Foundational Science: six credits required from BIOL 1000, BIOL 1001, BIOL 1010, CHEM 1000, CHEM 1001, PHYS 1010, PHYS 1410.

Science outside major: EECS 1560 + 6 Foundational Science credits + 15 non-MATH credits in science, 3 of which at 2000-level or above. (BIOL 1500, CHEM 1500, PHYS 1510 do not count.)

Non-science: twelve credits in human enquiry outside of science disciplines.

At least 120 credits must be completed with at least 63 credits from the Major.

At least 42 credits must be at the 3000 level or higher, 18 of these 42 must be in the Major.

MATH courses with second digit 5 do not count towards the Applied Mathematics program requirements.

Honours B.Sc. Program in Applied Mathematics (120 credits)

Math/Stats Core: MATH 1200 3.0; MATH 1300 3.0; MATH 1310 3.0; MATH 2310 3.0; MATH 1021 3.0; MATH 2022 3.0; MATH 1131 3.0; MATH 2030 3.0;

Major requirements:
- EECS 1560 3.0; MATH 2041 3.0; MATH 2270 3.0; MATH 3241 3.0; MATH 3271 3.0; MATH 4090 3.0;
- at least three credits in MATH 3242 3.0 or MATH 3260 3.0 or both MATH 3171 3.0 and MATH 3172 3.0;
- 9 additional credits selected from mathematics courses at the 4000 level.

	Fall Term	Winter Term
Year 1	MATH 1021 3.0 (core) MATH 1200 3.0 (core) MATH 1300 3.0 (core)	MATH 1131 3.0 (core) MATH 1310 3.0 (core) MATH 2022 3.0 (core) EECS 1560 3.0
	Nine additional credits in Foundational Science, Science-outside-major, Non-science or elective courses	
Year 2	MATH 2041 3.0 MATH 2310 3.0 (core)	MATH 2030 3.0 (core) MATH 2270 3.0
	Eighteen additional credits in Foundational Science, Science-outside-major, Non-science or elective courses, or Math courses without the second digit 5	
Year 3	MATH 3241 3.0 MATH 3271 3.0	
	MATH 3242 3.0 or MATH 3260 3.0 or both MATH 3171 3.0 and MATH 3172 3.0 18-21 additional credits in Foundational Science, Science-outside-major, Non-science or elective courses, or Math courses without the second digit 5	
Year 4		MATH 4090 3.0
	Nine credits in MATH 4XYZ Eighteen additional credits in Foundational Science, Science-outside-major, Non-science or elective courses, or Math courses without the second digit 5	

Foundational Science: six credits required from BIOL 1000, BIOL 1001, BIOL 1010, CHEM 1000, CHEM 1001, PHYS 1010, PHYS 1410.

Science outside major: EECS 1560 + 6 Foundational Science credits + 15 non-MATH credits in science, 3 of which at 2000-level or above. (BIOL 1500, CHEM 1500, PHYS 1510 do not count.)

Non-science: twelve credits in human enquiry outside of science disciplines.

At least 120 credits must be completed with at least 51 credits from the Major.

At least 42 credits must be at the 3000 level or higher, 18 of these 42 must be in the Major.

MATH courses with second digit 5 do not count towards the Applied Mathematics program requirements.

Honours Minor B.A.\B.Sc Program in Applied Mathematics

- EECS 1560 3.0; MATH 1021 3.0; MATH 1300 3.0; MATH 1310 3.0; MATH 2310 3.0;
- six credits chosen from MATH 2022 3.0, MATH 2041 3.0, MATH 2270 3.0;
- at least twelve more MATH credits at 3000-level or higher, including at least six credits from MATH 3090 3.0, both MATH 3171 3.0 and MATH 3172 3.0, MATH 3241 3.0, MATH 3242 3.0, MATH 3260 3.0, MATH 3271 3.0, MATH 3410 3.0.

Minor Degree Options for Physics or Lassonde Students

As part of their regular degree programs, students enrolled in Physics and Astronomy or the Lassonde School of Engineering must complete several courses in Mathematics. With a small additional selection of courses in Mathematics, many of those students may qualify for a minor degree option in Applied Mathematics. The minor degree option outlined here is available to students enrolled in B.A. and B.Sc. programs, but not B.Eng. programs.

Mathematics courses that are taken by most Physics and Lassonde students will be counted towards a minor degree option in Applied Mathematics according to the following course equivalences:

- SC/Math 1013 3.0 Applied Calculus I and SC/Math 1300 3.0 Differential Calculus with Applications;
- SC/Math 1014 3.0 Applied Calculus II and SC/Math 1310 3.0 Integral Calculus with Applications;
- SC/Math 1025 3.0 Applied Linear Algebra and SC/Math 1021 3.0 Linear Algebra I;
- SC/Math 2015 3.0 Applied Multivariate and Vector Calculus and SC/Math 2310 3.0 Calculus of Several Variables with Applications;
- SC/Math 2270 3.0 Differential Equations and SC/Math 2271 3.0 Differential Equations for Scientists and Engineers.

The program in Applied Mathematics also requires LE/EECS 1560 3.0 Introduction to Computing for Mathematics and Statistics for students enrolled in a minor degree option. For the purpose of completing the minor degree option in Applied Mathematics, LE/EECS 1541 3.0 Introduction to Computing for the Physical Sciences or LE/EECS 1011 3.0 Computational Thinking through Mechatronics are considered course equivalences for EECS 1560 3.0.

With the courses listed above completed, a student enrolled in an Applied Mathematics minor option must complete the following requirements:

- SC/Math 2022 3.0 Linear Algebra II (suggested option, frequently offered in summer) or SC/Math 2041 3.0 Symbolic Computing Laboratory;
- 12 additional credits selected from Mathematics courses (without second digit 5) at the 3000 level or higher including at least 6 credits selected from SC/Math 3090 3.0, SC/Math 3171 3.0, SC/Math 3172 3.0, SC/Math 3241 3.0, SC/Math 3242 3.0, SC/Math 3260 3.0, SC/Math 3271 3.0 or SC/MATH 3410 3.0 for an overall count of at least 30 credits from major Mathematics courses.

Students from Physics and Astronomy or the Lassonde School of Engineering are specifically encouraged to choose Mathematics electives from the following list:

- SC/Math 3241 3.0 Numerical Methods I
- SC/Math 3242 3.0 Numerical Methods II
- SC/Math 3010 3.0 Vector Integral Calculus
- SC/Math 3271 3.0 Partial Differential Equations
- SC/Math 3410 3.0 Complex Variables
- SC/Math 4271 3.0 Applied Dynamical Systems

A small number of courses offered by Physics and Astronomy or the Lassonde School of Engineering are cross-listed to Mathematics courses. Examples include:

- SC/Math 3241 3.0 Numerical Methods I and LE/EECS 3121 Numerical Methods I;
- SC/Math 3242 3.0 Numerical Methods II and LE/EECS 3122 Numerical Methods II;
- SC/Math 4120 3.0 Gas and Fluid Dynamics and SC/Phys 4120 3.0 Gas and Fluid Dynamics.

In general, courses that are cross-listed to the major program of a student are counted as credits in the major program. For example, SC/Math/Phys 4120 would count as a Physics course to a student from Physics and Astronomy, even if that student enrolls in SC/Math 4120. In these situations, some cross-listed courses may be counted against the corresponding course requirements of the Applied Mathematics minor degree option, but they must be replaced by other elective courses in Mathematics at the 3000 or 4000 level so a total of 30 credits in major Mathematics are completed.

SC/Math 1028 3.0 Discrete Math for Engineering and SC/Math 2565 3.0 Introduction to Applied Statistics are taken by several Lassonde students, but these are not required for a minor degree option in Applied Mathematics and may not be used to replace the courses listed above.

Specialized Honours B.A. Program in Applied Mathematics – Financial Mathematics Stream (120 credits)

Math/Stats Core: MATH 1200 3.0; MATH 1300 3.0; MATH 1310 3.0; MATH 2310 3.0; MATH 1021 3.0; MATH 2022 3.0; MATH 1131 3.0; MATH 2030 3.0;

Major requirements:

- EECS 1560 3.0;
- MATH 2001 3.0; MATH 2131 3.0; MATH 2270 3.0; MATH 2280 3.0; MATH 2281 3.0; MATH 3241 3.0; MATH 3242 3.0; MATH 3271 3.0; MATH 3282 3.0; MATH 3330 3.0; MATH 4090 3.0; MATH 4143 3.0; MATH 4931 3.0
- MATH 4430 3.0 or MATH 4431;

	Fall Term	Winter Term
Year 1	MATH 1021 3.0 (core) MATH 1200 3.0 (core) MATH 1300 3.0 (core)	MATH 1131 3.0 (core) MATH 1310 3.0 (core) MATH 2022 3.0 (core) EECS 1560 3.0
	Nine additional credits in Gen. Ed. or elective courses (ECON 1000 3.0 and ECON 1010 recommended)	
Year 2	MATH 2001 3.0 MATH 2030 3.0 (core) MATH 2280 3.0 MATH 2310 3.0 (core)	MATH 2131 3.0 MATH 2270 3.0 MATH 2281 3.0
	Nine additional credits in Gen. Ed. or elective courses, or Math courses without the second digit 5 (ECON 2300 3.0 and ECON 2350 3.0 recommended)	
Year 3	MATH 3241 3.0 MATH 3271 3.0 MATH 3330 3.0	MATH 3242 3.0 MATH 3282 3.0
	Fifteen additional credits in Gen. Ed. or elective courses, or Math courses without the second digit 5	
Year 4	MATH 4143 3.0 MATH 4430 3.0 or MATH 4431 3.0	MATH 4090 3.0 MATH 4931 3.0
	Eighteen additional credits in Gen. Ed. or elective courses, or Math courses without the second digit 5 (ECON 4400 3.0 recommended)	

Gen. Ed.: 24 credits from the following areas: Humanities, Models of Reasoning, Natural Science, Social Science. Of these 24 credits, students must complete the following minimum requirements: at least six credits from Humanities, Natural Science and Social Science (with no more than 9 credits in each counting towards the general education requirement).

Outside-major: At least 18 credits must be non-MATH courses nor EECS 1560 – fulfilled by Gen. Ed. courses.

Suggested electives: ECON 1000 3.0; ECON 1010 3.0; ECON 2300 3.0; ECON 2350 3.0; ECON 4400 3.0 are recommended.

At least 120 credits must be completed with at least 66 credits from the Major.

At least 36 credits must be at the 3000 level or higher, 18 of these 36 credits must at 4000 level.

MATH courses with second digit 5 do not count towards the Applied Mathematics program requirements.

Specialized Honours B.Sc. Program in Applied Mathematics – Financial Mathematics Stream (120 credits)

Math/Stats Core: MATH 1200 3.0; MATH 1300 3.0; MATH 1310 3.0; MATH 2310 3.0; MATH 1021 3.0; MATH 2022 3.0; MATH 1131 3.0; MATH 2030 3.0;

Major requirements:

- EECS 1560 3.0;
- MATH 2001 3.0; MATH 2131 3.0; MATH 2270 3.0; MATH 2280 3.0; MATH 2281 3.0; MATH 3241 3.0; MATH 3242 3.0; MATH 3271 3.0; MATH 3282 3.0; MATH 3330 3.0; MATH 4090 3.0; MATH 4143 3.0; MATH 4931 3.0
- MATH 4430 3.0 or MATH 4431;

	Fall Term	Winter Term
Year 1	MATH 1021 3.0 (core) MATH 1200 3.0 (core) MATH 1300 3.0 (core)	MATH 1131 3.0 (core) MATH 1310 3.0 (core) MATH 2022 3.0 (core) EECS 1560 3.0
	Nine additional credits in Foundational Science, Science-outside-major, Non-science or elective courses (ECON 1000 3.0 and ECON 1010 recommended)	
Year 2	MATH 2001 3.0 MATH 2030 3.0 (core) MATH 2280 3.0 MATH 2310 3.0 (core)	MATH 2131 3.0 MATH 2270 3.0 MATH 2281 3.0
	Nine additional credits in Foundational Science, Science-outside-major, Non-science or elective courses, or Math courses without the second digit 5 (ECON 2300 3.0 and ECON 2350 3.0 recommended)	
Year 3	MATH 3241 3.0 MATH 3271 3.0 MATH 3330 3.0	MATH 3242 3.0 MATH 3282 3.0
	Fifteen additional credits in Foundational Science, Science-outside-major, Non-science or elective courses, or Math courses without the second digit 5	
Year 4	MATH 4143 3.0 MATH 4430 3.0 or MATH 4431 3.0	MATH 4090 3.0 MATH 4931 3.0
	Eighteen additional credits in Foundational Science, Science-outside-major, Non-science or elective courses, or Math courses without the second digit 5 (ECON 4400 3.0 recommended)	

Foundational Science: six credits required from BIOL 1000, BIOL 1001, BIOL 1010, CHEM 1000, CHEM 1001, PHYS 1010, PHYS 1410.

Science outside major: EECS 1560 + 6 Foundational Science credits + 15 non-MATH credits in science, 3 of which at 2000-level or above. (BIOL 1500, CHEM 1500, PHYS 1510 do not count.)

Non-science: twelve credits in human enquiry outside of science disciplines: ECON 1000 3.0; ECON 1010 3.0; ECON 2300 3.0; ECON 2350 3.0; ECON 4400 3.0 are recommended.

At least 120 credits must be completed with at least 66 credits from the Major.

At least 42 credits must be at the 3000 level or higher, 18 of these 42 must be in the Major.

MATH courses with second digit 5 do not count towards the Applied Mathematics program requirements.

Specialized Honours B.A. Program in Mathematics (120 credits)

Math/Stats Core: MATH 1200 3.0; MATH 1300 3.0; MATH 1310 3.0; MATH 2310 3.0; MATH 1021 3.0; MATH 2022 3.0; MATH 1131 3.0; MATH 2030 3.0-total 24 credits;

Major requirements:

- EECS 1560 3.0; MATH 2001 3.0; MATH 3001 3.0; MATH 3010 3.0; MATH 3021 3.0; MATH 3022 3.0; MATH 4011 3.0; MATH 4021 3.0;
- six additional MATH credits at the 4000 level;
- 15 additional MATH credits without second digit 5;

	Fall Term	**Winter Term**
Year 1	MATH 1131 3.0 (core) MATH 1200 3.0 (core) MATH 1300 3.0 (core)	MATH 1021 3.0 (core) MATH 1310 3.0 (core) EECS 1560 3.0
	Twelve additional credits in Gen. Ed. or elective courses	
Year 2	MATH 2001 3.0 MATH 2022 3.0 (core) MATH 2310 3.0 (core)	MATH 2030 3.0 (core)
	MATH 2XYZ 3.0* with Math 2270 3.0 strongly recommended Fifteen additional credits in Gen. Ed., elective courses, or Math courses without the second digit 5 (Item 3 above)	
Year 3	MATH 3010 3.0 MATH 3021 3.0	MATH 3001 3.0 MATH 3022 3.0
	Six credits in MATH 3XYZ with Math 3271 3.0 strongly recommended Twelve additional credits in Gen. Ed., elective courses, or Math courses without the second digit 5 (Item 3 above)	
Year 4	MATH 4011 3.0 MATH 4021 3.0	
	Six credits in MATH 4XYZ Eighteen additional credits in Gen. Ed., elective courses, or Math courses without the second digit 5 (Item 3 above)	

Gen. Ed.: 24 credits from the following areas: Humanities, Models of Reasoning, Natural Science, Social Science. Of these 24 credits, students must complete the following minimum requirements: at least six credits from Humanities, Natural Science and Social Science (with no more than 9 credits in each counting towards the general education requirement).

Outside-major: At least 18 credits must be non-MATH courses nor EECS 1560 – fulfilled by Gen. Ed. courses.

At least 120 credits must be completed with at least 51 credits from the major (MATH).

At least 36 credits must be at the 3000 level or higher, 18 of these 36 credits must at 4000 level.

MATH courses with second digit 5 do not count towards the Applied Mathematics program requirements.

Honours B.A. Program in Mathematics (120 credits)

Math/Stats Core: MATH 1200 3.0; MATH 1300 3.0; MATH 1310 3.0; MATH 2310 3.0; MATH 1021 3.0; MATH 2022 3.0; MATH 1131 3.0; MATH 2030 3.0 - total 24 credits;

Major requirements:

- EECS 1560 3.0; MATH 2001 3.0; MATH 3001 3.0; MATH 3010 3.0; MATH 3021 3.0; MATH 3022 3.0; MATH 4011 3.0; MATH 4021 3.0;
- six additional MATH credits at the 4000 level;

	Fall Term	Winter Term
Year 1	MATH 1131 3.0 (core) MATH 1200 3.0 (core) MATH 1300 3.0 (core)	MATH 1021 3.0 (core) MATH 1310 3.0 (core) EECS 1560 3.0
	Twelve additional credits in Gen. Ed. or elective courses	
Year 2	MATH 2001 3.0 MATH 2022 3.0 (core) MATH 2310 3.0 (core)	MATH 2030 3.0 (core)
	Eighteen additional credits in Gen. Ed., elective courses, or Math courses without the second digit 5	
Year 3	MATH 3010 3.0 MATH 3021 3.0	MATH 3001 3.0 MATH 3022 3.0
	Eighteen additional credits in Gen. Ed., elective courses, or Math courses without the second digit 5	
Year 4	MATH 4011 3.0 MATH 4021 3.0	
	Six credits in MATH 4XYZ Eighteen additional credits in Gen. Ed., elective courses, or Math courses without the second digit 5 (Item 3 above)	

Gen. Ed.: 24 credits from the following areas: Humanities, Models of Reasoning, Natural Science, Social Science. Of these 24 credits, students must complete the following minimum requirements: at least six credits from Humanities, Natural Science and Social Science (with no more than 9 credits in each counting towards the general education requirement).

Outside-major: At least 18 credits must be non-MATH courses nor EECS 1560 – fulfilled by Gen. Ed. courses.

At least 120 credits must be completed with at least 51 credits from the major (MATH).

At least 36 credits must be at the 3000 level or higher, 18 of these 36 credits must at 4000 level.

MATH courses with second digit 5 do not count towards the Applied Mathematics program requirements.

Specialized Honours B.Sc. Program in Mathematics (120 credits)

Math/Stats Core: MATH 1200 3.0; MATH 1300 3.0; MATH 1310 3.0; MATH 2310 3.0; MATH 1021 3.0; MATH 2022 3.0; MATH 1131 3.0; MATH 2030 3.0 - total 24 credits;

Major requirements:

- EECS 1560 3.0; MATH 2001 3.0; MATH 3001 3.0; MATH 3010 3.0; MATH 3021 3.0; MATH 3022 3.0; MATH 4011 3.0; MATH 4021 3.0;
- six additional MATH credits at the 4000 level;
- 15 additional MATH credits without second digit 5.

	Fall Term	Winter Term
Year 1	MATH 1131 3.0 (core) MATH 1200 3.0 (core) MATH 1300 3.0 (core)	MATH 1021 3.0 (core) MATH 1310 3.0 (core) EECS 1560 3.0
	Twelve additional credits in Foundational Science, Science-outside-major, Non-science or elective courses	
Year 2	MATH 2001 3.0 MATH 2022 3.0 (core) MATH 2310 3.0 (core)	MATH 2030 3.0 (core)
	MATH 2XYZ 3.0* with Math 2270 3.0 strongly recommended Fifteen additional credits in Foundational Science, Science-outside-major, Non-science or elective courses, or Math courses without the second digit 5 (Item 3 above)	
Year 3	MATH 3010 3.0 MATH 3021 3.0	MATH 3001 3.0 MATH 3022 3.0
	Six credits in MATH 3XYZ with Math 3271 3.0 strongly recommended Twelve Foundational Science, Science-outside-major, Non-science or elective courses, or Math courses without the second digit 5 (Item 3 above)	
Year 4	MATH 4011 3.0 MATH 4021 3.0	
	Six credits in MATH 4XYZ Eighteen additional credits in Foundational Science, Science-outside-major, Non-science or elective courses, or Math courses without the second digit 5 (Item 3 above)	

Foundational Science: six credits required from BIOL 1000, BIOL 1001, BIOL 1010, CHEM 1000, CHEM 1001, PHYS 1010, PHYS 1410.

Science outside major: EECS 1560 + 6 Foundational Science credits + 15 non-MATH credits in science, 3 of which at 2000-level or above. (BIOL 1500, CHEM 1500, PHYS 1510 do not count.)

Non-science: twelve credits in human enquiry outside of science disciplines.

At least 120 credits must be completed with at least 66 credits from the Major.

At least 42 credits must be at the 3000 level or higher, 18 of these 42 must be in the Major.

MATH courses with second digit 5 do not count towards the Mathematics program requirements.

Honours B.Sc. Program in Mathematics (120 credits)

Math/Stats Core: MATH 1200 3.0; MATH 1300 3.0; MATH 1310 3.0; MATH 2310 3.0; MATH 1021 3.0; MATH 2022 3.0; MATH 1131 3.0; MATH 2030 3.0 - total 24 credits;

Major requirements:

- EECS 1560 3.0; MATH 2001 3.0; MATH 3001 3.0; MATH 3010 3.0; MATH 3021 3.0; MATH 3022 3.0; MATH 4011 3.0; MATH 4021 3.0;
- six additional MATH credits at the 4000 level;

	Fall Term	Winter Term
Year 1	MATH 1131 3.0 (core) MATH 1200 3.0 (core) MATH 1300 3.0 (core)	MATH 1021 3.0 (core) MATH 1310 3.0 (core) EECS 1560 3.0
	Twelve additional credits in Foundational Science, Science-outside-major, Non-science or elective courses,	
Year 2	MATH 2001 3.0 MATH 2022 3.0 (core) MATH 2310 3.0 (core)	MATH 2030 3.0 (core)
	Eighteen additional credits in Foundational Science, Science-outside-major, Non-science or elective courses, or Math courses without the second digit 5	
Year 3	MATH 3010 3.0 MATH 3021 3.0	MATH 3001 3.0 MATH 3022 3.0
	Eighteen additional credits in Foundational Science, Science-outside-major, Non-science or elective courses, or Math courses without the second digit 5	
Year 4	MATH 4011 3.0 MATH 4021 3.0	
	Six credits in MATH 4XYZ Eighteen additional credits in Foundational Science, Science-outside-major, Non-science or elective courses, or Math courses without the second digit 5 (Item 3 above)	

Foundational Science: six credits required from BIOL 1000, BIOL 1001, BIOL 1010, CHEM 1000, CHEM 1001, PHYS 1010, PHYS 1410.

Science outside major: EECS 1560 + 6 Foundational Science credits + 15 non-MATH credits in science, 3 of which at 2000-level or above. (BIOL 1500, CHEM 1500, PHYS 1510 do not count.)

Non-science: twelve credits in human enquiry outside of science disciplines.

At least 120 credits must be completed with at least 51 credits from the Major.

At least 42 credits must be at the 3000 level or higher, 18 of these 42 must be in the Major.

MATH courses with second digit 5 do not count towards the Mathematics program requirements.

Honours Minor B.A.\B.Sc. Program in Mathematics

- EECS 1560 3.0;
- MATH 1021 3.0; MATH 1300 3.0; MATH 1310 3.0; MATH 2022 3.0; MATH 2310 3.0;
- three credits chosen from MATH 1019 3.0; MATH 1090 3.0; MATH 1190 3.0; MATH 1200 3.0; MATH 2030 3.0;
- twelve additional MATH credits at 3000-level or higher.

Specialized Honours B.Sc. Program in Mathematical Biology (120 credits)

Math/Stats Core: MATH 1200 3.0; MATH 1300 3.0; MATH 1310 3.0; MATH 2310 3.0; MATH 1021 3.0; MATH 2022 3.0; MATH 1131 3.0; MATH 2030 3.0 - total 24 credits;

Major requirements:

- EECS 1560 3.0; MATH 2001 3.0; MATH 2041 3.0; MATH 2270 3.0; MATH 3010 3.0; MATH 3241 3.0; MATH 3250 3.0; MATH 3410 3.0; MATH 4250 3.0;
- one of MATH 3050 6.0, MATH 3050 6.0 or MATH 3052 6.0, MATH 3090 3.0, MATH 3171 3.0, MATH 3172 3.0, MATH 3242 3.0, MATH 3260 3.0 or MATH 3271 3.0;
- six additional credits selected from MATH 4090 3.0, MATH 4171 3.0, MATH 4172 3.0; MATH 4271 3.0, MATH 4430 3.0 or MATH 4431 3.0;
- BIOL 1000 3.0; BIOL 1001 3.0;
- at least 15 credits in Biology at 2000 level or higher including at least nine credits at 3000 level or higher.

	Fall Term	**Winter Term**
Year 1	MATH 1131 3.0 (core) MATH 1200 3.0 (core) MATH 1300 3.0 (core) BIOL 1000 3.0 CHEM 1000 3.0	MATH 1021 3.0 (core) MATH 1310 3.0 (core) EECS 1560 3.0 BIOL 1001 3.0 CHEM 1001 3.0
Year 2	MATH 2001 3.0 MATH 2041 3.0 MATH 2310 3.0 (core)	MATH 2022 3.0 (core) MATH 2030 3.0 (core) MATH 2270 3.0
	Six credits in Biology at 2000 level or higher Six credits electives (See * below)	
Year 3	MATH 3010 3.0 MATH 3241 3.0	MATH 3250 3.0 MATH 3410 3.0
	MATH 3XYZ 3.0 selected from Item 2 above Nine credits in Biology at 3000 level or higher Six credits electives (See * below)	
Year 4	MATH 4250 6.0 Practicum in Mathematical Biology Six MATH credits selected from Item 3 above Eighteen additional credits in non-science or elective courses, or Math courses without the second digit 5	

Foundational Science: CHEM 1000 3.0 and CHEM 1001 3.0.

Science outside major: EECS 1560; Biology courses required above.

Non-science: twelve credits in human enquiry outside of science disciplines.

***Recommended electives:** CHEM 2020 6.0 (prerequisite for some biology courses at 3000 and 4000 level), both KINE 2011 3.0 and KINE 2031 3.0, PHYS 1010 6.0, PHYS 1410 6.0, or ENVS 1000 6.0.

At least 120 credits must be completed with at least 60 credits from the Major.

At least 42 credits must be at the 3000 level or higher, 18 of these 42 must be in the Major.

MATH courses with second digit 5 do not count towards the Mathematical Biology program requirements.

Honours B.Sc. Program in Mathematical Biology (120 credits)

Math/Stats Core: MATH 1200 3.0; MATH 1300 3.0; MATH 1310 3.0; MATH 2310 3.0; MATH 1021 3.0; MATH 2022 3.0; MATH 1131 3.0; MATH 2030 3.0 - total 24 credits;

Major requirements:

- EECS 1560 3.0; MATH 2041 3.0; MATH 2270 3.0; MATH 3250 3.0; MATH 3410 3.0; MATH 4250 3.0;
- one of MATH 3090 3.0, MATH 3171 3.0, MATH 3172 3.0, MATH 3241 3.0, MATH 3260 3.0 or MATH 3271 3.0;
- six additional credits selected from MATH 4090 3.0, MATH 4171 3.0, MATH 4172 3.0; MATH 4271 3.0, MATH 4430 3.0 or MATH 4431 3.0;
- BIOL 1000 3.0; BIOL 1001 3.0;
- at least 15 credits in Biology at 2000 level or higher including at least nine credits at 3000 level or higher.

	Fall Term	**Winter Term**
Year 1	MATH 1131 3.0 (core) MATH 1200 3.0 (core) MATH 1300 3.0 (core) BIOL 1000 3.0 CHEM 1000 3.0	MATH 1021 3.0 (core) MATH 1310 3.0 (core) EECS 1560 3.0 BIOL 1001 3.0 CHEM 1001 3.0
Year 2	MATH 2041 3.0 MATH 2310 3.0 (core)	MATH 2022 3.0 (core) MATH 2030 3.0 (core) MATH 2270 3.0
	Six credits in Biology at 2000 level or higher Six credits electives (See * below) Three credits in non-science or elective courses	
Year 3		MATH 3250 3.03.0
	MATH 3XYZ 3.0 selected from Item 2 above Nine credits in Biology at 3000 level or higher Six credits electives (see * below) Nine additional credits in non-science or elective courses	
Year 4	MATH 4250 6.0 Practicum in Mathematical Biology Six MATH credits selected from Item 3 above Eighteen additional credits in non-science or elective courses, or Math courses without the second digit 5	

Science outside major: EECS 1560; Biology courses required above.

Non-science: twelve credits in human enquiry outside of science disciplines.

***Recommended electives:** CHEM 2020 6.0 (prerequisite for some biology courses at 3000 and 4000 level), both KINE 2011 3.0 and KINE 2031 3.0, PHYS 1010 6.0, PHYS 1410 6.0, or ENVS 1000 6.0.

At least 120 credits must be completed with at least 48 credits from the Major.

At least 42 credits must be at the 3000 level or higher, 18 of these 42 must be in the Major.

MATH courses with second digit 5 do not count towards the Mathematical Biology program requirements.

Honours Minor B.Sc. Program in Mathematical Biology

- This Honours minor may only be combined with a Biology major or a Kinesiology and Health Science major.
- EECS 1560 3.0;
- MATH 1021 3.0; MATH 1300 3.0; MATH 1310 3.0; MATH 2310 3.0; MATH 3250 3.0;
- Six credits chosen from MATH 2022 3.0, MATH 2030 3.0; MATH 2041 3.0, MATH 2270 3.0;
- Three additional credits from MATH 3090 3.0, MATH 3171 3.0, MATH 3172 3.0, or Math 3241 3.0;
- Six additional credits selected from MATH 4090 3.0, MATH 4171 3.0, MATH 4172 3.0, MATH 4430 3.0 or MATH 4431 3.0 or MATH 4250 3.0;
- The requirements of the Biology or Kinesiology and Health Science major.

Honours B.A. Program in Mathematics for Education (120 credits)

Math/Stats Core: MATH 1200 3.0; MATH 1300 3.0; MATH 1310 3.0; MATH 2310 3.0; MATH 1021 3.0; MATH 2022 3.0; MATH 1131 3.0; MATH 2030 3.0 - total 24 credits;

Major requirements:

- EECS 1560 3.0; MATH 3050 6.0 or MATH 3052 6.0; MATH 4100 3.0;
- three additional credits selected from mathematics courses without second digit 5: one of MATH 3090 3.0 and MATH 4090 6.0 is recommended;
- nine additional credits selected from mathematics courses at the 4000-level: MATH 4400 6.0 is recommended.

<table>
<tr><th></th><th>Fall Term</th><th>Winter Term</th></tr>
<tr><td rowspan="2">Year 1</td><td>MATH 1131 3.0 (core)
MATH 1200 3.0 (core)
MATH 1300 3.0 (core)</td><td>MATH 1021 3.0 (core)
MATH 1310 3.0 (core)
EECS 1560 3.0</td></tr>
<tr><td colspan="2">Twelve additional credits in Gen. Ed. or elective courses</td></tr>
<tr><td rowspan="2">Year 2</td><td>MATH 2030 3.0 (core)
MATH 2310 3.0 (core)</td><td>MATH 2022 3.0 (core)</td></tr>
<tr><td colspan="2">Twenty-one additional credits in Gen. Ed., elective courses, or Math courses without the second digit 5</td></tr>
<tr><td>Year 3</td><td colspan="2">MATH 3050 6.0 or MATH 3052 6.0
Three credits in Math course without second digit 5 with one of MATH 3090 3.0 and MATH 4090 recommended.
Twenty-one additional credits in Gen. Ed., elective courses, or Math courses without the second digit 5</td></tr>
<tr><td rowspan="2">Year 4</td><td></td><td>MATH 4100 3.0</td></tr>
<tr><td colspan="2">Nine credits in MATH 4XYZ with Math 4400 6.0 recommended
Eighteen additional credits in Gen. Ed., elective courses, or Math courses without the second digit 5</td></tr>
</table>

Gen. Ed.: 24 credits from the following areas: Humanities, Models of Reasoning, Natural Science, Social Science. Of these 24 credits, students must complete the following minimum requirements: at least six credits from Humanities, Natural Science and Social Science (with no more than 9 credits in each counting towards the general education requirement).

Outside-major: At least 18 credits must be non-MATH courses nor EECS 1560 – fulfilled by Gen. Ed. courses.

At least 120 credits must be completed with at least 45 credits from the Major.

At least 36 credits must be at the 3000 level or higher, 18 of these 36 credits must at 4000 level.

MATH courses with second digit 5 do not count towards the Applied Mathematics program requirements.

Honours B.Sc. Program in Mathematics for Education (120 credits)

Math/Stats Core: MATH 1200 3.0; MATH 1300 3.0; MATH 1310 3.0; MATH 2310 3.0; MATH 1021 3.0; MATH 2022 3.0; MATH 1131 3.0; MATH 2030 3.0 - total 24 credits;

Major requirements:

- EECS 1560 3.0; MATH 3050 6.0 or MATH 3052 6.0; MATH 4100 3.0;
- three additional credits selected from mathematics courses without second digit 5: one of MATH 3090 3.0 and MATH 4090 6.0 is recommended;
- nine additional credits selected from mathematics courses at the 4000-level: MATH 4400 6.0 is recommended.

	Fall Term	Winter Term
Year 1	MATH 1131 3.0 (core) MATH 1200 3.0 (core) MATH 1300 3.0 (core)	MATH 1021 3.0 (core) MATH 1310 3.0 (core) EECS 1560 3.0
	Twelve additional credits in Foundational Science, Science-outside-major, Non-science or elective courses	
Year 2	MATH 2030 3.0 (core) MATH 2310 3.0 (core)	MATH 2022 3.0 (core)
	Twenty-one additional credits in Foundational Science, Science-outside-major, Non-science or elective courses, or Math courses without the second digit 5 (see Item 2)	
Year 3	MATH 3050 6.0 or MATH 3052 6.0 Three credits in Math course without second digit 5 with one of MATH 3090 3.0 and MATH 4090 recommended. Twenty-one additional credits in Foundational Science, Science-outside-major, Non-science or elective courses, or Math courses without the second digit 5 (see Item 2)	
Year 4		MATH 4100 3.0
	Nine credits in MATH 4XYZ with Math 4400 6.0 recommended Eighteen additional credits in Foundational Science, Science-outside-major, Non-science or elective courses, or Math courses without the second digit 5	

Foundational Science: six credits required from BIOL 1000, BIOL 1001, BIOL 1010, CHEM 1000, CHEM 1001, PHYS 1010, PHYS 1410.

Science outside major: EECS 1560 + 6 Foundational Science credits + 15 non-MATH credits in science, 3 of which at 2000-level or above. (BIOL 1500, CHEM 1500, PHYS 1510 do not count.)

Non-science: twelve credits in human enquiry outside of science disciplines.

At least 120 credits must be completed with at least 45 credits from the Major.

At least 42 credits must be at the 3000 level or higher, 18 of these 42 must be in the Major.

MATH courses with second digit 5 do not count towards the Mathematics for Education program requirements.

Honours Minor B.A.\B.Sc. Program in Mathematics for Education

- EECS 1560 3.0;
- MATH 1021 3.0; MATH 1131 3.0; MATH 1200 3.0; MATH 1300 3.0; MATH 1310 3.0; MATH 2022 3.0; MATH 2030 3.0;
- at least nine MATH credits at 3000-level or above, including at least six credits at 4000 level to include MATH 4100 3.0 or MATH 4400 6.0;
- at least three credits above should be chosen from proof-based courses approved by the director such as MATH 2001 3.0; MATH 3050 6.0 or MATH 3052 6.0; MATH 3021 3.0; MATH 3022 3.0; MATH 3141 3.0; MATH 3260 3.0; MATH 4160 3.0.

Specialized Honours B.A. Program in Statistics (120 credits)

Math/Stats Core: MATH 1200 3.0; MATH 1300 3.0; MATH 1310 3.0; MATH 2310 3.0; MATH 1021 3.0; MATH 2022 3.0; MATH 1131 3.0; MATH 2030 3.0 - total 24 credits;

Major requirements:

- EECS 1560 3.0;
- MATH 2001 3.0; MATH 2131 3.0; MATH 3001 3.0; MATH 3330 3.0; MATH 3131 3.0; MATH 3132 3.0 MATH 3430 3.0; MATH 4330 3.0; MATH 4730 3.0; MATH 4939 3.0;
- three additional MATH credits at the 4000 level with third digit 3;
- nine additional credits from major (second digit not 5) mathematics courses.

	Fall Term	**Winter Term**
Year 1	MATH 1021 3.0 (core) MATH 1131 3.0 (core) MATH 1300 3.0 (core)	MATH 1200 3.0 (core) MATH 1310 3.0 (core) MATH 2022 3.0 (core) EECS 1560 3.0
	Nine additional credits in Gen. Ed. or elective courses	
Year 2	MATH 2001 3.0 MATH 2030 3.0 (core) MATH 2310 3.0 (core)	MATH 2131 3.0
	Eighteen additional credits in Gen. Ed., elective courses, or Math courses without the second digit 5 (see Item 3)	
Year 3	MATH 3131 3.0 MATH 3330 3.0	MATH 3001 3.0 MATH 3132 3.0 MATH 3430 3.0
	Twelve additional credits in Gen. Ed., elective courses, or Math courses without the second digit 5 (see Item 3)	
Year 4	MATH 4330 3.0	MATH 4730 3.0 Math 4939 3.0
	Three credits in MATH 4X3Z Eighteen additional credits in Gen. Ed., elective courses, or Math courses without the second digit 5 (see Item 3)	

Gen. Ed.: 24 credits from the following areas: Humanities, Models of Reasoning, Natural Science, Social Science. Of these 24 credits, students must complete the following minimum requirements: at least six credits from Humanities, Natural Science and Social Science (with no more than 9 credits in each counting towards the general education requirement).

Outside-major: At least 18 credits must be non-MATH courses nor EECS 1560 – fulfilled by Gen. Ed. courses.

At least 120 credits must be completed with at least 66 credits from the major (MATH).

At least 36 credits must be at the 3000 level or higher, 18 of these 36 credits must at 4000 level.

MATH courses with second digit 5 do not count towards the Applied Mathematics program requirements.

Honours B.A. Program in Statistics (120 credits)

Math/Stats Core: MATH 1200 3.0; MATH 1300 3.0; MATH 1310 3.0; MATH 2310 3.0; MATH 1021 3.0; MATH 2022 3.0; MATH 1131 3.0; MATH 2030 3.0 - total 24 credits;

Major requirements:

- EECS 1560 3.0;
- MATH 2131 3.0; MATH 3330 3.0; MATH 3131 3.0; MATH 3132 3.0 MATH 3430 3.0; MATH 4330 3.0; MATH 4730 3.0; MATH 4939 3.0;
- three additional MATH credits at the 4000 level with third digit 3.

	Fall Term	**Winter Term**
Year 1	MATH 1021 3.0 (core) MATH 1131 3.0 (core) MATH 1300 3.0 (core)	MATH 1200 3.0 (core) MATH 1310 3.0 (core) MATH 2022 3.0 (core) EECS 1560 3.0
	Nine additional credits in Gen. Ed. or elective courses	
Year 2	MATH 2030 3.0 (core) MATH 2310 3.0 (core)	MATH 2131 3.0
	Twenty-one additional credits in Gen. Ed., elective courses, or Math courses without the second digit 5	
Year 3	MATH 3131 3.0 MATH 3330 3.0	MATH 3132 3.0 MATH 3430 3.0
	Eighteen additional credits in Gen. Ed., elective courses, or Math courses without the second digit 5	
Year 4	MATH 4330 3.0	MATH 4730 3.0 Math 4939 3.0
	Three credits in MATH 4X3Z Eighteen additional credits in Gen. Ed., elective courses, or Math courses without the second digit 5	

Gen. Ed.: 24 credits from the following areas: Humanities, Models of Reasoning, Natural Science, Social Science. Of these 24 credits, students must complete the following minimum requirements: at least six credits from Humanities, Natural Science and Social Science (with no more than 9 credits in each counting towards the general education requirement).

Outside-major: At least 18 credits must be non-MATH courses nor EECS 1560 – fulfilled by Gen. Ed. courses.

At least 120 credits must be completed with at least 51 credits from the major (MATH).

At least 36 credits must be at the 3000 level or higher, 18 of these 36 credits must at 4000 level.

MATH courses with second digit 5 do not count towards the Statistics program requirements.

Specialized Honours B.Sc. Program in Statistics (120 credits)

Math/Stats Core: MATH 1200 3.0; MATH 1300 3.0; MATH 1310 3.0; MATH 2310 3.0; MATH 1021 3.0; MATH 2022 3.0; MATH 1131 3.0; MATH 2030 3.0 - total 24 credits;

Major requirements:

- EECS 1560 3.0;
- MATH 2001 3.0; MATH 2131 3.0; MATH 3001 3.0; MATH 3330 3.0; MATH 3131 3.0; MATH 3132 3.0 MATH 3430 3.0; MATH 4330 3.0; MATH 4730 3.0; MATH 4939 3.0;
- three additional MATH credits at the 4000 level with third digit 3;
- nine additional credits from major (second digit not 5) mathematics courses.

	Fall Term	**Winter Term**
Year 1	MATH 1021 3.0 (core) MATH 1131 3.0 (core) MATH 1300 3.0 (core)	MATH 1200 3.0 (core) MATH 1310 3.0 (core) MATH 2022 3.0 (core) EECS 1560 3.0
	Nine additional credits in Foundational Science, Science-outside-major, Non-science or elective courses	
Year 2	MATH 2001 3.0 MATH 2030 3.0 (core) MATH 2310 3.0 (core)	MATH 2131 3.0
	Eighteen additional credits in Foundational Science, Science-outside-major, Non-science, elective, or Math courses without the second digit 5 (see Item 3)	
Year 3	MATH 3131 3.0 MATH 3330 3.0	MATH 3001 3.0 MATH 3132 3.0 MATH 3430 3.0
	Fifteen additional credits in Foundational Science, Science-outside-major, Non-science, elective, or Math courses without the second digit 5 (see Item 3)	
Year 4	MATH 4330 3.0	MATH 4730 3.0 MATH 4939 3.0
	Three credits in MATH 4X3Z Eighteen additional credits in Foundational Science, Science-outside-major, Non-science, elective, or Math courses without the second digit 5 (see Item 3)	

Foundational Science: six credits required from BIOL 1000, BIOL 1001, BIOL 1010, CHEM 1000, CHEM 1001, PHYS 1010, PHYS 1410.

Science outside major: EECS 1560 + 6 Foundational Science credits + 15 non-MATH credits in science, 3 of which at 2000-level or above. (BIOL 1500, CHEM 1500, PHYS 1510 do not count.)

Non-science: twelve credits in human enquiry outside of science disciplines.

At least 120 credits must be completed with at least 66 credits from the Major.

At least 42 credits must be at the 3000 level or higher, 18 of these 42 must be in the Major.

MATH courses with second digit 5 do not count towards the Statistics program requirements.

Honours B.Sc. Program in Statistics (120 credits)

Math/Stats Core: MATH 1200 3.0; MATH 1300 3.0; MATH 1310 3.0; MATH 2310 3.0; MATH 1021 3.0; MATH 2022 3.0; MATH 1131 3.0; MATH 2030 3.0 - total 24 credits;

Major requirements:

- EECS 1560 3.0;
- MATH 2131 3.0; MATH 3330 3.0; MATH 3131 3.0; MATH 3132 3.0 MATH 3430 3.0; MATH 4330 3.0; MATH 4730 3.0; MATH 4939 3.0;
- three additional MATH credits at the 4000 level with third digit 3.

	Fall Term	Winter Term
Year 1	MATH 1021 3.0 (core) MATH 1131 3.0 (core) MATH 1300 3.0 (core)	MATH 1200 3.0 (core) MATH 1310 3.0 (core) MATH 2022 3.0 (core) EECS 1560 3.0
	Nine additional credits in Foundational Science, Science-outside-major, Non-science or elective courses	
Year 2	MATH 2030 3.0 (core) MATH 2310 3.0 (core)	MATH 2131 3.0
	Twenty-one additional credits in Foundational Science, Science-outside-major, Non-science, elective, or Math courses without the second digit 5	
Year 3	MATH 3131 3.0 MATH 3330 3.0	MATH 3132 3.0 MATH 3430 3.0
	Eighteen additional credits in Foundational Science, Science-outside-major, Non-science, elective, or Math courses without the second digit 5	
Year 4	MATH 4330 3.0	MATH 4730 3.0 MATH 4939 3.0
	Three credits in MATH 4X3Z Eighteen additional credits in Foundational Science, Science-outside-major, Non-science, elective, or Math courses without the second digit 5	

Foundational Science: six credits required from BIOL 1000, BIOL 1001, BIOL 1010, CHEM 1000, CHEM 1001, PHYS 1010, PHYS 1410.

Science outside major: EECS 1560 + 6 Foundational Science credits + 15 non-MATH credits in science, 3 of which at 2000-level or above. (BIOL 1500, CHEM 1500, PHYS 1510 do not count.)

Non-science: twelve credits in human enquiry outside of science disciplines.

At least 120 credits must be completed with at least 51 credits from the Major.

At least 42 credits must be at the 3000 level or higher, 18 of these 42 must be in the Major.

MATH courses with second digit 5 do not count towards the Statistics program requirements.

Honours Minor B.A.\B.Sc. Program in Statistics

- EECS 1560 3.0;
- MATH 1021 3.0; MATH 1131 3.0; MATH 1300 3.0; MATH 1310 3.0; MATH 2022 3.0; MATH 2030 3.0; MATH 2131 3.0;
- MATH 3330 3.0; MATH 3131 3.0; MATH 3430 3.0; MATH 4330 3.0; MATH 4730 3.0;

Bachelor B.A. Program in Applied Mathematics

- **Math/Stats Core:** MATH 1200 3.00; MATH 1300 3.00; MATH 1310 3.00; MATH 2310 3.00; MATH 1021 3.00; MATH 2022 3.00; MATH 1131 3.00; MATH 2030 3.00;
- EECS 1560 3.0;
- MATH 2041 3.0; MATH 2270 3.0; MATH 2280 3.0; MATH 3171 3.0; MATH 3330 3.0; MATH 3333 3.0.
- Plus 3 additional credits selected from MATH courses without second digit "5" at the 3000 level or higher.

	Fall Term	**Winter Term**
Year 1	MATH 1021 3.0 (core) Math 1200 3.0 (core) MATH 1300 3.0 (core)	MATH 1131 3.0 (core) MATH 1310 3.0 (core) MATH 2022 3.0 (core) EECS 1560 3.0
	Nine additional credits in Gen. Ed. or elective courses	
Year 2	MATH 2030 3.0 (core) MATH 2041 3.0 MATH 2280 3.0 MATH 2310 3.0 (core)	MATH 2131 3.0 MATH 2270 3.0
	Twelve additional credits in Gen. Ed. or elective ccourses	
Year 3	MATH 3171 3.0 MATH 3330 3.0	MATH 3333 3.0 MATH 3XYZ or MATH 4XYZ 3.0
	Eighteen additional credits in Gen. Ed. or elective courses	

Gen. Ed.: 24 credits from the following areas: Humanities, Models of Reasoning, Natural Science, Social Science. Of these 24 credits, students must complete the following minimum requirements: at least six credits from Humanities, Natural Science and Social Science (with no more than 9 credits in each counting towards the general education requirement).

Outside-major: At least 18 credits must be non-MATH courses nor EECS 1560 – fulfilled by Gen. Ed. courses.

At least 90 credits must be completed with at least 42 credits in the Major.

At least 18 credits must be at the 3000 level or higher. 12 of these 18 must be in MATH courses without second digit "5".

MATH courses with second digit 5 do not count towards the Applied Mathematics program requirements.

Bachelor BSc Program in Applied Mathematics

- **Math/Stats Core:** MATH 1200 3.00; MATH 1300 3.00; MATH 1310 3.00; MATH 2310 3.00; MATH 1021 3.00; MATH 2022 3.00; MATH 1131 3.00; MATH 2030 3.00;
- EECS 1560 3.0;
- MATH 2041 3.0; MATH 2270 3.0; MATH 2280 3.0; MATH 3171 3.0; MATH 3330 3.0; MATH 3333 3.0.
- Plus 3 additional credits selected from MATH courses without second digit "5" at the 3000 level or higher.

	Fall Term	**Winter Term**
Year 1	MATH 1021 3.0 (core) Math 1200 3.0 (core) MATH 1300 3.0 (core)	MATH 1131 3.0 (core) MATH 1310 3.0 (core) MATH 2022 3.0 (core) EECS 1560 3.0
	Six additional credits in Foundational Science, three additional credits in Science outside major or non-Science courses	
Year 2	MATH 2030 3.0 (core) MATH 2041 3.0 MATH 2280 3.0 MATH 2310 3.0 (core)	MATH 2131 3.0 MATH 2270 3.0
	Twelve additional credits in Science outside major or non-Science courses	
Year 3	MATH 3171 3.0 MATH 3330 3.0	MATH 3333 3.0 MATH 3XYZ or MATH 4XYZ 3.0
	Eighteen additional credits in Science outside major, non-Science credits, or elective courses	

Foundational Science: six credits required from BIOL 1000, BIOL 1001, BIOL 1010, CHEM 1000, CHEM 1001, PHYS 1010, PHYS 1410.

Science outside major: EECS 1560 + 6 Foundational Science credits + 15 non-MATH credits in science, 3 of which at 2000-level or above. (BIOL 1500, CHEM 1500, PHYS 1510 do not count.)

Non-science: twelve credits in human enquiry outside of science disciplines.

At least 90 credits must be completed with at least 42 credits from the Major.

At least 18 credits must be at the 3000 level or higher. 12 of these 18 must be in the Major.

MATH courses with second digit 5 do not count towards the Applied Mathematics program requirements.