THE UNIVERSITY OF MELBOURNE
SCHOOL OF MATHEMATICS AND STATISTICS

Master of Science (Mathematics and Statistics) and Advanced Graduate Diploma Guide 2020*

Version 1.11†

*This guide has been prepared to assist you in deciding whether to apply for the Master of Science or Advanced Graduate Diploma programs in the area of Mathematics and Statistics and in designing your course. You are advised that the rules governing the programs are definitively stated in the official University Handbook. In the event of a disagreement between this Guide and the Handbook, it is the Handbook that is to prevail. The information in this Guide is given in good faith and correct (to the best of our knowledge) at the time of writing (October 2019). It has been carefully checked, but the School of Mathematics and Statistics accepts no responsibility for the accuracy of the information.

†Prepared by C. Haesemeyer. and D. Crowley. The Guide contains material prepared for its past editions by, or with participation of, K. Borovkov, S. Zhou, P. Norbury and O. Foda.

Contents

1 Overview

In 2020 the following advanced level programs will be offered in the School of Mathematics & Statistics:

- **MC-SCIMAT** Master of Science: Mathematics and Statistics
  Coordinator: A/Prof Diarmuid Crowley
- **GDA-SCI** Graduate Diploma in Science (Advanced): Mathematics and Statistics
  Coordinator: A/Prof Diarmuid Crowley
- **MC-DATASC** Master of Data Science
  Coordinator: Prof Howard Bondell. *This course is not covered in this guide.*
- **MC-COMPBIO** Master of Computational Biology
  Coordinator: Prof James McCaw. *This course is not covered in this guide.*

The Master of Science (MSc) program (two years full time) and Graduate Diploma in Science (Advanced, AGDip) program (one year full time study) in Mathematics and Statistics are flexible programs allowing students to study subjects in four broad specialisations:

- Applied Mathematics and Mathematical Physics,
- Discrete Mathematics and Operations Research,
- Pure Mathematics,
- Statistics and Stochastic Processes.

The Master of Science program serves as a necessary preparation for research in Mathematics and Statistics, including PhD studies; it has both a coursework and a thesis component. The AGDip is a one-year, coursework only program.

Both programs have substantial coursework components:

- MSc: 200 credit points = 150 points coursework + a 50 points research project component;
- AGDip: 100 credit points = 100 points coursework

(recall that the standard full-time student load is 100 credit points per year, which is equivalent to eight standard one-semester subjects).

Be aware that the **maximum course duration** for full-time MSc (AGDip) program is six (four) years, [1]

It is expected that you would nominate your preferred specialisation on enrolment. To successfully complete the coursework subjects in the chosen specialisation, you will have to have the undergraduate level prerequisites (or their equivalents) for the masters level subjects from that specialisation completed by the time you attempt them. There is a space in the MSc program for a couple of such prerequisite subjects, in case you miss some of them, but **you must have sufficient background in the chosen specialisation area prior to commencing the program**.

Each MSc student will be assigned an academic supervisor from a specialisation, who will give individual advice on the student's research project and assist in developing an individual course plan for that student. The School has several MSc advisers whose names will be communicated to newly enrolled students at induction. These advisers will be able to assist AGDip students (and also beginning MSc students, should they have no supervisor at the time) with course planning.

Students will have to do a prescribed number of masters level discipline subjects offered by the School of Mathematics & Statistics. For the masters level Mathematics & Statistics discipline subjects available to MSc and AGDip students in 2020 and 2021, please see the table in Section 14 showing the subjects' semester allocation. A few of these subjects may be replaced by masters level subjects offered by other schools or even undergraduate subjects (subject to the approval of the supervisor and the program coordinator). For precise formulations, see the program descriptions in the next section and refer to the University Handbook entries for the programs.

[1] According to Section 4.175 of MPF1327.

MSc students are required to undertake a research project and a professional tools subject.

Note that MSc students in mathematics and statistics are usually **NOT** allowed to go on exchange unless they are prepared to extend the duration of their course.

2 Course Structure

2.1 MSc

The Master of Science in Mathematics and Statistics is one of the research training streams of the Master of Science. The research training streams give students the opportunity to undertake a substantive research project in a field of choice as well as a broad range of coursework subjects including a professional tools component, as a pathway to PhD study or to the workforce.

Students must complete a total of **200** credit points over the two year full-time (or an equivalent part-time) program, comprising:

- Discipline Subjects: 137.5 points
- Professional Tools Subject: 12.5 points
- Research Project: 50 points

It is **very important to carefully plan** one's coursework from the very beginning, ensuring that one will satisfy prerequisites for all the subjects, and that one will eventually satisfy the coursework program requirements listed in the Handbook (see the table below). Seek advice from you supervisor. If you do not have one yet — see the respective MSc course adviser (the Academic Support Officer provides all enrolled students with the list of advisers at the start of the program).

On enrolment, students must select one of the four specialisations (A)–(D) listed on p.3. They must complete **eleven** 12.5 point subjects as indicated in the table below. The list of compulsory and elective masters level subjects from different specialisations is presented after the table.

Number of Subjects	Total Points	Chosen From
Two	25	Compulsory masters level subjects from the student's selected specialisation
Three	37.5	Elective masters level subjects from the student's selected specialisation
Two	25	Any masters level subjects from a single specialisation different to the student's selected specialisation
Four	50	Any masters level subjects from any of the specialisations (including up to two approved masters level subjects from other schools, which includes up to one **approved** AMSI Summer School[2] subject; fees and enrollment rules apply to that subject, see Section 6 for more detail). Up to two of these subjects can be replaced with approved undergraduate subjects. Where it is necessary for the student to acquire the required knowledge for masters level Mathematics & Statistics discipline subjects, up to two further masters level subjects can be replaced with approved undergraduate subjects.

Masters Level Discipline Subjects. Some of the discipline subjects listed below are offered each year, but others are **offered in alternate years**. Subjects offered in odd years are labelled with (o), the ones offered in even years are labelled with (e). For semester allocation of the subjects, see the table on p. 16.

Applied Mathematics and Mathematical Physics Specialisation

Compulsory Subjects
MAST90064 Advanced Methods: Differential Equations (o)
MAST90067 Advanced Methods: Transforms (e)

Elective subjects
MAST90060 Mathematical Statistical Mechanics (o)

[2]The 2020 AMSI SS will be held from 6 January to 31 January, at LaTrobe University, https://ss.amsi.org.au/.

MAST90065 Exactly Solvable Models (o)
MAST90113 Continuum Mechanics (o)
MAST90132 Lie algebras (o)
MAST90129 Infectious Disease Dynamics (o)
MAST90026 Computational Differential Equations (e)
MAST90011 Mathematical Biology (e)
MAST90069 Introduction to String Theory (e)
MAST90103 Random Matrix Theory (e)

Discrete Mathematics and Operations Research Specialisation

Compulsory Subjects
MAST90030 Advanced Discrete Mathematics
MAST90014 Optimisation for Industry

Elective subjects
MAST90013 Network Optimisation (o)
MAST90031 Enumerative Combinatorics (o)
MAST90050 Scheduling and Optimisation (o)
MAST90053 Experimental Mathematics (e)
MAST90098 Approximation Algorithms and Heuristics (e)
MAST90137 Mathematical Game Theory (o)

Pure Mathematics Specialisation

Compulsory Subjects
MAST90012 Measure theory (o)
MAST90023 Algebraic Topology (e)

Elective subjects
MAST90017 Representation Theory (o)
MAST90056 Riemann Surfaces and Complex Analysis (o)
MAST90029 Differential Topology and Geometry (o)
MAST90133 Partial Differential Equations (o)
MAST9xxxx Lie Algebras (o)
MAST90068 Groups, Categories and Homological Algebra (e)
MAST90020 Functional Analysis (e)
MAST90136 Algebraic Number Theory (e)
MAST90097 Algebraic Geometry (e)
MAST90124 Advanced Topics in Geometry & Topology (e)

Statistics and Stochastic Processes Specialisation

Compulsory Subjects
MAST90082 Mathematical Statistics
MAST90019 Random Processes

Elective subjects
MAST90081 Advanced Probability
MAST90083 Computational Statistics and Data Science
MAST90085 Multivariate Statistical Techniques
MAST90084 Statistical Modelling
MAST90122 Inference for Spatio-temporal Processes
MAST90123 Advanced Mathematical Statistics (o)
MAST90125 Bayesian Statistical Learning
MAST90059 Stochastic Calculus with Applications (o)
MAST90027 Practice of Statistics and Data Science (e)
MAST90111 Advanced Statistical Modelling (e)
MAST90112 Advanced Topics in Stochastic Models (e)
MAST90051 Mathematics of Risk (e)

Professional Tools. MSc students must complete a professional tools subject. They must choose either MAST90045 Systems Modelling and Simulation, or COMP90072 The Art of Scientific Computation. Students who have completed one of the introductory programming subjects MAST30028, COMP10001, COMP10002, COMP20005 or INFO10001 (or equivalent) may instead select SCIE90012 Science Communication or SCIE90013 Communication for Research Scientists instead.

Research Project Component. The Research Project (50 points) is an integral part of the MSc program in Mathematics and Statistics, and a thesis is the main requirement for this component. Candidates must pass the Research Project to be awarded the Degree.

For technical reasons, students will have to enrol in one or more "Research Project subjects", to ensure they have completed a total of 50 points by the end of their course.

Full time students are advised to structure their enrolments as follows:

Semester 1: 50 points of coursework and **no research project**.
Semester 2: 37.5 points of coursework and 12.5 points of research project.
Semester 3: 37.5 points of coursework and 12.5 points of research project.
Semester 4: 25 points of coursework and 25 points of research project.

Other structures that are suitable for part time study, or for students who enroll with credit from earlier degrees, can be negotiated with the student's supervisor and the school MSc program coordinator.

Under special circumstances, with the permission of the program coordinator, students may be allowed to complete two 25 point research projects instead of a single 50 point project.

For more information about the rules for the Research Project Component, please refer to Section 8 of the present Guide (p. 10).

2.2 AGDip

The AGDip program in Mathematics and Statistics consists of **eight** coursework discipline subjects (**100** credit points). At least **four** of them must be masters level Mathematics and Statistics discipline subjects, at least three of which normally being within a common specialisation. The remaining subjects can be higher undergraduate (normally third year) level or masters level Mathematics and Statistics subjects (including MAST90045).

2.3 Some Common Comments on the Programs

The MSc and AGDip in Mathematics and Statistics are graduate coursework programs. The aims of these programs are to train students to enable them to proceed to further postgraduate study at the University of Melbourne or other institutions, and equip students with a range of skills demanded by today's employers. The programs are well regarded and recognised both in academia and the industry.

For many students, the advanced courses and project that they do after their undergraduate courses is the most exciting and valuable time in their studies. Following up their special interests enables students to develop their research and analytic skills and substantially extends the knowledge gained in earlier years. In some areas there is a possibility of applying theory to real-world problems. The MSc program in Mathematics and Statistics provides an opportunity for students to carry out a research project under the supervision of a staff member who is an expert in the area. They will also learn how to effectively present their findings in print by using document preparation programs such as LaTeX, and how to prepare and deliver a professional oral presentation. Students will have the opportunity to share the findings of their research project with other students and staff in two presentations during the program. They will have the opportunity to acquaint themselves with the Internet-based tools essential in mathematical and statistical research such as *MathSciNet* (AMS Mathematical Reviews online), to attend seminars that are designed to further extend their specialised knowledge and to inform them about research and job opportunities in Mathematics and Statistics.

MSc and AGDip students are part of the Australian mathematical and statistical community and should consider membership in professional organizations. New full-time graduate students in Australian Universities receive their first year of membership in the Australian Mathematical Society free and half-price membership to the Statistical Society of Australia.

3 Entry Requirements

For both the MSc and the AGDIP program, the *necessary* entry requirement comprises an undergraduate degree with a major in Mathematics, Statistics, or Mathematical Physics, with at least an H3 (65%) in the major, or equivalent. By "major" the University means *completion of 50 points of study at third year level*, so that the average will be calculated for the prescribed (by the University Handbook) third year subjects constituting the respective specialisation in the major.

Quotas may be applied and preference may be given to applicants with evidence of appropriate preparation or potential to undertake research. Entry to the MSc is subject to the capacity of the School to provide adequate supervision in, and resources for, a research project appropriate to the interests and preparation of the individual student and may be subject to the agreement of a member of academic staff to supervise the project module. Selection is not automatic and, in particular, is subject to competition.

4 How to Apply

Applications to the Master of Science and AGDip programs are made online: please go to

https://study.unimelb.edu.au/find/courses/graduate/master-of-science-mathematics-and-statistics/how-to-apply/
https://study.unimelb.edu.au/find/courses/graduate/graduate-diploma-in-science/how-to-apply/

Please refer to the above web site for application deadline(s). If you experience any difficulties with the online application process, please contact the Melbourne Graduate School of Science.

Letters of acceptance are usually sent by the Faculty of Science in mid-December for commencement in Semester 1.

5 CSPs and Scholarships

5.1 CSPs

The MSc programs will have Commonwealth Supported Places (CSPs) available for domestic students, although students with relatively low Weighted Average Mark may be offered an Australian Fee Place:

> A limited number of Commonwealth Supported Places (CSP) will be available to domestic students. To be considered, you will need to have achieved a Weighted Average Mark (WAM) of at least 70% in the best 50 points of appropriate discipline studies at third year level. A Commonwealth Supported Place is subsidised by the Australian Government. Students pay a contribution amount that is determined by the Australian Government, based on the subjects undertaken. You may be eligible for HECS-HELP to assist with payment of your tuition fees
>
> If you are not eligible for a Commonwealth Supported Place, you will automatically be considered for an Australian Fee (AF) place if you have achieved a WAM of at least 65% in the best 50 points of appropriate discipline studies at third year level. You may be eligible for FEE–HELP to assist with payment of your tuition fees.

For more information, visit

https://study.unimelb.edu.au/find/courses/graduate/master-of-science-mathematics-and-statistics/fees/

The AGDip program is supported by the Commonwealth. For more details, see

https://study.unimelb.edu.au/find/courses/graduate/graduate-diploma-in-science/fees/

For more detail concerning CSPs, please visit the Commonwealth Government's Department of Education Web site:

http://studyassist.gov.au/sites/StudyAssist/

For information for future International students (incl. tuition fees) please refer to:

https://study.unimelb.edu.au/how-to-apply/graduate-coursework-study/international-applications

MSc students may wish to consider undertaking some part-time tutoring in the School in the first half of their programs. For further information please see the Director of the Mathematics and Statistics Learning Centre[3] as early as possible to register your interest.

5.2 Scholarships, Studentships, Awards and Prizes

Faculty of Science

The Faculty of Science offers a range of scholarships, awards and prizes. For more information, visit:

http://science.unimelb.edu.au/students/scholarships

For the Faculty of Science awards, prizes and scholarships, visit

http://www.science.unimelb.edu.au/students/scholarships

Graduate Access Melbourne provides access to applicants whose personal circumstances have had a sustained adverse effect on their academic achievement at undergraduate level or who are members of a specified group known to be under-represented in higher education. For more information, visit:

https://study.unimelb.edu.au/how-to-apply/special-entry-access-schemes/access-melbourne-graduate

School of Mathematics and Statistics Scholarships

Our School provides scholarships for MSc (Mathematics and Statistics) students who satisfy certain criteria. After each semester of the student's study, the average mark for all the coursework subjects attempted by the student by that time in the MSc program will be calculated. Provided that the current average mark is 75 or greater, the student was studying full-time in the last completed semester and is enrolled full-time in the next one, and is not in receipt of a "National Scholarship" or any other Scholarship over $4,000 dollars in value in that year, the student will be paid a scholarship installment of $2,000 (so that the total maximum scholarship amount is $6,000 over the course of the degree).

Maurice Belz Scholarships

The School may offer up to three Maurice Belz scholarships (valued at $7,000 each) to students enrolled in our MSc program, specialising in Statistics and undertaking a research project in one of these areas: Applied Statistics, Applied Probability and Stochastic Processes, Operations Research. For more detail, please contact our Academic Support Officer (contact details are on p.13).

[3] http://www.mslc.ms.unimelb.edu.au

Prizes

The School also awards the following scholarship and prizes for which MSc students are eligible:

- *Wyselaskie Scholarship*: awarded to the best MSc student in Mathematics and Statistics.
- *Dwight's Prize*: awarded to the best MSc student in Statistics.
- *Urquhart Prize*: awarded to the student with the best overall performance in Mathematics in their MSc program.
- *Nanson/Wilson Prizes*: awarded to the best original memoir by a student within seven years of first enrolment.

6 How to Enrol in Individual Subjects

Enrolment is managed by Student Services and is to be done online whenever possible. **Always seek course advice** from your supervisor or, in the absence thereof, from the masters student adviser for your specialisation area. If in doubt, talk to the program coordinator. In case you have any difficulties with the enrolment procedure, talk to our Academic Support Officer.

(i) If the subject in question is a discipline masters level subject offered either by our School (see p.16) or by another school **and** approved for our program (i.e. it appears in the Handbook list of approved Masters level subjects from other Schools) then:

(i.a) if you meet all the prerequisites for that subject, login to Student Portal to use it to enrol online. For more detail, visit

http://students.unimelb.edu.au/admin/enrol-in-subjects

(i.b) If you **do not meet** the formal prerequisites for that subject, but you believe that you will have the prerequisite knowledge, you can still ask the subject coordinator to give you a requisite waiver. You will need to justify your request to persuade the coordinator to give you permission to enrol (send her/him a scan of your academic transcript, see her/him to talk about your background etc). If the coordinator gives you the desired permission (an email to that effect from the subject coordinator would suffice), submit it with an *Enrolment Variation Form* online to enrol.

(ii) if this is a third year Mathematics & Statistics undergraduate subject or a masters level subject which is offered by another school but not automatically approved for our program (i.e. it does not appear in the Handbook list of Masters level subjects from other Schools) then:

(ii.a) if you meet all the prerequisites for that subject, contact your supervisor to get her/his approval to enrol in that subject. Once the approval is granted, contact our MSc & AGDip Coordinator to get her/his approval to enrol. If you are allowed to enrol, submit the approval (an email from the program coordinator would suffice) with an *Enrolment Variation Form* online to enrol.

(ii.b) if you **do not meet** the formal prerequisites for that subject, but you believe that you will have the prerequisite knowledge, you can still ask the subject coordinator to give you a requisite waiver. First you will need to obtain the School approval as described in (ii.a), and then to get requisite waiver from the subject coordinator, as described in (i.b) above. Once you have got both the School approval and requisite waiver, submit them (emails are fine) with an *Enrolment Variation Form* online to enrol.

(iii) If this is an AMSI Summer School Subject, first of all you need to talk to the MSc program coordinator to find out if you will be allowed to take that subject for credit. Note that it may happen that only a few of the AMSI Summer School Subjects will be approved for credit in a given year. You are allowed to take at most one such subject for credit during your program.

To participate in an AMSI Summer School you will need to register and pay the registration fee. That can be done from the Summer School webpage[4]. Beware of the early bird registration and registration deadlines!

The School of Mathematics & Statistics can reimburse part of the registration fee provided that you are taking a subject from the Summer School for credit and formally enrol in the specially created subject MAST90079 AMSI Summer School.

If the Summer School is run outside of Melbourne, you can apply for a Travel Grant from AMSI (go to the Summer School webpage to do that). The School of Mathematics & Statistics does not cover any associated travel expenses or accommodation costs.

7 How to Find a Supervisor

You are not required to have found or confirmed a supervisor at the time when you submit your application, but you will have to have a confirmed supervisor prior to commencing the first component of the Research Project.

It is wise to think both about choosing specialisation and supervisor for your project in that specialisation well in advance though. Information about the School, in particular the research activities of various research groups, can be found on the School web site:

http://www.ms.unimelb.edu.au

Research interests of individual staff members in the School can be searched online at:

http://ms.unimelb.edu.au/study/supervisors-list

A supervisor and a second examiner will be appointed for each MSc student. To assist in this, a student must contact a potential supervisor ahead or during the first semester of the program. The program coordinator should be advised after the supervision arrangement is finalised.

The role of the supervisor is to suggest the content and aim of the project, discuss relevant sources including textbooks, papers, reports, industry materials etc., as well as the timeline for the project and the best strategy for combining the coursework and project. During the year, the supervisor should oversee the student's progress and provide advice and feedback. See also **Section 16** below.

The student is expected to provide a draft of the thesis in good time for the supervisor to read and comment on (doing that **at least two weeks** prior to the thesis submission date would be appropriate) and is responsible for submitting two final (bound hard) copies of the thesis by the deadline specified in this Guide. The supervisor and the second examiner will be responsible for marking the thesis.

AGDip students do not have supervisors. To assist them with coursework planning, the School has several advisers whose names will be communicated to newly enrolled students at induction. The advisers will also be able to assist MSc students with coursework planning and, in case the student will not be able to find a supervisor prior to the beginning of their program, with choosing a suitable supervisor as well.

8 The Research Project Component

During the first semester of their MSc program, students must finalise their choice of research project supervisor and research topic. The research project starts at the beginning of the second semester of study and should be conducted in three consecutive semesters. Typically, work on the project, including associated thesis and presentation, is conducted in 60 of the next 66 weeks. An indicative total time commitment of 800 hours for the duration of the project is expected.

Leave of absence during enrolment in a research project and outside of university holidays requires the approval of the student's supervisor.

A preliminary literature survey and research plan (of 2 pages) is due at the end of week eight of the first research project enrolment semester (**hurdle; pass/fail**).

[4] Here is the link for the 2020 AMSI Summer School: https://ss.amsi.org.au/

An intermediate report on the progress in the research project (of 2 pages) is due at the end of week eight of the second research project enrolment semester (**hurdle; pass/fail**).

A thesis (90% of assessment) is the main requirement due after the full 50 points of enrolment in the research project component. Two bound hard copies and a soft copy (a PDF file) of the research thesis are to be submitted to the General Office of the School two weeks prior to the end of the teaching period in the final semester of research project enrolment.

Students will have to give a 30 minute presentation (10% of assessment) on their research projects in the last week of that teaching period, on a date to be announced by the School of Mathematics and Statistics in the middle of the semester.

The students unable to meet the submission deadline need to apply for an extension. Applications for extension of up to two weeks should be made to the program coordinator. If an extension of more than two weeks is required, the student should apply online, see

http://students.unimelb.edu.au/admin/special-consideration.

The student may request that his/her supervisor supply a supporting letter in addition to submitting the HCAP form.

It is expected that the theses will be prepared to a professional standard using a typesetting program such as LaTeX. They are expected to be 40-60 pages in length, excluding references, appendices, figures and tables (usually, the volume is slightly bigger for applied and statistics topics and slightly less for pure ones). Samples of recent projects can be found on the Web site of the School of Mathematics and Statistics. For more information concerning research projects, see Section 16.

The project will be assessed on criteria which will take into account the research areas (pure mathematics, applied mathematics, mathematical physics, operations research, probability, applied statistics etc.) and different forms (such as predominantly survey, new research, biological or industrial application, modelling etc.) a thesis may take. These criteria will include:

- clarity of exposition;
- mathematical accuracy;
- mathematical insight displayed;
- coverage of the field and references;

and may be complemented by one or more of the following:

- description of the application and/or business context;
- mathematical modelling;
- presentation and analysis of numerical results.

The weights given to these components will take into account the nature of the project.

Student Seminars

During their candidature, MSc students **must give at least two talks**. The first one could be a progress talk on their project or on another related topic and may be given before their research group. The second one will be a 30 minute presentation (including three minutes of question time) to be given by students at a special "mini-conference" at the end of the semester when they complete the research project component of their degrees (see Section 12 for the dates). This presentation is assessed as part of the research project component, its weight being 10% (the weight of the written thesis is 90%).

MSc and AGDip students should consider themselves as part of the research strength of the School and view the School seminars as a means for broadening their knowledge. It is expected that students will attend all research seminars in the broader area of their chosen field.

9 Extensions and Special Consideration

The University policies for Extensions and Special Consideration (see Assessment and Results Policy, MPF1326) apply to coursework programs and to coursework subjects in our MSc and AGDip programs. For further details visit

https://policy.unimelb.edu.au/MPF1326
https://students.unimelb.edu.au/admin/special

10 Computer Literacy

There are many useful mathematics & statistics resources that can be found on the Web. One of the most valuable of them is the research publications database **MathSciNet** published by the American Mathematical Society. The database provides BibTEX entries with all reviews, and its abbreviations of journal titles have become a *de facto* standard in mathematical publishing.

An alternative (and bigger) major international reviewing service that covers the entire field of mathematics is **Zentralblatt MATH**, which is edited by the European Mathematical Society. Both databases can be accessed via the University Library Web site.

Modern computational hard- and software have tremendously enhanced research in the areas of applied mathematics and statistics and had a serious effect on theoretical research as well. Perhaps the most powerful and popular symbolic and/or numerical mathematics software packages available nowadays are **Maple**, **Mathematica** and **Matlab**. For all three, the School has licenses for School computers, so the students will be able to use the software on the desktop machines in the Richard Berry building. Moreover, student stand-alone licenses are available for all three, at a price below $150 each (these licenses are restricted to use by students enrolled in a course offered by a degree-granting institution or in a continuing education course). A very useful source of expertise and research-specific IT advice is **Research Bazaar**:

http://melbourne.resbaz.edu.au/

This is a training/workshops program with a strong focus on community building, run by the *Research Platform Services.* The latter is the "department within the University of Melbourne that helps researchers with the research-specific IT things they do. We offer data storage, cloud and high performance computing services and run workshops on the latest digital research skills."

Even if you will not need any symbolic/numerical computation for your own research project and/or coursework subjects, it is highly recommended for your future professional life that you learn how to work with at least one of the above packages. The same applies to **LATEX**, an excellent high level typesetting system suitable for scientific literature that we recommend students to use for their theses' preparation. Useful LATEX-related links can be found here:

http://ms.unimelb.edu.au/study/current-masters-and-pgdip-students/latex

Statistics students will in all likelihood be familiar with **R**, a freely available programming language and environment which provides a wide variety of statistical and graphical techniques and which has become a de facto standard among statisticians for developing statistical software (see http://cran.r-project.org/ for more info). Due to its rich capabilities and efficient syntax, **R** is becoming an increasingly popular programming tool in areas other than statistics.

It is important to realise that quite a few (if not all) industry (and actually academic as well) jobs of quantitative character require certain programming skills. Quite often successful candidates are expected to have experience with a number of programming languages, and very often the "wish list" includes such items as SAS, SPSS and SQL. There are a few opportunities to get such an experience (if you haven't got it yet) while you are doing your postgraduate coursework degree:

SAS (Statistical Analysis System, http://www.sas.com) is a comprehensive and powerful software system for data management and data analysis. It consists of the *Base SAS module* and a number of separate add on modules. As a student of this University, you will have free access to both SAS itself and eight *eLearning SAS courses.* For more information, please visit

http://unimelb.libguides.com/c.php?g=402784&p=2740902

SPSS (Statistical Package for the Social Sciences) is a relatively basic computer program used for statistical analysis. One possibility to learn how to work with it is to take part in an SPSS-based version of the course "Statistics for Research Workers" run by our Statistical Consulting Centre (visit http://www.scc.ms.unimelb.edu.au/statistics-courses for more information). The course is not free, unfortunately (unless it's taken for credit, which is not an option for our MSc students).

SQL (Structured Query Language) is a database computer language designed for managing data in relational database management systems. There are many free Web-based resources where one learn the basics of SQL. Elements of SQL are covered in the masters level subject SINF90001 Database Systems & Information Modelling which is offered in both semesters. However, because of the overall content of this subject, we do not recommended it for our MSc students.

11 Contact Details

- A/Prof Diarmuid Crowley, MSc & AGDip (Mathematics & Statistics) Coordinator; phone: (03) 8344 4712, email: dcrowley@unimelb.edu.au.
- Ms Kirsten Hoak, Academic Support Officer; phone: (03) 9035 8013, email: khoak@unimelb.edu.au.

12 Key Dates

Application Dates for students to commence their studies in 2020:

- Please check the Faculty Web site referred to in Section 4 above.

Applications may be accepted after these dates.

MSc/AGDip Commencement/orientation:

- Usually, it is in "Week O" (i.e. the last week before the start of lectures in the respective semester). The successful applicants will be contacted in advance by the Faculty of Science via e-mail.

MSc Thesis Submission Deadline:

- 2:00pm on Friday, two weeks prior to the end of the teaching period in the final semester of research project enrolment (in 2020, it will be on Friday 15 May in Semester 1, and on Friday 9 October in Semester 2). For those students who do not meet the submission deadline, the Examiners will take this into account at the Examiners' Meeting.

Research Project Seminars:

- In the last week of teaching in the final semester of your research project enrolment. The exact date will be announced around week eight in that semester.

13 Some Useful Web Sites

School of Mathematics and Statistics:

http://www.ms.unimelb.edu.au

School Website for prospective MSc students:

http://ms.unimelb.edu.au/study/master-of-science

School Website for prospective AGDip students:

http://ms.unimelb.edu.au/study/graduate-diploma-in-science-advanced

Melbourne Graduate School of Science:

http://graduate.science.unimelb.edu.au/

Faculty of Science MSc (Mathematics and Statistics) Website:

https://study.unimelb.edu.au/find/courses/graduate/master-of-science-mathematics-and-statistics/

Melbourne Scholarships Office:

http://www.services.unimelb.edu.au/scholarships/

University Career and Employment Website:

http://www.careers.unimelb.edu.au/

14 Discipline Subjects in 2020–21: Semester Allocation

The table below shows year/semester allocation of masters level discipline subjects in Mathematics and Statistics in 2020–21. Some subjects are taught each year, some subjects alternate. The units appearing in the 2020 half of the table will be offered in even years (i.e., in 2020, 2022 etc.), whereas the ones in the 2021 half—in odd years. The names of the compulsory subjects within the four specialisations are typeset in **bold-face**.

2020		**2021**	
Semester 1	**Semester 2**	**Semester 1**	**Semester 2**
<u>Pure Mathematics</u>			
MAST90023 **Algebraic Topology**	MAST90097 Algebraic Geometry	MAST90012 **Measure Theory**	MAST90017 Representation Theory
MAST90136 Algebraic Number Theory	MAST90068 Groups, Categories & Homological Algebra	MAST90029 Differ. Topology & Geometry	MAST90056 Riemann Surfaces & Complex Analysis
MAST90020 Functional Analysis	MAST90124 Advanced Topics in Geom. & Topol.	MAST90133 Partial Differential Equations	MAST90132 Lie Algebras
<u>Applied Mathematics & Mathematical Physics</u>			
MAST90067 **Adv. Methods: Transforms**	MAST90011 Mathematical Biology	MAST90064 **Adv. Methods: Differential Equations**	MAST90113 Continuum Mechanics
MAST90026 Computational Differ. Equations	MAST90069 Introduction to String Theory	MAST90060 Mathematical Statist. Mechanics	MAST90065 Exactly Solvable Models
MAST90103 Random Matrix Theory			MAST90132 Lie Algebras
			MAST90129 Infectious Disease Dynamics
<u>Discrete Mathematics & Operations Research</u>			
MAST90014 **Optimisation for Industry**	MAST90030 **Advanced Discrete Mathematics**	MAST90014 **Optimisation for Industry**	MAST90030 **Advanced Discrete Mathematics**
MAST90053 Experimental Mathematics	MAST90098 Approximation Algorithms & Heuristics	MAST90031 Enumerative Combinatorics	MAST90013 Network Optimisation
		MAST90137 Mathematical Game Theory	MAST90050 Scheduling and Optimisation

2020		**2021**	
Semester 1	**Semester 2**	**Semester 1**	**Semester 2**
<u>**Statistics & Stochastic Processes**</u>			
MAST90082 **Mathematical Statistics**	MAST90019 **Random Processes**	MAST90082 **Mathematical Statistics**	MAST90019 **Random Processes**
MAST90081 Advanced Probability	MAST90083 Computational Statistics & Data Science	MAST90081 Advanced Probability	MAST90083 Computational Statistics & Data Science
MAST90112 Advanced Topics in Stochastic Models	MAST90085 Multivariate Statistical Techniques	MAST90059 Stochastic Calculus with Applications	MAST90085 Multivariate Statistical Techniques
MAST90084 Statistical Modelling	MAST90111 Advanced Statistical Modelling	MAST90084 Statistical Modelling	
MAST90122 Inference for Spatio-temporal Processes	MAST 90125 Bayesian Statistical Learning	MAST90122 Inference for Spatio-temporal Processes	MAST 90125 Bayesian Statistical Learning
	MAST90051 Mathematics of Risk		MAST90123 Advanced Math. Statistics
	MAST90027 Practice of Statistics and Data Science		

15 Discipline Subjects: Brief Descriptions

Some of the subjects are offered in either odd or even years only—for such subjects, the year of offering is indicated by an (o) or (e) after the subject code. Note that the names of all the subject coordinators below are tentative. For semester allocation of the subjects, see the table on p. 16. The italicised text in the prerequisite sections describes the *"recommended background knowledge"* for the subject. You are advised that the discipline subjects' descriptions are definitively stated in the official University Handbook. In the event of a disagreement between this Guide and the Handbook, it is the Handbook that is to prevail.

Advanced Discrete Mathematics MAST90030
Coordinator: Richard Brak
The subject consists of three main topics. The bijective principle with applications to maps, permutations, lattice paths, trees and partitions. Algebraic combinatorics with applications rings, symmetric functions and tableaux. Ordered sets with applications to generating functions and the structure of combinatorial objects.
Prerequisites: MAST30021 Complex Analysis. *It is recommended that students have completed third year subjects in graph theory and/or discrete mathematics equivalent to one of the following: MAST30011 Graph Theory, MAST30012 Discrete Mathematics.*

Advanced Mathematical Statistics MAST90123 (o)
Coordinator: Aurore Delaigle
This is an advanced course that prepares students for research careers in statistics, which nowadays typically require a combination of applied, methodological and theoretical skills. By considering a variety of statistical topics in depth it introduces students to the technical skills and methods of proof needed to conduct research in modern statistics. Topics covered may include U-statistics, asymptotic distributions of statistics, inference in parametric and nonparametric models, curve estimation, Edgeworth expansions and the bootstrap and sequential methods.
Prerequisites: MAST90081 Advanced Probability and MAST90082 Mathematical Statistics.

Advanced Methods: Differential Equations MAST90064 (o)
Coordinator: James Osborne
This subject develops the mathematical methods of applied mathematics and mathematical physics with an emphasis on ordinary differential equations. Both analytical and approximate techniques are used to determine solutions of ordinary differential equations. Exact solutions by localised series expansion techniques of second-order linear ordinary differential equations and Sturm-Liouville boundary value problems are explored. Special functions are introduced here. Regular and singular perturbation expansion techniques, asymptotic series solutions, dominant balance, and WKB theory are used to determine approximate solutions of linear and nonlinear differential equations. Throughout, the theory is set in the context of examples from applied mathematics and mathematical physics such as nonlinear oscillators, boundary layers and dispersive phenomena.
Prerequisites: MAST20030 Differential Equations, or equivalent. *It is recommended that students have completed a subject in real analysis. Completion of, or concurrent enrolment in, a subject in complex analysis may also be helpful.*

Advanced Methods: Transforms MAST90067 (e)
Coordinator: Thomas Quella
This subject develops the mathematical methods of applied mathematics and mathematical physics with an emphasis on integral transform and related techniques. An introduction is given to the calculus of variations and the Euler-Lagrange equation. Advanced complex contour integration techniques are used to evaluate and invert Fourier and Laplace transforms. The general theory includes convolutions, Green's functions and generalized functions. The methods of Laplace, stationary phase, steepest descents and Watson's lemma are used to asymptotically approximate integrals. Throughout, the theory is set in the context of examples from applied mathematics and mathematical physics such as the brachistochrone problem, Fraunhofer diffraction, Dirac delta function, heat equation and diffusion.
Prerequisites: Both of the following, or equivalent: MAST20030 Differential Equations, MAST30021 Complex Analysis. *It is recommended that students have completed a subject in real analysis, and at least one of MAST30030 Applied Mathematical Modelling or MAST30031 Methods of Mathematical Physics.*

Advanced Probability MAST90081 (e)
Coordinator: Xi Geng
This subject mostly explores the key concept from Probability Theory: convergence of probability distributions, which is fundamental for Mathematical Statistics and is widely used in other applications. We study in depth the classical method of characteristic functions and discuss alternative approaches to proving limit theorems of Probability Theory.
Prerequisites: MAST30020 Probability for Inference or equivalent.

Advanced Statistical Modelling MAST90111 (e)
Coordinator: Guoqi Qian
Complex data consisting of dependent measurements collected at different times and locations are increasingly important in a wide range of disciplines, including environmental sciences, biomedical sciences, engineering and economics. This subject will introduce you to advanced statistical methods and probability models that have been developed to address complex data structures, such as functional data, geo-statistical data, lattice data, and point process data. A unifying theme of this subject will be the development of inference, classification and prediction methods able to cope with the dependencies that often arise in these data.
Prerequisites: MAST30025 Linear Statistical Models and MAST90082 Mathematical Statistics. *It is recommended that students have completed MAST90085 Multivariate Statistical Techniques, MAST90083 Computational Statistics & Data Science, or MAST90084 Statistical Modelling.*

Advanced Topics in Geometry & Topology MAST90124 (e)
Coordinator: David Gepner
This subject will discuss a selected topic in the areas of geometry and topology.
Prerequisites: One of MAST90023 Algebraic Topology, MAST90029 Differential Topology and Geometry, or MAST90056 Riemann Surfaces and Complex Analysis.

Advanced Topics in Stochastic Models MAST90112 (e)
Coordinator: Nathan Ross
This subject develops the advanced topics and methods of stochastic processes and discusses possible applications of the models covered in the course. It serves to prepare students for research in Probability Theory.
Prerequisites: MAST30020 Probability for Inference.

Algebraic Geometry MAST90097 (e)
Coordinator: Christian Haesemeyer
This course is an introduction to algebraic geometry. Algebraic geometry is the study of zero sets of polynomials. It exploits the interplay between rings of functions and the underlying geometric objects on hwich they are defined. It is a fundamental tool in may areas of mathematics, including number theory, physics and differential geometry. The syllabus includes affine and projective varieties, coordinate ring of functions, the Nullstellensatz, Zariski topology, regular morphisms, dimension, smoothness and singularities, sheaves, schemes.
Prerequisites: MAST30005 Algebra.

Algebraic Number Theory MAST90136 (e)
Coordinator: Chenyan Wu
This course is an introduction to algebraic number theory. Algebraic number theory studies the structure of the integers and algebraic numbers, combining methods from commutative algebra, complex analysis, and Galois theory. This subject covers the basic theory of number fields, rings of integers and Dedekind domains, zeta functions, decomposition of primes in number fields and ramification, the ideal class group, and local fields. Additional topics may include Dirichlet L-functions and DirichletâĂŹs theorem; quadratic forms and the theorem of Hasse-Minkowski; local and global class field theory; adeles; and other topics of interest.
Prerequisites: MAST30005 Algebra.

<u>Algebraic Topology</u> MAST90023 (e)
Coordinator: Diarmuid Crowley
This subject studies topological spaces and maps between them. It shows how topology can be applied to many areas, including geometry, analysis, group theory and physics. The aim is to reduce questions in topology to problems in algebra by introducing algebraic invariants associated to spaces and maps. Important classes of spaces studied are manifolds (locally Euclidean spaces) and CW complexes, built by gluing together cells of various dimensions. Topics include: homotopy of maps and homotopy equivalence of spaces, homotopy groups of spaces, the fundamental group, covering spaces; homology theory, including singular homology theory, the axiomatic approach of Eilenberg and Steenrod, and cellular homology.
Prerequisites: Both of the following, or equivalent: MAST30005 Algebra, MAST30026 Metric and Hilbert Spaces.

<u>Approximation Algorithms and Heuristics</u> MAST90098 (e)
Coordinator: Charl Ras
Many discrete optimisation problems encountered in practice are too difficult to solve exactly in a reasonable time frame. Approximation algorithms and heuristics are the most widely used approaches for obtaining reasonably accurate solutions to such hard problems. This subject introduces the basic concepts and techniques underlying these ”inexact” approaches. We will address the following fundamental questions in the subject: How difficult is the problem under consideration? How closely can an optimal solution be approximated? And how can we go about finding near-optimal solutions in an efficient way? We will discuss methodologies for analysing the complexity and approximability of some important optimisation problems, including the travelling salesman problem, knapsack problem, bin packing, scheduling, network design, covering problems and facility location. We will also learn about various metaheuristics (simulated annealing, Tabu search, GRASP, genetic algorithms) and matheuristics (relax-and-fix, fix-and-optimise, local branching) that are widely used in solving real-world optimisation problems.
Prerequisites: MAST30013 Techniques in Operations Research.

<u>Bayesian Statistical Learning</u> MAST90125
Coordinator: John Holmes
Bayesian inference treats all unknowns as random variables, and the core task is to update the probability distribution for each unknown as new data is observed. After introducing Bayes? Theorem to transform prior probabilities into posterior probabilities, the first part of this subject introduces theory and methodological aspects underlying Bayesian statistical learning including credible regions, comparisons of means and proportions, multi-model inference and model selection. The second part of the subject focuses on advanced supervised and unsupervised Bayesian machine learning methods in the context of Gaussian processes and Dirichlet processes. The subject will also cover practical implementations of Bayesian methods through Markov Chain Monte Carlo computing and real data applications.
Prerequisites: MAST20005 Statistics, and one of MAST30001 Stochastic Modelling, MAST30025 Linear Statistical models, MAST30027 Modern Applied Statistics, MAST30020 Probability for Inference.

<u>Computational Differential Equations</u> MAST90026 (e)
Coordinator: Hailong Guo
Many processes in the natural sciences, engineering and finance are described mathematically using ordinary or partial differential equations. Only the simplest or those with special structure can be solved exactly. This subject discusses common techniques to computing numerical solutions to differential equations and introduces the major themes of accuracy, stability and efficiency. Understanding these basic properties of scientific computing algorithms should prevent the unwary from using software packages inappropriately or uncritically, and provide a foundation for devising methods for nonstandard problems. We cover both time-independent problems, in one and higher space dimensions, and evolution equations of hyperbolic or parabolic type.
Prerequisites: Students should be able to program in one of: C, Matlab, Mathematica, Perl, Fortran, Python etc. *Students are required to write programs in MATLAB so previous experience in writing and debugging procedural computer programs is expected. It is recommended that students have completed a subject in differential equations.*

Computational Statistics & Data Science MAST90083
Coordinator: TBA
Computing techniques and data mining methods are indispensable in modern statistical research and applications, where "Big Data" problems are often involved. This subject will introduce a number of recently developed statistical data mining methods that are scalable to large datasets and high-performance computing. These include regularized regression such as the Lasso; tree based methods such as bagging, boosting and random forests; and support vector machines. Important statistical computing algorithms and techniques used in data mining will be explained in detail. These include the bootstrap, cross-validation, the EM algorithm, and Markov chain Monte Carlo methods including the Gibbs sampler and Metropolis–Hastings algorithm.
Prerequisites: MAST30027 Modern Applied Statistics or MAST30025 Linear Statistical Models.

Continuum Mechanics MAST90113 (o)
Coordinator: Doug Brumley
This subject develops mathematical methods for the study of the mechanics of fluids and solids and illustrates their use in several contexts. Topics covered include Newtonian fluids at low and at high Reynolds number and the linear theory of elasticity. Applications may be drawn from biological, earth sciences, engineering or physical contexts.
Prerequisites: MAST30030 Applied Mathematical Modelling (or equivalent).

Differential Topology and Geometry MAST90029 (o)
Coordinator: Craig Hodgson
This subject extends the methods of calculus and linear algebra to study the geometry and topology of higher dimensional spaces. The ideas introduced are of great importance throughout mathematics, physics and engineering. This subject will cover basic material on the differential topology of manifolds including integration on manifolds, and give an introduction to Riemannian geometry. Topics include: Differential Topology: smooth manifolds, tangent spaces, inverse and implicit function theorems, differential forms, bundles, transversality, integration on manifolds, de Rham cohomology; Riemanian Geometry: connections, geodesics, and curvature of Riemannian metrics; examples coming from Lie groups, hyperbolic geometry, and other homogeneous spaces.
Pre-requisites: Both of the following, or equivalent: MAST20009 Vector Calculus, MAST30026 Metric and Hilbert Spaces.

Enumerative Combinatorics MAST90031 (o)
Coordinators: Michael Wheeler
The subject is about the use of generating functions for enumeration of combinatorial structures, including partitions of numbers, partitions of sets, permutations with restricted cycle structure, connected graphs, and other types of graph. The subject covers the solution of recurrence relations, methods of asymptotic enumeration, and some applications in statistical mechanics. The methods covered have widespread applicability, including in areas of pure and applied mathematics and computer science.
Prerequisites: MAST30021 Complex Analysis, or equivalent. *Use of mathematical symbolic computation packages such as Mathematica and Maple is encouraged.*

Exactly Solvable Models MAST90065 (o)
Coordinators: Paul Zinn-Justin
In mathematical physics, a wealth of information comes from the exact, non-perturbative, solution of quantum models in one-dimension and classical models in two-dimensions. This subject is an introduction into Yang-Baxter and Bethe Ansatz integrability, and the orthogonal polynomial method of random matrix theory. Transfer matrices, Yang-Baxter equation and Bethe ansatz are developed in the context of the 6-vertex model, quantum spin chains and other examples. As a solvable model, random matrix theory aims to first identify the explicit eigenvalue distributions for a given matrix distribution. The method of orthogonal polynomials is then used to compute eigenvalue correlation functions that can be compared against (numerical) experiments.
Prerequisites: MAST30021 Complex Analysis, or equivalent. *It is recommended that students have completed MAST10007 Linear Algebra, or equivalent. No prior knowledge of physics is assumed.*

Experimental Mathematics MAST90053 (e)
Coordinator: Alex Ghitza
Modern computers have developed far beyond being great devices for numerical simulations or tedious but straightforward algebra; and in 1990 the first mathematical research paper was published whose sole author was a thinking machine known as Shalosh B Ekhad. This course will discuss some of the great advances made in using computers to purely algorithmically discover (and prove) nontrivial mathematical theorems in, for example, Number Theory and Algebraic Combinatorics. Topics include: Automated hypergeometric summation, Groebner basis, Chaos theory, Number guessing, Recurrence relations and BBP formulas.
Prerequisites: One of the following, or equivalent: MAST30028 Numerical Methods and Scientific Computing; MAST30005 Algebra; MAST30012 Discrete Mathematics. *It is recommended that students have completed MAST30028 Numerical Methods and Scientific Computing or a similar subject.*

Functional Analysis MAST90020 (e)
Coordinator: Jesse Gell-Redman
Functional analysis is a fundamental area of pure mathematics, with countless applications to the theory of differential equations, engineering, and physics. The students will be exposed to the theory of Banach spaces, the concept of dual spaces, the weak-star topology, the Hahn-Banach theorem, the axiom of choice and Zorn's lemma, Krein-Milman, operators on Hilbert space, the Peter-Weyl theorem for compact topological groups, the spectral theorem for infinite dimensional normal operators, and connections with harmonic analysis.
Prerequisites: Both of the following, or equivalent: MAST20022 Group Theory and Linear Algebra; MAST30026 Metric and Hilbert Spaces.

Groups, Categories and Homological Algebra MAST90068 (e)
Coordinator: Marcy Robertson
As well as being beautiful in its own right, algebra is used in many areas of mathematics, computer science and physics. This subject provides a grounding in several fundamental areas of modern advanced algebra including Lie groups, combinatorial group theory, category theory and homological algebra. The material complements that covered in the subject Commutative and Mutlilinear Algebra without assuming it as prerequisite.
Prerequisites: MAST30005 Algebra, or equivalent.

Infectious Disease Dynamics MAST90129 (o)
Coordinator: James McCaw
This subject introduces the fundamental mathematical models used to study infectious diseases at both the epidemiological and within-host scale. The emphasis is on: 1) how models are developed, from conceptualisation through to implementation in software; and 2) how to apply models to questions of epidemiological, public health and biological importance. Statistical techniques for the model-based analysis of relevant data resources will be introduced. Epidemiology: epidemic/endemic behaviour and intervention strategies to reduce transmission, the SIR model, including demography, threshold behaviour, phase-plane analysis;
Viral dynamics: host-pathogen interactions, the mediating influences of immunomodulatory agents and antimicrobials, the TIV model, including the immune response, pharmacokinetic-pharmacodynamic models;
Model sensitivity and uncertainty analysis, scenario analysis, parameter estimation, model comparison.
Prerequisites: One of MAST30032, MAST30028, COMP10001, COMP90059; and one of MAST30030, MAST20030, MAST20029, PHYC20014 .

Inference for Spatio-temporal Processes MAST90122
Coordinator: Tingjin Chu
Modern data collection technologies are creating unprecedented challenges in statistics and data science related to the analysis and interpretation of massive data sets where observations exhibit patterns through time and space. This subject introduces probability models and advanced statistical inference methods for the analysis of temporal and spatio-temporal data. The subject balances rigorous theoretical development of the methods and their properties with real-data applications.

Topics include inference methods for univariate and multivariate time series models, spatial models, lattice models, and inference methods for spatio-temporal processes. The subject will also address aspects related to computational and statistical trade-offs, and the use of statistical software.
Prerequisites: MAST90082 Mathematical Statistics.

Introduction to String Theory MAST90069 (e)
Coordinator: Johanna Knapp
The first half of this subject is an introduction to two-dimensional conformal field theory with emphasis on the operator formalism and explicit calculations. The second half is an introduction to string theory based on the first half. For concreteness, the representation theory of Virasoro algebra and bosonic strings will be emphasized.
Prerequisites: Both of the following, or equivalent: MAST30021 Complex Analysis; MAST20009 Vector Calculus. *No prior knowledge of physics is assumed.*

Lie Algebras MAST90132 (o)
Coordinator: David Ridout
The theory of Lie algebras is fundamental to the study of groups of continuous symmetries acting on vector spaces, with applications to diverse areas including geometry, number theory and the theory of differential equations. Moreover, since quantum mechanical systems are described by Hilbert spaces acted on by continuous symmetries, Lie algebras and their representations are also fundamental to modern mathematical physics. This subject develops the basic theory in a way accessible to both pure mathematics and mathematical physics students, with an emphasis on examples. The main theorems are: the classification of complex semi-simple Lie algebras in terms of Cartan matrices and Dynkin diagrams, and the classification of finite-dimensional representations of these algebras in terms of highest weight theory.
Prerequisites: MAST30021 Complex Analysis

Mathematical Biology MAST90011 (e)
Coordinator: James McCaw
Modern techniques have revolutionised biology and medicine, but interpretative and predictive tools are needed. Mathematical modelling is such a tool, providing explanations for counter-intuitive results and predictions leading to new experimental directions. The broad flavour of the area and the modelling process will be discussed. Applications will be drawn from many areas including population growth, epidemic modelling, biological invasion, pattern formation, tumour modelling, developmental biology and tissue engineering. A large range of mathematical techniques will be discussed, for example discrete time models, ordinary differential equations, partial differential equations, stochastic models and cellular automata.
Prerequisites: MAST20030 Differential Equations, or equivalent.

Mathematical Game Theory MAST90137 (o)
Coordinator: Mark Fackrell
This subject provides a rigorous mathematical treatment of game theory, and will include applications selected from queueing theory, biology, population dynamics, resource allocation, auction theory, political science, and military applications.
Prerequisites: MAST30022 Decision Making, or equivalent.

Mathematical Statistical Mechanics MAST90060 (o)
Coordinator: Thomas Quella
The goal of statistical mechanics is to describe the behaviour of bulk matter starting from a physical description of the interactions between its microscopic constituents. This subject introduces the Gibbs probability distributions of classical statistical mechanics, the relations to thermodynamics and the modern theory of phase transitions and critical phenomena. The central concepts of critical exponents, universality and scaling are emphasized throughout. Applications include the ideal gases, magnets, fluids, one-dimensional Ising and Potts lattice spin models, random walks and percolation as well as approximate methods of solution.
Prerequisites: MAST20009 Vector Calculus, or equivalent. *It is recommended that students have completed MAST20026 Real Analysis, or equivalent.*

Mathematical Statistics MAST90082
Coordinator: Liuhua Peng
The theory of statistical inference is important for applied statistics and as a discipline in its own right. After reviewing random samples and related probability techniques including inequalities and convergence concepts the theory of statistical inference is developed. The principles of data reduction are discussed and related to model development. Methods of finding estimators are given, with an emphasis on multiparameter models, along with the theory of hypothesis testing and interval estimation. Both finite and large sample properties of estimators are considered. Applications may include robust and distribution free methods, quasi-likelihood and generalized estimating equations. It is expected that students completing this course will have the tools to be able to develop inference procedures in novel settings.
Prerequisites: MAST20005 Statistics and any third-year subject in statistics or stochastic processes. *It is recommended that students have completed MAST30020 Probability for Inference, MAST30025 Linear Statistical Models and MAST30027 Modern Applied Statistics.*

Mathematics of Risk MAST90051 (e)
Coordinator: Kostya Borovkov
Mathematical modelling of various types of risk has become an important component of the modern financial industry. The subject discusses the key aspects of the mathematics of market risk. Main concepts include loss distributions, risk and dependence measures, copulas, risk aggregation and allocation principles elements of extreme value theory. The main theme is the need to satisfactorily address extreme outcomes and the dependence of key risk drivers.
Prerequisites: MAST20026 Real Analysis and one of the following subjects: MAST20004 Probability, MAST20006 Probability for Statistics, or equivalent.

Measure Theory MAST90012 (o)
Coordinator: Volker Schlue
Measure Theory formalises and generalises the notion of integration. It is fundamental to many areas of mathematics and probability and has applications in other fields such as physics and economics. Students will be introduced to Lebesgue measure and integration, signed measures, the Hahn-Jordan decomposition, the Radon-Nikodym derivative, conditional expectation, Borel sets and standard Borel spaces, product measures, and the Riesz representation theorem.
Prerequisites: Both of the following subjects, or equivalent: MAST20022 Group Theory and Linear Algebra, MAST30026 Metric and Hilbert Spaces.

Multivariate Statistical Techniques MAST90085
Coordinator: Dennis Leung
Multivariate statistics concerns the analysis of collections of random variables that has general applications across the sciences and more recently in bioinformatics. It overlaps machine learning and data mining, and leads into functional data analysis. Here random vectors and matrices are introduced along with common multivariate distributions. Multivariate techniques for clustering, classification and data reduction are given. These include discriminant analysis and principal components. Classical multivariate regression and analysis of variance methods are considered. These approaches are then extended to high dimensional data, such as that commonly encountered in bioinformatics, motivating the development of multiple hypothesis testing techniques. Finally, functional data is introduced.
Prerequisites: MAST30025 Linear Statistical Models and MAST90082 Mathematical Statistics.

Network Optimisation MAST90013 (o)
Coordinator: Sanming Zhou
Many practical problems in management, operations research, telecommunication and computer networking can be modelled as optimisation problems on networks. Here the underlying structure is a graph. This subject is an introduction to optimisation problems on networks with a focus on theoretical results and efficient algorithms. It covers classical problems that can be solved in polynomial time, such as shortest paths, maximum matchings, maximum flows, and minimum cost flows. Other topics include complexity and NP-completeness, matroids and greedy algorithms, approximation algorithms, multicommodity flows, and network design. This course is beneficial for all students of discrete mathematics, operations research, and computer science.

Prerequisites: MAST30011 Graph Theory, or equivalent. *An introductory-level subject in operations research equivalent to MAST20018 Discrete Maths and Operations Research is recommended.*

<u>**Optimisation for Industry**</u> MAST90014
Coordinator: Alysson Costa
The use of mathematical optimisation is widespread in business, where it is a key analytical tool for managing and planning business operations. It is also required in many industrial processes and is useful to government and community organizations. This subject will expose students to operations research techniques as used in industry. A heavy emphasis will be placed on the modelling process that turns an industrial problem into a mathematical formulation. The focus will then be on how to solve the resulting mathematical problem. Mathematical programming and (meta)-heuristic techniques will be reviewed and applied to selected problems.
Prerequisites: MAST10007 Linear Algebra or MAST10008 Accelerated Mathematics 1, or equivalent. *It is recommended that students have completed a third year subject in linear and non-linear programming equivalent to MAST30013 Techniques in Operations Research or MAST30022 Decision Making.*

<u>**Partial Differential Equations**</u> MAST90133 (o)
Coordinator: Jesse Gell-Redman
This subject offers a wide ranging introduction to the modern theory of partial differential equations in pure mathematics. A starting point is the discussion of the classical equations (Laplace's equation, the heat equation, and the wave equation) which will lead us to the broader theory of elliptic, parabolic, and hyperbolic equations. The course covers mostly linear equations, but exposes the student also to some of the most interesting non-linear equations arising in physics and geometry. Further topics may include: Calculus of variations, Hamilton-Jacobi equations, Systems of Conservation laws; Non-linear elliptic equations, Schauder theory; Quasi-linear hyperbolic equations, propagation of singularities, blow up phenomena.
Prerequisites: Both of the following subjects, or equivalent: MAST20030 Differential Equations, MAST30021 Complex Analysis.

<u>**Random Matrix Theory**</u> MAST90103 (e)
Coordinator: Mario Kieburg
Random matrix theory is a diverse topic in mathematics. It draws together ideas from linear algebra, multivariate calculus, analysis, probability theory and mathematical physics, amongst other topics. It also enjoys a wide number of applications, ranging from wireless communication in engineering, to quantum chaos in physics, to the Reimann zeta function zeros in pure mathematics. A self contained development of random matrix theory will be undertaken in this course from a mathematical physics viewpoint. Topics to be covered include Jacobians for matrix transformation, matrix ensembles and their eigenvalue probability density functions, equilibrium measures, global and local statistical quantities, determinantal point processes, products of random matrices and Dyson Brownian motion.
Prerequisites: MAST30021 Complex Analysis. *It is recommended that students have completed MAST30031 Methods of Mathematical Physics and MAST20004 Probability.*

<u>**Random Processes**</u> MAST90019
Coordinator: Aihua Xia
The subject covers the key aspects of the theory of stochastic processes that plays the central role in modern probability and has numerous applications in natural sciences and in industry. It begins with a discussion of ways to construct and specify random processes, then proceeds to distributional convergence of processes, covers the functional central limit theorem and its counterpart for empirical processes, and finally discusses Levy processes and more general continuous time Markov processes. Applications to modelling random phenomena evolving in time are discussed throughout the course.
Prerequisites: Both of the following subjects, or equivalent. MAST30001 Stochastic Modelling, MAST30020 Probability for Inference.

Representation Theory MAST90017 (o)
Coordinator: Ting Xue
Symmetries arise in mathematics as groups and Representation Theory is the study of groups via their actions on vector spaces. It has important applications in many fields: physics, chemistry, economics, biology and others. This subject will provide the basic tools for studying actions on vector spaces. The course will focus on teaching the basics of representation theory through some favourite examples: symmetric groups, diagram algebras, matrix groups, reflection groups. In each case the irreducible characters and irreducible modules for the group (or algebra) will be analysed, developing more and more powerful tools as the course proceeds. Examples that will form the core of the material for the course include SL2, cyclic and dihedral groups, diagram algebras: Temperley-Lieb, symmetric group and Hecke algebras, Brauer and BMW algebras, compact Lie groups. Among the tools and motivation that will play a role in the study are characters and character formulas, Induction, restriction and tensor products, and connections to statistical mechanics, mathematical physics and geometry. If time permits, there may be some treatment of loop groups, affine Lie algebras and Dynkin diagrams.
Prerequisites: MAST30005 Algebra, or equivalent.

Riemann Surfaces and Complex Analysis MAST90056 (o)
Coordinator: Marcy Robertson
Riemann surfaces arise from complex analysis. They are central in mathematics, appearing in seemingly diverse areas such as differential and algebraic geometry, number theory, integrable systems, statistical mechanics and string theory.
The first part of the course studies complex analysis. It assumes students have completed a first course in complex analysis so begins with a quick review of analytic functions and Cauchy's theorem, emphasising topological aspects such as the argument principle and Rouche's theorem. Topics also include: Schwarz's lemma; limits of analytic functions, normal families, Riemann mapping theorem; multiple-valued functions, differential equations and Riemann surfaces. The second part of the course studies Riemann surfaces and natural objects on them such as holomorphic differentials and quadratic differentials. Topics may also include: divisors, Riemann-Roch theorem; the moduli space of Riemann surfaces, Teichmüller space; integrable systems.
Prerequisites: MAST30021 Complex Analysis, or equivalent.

Scheduling and Optimisation MAST90050 (o)
Coordinator: Joyce Zhang
Scheduling is critical to manufacturing, mining, and logistics, and is of increasing importance in healthcare and service industries. Most automated systems, ranging from elevators to industrial robots, embed some kind of scheduling algorithms. Building on the Optimisation background provided in Optimisation for Industry, this subject teaches students how to solve more advanced problems. A particular focus will be scheduling problems, but other more general assignment problems will be discussed.
Prerequisites: MAST90014 Optimisation for Industry.

Statistical Modelling MAST90084 (e)
Coordinator: Dennis Leung
Statistical models are central to applications of statistics and their development motivates new statistical theories and methodologies. Commencing with a review of linear and generalized linear models, analysis of variance and experimental design, the theory of linear mixed models is developed and model selection techniques are introduced. Approaches to non and semiparametric inference, including generalized additive models, are considered. Specific applications may include longitudinal data, survival analysis and time series modelling.
Prerequisites: MAST30025 Linear Statistical Models and MAST90082 Mathematical Statistics.

Stochastic Calculus with Applications MAST90059 (o)
Coordinator: Nathan Ross
This subject provides an introduction to stochastic calculus and mathematics of financial derivatives. Stochastic calculus is essentially a theory of integration of a stochastic process with respect to another stochastic process, created for situations where conventional integration will not be

possible. Apart from being an interesting and deep mathematical theory, stochastic calculus has been used with great success in numerous application areas, from engineering and control theory to mathematical biology, theory of cognition and financial mathematics.
Prerequisites: Both of the following subjects, or equivalent: MAST30001 Stochastic Modelling; MAST30020 Probability for Inference.

Practice of Statistics and Data Science MAST90027 (e)
Coordinator: Ian Gordon
This subject builds on methods and techniques learned in theoretical subjects by studying the application of statistics in real contexts. Emphasis is on the skills needed for a practising statistician, including the development of mature statistical thinking, organizing the structure of a statistical problem, the contribution to the design of research from a statistical point of view, measurement issues and data processing. The subject deals with thinking about data in a broad context, and skills required in statistical consulting.
Prerequisites: Either of the following, or equivalent: MAST30025 Linear Statistical Models; MAST30027 Modern Applied Statistics.

16 Research Project: Thesis & Oral Presentation

16.1 Your Supervisor

It is expected that MSc students choose a supervisor and a topic of their research project by the end of the first semester of their program at the latest. The School formally appoints a supervisor and a second examiner to each MSc student, and any changes in supervision arrangements must be reported to the Academic Support Officer in the General Office within a week.

Most students see their supervisor about once a week, although this may vary and is negotiable between the student and the supervisor. Even if the student has not made substantial progress between visits, it is still a good idea to have regular meetings as that makes it possible for the supervisor to keep track of how the student is going.

Supervisor's role includes:

- giving a general course advice, including assistance with coursework subjects selection and approval thereof;
- helping the student with topic selection and/or modification;
- directing the student to useful references on the project topic and
- explaining difficult points;
- providing students with feedback on the direction and progress of their research;
- reading and commenting on thesis drafts (provided they are submitted in good time for doing so; giving your supervisor a couple of weeks for reading your first draft is reasonable; the sooner your supervisor will see your work, the better);
- giving students general advice on talk preparation.

The second examiner acts as an advisor to the student when the principal supervisor is absent from the School.

16.2 Your Thesis: General Advice

Although an MSc thesis in mathematics & statistics is not necessarily an original contribution to mathematical/statistical research, students are encouraged to make efforts towards making independent advances whenever possible. In any case, the originality of presentation is certainly expected. MSc students should be enrolled in the research project component for three consecutive semesters, and it is expected that during such a long time period they will be able to produce well-written theses on well-researched topics of their projects. The students should study several sources (which are usually research papers and/or monographs) of the subject until it is thoroughly assimilated. Theses that are drawn from a single source are not acceptable.

The acquired knowledge and understanding of the area will make the basis for writing the thesis. In a good MSc research project, student's own well-written presentation of the subject is complemented by some independent advances in the direction of the study. Such original contributions are certainly more than welcome, but a student is ill-advised to start work on an MSc thesis determined to solve some outstanding classical problem. Progress in research is usually made by acquiring a good grasp of existing knowledge and answering successive small questions. If you do discover something new, be sure to consult with your supervisor or some other staff member about it. They may be able to help you go further or save you from the embarrassment of a serious mistake.

Mathematical sciences form a very diverse research area, and so MSc research projects can differ in their nature quite a lot. Some are essentially surveys of a particular area of mathematics, others may include numerical investigations of particular problems, some may fill in gaps in published papers. Accordingly, projects are assessed on criteria which take into account the research areas and different forms a thesis may take. The general assessment criteria are listed in Section 8, the weights given to them will take into account the nature of the project. Note that in the final mark for the research project component, the written thesis has a weight of 90%, while the mark for the final oral presentation of the project contributes the remaining 10%.

MSc theses are expected to be 40–60 pages in length, excluding references, appendices, figures and tables (the format of the theses is discussed below, in Section 16.3). Please note that theses exceeding 60 typewritten pages put a considerable strain on the staff and rarely get as much attention as they may deserve. Theses are not judged by their volume, but rather by their content.

The thesis must be printed on A4 size (297 × 210 mm) paper. The typing should be 1–1.5 spaced and presented in a clear and legible 12pt font and would normally be expected to be double-sided. All the margins should be 30 mm, and page numbers should appear inside the margins. Pages should be numbered consecutively and clearly. Two bound copies should be submitted to the General Office (see Section 12 for deadlines). The School has several plastic comb binding machines that you can use. Please ask the Academic Support Officer for assistance. You will also have to submit a soft copy of the thesis (in the form of a PDF file).

A thesis must be preceded by a title page. The title page of the thesis should show:

- the name of the school and university in which the research was carried out;
- the title of the thesis;
- the full name of the author (as it appears on the enrolment record);
- the degree for which the thesis is being submitted;
- month and year.

The use of the University logo in the thesis is not permitted.

Before producing final copies of a thesis for submission, the student should ensure that all the spelling, grammar, punctuation and choice of language are of an appropriate standard and the bibliography is complete and exact.

It is necessary to plan your work on the research project component so that you will be able to submit it by the due date (see Section 12). If your progress has been significantly affected by circumstances outside your control, you can follow the standard procedures to apply for extension for the research project submission. Extension for up to two weeks can be granted by our MSc program coordinator, whereas to be granted extensions for longer time periods students should apply for Special Consideration via the Student Portal, see Section 9 for references.

16.3 Your Thesis: How to Write It

Your thesis is an overview of what you have been doing while working on your Research Project. Write it as if you were trying to explain the research topic to a fellow student.

The thesis should be a coherent, self-contained piece of work. Your writing should conform to a high standard of the English language. Aim at clarity, precision and correct grammar. Start sentences with capital letters and end them with full-stops. Never ever start a sentence with a symbol/formula! Think hard about notation prior to writing up the thesis: it will save you a lot of time, and help the reader to understand what you were trying to say. Including a list of notation (either at the beginning or at the end of the thesis) is a good idea.

Your thesis should start with an introduction that explains what the project is about, and what its contents are. Wise people always leave writing this part to the end, when you will already know what to explain in the introduction. Sometimes, including a conclusion or summary can be appropriate. The introduction is usually followed by a literature review, presenting the key results concerning the topic of your thesis that have already been published. What follows after that, will depend on the nature of your project.

Be careful not to plagiarise: it is expected that the thesis will be written in your own words, and for any fact, idea, result that appear in your thesis, the reader should be able to figure out if it is your own, and if it is not then where you got it from. This means that good bibliographic referencing is a must: wherever some material has an external source, this should be clear to the reader. On the other hand, the list of references in your thesis should contain no items that are not referred to in the text.

A nice *Guide to Writing MSc Dissertations* by Bernhard von Stengel (Dept. of Mathematics, London School of Economics) can be found at

http://www.maths.lse.ac.uk/Personal/stengel/TEXTE/diss-how-final.pdf

It contains a lot of useful recommendations, including how to write mathematics and helpful LaTeX hints. In particular, you can use the format for bibliographic entries that is used in that paper.

Anther very useful (and interesting) resource is *Mathematical Writing* by Donald E. Knuth, Tracy Larrabee and Paul M. Roberts that can be found at http://tex.loria.fr/typographie/mathwriting.pdf

(in particular, their § 1 is an excellent "Minicourse on technical writing").

Yet one more instructive essay on the topic is *How to Write Mathematics* by Paul R. Halmos. It was published in *L'Enseignement Math.* 16 (1970), pp.123–152, and can be accessed at

http://www.math.washington.edu/ lind/Resources/Halmos.pdf

Finally, for the *Ten Simple Rules For Mathematical Writing* by Dimitri Bertsekas (M.I.T.), see

http://mit.edu/dimitrib/www/Ten_Rules.pdf

16.4 Your Final Presentation

In the last week of the last semester of your enrollment in the Research Project Component, you will have to give an oral talk at a student "mini-conference" organised by the School. The exact date of the event will be announced at the beginning of the semester.

About two weeks prior to the mini-conference, you will be asked to submit the title and abstract of your talk (and possibly some further necessary information). The title should be the same as the thesis title, the abstract should not exceed 150 words. The standard policy of international conferences and research journals in the area of mathematics & statistics is that the formulae usage in one's abstract should be reduced to the absolute minimum, and the School asks you to comply with that policy as well. If you cannot avoid using formulae in your abstract, please use LaTeX commands for them in the body of your email (no attachments, no PDF files etc please).

Each talk will be assigned a 30 minute time slot, of which the last three minutes are for the question time. Please note that the final presentation is worth 10% of the Research Project mark. Criteria to be used to assess the presentation will include:

- clarity of the presentation (both verbal and slides/figures, if any);
- knowledge displayed;
- description of the main goal of the research project;
- description of results and achievements;
- keeping on time;
- responses to questions.

As with the thesis, your talk must be aimed at our masters level students and should be self-contained. Note that it is easy to overestimate what the audience understands, and if you (and/or your supervisor) understand from the first glance what is written on your presentation slides, it does not necessarily mean that the audience will — if you have already been at research seminars, you would know that this is not necessarily the case.

The general advice is to start the talk with a low-tech introduction, to make sure that everybody understands what your project is about. One usually pitches the talk at a higher level later on, but try to avoid situations where there is only one person in the room who understands what the speaker is talking about. It would be great if everybody in the audience could take something home from your talk.

Try to speak facing the audience and avoid spending too much time looking at the screen behind or in front of you and reading from it. If appropriate, you may wish to liven up your presentation drawing by hand a couple of pictures illustrating the talk on the white- or blackboard.

In all likelihood, you will prepare computer slides for your presentation (there exists several LaTeX document classes that you can use for that purpose). It is very important to avoid over-crowding slides. The general recommendation is to have at most 10–12 lines of text/formulae on a slide, using a reasonably large font. Of course, one can pack much more material into one slide, but that would make it heavy and indigestible. To see if you are doing alright, project your slide(s) on the screen in the venue where you will be giving the presentation and check if a human with average eye sight will be able to read the text from the last row of seats in the room.

It certainly makes sense to discuss with your supervisor what parts of the project to cover in the talk. Moreover, some students give practice talks to their supervisors and fellow students a few days prior to the mini-conference. Also, go to the talks by other completing students — over 2+

years of your studies in the MSc program, there will be several occasions for you to do that — and make sure you will not repeat their mistakes (if any).

As a rule, a few questions are asked at the end of each talk. They are usually asked because the questioner wants to know the answer, not because somebody wants to catch you out. Don't panic if you don't know the answer, just say frankly that you don't know it (it may happen that nobody knows). Thanking for an instructive question/comment is always a good idea.

And don't be too nervous, everybody understands that's your first important talk.

Good luck!!