EPSRC

Engineering and Physical Sciences Research Council

InFoMM

Industrially Focused Mathematical Modelling

InFoMM

Industrially Focused Mathematical Modelling

EPSRC Centre for Doctoral Training in Industrially Focused Mathematical Modelling

Mathematical Institute

University of Oxford

Cohort 6

2019

Table of Contents

CDT Vision and Principles 1

The Core CDT Team 2

CDT Modus operandi 4

Supervision, mentoring and support 6

Progression and progress monitoring during your first year 7

The CDT partnership with companies & confidentiality 8

Projects and project selection 9

Student Involvement in how the CDT is run 10

Financial Information 11

Logistical Information 12

Resources available to CDT Students 13

Chris and Colin's Counsel for Convivial Cohorts 14

Appendix A: Week by Week 2019-2020 15

Appendix B: Academic Course Synopses 15

Appendix C: Skills Training 40

Appendix D: Milestones and Assessment in the DPhil Journey 41

Appendix E: Research Project Review Form 43

Appendix F: Finance & Travel Guidelines 45

Appendix G: Publications & Research Outputs 49

Appendix H: Supervisors and Buddies 51

Appendix I: InFoMM CDT Academic Team: 52

Appendix J: Project Choice Form 56

Appendix K: Mini-project deliverables 57

Appendix L: Building & University Card Information 58

Directors Welcome

Dear members of Cohort 6,

Welcome to the EPSRC Centre for Doctoral Training in Industrially Focused Mathematical Modelling (InFoMM), which is part of the Mathematical Institute, within the Mathematical, Physical and Life Sciences (MPLS) division of the University of Oxford.

Our CDT provides an innovative 4-year DPhil training programme in cutting-edge mathematical methods focused on solving industrial challenges. It is supported by a partnership between the EPSRC, the University of Oxford (a major applied mathematics training and research hub), and a large number of industry partners (currently over 70).

Whether you have studied in Oxford previously and are familiar with our procedures and activities or are completely new, this booklet should act as a valuable resource giving you an overview of what to expect in the coming year and beyond. It will provide you with information about the programme and what is involved in studying at the CDT and in Oxford more generally. It should be a companion to the MPLS Graduate Student Handbook and the Mathematical Institute Research Student Handbook which will provide you with information that should be useful throughout your time at Oxford. The CDT handbook will, at times, contain information which is at odds with these other handbooks. Our instructions here supersede the guidance in them.

Your point of contact for all day to day CDT matters should be our InFoMM Administrator in office S2.11.

We look forward to the interactions, hard work and fun of applying mathematics at the industrial interface.

We wish you a stimulating productive and enjoyable time with us.

Best wishes for the coming years,

Prof Colin Please & Prof Chris Breward

CDT Vision and Principles

Vision:

Our vision is that the CDT will be an outward-facing centre where students learn about the challenges that face modern companies and develop a portfolio of mathematical techniques to enable them to address these challenges.

Principles:

The following are the principles that we endeavour to follow in designing and delivering the CDT training and research programme. These guide the interactions between the different participants involved in the CDT.

- The CDT will provide high quality training to students to enable them to apply modern mathematical methods to a wide range of industrial problems
- The CDT will provide an environment where both academic freedom and industrial professionalism are supported
- The CDT will provide an environment in which students can readily discuss mathematical research ideas with their peers
- The CDT is funded through a combination of public and non-public money and must demonstrate the wider benefits of the research, including taking steps to maximise its impact in accordance with EPSRC policy
- The CDT will respect the confidentiality and existing rights of proprietary information provided by companies
- The CDT will provide sufficient projects so that students have genuine choice in their research endeavours
- The CDT will fund, where appropriate, partial bursaries for Small and Medium sized Enterprises (SMEs) to enable wide SME participation in CDT research activities

The Core CDT Team

Professor Colin Please, Director: Colin is Professor of Applied Mathematics and Tutorial Fellow at Mansfield College. He worked in the electrical power industry for 6 years and was head of Applied Mathematics at Southampton University before moving to Oxford in 2012. His research is at the interface of mathematics with other disciplines primarily engineering (including battery and solar cell behaviour), and bio-science, (including cartilage and skin growth). Room: S2.03 Telephone: (2) 83884

Professor Chris Breward, Director: Chris is a Senior Research Fellow in Applied Mathematics and Lecturer at Christ Church. He has been at Oxford since 2001 and has held several leadership roles in the department. His current research includes the mathematical modelling of fluid mechanical, industrial and medical problems. Recent problems in these areas include tear film dynamics, reactive decontamination, surfactant-driven flows and other thin-film flows. Room: S2.18 Telephone: (2) 70505

Dr Jonathan Mason, Industry Facilitator: Before going to University Jonathan worked for ten years in the high technology sector in Oxfordshire. He worked on advanced fibre-optic product production technology (JDSU Corporation) and Excimer laser micro machining (Exitech advanced laser research). Jonathan received his PhD in mathematics from the University of Nottingham and has research interests in the areas of function spaces and mathematical neuroscience. He has been our Industry Facilitator since 2014. Room: S2.10 Telephone: (2)80615

Sarah Howle, InFoMM Administrator: Sarah joined the InFoMM team in June 2019. Previously Sarah worked for Jesus College and OUP, and has experience in administration, marketing and event management . Room: S2.11 Telephone: (6) 11512

EPSRC
Engineering and Physical Sciences Research Council

InFoMM
Industrially Focused Mathematical Modelling

Other Key Team Members include:

Professor Jon Chapman, Steering Committee Chair: Jon is the Professor of Mathematics and Its Applications and a Professorial Fellow of Mansfield College. He has won the LMS Whitehead Prize and the SIAM Julian Cole Prize. Jon's research interests are centred on modelling and asymptotic analysis for a wide range of problems. Current applications include immunology, water waves, porous media, lithium ion batteries, electrochemistry, collective behaviour and oil recovery. Room: S2.01 Telephone: (2) 70507

Giles Pavey, Industrial Engagement Committee Chair: Giles Pavey is Global Director of Data Science at Unilever. Previously he has been Chief Data Scientist at dunnhumby Ltd and Head of Data Strategy at the Department for Work and Pension. Giles is Honorary Professor of Computer Science at UCL where he lectures and supervises research. Additionally he is Fellow of the Institute of Mathematic & Applications and of the Royal Statistical Society.

Professor Jared Tanner, Cohort Mentor: Jared is Professor of the Mathematics of Information and a Tutorial Fellow at Exeter College. He is the Oxford University liaison Director to the Alan Turing Institute. He was SIAM UKIE Vice President (2011-2013) and Founding Editor-in-Chief of Information and Inference: A Journal of the IMA. His research focus is on the design, analysis, and application of numerical algorithms for information inspired applications in signal & image processing. Room S2.40 Telephone: (6) 15311

CDT Modus operandi

Course structure

First Year

The first year of the CDT is highly structured and has been developed to equip you with

- Fluency in a wide range of mathematical techniques,
- Breadth of modelling experience,
- A set of interpersonal and team working skills,
- so that you can effectively tackle company challenges.

The first year is broken down into several phases. We start with two periods of concentrated training covering core and specialised material, punctuated by two industrial enrichment programmes (IEP). Through these IEPs, you will

- Gain a comprehensive exposure to a wide range of industrial sectors and their challenges,
- Learn valuable interpersonal and team working skills,
- Deepen your knowledge of the mathematics used by some of our partner companies,
- Experience bringing your skills to bear on timely industrial problems,
- Visit company premises to experience different working environments.

After the second IEP, you will undertake two 10-week mini-projects. At least one of these must be based at a partner company. Most of these companies are not based locally and so these mini-projects will necessarily involve being away from Oxford. Details of the procedure for selecting mini-projects and research projects are given later on page 9.

The timetable for year one is in Appendix A, and the synopses for each of the academic courses are given in Appendix B. You will also have industrial and interdisciplinary workshops and skills training (see Appendix C) to attend each Friday during Michaelmas Term. We will organise skills training for Hilary term once we have agreed your options choices.

Subsequent years

During years 2-4, you will undertake a research project in collaboration with one of our partners. We anticipate you spending at least one month each year at the premises of the partner including for formal project meetings. Alongside your research, you will also need to complete further skills training as detailed in Appendix C. The key milestones and assessments for your DPhil journey are given in Appendix D.

You should take the lead in organising formal meetings of your whole supervisory teams, which should occur at least quarterly. The CDT Directors will undertake an annual health check of each project to ensure that non-scientific aspects of the project are progressing well. These meetings will be organised to coincide with one of your quarterly meetings; the research project review from (see Appendix E) should be completed by the whole team and submitted to the reviewing Director a week before the meeting.

During years 2-4 you should also attend:

- The CDT annual meeting, where you will present your research and the Reddick Lecture
- Friday morning workshops, where companies will be presenting challenges
- Relevant weekly seminars during term time
- CDT monthly group meetings, where you will present your work
- Relevant conferences (more details in Appendix F)
- Study Groups with Industry (more details in Appendix F)

We hope you will write papers based on the results from your mini-projects and research projects. Any papers you write will need to be deposited in the Oxford Research Archive (ORA) to comply with the University's open access policy, and you will also need to upload the data used to make any figures. Each year you will also need to complete EPSRC's Research Fish. Instructions will be emailed annually. Further details are given in Appendix G.

We will run a competition in your final year to appoint several 3-6 month Knowledge Transfer Ambassadors. These post-submission positions will be awarded to those who identify the best plans for knowledge transfer activities into their collaborating company or more broadly into the sector.

Supervision, mentoring and support

As part of your welcome and induction into the department we have allocated a 'buddy' for each of you. These buddies are Cohort 4 students. We hope that you will meet with your 'buddy' a few times over your first three weeks. They will also help that you become familiar with Latex documents and support you with other student specific administration. The list of assigned buddies can be found in Appendix H.

We have given you a formal supervisor, drawn from the list you provided over the summer, who will take a guiding role in your progression until your research project supervisors are agreed and you should aim to meet with them approximately twice a term; the supervisor list can be found in Appendix H. Your supervisory team will include at least one academic and at least one person from the partner company. Regular contact between you and supervisor team is essential, especially at the start of your research project. You should have weekly contact with your supervision team (unless you or they are away on a course, a conference or on holiday). A list of supervisors, along with their research interests, can be found in Appendix I.

The supervisory relationship is one of the most crucial ingredients underpinning successful research. The relationship is two-sided with obligations on supervisors as well as the student. Like any relationship, it has to be worked at and nurtured. It is therefore important to establish clear and explicit mutual expectations in order to minimise the risks and possible difficulties of personality clashes.

In the early stages of your research project, your supervisors will take responsibility to ensure that meetings take place. You should assume this responsibility as soon as possible and certainly from the second year onward. It is suggested that the programme of meetings is drawn up well in advance and that supervisors and students avoid rescheduling.

Each cohort will also have a mentor for their first year (yours is Professor Jared Tanner). He will meet informally with you to check that you are on track. In years 2-4 the cohort mentor will be replaced by a departmental advisor who will normally be the head of the research group that you work with.

Colin will take a guiding interest in the progress of all students across all years, as will the Department's Directors of Graduates Studies (Professors Raphael Hauser and James Sparks). During your first year, you will have formal meetings with Colin during each IEP to ensure that your progress is at an appropriate level, given your background.

All colleges have a comprehensive pastoral support system for Graduate Students, with a dedicated member of staff responsible for Graduate matters. Each student will have a College Advisor who will provide access to tailored pastoral, financial, welfare and academic related support independent of the CDT.

The University of Oxford Learning Institute's research supervision website (https://www.ox.ac.uk/research/support-researchers/teaching-and-supervision) is useful to DPhil students. The EPSRC also provide advice on good supervisory practice on their website in an appendix to the Studentship Handbook (http://www.epsrc.ac.uk/skills/students/). If further guidance or advice is required the Directors should be contacted in the first instance.

Progression and progress monitoring during your first year

The University requires you to complete a termly self-reflection on GSR (the University's online graduate student system) and supervisors will complete a termly report. These reports will supply information to the CDT, maths department, MPLS division and your college.

Students arrive as "probationary research students" and during your second year you transfer to "DPhil students" on completion of "transfer of status" which involves a viva voce (an oral examination) by two academics from outside their supervisory team. Further details can be found in Appendix D.

In the first year, each course will have appropriate assessment and students will be awarded a grade of A, B, C, & fail with those obtaining a C or fail being required to discuss their performance with Colin. Students will be required to pass every module; those failing any course will need to do additional work to demonstrate competence.

You should submit your work through the portal at: https://courses.maths.ox.ac.uk/. Click on the Postgraduate Courses on the top, and then click on the 'Industrially Focused Mathematical Modelling' tab on the left hand side.

Please preface all the titles of all your submitted files with your surname and where it asks for your student number, please use your surname.

The grade categories are:

A – An excellent piece of work showing very good understanding and integration of material, which is very well structured and well-presented. No notable weaknesses, only minor improvements possible.

B – A good assignment that addresses the major points and assessment criteria and shows a good level of understanding, but with inadequacies. We anticipate that most assignments will be in this bracket.

C – An assignment that attempts to address the assessment criteria, with sufficient evidence of effort and achievement to warrant a pass, but with important weakness or misunderstandings in certain areas. An assignment that is incomplete, badly organised or poorly argued.

Fail – A seriously flawed piece of work with major weaknesses in several assessment criteria, or little evidence of effort.

Deadlines for work should be strictly adhered to because of the intensity of the workload.

Work which is submitted late without prior arrangement will automatically receive at best a C.

A member of the CDT team will hold a review of your mini-project in weeks five or six of each mini-project.

The CDT partnership with companies & confidentiality

Our partner companies are crucial to the success of the CDT. They are involved in the delivery of the training and in all the mini-projects and research projects. Our aim is to ensure that all students interact with a wide variety of companies during the first year before focusing in on a specific company's scientific problems in years 2-4. There will be plenty of opportunities to meet with partners both formally and informally. First impressions are really important. Some companies will expect more formal attire than others; if in doubt, it's better to dress more formally than informally. Remember that you are representatives of the CDT and that everyone has an obligation to make the relationships work.

The opportunities for interacting with companies during the first year can be seen in the timetable in Appendix A.

Some partners will want to protect confidential information that they share with us. The terms of such protection will be included in the contracts between the University and the company and the terms will apply to you as a student of the CDT. As a general guide you should:

- Feel free to openly discuss your project within the CDT
- Use reasonable endeavours to protect confidential information and not disclose it to anyone outside the CDT. Failure to comply may have legal implications
- Submit proposed publications in advance for approval by your partner company

Working with industry is rewarding but there are several pitfalls that you should be aware of:

- The language used by the company is unlikely to align with mathematical language and vice versa; so care must be taken to learn the company's language
- The timescale on which companies work is often much shorter than the timescale associated with mathematical research. It is important to manage the company's expectations

It will be important for you to learn how to balance industrial demand with your academic research.

Please set up a profile on LinkedIn and join the InFoMM Group (called the EPSRC Centre for Doctoral Training in Industrially Focused Mathematical Modelling). Please keep your maths webpage up-to-date, in case our company colleagues google you.

Jonathan should be your first port of call about industry matters.

Projects and project selection

We have a two-pronged approach to sorting out your mini-projects and research projects. Firstly, we will work with you individually to agree a small number of academic supervisors who might supervise you for your research project. We will then approach companies to find a research topic of interest to you and your supervisors. This research project will come with a precursor mini-project, which will usually be based at the company to enable you to immerse yourself in the project along with the company ethos and values. We anticipate agreeing these projects by the end of March 2020.

Secondly, we aim to have enough stand-alone mini-projects available so that you have genuine choice in project selection. Each project will have been developed in a collaborative interaction between faculty and company employees so that there are sufficient mathematical challenges while retaining content of significant interest to the company.

Project day will take place on Friday week 5 of Hilary Term (21 February 2020). The aim of the day is to present stand-alone mini-project options in order that you can have all relevant information to make your priority list of projects.

The day will be split into several blocks. In each block, there will be short presentations by the teams supervising projects, followed by around 30 minutes for individual discussion between students and the team.

Following Project day, please give us your top 3 choices for stand-alone mini-projects by Tuesday week 6 of Hilary Term (25 February 2020) by emailing the form to the InFoMM Administrator. You will need to complete at least one mini-project at a company premises.

Once we've got your (independently submitted) lists, we will make all the lists available to you. On Friday week 6 of Hilary Term (28 February 2020), we will meet together and we will facilitate you arriving at a feasible solution for your mini-projects. We will ask for confidential individual comments on the solution you collectively arrived at and the Directors will then optimise the solution, resolving any conflicts that may still arise. You may find it helpful to get together in advance of our meeting in order to talk through your options.

During each mini-project, there will be a mid-project progress meeting between your project team and one of the CDT Directors. In these meetings, there will be a short discussion about your technical progress but the meeting will mainly focus on how the non-scientific aspects are going.

At the end of each mini-project, you will need to submit a technical report and a short lay-person report describing your research findings. You will also need to deliver a 15-minute presentation. It's likely that your supervisors and the CDT Directors will ask you to make revisions to these submitted reports before they are released to companies. The lay-person reports will form the basis of our impact reporting to EPSRC, and will also be put onto our website. Further details about these documents can be found in Appendix K.

Student Involvement in how the CDT is run

Each year your cohort will be asked to nominate a Cohort Representative, and we encourage all students to pass concerns or bring suggestions to the Directors through him/her. The Cohort Representative will also take the lead in facilitating project selection.

The CDT is formally run by the two Directors, supported by the InFoMM Administrator and industry facilitator. There are two key committees:

- **Steering committee,** which oversees the training, research, operations and management of the centre, monitors progress against expectations, and suggests improvements where necessary. The committee involves approximately 12 academics (with interests spanning the research areas of the CDT), an external academic member the chair of the Industrial Engagement Committee, and student representatives from each year for non-confidential business. The student reps provide key input into how CDT activities are delivered for future cohorts and give the student perspective on the current provision.
- **Industrial Engagement Committee,** which is the key conduit for providing a non-academic perspective to all aspects of the CDT. The committee involves approximately 10 company representatives and the Directors.

Financial Information

All CDT students in Cohort 6 are fully funded, meaning that your college and university fees are paid directly and that you each receive a maintenance grant to cover your living expenses (the maintenance grant is not subject to UK income tax). For all students who are not funded the Oxford-Radcliffe Scheme, the CDT is responsible for your maintenance payments, which you will receive quarterly in October, January, April and July. If you have not received your first payment by the end of October, or there are any changes to your bank details please let the InFoMM Administrator know. The Oxford-Radcliffe Scheme shares responsibility with the CDT for funding of its studentships. If you are unsure of who to speak to, the InFoMM Administrator will point you in the right direction.

There will be activities that you undertake as part of your CDT programme which will require you to incur travel, accommodation and subsistence expenses, which you will want to claim back from the CDT. Full details of the travel and expenses guidelines can be found in Appendix F. Travel advances are possible in extreme situations. Please contact the InFoMM Administrator as soon as you think this may be needed (at least two weeks in advance).

Logistical Information

Attendance

Your first year in the CDT is likely to be hectic and demanding. You can expect to need to work some evenings and weekends to keep on top of the material in the courses and get your assignments completed. A reasonable number of activities will need to be undertaken in small groups and you will need to collectively organise your time. It will be essential for you to be in the department during the core working hours of 09:00-17:30 during taught phases of the training.

From your second year onwards, you will occasionally be required to attend taught modules and visit companies. The dates for taught modules will be publicised in adv ance and students should build these into their research planning. Time should be allowed for completing any associated assignments. Information about building access is given in Appendix L.

Holidays, illness and absences from the department

Students should only take holidays in the first year during the weeks identified in the timetable. In later years, students are entitled to take 38 days holiday (including bank holidays) per year. These should be checked for conflicts, agreed with your supervisor, and the details given to the InFoMM Administrator via a spreadsheet. Please also use this spreadsheet to record your travel to conferences, study groups and companies.

If you are unable to come into the department due to illness or unforeseen circumstances it is essential that you contact the InFoMM Administrator as soon as you are able to, either by phone or by e-mail. Recording all periods away from the department is especially important for students studying under a Tier 4 visa as we have a legal responsibility to the UKBA to know where you are.

Travel

You will have to travel outside the University, for example to companies, conferences and Study Groups, at different points of your CDT life. While you are travelling, your personal safety and welfare are very important to us. The University provides travel insurance for students travelling within the UK and abroad on University business and has many guidelines on your safety when abroad. These can be found on the University's travel insurance webpage http://www.admin.ox.ac.uk/finance/insurance/travel/.

Before every trip you should complete the online travel insurance form:
https://www.maths.ox.ac.uk/members/health-safety/foreign-travel

You need to allow **at least five working days** before a proposed trip when putting in an application for travel insurance, in order that all the apporpiate approvals can be completed.

Resources available to CDT Students

In the first year you will all be based in room S3.06. You will each have signed for a CDT laptop which we will expect you to use for you coursework and will be useful when you visit companies. It remains the property of the Mathematical Institute, and needs to be returned at the end of your time with us. There will initially be eight desktop computers in the room; should this prove insufficient then we will address this issue. These machines will provide access to mathematical software. In later years, you will be physically located within the research group of your primary supervisor.

The CDT has a large CPU/GPU cluster for student use during both teaching and research phases. Access is managed by Jared Tanner. This is a dedicated machine for the CDT and there may be periods of time where the machine is only available for supporting CDT teaching.

InFoMM' s internal webpage [https://www.maths.ox.ac.uk/study-here/postgraduate-study/industrially-focused-mathematical-modelling-epsrc-cdt/infomm-current] houses lots of important information, such as the templates for CDT documents and forms, links to useful websites, guidelines for publications, and copies of the handbook. If you have suggestions for other content, please speak with the InFoMM Administrator.

As members of the department, all CDT students have access to

- Electronic & paper journals (NB you need to use an Oxford VPN or laptop departmental machine to access the electronic ones)
- Department bench collections (small collections of relevant books)
- Libraries
- Bookable teaching space
- Black & white and colour printers throughout the building.
- Social spaces including the common room and the café
- The Mathematics Observatory (laboratory for bench top experiments)

We encourage you to make use of all of these resources.

Chris and Colin's Counsel for Convivial Cohorts

1. Work together. You will learn as much from each other, your buddies, and students in other Cohorts, as you will from anyone else.
2. Don't struggle in silence. Make use of your peers, and departmental and college support. If there's a problem, let someone know (eg your cohort mentor, Jared Tanner).
3. Stay on top of your workload. There is a lot to do.
4. Pass on comments and suggestions to the Directors so that the CDT experience is continually improved.
5. Make the most of your interactions with industry. They provide stimulation for your research projects (and the company might want to employ you).
6. Come to coffee. We meet for coffee every morning at 11.00. This is an opportunity to meet peers and faculty in an informal setting. Sometimes we'll discuss maths, sometimes less academic matters. There are cakes on Monday.

From year 2

1. Attend CDT group meetings. These will be monthly on Friday lunchtimes and will involve students giving presentations (followed by lunch).
2. Come to seminars. The numerical analysis seminar is on Thursday at 2.00pm and the industrial and applied mathematics seminar is on Thursday at 4.00pm. As well as broadening your scientific knowledge, attending seminars is useful for developing your own presentational skills. If a seminar strikes you as good or bad think about what makes it so. Don't worry if the seminar is not in your research area - it's still worth attending.
3. Come to the Friday morning industrial & interdisciplinary workshops. These are more informal than seminars and often lead to brainstorming sessions on industrial problems that may turn into projects for future CDT students. Participating in these workshops will broaden your scientific outlook and help you develop modelling skills outside your own particular research project. And they're fun.
4. Go to JAMS (Junior Applied Mathematics Seminars). These are "Junior" seminars to which faculty can't go. You'll probably be encouraged to give a seminar in this series in your third year.
5. Go to Fridays@4. They have a particular focus on graduate students and early career researchers. They will include skills sessions, careers events, Department Colloquia and junior colloquia. They will be followed by a department happy hour at 5pm.

Appendix A: Week by Week 2019-2020

Week	W/C	Ox Term			Monday	Tuesday	Wednesday	Thursday	Friday
51	30-Sep	MT -1		Core Training	Introduction and orientation				
52	07-Oct	MT 0			Introduction and orientation				
1	14-Oct	MT 1	AM		Mathematical Modelling				
			PM		Scientific Computing				
2	21-Oct	MT 2	AM		Mathematical Modelling				
			PM		Scientific Computing				
3	28-Oct	MT 3	AM		Modelling and Analysis of continuous real-world problems				Workshops
			PM						Skills
4	04-Nov	MT 4	AM		Modelling and Analysis of continuous real-world problems				Workshops
			PM						Skills
5	11-Nov	MT 5	AM		Computational Techniques				Workshops
			PM						Skills
6	18-Nov	MT 6	AM		Computational Techniques				Workshops
			PM						Skills
7	25-Nov	MT 7	AM		Mathematical Analytics				Workshops
			PM						Skills
8	02-Dec	MT 8	AM		Mathematical Analytics				Workshops
			PM						Skills
9	09-Dec	MT 9	AM		Optimisation				Workshops
			PM						Skills
10	16-Dec	MT 10		IEP1	IEP1 & Crash Courses				
11	23-Dec				Holiday				
12	30-Dec				Holiday				
13	06-Jan	HT -1			IEP1 & Crash Courses				
14	13-Jan	HT 0			IEP1 & Crash Courses				
15	20-Jan	HT 1	AM PM	Specialist Training	Options courses & case studies				
16	27-Jan	HT 2	AM PM		Options courses & case studies				
17	03-Feb	HT 3	AM PM		Options courses & case studies				
18	10-Feb	HT 4	AM PM		Options courses & case studies				
19	17-Feb	HT 5	AM PM		Options courses				Project Day
20	24-Feb	HT 6	AM PM		Options courses				
21	02-Mar	HT 7	AM PM		Options courses & case studies				
22	09-Mar	HT 8	AM PM		Options courses & case studies				
23	16-Mar	HT 9		IEP 2	IEP 1C course				Annual Meeting
24	23-Mar	HT10			Company Visits | IEP 2				
25	30-Mar				Company Visits | IEP 2				
26	06-Apr				Holiday				
27	13-Apr				Holiday				
28	20-Apr	TT0		Miniprojects	Miniproject 1				
29	27-Apr	TT1			Miniproject 1				
30	04-May	TT2			Miniproject 1				
31	11-May	TT3			Miniproject 1				
32	18-May	TT4			Miniproject 1				
33	25-May	TT5			Miniproject 1				
34	01-Jun	TT6			Miniproject 1				
35	08-Jun	TT7			Miniproject 1				
36	15-Jun	TT8			Miniproject 1				
37	22-Jun	TT9			Miniproject 1				MP Talks
38	29-Jun	TT10			Holiday				
39	06-Jul				Holiday				
40	13-Jul				IEP 1C course	UK Graduate Modelling Camp			
41	20-Jul				UK Study Group with Industry				
42	27-Jul				Miniproject 2				
43	03-Aug				Miniproject 2				
44	10-Aug				Miniproject 2				
45	17-Aug				Miniproject 2				
46	24-Aug				Miniproject 2				
47	31-Aug				Miniproject 2				
48	07-Sep				Miniproject 2				
49	14-Sep				Miniproject 2				
50	21-Sep				Miniproject 2				
51	28-Sep	MT -1			Miniproject 2				MP Talks
52	05-Oct	MT 0			Holiday				

Appendix B: Academic Course Synopses

Core 01 - Mathematical Modelling – Prof Breward

Mon/Tues/Wed/Thurs/Fri AM, MT Weeks 1&2

Assessment method: Short summary of one of the modelling challenges

Overview

Mathematical modelling is the process of formulating real-world situations or processes in mathematical terms. In this course we will consider some recipes and techniques that are common to formulating and analysing many models. Students will gain hands-on experience of making, solving and interpreting models.

Synopsis

Introduction to modelling with examples; conservation of mass; continuous and discrete models.

Dimensions and units; dimensional analysis; Buckingham Pi Theorem; Scaling and Nondimensionalisation.

Simple asymptotic analysis.

Modelling challenges will include: soap film rupture, buses turning corners, T-shirt box packing, calibration of robot arms, and extraction of sugar from sugar cane.

Reading list

- S.D. Howison, *Practical Applied Mathematics: Modelling, Analysis, Approximation,* CUP, 2005

Core 02 - Scientific Computing – Dr Dallas

Mon/Tues/Wed/Thurs/Fri PM, MT Weeks 1&2

Assessment method: Assessment will be based on solutions/code for both the individual tasks and the group task. Work must be submitted electronically.

Overview

This course will address some important aspects of scientific computing, largely through the lens of Matlab, a programming environment designed specifically for numerical mathematical modelling. A crash course in the essentials of programming in Matlab will be followed by its application to fundamental numerical topics including linear algebra, differential equations and optimization. These applications will involve exploring various inbuilt solvers and toolboxes. Other aspects of scientific computing will then be explored, including the public sharing of code, documentation, demos, parallel computing and GPUs. There will be a final group programming task which will be an opportunity to explore issues around developing code in teams for industry.

Synopsis

Introduction to programming in Matlab: The Matlab work environment; variables and basic mathematical functions; arrays (manipulation and indexing); function handles; their use in numerical equation solving, finding stationary points, root finding, numerical integration and graph plotting; logical operations, m-files and functions; sparse matrices; advantages of sparse matrices and implicit matrix-vector products.

Applications of programming in Matlab: linear algebra; solving systems of linear equations; SVD and eigen-decomposition; image compression; numerical solution of ODEs; optimization.

Aspects of scientific computing: using external code; Matlab Central; exploring documentation and demos; sharing code publicly; using remote servers, parallel computing and GPUs.

Group task: developing software as a team.

Reading list

- T. Davis, *Matlab Primer, 8th edition*, CRC Press, 2010

Core 03 – Modelling and Analysis of Continuous Real-World Problems - Prof Please

Mon/Tues/Wed/Thurs all day, MT weeks 3-4

Assessment method: A written report

Overview:

Modelling and Analysis of Continuous Real-World Problems will introduce a number of key methods for studying continuum models. Each week we start from real-world problems and show how to derive the corresponding mathematical model. We then use these models as vehicles to demonstrate the relevant analytical and computational methods. At the end of each week, the students will have the complete set of tools needed to set up, analyse and solve a class of mathematical models.

Synopsis:

Diffusion problems arising in heat flow, chemical reactions, pattern formation, and thermal runaway. Conservation laws; well-posedness; separation of variables; transforms; similarity solutions; nonlinear equilibria; linear stability.

Elastic waves; acoustics; Stokes waves; electromagnetism; optics. Method of characteristics; separation of variables; eigenvalue problems; resonance; high-frequency asymptotics.

River flow; porous-medium flow; two-phase flow. Shocks, causality, regularization, weakly nonlinear theory.

Capillary statics; elasticity; buckling; liquid crystals; Calculus of variations; bifurcations; weakly nonlinear analysis.

Reading list:

- J. Nocedal and S.J. Wright, *Numerical Optimization, Second edition*, Springer, 2006
- S.D. Howison, *Practical Applied Mathematics: Modelling, Analysis, Approximation*, CUP, 2005
- M. Holmes, *Introduction to the Foundations of Applied Mathematics*, Springer, 2009

Core 04 – Computational Techniques – Prof. Nakatsukasa

Mon/Tues/Wed/Thurs all day, MT weeks 5-6

Assessment method: A written report

Overview:

Computational Techniques will introduce a number of key methods for studying continuum models. The first week will focus on the basics and applications of numerical linear algebra, treating linear systems, eigenvalue problems and the singular value decomposition (SVD). On the second week we treat finite differences and finite element methods for solving differential equations, showing how to derive the corresponding mathematical model. We then use these models as vehicles to demonstrate the relevant analytical and computational methods. At the end of each week, the students will have the complete set of tools needed to set up, analyse and solve a class of mathematical models.

Synopsis:

SVD, eigenvalues, linear systems, Krylov subspace methods, randomized algorithms

Finite difference methods, error analysis, stability analysis, stiff problems. Multidimensional finite difference and finite element methods for elliptic problems. Finite element and discontinuous Galerkin methods.

Reading list:

- P. E. Farrell, *Finite Element Methods for PDEs*, C 6.4 course lecture notes
- R. LeVeque, *Finite Difference Methods for Ordinary and Partial Differential Equations*, SIAM, 2007
- E. Süli and D. Mayers, *An Introduction to Numerical Analysis,* CUP 2003
- L. N. Trefethen and D. Bau, *Numerical Linear Algebra*, SIAM 1997

Core 05 – Mathematical Analytics – Prof. Grindrod

Mon/Tues/Wed/Thurs all day, MT weeks 7-8

Assessment method: Summaries of implemented methods and results in a style suitable for a general technical reader (eg an industry professional). Student may choose to summarise using digital media such as videos or ppt.

Overview

This course addresses short- and long-term challenges arising in customer-facing industries and will exploit data available from shopping baskets, twitter, mobile telecoms and energy demands. The course will start with probability, covers graphs and their application to social networks, looks at dynamically evolving networks, clustering and classification, hypothesis testing and forecasting.

Synopsis

Odds, likelihoods and evidence; Common pitfalls; Bayes' theorem, updating, probability distributions, Laplace's law of succession, Monte Hall problem, conjugate priors, transposed conditionals.

Self-adjoint matrices, non-negative matrices, Perron-Frobenius theory, Singular value decomposition, graph theory, similarity matrices, random matrices, clustering, range dependent networks, small world networks, scale-free networks., inverse problems for networks.

Katz centrality, matrix valued functions, corporate email networks, mobile phone call networks, fragility of networks, discrete time evolving networks, and continuous time evolving networks.

Twitter networks, diffusion on networks, fully coupled networks, activator-inhibitor systems, homophily, Turing instabilities, transient influencers, Event driven activity spikes, justifying investments in digital advertising, Bootstrap sampling, embedding, Bayes Factors

K-means clustering, the EM algorithm, finite mixture modelling, behavioural segmentations, energy demand, mobile phone usage, supermarket customer shopping missions.

Multiple hypotheses, Bayesian updating, Beatles versus Stones, Mobile phone networks, logistic regression.

Bayesian updating, product launches, linear models, domestic energy demand, smart meter data, discrete and continuous optimization.

Customer behaviour and customer value, Markov chains, genetic algorithms, behavioural dynamics, seasonality, case studies.

Reading List

- P. Grindrod, *The Mathematical Underpinnings of Analytics*, OUP, 2014
- E.T. Jaynes and G.L. Bretthorst, *Probability Theory: The Logic of Science,* CUP, 2003

Core 06 – Optimisation – Prof. Raphael Hauser

Mon/Tues/Wed/Thurs all day, MT week 9

Assessment method: Short written report

Overview:

In many practical problems that can be approached via linear optimisation problems, some or all of the variables are constrained to take binary or integer values. For example, in optimal crew scheduling a pilot cannot be fractionally assigned to two different flights at the same time. Likewise, in combinatorial optimisation an element of a given set either belongs to a chosen subset or it does not. Integer programming is the mathematical theory of such problems and of algorithms for their solution. The aim of this course is to provide an introduction to some of the general ideas on which attacks to integer programming problems are based: generating bounds through relaxations by problems that are easier to solve, and branch-and-bound.

Students will understand some of the theoretical underpinnings that render certain classes of integer programming problems tractable ("easy" to solve), and they will learn how to solve them algorithmically. Furthermore, they will understand some general mechanisms by which intractable problems can be broken down into tractable subproblems, and how these mechanisms are used to design good heuristics for solving the intractable problems. Understanding these general principles will enable the students to guide the modelling phase of a real-world problem towards a mathematical formulation that has a reasonable chance of being solved in practice.

This course is primarily structured as a reading course with students watching online lectures and attending regular sessions to discuss particular issues.

Synopsis:

Linear programming, Total Unimodularity, Branch-and-Bound, Preprocessing of LPs and IPs, generating valid cuts, cutting plane algorithm, Chvatal cuts, Gomoroy cuts, branch-and-cut algorithm, the Generalised Assignment Problem.

Reading list:

- Course lecture notes (Oxford B6.3 Integer Programming).
- M. Conforti, G. Cornuejols, G. Zambelli, *Integer Programming* (Springer 2014), ISBN 978-3-319-11007-3.
- L. A. Wolsey, *Integer Programming* (John Wiley & Sons, 1998), parts of chapters 1-5 and 7.

Specialist Courses

You will need to pick three courses from the following list to study during Hilary Term

- C3.5 Lie Groups
- C3.9 Computational Algebraic Topology
- C4.6 Fixed Point Methods for Nonlinear PDEs
- C5.2 Elasticity and Plasticity
- C5.4 Networks
- C5.6 Applied Complex Variables
- C5.9 Mathematical Mechanical Biology
- C6.2 Continuous Optimisation
- C6.4 Finite Element Methods for PDEs
- C8.2 Stochastic Analysis and PDEs
- C8.4 Probabilistic Combinatorics
- SC4 Advanced Topics in Statistical Machine Learning

You will need to let us know which courses you intend to study by 13 December 2019.

Those who have previously studied in Oxford should pick courses that they have not read before.

Specialist Training - Case Studies

You will complete three case studies during Hilary term, one each in Modelling, Scientific Computing and Data Analytics. Working in small teams, you will address real-world challenges from these areas. This may involve translating problem statements into mathematical formulations, analysing models and making predictions, developing code to solve a particular challenge, or identify structures in, or classifying, data.

The case study challenges will be posed in 1st week, 3rd week and 7th week and you will be expected to complete at least 20 hours of work on each challenge, fitted around your other academic commitments. Each case study will have a mentor who will meet with you for 6 hours at guide your progress.

C3.5 Lie Groups - Prof. A Dancer

General Prerequisites:

Part A Group Theory, Topology and Introduction to Manifolds are all useful but not essential. It would be desirable to have seen notions of derivative of maps from R^n to R^m, inverse and implicit function theorems, and submanifolds of R^n. Acquaintance with the notion of an abstract manifold would be helpful but not really necessary.

Assessment Method: a short written report

Course Overview:

The theory of Lie Groups is one of the most beautiful developments of pure mathematics in the twentieth century, with many applications to geometry, theoretical physics and mechanics. The subject is an interplay between geometry, analysis and algebra. Lie groups are groups which are simultaneously manifolds, that is geometric objects where the notion of differentiability makes sense, and the group multiplication and inversion are differentiable maps. The majority of examples of Lie groups are the familiar groups of matrices. The course does not require knowledge of differential geometry: the basic tools needed will be covered within the course.

Learning Outcomes:

Students will have learnt the fundamental relationship between a Lie group and its Lie algebra, and the basics of representation theory for compact Lie groups. This will include a firm understanding of maximal tori and the Weyl group, and their role for representations.

Course Synopsis:

Brief introduction to manifolds. Classical Lie groups. Left-invariant vector fields, Lie algebra of a Lie group. One-parameter subgroups, exponential map. Homomorphisms of Lie groups and Lie algebras. Ad and ad. Compact connected abelian Lie groups are tori. The Campbell-Baker-Hausdorff series (statement only).

Lie subgroups. Definition of embedded submanifolds. A subgroup is an embedded Lie subgroup if and only if it is closed. Continuous homomorphisms of Lie groups are smooth. Correspondence between Lie subalgebras and Lie subgroups (proved assuming the Frobenius theorem). Correspondence between Lie group homomorphisms and Lie algebra homomorphisms. Ado's theorem (statement only), Lie's third theorem.

Basics of representation theory: sums and tensor products of representations, irreducibility, Schur's lemma. Compact Lie groups: left-invariant integration, complete reducibility. Representations of the circle and of tori. Characters, orthogonality relations. Peter-Weyl theorem (statement only).

Maximal tori. Roots. Conjugates of a maximal torus cover a compact connected Lie group. Weyl group. Reflections. Weyl group of U(n). Representations of a compact connected Lie group are the Weyl-invariant representations of a maximal torus (proof of inclusion only). Representation ring of T&subn; and U(n).

Killing form. Remarks about the classification of compact Lie groups.

Reading List:

- J. F. Adams, *Lectures on Lie Groups* (University of Chicago Press, 1982).
- T. Bröcker and T. tom Dieck, *Representations of Compact Lie Groups* (Graduate Texts in Mathematics, Springer, 1985).

Further Reading:

- R. Carter, G. Segal and I. MacDonald, *Lectures on Lie Groups and Lie Algebras* (LMS Student Texts, Cambridge, 1995).
- W. Fulton, J. Harris, *Representation Theory: A First Course* (Graduate Texts in Mathematics, Springer, 1991).
- F. W. Warner, *Foundations of Differentiable Manifolds and Lie Groups* (Graduate Texts in Mathematics, 1983).

C3.9 Computational Algebraic Topology – Prof. V Nanda, Prof. S Abramsky

General Prerequisites:

Some familiarity with the main concepts from algebraic topology, homological algebra and category theory will be helpful.

Assessment Method: A mini-project on a topic from a choice of two.

Course Overview:

Ideas and tools from algebraic topology have become more and more important in computational and applied areas of mathematics. This course will provide at the masters level an introduction to the main concepts of (co)homology theory, and explore areas of applications in data analysis and in foundations of quantum mechanics and quantum information.

Learning Outcomes:

Students should gain a working knowledge of homology and cohomology of simplicial sets and sheaves, and improve their geometric intuition. Furthermore, they should gain an awareness of a variety of application in rather different, research active fields of applications with an emphasis on data analysis and contextuality.

Course Synopsis:

The course has two parts. The first part will introduce students to the basic concepts and results of (co)homology, including sheaf cohomology. In the second part applied topics are introduced and explored.

Core: Homology and cohomology of chain complexes. Algorithmic computation of boundary maps (with a view of the classification theorm for finitely generated modules over a PID). Chain homotopy. Snake Lemma. Simplicial complexes. Other complexes (Delaunay, Cech). Mayer-Vietoris sequence. Poincare duality. Alexander duality. Acyclic carriers. Discrete Morse theory. (6 lectures)

Topic A: Persistent homology: barcodes and stability, applications todata analysis, generalisations. (4 lectures)

Topic B: Sheaf cohomology and applications to quantum non-locality and contextuality.Sheaf-theoretic representation of quantum non-locality and contextuality asobstructions to global sections. Cohomological characterizations and proofs of contextuality.(6 lectures)

Reading List:

- H. Edelsbrunner and J.L. Harer, *Computational Topology - An Introduction*, AMS (2010).
- See also, U. Tillmann, Lecture notes for CAT 2012, in http://people.maths.ox.ac.uk/tillmann/CAT.html

Topic A:

- G. Carlsson, *Topology and data*, Bulletin A.M.S.46 (2009), 255-308.
- H. Edelsbrunner, J.L. Harer, *Persistent homology: A survey, Contemporary Mathematics 452* A.M.S. (2008), 257-282.
- S. Weinberger, *What is ... Persistent Homology?,* Notices A.M.S. 58 (2011), 36-39.
- P. Bubenik, J. Scott, *Categorification of Persistent Homology, Discrete Comput.* Geom. (2014), 600-627.

Topic B:

- S. Abramsky and Adam Brandenburger*, The Sheaf-Theoretic Structure Of Non-Locality and Contextuality.* In New Journal of Physics, 13(2011), 113036, 2011.
- S. Abramsky and L. Hardy, *Logical Bell Inequalities*, {Phys. Rev. A} 85, 062114 (2012).
- S. Abramsky, S. Mansfield and R. Soares Barbosa, *The Cohomology of Non-Locality and Contextuality, in Proceedings of Quantum Physics and Logic* 2011, Electronic Proceedings in Theoretical Computer Science, vol. 95, pages 1-15, 2012.

C4.6 Fixed Point Methods for Nonlinear PDEs - Prof. M Rupflin

General Prerequisites:

Basic results on weak derivatives and Sobolev spaces either from B4.3 Distribution Theory or from C4.3 Functional Analytic Methods for PDEs. Some knowledge of functional analysis, mainly notions of Banach spaces, and weak convergence, is useful.

Assessment Method: 10minute presentation

Course Overview:

This course gives an introduction to the techniques of nonlinear functional analysis with emphasis on the major fixed point theorems and their applications to nonlinear differential equations and variational inequalities, which abound in applications such as fluid and solid mechanics, population dynamics and geometry.

Learning Outcomes:

Besides becoming acquainted with the fixed point theorems of Banach, Brouwer and Schauder, students will see the abstract principles in a concrete context. Hereby they also reinforce techniques from elementary topology, functional analysis, Banach spaces, compactness methods, calculus of variations and Sobolev spaces.

Course Synopsis:

Examples of nonlinear differential equations and variational inequalities. Contraction Mapping Theorem and applications. Brouwer's fixed point theorem, proof via Calculus of Variations and Null-Lagrangians. Compact operators and Schauder's fixed point theorem. Recap of basic results on Sobolev spaces. Applications of Schauder's fixed point theorem to nonlinear elliptic equations. Variational inequalities and monotone operators. Applications of monotone operator theory to nonlinear elliptic equations (p-Laplacian, stationary Navier-Stokes)

Reading List:

- Lawrence C. Evans, *Partial Differential Equations*, Graduate Studies in Mathematics (American Mathematical Society, 2004).
- E. Zeidler, *Nonlinear Functional Analysis I & II* (Springer-–Verlag, 1986/89).
- M. S. Berger, *Nonlinearity and Functional Analysis* (Academic Press, 1977).
- K. Deimling, *Nonlinear Functional Analysis* (Springer-Verlag, 1985).
- L. Nirenberg, *Topics in Nonlinear Functional Analysis,* Courant Institute Lecture Notes (American Mathematical Society, 2001).
- R.E. Showalter, *Monotone Operators in Banach Spaces and Nonlinear Partial Differential Equations*, Mathematical Surveys and Monographs, vol.49 (American Mathematical Society, 1997).

C5.2 Elasticity and Plasticity - Prof. P Howell

General Prerequisites:

Familiarity will be assumed with Part A Complex Analysis, Differential Equations 1 and 2 and Calculus of Variations. A basic understanding of stress tensors from either B5.3 Viscous Flow or C5.1 Solid Mechanics will also be required. The following courses are also helpful: B5.1 Techniques of Applied Mathematics, B5.2 Applied Partial Differential Equations, C5.5 Perturbation Methods, C5.6 Applied Complex Variables.

Assessment Method: Two worked example problems

Course Overview:

The course starts with a rapid overview of mathematical models for basic solid mechanics. Benchmark solutions are derived for static problems and wave propagation in linear elastic materials. It is then shown how these results can be used as a basis for practically useful problems involving thin beams and plates. Simple geometrically nonlinear models are then introduced to explain buckling, fracture and contact. Models for yield and plasticity are then discussed, both microscopically and macroscopically.

Course Synopsis:

Review of tensors, conservation laws, Navier equations. Antiplane strain, torsion, plane strain. Elastic wave propagation, Rayleigh waves. Ad hoc approximations for thin materials; simple bifurcation theory and buckling. Simple mixed boundary value problems, brittle fracture and smooth contact. Perfect plasticity theories for granular materials and metals.

Reading List:

- P. D. Howell, G. Kozyreff and J. R. Ockendon, *Applied Solid Mechanics* (Cambridge University Press, 2008)
- S. P. Timoshenko and J. N. Goodier, *Theory of Elasticity* (McGraw-Hill, 1970)
- L.D. Landau and E.M. Lifshitz, *Theory of Elasticity* (Pergamon Press, 1986)

C5.4 Networks - Prof. R Lambiotte

General Prerequisites:

Basic notions of linear algebra, probability and some computational experience. Numerical codes will be illustrated in Python in tutorials, but the student has the possibility to use the language of their choice. Relevant notions of graph theory will be reviewed.

Assessment Method: Analyse a dataset given by the lecturer, and provide one original network visualisation emphasising an aspect of their choice, together with the codes used to generate it, and a one-page report with interpretations and choice justification.

Course Overview:

Network Science provides generic tools to model and analyse systems in a broad range of disciplines, including biology, computer science and sociology. This course aims at providing an introduction to this interdisciplinary field of research, by integrating tools from graph theory, statistics and dynamical systems. Most of the topics to be considered are active modern research areas.

Learning Outcomes:

Students will have developed a sound knowledge and appreciation of some of the tools, concepts, models, and computations used in the study of networks. The study of networks is predominantly a modern subject, so the students will also be expected to develop the ability to read and understand current (2010-2020) research papers in the field.

Course Synopsis:

1. Introduction and short overview of useful mathematical concepts (2 lectures): Networks as abstractions; Renewal processes; Random walks and diffusion; Power-law distributions; Matrix algebra; Markov chains; Branching processes.

2. Basic structural properties of networks (2 lectures): Definition; Degree distribution; Measures derived from walks and paths; Clustering coefficient; Centrality Measures; Spectral properties.

3. Models of networks (2 lectures): Erdos-Rényi random graph; Configuration model; Network motifs; Growing network with preferential attachment.

4. Community detection (2 lectures): Newman-Girvan Modularity; Spectral optimization of modularity; Greedy optimization of modularity.

5. Dynamics, time-scales and Communities (2 lectures): Consensus dynamics; Timescale separation in dynamical systems and networks; Dynamically invariant subspaces and externally equitable partitions

6. Dynamics I: Random walks (2 lectures): Discrete-time random walks on networks; PageRank; Mean first-passage and recurrence times; Respondent-driven sampling; Continous-Time Random Walks

7. Random walks to reveal network structure (2 lectures): Markov stability; Infomap; Walktrap; Core–periphery structure; Similarity measures and kernels

8. Dynamics II: Epidemic processes (2 lectures): Models of epidemic processes; Mean-Field Theories and Pair Approximations

Reading List:

Self-contained lecture notes will be made available at the end of Michaelmas.

EPSRC
Engineering and Physical Sciences
Research Council

InFoMM
Industrially Focused
Mathematical Modelling

C5.6 Applied Complex Variables - Prof. I Hewitt

General Prerequisites:

The course requires second year core analysis (A2 complex analysis). It continues the study of complex variables in the directions suggested by contour integration and conformal mapping. A knowledge of the basic properties of Fourier Transforms is assumed. Part A Waves and Fluids and Part C Perturbation Methods are helpful but not essential.

Assessment Method: Short presentation

Course Overview:

The course begins where core second-year complex analysis leaves off, and is devoted to extensions and applications of that material. The solution of Laplace's equation using conformal mapping techniques is extended to general polygonal domains and to free boundary problems. The properties of Cauchy integrals are analysed and applied to mixed boundary value problems and singular integral equations. The Fourier transform is generalised to complex values of the transform variable, and used to solve mixed boundary value problems and integral equations via the Wiener-Hopf method.

Learning Outcomes:

Students will learn advanced techniques in complex analysis and use them to solve free and mixed boundary value problems, integral equations and differential equations.

Course Synopsis:

Review of core complex analysis, analytic continuation, multifunctions, contour integration, conformal mapping and Fourier transforms.

Riemann mapping theorem (in statement only). Schwarz-Christoffel formula. Solution of Laplace's equation by conformal mapping onto a canonical domain; applications including inviscid hydrodynamics; Free streamline flows in the hodograph plane. Unsteady flow with free boundaries in porous media.

Application of Cauchy integrals and Plemelj formulae. Solution of mixed boundary value problems motivated by thin aerofoil theory and the theory of cracks in elastic solids. Reimann-Hilbert problems. Cauchy singular integral equations. Complex Fourier transform. Contour integral solutions of ODE's. Wiener-Hopf method.

Reading List:

- G. F. Carrier, M. Krook and C.E. Pearson, *Functions of a Complex Variable* (Society for Industrial and Applied Mathematics, 2005.) ISBN 0898715954.
- M. J. Ablowitz and A. S. Fokas, *Complex Variables: Introduction and Applications* (2nd edition, Cambridge University Press, 2003). ISBN 0521534291.
- J. R. Ockendon, S. D. Howison, A. A. Lacey and A. B. Movchan, *Applied Partial Differential Equations: Revised Edition* (Oxford University Press, 2003). ISBN 0198527713. Pages 195-212.

C5.9 Mathematical Mechanical Biology - Prof. D Moulton

General Prerequisites:

Fluid Mechanics: Part A Waves and Fluids and Part B Viscous flow are recommended. Solid mechanics: The Part C courses Solid Mechanics and Elasticity/Plasticity are recommended. Mathematical biology or physiology is desirable but not necessary as the material for a particular biological system will be part of the course.

Assessment Method: Do one of the following (i) a 10min presentation on a topic in the course on the final day, (ii) a 10 min video of a topic in the course, (iii) a short report (six pages or less) on a topic in the course

Course Overview:

The course will be motivated by outstanding problems in physiology and biology but the emphasis is on the mathematical tools needed to answer some biologically relevant problems. The course is divided into modules and three modules will be given during a term but these modules can change from one year to the next.

Learning Outcomes:

The goal of this course is to learn the physical background and mathematical methods behind many problems arising in mechanical biology from the cellular level and upwards. Students will familiarise themselves with key notions used in modern research in bio-physics and mechano-biology.

Course Synopsis:

1. 1D Biological Mechanics. Bio-Filaments (2 1/2 weeks)
(a) Introduction: bio-molecules (actin, microtubules, DNA, etc)
(b) Randomly fluctuating chains (statistical mechanics)
(c) Continuous filaments (neurons, stems, roots, plants)
(d) Differential geometry of curves: Kirchhoff rod theory and beam theory

2. 2D Biological Mechanics. Bio-Membranes (2 1/2 weeks)
(a) Introduction: lipid bilayer, cell membranes
(b) Differential geometry of surfaces: curvatures, Gauss–Bonnet theorem
(c) Fluid membranes: shape equation, fluctuating membranes
(d) Solid membranes, shells and their application to the cell, plants and microbes.

3. Bio-solids and growth (3 weeks)
(a) Introduction: nonlinear elasticity for soft tissues
(b) one-dimensional growth theory
(c) Application to mechanical pattern formation
(d) volumetric growth: multiplicative decomposition

The following module will not be taught in 2019-20:
3. 3D Biological Mechanics.
(a) Low Reynolds number flows: Scallop theorem, Cell Motility, Ciliary Pumping.
(b) Introduction to nonlinear 3D elasticity for soft tissues
(c) Coupling low Reynolds fluids and non-linear elastic solids, with application to poro-elastic tissue

Reading List:

- *Physical Cell Biology, second ed*. Rob Phillips et al. Garland Science.
- *Cardiovascular solid mechanics. Cells, tissues, and organs,* Humpherey, 2002, Springer.
- *Nonlinear Solid Mechanics: A Continuum Approach for Enineering: A Continuum Approach for Engineering*, G. Holzapfel, 200, Wiley.
- *The Mathematics and Mechanics of Biological Growth*, A. Goriely, 2017, Springer.

C6.2 Continuous Optimisation – Prof. C Cartis

General Prerequisites:

Basic linear algebra (such as eigenvalues and eigenvectors of real matrices), multivariate real analysis (such as norms, inner products, multivariate linear and quadratic functions, basis) and multivariable calculus (such as Taylor expansions, multivariate differentiation, gradients).

Assessment Method: a short report (no longer than 5 pages) or a numerical exercise with discussion of results

Course Overview:

The solution of optimal decision-making and engineering design problems in which the objective and constraints are nonlinear functions of potentially (very) many variables is required on an everyday basis in the commercial and academic worlds. A closely-related subject is the solution of nonlinear systems of equations, also referred to as least-squares or data fitting problems that occur in almost every instance where observations or measurements are available for modelling a continuous process or phenomenon, such as in weather forecasting. The mathematical analysis of such optimization problems and of classical and modern methods for their solution are fundamental for understanding existing software and for developing new techniques for practical optimization problems at hand.

Course Synopsis:

Part 1: Unconstrained Optimization
Optimality conditions, steepest descent method, Newton and quasi-Newton methods, General line search methods, Trust region methods, Least squares problems and methods.

Part 2: Constrained Optimization
Optimality/KKT conditions, penalty and augmented Lagrangian for equality-constrained optimization, interior-point/ barrier methods for inequality constrained optimization. SQP methods.

Reading List:

- Lecture notes will be made available for downloading from the course webpage
- A useful textbook is J.Nocedal and S.J.Wright, Numerical Optimisation, (Springer, 1999 or 2006).

C6.4 Finite Element Method for PDEs – Prof. P Farrell

General Prerequisites:

No formal prerequisites are assumed. The course builds on elementary calculus, analysis and linear algebra and, of course, requires some acquaintance with partial differential equations such as the material covered in the Prelims Multivariable Calculus course, in particular the Divergence Theorem. Part A Numerical Analysis would be helpful but is certainly not essential. Function Space material will be introduced in the course as needed.

Assessment Method: 10 minute presentation on a finite element discretisation of a PDE of your choice.

Course Overview:

Computational algorithms are now widely used to predict and describe physical and other systems. Underlying such applications as weather forecasting, civil engineering (design of structures) and medical scanning are numerical methods which approximately solve partial differential equation problems. This course gives a mathematical introduction to one of the more widely used methods: the finite element method.

Course Synopsis:

Finite element methods represent a powerful and general class of techniques for the approximate solution of partial differential equations. The aim of this course is to introduce these methods for boundary value problems for the Poisson and related elliptic partial differential equations.

Attention will be paid to the formulation, the mathematical analysis and the implementation of these methods.

Reading List:

- H. Elman, D. Silvester & A. Wathen, *Finite Elements and Fast Iterative Solvers. Second edition*. OUP, 2014. [Mainly Chapters 1 and 3], or
- H. Elman, D. Silvester & A. Wathen, *Finite Elements and Fast Iterative Solvers.* OUP, 2005. [Mainly Chapters 1 and 5].

Further Reading:

- S.C. Brenner & L.R. Scott, *The Mathematical Theory of Finite Element Methods.* Springer, 2nd edition, 2002. [Chapters 0,1,2,3; Chapter 4: Secs. 4.1-4.4, Chapter 5: Secs. 5.1-5.7].
- C. Johnson, *Numerical Solution of Partial Differential Equations by the Finite Element Method.* CUP, 1990. [Chapters 1-4; Chapter 8:Secs. 8.1-8.4.2; Chapter 9: Secs. 9.1-9.5].

Typed lecture notes covering a previous version of the entire course (and more) are available from the course material webpage:
Endre Süli, *Finite Element Methods for Partial Differential Equations*. Mathematical Institute, University of Oxford, 2011

Some of the introductory material is covered in:
Endre Süli & David Mayers, An Introduction to Numerical Analysis,CUP 2003; Second Printing 2006. [Chapter 11 and in particular Chapter 14].

C8.2 Stochastic Analysis and PDEs – Dr. I Chevyrev

General Prerequisites:

Integration and measure theory, martingales in discrete and continuous time, stochastic calculus. Functional analysis is useful but not essential.

Assessment Method: 4-5 page report

Course Overview:

Stochastic analysis and partial differential equations are intricately connected. This is exemplified by the celebrated deep connections between Brownian motion and the classical heat equation, but this is only a very special case of a general phenomenon. We explore some of these connections, illustrating the benefits to both analysis and probability.

Learning Outcomes:

The student will have developed an understanding of the deep connections between concepts from probability theory, especially diffusion processes and their transition semigroups, and partial differential equations.

Course Synopsis:

Feller processes and semigroups. Resolvents and generators. Hille-Yosida Theorem (without proof). Diffusions and elliptic operators, convergence and approximation. Stochastic differential equations and martingale problems. Duality. Speed and scale for one dimensional diffusions.
Green's functions as occupation densities. The Dirichlet and Poisson problems. Feynman-Kac formula.

Reading List:

A full set of typed notes will be supplied.

Important references:

- O. Kallenberg. Foundations of Modern Probability. Second Edition, Springer 2002. This comprehensive text covers essentially the entire course, and much more, but should be supplemented with other references in order to develop experience of more examples.

- L.C.G Rogers & D. Williams. Diffusions, Markov Processes and Martingales; Volume 1, Foundations and Volume 2, Itô calculus. Cambridge University Press, 1987 and 1994. These two volumes have a very different style to Kallenberg and complement it nicely. Again they cover much more material than this course.

Further Reading:

- S.N. Ethier & T.G. Kurtz. *Markov Processes: characterization and convergence.* Wiley 1986. It is not recommended to try to sit down and read this book cover to cover, but it is a treasure trove of powerful theory and elegant examples.
- S. Karlin & H.M. Taylor. *A second course in stochastic processes.* Academic Press 1981. This classic text does not cover the material on semigroups and martingale problems that we shall develop, but it is a very accessible source of examples of diffusions and things one might calculate for them.
- A fuller list of references will be included in the typed notes.

EPSRC
Engineering and Physical Sciences Research Council

InFoMM
Industrially Focused Mathematical Modelling

C8.4 Probabilistic Combinatorics - Prof. O Riordan

General Prerequisites:

Part B Graph Theory and Part A Probability. C8.3 Combinatorics is not as essential prerequisite for this course, though it is a natural companion for it.

Assessment Method: Written answers to a small set of questions.

Course Overview:

Probabilistic combinatorics is a very active field of mathematics, with connections to other areas such as computer science and statistical physics. Probabilistic methods are essential for the study of random discrete structures and for the analysis of algorithms, but they can also provide a powerful and beautiful approach for answering deterministic questions. The aim of this course is to introduce some fundamental probabilistic tools and present a few applications.

Learning Outcomes:

The student will have developed an appreciation of probabilistic methods in discrete mathematics.

Course Synopsis:

First-moment method, with applications to Ramsey numbers, and to graphs of high girth and high chromatic number. Second-moment method, threshold functions for random graphs. Lovász Local Lemma, with applications to two-colourings of hypergraphs, and to Ramsey numbers. Chernoff bounds, concentration of measure, Janson's inequality. Branching processes and the phase transition in random graphs. Clique and chromatic numbers of random graphs.

Reading List:

- N. Alon and J.H. Spencer, *The Probabilistic Method* (third edition, Wiley, 2008).

Further Reading:

- B. Bollobás, *Random Graphs* (second edition, Cambridge University Press, 2001).
- M. Habib, C. McDiarmid, J. Ramirez-Alfonsin, B. Reed, ed., *Probabilistic Methods for Algorithmic Discrete Mathematics* (Springer, 1998).
- S. Janson, T. Luczak and A. Rucinski, *Random Graphs* (John Wiley and Sons, 2000).
- M. Mitzenmacher and E. Upfal, *Probability and Computing: Randomized Algorithms and Probabilistic Analysis* (Cambridge University Press, New York (NY), 2005).
- M. Molloy and B. Reed, *Graph Colouring and the Probabilistic Method* (Springer, 2002).
- R. Motwani and P. Raghavan, *Randomized Algorithms* (Cambridge University Press, 1995).

SC4/SM8 Advanced Topics in Statistical Machine Learning - Prof. Y W Tee

Lectures: weeks 1-6,8: Tue 3pm & Thu 4pm, LG.01; week 7: Thu 4pm & Fri 4pm, LG.01 (note the time change in week 7)

There will be no lecture at Tue 3pm in week 7. Lectures will be held at Thu 4pm (Feb 28th) and Fri 4pm (Mar 1st) that week.

Solutions to problem sheets 1-3 will be made available on the course website by the end of HT week 8. Solutions to problem sheet 4 will be made available during TT week 0.

Course Prerequisites:

You should be familiar with the material in A8 Probability and A9 Statistics.
Some material from this year's syllabus of SB2.2 Statistical Machine Learning, PCA and the basics of clustering, will be used (which is mainly taught in the first three lectures of SB2.2, also in HT2019), but SB2.2 is not a prerequisite and background notes will be provided. Knowledge of Python is not required for this course, but some descriptive examples in lectures may be done in Python.

Assessment Method: presentation

Course Overview:

Machine learning is widely used across many scientific and engineering disciplines to construct methods for finding interesting patterns in large datasets, devising complex models and prediction tools. This course introduces several widely used machine learning techniques and describes their underpinning statistical principles and properties. The course studies both unsupervised and supervised learning and several advanced topics are covered in detail, including some state-of-the-art machine learning techniques. The course will also cover computational considerations of machine learning algorithms and how they can scale to large datasets.

Course Synopsis:

Review of unsupervised and supervised learning.
Duality in convex optimization and support vector machines.
Kernel methods and reproducing kernel Hilbert spaces. Representer theorem. Representation of probabilities in RKHS.
Kernel PCA. Spectral clustering. Manifold regularization.
Probabilistic and Bayesian machine learning: latent variable models, variational free energy, EM algorithm, mixtures, probabilistic PCA.
Laplace Approximation. Variational Bayes, Latent Dirichlet Allocation.
Collaborative filtering models, probabilistic matrix factorization.
Gaussian processes for regression and classification. Bayesian optimization.

Reading List:

The course materials will appear at http://www.stats.ox.ac.uk/~sejdinov/atsml19/. They consist of notes, slides, problem sheets and Jupyter notebooks. Notes may not be exhaustive and should be used in conjunction with the slides. All materials may be updated during the course and are thus best read on screen.

- Bishop, *Pattern Recognition and Machine Learning*, Springer.
- Murphy, *Machine Learning: A Probabilistic Perspective*, MIT Press.
- Hastie, Tibshirani and Friedman, *The Elements of Statistical Learning*, Springer. (ebook)

- Shalev-Shwartz and Ben-David, *Understanding Machine Learning: From Theory to Algorithms,* Cambridge University Press.

Background Review Aids: (see http://www.stats.ox.ac.uk/~sejdinov/atsml19/ for additional background material and instructions for software installation

Appendix C: Skills Training

First Year

- C++ (4 days)
- R (full Day)
- Communication skills
- Influencing people
- Presentation skills
- Protecting confidentiality & IP
- Writing Skills I, II, III
- Using tabletop experiments to enhance modelling
- Reading Research Papers
- Crash courses in Mathematical topics

Second Year

- Managing your supervisor
- Reading research papers
- Outreach training & outreach activity
- Academic project management

Third Year

- Outreach activity
- Managing your DPhil
- Starting a new company

Fourth Year

- Finishing your DPhil
- Industrial Ethics
- Careers workshop / Employability training
- Realising impact from research

Teaching Development

You will not start your teaching programme until the second year; however you will undertake departmental training with all other DPhil students at the start of your first year. You will normally mark for two sets of undergraduate classes in each of your second and third years. In your fourth year, there will be opportunities to teach (or mark) for undergraduate classes. Permission must be obtained from your supervisors and the Directors to do teaching outside the department (including for any college teaching).

Appendix D: Milestones and Assessment in the DPhil Journey

These notes are a CDT-specific précis of the information given in section 7 of the Mathematics Graduate Student Handbook. Much more information is given there and it is important that you read it carefully. CDT students arrive in Oxford as "probationary research students". All students have to undergo "transfer of status" to full DPhil status. In order to transfer, you must write a short dissertation which is specifically for the purpose of supporting your transfer application. It may consist of a short piece of original mathematics, or work that could be included or developed as part of a doctoral thesis or a critical review of some part of your subject area, and so on. It need not contain original mathematics but it must offer something which is not readily available in the existing literature. Simply interlacing sections of existing texts and papers is not enough. The dissertation may include work done as part of a related mini-project but the material must be presented in an appropriate mathematical way in order to satisfy the examiners. Don't underestimate the amount of time it will take to write your dissertation and polish it to the required standard.

We recommend you use a form called "Transfer of status – checklist for students" to support you in your preparation.

- A "Preparing for transfer of status" form should be submitted along with your report on GSR in either week 6 or 7 of **Hilary term** 2020.

Dissertations should be submitted along with:

- A list of seminars, workshops and colloquia attended, with short extended abstracts of two of these
- A print out of your website
- Appropriate completed forms (see the Mathematics Handbook Section 8). These forms need signing by College officials so don't leave it until the last minute.

You should strive to submit these documents by Week 6 of Trinity Term *(*Friday 7 June 2020*)*, to allow sufficient time for the transfer process to be completed.

As part of the transfer process, you will give a short presentation on your research. The assessment of your transfer documents will be done in a viva voce examination by two academics (assessors) who are not part of your supervisory team. You should discuss the arrangements for your viva voce examination with your supervisors; we strongly suggest that the viva takes place in the early part of the summer vacation because most faculty take holiday during mid/late summer and finding a suitable date may become problematic. However, it must take place by Friday of Week 0 of Michaelmas Term (Friday 8 October 2021). After the examination, the assessors will make a report to the department's Director of Graduate Studies who will take appropriate action as described in section 8 of the Mathematics Graduate Student Handbook.

By the end of Michaelmas Term in your fourth year, you will need to have your DPhil status "confirmed". The purpose of confirmation is to enable you to receive an assessment of your work and to provide an important indication that, if work continues to develop satisfactorily, it would be reasonable for you to submit your thesis within three terms. The confirmation involves an interview with two assessors who are not part of your supervisory team.

You will need to submit:

- A list of chapters making up your thesis
- An outline of the content of the chapters
- A detailed presentation of some results

You should strive to submit these documents by the end of week 6 of Michaelmas Term (18 November 2022) in order to ensure the interview happens by the end of the week 0 of Hilary Term 2023 (13 January 2023). You should contact your assessors to arrange your Interview by this date. Note that CDT students do not have to provide details of skills training: we will keep those records for you. For details of the post-interview process, please see the Mathematics Graduate Student handbook.

We expect all students to have submitted their DPhil thesis by the end of their 4^{th} year. You will also need to produce a lay report (6-10 pages) which summarises your research project, which should be submitted to the InfoMM Administrator at the same time as you submit your thesis to the university.

Please put 30 September 2023 in your diary now to celebrate handing in your thesis!

InFoMM will pay for a bound copy of your final approved thesis, to live in an InFoMM thesis library.

Appendix E: Research Project Review Form

Research project Title:
Student Name:
Company:
Supervisors:
Date:

1. List the key results achieved since the last project review
2. Comments from academic supervisors on mathematical progress
3. Comments from company supervisors on addressing company challenge
4. List visits student has made to company since last review

5. **List meetings of the whole project team since last review (indicate whether in meeting/skype/phone)**

6. **What is the potential impact of the project?**

7. **Please list any other points you wish to raise:**

Appendix F: Finance & Travel Guidelines

Research-related expenses

InFoMM provides significant financial support for your research endeavours. Each student has a £1000 "support fund" allocated to use for supporting their research project (eg to cover attendance at events, funding small experiments etc). The precise decisions on what to spend this on are left for students to agree with their supervisors.

In addition, we will cover expenses associated with mini-projects (travel and accommodation only), visits to companies, along with some conferences and Study Groups. Details are given below. If you find you do not have sufficient funds to support your research plans, please approach the Directors through the InFoMM Administrator.

For all expenses to be reimbursed by Oxford, receipts should be kept and the expenses can be claimed back using the universities expenses form:
http://www.admin.ox.ac.uk/finance/epp/forms/expensesandrelocation/.

All expenses should follow the university guidelines, and there are some tips later in this document. Expenses claims should be submitted within one month of the expenditure.

If in doubt about claiming expenses, please check with the InFoMM Administrator, but the following notes should cover all standard arrangements. The key is "economy of time versus economy of cost", and we would expect you to book your trips as early as possible

We are not able to reimburse expenses for activities that occur after you have submitted your thesis.

Mini-projects:

The handling of expenses associated with each mini-project is covered in the agreement letter. We will reimburse travel and reasonable accommodation costs (when necessary) for mini-projects, but not food costs.

- If the Company covers the cost, you should claim from them.
- If Oxford covers the cost and then invoices the company, please record all expenses on a claim form and remember to include all the original receipts

Conferences (years 2-4):

InFoMM is keen that you disseminate the results of your research to the mathematical community (especially in the UK), and thus generously supports conference attendance at meetings where you present your work.

Please ensure that you apply for conference / travel grants from your college.

InFoMM will cover the registration fee, travel, food and accommodation costs of the following conference attendances:

- In year 2, one UK Conference (for example, BAMC or the Biennial Numerical Analysis Conference), where you should present a poster or give a talk
- In year 3, one UK or EU conference, where you should give a talk.
- In year 4, one international conference, where you should give a talk.

If there's a scientific reason to alter the schedule (for example, because a specific international conference happens once every 4 years), that's fine provided your supervisor supports this.

Conference-specific expenses:

- If there is a banquet or a group meal, we will cover the cost (remember to get a receipt)
- If the conference is at an expensive hotel, do see if there are local cheaper alternatives but we don't expect you to travel very far.
- InFoMM will cover the cost of printing posters.

We would not expect to pay more than £750 for a UK conference, £1,000 for an EU conference, and £1,250 for a non-EU conference.

If you wish to attend additional conferences, or your conferences are more expensive than specified above, you should use your £1000 support fund, apply for additional college travel funds, or request the cost from your supervisor.

Study Groups with Industry (years 2-4):

InFoMM is keen for you to interact with a wide range of companies during your research project years and Study Groups with Industry provide the ideal forum for doing this.

The financial and logistical advice for conferences also applies for Study Groups.

InFoMM will pay for the following Study Groups:

- In year 1, the UK European Study Group with Industry (ESGI)
- In year 2, the UK ESGI, or another UK Study Group
- In year 3, an ESGI (UK or EU). You should agree the overall plan as a cohort to ensure that as many meetings benefit from the participation of InFoMM students.
- In year 4, an international Study Group, where you will act as an ambassador for UK Industrial Mathematics. You should agree the overall plan as a cohort to ensure that as many meetings benefit from the participation of InFoMM students.

We would not expect to pay more than £1,200 towards a non-EU Study Group.

Company visits (years 2-4):

We expect you to visit your company for a minimum of one month per year, which could be achieved as a collection of individual days or weeks, or in one long visit. If you intend to go for more than 6 weeks in any one year, please check with the InFoMM Administrator.

InFoMM will cover all expenses for company visits, including

- Economy travel. This can be by public transport or car. Train trips should be done in second class; air trips in economy class.
- Reasonable food costs. You can eat out, eat healthy or do food shops, but please be economical.
- Accommodation. Your accommodation should be low to medium cost, and could be in a hotel or university accommodation.

The key is "economy of time versus economy of cost"

Workshops and Summer Schools:

If you wish to attend long workshops or summer schools, you should pay for this from your support fund, or apply for funds from the event organisers and/or your college.

Advances and Expenses Claims:

- The department can provide you with an advance for travel, if you wish to apply for one please check with the InFoMM Administrator
- Please keep itemised receipts; credit/debit card receipts are not accepted by the University
- Taxis should only be taken for the following reasons: (i) you have heavy luggage; (ii) you are running late; (iii) you are travelling very early or very late; or (iv) there is no public transport alternative.

Travel and Holiday Spreadsheet:

- From year 2, you will each have a tab on the InFoMM Google spreadsheet on which to record all holidays and work-related travel. Please keep your spreadsheet up to date with historical and upcoming travel. An example is below.

Student Name:					
	Start Date	End Date	Reason Hol / Comp V / Conf	No of Hol Days taken (max 38)	No of Days at Comp (approx. 20)
1					
2					
3					
4					
5					
6					
9					
			Total	0	0

Appendix G: Publications & Research Outputs

InFoMM Publications Portal

The InFoMM Publications Portal, accessed via the internal webpage, allows InFoMM CDT students to report and upload all papers and reports (company/ Study Groups etc) written by students or based on CDT projects. Please remember that most companies will require you to have your papers reviewed by them before submission (please refer to your individual contracts and NDAs), and some can ask for a 6 month delay in publication.

1. When you submit a paper (or report), please provide the following information:

   I. Title
   II. Authors
   III. Journal/Study Group Proceedings you have submitted to (or state "Company report")
   IV. Date of submission

2. When your paper is accepted, please *resend* the information above, adding:

   I. Date of acceptance

3. When you have full citation data, please *resend* the information above, adding:

   I. Journal volume and number
   II. Page numbers
   III. DOI
   IV. Year of publication

Submitting the information 3 times enables us to accurately track the progress of each paper (and keep a log that we can let EPSRC have whenever they need it).

Acknowledgements:

Please include the following acknowledgement in all papers:

"This publication is based on work supported [or partially supported] by the EPSRC Centre for Doctoral Training in Industrially Focused Mathematical Modelling (EP/L015803/1) in collaboration with [insert company name]"

For Company or Study Group reports, it may be more appropriate to write:

" [initials] acknowledges the support provided by the EPSRC Centre for Doctoral Training in Industrially Focused Mathematical Modelling (EP/L015803/1)."

Act on Acceptance / ORA

ORA is the permanent and secure archive of the University which preserves an array of research publications, journal articles, conference papers, working papers, theses, reports, book sections and more. Unpublished academic work is also deposited into ORA, maximising the University's research output. All papers and your final thesis must be submitted to ORA.

When you've had a paper accepted for publication, please Act on Acceptance – deposit the accepted manuscript (the final peer-reviewed version) into the ORA within 3 months of acceptance. A guide on how to submit can be found here: http://openaccess.ox.ac.uk/wp-content/uploads/sites/2/2017/08/Symplectic-ORA-deposit-guide-v3.5-Aug-2017.pdf

Research Data management

In order to ensure that it is easy for researchers to compare their work quantitatively to others, to check whether the results printed in papers can indeed by obtained by the stated mathematical method, and to see whether the results of new research are better, for example in terms of accuracy, EPSRC require authors of journal articles and conference papers to make their "underlying data" openly available, after a potential embargo period.

For typical Maths papers, this means the following: for each plot, unless it is a very simple function specified in the paper, the authors must provide either a file with the relevant tabulated data, or the software which generated the data and plot. The collected data forms a dataset which must be openly available and archived for at least 10 years using a permanent DOI label, and this DOI must be provided in the paper, typically in the Acknowledgements section after acknowledging EPSRC funding. There is no particular format required, but a csv text file is recommended.

In practice, this means that InFoMM students should upload the data associated with the plots in their papers onto ORA alongside submitting their paper.

Further information, including on how to upload data into ORA, can be found at https://www.maths.ox.ac.uk/members/research-support-ref-open-access/research-data-management

ResearchFish

The UK Research Councils ask students supported by Research Council studentships to provide, via researchfish®, up-to-date information about the outputs and outcomes arising from their research. It is important that doctoral students update the Councils about their research activities and successes, and the information helps the Councils understand how students contribute to their respective areas of research and engage with partner organisations and other communities. It allows the Councils to acknowledge and further promote students' achievements and to make the case to Government for continue public funding of similar studentships in the future.

RCUK Submission Period in researchfish® usually takes place in February each year.

When you register for a researchfish account you have to set up your own username and password and should use these to login at https://www.researchfish.com/.

Appendix H: Supervisors and Buddies

Year 1 Supervisors

Sophie Abrahams	Colin Please
Anna Berryman	Doyne Farmer
Georgia Brennan	Chris Breward
Markus Dablander	Renaud Lambiotte
James Harris	Ian Griffiths
Deqing Jiang	Yuji Nakatsukasa
Brady Metherall	Jim Oliver
Constantin Puiu	Coralia Cartis
Joseph Roberts	Sarah Waters

Buddies

Sophie Abrahams	Lingyi Yang
Anna Berryman	Ambrose Yim
Georgia Brennan	Oliver Whitehead
Markus Dablander	Rodrigo Leal Cervantes
James Harris	Rahil Sachak-Patwa
Deqing Jiang	Giuseppe Ughi
Brady Metherall	Ellen Luckins
Constantin Puiu	Zhen Shao
Joseph Roberts	Harry Reynolds

Appendix I: InFoMM CDT Academic Team:

Ruth Baker	Computational models, stochastic modelling of reaction-diffusion processes, testing of cell biology models using Bayesian and quantitative approaches
Chris Breward	Fluid mechanics, surfactants, modelling biological and industrial systems
Matteo Burzoni	Mathematical finance, Knightian uncertainty, risk management, Mean Field Games, stochastic optimal control.
Helen Byrne	Mathematical and computational models of biomedical systems, with application to tumours, wound healing, and tissue engineering
Álvaro Cartea	High-frequency and algorithmic trading, mathematical finance, financial economics, asset pricing, energy markets
Coralia Cartis	Algorithms for diverse classes of optimisation problems, inverse problems data assimilation, compressed sensing
Jon Chapman	Modelling, asymptotics, and differential equations for fluid and solid mechanics
Samuel Cohen	Mathematical and probabilistic modelling, risk management, stochastic optimal control, Game theory, statistical estimation and uncertainty, Machine learning
Mohit Dalwadi	Cleaning and decontamination, tissue engineering, metabolic engineering, asymptotic methods.
Paul Dellar	Lattice Boltzmann, magneto hydrodynamics, scientific computing, kinetic theory
Jeff Dewynne	Free boundary problems, financial derivatives
Radek Erban	Molecular dynamics, swarm robotics, biophysics, collective behaviour, numerical methods, stochastic processes
Chris Farmer	Inverse problems and uncertainty, wave propagation, flow through porous media
Doyne Farmer	Economics, agent-based modelling, financial instability, complex systems, dynamical systems
Patrick Farrell	Fast solvers for PDEs, PDE-constrained optimisation, bifurcation analysis
Jaroslav Fowkes	Revenue management, Bayesian optimization, surrogate global optimization, statistical pattern mining
Andrew Fowler	Environmental, geophysical and medical problems, dynamical systems

Eamonn Gaffney	Modelling for Pharma, mathematical and computational biology, physiological and cellular fluid dynamics.
Mike Giles	Stochastic models, methods and numerical analysis, HPC
Kathryn Gillow	Numerical methods for biological and electrochemical problems, inverse problems
Alain Goriely	Solid mechanics, morphogenesis, growth, dynamical systems
Ian Griffiths	Viscous flows, particle-laden flows, surfactant systems
Pete Grindrod	Evolving networks, data analytics, smart meters, complex systems
Ben Hambly	Probability, stochastic processes, fractals, mathematical finance
Heather Harrington	Algebraic systems biology, topological data analysis, complexity science
Raphael Hauser	Convex optimisation, probabilistic analysis of algorithms, mathematical finance
Matt Hennessy	Interfacial instabilities, poroelasticity, complex fluids, non-Fourier heat conduction, phase change, lithium-ion batteries
Ian Hewitt	Modelling, continuum mechanics, porous media flows, geoscience
Peter Howell	Modelling, asymptotics and differential equations for fluid and solid mechanics
David Howey	Electrical engineering and modelling of energy storage systems
Sam Howison	Mathematical finance, fluid mechanics, superconductivity, industrial problems
Yakov Kremnitzer	Geometric representation theory, symmetries formalized by algebraic structures, Quantum Mechanics, and applications of Integrated Information Theory
Renaud Lambiotte	Complex systems, dynamics on networks, temporal networks, modelling large network processes, social and brain networks
Andrew Mellor	Temporal networks, social networks, complexity science, visualising networks and dynamics on networks
Charles Monroe	Discovery, design, characterisation, and modelling of electrochemical energy storage systems
Matthew Moore	Fluid dynamics, perturbation methods, matched asymptotics, complex analysis, particularly singular integral equations and Riemann-Hilbert problems
Irene Moroz	Geophysical fluids, wavelets, dynamical systems, time series, data assimilation, plankton modelling

Derek Moulton	Biomechanics, continuum modelling, growth, elasticity
Andreas Muench	Nano and microfluidics, capillary interfaces, asymptotics, scientific computing, suspensions, phase field models
Yuji Nakatsukasa	Numerical linear algebra (especially eigenvalues), approximation theory, continuous optimization, statistics
Vidit Nanda	Applied and computational algebraic topology
Harald Oberhauser	Modelling systems that evolve under the influence of randomness, machine learning and stochastic analysis, time series, text, streams etc
Hilary Ockendon	Fluid and solid mechanics, continuum models of industrial processes especially textiles.
John Ockendon	Differential equations, asymptotics, applications
Jim Oliver	Free boundary problems in fluid dynamics, splashing and jet impact, biomechanics
Colin Please	Fluid mechanics, electrochemistry, continuum models
Christoph Reisinger	Numerical analysis of PDEs and SPDEs, Bayesian parameter estimation, computational finance, stochastic control
Oliver Riordan	Random graphs, phase transitions, percolation in random environments
Alex Scott	Combinatorics, probability, algorithms
Anna Seigal	Applied algebraic geometry, tensors and multilinear algebra, algebraic statistics
Priya Subramanian	nonlinear dynamics; pattern formation; delay differential equations; quasipatterns; inclined layer convection; thermoacoustics
Endre Suli	Numerical analysis of nonlinear PDEs especially in fluid and solid mechanics
Jared Tanner	Mathematics of information, compressed sensing, matrix completion, topological data analysis, inverse problems, and data analysis generally
Ulrike Tillmann	Algebraic Topology and its applications, recent interest includes applications of topology to data analysis
Nick Trefethen	Numerical linear algebra, approximation theory including Chebfun and spectral methods
Carolina Urzua-Torres	Numerical analysis, numerical methods for solving PDES, acoustic and electromagnetic scattering.

Dominic Vella	Surface tension, thin elastic objects, flow in porous media
Sarah Waters	Mathematical medicine and biology, biofluids biomechanics, tissue engineering
Andy Wathen	Numerical linear algebra, preconditioners, PDE constrained optimisation
Jonathan Whiteley	Mathematical modelling and scientific computing related to multiscale, multiphysics problems arising in physiology and biology
Francis Woodhouse	Mechanical networks, biophysics, networked dynamical systems, collective behaviour, non-equilibrium physics

Appendix J: Project Choice Form

InFoMM Project Choice Form

Name:

Please list mini-project choices (1=top)

Choice	Company	Mini-project title	Location (Oxf/Comp)	Mini-project slot (1/2)
1				
2				
3				

Comments:

Appendix K: Mini-project deliverables

By the end of each 10-week project, you will need to have written:

1. A technical report; which should be no longer than 25 descriptive pages including appendices, together with front page, table of contents, bibliography (making a total of no more than 30 pages). A latex template will be provided. This report will not be made public.
2. A 2-page lay-person report, including comments from your company supervisor about the impact of your work. A template will be provided. This report will be made public.
3. A presentation for delivery to the CDT and partners. These presentations should last no longer than 15 minutes and should not contain any sensitive company information. A latex template will be provided.

The presentation must be submitted by 9am and the two reports by noon on the final Friday of each mini-project slot; you will need to agree with your supervisors the timeline for them reviewing these documents before submission. Your supervisors will also review the final submitted technical reports and are likely to ask you to make changes. Similarly, one of the Directors will review the lay-person reports. We aim to release final versions of the documents to companies around a month after the end of the mini-project.

Appendix L: Building & University Card Information

Building floor plans can be found by following the link below:

https://www.maths.ox.ac.uk/members/building-information/floor-plans

University Card

Your University Card should already be activated for access to the Andrew Wiles Building, however if you have trouble accessing the building please contact door-entry@maths.ox.ac.uk. Please include your card number and full name in the email with a description of the problem you are experiencing.

The first time you use your card to access the building you will need to hold the card up against one of the external sensors. In the first instance it may take a little while for the light to turn from blue to green. Once you have held your card up against the internal sensor you should then have complete access to the north and south wings as well as your office.

After-hours access

Between the hours of 6pm and 8am and on weekends in addition to your university card you will also require a pin code to access the building.

You will need to set your own pin. Please follow the link below for further instructions

https://www.maths.ox.ac.uk/members/building-information/opening-hours-access-control