Guide to

Graduate Studies

in

APPLIED MATHEMATICS

at

Florida State University

1993/1994

Contents

Foreword

Welcome to Florida State University's Graduate Program in Applied Mathematics. The faculty hopes that your time in the program will be both productive and enjoyable.

The program is designed to transform you from student to professional mathematician. The award of a master's degree signifies that you have specialized knowledge of mathematics from which to advance to positions of responsibility in education, government or industry, or with which to enter a doctoral program. The award of a doctorate signifies that you are recognized as an authority in applied mathematics and are qualified to join the international community of scholars as a member of faculty in a college or university, or as a research scientist in a university, in industry, in a government organization or in a variety of other institutions.

The purpose of this guide is to facilitate your progress through graduate school by providing details of the program, its faculty and staff, and its degree requirements. It is intended to be read once in its entirety on admission to the program, and subsequently to be consulted for specific information through the index at the back. The guide complements the 1993/1995 *FSU Graduate Bulletin* and the 1993/1994 *FSU General Bulletin*. But it does not replace them, and the ultimate responsibility for being in compliance with university regulations is yours.

This is the first edition of the *Guide to Graduate Studies in Applied Mathematics at FSU*, and thanks are due to Karen Ball, Mickey Boyd, Fabio Guerinoni, Bill Richmond, Melissa Smith, Karen Watson, Jay Webb and the FSU Department of Physics for contributing in various ways to making it possible. The guide will be updated from year to year, and suggestions for improvements are always welcome.

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Advanced Degrees: Synopsis of Requirements

The graduate program in applied mathematics at FSU provides a course of studies leading to the degree of Master of Arts (M.A.), Master of Science (M.S.) or Doctor of Philosophy (Ph.D.) in Mathematics. This section contains a synopsis of degree requirements. Checklists of degree requirements appear in Appendix D.

1.1 M.A. or M.S.

To obtain a master's in applied mathematics you must complete the required number of semester hours of graduate courses (See Section 1.1.3 below), including at least 22 semester hours in courses offered by this department, and

1.1.1 Complete one of the following two options:

(a) Applied Mathematics. You must take MAA 5306-5307, MAD 5708, 5738, either MAP 5207 or MAD 5420, 5345-5346, 5423 and either MAP 5431 or MAP 5XXX (see Section 3.1. for titles of courses). A course of equivalent level in another area of application may be substituted for MAP 5431 or MAP 5XXX, but only with the prior approval of the Director of Applied Mathematics. This option is called Option (b) in the *FSU Graduate Bulletin*.

(b) Computational Mathematics. You must take three of MAP 5345, 5346, 5423, 5441, 5217; two of MAP 5431, 5512, 5513, OCP 5253, 5271, PHY 4323, 4324, 5346 (or equivalents); and four of MAD 5395, 5420, 5708, 5738, 5739, 5745. This option is called Option (d) in the *FSU Graduate Bulletin*.

1.1.2 Either write and successfully defend a thesis; or else pass the Master's Comprehensive Examination (MCE). The MCE is offered once every academic year, toward the end of the Spring semester. See Section 5.1.

1.1.3 For a course-type program, the required number of graduate semester hours is 32; for a thesis-type program the required number of hours is 30, including at least six in MAT 5971r.

1.2 Ph.D

To obtain a Ph.D. in applied mathematics, above all else you must establish your credentials for independent scholarly work by making sufficient original contributions to the scientific literature. You are considered successful in this regard if you defend your dissertation successfully (see Sections 5.4 and 6.4). In addition, you must demonstrate:

1. Broad knowledge of applicable mathematics and the modelling skills to apply it
2. In-depth knowledge of at least one area of application, together with the ability to identify both unsolved problems and worthwhile approaches to their solution
3. Proficiency in a minor area of study
4. Significant teaching experience
5. A high degree of commitment to the mission and integrity of the academic community
6. Reading knowledge of French, German or Russian
7. Compliance with all other university and college requirements

In practice, you satisfy these extra conditions as follows:

1.2.1 You are considered to have demonstrated broad knowledge of applicable mathematics and associated modelling skills if you pass the written part of the Doctoral Preliminary Examination (DPE), which is offered toward the end of each spring semester. See Section 5.3.1.

1.2.2 To proceed beyond the written part of the DPE you must prepare a prospectus of your proposed dissertation. You are considered to have demonstrated in-depth knowledge of at least one area of application, together with the ability to identify both unsolved problems and worthwhile approaches to their solution, if you defend this prospectus successfully, thereby passing the oral part of the DPE and indicating your aptitude and preparedness for independent research. See Sections 5.3.2 and 6.3.

1.2.3 You are considered to have demonstrated proficiency in a minor area of study if you have completed six semester hours in an approved mathematics related minor with a grade point average (GPA) of at least 3.0. But see Section 7.1.2.

1.2.4 You are considered to have demonstrated significant teaching experience if you have taught for at least two semesters. Note, however, that if English is not your native language then you cannot teach unless you have first of all demonstrated an acceptable standard of spoken English (which is technically an admissions requirement, even though you may not actually fulfill it until you are here).

1.2.5 You demonstrate a degree of commitment to the mission and integrity of the academic community by – in addition to all the above – attending colloquia regularly and abiding by the Academic Honor Code (see pp. 34-35 of the 1993/1995 *FSU Graduate Bulletin*) throughout your graduate studies.

1.2.6 You are considered to have reading knowledge of French, German or Russian if you pass the corresponding reading examination. See the *FSU Graduate Bulletin*.

1.2.7 You have satisfied all other university and college requirements if you are in compliance with the regulations described on pp. 26–41 and pp. 75-76 of the 1993/1995 *FSU Graduate Bulletin*. Note in particular the residency requirement. Having either completed 30 semester hours of graduate work or obtained a master's degree, you must be continuously enrolled on the FSU campus for a minimum of 24 semester hours in any period of 12 consecutive months. The intent of the residency requirement is to ensure that you contribute to, and benefit from, the full spectrum of FSU's educational, professional and enrichment opportunities. Note also the time limit: all requirements for the doctoral degree degree must be met within 5 calendar years of passing the DPE; otherwise you will be required to take and pass the DPE again.

1.3 Areas of Specialization for Master's Degree or Doctorate

Currently, you may write a Ph.D. dissertation or master's thesis in any of the following areas of specialization, with one of the faculty in parentheses as major professor. Subject to these constraints, it is your responsibility both to find a topic on which you want to work and to find a major professor with whom you want to work, and who is willing to work with you; see Section 4.2. For further details of faculty and their research projects, see Appendix A (and consult the relevant members of faculty).

1.3.1 Computational mathematics;

Computational fluid dynamics and acoustics (Professor Tam)
Computing applications to physical systems (Professors Hunter, Kopriva, Loper, Magnan, Navon and Tam)
Finite element method (Professor Navon)
Multidomain spectral methods (Professor Kopriva)
Numerical optimization (Professor Navon)
Physical computation by adaptive nonlinear computational networks with emergent properties (Professors Howard and Magnan)
Vectorized and parallel computing (Professor Magnan)

1.3.2 Fluid dynamics

Acoustics and jet noise (Professors Tam and Young)
Dynamics of partially solidified systems (Professor Loper)
Hydrodynamic stability (Professor Howard)
Rotating flows (Professor Howard)
Slow viscous flows (Professor Blumsack)
Topographical effects in rotating fluids (Professor Blumsack)
Turbulence (Professors Howard and Tam)

1.3.3 Geophysics and Astrophysics

Evolution and structure of earth's core and mantle (Professor Loper)
Galactic dynamics (Professor Hunter)

1.3.4 Methods of applied mathematics

Asymptotic analysis (Professor Hunter)
Bifurcation theory (Professor Magnan)
Game theory and applications (Professor Mesterton-Gibbons)
Nonlinear dynamics and chaos (Professor Magnan)
Nonlinear waves (Professor Howard)
Partial differential equations (Professor Young)
Perturbation theory (Professor Hunter)

1.3.5 Theoretical biology;

Ecology and Evolutionary Biology (Professor Mesterton-Gibbons)
Neural networks (Professor Magnan)

2
Your First Semester

2.1 Adapting to Your New Environment

2.1.1 Familiarizing yourself with your inanimate surroundings. The day you arrive in the Mathematics Department, you should find out where your office is and obtain a key for it from Lynn Hobby in Room 208 of the Love Building. You have a mailbox in 208 Love, and you are expected to check it daily. You also have a computer account and electronic mail address; see Appendix B. Later in the semester (but as early as possible) you should familiarize yourself with the library system – not just where it is but how to use it (see Appendix C) – and similarly for the computing system.

2.1.2 Telephone-number prefixes. All telephone numbers (such as those listed in Sections 2.1.3 and 2.1.4) should be preceded by 4 when dialled on campus, by 644 when dialled from elsewhere within the Tallahassee area, and by 904 644 when dialled from elsewhere in the United States.

2.1.3 Faculty, students and staff. You should get to know the faculty and other students as soon as possible; they are all your colleagues. Every professor is a potential advisor, every student a potential collaborator for a research project. Consult the departmental staff for help with administrative problems, about which they are very knowledgeable. Currently the program has ten faculty and the department has ten staff, as follows:

FACULTY MEMBER	TITLE	OFFICE	PHONE
Blumsack, Steven L.	Associate Professor	105D LOVE	2488
Howard, Louis N.	Professor	118 LOVE	8707
Hunter, Christopher	Professor, Chairman, and Director of Applied Mathematics	227 LOVE	8704
Kopriva, David	Associate Professor	002E LOVE/450 SCL	7196/7037
Loper, David E.	Professor	018 KEEN	6467
Magnan, Jerry F.	Associate Professor	121 MCH/471 SCL	8966
Mesterton-Gibbons, Michael P.	Associate Professor	105B LOV	2580
Navon, I. Michael	Professor	111 LOV/415 SCL	7405/6560
Tam, Christopher K.W.	Professor	314 LOV	2455
Young, Eutiquio C.	Professor	318 LOV	6419

STAFF MEMBER	OFFICE	PHONE	AREAS OF SPECIALIZATION
Sharon Austin	225 LOVE	5868	Academic Support Program Coordinator
Karen Ball	225 LOVE	8716	Program Assistant
Sheila Bernstein	224 LOVE	8714	Office Manager
Mickey Boyd	004B LOVE	7167	Computer Systems Administrator
Charlene Hall	115L MCH	3768	Office Assistant
Lynn Hobby	208 LOVE	2202	Sr. Clerk
Amber Jessup	208 LOVE	2205	Receptionist
Kelly D. Lee	205D LOVE	8708	Sr. Word Processor
Chris Noakes	205D LOVE	8708	Sr. Fiscal Assistant
Melissa Smith	205B LOVE	4053	Sr. Art/Publication Production Spec.: TeX

2.2 Preparing To Be a Graduate Student

You are expected on arrival to know calculus, linear algebra, some differential equations, some numerical analysis and a programming language, and to have some experience of mathematical modelling – altogether, you are expected to have taken the equivalents of at least the following courses (described in more detail on pp. 272-273 of the 1993/1994 *FSU General Bulletin*): Complex Variables (MAA 4402), Numerical Analysis I (MAD 3703), Ordinary Differential Equations (MAP 3302), Mathematical Modelling (MAP 4103) and Applied Linear Algebra (MAS 3105). For fluid dynamics, you are also expected to have taken the equivalents of General Physics (PHY 3048-9C) and Vector Calculus with Introduction to Tensors (MAP 4153). Any deficiencies in this regard must be identified and remedied at the earliest opportunity; see Section 2.2.1. The effect of a deficiency will depend on the degree you are seeking. For example, if you wish to obtain a Master's in Computational Mathematics within the target time of 2 years (Section 3.4.2), then you will need to have taken not only the above courses but also the equivalents of at least Elementary Partial Differential Equations I-II (MAP 4341-2) and Numerical Analysis II (MAD 4704) when you enter the graduate program.

2.2.1 Initial advisement. During your first week at FSU you must meet with the Applied Mathematics Advisory Committee for an initial discussion of your program of study. Unless you are a research assistant, members of this committee will act as your supervisory committee (Section 4.2) during your first year of graduate study; moreover, if you are a terminal master's student who is not writing a thesis then they will act as your supervisory committee during the second year as well. The committee will assess your background in applied mathematics, decide whether any remedial courses are necessary, and offer you advice on planning your course of studies (including, in particular, which courses to take during your first semester). Research assistants are normally advised by the professors for whom they are working.

2.2.2 Minimum and maximum course loads during Fall or Spring semester. If you are being supported as a research assistant (RA), then a minimum course load is 12 semester hours. If you are being supported as a teaching assistant (TA), then a minimum course load is 9 semester hours. Lighter course loads ("underloads") require special approval from the Dean of Arts and Sciences (request a *Graduate Student Underload/Overload Permission* form). Likewise, more than 15 semester hours is technically an overload, and also requires written approval (same form). Note that minimum course loads are lower during the summer term; 6 semester hours for a teaching assistant and 9 for a research assistant are typical, but the precise numbers depend on the economy.

2.3 Preparing To Be a Research Assistant

If you are being supported as a research assistant (RA), then you should see your employer as soon as possible after arrival (and certainly within your first week) for initial assignment of duties and hours of work, etc.

2.4 Preparing To Be a Teaching Assistant

2.4.1 Initial advisement. If you are being supported as a teaching assistant (TA), then you are ordinarily required to work 20 hours a week in teaching or related duties, e.g., grading papers. You should see Professor McWilliams in 221 Love as soon as possible after arrival (and certainly within your first week) for initial advisement of duties.

2.4.2 SIRS forms. If you are teaching during your first (or any subsequent) semester then your students must be given the opportunity to evaluate you by filling out SIRS (Student Instructional Ratings Service) forms. Instructions on how to obtain and administer these forms – which is your responsibility – will appear in your mailbox quite early in the semester.

3
Planning Your Course of Studies

Time does not stand still, so don't waste it: Start planning your course of studies right away. In any event, the department requires you during your first semester to complete a form, either the *Tentative Program of Studies Toward Master's Degree in Mathematics* or the (tentative) *Doctoral Program of Studies in Mathematics,* depending of course on whether you have been admitted as a master's or doctoral student. So you have no choice but to think ahead. Start thinking about research, even if you are only a master's student, because then you retain the option of either taking the MCE or submitting a thesis; see Sections 1.2.2 and 6.2. Moreover, you retain the option of switching to the Ph.D. track if you later discover that research is your element. Thinking about research implies talking to the faculty, reading lots of books and papers and going to as many talks as possible; many projects arise out of chance conversations, so make sure that you have plenty of them. Eventually, you must find both a topic for your dissertation or thesis and a major professor who agrees to supervise your work on that topic. Then you need to assemble the rest of your supervisory committee (Section 4.2); don't forget that your initial advisors are only temporary.

To help you plan ahead, there follows a list of courses in applied mathematics, together with typical schedules for meeting the target dates of two years for a master's degree or five years for a Ph.D. The courses listed in these schedules are only suggestions and much variation is possible, subject to constraints in the *FSU Graduate Bulletin* (principally, that the course is offered when you want to take it, that you have the prerequisite(s), and that you end up satisfying all degree requirements). Any number of reasons might cause you to fall behind the target dates; after all, research would not be research if you could guarantee to complete it within a given period of time. But bear in mind that only in special circumstances will the department sponsor you as a teaching assistant for more than five years.

Information about the scheduling of classes for a given semester appears in the *FSU Directory of Classes* for that semester.

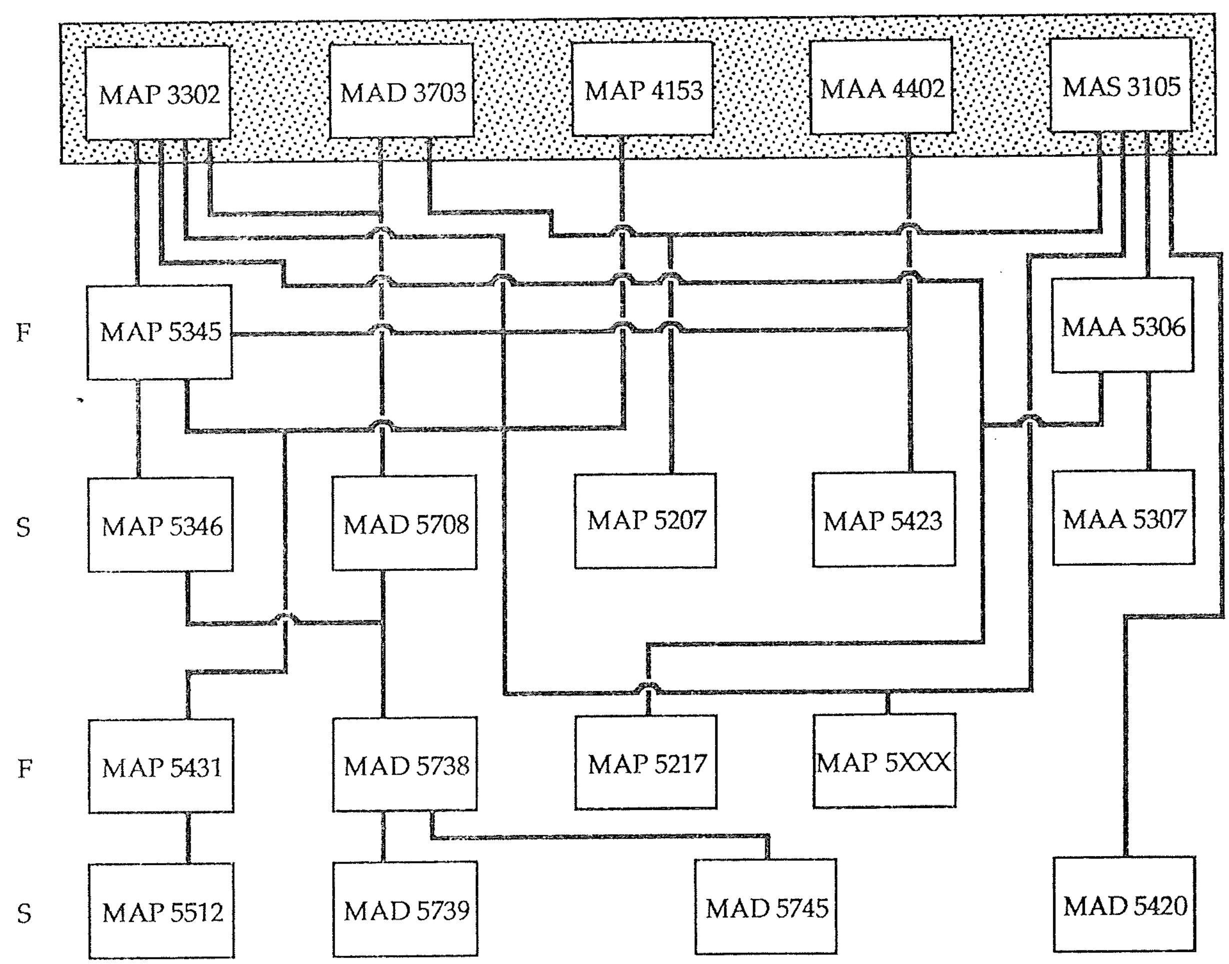
3.1 Regular Courses

Regular courses – whose syllabi appear in the 1993/1995 *FSU Graduate Bulletin* (p. 270) – and their frequencies are listed on the following page, where F = Fall, S = Spring, Su = Summer, 2 = every two years, V = variable. The flowchart indicates the principal relationships between these courses and their prerequisites. The shaded rectangle shows some mathematics courses at the bachelor's level; these courses, or their equivalents, are the background required on entry to the program:

MAA 4402 Complex Variables
MAD 3703 Numerical Analysis I
MAP 3302 Ordinary Differential Equations
MAP 4153 Vector Calculus With Introduction to Tensors
MAS 3105 Applied Linear Algebra I

Syllabi for these courses appear in the 1993/1994 *FSU General Bulletin* (pp. 272-273).

Number	Title	Offered
MAA 5306	Advanced Calculus I	FS
MAA 5307	Advanced Calculus II	S, Su
MAD 5420	Numerical Optimization	S
MAD 5708	Numerical Analysis II	S
MAD 5738	Numerical Solution of Partial Differential Equations I	F
MAD 5739	Numerical Solution of Partial Differential Equations II	S
MAD 5745	Spectral Methods for Partial Differential Equations	2
MAP 5207	Optimization	S
MAP 5217	Calculus of Variations	F
MAP 5326	Theory of Ordinary and Partial Differential Equations	V
MAP 5336	Qualitative Theory of Ordinary Differential Equations	2F
MAP 5345	Elementary Partial Differential Equations I	F, Su
MAP 5346	Elementary Partial Differential Equations II	S
MAP 5395	Finite Element Methods	2F
MAP 5423	Complex Variables, Asymptotic Expansions and Integral Transforms	S
MAP 5431	Introduction to Fluid Dynamics	F
MAP 5441	Perturbation Theory	F
MAP 5512	Hydrodynamic Stability	2
MAP 5513	Wave Propagation Theory	2
MAP 5XXX	Mathematical Bioeconomics	V



3.2 Special Topics Courses

In addition, the following special topics courses are offered from time to time. Note that the same course numbers may be used for quite different topics on different occasions. For example, topics taught under MAP 6437r in recent years have included mathematical bioeconomics (Summer 1990), Hilbert spaces and differential operators (Summer 1991), applications of Hilbert spaces to quantum mechanics (Summer 1992) and Monte Carlo methods (Summer 1993). Planned future topics include parallel algorithms.

Number	Title
MAD 6408r	Advanced Topics in Numerical Analysis
MAP 6316r	Advanced Topics in Differential Equations
MAP 6434r	Advanced Topics in Hydrodynamics
MAP 6437r	Advanced Topics in Applied Mathematics

3.3 Directed Individual Study (DIS)

If you have particular interests or projects outside the scope of the regular curriculum, then you may arrange with some faculty member to receive direction and credit for your work. The procedure for this is to submit a *DIS Approval* form for one of the following two courses:

MAT 5907r	Directed Individual Study for Master's Degree
MAT 6908r	Directed Individual Study for Ph.D.

You may use a DIS course for extended reading on a particular topic or in a particular field of applied mathematics, and the credit hours earned may be used to satisfy course load and graduation requirements.

First, however, you must find a professor who is willing to direct your work. In this regard, you should bear in mind that DIS courses involve faculty in additional work over and above normal teaching loads: The more complete your idea of what you wish to accomplish and the higher the reputation you have established as a graduate student, the greater your chance that the professor you approach will agree to direct you. Professors vary in their methods of handling a DIS – some require weekly meetings, whereas others prefer written reports or meetings on a less frequent basis – and so an acceptable arrangement must be mutually agreed upon in each individual case.

In any event, the grade assigned for a DIS is either S for satisfactory or U for unsatisfactory.

3.4 Schedule Samples

The following are samples of schedules that could be followed to achieve the master's degree within the target time of two years or the doctoral degree within the target time of four years. Additional course definitions as follows:

MAT 5946r	Supervised Teaching
MAT 5911r	Supervised Research
MAT 5971r	Master's Thesis
MAT 6980r	Dissertation for Ph.D.
MAT 8964	Doctoral Preliminary Examination
MAT 8966	Master's Comprehensive Examination
MAT 8976	Master's Thesis Defense
MAT 8985	Defense of Dissertation

3.4.1 M.S. in applied mathematics by coursework: Sample target schedule

YEAR	FALL SEMESTER		SPRING SEMESTER		SUMMER SEMESTER
1.	MAA 5306	(3)	MAA 5307	(3)	Two electives (6)
	MAP 5345	(3)	MAD 5708	(3)	
	MAT 5946r	(3)	MAP 5346	(3)	
2.	MAD 5738	(3)	MAP 5207 or		
	MAP 5431	(3)	MAD 5420	(3)	
	Elective	(3)	MAP 5423	(3)	
			MAT 8966	(0)	

3.4.2 M.S. in computational mathematics by coursework: Sample target schedule

YEAR	FALL SEMESTER		SPRING SEMESTER		SUMMER SEMESTER
1.	MAD 5738	(3)	MAD 5739	(3)	Two electives (6)
	MAP 5217	(3)	MAP 5423	(3)	
	MAT 5946r	(3)	MAD 5420	(3)	
2.	MAP 5431	(3)	MAD 5739	(3)	
	MAP 5441	(3)	OCP 5253	(3)	
	MAD 5745	(3)	Elective	(3)	
			MAT 8966	(0)	

3.4.3 Master's by thesis: Sample target schedule

YEAR	FALL SEMESTER		SPRING SEMESTER		SUMMER SEMESTER
1.	Two courses (9)		Three courses (9)		One course (3)
	MAT 5946r	(3)			MAT 5907r (3)
2.	Two courses (9)		One course	(3)	
	MAT 5971r	(3)	MAT 5971r	(6)	
			MAT 8976	(0)	

3.4.4 Ph.D.: Sample target schedule for students entering with a master's degree in mathematics

YEAR	FALL SEMESTER		SPRING SEMESTER		SUMMER SEMESTER
1.	Two courses MAT 5946r	(6) (3)	Three courses	(9)	MAT 5907r (6)
2.	Three courses	(9)	Three courses MAT 8964, I	(9) (0)	MAP 6437r (3) MAT 5907r (3)
3.	MAT 5911r MAT 8964, II	(9) (0)	MAP 6939r MAT 6980r	(1) (8)	MAP 6437r (3) MAT 6980r (6)
4.	MAP 6939r MAT 6980r	(1) (8)	MAP 6939r MAT 6980r MAT 8985r	(1) (8) (0)	

3.5 Colloquia and Seminars

The department expects you to attend colloquia and seminars regularly. You are encouraged to attend both the departmental colloquium on Fridays at 3:30 p.m. in 101 Love and the advanced seminar in either applied mathematics or scientific computing (both listed as MAP 6939r), or an equivalent, whenever they are held. In any event, if you have already passed the Doctoral Preliminary Examination then you are actually required to enroll for the advanced seminar whenever it is held while you are in residence; see Section 5.3.3.

4

Beyond Your First Semester

Some things you did in your first semester may never have to be done again, e.g., familiarizing yourself with the library and computer system; and some things you did in your first semester must always be repeated every semester, e.g., satisfying course load requirements, attending colloquia regularly and administering SIRS forms (whenever you are teaching). By contrast, this and the following section are mainly about isolated events beyond your first semester.

4.1 What Constitutes Normal Progress?

By the start of your second year, you should have found a permanent major professor (Section 4.2.1.) and a supervisory committee (Section 4.2.2); if you haven't, then you are not making normal progress. You should see your major professor at least once a semester to discuss your progress and revise, if necessary, your program of studies. Thus, to a large extent, you are making normal progress if your major professor says you are. Following the schedules in Section 3.4 would certainly be regarded as normal progress.

In any event, the program is designed so that the normal time for a well qualified Fall entrant either to take the Master's Comprehensive Examination (MCE) or to defend a master's thesis is toward the end of the second year; and then Part 1 of the Doctoral Preliminary Examination (DPE) toward the end of the third year if continuing in the Ph.D. program. Entrants who already have a master's degree in mathematics must take Part 1 of the DPE during their second year in the program. The program is also designed so that financial support is necessary for no more than five academic years, and only in special circumstances is support extended for a longer period.

You should therefore strive to keep as close as possible to the target times of two years for a master's degree and five years for a Ph.D. Nevertheless, there are several reasons why you might fall behind the schedules set in Section 3.4. For example, the target schedule for a master's in computational mathematics assumes a year of numerical analysis and partial differential equations at the senior level; if you haven't already taken these courses, then completing the degree may take you as much as an additional academic year. Even if you defend your Ph.D. prospectus on schedule, your research may take longer than the time allotted in Section 3.3.4 – research would not be research if its completion date could be predicted with certainty!

4.2 Your Supervisory Committee

During their first year, all new students have the same supervisory committee, one of whom acts as temporary major professor; see Section 2.2.1. This arrangement is temporary, and expires at the end of the first year. By that time you should have found yourself a permanent major professor.

4.2.1 Choosing a major professor. A good relationship with your major professor is critical to the success of your graduate studies. It is therefore vital that you make an informed decision concerning whom you would like to direct your studies. Find out as much as possible about who the faculty are (see Appendix A) and what they do (read their publications) before asking one of them to be your major professor. Remember, however, that few professors will be inclined to agree until they know you well enough for you to make a favorable impression on them. So make one! (Section 7 contains some pertinent advice).

4.2.2 Completing your committee. Regardless of whether you are a master's or a Ph.D. student, you will need at least two additional committee members. If you are a master's student, then at least one of the two additional members must be a math professor (and both must have master's directive status). If you are a Ph.D. student, then at least one of the two additional members must belong to a separate department within the College of Arts and Sciences - i.e., must NOT be a math professor (and both must have doctoral directive status). A good relationship with committee members is also important to the success of your graduate studies, and so the above remarks still apply.

In any event, you must submit either the *Master's Supervisory Committee* form or the *Doctoral Supervisory Committee* form, whichever is appropriate.

4.3 Revising Your Plans

Although your program of studies must be kept up to date, you can change it at virtually any time – provided you first obtain your major professor's signature of approval. (Don't forget to complete a *Drop/Add Permit* where necessary.) There are several reasons for changing plans. For example, you may have begun your graduate studies as a Ph.D. student but wish to become a master's student, or vice versa; or you may have failed to pass Part 1 of the DPE outright (Section 5.3.1) and wish to adapt your schedule to this circumstance. In either case, you should discuss the matter with your major professor.

Again, while studying for the doctorate, you may lose interest in one subject and become enthusiastic about another, and therefore need to change your major professor (and perhaps some other members of your committee); or your relationship with your major professor may prove unsatisfactory for a variety of administrative or personal reasons. In either case, you should bear in mind that neither your commitment to conduct research under a given faculty member nor the faculty member's commitment to serve as your major professor is binding (and the procedure for finding replacements is the same as in Section 4.2).

5
Examinations

For the MCE or Part 1 of the DPE, copies of past examination papers can be obtained from the Director of Applied Mathematics. If you would like to review prospectuses written by previous graduate students, then it is best to request them from individual faculty members. Successfully defended theses and dissertations are available in the Dirac Science Library.

5.1 Master's Comprehensive Examination (MCE)

The MCE is set once a year toward the end of the Spring semester. It consists of two written papers (set on separate, usually consecutive, days) consisting of questions on analysis, numerical analysis and methods of applied mathematics. Approximately two-and-a-half hours are allowed for each paper. To be adequately prepared for this examination, you should have taken at least MAA 5306-5307, MAD 5708, MAP 5207, MAP 5345-5346 and MAP 5423, or their equivalents.

To pass the examination outright, you must perform satisfactorily in both papers; otherwise the examiners may require you to retake one or both papers the following year. Papers may be retaken no more than once.

5.2 Master's Thesis Defense

Your major professor should receive a copy of your master's thesis at least a month in advance of your defense. After making any necessary changes, you should provide all committee members with a revised copy of your thesis at least one week prior to the date of the defense.

Your defense consists of an oral presentation, usually lasting about 45 minutes, followed by an oral examination. All faculty and students – not just your committee – are invited to attend the presentation and pose questions afterwards as part of the oral examination. Although any question falling within your general area of study is legitimate, questions typically arise from the thesis itself. Both the presentation of your work and your response to any questions will be taken into account in deciding whether to approve your thesis.

The result of this decision must be communicated immediately to the departmental office through submission of an *Examination Results* form.

5.3 Doctoral Preliminary Examination

The Doctoral Preliminary Examination (DPE) consists of two parts, a written examination and an oral examination (concerning the defense of a prospectus)

5.3.1 Written Examination. Currently, the written part of the DPE (Part 1) is set toward the end of the Spring semester. It consists of three papers (taken on separate days):

1. Analytical Concepts and Methods
2. Formulation, Modelling and Applications
3. Numerical Concepts and Methods

To be adequately prepared for the examination, you should have taken at least the required master's curriculum.

To pass the examination outright, you must perform satisfactorily in all three papers; otherwise the examiners may require you to retake one or more papers the following year. Papers may be retaken no more than once.

If at your last (whether first or second) attempt you narrowly fail to pass all three papers, then the examiners may recommend the award of a master's degree without further examination. If, however, the examiners decide that you failed Part 1 of the DPE by a wide margin, then even to obtain a master's you must still take the MCE (as well as any regular courses you may still require to qualify).

5.3.2 Oral Examination. Having passed Part 1, you immediately get down to finalizing your research topic and preparing a prospectus; see Section 6.3. This prospectus should contain an overview of your area of study – enough to convince the reader that you are familiar with all important work that has already been done in the area – and identify the particular problem(s) you propose to work on, thoroughly justifying the time and effort you propose to expend. As you explore your area of study you may wish to increase the size of your committee to 4-6 individuals by adding faculty with relevant expertise.

The oral part of the DPE (Part 2) consists of defending the prospectus in front of your (recently expanded) committee, each of whom should receive a copy of your prospectus at least one week prior to the date of the examination. As in the case of a master's thesis, the defense consists of an oral presentation followed by questions from your committee; again, although most questions are likely to arise from the prospectus itself, any question that falls within your general area of study is legitimate.

Both the presentation of your work and your response to any questions will be taken into consideration in deciding whether to approve your prospectus. If you fail to obtain your committee's approval, then you will be allowed one further opportunity to retake Part 2 of the DPE at a later date, after suitably revising your prospectus and arranging a second defense.

5.3.3 Examination result. If your committee approves your prospectus, then your grade for the DPE is P for Pass. If your committee fails to approve your prospectus, then your grade for the DPE is I for Incomplete. This result must be communicated immediately to the departmental office through submission of an *Examination Results* form.

Having passed Part 1, you are absolutely required to enroll in MAP 6939r, or an acceptable equivalent, for at least three semesters.

5.4 Doctoral Dissertation Defense

After you have completed your dissertation (Section 6.4) you must defend it at an oral examination, to be presided over by your major professor. This examination must take place at least two weeks prior to graduation, at a time to be arranged in consultation with your major professor.

At least two weeks prior to the date of the examination, you must submit an abstract of your dissertation (Section 6.1.1), a list of committee members and an announcement of the dissertation title and date, time and place of examination to the Office of Graduate Studies in Room 408 Westcott, who will announce your defense to the university at large. All members of the graduate faculty are invited to attend.

All members of your supervisory committee should receive a copy of your Ph.D. dissertation (Section 6.4) at least one month in advance of your defense. After a mutually agreed time has elapsed, you should check with all committee members for any criticisms they may have. After making any suggested changes, you should provide each committee member with a revised copy of your dissertation and abstract at least one week prior to the date of the defense.

The defense itself consists of an oral presentation, usually lasting about an hour, followed by an oral examination to which the remarks in Section 5.2 are still applicable. Again, both the presentation of your work and your responses to questions will play a role in deciding whether the committee approves the dissertation. The result of this decision must be communicated immediately to the departmental office through submission of an *Examination Results* form.

If you fail to obtain your committee's approval, then you will be allowed one further opportunity to retake this examination at a later date, after suitably revising your dissertation and arranging a second defense.

6

Writing a Thesis, Prospectus or Dissertation

If you conclude your graduate studies at FSU with a master's by coursework, and if no course you take includes a project as part of its requirements, then you may never need to produce a typed manuscript for examination; but in all other circumstances you will have to do so at least once. For a master's by thesis you will have to produce the thesis, whereas for a Ph.D you will have to produce both a prospectus and a dissertation. This section contains advice on all three kinds of manuscript. A thesis or dissertation must, of course, be produced in accordance with university and college degree requirements: see Section 9.1 and the *FSU Graduate Bulletin.*

If you embark on a research career, then at some stage you will begin to submit work to journals for publication. In a sense this is also producing a manuscript for examination, and so many of the following remarks still apply; but in this case it is best to consult your major professor for specific advice – especially since requirements vary so greatly from journal to journal. One general piece of advice, however, is to browse through the most recent three or four volumes of the journal to which you plan to submit your work, and then adapt your paper to conform in style and presentation to those you see published.

6.1 General Requirements

6.1.1 Abstract. Every thesis or dissertation must include an abstract, i.e., a concise but independently intelligible summary of the contents of the work, normally placed just prior to the first page of text. Provided it is concise, there is no formal limit to its length.

In addition to the above abstract, which forms an integral part of the thesis or dissertation, a second independent abstract limited to 250 words must be submitted to the Graduate Office in Room 408 Westcott for use by FSU. If the thesis or dissertation abstract is 250 words or less in length, then with appropriate reformatting it may also be used for the FSU abstract.

6.1.2 Format and style. You should consult your major professor about the format and style of your work. Whatever style is chosen, however, must be consistent with FSU clearance guidelines, as described in the brochure *Guidelines and Requirements for Thesis, Treatise and Dissertation Writers,* a copy of which may be obtained from the Graduate Dean's office in Room 408 Westcott.

6.1.3 Thesis or dissertation credits. Writing a thesis or dissertation counts toward your course load for graduation; see Section 3.4. You must register for MAT 5971r during any semester in which you do a substantial amount of work toward a master's thesis, and for MAT 6980r during any semester in which you do a substantial amount of work toward a Ph.D. dissertation.

A minimum credit of 6 semester hours in MAT 5971r is required for a master's thesis, and a minimum credit of 24 semester hours in MAT 6980r is required for a Ph.D. dissertation.

6.2 Master's Thesis

To obtain a master's degree by thesis you must carry out an independent research project and prepare a thesis – that is, a written account of your research and its results – under the supervision of your major professor. Your thesis should ideally contain the following:

(i) A clear statement of the problem you address and its significance.
(ii) A review of related published work.
(iii) A review of mathematical techniques and terminology.
(iv) A thorough presentation of your solution.
(v) A discussion of your results and a critique of their impact on your field of study.
(vi) A summary of what was original and significant in your thesis, together with suggestions for future work.

Nevertheless, it is not essential (though of course desirable) that your results be original: a work of the survey type, whose originality lies in the synthesis of known (but widely scattered) results – as opposed to in the results themselves – is acceptable for a master's degree (but not a doctorate). Broadly speaking, such a thesis would place greater emphasis on (i) and (ii) and replace (iv) by a discussion of the difficulties encountered in attempting to obtain a solution.

6.3 Ph.D. Prospectus

Before you can begin to work in earnest on your doctoral dissertation, you must prepare a prospectus, i.e., a written outline of your proposed research. This prospectus should describe the problems you hope to address and their significance, provide sufficient background material to convince your committee that the research is worth doing (and has not already been done), and demonstrate convincingly that you have both the mathematical skills and the in-depth knowledge of your field of application to undertake the research. You must defend this prospectus in front of your committee at Part 2 of the DPE; see Section 5.4.

One piece of advice: review prospectuses of previous graduate students (request them from individual faculty members) to form an impression of what will constitute an acceptable outline of research.

6.4 Ph.D. Dissertation

To obtain the doctoral degree, you must complete a dissertation on a mathematical topic in your area of specialization. To be acceptable, it must be an original research achievement; it must constitute a significant contribution to knowledge; and it must represent substantial scholarly effort on your part. Whether your dissertation meets these standards is a matter to be decided by your supervisory committee.

Your dissertation will ordinarily contain the following information (though not necessarily in quite the following order):

6.4.1 Introduction. Your dissertation should begin with a clear statement of the problem you address, its significance, the scope and originality of your solution, and a brief chapter-by-chapter guide to the organization of your work.

6.4.2 Review of the literature. A thorough survey of pertinent published work on your subject not only places your problem in context, but also provides criteria for judging the originality of your results.

6.4.3 Mathematical background. Not everyone who reads your dissertation will be as familiar as you are with the mathematical methods, notation and terminology you employ, and so an early chapter of your dissertation should review them. Not only will this review make your dissertation more accessible to your reader, but also writing the review will help to clarify your understanding of the material.

6.4.4 Physical, biological or engineering background. Again, not everyone who reads your dissertation will be as familiar as you are with your field of application, and so an early chapter of your dissertation should survey pertinent material.

6.4.5 Presentation of original work. Your original contribution is the heart of your dissertation. You should describe it thoroughly, clearly identifying original results by stressing differences with previous related work.

6.4.6 Critique. You should evaluate your work and assess its impact on your field of study at large. Be honest and objective. You should claim to have accomplished neither more nor less than is actually the case.

6.4.7 Summary and outlook. Your dissertation should conclude with a concise summary of your most important results, again distinguishing original results from those that were previously known, and offer suggestions for future research in your area.

7

Getting the Most Out of Your Graduate Studies

What you get out of your graduate studies depends entirely on what you put into them. The ultimate value of your graduate education at FSU is less your degree than the intangible benefits that accompany it – the intellectual maturity you develop and the professional relationships you establish (neither of which is recorded on your certificate at graduation). Indeed if all you do to obtain your degree is satisfy the graduation requirements listed in the *FSU Bulletin*, then you may have wasted a golden opportunity. The academic community offers you tremendous resources for personal and professional development, but it is your responsibility to exploit them while you are here. This section offers advice.

7.1 Becoming a Scholar

All scholars must read widely, both within their field of specialization and without – but it is especially important for applied mathematicians to read widely in other areas, because good applied mathematics is also good science. No matter how talented you are mathematically, you cannot do good physical modelling – whether in aeroacoustics, galactic dynamics, mechanical engineering, meteorology or oceanography – unless you are also a competent physicist. Regardless of how much mathematics you know, you cannot do good biological modelling – whether in physiology, population biology, or structural biology – unless you are also a competent biologist. And so on. So you must study widely throughout your time in graduate school (and beyond).

7.1.1 Reading comprehensively. At no time is comprehensive reading across the sciences more important than during your first year in graduate school (though it continues to be important throughout your academic career). This is the time when you need to discover which outstanding scientific problems most capture your interest, so that you can identify a field of study and make it the focus of subsequent research. A good choice of specialization – one that is right for you – is critical to your academic success in later years, and so time spent in making this choice is time well invested. Recommended journals include *American Scientist, Nature, Science* and *Scientific American* and. For book recommendations, consult individual members of faculty.

7.1.2 Making good use of your minor. Choose courses in your minor area of study (Section 1.1.4) for their ultimate value – the perspective they offer on a separate field of study – and not for the ease with which graduation requirements can be fulfilled. Remember that 6 semester hours is merely the minimum number of credits, and that additional courses may be valuable – both for their intrinsic merit and for the contacts you develop with faculty in a separate department. Your major professor is the person to contact for advice in this regard.

7.2 Broadening Your Professional Horizons

7.2.1 Joining a Professional Society. Membership of a professional society will boost your career prospects by keeping you abreast of trends in your field and the employment opportunities that accompany them. Membership can be especially good value for graduate students, whose subscription rate is typically much less than 50% of the regular one. Subscriptions include journals and newsletters to keep you up to date in applied mathematics as well as discounts on books and conference fees. Societies you should consider joining include the Society for Industrial and Applied Mathematics (SIAM), the Society for Mathematical Biology (SMB), the American Physical Society (APS) and the American Institute of Acoustics (AIA). For details of membership, consult members of faculty.

7.2.2 Going to Conferences. Going to conferences is an excellent way to find out what is happening in your field and to meet the people who are making it happen. It doesn't have to be expensive (especially if you belong to a professional society): greatly reduced conference fees are the norm for graduate students, and travel and accommodation costs can be kept to a minimum by sharing. Consult your major professor for conference suggestions.

7.2.3 Doing an Experiment. Applied mathematics is often most effective and most impressive when done in conjunction with an experiment. Several departments at FSU offer opportunities for collaboration with experimenters, e.g., the Geophysical Fluid Dynamics Institute, and the Department of Mechanical Engineering. So think about doing an experiment – talk to individual faculty members about the possibilities.

8

Recreational Activities

Tallahassee and FSU offer a variety of recreational activities; and if you cannot find what you like locally, you probably won't have to travel too far.

FSU sponsors intramural sporting events every semester. Among the many sports offered are softball, flag football, basketball, soccer, volleyball, tennis, and track. For most of these, the math department fields teams consisting of faculty and graduate students. (It's a good thing we have jobs to do; athletes we ain't!).

The new Bobby E. Leach Center on campus has a *fully* equipped weight room, bicycle and stair machines, indoor track, aerobics classes, indoor pool, sauna and whirlpool, racquetball, squash, volleyball, basketball and badminton courts and ping-pong tables. This facility is free to students. Also on campus there are tennis courts and outdoor racquetball courts, a pool and a running track.

The FSU Reservation, located just a few miles from campus, offers facilities for swimming, sailing, canoeing and picnics, as well as an occasional free concert. Admittance is free to students, but there is a small boat rental fee.

If you like hiking, there are nice trails around the Leon Sink Holes, just 15 minutes away. For cyclists, there is a 16-mile bike trail from Tallahassee to St. Marks on the coast.

In addition to several city parks, there are many state and national parks nearby. Wakulla Springs and the St. Marks Wildlife Refuge are within 20 minutes of Tallahassee. There are beautiful beaches along the Gulf Coast at St. George Island, Port St. Joe, Panama City, Fort Walton and Destin, all within 2 or 3 hours away. Besides swimming, Panama City Beach offers several additional activities. If you like to surf, there are big waves at Jacksonville Beach on the Atlantic coast, about 3 hours away. There are many more state parks nearby in Florida and Georgia.

There are many other things to do in and around Tallahassee, particularly in music and the arts, and it is hoped that future editions of this guide will describe them in detail. But first somebody must write about them from a graduate student's perspective. Would you like to volunteer?

9
Application for a Degree

During the first two weeks of the semester in which you expect to receive a degree, and prior to the deadline listed in the *FSU Directory of Classes*, you must apply for the degree at the Office of the Registrar in Room 214 of the William H. Johnston Building, Graduate Section (Phone 5850). You will receive a *Final Degree Clearance* form together with instructions on conditions to be fulfilled for the degree to be awarded. If it subsequently becomes clear that you will not complete the requirements by the end of the semester, then you should notify the Registrar and the College of Arts and Sciences as soon as possible; moreover, you must reapply for the degree during the appropriate period of the following semester (or the semester in which you subsequently plan to graduate, if later).

9.1 Degree Requiring a Thesis or Dissertation

For a Ph.D. or master's by thesis, early in the term of graduation you should obtain from the Manuscript and Final Clearance Advisor in Room 408 Westcott a copy of the brochure *Guidelines and Requirements for Thesis, Treatise, and Dissertation*

Writers, together with a set of forms described therein and to be completed prior to graduation. In particular, your thesis or dissertation must be approved by the Office of Graduate Studies (located in Room 408 Westcott). The procedure you must go through to obtain this approval is described in detail in the brochure.

9.1.1 Minimum credit for thesis or dissertation in term of graduation. For a Ph.D. or master's by thesis, you must register for a minimum of one semester hour of (dissertation or thesis) credit during the term in which the degree is awarded, even if all requirements have already been completed in previous semesters. This credit hour is to reimburse FSU for the administrative costs of manuscript clearance and final degree procedures. Moreover, if you have not enrolled for the previous two terms then you must seek readmission before you can register for the requisite semester hour.

9.2 Receiving a doctorate at commencement

To receive a doctorate in person, you should rent cap, gown and hood from the University Bookstore at least four weeks prior to the relevant commencement ceremony. If, however, you are unable to attend this ceremony in person, then the degree can instead be awarded in absentia.

Appendix A
Faculty and Their Research Projects

(This appendix contains research summaries supplied by individual members of faculty. Note that GFDI stands for Geophysical Fluid Dynamics Institute and SCRI for Supercomputer Research Institute.)

STEVEN L. BLUMSACK, Ph. D., Massachusetts Institute of Technology, 1969. Associate Professor of Mathematics and Associate of GFDI

Mudwaves in the ocean. There exist at many locations in the ocean bottom sediment deposits that have the appearance of regular waves. Typical scales for these wavy patterns are several kilometers in wavelength and tens of meters in height. These patterns are in the form of sets of long ridges fairly evenly spaced. Several questions are natural for this situation. What determines the orientation, spacing and height of the ridges? Have these patterns reached a quasi-steady state or are they in the transient part of their development? Why do mudwaves occur in certain locations and not others?

Dr. G. Weatherly and I recently wrote a paper in which we propose a mechanism for the determination of the orientation and spacing of the ridges of sediment. The model is quite simple: small ridges produce water waves which generate preferential erosion over certain locations. Those mudwaves for which this erosion occurs over a trough will grow. There is evidence that these mudwaves migrate slowly; the model also can explain this migration. The models used thus far have been quite crude. More sophisticated models, combined with analytical, numerical and possibly experimental analysis are needed to fully understand the existence, growth and movement of these mudwaves.

LOUIS N. HOWARD, Ph. D., Princeton, 1953. McKenzie Professor of Mathematics, Associate of GFDI and Member, National Academy of Sciences.

Most of my current research is in fluid mechanics. This includes work on:

a) Turbulent convection: estimates on heat and momentum fluxes in turbulent convection with large scale flow, and attempts to understand better the structure of such flows.
b) Subcritical double diffusive convection.
c) Hydrodynamic stability: methods of determining the number of unstable modes.
d) Low Reynolds number flow: investigation of the effect of flows on the motion and orientation of small particles immersed in the fluid.
e) Certain compressible vortex flows.

In the recent past I have also worked on a number of other topics, including models related to the propagation and absorption of light in rod cells, the structure of certain polymers, techniques for determining normal forms of bifurcation problems, and a new method for solving Carleman's integral equation.

CHRISTOPHER HUNTER, Ph. D., Cambridge, 1960. McKenzie Professor of Mathematics, Chairman, Director of Applied Mathematics, and Associate of GFDI

I am interested in several problems that are related to the internal dynamics of galaxies. Galaxies are composed of very large numbers, i.e. 10^{10} to 10^{12}, of stars. On the galactic scale, the stars are essentially point masses which move, according to the laws of classical mechanics, in the gravitational field of the ensemble to which they belong. Because this ensemble consists of so many stars, the gravitational field can be calculated as that arising from a smeared-out density distribution, rather than from a set of point masses. Each individual star describes an orbit in this gravitational field. Many of the orbits are regular, though some are chaotic. Mathematically, the study of orbits involves the analysis of the orbits of the individual stars, that is of the solutions of the governing system of ordinary differential equations.

Galactic Dynamics is an exciting and attractive field to be working in nowadays. It is exciting because of the flood of new astronomical observations that are currently being made. It is attractive because only a fairly basic background in mechanics is needed to understand the fundamental issues in the subject and to get to its research frontiers. Theories are needed to make sense of the observations and relatively few theorists have ever worked in this field. And it is also a field with problems that are interesting and significant both scientifically and mathematically.

Much of my recent work has been directed towards constructing self-consistent models of elliptical galaxies. Here one needs to find out which combinations of stars in orbit reproduce the density that is needed to cause the gravitational field that one assumed in the first place when computing the orbits. Mathematically, this requires the solution of integral equations. It is challenging because of the occurrence of integral equations of kinds which are not yet fully understood. The problems are complicated by the fact that the three-dimensional shapes of most elliptical galaxies, which are seen only in projection on the sky, are probably triaxial ellipsoids, rather than rotating axisymmetric spheroids as had previously been thought. A further challenge is to build models which are consistent with observations of line-of-sight velocities. Like the distribution of light, the kinematics of a galaxy is also observed only in projection on the plane of the sky.

One of my students is studying the stability of a special class of galactic models. Stability is a fundamental requirement of any galactic model. Much more theoretical understanding of the stability of stellar systems is still needed. This topic has been explored far less than the related one of the stability of hydrodynamic flows. The major reason for this difference is that the stellar dynamic problems are harder because they arise in a phase space with twice as many dimensions as physical space. Some results on the stability of particular models have come from numerical N-body simulations, which can act as a guide to theoretical understanding, but cannot replace it.

I expect in the future to become more heavily involved with numerical N-body simulations. This is a major tool for understanding the dynamics of galaxies, as it also is for other areas of physics such as plasma physics. We have excellent computing facilities at FSU for performing such simulations which need to be done, efficiently, for large values of N. Last year, a student and I were a part of a collaboration with faculty and students at the Universities of Florida and South Florida to use N-body simulations to study collisions and mergers of galaxies.

Although Galactic Dynamics is my main current preoccupation, I have worked with former students in applied areas of analysis, such as asymptotic expansions and perturbation theory. In fact, interesting problems in both of these areas arise also in Galactic Dynamics!

DAVID KOPRIVA, Ph. D., University of Arizona, 1982. Associate Professor of Mathematics and Associate of SCRI

Multidomain Spectral Methods. Spectral methods are global approximation methods in which variables are expanded in polynomials which are the eigenfunctions of a singular Sturm-Liouville problem. The primary advantage of these expansions is the rapid rate of convergence for problems with smooth solutions. However, the global nature of the approximation can also be a drawback. In particular, it is difficult to handle complicated geometries and to resolve locally important features.

Domain decomposition is one way to avoid the disadvantages of global approximation functions. The need for global mappings is eliminated when a computational domain is broken down into several smaller subdomains. It also becomes easy to resolve important features if a solution since expansions of different orders can be used in different subdomain. The main advantage of a multidomain spectral method over the usual formulation is its flexibility allowing solution of problems with complex geometries, multiple coordinate systems, multiple solution methods and grid refinement for resolution of important features.

In the multidomain method a general domain is divided into a number of rectangular subdomains. The subdomains need not be represented in a single coordinate system and they are allowed to overlap. Each subdomain ("grid") is assigned a grid number and level. Grids on the same level have boundaries which share a common line called "patch" boundaries. Subdomains on different levels have "overlap" boundaries between them. Within each subdomain the standard collocation method is used and interface conditions are applied at the boundaries.

Chebyshev Collocation for Hyperbolic Equations. We are interested in the solution of hyperbolic systems of the form $Q_t + A(Q)Q_x + B(Q)Q_y = F$ where Q is in R^m and A and B are $m \times m$ matrices, subject to suitable initial and boundary conditions. Spectral collocation methods are powerful techniques for solving such systems. their main attraction is their high "spectral accuracy", with the error decay rate determined by the smoothness of the solution. If the solution and the coefficients are C^∞ on the computational domain then the error decays faster than any power of the reciprocal of the number of grid points. In contrast, the errors of finite difference methods decay with constant power. Furthermore, spectral methods are characterized by low dissipation and dispersion errors when compared to typical finite difference methods. For example, in wave propagation problems the waves are not seriously damped for long time integrations and that wave components travel at their correct speeds, while in steady problems in inviscid aerodynamics the errors due to implicit artificial viscosity are less important.

DAVID LOPER, Ph. D., Carnegie Institute of Technology, 1965. Professor of Mathematics, and Associate of GFDI

Convective motions within the Earth's mantle and core, induced by the gradual cooling of the Earth over geologic time, are responsible for many of the processes which shape the world in which we live: earthquakes, volcanoes, mountains, ore deposits, the geomagnetic field, etc. My research consists of the construction and verification of mathematical models of the structures and processes occurring within the mantle and core.

Core Structure and Dynamics. The Earth's magnetic field is sustained by dynamo action within the liquid outer core. Solution of the "dynamo problem" is one of the main unsolved problems of mathematical geophysics. Rather than tackle this problem head-on, I have concentrated on the energy supply for the dynamo. For many years the most favored energy supply was thermal convection in the outer core driven by cooling from above. However, it now appears that compositional convection dominates thermal convection in the outer core. Compositional convection arises as the inner core of nearly pure iron solidifies from the liquid outer core due to the slow cooling. The structure of the convective motions within the outer core driven by this mechanism is likely to be significantly different than that driven by thermal convection. The details of this motion are yet to be worked out. As the solid inner core grows, a static solution with a spherical inner-core boundary is subject to two instabilities. First is the familiar convective instability if the light fluid released at the freezing interface cannot be distributed by diffusive mechanisms. The second (morphological) instability is of the shape of the interface itself. It may be shown that a spherical inner core boundary is unstable and that the interface is likely to be a convoluted, space-filling structure.

Partially Solidified Systems. It turns out that there are surprisingly many physical situations in which a melting-freezing interface is volume-filling on the macroscopic scale. Perhaps the most well-known occurrence involves the solidification of metallic alloys. Typically as a molten alloy is cooled, the solid phase advances from the cold boundary into the liquid as a branching forest of dendritic crystals. This creates a region of mixed solid and liquid phases, commonly referred to as a mushy zone, in which the solid forms a rigidly interconnected framework with the liquid filling the intercrystalline gaps. In addition to the casting of metallic alloys, mushy zones can occur in the Earth's core (see above) and mantle, magma chambers, temperate glaciers, frozen soils, sea ice and weld pools. A second mechanical configuration for the solid phase is as a suspension of small crystals within the liquid; this is referred to as a slurry. Typically slurries occur in very viscous systems such as magma chambers or in rapidly moving systems such as jets of liquid metal or frazil ice in rivers. I am in the process of developing systematically governing equations for both the slurry and mush. This is a long-term project with many facets.

Mantle Convection. The Earth's mantle is in convective motion due to cooling from above, as the Earth's internal heat is lost by radiation to space, and also due to the heating from below by the heat cast off from the core. Convection within the mantle is dominated by the fact that the viscosity is a very strong function of temperature. This leads to counter-intuitive phenomena such as narrow velocity structures within a low Reynolds number flow. Two such structures are the D" layer at the base of the mantle and plumes within the mantle. It is believed that certain long-lived volcanic features, such as at Hawaii, Iceland, the Galapagos and Yellowstone, are the surface expression of such plumes. Several years ago, analytic solutions were obtained for these structures, clearly showing that they are mathematically possible. More recently the dynamic stability of the D" layer has been studied. Further work on these structures needs to be done. Particularly the time-dependent behavior of these structures needs to be worked out. Laboratory analog experiments indicate that these flows can take the form of solitary waves. Of particular interest is the surface effects of such episodic flows. They can result in periods of very active volcanic activity, which may be related to mass extinctions. This is currently a very controversial topic.

JERRY F. MAGNAN, Ph. D., University of Miami, 1979. Associate Professor of Mathematics and Associate of GFDI and SCRI

Bifurcations, nonlinear dynamics and spatial-temporal chaos. These mathematical phenomena arise in diverse applications such as thermal convection systems, reaction-diffusion systems and nonlinear optics. These phenomena are being investigated by a combination of analytical methods, principally asymptotic analysis, and computational methods, including symbolic manipulation using MACSYMA, numerical techniques and cellular automata. The main idea is to understand and predict the increasingly complex nonlinear behavior of the physical models as system parameters change.

Nonlinear Scientific Computation. A number of distinct projects related to parallel algorithms for supercomputers are included in this category. These involve numerical linear algebra, dynamically adaptive meshes, and numerical optimization. The main idea is to improve computer methods for investigating natural and technological phenomena by designing new algorithms which provide qualitative advantages over existing algorithms, and which run efficiently on vector and parallel computer architectures.

MICHAEL P. MESTERTON-GIBBONS, Ph. D., Oxford University, 1977. Associate Professor of Mathematics

In general, my research consists of game-theoretic and dynamic modelling in ecology, evolutionary biology and natural resource management; however, for the next four or five years I will be working almost exclusively on cooperation among animals (in particular, insects, fishes, birds and mammals) and related social structures (e.g., dominance hierarchies). In collaboration with biologists, I have embarked on a long-term and in-depth study of cooperation among animals from a modern evolutionary perspective. The goals of this study are to develop new mathematical models for investigating the evolution of cooperative behavior in animals, and to provide detailed methodologies for both laboratory and field researchers to distinguish among different mechanisms for achieving cooperation. The study will examine both why cooperation is evident in some taxa but not others, and why cooperation takes the form it does in taxa where it is common. The best way to discover what's involved would be to read my September, 1992 paper in *Quarterly Review of Biology* (Volume 67, pp. 267-281).

I. MICHAEL NAVON, Ph. D., University of the Witwatersrand, 1979. Professor of Mathematics and Associate of GFDI and SCRI

Ellpack. This is an advanced scientific computer package for solving elliptic PDE's, both linear and nonlinear and in two or three dimensions. The current version runs on the Cyber 205. Future plans are to develop a parallel version, allow it to function as an expert system and to implement multi-domain capability.

Finite element research. Ongoing research efforts on finite elements include: a Numerov-Galerkin technique for extracting higher accuracy from non-linear advective terms, implementation of "a posteriori" integral-invariants conservation via augmented-lagrangian constrained minimization, a two-stage Galerkin approach using high-order generalized splines. The impact of these developments on the long-term integration of the shallow-water equations is being studied. Future work will include variable-resolution mesh with adaptive mesh refinement using a posteriori error estimates.

Conjugate gradient method for large-scale minimization. This method is used, for example, to smooth a set of initial data, making them self-consistent. A cost functional is constructed and its gradient is minimized using the adjoint optimal control method. Applications arise frequently in meteorology and oceanography. The conjugate gradient method is an efficient method which minimizes memory use and CPU costs. Current efforts are concentrated on vectorization of the method, and future efforts will be aimed at parallelization.

Transfer-function analysis of the Turkel-Zwas explicit large-time-step scheme. The Turkel-Zwas scheme is a multiple-grid scheme which treats the terms representing the fast-moving gravity waves in the shallow-water equations on a coarser grid than the terms which generate the synoptic slower moving Rossby waves. The transfer function analysis allows us to understand the different distortions introduced by various discretization schemes and how they affect the process of geostrophic adjustment. A transfer function analysis for the linear one-dimensional shallow-water wave equations was carried out for the Turkel-Zwas scheme. Amplitude and phase distortion were found to be controlled by a combination of low-pass, band-pass and high-pass filters.

Variational 4-D data-assimilation methods. Data-assimilation methods are very important to observationally based sciences such as dynamic meteorology wherein data collected over a physical domain and a finite span of time must be incorporated into a self-consistent set of initial conditions. Important issues to be addressed include spin up, data rejection or retention, etc. The basic idea of these methods is to define a measure, called a cost functional, of the misfit between the observations and the output of a model. The cost functional is minimized subject to certain constraints by finding a control variable such that the corresponding solution minimizes the cost functional and satisfies the model equations. Each minimization entails a forward integration of the model equations and a backward integration of the adjoint model equation. Computational costs of this method include solution of the adjoint model, storage of intermediate model states up to the end of the assimilation period, and minimization of the gradient of the cost functional.

Quasi-Newton-like memoryless conjugate gradient methods. These methods are designed to mimic the behavior of variable-metric quasi-Newton methods which have an enhanced convergence rate. In these memoryless methods the Hessian matrix is updated but not stored. Future work on these methods will include tests of the bundle algorithm for minimization of discontinuous functions and a study of the effects of vectorization and parallelization.

CHRISTOPHER K.W. TAM, Ph. D., California Institute of Technology, 1966. Professor of Mathematics and SCRI Faculty Associate.

My research interests are mainly in the areas of (A) Acoustics and Fluid Mechanics and (B) Scientific Computing. The current research activities of my students and myself in these areas are:

(A) ACOUSTICS AND FLUID MECHANICS

Supersonic Jet Noise Theory. The objectives of this work, which has been sponsored by NASA for many years, are to develop a mathematical theory that allows one to predict the noise of high speed jets and to understand the mechanisms of noise generation. A theory we have developed is currently being used by Lockheed and the Aircraft Engine Division of the General Electric Company for noise prediction. At this time we are working on a noise theory for high temperature supersonic jets in support of NASA's effort to develop a second generation supersonic civil transport.

Turbulent Mixing Noise Theory for Low Speed Shear Flows. Noise of low speed shear flows are generated by fine scale turbulence. As yet there is no self-contained theory. The Office of Naval Research is interested in supporting our effort to develop such a theory based on a turbulence modelling approach. This is an entirely new research area.

Supersonic Mixing. Current work involves the modelling and understanding of high speed mixing processes and mechanisms. Computational and analytical studies of parametric excitation of these mixing layers are part of the present research.

Instabilities of Jets with Arbitrary Cross-section. Classical hydrodynamic stability theory deals with flows with separable velocity profiles. Recent interest in large scale motion of rectangular or elliptic jets forces one to extend the treatment to instabilities of non-separable flows. A large component of the research activities is computational in nature.

(B) SCIENTIFIC COMPUTING.

Boundary Elements Method. These methods have the distinct advantage of being able to reduce the computational dimension of a problem by one, making it very attractive for large complex problems. We are actively developing and applying these methods to flow instability and advanced propeller noise and aerodynamic calculations.

Computational Acoustics. Computational acoustics is a new area of research in computational mathematics, overlapping somewhat with computational fluid dynamics. However, because of the nature of the problems one deals with and the type of information one wishes to obtain, methods used in computational acoustics may differ significantly from those of computational fluid dynamics. In computational fluid dynamics interest is often focussed primarily on the flow field in the immediate vicinity of an aerodynamic body, and the objectives are to determine aerodynamic quantities such as pressure distribution, lift, drag, et cetera. On the other hand, in computational acoustics attention is directed to both the near-field acoustic oscillations and the far-field radiation away from the body. The objectives are to find the directivity and the spectral characteristics of the acoustic field.

We are currently involved in developing new computational schemes to overcome two main obstacles in computational acoustics. (a) *Radiation boundary conditions*. Reflections of acoustic disturbances by the artificial boundaries of a computational domain can totally destroy the near-field solution. Our current effort is to develop non-reflective boundary conditions to allow smooth passage of the acoustic waves out of the computational domain. (b) *High frequency waves*. The wave length of high frequency waves are short. To resolve the waves properly four to eight mesh points are required if traditional computational schemes are used. With finite computer memory this imposes a severe constraint in the size of the computational domain one can use. We are experimenting with the use of a wave-envelope approach to deal with this high resolution problem.

Direct Numerical Simulation. In the past. progresses in physical sciences were made either through theories or experiments. In the years to come a new way to do scientific investigation is by direct numerical simulation. We are developing the necessary mathematical and computational methods to perform computer simulations of fluid and acoustic problems. Our present effort is to create new least-dispersive least-anisotropic time-accurate algorithms for the solution of the Euler and Navier Stokes equations. Issues of the proper wall and in-flow and out-flow boundary conditions are being studied and analyzed by computer experiments.

EUTIQUIO C. YOUNG, Ph. D., Maryland, 1962. Professor of Mathematics.

In general I am interested in analytical solutions of Cauchy or initial-boundary-value problems for partial differential equations of hyperbolic type with some singularities, e.g., the Euler-Poisson-Daboux equation. This involves determining some methods for finding the solutions of the problem. I have also been interested in the uniqueness conditions for ill-posed problems for hyperbolic and parabolic equations. Oscillations of solutions of such problems have been investigated by other workers. Also, ill-posed problems for elliptic equations remain a fertile ground for exploration.

I have also worked on integral inequalities of Gronwall-Bellman type for functions of several variables. These have some applications in proving existence and uniqueness of solutions of partial differential equations. Recently I have been developing numerical solutions of the Helmholtz equation in oceanic environments, which arises in studies of underwater acoustic-wave propagation. An efficient algorithm for solving this problem is now being sought.

Appendix B

Computer Resources in Mathematics

The Department of Mathematics has a number of computers, including Sun SPARC stations, IBM RS6000s, PCs, Macintoshes, and a Silicon Graphics Crimson VGXT. The department also has full access to the Internet. A complete description of, and introduction to, departmental computer resources can be found in a separate document entitled *The Hitchhiker's Guide to FSU Mathematics Computing*, available from the system support staff. Departmental resources should suffice at least initially. As your research progresses, however, you may need access to specialized equipment – e.g., Cray YMP or Connection Machine supercomputers – which is available outside the department. If so, then you should discuss the matter with your major professor.

Your first concern should be to obtain a UNIX computer account as soon as possible. Such an account will allow you to communicate with your fellow graduate students and instructors using e-mail (electronic mail). Many interdepartmental announcements are made via e-mail; thus, even if your research does not require the use of a computer, you should still obtain an account and check your e-mail regularly. Of course, the account will also enable you to prepare documents, program, and use application packages (e.g., Maple, Mathematica, IMSL) on our machines. To obtain an account, make an appointment with the system administrator (Mickey Boyd, 644-7167).

There are two main sources of information concerning departmental computing resources. One is the aforementioned *Hitchhiker's Guide.* The other is called *gopher.* It is an online information system that will allow you to find out more about our computers and other computer resources around the world. The *Hitchhiker's Guide* will get you started and instruct you on how to run *gopher.*

Appendix C
Using the Library System

Florida State University's collections are housed in several buildings, the most important of which are the R.H. Strozier building and the Science Center Library (Dirac Science Library). The R.H. Strozier building contains books and journals on the humanities and social and behavioral sciences, whereas the Science Center Library contains books and journals on mathematics and the physical and life sciences. Thus most of the books and journals you need will be found in the Science Center Library.

From either building you can obtain copies of leaflets describing the library system in detail. The following, in particular, are recommended:

Computers in the FSU Libraries
Beginning Your Research
Databases on CD-ROM
Introduction to LUIS: Library User Information Service
LUIS: Keyword Searching
LUIS: Indexes to Articles
LUIS: Remote Access

You can obtain information about the library's holdings – including whether an item is checked out – by accessing LUIS (Library User Information Service) via telnet from a terminal in the Mathematics Department computer laboratory. (First type telnet FSU1; when the terminal prompts you for a user name, type IBM.) Even if FSU does not own a copy of the item you require, you can obtain it via interlibrary loans from another library in one of Florida's nine state universities (whose holdings can also be checked via LUIS) or elsewhere.

Appendix D
Checklists of Degree Requirements

D.1 Checklist of requirements for master's by coursework

To qualify for a master's by coursework you must:

- ☐ 1. Demonstrate an acceptable standard of spoken English if English is not your native language.
- ☐ 2. Complete at least 32 hours of acceptable course work
- ☐ 3. Maintain a 3.0 grade point average
- ☐ 4. Teach a class
- ☐ 5. Have a major professor and supervisory committee appointed
- ☐ 6. Submit an acceptable program of studies
- ☐ 7. Take and pass the Master's Comprehensive Examination
- ☐ 8. Be in residence a minimum of 2 semesters
- ☐ 9. Complete all requirements within 7 years
- ☐ 10. Make formal application for the degree with the Registrar

D.2 Checklist of requirements for master's by thesis

To qualify for a master's by thesis you must:

- ☐ 1. Demonstrate an acceptable standard of spoken English if English is not your native language.
- ☐ 2. Complete at least 30 hours of acceptable course work
- ☐ 3. Maintain a 3.0 grade point average
- ☐ 4. Teach a class
- ☐ 5. Have a major professor and supervisory committee appointed
- ☐ 6. Submit an acceptable program of studies
- ☐ 7. Prepare and submit an acceptable prospectus
- ☐ 8. Prepare and submit an acceptable thesis
- ☐ 9. Prepare and submit an acceptable abstract of the thesis
- ☐ 10. Have the thesis approved by the University Graduate Affairs office
- ☐ 11. Register for at least 6 hours of thesis credit
- ☐ 12. Successfully defend the thesis
- ☐ 13. Be in residence a minimum of 2 semesters
- ☐ 14. Complete all requirements within 7 years
- ☐ 15. Make formal application for the degree with the Registrar

D.3 Checklist of requirements for Ph.D.;

To qualify for a Ph.D. you must:

- ☐ 1. Demonstrate an acceptable standard of spoken English if English is not your native language.
- ☐ 2. Complete an acceptable program of courses
- ☐ 3. Maintain a 3.0 grade point average
- ☐ 4. Teach a class
- ☐ 5. Have a major professor and supervisory committee appointed
- ☐ 6. Submit an acceptable program of studies
- ☐ 7. Take and pass the written part of the DPE
- ☐ 8. Prepare and submit an acceptable prospectus
- ☐ 9. Take and pass the oral part of the DPE (defend the prospectus)
- ☐ 10. Be admitted to candidacy
- ☐ 11. Prepare and submit an acceptable dissertation
- ☐ 12. Prepare and submit an acceptable abstract of the dissertation
- ☐ 13. Have the thesis approved by the University Graduate Affairs office
- ☐ 14. Register for at least 24 hours of dissertation credit
- ☐ 15. Successfully defend the dissertation
- ☐ 16. Be in continuous residence for a whole year after taking either 30 semester hours of graduate credit or a master's degree
- ☐ 17. Complete all requirements within 5 years of passing the DPE
- ☐ 18. Make formal application for the degree with the Registrar

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