S.90-19

SIMON FRASER UNIVERSITY

MEMORANDUM

To:	Senate	**From:**	L. Salter Chair, SCAP
Subject:	Department of Mathematics and Statistics - Curriculum Revisions Reference: SCAP 89-68	**Date:**	November 16, 1989

Action undertaken by the Senate Committee on Academic Planning/Senate Graduate Studies Committee gives rise to the following motion:

Motion:

"That Senate approve and recommend approval to the Board of Governors as set forth in S. 90-19 the following

New courses	MATH 852 - 4	Numerical Solutions of Partial Differential Equations
	MATH 853 - 4	Numerical Methods in Continuous Optimization
Renumbering of existing MATH 852-4 to	MATH 855 - 4	Selected Topics in Numerical Analysis"

S I M O N   F R A S E R   U N I V E R S I T Y

MEMORANDUM

DEPARTMENT OF MATHEMATICS AND STATISTICS

To:	Dr. P. Percival, Chairman Faculty of Science Graduate Program Cttee	From:	Dr. A. Lachlan Chairman, Graduate Program Committee Math & Stats Dept.
Re:	New Course Proposals - Numerical Analysis	Date:	June 28, 1989

In recent years we have been admitting more graduate students whose main interest lies in Numerical Analysis. It should also be noted that our courses in Numerical Analysis have proved popular amongst students whose main interest lies in Statistics or some other branch of Mathematics. A year ago the Department was fortunate to receive a new appointment in Numerical Analysis (filled by Dr. Trummer). As a result of increased activity our existing designated courses in this area (Math 850, 851) have proved inadequate to the needs of our students. The result has been that we have had to mount courses under the special topics number Math 852 more often than we would like.

In order that our students' transcripts should reflect more precisely what they have studied we are proposing that two of the topics which we have offered under the selected topics number: Numerical Solution of Partial Differential Equations and Numerical Methods in Continuous Optimization, be listed under regular course numbers 852-4, 853-4.

At the same time we wish to renumber the selected topics course from 852 to 855.

Accordingly, I am sending with this memo New Graduate Course Proposal Forms for:

Math 852-4 (Numerical Solution of Partial Differential Equations)
Math 853-4 (Numerical Methods in Continuous Optimization)
Math 855-4 (Selected Topics in Numerical Analysis)

In conclusion, I would like to add that the question of the actual numbers used for these courses is not crucial. We have indicated the numbering we prefer. However, if necessary, we are prepared to leave 852 unchanged and to number the two new courses 853 and 854.

C. H. Lachlan

EXISTING CALENDAR ENTRY

MATH 850-4 Numerical Linear Algebra
Direct methods for numerical solution of linear systems of equations are considered with emphasis on various applications such as statistical computing.

MATH 851-4 Numerical Solution of Ordinary Differential Equations
Study of the practical numerical methods for solving initial and boundary value problems for ordinary differential equations.

MATH 852-4 Selected Topics in Numerical Analysis
Study of a specialized area of numerical analysis such as partial differential equations, continuous optimization, or approximation theory.

PROPOSED NEW CALENDAR ENTRY

MATH 850-4 Numerical Linear Algebra
Direct and iterative methods for the numerical solution of linear systems, factorization techniques, linear least squares problems, eigenvalue problems. Techniques for parallel architectures.

MATH 851-4 Numerical Solution of Ordinary Differential Equations
Study of the practical numerical methods for solving initial and boundary value problems for ordinary differential equations.

MATH 852-4 Numerical Solution of Partial Differential Equations
Analysis and application of numerical methods for solving partial differential equations. Finite difference methods, spectral methods, multigrid methods.

MATH 853-4 Numerical Methods in Continuous Optimization
Numerical solution of systems of nonlinear equations, and unconstrained optimization problems. Newton's method, Quasi-Newton methods, secant methods, and conjugate gradient algorithms.

MATH 855-4 Selected Topics in Numerical Analysis
Study of a specialized area of numerical analysis such as computational fluid dynamics, approximation theory, integral equations, integral transforms, computational complex analysis, special functions, numerical quadrature and multiple integrals, constrained optimization, finite element methods, sparse matrix techniques, or parallel algorithms in scientific computing.

SIMON FRASER UNIVERSITY

New Graduate Course Proposal Form

CALENDAR INFORMATION:

Department: Mathematics & Statistics Course Number: MATH 852-4

Title: Numerical Solution of Partial Differential Equations

Description: Analysis and application of numerical methods for solving partial differential equations. Finite difference methods, spectral methods, multigrid methods.

Credit Hours: 4 Vector: _____ Prerequisite(s) if any: _____

ENROLLMENT AND SCHEDULING:

Estimated Enrollment: 15-20 When will the course first be offered: _____

How often will the course be offered: Once every two years

JUSTIFICATION: consti[tute]

PDE's are perhaps the central subject of numerical analysis. A course like this is a must for students in numerical analysis, and applied mathematics, and should also appeal to students in Science and Applied Science

RESOURCES:

Which Faculty member will normally teach the course: Russell, Trummer, Lardner, visitor ?

What are the budgetary implications of mounting the course: Nil

Are there sufficient Library resources (append details): Yes

Appended:
a) Outline of the Course
b) An indication of the competence of the Faculty member to give the course.
c) Library resources

Approved: Departmental Graduate Studies Committee: A.H. Lachlan Date: June 29, 89

Faculty Graduate Studies Committee: P.W. Percival Date: 11 July '89

Faculty: C.H.W. Jones Date: Oct 17 '89

Senate Graduate Studies Committee: [signature] Date: 31 Oct/89

Senate: _____ Date: _____

SIMON FRASER UNIVERSITY

New Graduate Course Proposal Form

CALENDAR INFORMATION:

Department: Mathematics and Statistics Course Number: MATH 853-4

Title: Numerical Methods in Continuous Optimization

Description: Numerical solution of systems of nonlinear equations, and unconstrained optimization problmms. Newton's method, Quasi-Newton methods, secant methods, and conjugate gradient algorithms

Credit Hours: 4 Vector: Prerequisite(s) if any:

ENROLLMENT AND SCHEDULING:

Estimated Enrollment: 12 When will the course first be offered:

How often will the course be offered: Once every two years

JUSTIFICATION:

Numerical optimization is another exteemely important branch of scientific computing for which we do not offer a regular course.

RESOURCES:

Which Faculty member will normally teach the course: Russell, Trummer

What are the budgetary implications of mounting the course: Nil

Are there sufficient Library resources (append details): Yes

Appended: a) Outline of the Course
b) An indication of the competence of the Faculty member to give the course.
c) Library resources

Approved: Departmental Graduate Studies Committee: A. H. Lachlan Date: June 29, 89

Faculty Graduate Studies Committee: P. W. Percival Date: 11 July '89

Faculty: C. H. W. Jones Date: Oct 17 89

Senate Graduate Studies Committee: B. P. Clayman Date: 31 Oct '89

Senate: Date:

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SIMON FRASER UNIVERSITY

New Graduate Course Proposal Form

CALENDAR INFORMATION:

Department: Mathematics and Statistics Course Number: MATH 855-4

Title: Selected Topics in Numerical Analysis

Description: Study of a specialized area of numerical analysis such as computational fluid dynamics, approximation theory, integral equations and transforms, computational complex analysis, numerical quadrature, constrained optimization, or parallel computing.

Credit Hours: 4 Vector: Prerequisite(s) if any:

ENROLLMENT AND SCHEDULING:

Estimated Enrollment: 12 When will the course first be offered:

How often will the course be offered: Irregular intervals

JUSTIFICATION:

(Course renumbering).

RESOURCES:

Which Faculty member will normally teach the course: Russell, Trummer, visitors

What are the budgetary implications of mounting the course: Nil

Are there sufficient Library resources (append details): Yes

Appended: a) Outline of the Course
b) An indication of the competence of the Faculty member to give the course.
c) Library resources

Approved: Departmental Graduate Studies Committee: A. H. Lachlan Date: June 29, 89

Faculty Graduate Studies Committee: P. W. Percival Date: 11 July '89

Faculty: C. H. W. Jones Date: Oct. 17 89

Senate Graduate Studies Committee: B. P. Clayman Date: 31 Oct/89

Senate: Date:

Course Outline

1. FOUNDATIONS

1.1. Notations and definitions

1.2. Matrix and vector multiplication. Matrix norms

1.3. Eigenvalues, singular values, and the SVD

1.4. Conditioning and numerical stability

1.5. Condition of linear systems

1.6. Givens and Householder transformations

2. LINEAR SYSTEMS OF EQUATIONS

2.1. Introduction

2.2. Orthogonal methods

2.3. Gaussian elimination

2.4. Stability. Pivoting

3. LEAST SQUARES PROBLEMS

3.1. Least squares problem. Conditioning

3.2. Normal equations

3.3. QR decomposition methods

3.4. Computation of subspaces. Rank deficiency

4. EIGENVALUE PROBLEMS

4.1. Theory

4.2. Reduction to standard form

4.3. Power method, inverse iteration

4.4. QR algorithm

4.5. Computing the SVD

4.6. Jacobi methods. Bisection

5. ITERATIVE METHODS

5.1. Overview

5.2. The classical iterative methods

5.3. Conjugate gradient methods

5.4. Convergence rates for CG. Preconditioning

5.5. Lanczos methods

Course Outline

1. NUMERICAL ANALYSIS BACKGROUND

1.1. Errors in computation. Conditioning and numerical stability

1.2. Review of numerical linear algebra

1.3. Nonlinear equations

1.4. Spline functions

1.5. Numerical quadrature

2. THEORY OF ORDINARY DIFFERENTIAL EQUATIONS

2.1. Existence and uniqueness results

2.2. Green's functions

2.3. Stability of initial value problems

2.4. Conditioning of boundary value problems

2.5. Analytical solution methods

3. INITIAL VALUE PROBLEMS

3.1. Euler's method. Taylor methods

3.2. Linear multistep methods

3.3. Stability, consistency, convergence

3.4. Zero-stability vs. Time-stability

3.5. Predictor-corrector methods

3.6. Runge-Kutta methods

3.7. Stiff problems

3.8. Error control and step size selection

4. BOUNDARY VALUE PROBLEMS: INITIAL VALUE METHODS

4.1. Shooting methods: Introduction

4.2. Superposition

4.3. Multiple shooting

4.4. Riccati transformation

4.5. Shooting for nonlinear problems

5. BOUNDARY VALUE PROBLEMS: FINITE DIFFERENCE METHODS

5.1. Simple one-step schemes

5.2. Consistency, stability, and convergence

5.3. Runge-Kutta schemes

5.4. Collocation methods

5.5. Acceleration techniques

5.6. Finite element methods

6. SOFTWARE FOR DIFFERENTIAL EQUATIONS

Course Outline

1. FOUNDATIONS

1.1. Computer arithmetic, conditioning, and stability

1.2. Review of linear algebra

1.3. Ordinary differential equations

1.4. Fourier analysis

2. INTRODUCTION TO PDE's

2.1. Scalar model equations

2.2. Classification. Advection, dissipation, and dispersion

3. INITIAL VALUE PROBLEMS

3.1. Finite difference formulas

3.2. Semidiscretization: Method of lines

3.3. Implicit formulas

3.4. Fourier analysis in finite difference methods

4. ACCURACY, STABILITY, AND CONVERGENCE

4.1. The Lax equivalence theorem

4.2. The CFL condition

4.3. The von Neumann condition

4.4. Stability vs. Time-stability

5. SPECTRAL METHODS

5.1. Fourier spectral methods

5.2. Polynomial spectral methods

6. ELLIPTIC PROBLEMS

6.1. Direct and fast methods

6.2. Iterative methods. SOR

6.3. Multigrid methods

6.3.1. Smoothing properties of iterative methods

6.3.2. Coarse grid correction

6.3.3. Interpolation and restriction

6.3.4. Multigrid recursion

6.3.5. The FMG/FAS scheme

7. APPLICATIONS

7.1. Acoustics and elasticity

7.2. Nonlinear waves

7.3. Gas dynamics

7.4. Shallow-water equations

7.5. Navier-Stokes equations

Course Outline

1. FOUNDATIONS

1.1. Nonlinear problems in one variable

1.2. Numerical linear algebra review

1.3. Multivariable calculus review

2. NEWTON'S METHOD FOR UNCONSTRAINED MINIMIZATION

2.1. Systems of nonlinear equations

2.2. Local convergence of Newton's method

2.3. The Kantorovich and contractive mapping theorems

2.4. Finite difference derivative methods

3. QUASI-NEWTON METHODS

3.1. Descent directions. Steepest descent

3.2. Line search

3.3. The model-trust region approach

3.4. Stopping, scaling, testing

4. SECANT METHODS

4.1. Broyden updates

4.2. The symmetric secant update of Powell

4.3. Convergence results

5. CONJUGATE GRADIENT METHOD

5.1. Conjugate directions

5.2. The conjugate gradient method

5.3. CG as an optimal process

5.4. Extension to nonquadratic problems

5.5. DFP and Broyden updates revisited

6. NONLINEAR LEAST SQUARES

6.1. The nonlinear least squares problem

6.2. Gauss-Newton type methods

6.3. Full Newton type methods