Term Information

Effective Term   Autumn 2023

General Information

Course Bulletin Listing/Subject Area   Mathematics
Fiscal Unit/Academic Org   Mathematics - D0671
College/Academic Group   Arts and Sciences
Level/Career   Graduate, Undergraduate
Course Number/Catalog   5571
Course Title   Linear Algebra for Machine Learning
Transcript Abbreviation   Lin Alg Mchn Lrn
Course Description   This course is an in-depth introduction to linear algebra needed in machine learning and its application.
Semester Credit Hours/Units   Fixed: 3

Offering Information

Length Of Course   14 Week, 12 Week, 8 Week, 7 Week, 6 Week
Flexibly Scheduled Course   Never
Does any section of this course have a distance education component?   No
Grading Basis   Letter Grade
Repeatable   No
Course Components   Lecture
Grade Roster Component   Lecture
Credit Available by Exam   No
Admission Condition Course   No
Off Campus   Never
Campus of Offering   Columbus

Prerequisites and Exclusions

Prerequisites/Corequisites   A grade of C- or better in 2153 or equivalent; and in 2568 or equivalent; and in 4530 or Stat 4201 or Stat 3201 or equivalent; and in Stat 4202 or Stat 3202 or equivalent.
Exclusions
Electronically Enforced   Yes

Cross-Listings

Cross-Listings

Subject/CIP Code

Subject/CIP Code   27.0101
Subsidy Level   Doctoral Course
Intended Rank   Junior, Senior, Masters, Doctoral

Requirement/Elective Designation

The course is an elective (for this or other units) or is a service course for other units

Course Details

Course goals or learning objectives/outcomes	• Understand the basic concepts and results of linear algebra used in machine learning.
	• Perform fundamental operations on matrices and subspaces for machine learning problems.
	• Understand the design ideas of machine learning algorithms that related to linear algebra.
	• Implement advanced linear algebra techniques in machine learning and interpret the results.
Content Topic List	• Geometric meaning of multiplication and fundamental subspaces
	• Orthogonal matrices and subspaces, eigenvalues and eigenvectors, symmetric positive definite matrices, singular values and singular vectors in SVD
	• Principal components, generalized eigenvalues, factoring matrices and tensors, numerical linear algebra
	• Least squares, bases of column space, randomized linear algebra
	• Changes in the inverse, interlacing eigenvalues and low rank signals, rapidly decaying singular values, split algorithms
	• Compressed sensing and matrix completion, Fourier transforms, shift matrices and circulant matrices, Kronecker product
	• Sine and Cosine transforms, Toeplitz matrices and shift invariant filters, graph and Laplacians, clustering
	• Completing rank one matrices, the orthogonal Procrustes problem, distance matrices
	• Mean, variance, probability distribution, moments, cumulants, inequalities of statistics
	• Covariance and joint probabilities, multivariate Gaussian, weighted least squares, Markov chains
	• Optimization, convexity, Newton's method, Lagrange multipliers
	• Linear programming, game theory, duality, gradient descent, and stochastic gradient descent
	• Deep neural networks, convolutional neural nets
	• Back-propagation and the chain rule, hyper-parameters
Sought Concurrence	No

Attachments

• 5571.pdf: Syllabus

  (Syllabus. Owner: Husen,William J)

• Curriculum_map_actsci_03272023.docx: Curriculum map - Act Sci

  (Other Supporting Documentation. Owner: Husen,William J)

• Curriculum_map_math_03272023.docx: Curriculum map - math

  (Other Supporting Documentation. Owner: Husen,William J)

• stat_concurrence.pdf: Concurrence Statistics

  (Concurrence. Owner: Vankeerbergen,Bernadette Chantal)

Comments

Workflow Information

Status	User(s)	Date/Time	Step
Submitted	Husen,William J	03/27/2023 01:23 PM	Submitted for Approval
Approved	Husen,William J	03/27/2023 01:23 PM	Unit Approval
Approved	Vankeerbergen,Bernadette Chantal	04/05/2023 12:54 PM	College Approval
Pending Approval	Jenkins,Mary Ellen Bigler Hanlin,Deborah Kay Hilty,Michael Vankeerbergen,Bernadette Chantal Steele,Rachel Lea	04/05/2023 12:54 PM	ASCCAO Approval

New Course Proposal: Linear Algebra for Machine Learning

Rationale
Linear algebra is essential for machine learning. Many of the fundamental operations in machine learning, such as matrix multiplication, eigenvalue decomposition, and singular value decomposition, rely on linear algebra. Additionally, many machine learning algorithms are formulated using linear algebraic concepts and require a strong understanding of linear algebra to implement and optimize. Therefore, a strong foundation in linear algebra is crucial for anyone looking to study and work in machine learning. This course is an in-depth introduction to linear algebra needed in machine learning and its application.

Course Objectives
Upon completing the course, students will be able to
1. Understand the basic concepts and results of linear algebra used in machine learning.
2. Perform fundamental operations on matrices and subspaces for machine learning problems.
3. Understand the design ideas of machine learning algorithms that related to linear algebra.
4. Implement advanced linear algebra techniques in machine learning and interpret the results.

Number of Credit Hours
3 credit hours

Relationship to Other Courses
This course, or one similar to it, is not currently offered through any department in the College of Arts and Sciences. Course enrollment is open to all students who have completed Calculus, Linear Algebra, Probability and Statistics, a standard requirement for many degree programs such as Actuarial Science, Mathematics, Statistics, Data Analytics, and Computer Science in the College of Arts and Sciences, encouraging broad participation across programs.

Math 5571: Linear Algebra for Machine Learning

Course Description
Linear algebra is incredibly important in machine learning. Many of the fundamental operations in machine learning rely on linear algebra, and many machine learning algorithms are formulated based on linear algebraic concepts and require a strong understanding of linear algebra to implement and optimize. Therefore, a strong foundation in linear algebra is crucial for anyone looking to study and work in machine learning. This course is an in-depth introduction to linear algebra needed in machine learning and its application.

Learning Goals
Upon completing the course, students will be able to
- Understand the basic concepts and results of linear algebra used in machine learning.
- Perform fundamental operations on matrices and subspaces for machine learning problems.
- Understand the design ideas of machine learning algorithms that related to linear algebra.
- Implement advanced linear algebra techniques in machine learning and interpret the results.

Prerequisite
- Math 2153 or equivalent
- Math 2568 or equivalent
- Math 4530 or Stat 4201 or Stat 3201 or equivalent
- Stat 4202 or Stat 3202 or equivalent

Text
- *Linear Algebra and Learning from Data*, Gilbert Strang, Wellesley-Cambridge Press

Class Format and Expected Workload
- Lecture – 3 hours per week
- Students will be expected to be working on the course for an approximately a total of 6 hours per week, including reading and homework.

Homework and Exams
- Weekly homework assignment: Weekly homework assignments will be assigned and collected online via carmen.
- Two midterm exams: Each midterm will be one hour long.
- Final exam: The final exam will comprehensive, and it will be one and a half hours long.

Grade
The course grade will be based on

- Homework, 20%
- Two midterms, 50% (25% each)
- Final exam, 30%

Course grade will be determined by the total percentage obtained, roughly as 90-100 A, 80-89 B, 70-79 C, 60-69 D. Letter grade with + or – will be assigned according to the score distribution of the whole class.

Schedule

A tentative weekly schedule is below. This schedule and material covered may be changed without notice. It is the student's responsibility to keep track of these changes. Change may be announced in class verbally, through Carmen, or through email.

Week	Topics
1	Geometric meaning of multiplication Ax and column space of A, matrix multiplication AB, the four fundamental subspaces of a matrix A, elimination and $A = LU$.
2	Orthogonal matrices and subspaces, eigenvalues and eigenvectors, symmetric positive definite matrices, singular values and singular vectors in SVD.
3	Principal components, generalized eigenvalues, factoring matrices and tensors, numerical linear algebra
4	Least squares, bases of column space, randomized linear algebra
5	Changes in the inverse, interlacing eigenvalues and low rank signals, rapidly decaying singular values, split algorithms
6	Compressed sensing and matrix completion, Fourier transforms, shift matrices and circulant matrices, Kronecker product
7	Sine and Cosine transforms, Toeplitz matrices and shift invariant filters, graph and Laplacians, clustering
8	Completing rank one matrices, the orthogonal Procrustes problem, distance matrices
9	Mean, variance, probability distribution, moments, cumulants, inequalities of statistics
10	covariance and joint probabilities, multivariate Gaussian, weighted least squares, Markov chains
11	Optimization, convexity, Newton's method, Lagrange multipliers
12	linear programming, game theory, duality, gradient descent, and stochastic gradient descent
13	Deep neural networks, convolutional neural nets
14	Backpropagation and the chain rule, hyperparameters,

Statement on academic misconduct:
It is the responsibility of the Committee on Academic Misconduct to investigate or establish procedures for the investigation of all reported cases of student academic misconduct. The term "academic misconduct" includes all forms of student academic misconduct wherever committed; illustrated by, but not limited to, cases of plagiarism and dishonest practices in connection with examinations. Instructors shall report all instances of alleged academic misconduct to the committee (Faculty Rule 3335-5-487). For additional information, see the Code of Student Conduct http://studentlife.osu.edu/csc/.

Statement about disability services:
The University strives to make all learning experiences as accessible as possible. If you anticipate or experience academic barriers based on your disability (including mental health, chronic or temporary medical conditions), please let the instructor know immediately so that we can privately discuss options. To establish reasonable accommodations, I may request that you register with Student Life Disability Services. After registration, make arrangements with me as soon as possible to discuss your accommodations so that they may be implemented in a timely fashion. SLDS contact information: slds@osu.edu; 614-292-3307; slds.osu.edu; 098 Baker Hall, 113 W. 12th Avenue.

Mental health statement:
As a student you may experience a range of issues that can cause barriers to learning, such as strained relationships, increased anxiety, alcohol/drug problems, feeling down, difficulty concentrating and/or lack of motivation. These mental health concerns or stressful events may lead to diminished academic performance or reduce a student's ability to participate in daily activities. The Ohio State University offers services to assist you with addressing these and other concerns you may be experiencing. If you or someone you know are suffering from any of the aforementioned conditions, you can learn more about the broad range of confidential mental health services available on campus via the Office of Student Life's Counseling and Consultation Service (CCS) by visiting ccs.osu.edu or calling 614-292-5766. CCS is located on the 4th Floor of the Younkin Success Center and 10th Floor of Lincoln Tower. You can reach an on call counselor when CCS is closed at 614-292-5766 and 24 hour emergency help is also available through the 24/7 National Suicide Prevention Hotline at 1-800-273-TALK or at suicidepreventionlifeline.org.

Sexual misconduct/relationship violence statement:
Title IX makes it clear that violence and harassment based on sex and gender are Civil Rights offenses subject to the same kinds of accountability and the same kinds of support applied to offenses against other protected categories (e.g., race). If you or someone you know has been sexually harassed or assaulted, you may find the appropriate resources at http://titleix.osu.edu or by contacting the Ohio State Title IX Coordinator at titleix@osu.edu

Diversity statement:

The Ohio State University affirms the importance and value of diversity in the student body. Our programs and curricula reflect our multicultural society and global economy and seek to provide opportunities for students to learn more about persons who are different from them. We are committed to maintaining a community that recognizes and values the inherent worth and dignity of every person; fosters sensitivity, understanding, and mutual respect among each member of our community; and encourages each individual to strive to reach his or her own potential. Discrimination against any individual based upon protected status, which is defined as age, color, disability, gender identity or expression, national origin, race, religion, sex, sexual orientation, or veteran status, is prohibited.

Re: Math Major Data Science and Computation Track

Craigmile, Peter <pfc@stat.osu.edu>
Fri 3/17/2023 5:37 PM

To: Ban, Chunsheng <cban@math.ohio-state.edu>;MacEachern, Steven <snm@stat.osu.edu>;Hans, Christopher <hans@stat.osu.edu>;Fowler, Jim <fowler@math.osu.edu>

Dear Chunsheng,

I hope your spring break is going well.

The curriculum committee looked over the revised track proposal. The Department of Statistics gives concurrence for the new undergraduate track in Computational Math, along with concurrence for the new "Linear Algebra for Machine Learning" course. All the best in the new program!

Please let us know if you have any other questions that come up in the future.

My best,
Peter

Peter Craigmile, Ph.D.,
Professor, Department of Statistics, The Ohio State University.

From: "Ban, Chunsheng" <cban@math.ohio-state.edu>
Date: Monday, March 6, 2023 at 9:14 PM
To: "MacEachern, Steven" <snm@stat.osu.edu>, "Craigmile, Peter" <pfc@stat.osu.edu>, "Hans, Christopher" <hans@stat.osu.edu>, "Fowler, Jim" <fowler@math.osu.edu>
Subject: Re: Math Major Data Science and Computation Track

Dear all,

Thank you for meeting with us last Friday to talk about our major track proposal! I fully understand your concerns, and I have made changes to the proposal accordingly. The revision is attached. The revised program has minimal overlap with stat or data analytics majors now, and it is a fully mathematics focused program. Would you please give concurrences of our major track and new courses? We would appreciate it very much!

Thanks,
Chunsheng

From: Ban, Chunsheng <cban@math.ohio-state.edu>
Sent: Wednesday, March 1, 2023 11:33 AM
To: MacEachern, Steven <snm@stat.osu.edu>; Craigmile, Peter <pfc@stat.osu.edu>; Hans, Christopher <hans@stat.osu.edu>; Fowler, Jim <fowler@math.osu.edu>
Subject: Re: Math Major Data Science and Computation Track

Thanks, and see you all on Friday!

Best,
Chunsheng

From: MacEachern, Steven <snm@stat.osu.edu>
Sent: Wednesday, March 1, 2023 7:36 AM
To: Craigmile, Peter <pfc@stat.osu.edu>; Ban, Chunsheng <cban@math.ohio-state.edu>; Hans, Christopher <hans@stat.osu.edu>; Fowler, Jim <fowler@math.osu.edu>
Subject: Re: Math Major Data Science and Computation Track

Works for me as well. Steve

From: Craigmile, Peter <pfc@stat.osu.edu>
Sent: Tuesday, February 28, 2023 11:09 AM
To: Ban, Chunsheng <cban@math.ohio-state.edu>; Hans, Christopher <hans@stat.osu.edu>; MacEachern, Steven <snm@stat.osu.edu>; Fowler, Jim <fowler@math.osu.edu>
Subject: Re: Math Major Data Science and Computation Track

That works for me. My office is Cockins Hall, Room 427.

Regards,
Peter

Peter Craigmile, Ph.D.,
Professor, Department of Statistics, The Ohio State University.

From: "Ban, Chunsheng" <cban@math.ohio-state.edu>
Date: Tuesday, February 28, 2023 at 11:08 AM
To: "Hans, Christopher" <hans@stat.osu.edu>, "MacEachern, Steven" <snm@stat.osu.edu>, "Craigmile, Peter" <pfc@stat.osu.edu>, "Fowler, Jim" <fowler@math.osu.edu>
Subject: Re: Math Major Data Science and Computation Track

Thanks, all! Let's meet on Friday at 2:15pm. Should we meet at Peter's office again? Jim and I will come over.

Best,
Chunsheng

From: Hans, Christopher <hans@stat.osu.edu>
Sent: Monday, February 27, 2023 4:01 PM
To: MacEachern, Steven <snm@stat.osu.edu>; Craigmile, Peter <pfc@stat.osu.edu>; Ban, Chunsheng <cban@math.ohio-state.edu>
Subject: Re: Math Major Data Science and Computation Track

I may have to attend a recruitment/open house event during that time, but please feel free to meet

without me if I can't make it.

Chris

THE OHIO STATE UNIVERSITY

Christopher M. Hans, Ph.D.
Associate Professor
Co-Director, Data Analytics Major
College of Arts and Sciences
Department of Statistics
614-292-7157

Major in Data Analytics:
https://data-analytics.osu.edu/

From: MacEachern, Steven <snm@stat.osu.edu>
Date: Monday, February 27, 2023 at 1:00 PM
To: Craigmile, Peter <pfc@stat.osu.edu>, Ban, Chunsheng <cban@math.ohio-state.edu>
Cc: Hans, Christopher <hans@stat.osu.edu>
Subject: Re: Math Major Data Science and Computation Track

Hi Chunsheng and all.

A busy week, but I can rearrange my schedule to meet on Friday from 2 - 3. Let me know if I should make changes.

My best,

Steve

From: Craigmile, Peter <pfc@stat.osu.edu>
Sent: Monday, February 27, 2023 12:27 PM
To: Ban, Chunsheng <cban@math.ohio-state.edu>; MacEachern, Steven <snm@stat.osu.edu>
Cc: Hans, Christopher <hans@stat.osu.edu>
Subject: Re: Math Major Data Science and Computation Track

Dear Chunsheng,

I teach at that time on Thursdays. I am available this Friday between 2 and 3pm.

Regards,
Peter

Peter Craigmile, Ph.D.,

Professor, Department of Statistics, The Ohio State University.

From: "Ban, Chunsheng" <cban@math.ohio-state.edu>
Date: Monday, February 27, 2023 at 12:12 PM
To: "MacEachern, Steven" <snm@stat.osu.edu>, "Craigmile, Peter" <pfc@stat.osu.edu>
Cc: "Hans, Christopher" <hans@stat.osu.edu>
Subject: Re: Math Major Data Science and Computation Track

Hi all,

Will you be available Thursday morning between 9 and 11am or Friday afternoon between 2 and 3pm? My colleague Jim Fowler will come too.

Thanks,
Chunsheng

From: Ban, Chunsheng <cban@math.ohio-state.edu>
Sent: Thursday, February 23, 2023 12:59 AM
To: MacEachern, Steven <snm@stat.osu.edu>; Craigmile, Peter <pfc@stat.osu.edu>
Cc: Hans, Christopher <hans@stat.osu.edu>
Subject: Re: Math Major Data Science and Computation Track

Thanks, Steve! Yes, let's set up a time for a discussion. I will get back with some names from mathematics and possible times.

Best,
Chunsheng

From: MacEachern, Steven <snm@stat.osu.edu>
Sent: Wednesday, February 22, 2023 5:31 PM
To: Ban, Chunsheng <cban@math.ohio-state.edu>; Craigmile, Peter <pfc@stat.osu.edu>
Cc: Hans, Christopher <hans@stat.osu.edu>
Subject: Re: Math Major Data Science and Computation Track

Hi Chunsheng.

I've read through the proposed major.

The proposal does raise some concerns for us, given the existing majors on campus. For some students moving through the proposed major, there seem to be considerable similarities to our Statistics major, and especially with our track that emphasizes advanced (undergraduate) mathematics. Having said this, I think there is much good in expanding the tracks within mathematics majors. To my eyes, it looks like the proposal contains the essence of a natural (and exciting!) Computational Mathematics major that could easily pair with a Statistics minor. I think there would be a big audience for such a major, especially if advisors recommended the major-minor pair.

Perhaps gathering a few people together for a discussion would be a good to move things

forward.

My best,

Steve

Dear Steve and Peter,

The mathematics department is working on developing an undergraduate math major track in Data Science and Computation and a new course Linear Algebra for Machine Learning for the new track. The major track proposal and the new course proposal are attached. We will submit the proposal to the college soon, and I am writing to seek concurrences from your department for the major track and for the new course. The new track requirement includes several statistics courses, some are required core courses and some others are electives. The new course on linear algebra application in machine/statistical learning deals with data science, but it is a math course, and it may be useful to students in your programs. We'd appreciate any comments and suggestions you can provide and appreciate your concurrence for our proposals so we can move forward.

Thank you for your assistance and please let me know if you have any question.

Best,
Chunsheng

Chunsheng Ban
Professor and Vice Chair for Undergraduate Studies
Department of Mathematics

Actuarial Science BS/BA Curriculum Map					
Goal 1	**To supply a strong general background in mathematics, statistics, and relevant concepts from the insurance industry**				
Goal 2	**To prepare students to take some of the national actuarial examinations administered by the Society of Actuaries and the Casualty Actuarial Society**				
Course	**Goal 1**	**Goal 2**			
Math 1151	Beginning	Beginning			
Math 1152	Beginning	Beginning			
ACCTMIS 2000	Beginning				
Econ 2001.01	Beginning				
Econ 2002.01	Beginning				
CSE 1222	Beginning	Intermediate			
CSE 1223	Beginning	Intermediate			
CSE 2111	Beginning	Intermediate			
Comm 2110	Beginning				
Comm 2131	Beginning				
Comm 2367	Beginning				
BusFin 3120	Intermediate	Beginning			
English 3304	Beginning				
Math 2153	Intermediate	Beginning			
Math 2568	Intermediate	Beginning			
Math 3588	Intermediate	Advanced			
Math 3618	Intermediate	Advanced			
Math 4530	Advanced	Advanced			
Stat 4201	Advanced	Advanced			
Math 5632	Advanced	Advanced			
Stat 4202	Advanced	Advanced			
Math 5571	**Advanced**	**Advanced**			
Math 5630	Advanced	Advanced			
Math 5631	Advanced	Advanced			
Math 5633	Advanced	Advanced			
Math 5634	Advanced	Advanced			
Math 5635	Advanced	Advanced			
Math 5636	Advanced	Advanced			
Math 5637	Advanced	Advanced			

Math - BS/BA Curriculum Map					
Goal 1	**Learn conceptual frameworks needed to study higher mathematics, including an introduction to mathematical reasoning and an understanding of how to read and write proofs.**				
Goal 2	**Aquire basic mastery of core areas of mathematics including calculus, analysis and algebra.**				
Goal 3	**Develop powerful mathematical problem solving skills.**				
Goal 4	**Learn to communicate mathematical understanding effectively.**				
Goal 5	**Become proficient in chosen tracks within the major.**				
Course	**Goal 1**	**Goal 2**	**Goal 3**	**Goal 4**	**Goal 5**
AcctMIS 2000			Beginning		Intermediate
Biochem 4511					Advanced
Biology 1113			Beginning		Intermediate
Biology 1114			Beginning		Intermediate
Biology 3401					Intermediate
BusFin 3120			Intermediate	Intermediate	Advanced
BusFin 3220			Intermediate	Intermediate	Advanced
Chem 1210			Beginning		Intermediate
Chem 1220			Beginning		Intermediate
Chem 2210					Advanced
Chem 2510					Advanced
Chem 4300					Advanced
Chem 4310					Advanced
CSE 1222			Beginning		Intermediate
CSE 1223			Beginning		Intermediate
CSE 2221			Beginning	Beginning	
CSE 2111			Beginning		Intermediate
Econ 2001.01			Beginning		Intermediate
Econ 2002.01			Beginning		Intermediate
EEOB 3310					Advanced
EEOB 3420					Advanced
EEOB 4520					Advanced
Math 1151	Beginning	Beginning	Beginning		
Math 1152	Beginning	Beginning	Beginning		
Math 1181H	Intermediate	Intermediate	Beginning		
Math 1295				Intermediate	Beginning
Math 2153	Intermediate	Intermediate	Beginning		

Math 2182H	Intermediate	Intermediate	Beginning		
Math 2255	Beginning	Intermediate	Intermediate	Beginning	
Math 2568	Beginning	Beginning	Beginning		Beginning
Math 2568H	Intermediate	Beginning	Intermediate	Beginning	Beginning
Math 3345	Advanced	Advanced	Intermediate	Intermediate	Intermediate
Math 3345H	Advanced	Advanced	Intermediate	Intermediate	Intermediate
Math 3350				Intermediate	Beginning
Math 3589			Intermediate	Intermediate	Advanced
Math 3607			Intermediate	Intermediate	Advanced
Math 3618			Intermediate	Advanced	Advanced
Math 4181H	Advanced	Advanced	Advanced	Advanced	Advanced
Math 4182H	Advanced	Advanced	Advanced	Advanced	Advanced
Math 4345	**Advanced**	**Advanced**	**Advanced**	**Intermediate**	**Advanced**
Math 4350			Intermediate	Advanced	Advanced
Math 4504	Advanced	Intermediate	Intermediate	Advanced	Advanced
Math 4507	Advanced	Intermediate	Intermediate	Advanced	Advanced
Math 4512	Intermediate		Intermediate	Intermediate	Intermediate
Math 4530	Intermediate	Beginning	Intermediate	Intermediate	Intermediate
Math 4547	Advanced	Advanced	Intermediate	Advanced	Beginning
Math 4548	Advanced	Advanced	Intermediate	Advanced	Beginning
Math 4551	Intermediate	Intermediate	Intermediate	Intermediate	Intermediate
Math 4552	Intermediate	Intermediate	Intermediate	Intermediate	Intermediate
Math 4556			Intermediate	Advanced	Advanced
Math 4557	Intermediate		Intermediate	Intermediate	Intermediate
Math 4570	Intermediate	Intermediate	Advanced	Intermediate	Intermediate
Math 4573	Advanced	Intermediate	Intermediate	Intermediate	Intermediate
Math 4575	Intermediate	Intermediate	Intermediate	Intermediate	Intermediate
Math 4578	Intermediate	Intermediate	Intermediate	Intermediate	Advanced
Math 4580	Advanced	Advanced	Intermediate	Advanced	Beginning
Math 4581	Advanced	Advanced	Intermediate	Advanced	Beginning
Math 5101	Beginning	Advanced	Intermediate		Intermediate
Math 5102	Beginning	Advanced	Intermediate		Intermediate
Math 5421	Beginning	Beginning	Intermediate	Beginning	Advanced
Math 5451	Beginning	Beginning	Intermediate	Beginning	Advanced

Math 5520H	Advanced	Advanced	Advanced	Advanced	Intermediate
Math 5522H	Advanced	Advanced	Advanced	Advanced	Intermediate
Math 5529H	Advanced	Advanced	Advanced	Advanced	Intermediate
Math 5530H	Advanced	Advanced	Advanced	Advanced	Intermediate
Math 5540H	Advanced	Advanced	Advanced	Advanced	Advanced
Math 5540H	Advanced	Advanced	Advanced	Intermediate	Beginning
Math 5571	**Advanced**	**Advanced**	**Advanced**	**Intermediate**	**Intermediate**
Math 5576H	Advanced	Advanced	Advanced	Advanced	Advanced
Math 5590H	Advanced	Advanced	Advanced	Advanced	Advanced
Math 5591H	Advanced	Advanced	Advanced	Advanced	Advanced
Math 5632			Intermediate	Advanced	Advanced
Math 5635			Intermediate	Advanced	Advanced
Math 5636			Intermediate	Advanced	Advanced
Math 5637			Intermediate	Advanced	Advanced
Math 5660					Intermediate
Math 5756			Beginning	Intermediate	Intermediate
Math 5757			Beginning	Intermediate	Intermediate
MolGen 4500					Advanced
MolGen 5601					Advanced
Physics 1250			Beginning		Intermediate
Physics 1251			Beginning		Intermediate
Physics 2300					Advanced
Physics 2301					Advanced
Stat 4201	Intermediate	Beginning	Intermediate	Intermediate	Intermediate
Stat 4202	Intermediate		Intermediate		Intermediate