CMDA 3606 · MATH MODELING: METHODS AND TOOLS II · Spring 2019 · Virginia Tech

CRN 12561	Lectures:	Monday/Wednesday, 2:30–3:45PM, McBryde 230
	Instructor:	Mark Embree (embree@vt.edu), McBryde 575
	Office Hours:	Monday 4–6pm, Wednesday 1–2pm, Thursday 1–2pm
CRN 12562	Lectures:	Tuesday/Thursday, 2:00–3:15PM, McBryde 240
	Instructor:	Christopher Beattie (beattie@vt.edu), McBryde 552
	Office Hours:	Tuesday, 4–6pm; Wednesday, 4–6pm
Web Site:	`http://www.math.vt.edu/people/embree/cmda3606` Canvas will be used for course announcements and for posting grades.	
Piazza:	We will use Piazza as a venue for posting questions and extending class discussion. Please use this forum vigorously! Sign up at: `http://piazza.com/vt/spring2019/cmda3606`.	

Prerequisites: CMDA 3605. Students should be comfortable with fundamental concepts from linear algebra (as acquired in MATH 2214 and CMDA 3605) and have basic MATLAB programming skills.

Grade Policy: 40% problem sets (approximately eleven during the semester)
40% midterm exams (**Thursday 28 February and 11 April, 100 minutes from 7–10pm**)
20% final exam: Monday 13 May: 2:05–4:05pm (MW section) or 4:25–6:25pm (TR section)
Scores of at least 90, 80, 70, and 60 guarantee grades of at least A−, B−, C−, and D−.

Participation: Please contribute to the class environment by asking questions and participating in discussions. Your interaction (in class and/or Piazza) will be considered when assigning borderline grades, as will improving performance throughout the course of the semester.

Electronics: Please silence and stow your phones before class begins. Laptop use is strongly discouraged, beyond specific in-class exercises. To avoid distracting other students, laptop users will kindly sit in the back row of the classroom.

Problem sets: Approximately eleven problem sets will be assigned, generally due at 5 pm on Thursday afternoons. *Students must turn in printed copies of their solutions to the instructor.* The exercises will involve both analysis of theoretical issues and illustrative examples. Clean, rigorous solutions are expected; strive for clarity and elegance. MATLAB coding will often be required.

You are encouraged to discuss these problem sets with each other (and via Piazza), *but your write-ups must be your independent work.* (A good rule of thumb: spend an hour on each problem by yourself, before consulting classmates.) Transcribed solutions and copied code are unacceptable. Specify your collaborators; credit outside sources you use (books, articles, websites).

Late policy: Your may submit two standard problem sets 24 hours late with no penalty. Subsequent late assignments will be penalized 25%. No work will be accepted more than 24 hours late without prior arrangement or a written excuse.

Exams: Midterm exams will be held on the evenings of Thursday 28 February and 11 April. The final exam on 13 May will be comprehensive.

Re-Grade Policy: If your work has been graded incorrectly, you may submit a re-grade request. Clearly explain the perceived error on a separate sheet of paper, staple it to the front of your graded paper, and give it to the instructor within one week of the paper's return.

Honor Code: Virginia Tech's Honor Code applies to all work in this course. Students must uphold the highest ethical standards, abiding by our Honor Code: "As a Hokie, I will conduct myself with honor and integrity at all times. I will not lie, cheat, or steal, nor will I accept the actions of those who do." From the Office for Undergraduate Academic Integrity: "Students enrolled in this course are responsible for abiding by the Honor Code. A student who has doubts about how the Honor Code applies to any assignment is responsible for obtaining specific guidance from the course instructor before submitting the assignment for evaluation. Ignorance of the rules does not exclude any member of the University community from the requirements and expectations of the Honor Code. For additional information about the Honor Code, please visit: www.honorsystem.vt.edu."

Any student with special needs or circumstances requiring accommodation in this course is encouraged to contact the instructor during the first week of class, as well as Virginia Tech's SSD Office. We will ensure that these needs are appropriately addressed.

Texts:	The instructors will provide notes for much of the semester's material. Several other resources are available freely online to Virginia Tech students: U. M. Ascher and C. Greif, *A First Course in Numerical Methods*, 2011. J. Nocedal and S. J. Wright, *Numerical Optimization*, 2nd ed., 2006. P. C. Hansen, J. G. Nagy, D. P. O'Leary, *Deblurring Images: Matrices, Spectra, and Filtering*, 2006. P. C. Hansen, *Discrete Inverse Problems: Insight and Algorithms*, 2010.

Assignment Schedule

The course assignments will follow the schedule below.

Problem Set 1	posted 23 January 2019	due 31 January 2019
Problem Set 2	posted 30 January 2019	due 7 February 2019
Problem Set 3	posted 6 February 2019	due 14 February 2019
Problem Set 4	posted 12 February 2019	due 21 February 2019
Exam 1	Thursday 28 February, 7–10pm (MW: McBryde 113; TR: McBryde 129)	
Problem Set 5	posted 1 March 2019	due 7 March 2019
Problem Set 6	posted 13 March 2019	due 21 March 2019
Problem Set 7	posted 20 March 2019	due 28 March 2019
Problem Set 8	posted 27 March 2019	due 4 April 2019
Exam 2	Thursday 11 April, 7–10pm, (MW: McBryde 113; TR: McBryde 129)	
Problem Set 9	posted 12 April 2019	due 18 April 2019
Problem Set 10	posted 17 April 2019	due 25 April 2019
Problem Set 11	posted 24 April 2019	due 2 May 2019
Final Exam	Monday 13 May (MW: 2:05–4:05, McBryde 230; TR: 4:25–6:25, McBryde 240)	

Tentative Lecture Schedule: CRN 12561 (MW Section)

The course will roughly follow the schedule below.
The exam dates are fixed, but the lecture schedule will adjust to fit the pace of the class.

1.	Wed	23 Jan	Origin of $Ax = b$ problems: Circuit modeling
2.	Mon	28 Jan	Origin of $Ax = b$ problems: Structures in 1d
3.	Wed	30 Jan	Origin of $Ax = b$ problems: Structures in 2d, null space
4.	Mon	4 Feb ⋆	Subspaces, Fundamental Theorem of Linear Algebra, orthogonality
5.	Wed	6 Feb ⋆	Gram–Schmidt orthogonalization and QR factorization
6.	Mon	11 Feb ⋆	Least squares via the FTLA
7.	Wed	13 Feb ⋆	Least squares via QR factorization
8.	Mon	18 Feb	Review of eigenvalues and eigenvectors
9.	Wed	20 Feb	Singular value decomposition (SVD)
10.	Mon	25 Feb	SVD: FTLA, sensitivity of $Ax = b$ solutions
11.	Wed	27 Feb	*catch-up and review*
	Thu	28 Feb	**Exam 1, 7–10pm, McBryde 113**
12.	Mon	4 Mar	SVD: Low-rank matrix approximation
13.	Wed	6 Mar	Principal Component Analysis
		11 Mar	*Spring Break*
		13 Mar	*Spring Break*
14.	Mon	18 Mar	Least squares via the SVD
15.	Wed	20 Mar	Regularization via truncated SVD
16.	Mon	25 Mar	Regularization via Tikhonov
17.	Wed	27 Mar	Regularization via the LASSO
18.	Mon	1 Apr	Image deblurring
19.	Wed	3 Apr ⋆	Image deblurring
20.	Mon	8 Apr	GMRES for $Ax = b$
21.	Wed	10 Apr	*catch-up and review*
	Thu	11 Apr	**Exam 2, 7–10pm, McBryde 113**
22.	Mon	15 Apr	Krylov iterations for deblurring
23.	Wed	17 Apr	Preconditioning
24.	Mon	22 Apr	Steepest descent and conjugate gradients for $Ax = b$
25.	Wed	24 Apr	Nonlinear optimization overview
26.	Mon	29 Apr	Line-search methods (gradient and other descent methods)
27.	Wed	1 May	Line-search methods (stochastic gradient descent)
28.	Mon	8 May	Line-search methods (Newton's method)
29.	Wed	10 May	Nonlinear least squares
	Mon	13 May	**Final Exam, 2:05–4:05pm, McBryde 230**

⋆ Embree traveling (Beattie will lecture)

Tentative Lecture Schedule: CRN 12562 (TR Section)

The course will roughly follow the schedule below.
The exam dates are fixed, but the lecture schedule will adjust to fit the pace of the class.

1.	Tue	22 Jan	Origin of $Ax = b$ problems: Circuit modeling
2.	Thu	24 Jan	Origin of $Ax = b$ problems: Structures in 1d
3.	Tue	29 Jan	Origin of $Ax = b$ problems: Structures in 2d, null space
4.	Thu	31 Jan	Subspaces, Fundamental Theorem of Linear Algebra, orthogonality
5.	Tue	5 Feb	Gram–Schmidt orthogonalization and QR factorization
6.	Thu	7 Feb	Least squares via the FTLA
7.	Tue	12 Feb	Least squares via QR factorization
8.	Thu	14 Feb	Review of eigenvalues and eigenvectors
9.	Tue	19 Feb	Singular value decomposition (SVD)
10.	Thu	21 Feb	SVD: FTLA, sensitivity of $Ax = b$ solutions
11.	Tue	26 Feb $\star$	SVD: Low-rank matrix approximation
12.	Thu	28 Feb $\star$	*catch-up and review*
	Thu	28 Feb	**Exam 1, 7–10pm, McBryde 129**
13.	Tue	5 Mar	Principal Component Analysis
14.	Thu	7 Mar	Least squares via the SVD
		12 Mar	*Spring Break*
		14 Mar	*Spring Break*
15.	Tue	19 Mar	Regularization via truncated SVD
16.	Thu	21 Mar	Regularization via Tikhonov
17.	Tue	26 Mar	Regularization via the LASSO
18.	Thu	28 Mar	Image deblurring
19.	Tue	2 Apr	Image deblurring
20.	Thu	4 Apr	GMRES for $Ax = b$
21.	Tue	9 Apr	Krylov iterations for deblurring
22.	Thu	11 Apr	*catch-up and review*
	Thu	11 Apr	**Exam 2, 7–10pm, McBryde 129**
23.	Tue	16 Apr	Preconditioning
24.	Thu	18 Apr	Steepest descent and conjugate gradients for $Ax = b$
25.	Tue	23 Apr	Nonlinear optimization overview
26.	Thu	25 Apr	Line-search methods (gradient and other descent methods)
27.	Tue	30 Apr	Line-search methods (stochastic gradient descent)
28.	Thu	2 May	Line-search methods (Newton's method)
29.	Tue	7 May	Nonlinear least squares
	Mon	13 May	**Final Exam, 2:05–4:05pm, McBryde 240**

$\star$ Beattie traveling (Embree will lecture)