DEPARTMENT OF APPLIED MATHEMATICS

Applied Mathematics Bachelor's Program

UNDERGRADUATE CURRICULUM GUIDE

2020-2021

Department of Applied Mathematics
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1. Overview of Guidelines and Introduction to Applied Mathematics

This *Applied Mathematics Undergraduate Curriculum Guide* provides an outline of the curriculum and policies of the Applied Mathematics (AMEN) Bachelor of Science degree offered by the College of Engineering and Applied Science of the University of Colorado at Boulder. These guidelines are written primarily for students and Faculty of the AMEN Program.

General College of Engineering and Applied Science policy information can be found on the college website: http://www.colorado.edu/engineering-advising/get-your-degree/academic-expectations-policies. CU students can also access course scheduling for each semester through the MyCUInfo portal: buffportal.colorado.edu.

1.1. Overview of Applied Mathematics

The Department of Applied Mathematics in the College of Arts and Sciences offers courses and degree programs for undergraduates and graduate students. The Department of Applied Mathematics currently has 23 full-time faculty, over a dozen instructors and post-doctoral associates, and maintains an active Visitor Program with researchers from around the world. Courses range from calculus to seminars in computation, discrete mathematics, probability and statistics, nonlinear phenomena, mathematical biology, and physical applied mathematics. The departmental roots go back to the turn of the last century when it originally was the Department of Engineering Mathematics. The Department teaches thousands of students and has a major research presence in computational and physical/biological mathematics and the statistical sciences.

The undergraduate program in AMEN prepares graduates to practice effectively in the field of mathematics, or to further their careers through advanced study. The principle focus of a major in applied math is to improve a student's mathematical, computational, and communication skills. The focus is on modeling problems from a variety of areas including business, engineering and science. Our students are particularly strong and each year they go on to excellent graduate schools and take positions in a wide range of companies and laboratories. The faculty are remarkable; they teach a broad spectrum of courses and carry on research in many fields including computational math, nonlinear dynamics, fluid dynamics, geophysics, optics, to theoretical physics. The Department of Applied Mathematics trains its students in the methods and strategies required to be able to solve real world problems.

1.2. Introduction to the Bachelor of Science in Applied Mathematics (AMEN-BS)

A Bachelor of Science degree in Applied Mathematics is available to students in the College of Engineering, as is a five-year Bachelor's-Accelerated Master's (BAM) degree program. CU students wishing to obtain a BS in Applied Mathematics and who are not in the College of Engineering must apply to Engineering through an Intra-University Transfer (IUT): http://www.colorado.edu/engineering-advising/intra-university-transfer-iut-engineering.

A minor in Applied Mathematics and an Applied Math Minor in Statistics are available to any undergraduate CU student who satisfies the requirements.

The undergraduate curriculum in Applied Mathematics is designed to give training in the applications of mathematics in engineering and science. The use of computational methods and implementation of algorithms on computers is central. Required technical electives should be selected after consultation with an Applied Mathematics advisor. They may be chosen from: mathematics, statistics, engineering, physics, chemistry, computer science, biology, astrophysics, geology, economics, finance and accounting. In general, non-technical electives should be broadening and have multicultural value.

1.3. Objectives and Program Outcomes

The undergraduate degree in applied mathematics emphasizes knowledge and awareness of:

- Differential and integral calculus in one and several variables;
- Vector spaces and matrix algebra;
- Ordinary and partial differential equations;
- At least one programming language;
- At least one application software package in either mathematics or statistics;
- Methods of complex variables as used in applications; and
- Numerical solutions of linear and nonlinear problems.

In addition, students completing a degree in applied mathematics acquire:

- An in-depth knowledge of an area of application (statistics, an engineering discipline or a natural science field or one of the quantitative areas of business and economics);
- Knowledge of problem-formulation, problem-solving, and modeling techniques and strategies central to applications;
- The ability to clearly and concisely, and in oral and written forms, communicate analytic arguments.

2. Bachelor of Science in Applied Mathematics Degree Requirements

2.1. Sample Curriculum for the BS Degree in Applied Mathematics

(128 hours needed for graduation)

Year One						
Fall Semester				Spring Semester		
Course #	Course Title	Credit Hours		Course #	Course Title	Credit Hours
APPM 1350	Calculus 1 for Engineers	4		APPM 1360	Calculus 2 for Engineers	4
CHEN 1201	General Chemistry for Engineers	4		PHYS 1110	General Physics 1	4
CHEM 1114	Engineering General Chemistry Lab	1			Free Electives	6
	Approved Computing Course	4			Humanities or Social Sciences Elective	3
	Humanities or Social Sciences Elective	3				
	Credit Hours	**16**			**Credit Hours**	**17**

Year Two						
Fall Semester				Spring Semester		
Course #	Course Title	Credit Hours		Course #	Course Title	Credit Hours
APPM 2350	Calculus 3 for Engineers	4		APPM 2360	Introduction to Differential Equations w/ Linear Algebra	4
PHYS 1120	General Physics 2	4		APPM 2460	Differential Equations Computer Lab (Recommended, Not Required)	1
PHYS 1140	Experimental Physics	1		APPM 3310	Matrix Methods and Applications	3
	Technical Electives (Area of Emphasis)	3			Technical Electives (Area of Emphasis)	3
	Humanities or Social Sciences Elective	3			Free Electives	3
					Humanities or Social Sciences Elective	3
	Credit Hours	**15**			**Credit Hours**	**17**

Year Three						
Fall Semester				Spring Semester		
Course #	Course Title	Credit Hours		Course #	Course Title	Credit Hours
APPM 4350	Methods in Applied Mathematics: Fourier Series and Boundary Value Problems	3		APPM 3XXX		3
APPM 4440 or MATH 3001 or MATH 3140	Undergraduate Applied Analysis 1	3		APPM 4360	Methods in Applied Mathematics: Complex Variables and Applications	3
	Technical Electives (Area of Emphasis)	6			Technical Electives (Area of Emphasis)	4
	College-Approved Writing Course	3			Free Electives	3
					Humanities or Social Sciences Elective	3
	Credit Hours	**15**			**Credit Hours**	**16**

Year Four						
Fall Semester				Spring Semester		
Course #	Course Title	Credit Hours		Course #	Course Title	Credit Hours
APPM 4650	Intermediate Numerical Analysis 1	3		APPM 4660 or Senior Sequence	Intermediate Numerical Analysis 2 or Senior Sequence	3
APPM 4XXX		3		APPM 4XXX		3
	Technical Electives (Area of Emphasis)	6			Technical Electives (Area of Emphasis)	3
	Free Electives	4			Free Electives	7
	Credit Hours	16			**Credit Hours**	16

NOTE: *This represents one possible scenario for taking the minimum number of Applied Math courses for the major. After the 24 credit option requirement is satisfied, further technical electives can be selected from additional APPM courses or from other areas of interest*

2.2. Bachelor's Degree Requirements

The B.S. degree in Applied Mathematics requires the completion of a minimum of 128 credit hours of acceptable coursework with cumulative and major grade point averages of C (2.25) or better. Students must complete the following minimum requirements:

1. **Three semesters of calculus** (APPM 1350, APPM 1360 and APPM 2350) with a minimum grade of C- in each course.

2. **Computing Experience**: Select one of CHEN 1310, CSCI 1300, CSCI 1320, or ECEN 1310. For Fall 2019, APPM 2720 (Python with Math/Stat Applications) is also accepted.

3. **Science requirement**: Completion of PHYS 1110, 1120, and 1140. Completion of at least 4 additional credits of chemistry, biology, or physics (including 1 credit of laboratory science) chosen from one of the following:

   a) CHEN 1201 and CHEM 1114, or CHEN 1211 and CHEM 1221, or CHEM 1113 and CHEM 1114
   b) EBIO 1210, 1220, 1230, and 1240
   c) MCDB 1150, 1151, 2150, and 2151
   d) PHYS 2130 or PHYS 2170, and PHYS 2150

   Note to IUT students: Students choosing options 3b or 3c must be enrolled in (or have completed) PHYS 1120 at the time of their IUT application.
   Note to MCEN double majors: MCEN double majors may choose MCEN 1024 in place of options a-d
   Note to ASEN students: ASEN double majors with AMEN may choose ASEN 1022 in place of options a-d
   **These options are only available to MCEN or ASEN students who complete the double major.*
   Note to ASEN: PHYS 1140 requirement is waived

4. **Completion of the following required courses**:

   APPM 2360 (Differential Equations with Linear Algebra.)
   APPM 3310 (Matrix Methods)
   APPM 4350 (Methods in Applied Mathematics I)
   APPM 4360 (Methods in Applied Mathematics II)
   APPM 4650 (Intermediate Numerical Analysis I)
   APPM 4440 (Applied Analysis 1); MATH 3001 or MATH 3140 are acceptable substitutes

5. **A two semester course sequence of applied mathematics, statistics, or mathematics courses numbered 4000 or above in addition to APPM 4350 and 4360**

   (Possible sequences include: APPM 4650/4660, or STAT 4000/4010, or APPM 4560/STAT 4520, or APPM 4440/4450, or APPM 4380/4390, or APPM 3570 and either STAT 4520 or APPM 4560).
   Note: APPM 3570 is the only 3000-level course that can be used to satisfy this requirement.

6. **A minimum of 24 credits in applied mathematics, statistics, or mathematics courses numbered 3000 or above** (including the required courses).
   a. No more than 3 credits of APPM 4840 may count towards these 24
   b. No more than 6 credits of independent study are allowed for credit towards the BS in Applied Math.

7. **A minimum of 24 credits in engineering courses** (or approved courses with significant mathematical content in A&S or Business)
   a. At least 15 credits in these courses must be numbered 2000 or above
   b. At least 6 credits in these courses must be numbered 3000 or above.
   c. These 24 credits are in addition to those required credits listed in numbers 2 and 3 (mentioned above). Several possible options are listed on the following pages # 5-10

   Note: Students may earn a BS in Applied Mathematics and a minor in Statistics. The 12 upper division credits of statistics required for the minor may not be counted towards the 24 credits of upper division math courses for the bachelor's. However, the 12 upper division credits of statistics may be counted towards the 24 credits of technical electives in the area of emphasis. (See page 11 for more information on the Statistics minor.)

8. **Humanities and Social Sciences requirements** of the College of Engineering and Applied Sciences (18credits),
   a. This includes a 3 credit writing requirement. Students may satisfy the writing requirement by taking ENES 1010 (first-year freshmen only), WRTG 3030, WRTG 3035, ENES 3100, or PHYS 3050.
   b. Humanities and social science electives should not be limited to a selection of unrelated introductory courses. At least 6 credit hours must be at the 3000-level or above (this does not include the writing requirement). A complete list of courses that can be used to satisfy this requirement can be found at http://www.colorado.edu/engineering-advising/get-your-degree/degree-requirements/humanities-social-sciences-and-writing-requirements.

2.3. Options for Applied Mathematics Majors Area of Emphasis

In order to fulfill their degree requirements, Applied Mathematics majors are required to take 24 credits in engineering or approved courses with significant mathematical content in A&S or Business courses, with at least 6 credits in courses numbered 3000 or above and at least 15 credits in courses numbered 2000 or above. Here are several possible options. It should be stressed that the listed courses and options are **suggestions** and not **requirements**. Final course selection should be made in consultation with an Applied Math advisor.

I. Actuarial Option

A. The following courses should be taken:

1. BCOR 2002 (Principles of Accounting and Finance - 3 cr.) or BCOR 2203 and BCOR 2204 (prerequisite waived for Actuarial Certificate students)
2. ECON 2010* (Principles of Microeconomics – 4 cr.)
3. ECON 2020* (Principles of Macroeconomics – 4 cr.)
4. ECON 3070^{+} (Intermediate Microeconomic Theory – 3 cr.)
5. ECON 3080^{+} (Intermediate Macroeconomic Theory – 3 cr.)
6. ECON 4070 (Topics in Microeconomics - 3 cr.)
7. FNCE 3010^{+} (Corporate Finance – 3 cr.)

***** ECON 2010 and 2020 may not count toward the 24 credits of the option requirement; however, they can be used to meet the 18 credits social science/humanities requirement of the College of Engineering.
+ The Society of Actuaries requires students to take certain college courses that will earn the Validation by Educational Experiences (VEE) credit. Courses marked with a + satisfy this requirement, provided a grade of B- or better is obtained. These courses are also required for students completing the Actuarial Certificate Program. VEE credit is granted for both BCOR 2002 and FNCE 3010. VEE certification is pending.

B. Some (or all) of the following courses should be taken:

1. FNCE 3030 (Investment and Portfolio Management - 3 cr.) *
2. FNCE 4040 (Derivative Securities – 3 cr.)
3. ECON 4818 (Intro to Econometrics – 3 cr.)

C. Students are required to take APPM 3570, STAT 4520^{+}, and STAT 4540^{+} for the Actuarial Option. Students are strongly advised to take APPM 4560.

D. Additional courses that may be useful include ACCT 3220, 3230, and BCOR 3000. These courses can be taken only if space is available on the first day of the semester.

Advising notes:

1. The first actuarial examination, Exam P/1, can be taken after completing APPM 3570.
2. The second actuarial examination, Exam FM/2, can be taken after completing ECON 3070, ECON 3080, FNCE 3010 and self-study in interest theory.
3. The third actuarial examination, Exam IFM/3, can be taken after completing APPM 4560, FNCE 4040, and self study on interest theory.
4. The fourth actuarial examination, Exam C/4, can be taken after completing: STAT 4520, STAT 4540, APPM 4560, and self-study.
5. **Students wishing to take courses in the College of Business cannot register until the first day of classes.** Students may also take BCOR/FNCE courses in summer sessions. Alternatively, students can apply for admittance to the Actuarial Studies and Quantitative Finance Certificate Program which requires grades of B+ or better in their three semesters of Calculus. Students accepted into this program receive preferential treatment with respect to other non-business students when registering for business courses. For more information, please see your Applied Math advisor and visit http://www.colorado.edu/program/asqf
6. Students desiring to sign up for an actuarial exam should visit: http://www.soa.org/

II. Aerospace Engineering Sciences

Students who pursue this option are usually double majors.
Advising Note: Students wishing to enroll in ASEN courses must register through an Aerospace advisor.

III. Chemical Engineering Option

A. CHEN 1211 (Gen. Chemistry for Eng. – 3 cr.) & CHEM 1221 (Eng. Gen. Chem Lab – 2 cr.)

B. Recommended courses (total of 25 credits):

1. CHEN 2120 (Material & Energy Balances – 3 cr.)
2. CHEN 3200 (Fluid Mechanics – 3 cr.)
3. CHEN 3210 (Heat Transfer – 3 cr.)
4. CHEN 3220 (Separations and Mass Transfer – 3 cr.)
5. CHEN 3320 (Thermodynamics – 3 cr.)
6. CHEM 4521 (Physical Chemistry for Engineers – 3 cr.)
7. CHEN 4330 (Reaction Kinetics – 3 cr.)
8. CHEM 3311 (Organic Chemistry 1 - 4 cr.)

C. Students choosing this option must take CHEN 1310 as part of their Applied Math major computing experience. CHEN 1310 is a prerequisite for CHEN 2120.

IV. Civil, Environmental and Architectural Engineering Option

A. Recommended basic courses (total of 12 credits):

1. CVEN 2121 (Analytical Mechanics 1 – 3 cr.)
2. AREN 2110 (Thermodynamics – 3 cr.)
3. CVEN 3161 (Mechanics of Materials 1 – 3 cr.)
4. CVEN 3313 (Theoretical Fluid Mechanics – 3 cr.) or AREN 2120 (Fluid Mechanics and Heat Transfer – 3 cr.)

B. Students take 2 courses from any one of the following groups plus additional courses to bring the total credits to 24:

1. CVEN 3414 (Fundamentals of Environmental Eng. – 3 cr.)
   CVEN 4333 (Engineering Hydrology – 3 cr.)
2. CVEN 3525 (Structural Analysis 1 – 3 cr.)
   CVEN 3708 (Geotechnical Engineering 1 – 3 cr.)
   CVEN 4545/4555 (Steel Design/ Reinforced Concrete Design – 3 cr.)
3. AREN 2050 (Building Materials and Systems – 3 cr.)
   AREN 3010 (Mechanical Systems for Buildings – 3 cr.)
   AREN 3540 (Illumination 1 – 3 cr.)

C. **Double Major APPM-CVEN:** The Applied Mathematics and Civil Engineering departments offer a streamlined dual-degree track for talented students who are interested in analytical and computational methods related to civil engineering and general engineering science. Students can complete a double major from both programs with a minimum of 143 credits. Consult APPM-CVEN double major program faculty advisors in Applied Mathematics and Civil Engineering for additional information.

D. Students wishing to enroll in CVEN courses that are restricted to majors only must do so through the documents available at https://www.colorado.edu/engineering-advising/departmental-course-request-forms

V. Computational Biology and Bioinformatics Option

A. The following concentration of selected courses from computer science, biology, and chemistry provide the foundation for work in mathematical biology, computational biology, and/or bioinformatics.

B. Required courses

1. CSCI 2270 (Data Structures – 4 cr.) (Note: CSCI 1300 is a prerequisite for CSCI 2270)
2. CHEM 3311 & 3321 (Organic Chemistry 1 and Lab – 5 cr.)
3. MCDB 1150 & 1152 (Introduction to Cellular and Molecular Biology and Problem Solving Co-Seminar – 4 cr.)
4. MCDB 2150 & 2152 (Principles of Genetics and Problem Solving Co-Seminar – 4 cr.)
5. MCDB 3135 & 3140 (Molecular Cell Biology 1 and Lab - 5 cr.)
6. CSCI 3104 (Algorithms – 4 cr.) (prereq.: CSCI 2824 or APPM 3170)
7. CSCI 4314 (Algorithms for Molecular Biology - 3 cr.)

Advising Note: Students selecting this option are advised to take APPM 3570 and 4390, and STAT 4520 and 4540 as part of their Applied Math coursework. Other recommended courses include CSCI 3287 (Database and Information Systems).

VI. Computer Science Option

A. Required Course (total of 4 credits):
   CSCI 2270 (Data Structures – 4cr.) (Note: CSCI 1300 is a prerequisite)

B. Additional courses to bring the total number of credits to 24; at least two of these must be at the 3000 level. Possible choices include:
   1. CSCI 2400 (Computer Systems - 4 cr.)*
   2. CSCI 3104 (Algorithms – 4 cr.)*
   3. CSCI 3155 (Principles of Programming Languages – 4 cr.)
   4. CSCI 3287 (Design & Analysis of Data Systems – 3 cr.)
   5. CSCI 3308 (Software Development Methods and Tools - 3 cr.)
   6. CSCI 3753 (Operating Systems – 4 cr.)
   7. Additional CSCI courses to bring the total number of credits to at least 24

Advising note: Students completing the computer science option should have a minor in computer science. Check with the Computer Science Department.

* CSCI 2400 AND CSCI 3104 has APPM 3170 or CSCI 2824 as a prerequisite.

VII. Electrical & Computer Engineering Option

The Department of Electrical and Computer Engineering offers two separate minor programs:

A. Students interested in this option should consult with an advisor, as several areas are available (computer engineering, electrical engineering, signals and systems, and electrical renewable energy systems). A minimum of 24 credits is required.

B. Student choosing this option should plan on taking CSCI 1300 and CSCI 2270.

ADVISING NOTE: Students interested in the ECE Option should contact the ECE department and visit http://www.colorado.edu/engineering/academics/degrees-minors-certificates/minors

VIII. Engineering Physics / Physics Option

A. Recommended courses after first-year Physics (23 or 24 credits):
   1. PHYS 2130 or 2170 (Foundations of Modern Physics – 3 cr.)
   2. PHYS 2150 (Experimental Physics – 1 cr.)
   3. PHYS 2210 (Classical Mechanics and Mathematical Methods 1– 3 cr.)
   4. PHYS 3210 (Classical Mechanics and Mathematical Methods 2 - 3 cr.)
   5. PHYS 3220 (Quantum Mechanics & Atomic Physics 1 – 3 cr.)
   6. PHYS 3310 (Principles of Electricity & Magnetism 1 – 3 cr.)
   7. PHYS 3320 (Principles of Electricity & Magnetism 2 – 3 cr.)
   8. PHYS 3330 (Electronics for the Physical Sciences – 2 cr.) ***OR***
      PHYS 4230 (Thermodynamics & Statistical Mechanics – 3 cr.)
   9. Additional physics courses to total at least 24 credits.

B. Students choosing this option are advised to take APPM 3570 (Applied Probability – 3 cr.). MATH 3140 (Abstract Algebra 1 – 3 cr.) may also be useful for students interested in theoretical physics.

Advising Note: Students completing the Physics Option should have a minor in Physics. Check with the Physics Department.

IX. Finance Option

A. The following courses should be taken as part of the 24 credits required in the option:
   1. BCOR 2002 (Principles of Accounting and Finance - 3 cr.) or BCOR 2203 and BCOR 2204
   2. FNCE 3010 (Corporate Finance – 3 cr.)
   3. ECON 2010**, 2020**, 3070 and 3080.
   4. ECON 4818 (Econometrics) - 3 cr.

** ECON 2010, 2020 may not count toward the 24 credits of the option requirement; however, they can be used to meet the 18 credit social science/humanities requirement of the College of Engineering.

B. A minimum of two of the following courses must be taken in order to meet the 24 credit requirements of the option. All of them must be taken to complete the requirements of the Quantitative Finance Certificate Program:
   1. ACCT 3220 (Corporate Financial Reporting 1 - 3 cr.)
   2. FNCE 3030 (Investment and Portfolio Management - 3 cr.)*
   3. FNCE 4040 (Derivative Securities - 3 cr.)
   4. FNCE 4820 (Topics in Finance: Mathematical Finance - 3 cr.)
   5. FNCE 4070 (Financial Markets and Institutions - 3 cr.)

C. Students are required to take APPM 3570 and STAT 4520 for the Finance Option. Students are advised to take APPM 4560 and STAT 4540 if time permits.

D. Additional courses that may be taken as time permits:
   1. ACCT 3230 (Corporate Financial Reporting 2 - 3 cr.)
   2. FNCE 4000 (Financial Institutions Management - 3 cr.)
   3. FNCE 4020 (Applied Business Finance - 3 cr.)
   4. FNCE 4050 (Capital Investment Analysis - 3 cr.)
   5. FNCE 4060 (Special Topics in Finance - variable)

Advising note: Students wishing to take College of Business courses cannot register until the first day of classes. However, students can register for BCOR/FNCE courses in summer sessions. Alternatively, students can apply for admittance to the Actuarial Studies and Quantitative Finance Certificate Program. Students accepted into this program receive preferential treatment with respect to other non-business students when registering for business courses. For more information, please see your Applied Math advisor and visit http://www.colorado.edu/program/asqf/.

X. Geographic Information Science Option

A. Required Courses
   1. GEOG 3023 (Statistics for Geography – 4 cr.)
   2. CSCI 2270 (Data Structures – 4 cr.)
   3. GEOG 3053 Cartography Visualization & Information Design – 4 cr.)
   4. GEOG 4103 (Introduction to GIS – 4 cr.) (Prereqs: GEOG 3023 & GEOG 3053)

B. Additional courses to bring the total number of credits to 24
   Possible choices include:
   1. GEOG 4023 (GIS Modeling Applications – 4 cr.)
   2. GEOG 4303 (Spatial Programming in GIScience – 4 cr.)
   3. GEOG 4403 (Space –Time Analytics – 3 cr.)
   4. GEOG 4503 (GIS Project Management – 3 cr.)
   5. GEOL 3050 (GIS for Geologists – 2 cr.)

C. Students choosing this option must take CSCI 1300 as part of their Applied Math major computing experience. CSCI 1300 is a prerequisite for CSCI 2270.

Advising Note: Students completing the Geographic Information Science Option should have a Certificate in GIS and Computational Science. Check with the faculty contacts of the GIS Certificate Program.

XI. Geological Sciences Option

A. One of the following introductory sequences should be taken as part of the 24 credits required in this option
   1. GEOL 1010 & 1020 (Introduction to Geology + Geology 2 – 6 cr.)
   2. GEOL 1010 & 1040 (Introduction to Geology + Geology of Colorado – 6 cr.)
   3. GEOL 1010 & 1060 (Introduction to Geology + Global Change – 6 cr.)

B. Required Laboratory
   1. GEOL 1030 (Introduction to Geology Laboratory – 1 cr.)

C. Additional courses to bring the total number of credits to 24; at least two of these must be at the 3000 level. Possible choices include:
   1. GEOL 2700 (Introduction to Field Geology – 2cr.)
   2. GEOL 3010 (Introduction to Mineralogy – 3 cr.)
   3. GEOL 3023 (Statics for Earth Sciences – 3 cr.)
   4. GEOL 3120 (Structural Geology – 4 cr.)
   5. GEOL 3410 (Paleobiology – 3 cr.)
   6. GEOL 3430 (Sedimentology and Stratigraphy – 4 cr.)
   7. GEOL 4130 (Principles of Geophysics – 3 cr.)
   8. GEOL 4093 (Remote Sensing of the Environment – 4 cr.)
   9. GEOL 4241 (Principles of Geomorphology – 4 cr.)

Advising Note: Students completing the Geological Sciences Option should have a minor in Geology. Check with the Geological Sciences Department.

XII. Mechanical Engineering Option

A. Recommended courses:
   1. MCEN 2023 (Statics & Structures – 3 cr.)
   2. MCEN 2063 (Mechanics of Solids – 3 cr.)
   3. MCEN 3012 (Thermodynamics – 3 cr.)
   4. MCEN 3021 (Fluid Mech. – 3 cr.)
   5. MCEN 3022 (Heat Transfer – 3 cr.)
   6. MCEN 3025 (Component Design – 3 cr.)
   7. MCEN 2043 (Dynamics – 3 cr.)
   8. MCEN 4043 (System Dynamics – 3 cr.)

B. Students choosing this option are advised to take STAT 4000 (Statistical Methods and Applications 1 – 3 cr.) or APPM 3570 (Applied Probability) and STAT 4520 (Introduction to Math Statistics) as part of their Applied Math major.

C. Students wishing to enroll in MCEN courses must do so through the documents available at https://www.colorado.edu/engineering-advising/departmental-course-request-forms

XIII. Statistics & Data Science

A. Students would take the courses in statistics for the statistics minor plus additional coursework chosen from Computer Science, College of Media, Communication and Information, ATLAS, or other relevant area as approved by the advisor.

B. It is recommended that students choosing this option complete both APPM 2720 (Python) and CSCI 2270 (Data Structures)

Advising Note: Students completing the Statistics & Data Science Option should have an Applied Math Minor in Statistics. Check with your advisor for confirmation.

**Students may earn a BS in Applied Mathematics and a minor in Statistics. The 12 upper division credits of statistics required for the minor may not be counted towards the 24 credits of upper division math courses for the bachelor's.

XIV. Technology, Arts & Media Option

A. Required Courses

1. ATLS 2000 (Meaning of Info Tech. - 3 cr.) *
2. ATLS 2100 (Image - 3 cr.)
3. ATLS 2200 (Web - 3 cr.)
4. ATLS 2300 (Text - 3 cr.)
5. ATLS 1300 (Code - 3 cr.)
6. CSCI 2270 (Data Structures – 4 cr.) (Prereq: CSCI 1300)
7. CSCI 3104 (Algorithms – 4 cr.) (Prereq: APPM 3170 or CSCI 2824)
8. CSCI 4229 (Computer Graphics – 3 cr.)

* This course may be used to satisfy EITHER 3 credits of H&SS requirement or the Applied Math area of emphasis, but not both.

B. Recommended additional courses to bring the total to at least 24 credits:

1. Advisor approved technical electives to complete the TAM minor.
2. CSCI 3202 (Intro to Artificial Intelligence – 3 cr.)
3. CSCI 4202 (Artificial Intelligence 2 – 3 cr.)
4. CSCI 4448 (Object Orientated Analysis and Design – 3 cr.)
5. Students are advised to take APPM 3570, 4560, and 4660 as part of their Applied Math coursework.

Advising Note: More information on the ATLAS/TAM Certificate in Digital Media, as well as the ATLS Minor in Technology, Arts & Media may be found at http://tam.colorado.edu

2.4. Double Majors/Double Degrees

Students in the College of Engineering and Applied Science may pursue a baccalaureate degree to graduate with more than one major under the same degree (BS) by completing all requirements for each major. The majors must be completed concurrently and will post to a degree record with the same graduation date. Within the College of Engineering and Applied Science, a minimum of 128 total credit hours is required for a degree with additional majors. This option is called a double major.

A double degree at the baccalaureate level is two different degrees (e.g., a BA from the College of Arts and Sciences and a BS in Applied Mathematics). In order to earn a double degree, students must meet all individual degree requirements and receive approval from the academic college for each degree. Both degrees must be confirmed within the same graduation date.

Colorado residents should be aware that the College Opportunity Fund (COF) may not cover all tuition costs associated with a double degree program (those beyond 145 semester credit hours).

2.5. Minor in Statistics and Data Science

The minor in statistics was developed to provide in-depth training in statistical methods and techniques well beyond the training usually received by science and engineering majors. The ability to understand, visualize, and analyze data is becoming an increasingly important skill in many disparate fields. This minor offers undergraduate students from any major the opportunity to develop their statistical knowledge.

Prerequisites for the Statistics minor are two semesters of calculus and computing experiences such as provided by CSCI 1300, CSCI 1320, or CHEN 1310.

Students may earn both a BS in Applied Mathematics and a minor in statistics. However, the 12 upper division credits of statistics required for the minor may not be counted towards the 24 credits of upper division applied math courses. The twelve upper division credits of statistics may, however, count towards the 24 credits of technical electives required for all applied math majors.

Residency
A *minimum* of 23 credits at the 2000-level and above is required. At least three APPM or STAT courses, two of which must be at the 3000-level or above, need to be taken on the Boulder campus. No more than nine credit hours may be applied from transfer work; of those nine, no more than six may be 3000-level or above.

Minimum Grades
A cumulative GPA of 2.00 or better is required in the courses that are used to satisfy the requirements for this minor. Each individual course that is counted towards these degree requirements must be passed with a grade of C- or better.

Course Requirements

Course Number	Credits	Course Title
APPM 2350 or **MATH 2400**	4	Calculus III
APPM 3310	3	Matrix Methods and Applications
STAT 2600	4	Introduction to Data Science
STAT 3100/APPM 3570	3	Applied Probability
STAT 3400	3	Applied Regression

And **TWO** of the following courses:

STAT 4400	3	Advanced Statistical Modeling
STAT 4430	3	Spatial Statistics
STAT/MATH 4520	3	Mathematical Statistics
STAT/MATH 4540	3	Time Series
STAT 4100/APPM 4560	3	Markov Chains
STAT 4610	3	Statistical Learning

Note: A student cannot earn a minor in Statistics and a minor in Applied Mathematics with the probability and statistics emphasis

2.6. BACHELOR'S-ACCELERATED MASTER'S DEGREE PROGRAM

Beginning July 1, 2019, students newly admitted to bachelor's/master's programs at CU Boulder will follow the new Bachelor's–Accelerated Master's (BAM) degree program structure.

What's Changing?

Under the concurrent degree structure, students are awarded a bachelor's and master's degree *simultaneously* after meeting the requirements for both degrees. Students admitted prior to July 2019 will continue to follow the concurrent bachelor's/master's structure. Information about the program prior to July 1, 2019 is further down on this page.

Students admitted beginning July 1, 2019 will follow the new BAM program structure. Students will be awarded a *bachelor's degree first*, once they have met the undergraduate degree requirements and have applied to graduate. They will transition into graduate student status by applying to continue with the master's degree. They will *then be awarded a master's degree* after fulfilling graduate degree requirements.

Under the BAM structure, students will begin taking a limited amount of graduate-level coursework as undergraduates (typically during senior year). Students may take up to 12 credit hours which can later be applied to the accelerated master's degree, and six credits can double count for both the undergraduate and graduate degrees.

Learn More

The new BAM intent application form will be available for students beginning July 1, 2019. For more information on the new program structure, including the background on the decision as well as how this impacts existing concurrent programs and related administrative procedures, visit the Office of the Registrar's Concurrent & BAM Degree webpage at https://www.colorado.edu/registrar/faculty-staff/policies/bam-program or view the full BAM Program Policy at https://www.colorado.edu/registrar/students/degree-planning/bam-program/policy

Bachelor's degree in Applied Mathematics, Master's degree in Applied Mathematics

The Bachelor's-Accelerated Master's (BAM) degree program offers currently enrolled CU Boulder undergraduate students the opportunity to receive a bachelor's and master's degree in a shorter period of time. Students receive the bachelor's degree first, but begin taking graduate coursework as undergraduates, typically in their senior year. Because up to six credits of courses are allowed to double count for both the bachelor's and the master's degrees, students receive a master's degree in less time and at a lower cost than if they were to enroll in a stand-alone master's degree program after completion of their baccalaureate degree. In addition, staying at CU Boulder to pursue a Bachelor's-Accelerated Master's program enables students to continue working with their established faculty mentors.

Admissions Requirements

In order to gain admission to the BAM program named above, a student must meet the following criteria:

- Have a cumulative GPA of 3.4 or higher
- Have a minimum GPA of 3.4 in APPM, STAT, and MATH courses
- Have completed a minimum of 60 credit hours of coursework
- Transfer students must have completed a minimum of 24 credit hours at CU Boulder
- Students must have completed a minimum of two APPM or STAT courses numbered 3000 or higher with grades of 3.4 GPA or higher

Program Requirements
Students may take up to and including 12 hours while in the undergraduate program which can later be used toward the master's degree. However, only 6 graduate credit hours may be double counted toward the bachelor's degree and the master's degree. Students must apply to graduate with the bachelor's degree, and apply to continue with the master's degree, early in the semester in which the undergraduate requirements will be completed.[1]

If you are interested in the Applied Mathematics BAM degree program, please meet with your advisor regarding the BAM program and then contact the APPM graduate coordinator at amgradco@colorado.edu for more information.

[1]Students who were admitted prior to July 2019 follow a concurrent Bachelor's/Master's structure, and the two degrees are awarded simultaneously when requirements for both degrees are met.

Curriculum
Students in the program should complete all requirements for the BS degree in Applied Mathematics by the end of their fourth year. Six credit hours of Applied Mathematics graduate courses can be counted towards both the undergraduate degree requirements and towards the requirements for the MS degree. All requirements for the MS degree should be completed by the end of the fifth year. If necessary, a sixth year will be allowed. For the MS portion of the BAM program, students may elect either the thesis or non-thesis option. In theory, the total minimum number of credit hours required for the BS and MS degrees is 152.

Advising
Students in the BAM program must have an Applied Math faculty advisor with whom they consult to compose a degree plan. This plan will include a list of courses to be taken from the semester following admission to the BAM program through the end of the graduate program and will ensure that the requirements for both the BS and the MS degrees are satisfied. This plan must be filed with the APPM Department Graduate Student Coordinator by the end of the third week of the first semester in which the student has been admitted into the program.

Continuation in the Program
The student must maintain an overall GPA of 3.4 in their undergraduate courses and 3.2 in courses numbered 5000 and above. Also, students must complete a minimum of six hours for graduate credit by the end of their senior year. (Included in these credits may be any of the "double-counting" courses described in the Curriculum section above.)

Regulations
Until a student in this program satisfies all requirements for the BS degree, he/she will be governed by the rules and regulations applicable to any undergraduate major in the Applied Math department. Students are admitted into the graduate school within one year of completing their undergraduate degree, and must provide a start term when applying for admission in their final undergraduate term.

Escape Plan
Students who decide not to continue in the BS/MS program must complete the usual BS requirements to obtain that degree.

SAMPLE CURRICULUM FOR BAM (Emphasis in Probability and Statistics)

Junior Year

- In general, the student should take at least four applied mathematics courses at the 3000 level or higher.
- **Fall semester:** APPM 4350 (Methods in Applied Mathematics I), APPM 4440 or MATH 3001
- **Spring semester:** APPM 3570 (Applied Probability) and APPM 4360 (Methods in Applied Mathematics II)

Senior Year

- The student should take at least six courses at the 3000 level or higher. At least two, and preferably four, of these courses should be at the 5000 level.
- **Fall semester:** APPM 4650 (Intermediate Numerical Analysis I), STAT 5520 (Introduction to Mathematical Statistics) or STAT 5530 (Mathematical Statistics), one other APPM or STAT course, 5XXX.
- **Spring semester:** APPM 4660 (Intermediate Numerical Analysis II), APPM 5560 (Markov Processes), one other STAT 5XXX course.

Fifth Year

- The student should take at least four graduate level (5000 or higher) applied mathematics courses together with an approved graduate-level, out-of-department sequence.
- **Fall semester:** APPM 5600 (Numerical Analysis I); APPM 5XXX; first course in approved out-of-department sequence, 5XXX.
- **Spring semester:** APPM 5610 (Numerical Analysis II); STAT 5540 (Applied Time Series Analysis); second course in approved out-of-department sequence, 5XXX.

SAMPLE CURRICULUM FOR BAM (Emphasis in Numerics and Modeling)

Junior Year

- In general, the student should take at least four applied mathematics courses at the 3000 level or higher.
- **Fall semester:** APPM 4650 (Intermediate Numerical Analysis I), APPM 4350 (Methods in Applied Mathematics I)
- **Spring semester:** APPM 4660 (Intermediate Numerical Analysis II), APPM 4360 (Methods in Applied Mathematics II)

Senior Year

- The student should take at least five courses at the 3000 level or higher. At least two, and preferably four, of these courses should be at the 5000 level.
- **Fall semester:** APPM 5600 (Numerical Analysis I), APPM 4440 or MATH 3001, APPM 5380 (Modeling in Applied Mathematics)
- **Spring semester:** APPM 5610 (Numerical Analysis II), APPM 5460 (Methods of Applied Mathematics: Dynamical Systems).

Fifth Year

- The student should take at least four graduate level (5000 or higher) applied mathematics courses together with an approved graduate-level, out-of-department sequence.
- **Fall semester:** APPM 5470 (Methods of Applied Mathematics: PDEs); APPM 5XXX; first course in approved out-of-department sequence, APPM 5XXX.
- **Spring semester:** APPM 5480 (Methods of Applied Mathematics: Approximation Methods); APPM 5xxx (special topics course); second course in approved out-of-department sequence, APPM 5XXX

Note

- These assume that APPM 1350 (Calculus I), APPM 1360 (Calculus II), APPM 2350 (Calculus III), APPM 2360 (Differential Equations) and APPM 3310 (Matrix Methods) are taken in the freshman and sophomore years.
- **These are sample curriculum only. There are many other possibilities for completing the BAM requirements in Applied Mathematics.**

3. Applied Mathematics Undergraduate Courses

All Courses Require a C- Grade or higher to advance to the next course in sequence

APPM 1235 Pre-calculus for Engineers
Prepares students for the challenging content and pace of the calculus sequence required for all engineering majors. The course covers algebra, trigonometry and selected topics in analytical geometry. It prepares students for the calculus courses offered for engineering students. It requires students to engage in rigorous work sessions as they review topics that they must be comfortable with to pursue engineering course work. The course is structured to accustom students to the pace and culture of learning encountered in engineering math courses. Formerly GEEN 1235. Restricted to College of Engineering or Pre-Engineering Arts and Sciences majors only. Requires an ALEKS math exam taken in 2016 or earlier with a score of 61% or higher, or placement into pre-calculus based on your admissions data and/or CU Boulder coursework. Credit not granted for this course and MATH 1150.

APPM 1340 Calculus 1 with Algebra, Part A.
Studies selected topics in analytical geometry and calculus: rates of change of functions, limits, derivatives and their applications. APPM 1340-1345 together are equivalent to APPM 1350. The sequence APPM 1340-1345 is specifically designed for students whose manipulative skills in the techniques of high school algebra and precalculus may be inadequate for APPM 1350. Requires prerequisite course of APPM 1235 or MATH 1021 or MATH 1150 or MATH 1160 or an ALEKS math exam taken in 2016 or earlier with a score of 61% or higher, or placement into pre-calculus based on your admissions data and/or CU Boulder coursework. Semester offered: Fall

APPM 1345 Calculus 1 with Algebra, Part B.
Continuation of APPM 1340. Studies selected topics in calculus: derivatives and their applications, integration, differentiation and integration of transcendental functions. Algebraic and trigonometric topics are studied throughout, as needed. Prereq., APPM 1340. Credit not granted for this course and APPM 1350 or MATH 1300 or ECON 1088 or MATH 1081 or MATH 1310 or MATH 1330. Semester offered: Spring

APPM 1350 Calculus 1 for Engineers
Topics in analytical geometry and calculus including limits, rates of change of functions, derivatives and integrals of algebraic and transcendental functions, applications of differentiations and integration. ***Note:*** COEN 1350 a 1-credit-workgroup, is available for students who would like more practice working calculus problems in a group learning environment. Requires prerequisite course of APPM 1235 or MATH 1021 or MATH 1150 or MATH 1160 or an ALEKS math exam taken in 2016 or earlier with a score of 76% or greater, or placement into calculus based on your admissions data and/or CU Boulder coursework. Students with credit in APPM 1350 may not receive credit for MATH 1080, 1081, 1090, 1100, 1300, 1310, or ECON 1088 or APPM 1345. Approved for arts and sciences core curriculum: quantitative reasoning and mathematical skills.

APPM 1360 Calculus 2 for Engineers
Continuation of APPM 1350. Focuses on applications of the definite integral, methods of integration, improper integrals, Taylor's theorem, and infinite series. Students may not receive credit for both APPM 1360 and MATH 2300.
Prereq., APPM 1350 or APPM 1345 or MATH 1300.

APPM 1390 A Game for Calculus
1 credit course coaches students to implement study strategies geared specifically toward APPM Calculus in a structured, supportive, small group environment. Department consent required.
Repeatable: Repeatable for up to 3.00 total credit hours.

APPM 2350 Calculus 3 for Engineers
Covers multivariable calculus, vector analysis, and theorems of Gauss, Green, and Stokes. Students may not receive credit for APPM 2350 and MATH 2400.
Prereq., APPM 1360 or MATH 2300.

APPM 2360 Introduction to Differential Equations with Linear Algebra
Introduces ordinary differential equations, systems of linear equations, matrices, determinants, vector spaces, linear transformations, and systems of linear differential equations. No credit is awarded to students already having credit in both MATH 2130 and MATH 3430, both APPM 3310 and MATH 3430, or APPM 2380.
Prereq., APPM 1360 or MATH 2300.

APPM 2450 Calculus 3: Computer Lab
Selected topics in analytic geometry and calculus with a focus on symbolic computation using Mathematica.
Coreq., APPM 2350. Grading basis: Pass/Fail

APPM 2460 Differential Equations: Computer Lab
Selected topics include differential equations and linear algebra, with a focus on symbolic computation using Matlab.
Coreq., APPM 2360. Grading basis: Pass/Fail

APPM 2720 Open Topics in Lower Division Applied Mathematics
This course provides a vehicle for the development and presentation of new topics that are accessible to lower division Applied Mathematics students. These topics have the potential to be incorporated into the core APPM curriculum. Prereqs., Calc 1. Semester offered: Varies

APPM 3010 Chaos in Dynamical Systems
Introduces undergraduate students to chaotic dynamical systems. Topics include smooth and discrete dynamical systems, bifurcation theory, chaotic attractors, fractals, Lyapunov exponents, synchronization and networks of dynamical systems. Applications to engineering, biology and physics will be discussed. Department enforced requisite, knowledge of a programming language.
Prerequisites: APPM 2360 or MATH 3430. Semester offered: Fall.

APPM 3050 Scientific Computing in Matlab
Topics covered include: approximations in computing, computer arithmetic, interpolation, matrix computations, nonlinear equations, optimization, and initial-value problems with emphasis on the computational cost, efficiency, accuracy of algorithms. The problem sets are application-oriented with examples taken from orbital mechanics, physics, genetics and fluid dynamics.
Prerequisites: APPM 2360 or MATH 3430. Semester offered: Spring.

APPM 3170 Discrete Applied Mathematics
Introduces students to ideas and techniques from discrete mathematics that are widely used in science and engineering. Mathematical definitions and proofs are emphasized. Topics include formal logic notation, proof methods; set theory, relations; induction, well-ordering; algorithms, growth of functions and complexity; integer congruencies; basic and advanced counting techniques, recurrences and elementary graph theory. Other selected topics may also be covered.
Prerequisites: APPM 1360 or MATH 2300. Semester Offered: Fall and Spring

APPM 3310 Matrix Methods and Applications
Introduces linear algebra and matrices, with an emphasis on applications, including methods to solve systems of linear algebraic and linear ordinary differential equations. Discusses computational algorithms that implement these methods. Some applications in operations research may be included as time permits. Prereq., APPM 2350 or MATH 2400 or APPM 2360. Semester offered: Fall and Spring.

APPM 3350 Advanced Engineering Calculus
Extends the treatment of engineering mathematics beyond the topics covered in Calculus 3 and differential equations. Topics include non-dimensionalization, elementary asymptotics and perturbation theory, Reynold's transport theorem and extensions of Leibnitz's rule, as applied to continuum conservation equations. Hamiltonian formulations, Legendre and Laplace transforms, special functions and their orthogonality properties. Prereq., (APPM 2350 or MATH 2400) and APPM 2360. Semester offered: usually in Fall.

APPM 3570 Applied Probability
Studies axioms, counting formulas, conditional probability, independence, random variables, continuous and discrete distribution, expectation, moment generating functions, law of large numbers, central limit theorem, Poisson process, and multivariate Gaussian distribution. Coreq., APPM 2350 or MATH 2400. Students may not receive credit for both APPM 3570 and either ECEN 3810 or MATH 4510. Semester offered: Spring and Fall.

APPM 4120 Introduction to Operations Research
Studies linear and nonlinear programming, the simplex method, duality, sensitivity, transportation and network flow problems, some constrained and unconstrained optimization theory and the Kuhn-Tucker conditions as time permits. Prereqs., APPM 3310. Same as APPM 5120 and MATH 4120/5120. Semester offered: Spring.

APPM 4350 Methods in Applied Mathematics: Fourier Series and Boundary Value Problems
Reviews ordinary differential equations, including solutions by Fourier series. Physical derivation of the classical linear partial differential equations (heat, wave, and Laplace equations). Solution of these equations via separation of variables, with Fourier series, Fourier integrals, and more general eigenfunction expansions. Prereqs., (APPM 2350 or MATH 2400) and APPM 2360. Coreq., APPM 3310. Same as APPM 5350. Semester offered: Fall.

APPM 4360 Methods in Applied Mathematics: Complex Variables and Applications
Introduces methods of complex variables, contour integration and theory of residues. Applies solving partial differential equations by transform methods, Fourier and Laplace transforms, Riemann-Hilbert boundary-value problems. Also applies conformal mapping to ideal fluid flow and/or electrostatics. Prereqs., (APPM 2350 or MATH 2400) and APPM 2360. Coreq., APPM 3310 or MATH 3130. Same as APPM 5360. Semester offered: Spring.

APPM 4370 Computational Neuroscience
Applies mathematical and computational methods to neuroscience. Techniques from linear algebra, differential equations, introductory dynamical systems, probability, stochastic processes, model validation, and machine learning will be learned and used. Neuroscience topics include neural spiking, network dynamics, probabilistic inference, learning, and plasticity. Will learn how the brain uses computational principles to enact decision making, vision, and memory. Recommended background includes linear algebra, differential equations, probability, and programming. Students will hone programming skills in MATLAB/Python and TensorFlow. Recommended prerequisite: APPM 3570/STAT 3100, STAT 2600 or CSCI 3022. Same as APPM 5370.

APPM 4380 Modeling in Applied Mathematics
An exposition of a variety of mathematical models arising in the physical and biological sciences. Students' modeling projects are presented in class. Topics can vary: GPS navigation, medical imaging, ocean waves, computerized facial recognition. Prereqs., APPM 2350 or MATH 2400 and 2360. Recommended prereqs., APPM 3310, 4350, and 4650. Same as APPM 5380. Semester offered: Fall.

APPM 4390 Modeling in Mathematical Biology
Investigates how complex systems in biology can be studied using applied mathematics. Examines several case studies which include topics from microbiology, enzyme reaction kinetics, neuroscience, ecology, epidemiology, physiology, and bioengineering. Coreq., APPM 2360 and (APPM 3310). Same as APPM 5390. Semester offered: Spring.

APPM 4440 Undergraduate Applied Analysis 1
Provides a rigorous treatment of topics covered in Calculus 1 and 2. Topics include convergent sequences, continuous functions, differentiable functions, Darboux sums, Reimann sums, and integration, Taylor and power series and sequences of functions. Prereq., (APPM 2350 or MATH 2400) and APPM 2360. Prereq or coreq., APPM 3310. Semester offered: Fall

APPM 4450 Undergraduate Applied Analysis 2
Continuation of APPM 4440. Study of multidimensional analysis including n-dimensional Euclidean space, continuity and uniform continuity of functions of several variables, differentiation, linear and nonlinear approximation, inverse function and implicit function theorems, and a short introduction to metric spaces. Prereq. APPM 4440 or MATH 3001. Semester offered: Spring

APPM 4490 Theory of Machine Learning
Presents the underlying theory behind machine learning in proofs-based format. Answers fundamental questions about what learning means and what can be learned via formal models of statistical learning theory. Analyzes some important classes of machine learning methods. Specific topics may include the PAC framework, VC-dimension and Rademacher complexity. Recommended prerequisite: CSCI 5622 (minimum grade C-).

APPM 4510 Data Assimilation in High Dimensional Dynamical Systems
Develops and analyzes approximate methods of solving the Bayesian inverse problem for high-dimensional dynamical systems. After briefly reviewing mathematical foundations in probability and statistics, the course covers the Kalman filter, particle filters, variational methods and ensemble Kalman filters. The emphasis is on mathematical formulation and analysis of methods. Prereqs., APPM 3310 and APPM 3570. Same as APPM 5510. Semester offered: Varies

APPM 4515 High-Dimensional Probability for Data Science
Provides students with an exposition of the most recent methods of high-dimensional probability for the analysis of high dimensional datasets. Applications include randomized algorithms and high-dimensional random models of datasets. Same as APPM 5515.

APPM 4530 Stochastic Analysis for Finance
Studies mathematical theories and techniques for modeling financial markets. Specific topics include the binomial model, risk neutral pricing, stochastic calculus, connection to partial differential equations and stochastic control theory. Prereqs., APPM 3310 and APPM 3570. Prereq or Coreq of APPM 4350. Same as APPM 5530. Semester offered: Varies

APPM 4560 Markov Processes, Queues, and Monte Carlo Simulations
Brief review of conditional probability and expectation followed by a study of Markov chains, both discrete and continuous time. Queuing theory, terminology, and single queue systems are studied with some introduction to networks of queues. Uses Monte Carlo simulation of random variables throughout the semester to gain insight into the processes under study. Prereq., APPM 3570 or MATH 4510. Same as APPM 5560. Semester offered: Fall. Beginning Spring 2019, APPM 4560 will be offered Spring Only.

APPM 4565 Random Graphs
Introduces mathematical techniques, including generating functions, the first- and second-moment method and Chernoff bounds to study the most fundamental properties of the Erdos-Renyl model and other celebrated random graph models such as preferential attachment, fixed degree distribution, and stochastic block models. Same as APPM 5565.

APPM 4650 Intermediate Numerical Analysis I
Focuses on numerical solution of nonlinear equations, interpolation, methods in numerical integration, numerical solution of linear systems, and matrix eigenvalue problems. Stresses significant computer applications and software. Prereqs., APPM 3310 and APPM 2360 and knowledge of a programming language. Same as MATH 4650. Semester offered: Fall, Spring and Summer.

APPM 4660 Intermediate Numerical Analysis II
Continuation of 4650. Examines numerical solution of initial-value problems, and two-point boundary-value problems for ordinary partial differential equations. Also looks at numerical methods for solving partial differential equations. Prereq., APPM 4650 and knowledge of a programming language. Same as MATH 4660. Semester offered: Spring.

APPM 4720 Open Topics in Applied Mathematics
Provides a vehicle for the development and presentation of new topics that may be incorporated into the core courses in applied mathematics. Prereqs., variable, depending on topic -- see instructor. Same as APPM 5720. Semester offered: Varies.

APPM 4840 Reading and Research in Applied Mathematics
Introduces undergraduate students to the research foci of the Department of Applied Mathematics. May be repeated up to 9 total credit hours. Semester offered: Fall, Spring and Summer.

APPM 4950 Seminar in Applied Mathematics
Introduces undergraduate students to the research foci of the Department of Applied Mathematics. It is also designed to be a capstone experience for the program's majors. Semester offered: Fall and Spring.

Statistics and Data Sciences Courses

STAT 2600 Introduction to Data Science
Introduces students to importing, tidying, exploring, visualizing, summarizing, and modeling data and then communicating the results of these analyses to answer relevant questions and make decisions. Students will learn how to program in R using reproducible workflows. During weekly lab sessions students will collaborate with their teammates to pose and answer questions using real-world datasets. Semester Offered: Spring

STAT 3100 Applied Probability
Studies axioms, counting formulas, conditional probability, independence, random variables, continuous and discrete distribution, expectation, joint distributions, moment generating functions, law of large numbers and the central limit theorem. Credit not granted for this course and ECEN 3810 or MATH 4510. Same as APPM 3570. Semester Offered: Fall and Spring

STAT 3400 Applied Regression
Introduces methods, theory, and applications of linear statistical models, covering topics such as estimation, residual diagnostics, goodness of fit, transformations, and various strategies for variable selection and model comparison. Examples will be demonstrated using statistical programming language R.
Prerequisites: STAT 2600 and STAT 3100 Semester Offered: Spring

STAT 4000 Statistical Methods and Application I
Introduces exploratory data analysis, probability theory, statistical inference, and data modeling. Topics include discrete and continuous probability distributions, expectation, laws of large numbers, central limit theorem, statistical parameter estimation, hypothesis testing, and regression analysis. Considerable emphasis on applications in the R programming language. Same as STAT 5000.
Corequisite: APPM 1360. Semester Offered: Fall and Spring

STAT 4010 Statistical Methods and Application II
Expands upon statistical techniques introduced in STAT 4000. Topics include modern regression analysis, analysis of variance (ANOVA), experimental design, nonparametric methods, and an introduction to Bayesian data analysis. Considerable emphasis on application in the R programming language. Same as STAT 5010.
Prerequisite: STAT 4000 or Instructor Consent. Semester Offered: Spring

STAT 4100 Markov Processes, Queues, and Monte Carlo Simulations
Brief review of conditional probability and expectation followed by a study of Markov chains, both discrete and continuous time, including Poisson point processes. Queuing theory, terminology and single queue systems are studied with some introduction to networks of queues. Uses Monte Carlo simulation of random variables throughout the semester to gain insight into the processes under study. Same as APPM 4560/5560.

STAT 4230 Stochastic Analysis for Finance
Studies mathematical theories and techniques for modeling financial markets. Specific topics include the binomial model, risk neutral pricing, stochastic calculus, connection to partial differential equations and stochastic control theory. Same as APPM 4530/5530 and STAT 5230.

STAT 4250 Data Assimilation in High Dimensional Dynamical Systems
Develops and analyzes approximate methods of solving the Bayesian inverse problem for high-dimensional dynamical systems. After briefly reviewing mathematical foundations in probability and statistics, the course covers the Kalman filter, particle filters, variational methods and ensemble Kalman filters. The emphasis is on mathematical formulation and analysis of methods. Same as APPM 4510/5510 and STAT 5250.

STAT 4400 Advanced Statistical Modeling
Introduces methods, theory and applications of modern statistical models, from hierarchical linear models, to generalized hierarchical linear models, including hierarchical logistic and hierarchical count regression models. Topics such as estimation, residual diagnostics, goodness of fit, transformations, and various strategies for variable selection and model comparison will be discussed in depth. Examples will be demonstrated using statistical programming language R.
Prerequisites: STAT 3400 and STAT 4520. Semester Offered: Spring

STAT 4430 Spatial Statistics
Introduces the theory of spatial statistics with applications. Topics include basic theory for continuous stochastic processes, spatial prediction and kriging, simulation, geostatistical methods, likelihood and Bayesian approaches, spectral methods and an overview of modern topics such as nonstationary models, hierarchical modeling, multivariate processes, methods for large datasets and connections to spines. Same as STAT 5430.

STAT 4520 Introduction to Mathematical Statistics
Examines point and confidence interval estimation. Principles of maximum likelihood, sufficiency, and completeness: tests of simple and composite hypotheses, linear models, and multiple regression analysis if time permits. Analyzes various distribution-free methods. Same as STAT 5520 and MATH 4520 and MATH 5520. Prerequisites: APPM 3570 or STAT 3100 or MATH 4510

STAT 4540 Introduction to Time Series
Studies basic properties, trend-based models, seasonal models modeling and forecasting with ARIMA models, spectral analysis and frequency filtration. Same as STAT 5540 and MATH 4540 and MATH 5540.

STAT 4610 Statistical Learning
Consists of applications and methods of statistical learning. Reviews multiple linear regression and then covers classification, regularization, splines, tree-based methods, support vector machines, unsupervised learning and Gaussian process regression.
Prerequisite: STAT 3400

STAT 4630 Computational Bayesian Statistics
Introduces Bayesian statistics, normal and non-normal approximation to likelihood and posteriors, the EM algorithm, data augmentation, and Markov Chain Monte Carlo (MCMC) methods. Additionally, introduces more advanced MCMC algorithms and requires significant statistical computing. Examples from a variety of areas, including biostatistics, environmental sciences, and engineering, will be given throughout the course. Recommended prerequisite: prior programming experience. Same as STAT 5630.

STAT 4680 Statistical Collaboration
Educates and trains students to become effective interdisciplinary collaborators by developing the communication and collaboration skills necessary to apply technical statistics and data science skills to help domain experts answer research questions. Topics include structuring effective meetings and projects; communicating statistics to non-statisticians; using peer feedback, self-reflection and video analysis to improve collaboration skills; creating reproducible statistical workflows; working ethically. Prereqs., STAT 4520. Same as APPM 5680. Semester offered: Fall

STAT 4690 Advanced Statistical Collaboration
Educates and trains students to become advanced interdisciplinary collaborators by developing and refining the communication, collaboration and technical statistics and data science skills necessary to collaborate with domain experts to answer research questions. Students work on multiple projects. Discussions center on technical skills necessary to solve research problems and video analysis to improve communication and collaboration skills. Prereqs., STAT 4680 or STAT 5690. Same as APPM 5690. Semester offered: Spring

STAT 4700 Philosophical and Ethical Issues in Statistics
Introduces students to philosophical issues that arise in statistical theory and practice. Topics include interpretations of probability, philosophical paradigms in statistics, inductive inference, causality, reproducible, and ethical issues arising in statistics and data analysis. Same as STAT 5700.

AMEN FAQs
(Frequently Asked Questions)

What courses fulfill the humanities and social science elective? Not every humanities or social science course fulfills the College of Engineering HSS requirement. Visit the College's website: http://www.colorado.edu/engineering-advising/get-your-degree/degree-requirements for a complete list of courses and requirements.

The Herbst Program for Engineering, Ethics & Society offers small classes that are designed to fit well with one another in a coherent, interdisciplinary program. These courses also satisfy the humanities and social sciences requirement. For more information, please visit their website, http://www.colorado.edu/herbst

What is considered a passing grade? Students must earn a D- or above in each course, unless the course is a prerequisite, then they must earn a C- or above.

What are the rules on taking courses Pass/Fail? P/F credit is permitted only for courses used as electives or for courses above and beyond degree requirements. Students on academic probation may not elect the P/F option. The College of Engineering and Applied Science allows a maximum of six Pass/Fail credit hours per semester toward degree requirements. Pass/Fail hours counting toward graduation shall not exceed a cumulative total of 16. Transfer students are allowed one (1) hour Pass/Fail for every nine (9) hours completed in this College as a degree student under the Standard Grading System.

What are the graduation requirements? In addition to satisfying all coursework requirements students must have a minimum cumulative grade point average of 2.25 for all courses attempted and for all courses that count toward graduation requirement, excluding P grades for courses taken Pass/Fail. (Pass/Fail courses do not count for graduation credit except as free electives.) A grade point average of 2.25 is also required for all Math and Applied Math coursework.

How do I graduate with distinction? Students in the college of Engineering graduating with a minimum of a 3.7, 3.8 or 3.9 GPA are awarded the honorifics "cum laude", "magna cum laude", and "summa cum laude", respectively. These students must have earned at least 50 semester hours on the Boulder campus. Grades earned during the semester immediately prior to graduation are not considered.

Does the College of Engineering have an Honors Program? Yes! The college introduced an Engineering Honors Program (EHP) in fall 2006, which offers high-achieving students the opportunity for an outstanding engineering education. EHP students benefit from close faculty interaction and mentoring, have preferential access to courses designated as "Honors" courses, and will write and defend a senior honors thesis. The program is a coherent multi-year program, with optional, but strongly encouraged, community activities. Additional details can be found at http://www.cuhonorsengineering.com/

Scot Douglass, a faculty member of the college's Herbst Program for Engineering, Ethics & Society, serves as faculty director. For more information, contact him at 303-492-6021 or scot.douglass@colorado.edu.

Who do I contact if I need assistance with registration? Contact the Student Coordinator for Applied Math, ECOT 225, (303) 492-4668, amassist@colorado.edu

How do I become involved with student organizations in Applied Math? Students have excellent opportunities to become involved in discipline-related activities outside of the classroom. Associated with the department is the undergraduate chapter of the Society of Industrial Applied Mathematicians (SIAM). This student group helps stimulate interest in applied math through seminars, contests (Putnam and the Mathematical Modeling Contest in Modeling) and social venues where students get to know other majors and faculty members. All undergraduates are encouraged to participate. Students can also participate in the Association for Women in Math (AWM) Boulder Chapter. For additional information on SIAM and AWM, please visit the website: http://www.colorado.edu/amath/organizations

Who is my advisor? How often should I see my advisor? There are several faculty advisors in Applied Mathematics. You are required to meet with your advisor at least once per semester. Before meeting with your advisor, you should (1) update your degree audit with the courses you have taken or are currently enrolled in and (2) prepare a list of courses you plan to take in the semesters remaining before you graduate. Advisors are assigned by your class standing – see the department (ECOT 225) for a list of advisors.

Are there additional advising resources? Yes! Please see http://www.colorado.edu/amath/ and follow the links to the undergraduate degree program for APPM. Also, the engineering website, http://www.colorado.edu/engineering-advising has many helpful links.

How do I petition the Undergraduate Committee? Send a letter or email to the chair of the undergraduate committee (Anne Dougherty, adougher@Colorado.edu) explaining your request and supplying all necessary documentation to support your petition.

Can I participate in a Study Abroad program? Yes! Many Applied Math students have participated in various programs over the years and have benefited from this broadening experience. You will need to work with both your applied math advisor and the Office of International Education (http://abroad.colorado.edu) to plan your study abroad program.

What should I do if I'm considering attending graduate school? Students considering graduate school should consult their faculty advisor early in their undergraduate education. Students are strongly advised to take both APPM 4440 and APPM 4450 in preparation for graduate study. MATH 3140, Abstract Algebra, is also useful for some graduate programs.

Where do I find information on careers and internships? Talk to your faculty advisor and read your email from Applied Math. We frequently receive information on careers and internships and will forward it on to our majors and minors. Most importantly, visit Career Services in C4C (http://www.colorado.edu/career/). You should visit their office at least once in your freshman year, and more frequently after that.

How do I enroll in an Independent Study? An independent study is a collaboration between a student and a faculty member on a special project that provides the student with a learning experience. An independent study may also fill an academic need of importance to the student that cannot be filled by the regular course offerings. Independent studies are opportunities for students to earn credit for learning outside the normal lecture and laboratory class structure. Students must work with a faculty member to develop a relationship to join the faculty member's research. The independent study project is under the supervision of a faculty member. Students should speak with their advisor about enrollment into an independent study after they have permission from a faculty member to join their research team.

APPLIED MATHEMATICS DEGREE AUDIT

Student Name: _____ SID #:_____

Email: _____ Graduation Date:_____

To be completed, along with a diploma card, within the first month of the semester in which graduation is anticipated. In filling out this form, indicate the semester and year the course was or will be taken, the letter grade you received and the number of credit hours (where necessary). (T = transfer, F = fall, Su = summer, Sp = Spring and the last 2 digits of the year).

Lower Division APPM/MATH	**Cr.**	**Sem**	**Gr.**
APPM 1350 or MATH 1300	4/5	____	____
APPM 1360 or MATH 2300	4/5	____	____
APPM 2350 or MATH 2400	4	____	____
APPM 2360	4	____	____

Computing	**Cr.**	**Sem**	**Gr.**
CSCI 1300 or CSCI 1320 or CHEN 1310 or APPM 2720 (Python)	3/4	____	____

Chemistry or Biology (Lec/Lab)	**Cr.**	**Sem**	**Gr.**
_____	___	____	____
_____	___	____	____

Physics	**Cr.**	**Sem**	**Gr.**
PHYS 1110	4	____	____
PHYS 1120	4	____	____
PHYS 1140	1	____	____

Upper Division APPM/MATH(24)	**Cr.**	**Sem**	**Gr.**
Approved Sequence: _____ _____			
APPM 3310 or MATH 3130	3	____	____
APPM 4350	3	____	____
APPM 4360	3	____	____
APPM 4650	3	____	____
APPM 4440 or MATH 3001	3	____	____
_____	___	____	____
_____	___	____	____
_____	___	____	____
_____	___	____	____
_____	___	____	____

Option: (24) _____	**Cr.**	**Sem**	**Gr.**
_____	___	____	____
_____	___	____	____
_____	___	____	____
_____	___	____	____
_____	___	____	____
_____	___	____	____
_____	___	____	____
_____	___	____	____
_____	___	____	____
_____	___	____	____

Free Elective	**Cr.**	**Sem**	**Gr.**
_____	___	____	____
_____	___	____	____
_____	___	____	____
_____	___	____	____
_____	___	____	____
_____	___	____	____
_____	___	____	____
_____	___	____	____
_____	___	____	____

Humanities – Social Sciences (18)	**Cr.**	**Sem**	**Gr.**
ENES 1010 or WRTG 3030 or WRTG 3035 or ENES 3100	___	____	____
_____	___	____	____
_____	___	____	____
_____	___	____	____
_____	___	____	____
_____	___	____	____

For office use only:

Total Credits completed:_____ Cumulative GPA: _____ MAPS:_____

Credits in progress: _____ APPM / MATH GPA:_____ Double Major:_____

Minor:_____

I certify that the information provided here is correct and complete.

Student Signature _____ Date _____

I certify that I have reviewed this degree audit. Subject to the successful completion of the courses in progress, and review by the Applied Mathematics Undergraduate Committee, this student will have satisfied the requirements for the B.S. degree in Applied Mathematics

Faculty Advisor _____ Date _____