

First Steps in Mathematics

Answers to the most frequently asked questions concerning freshman- and sophomore-level mathematics can be found within.

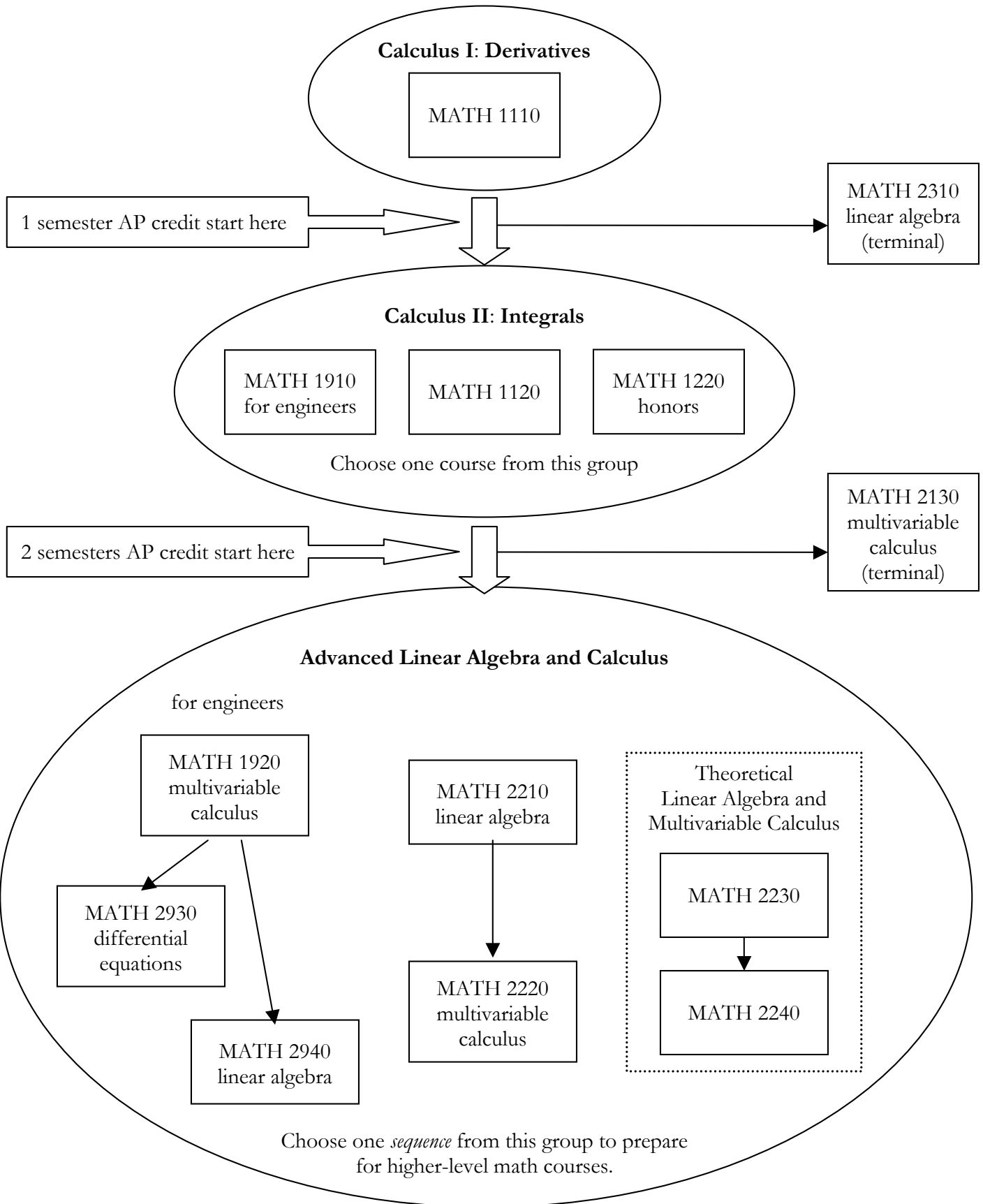
This guide, while informative, cannot replace a meaningful conversation between student and faculty advisor.

Send questions about enrollment to *hko1@cornell.edu*.
Send questions about placement to *mmk8@cornell.edu*.

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A Visual Guide to Calculus and Linear Algebra



Advanced Placement Credit for Calculus

Scores on the CEEB Calculus AB or BC exam, the General Certificate of Education Advanced (“A”) Level Exam (GCE), and the International Baccalaureate Higher Level Exam (IB) determine credit and placement as follows. (The GCE exam may not be used to place out of Calculus II unless it is taken in Singapore.)

<i>Calculus Credit and Placement for Students Not in Engineering</i>						
AB	BC	GCE	IB	Placement out of	Credits	Permission to take
3, 4, 5	3	A, B, C	6, 7	Calculus I (MATH 1106, 1110)	4	MATH 1120, 1220, 1910, or 2310
—	4, 5	Singapore A, B, C	—	Calculus I (MATH 1106, 1110) and Calculus II (MATH 1120, 1220, 1910)	8	MATH 1920, 2210, 2230, 2130, or 2310
<i>Calculus Credit and Placement for Students in Engineering Programs</i>						
AB	BC	GCE	IB	Placement out of	Credits	Permission to take
—	4, 5	Singapore A, B, C	—	MATH 1910	4	MATH 1920

Loss of AP Credit

Students with 4 or 8 AP credits will forfeit 4 credits if they take Calculus I at Cornell or receive transfer credit for an equivalent course. Students with 8 AP credits will forfeit 4 credits if they take Calculus II at Cornell or receive transfer credit for an equivalent course.

Placement Recommendations (see p. 4)

- Students who receive the borderline score of 3 on the Calculus AB exam are advised to follow their instincts when deciding between Calculus I and Calculus II, but are strongly advised not to take MATH 1220.
- Repeating a course at the honors level is advisable only if the student is willing to invest the extra time and effort that an honors course requires.
- Students who receive higher scores are strongly encouraged to start with the most advanced course they have permission to take, then drop back to a more elementary course if the advanced course is too difficult.
- Students who find the more advanced courses too difficult should not hesitate to forfeit their AP credit and drop back to an earlier course.

Cornell Placement Exams

Students who have had at least a semester of calculus but did not take a calculus placement exam and students who wish to improve their existing AP score may take one of the following placement exams during fall orientation. Students may use the higher of two placement recommendations.

<i>Calculus Placement Exams Offered at Cornell During Fall 2009 Orientation</i>			
Test	Date & Time	Location	Details
Engineering Math Advanced Standing Exam	Sunday, August 23, 10:15 AM	Announced during academic briefings	Optional for engineering majors. Determines placement in the engineering math sequence. Contact Engineering Advising for further information: (607) 255-7414.
Mathematics Department AP Exam	Sunday, August 23, 10:15 AM	228 Malott Hall (Bache Aud.)	Optional for non-engineering majors. Covers essentially the same material as the CEEB Calculus curriculum. No sign-up necessary.

Transferring Credit from Another Institution

Course Eligibility

The Mathematics Department will approve courses under the following conditions:

- The course is offered by a mathematics or statistics department.
- The course is highly comparable (in both content and level) to a course offered by the Cornell Mathematics Department¹ for academic credit towards graduation, *or* the course is taken through Cornell Abroad and is of comparable or greater depth and degree of difficulty to courses offered at Cornell.

Courses are not eligible if any of the following are true:

- The course is taught in a high school to high school students (even if the college provides a transcript).
- The course is used to satisfy high school graduation requirements.
- The course is labeled “college algebra” or “pre-calculus.”

Student Procedure for Requesting Transfer Credit

1. Submit information² about the course via www.math.cornell.edu/Courses/FSM/transcred.html. A faculty member will contact you with a decision.

If the course is approved:

2. Bring the email approval and a transfer credit form (see table below) to the faculty member’s office, or leave them at the front desk (310 Malott Hall) and you will be contacted when the form has been signed.
3. Return the signed form to your college office.
4. Upon completion of the course, arrange for a sealed transcript to be sent to your college registrar.

Transfer Credit Forms, Procedures, and Policies

Student’s College	Forms Available at	Procedures and Policies
Arts & Sciences	Academic Advising Center 55 Goldwin Smith Hall	www.arts.cornell.edu/stu-adv/ProcedforTransf.php
Agriculture & Life Sciences	Student Services 140 Roberts Hall	www.cals.cornell.edu/cals/current/registrar/current-students/transfer/non-cornell-credit-policy.cfm
Engineering	Advising Office 167 Olin Hall	www.engineering.cornell.edu/student-services/academic-advising/academic-information/transfer-credit/index.cfm

Good Advice

- Have courses evaluated in advance to avoid wasting time/money on an unsuitable course.
- Read your college’s transfer credit policy (see table above) before taking the course or applying for transfer credit. Some colleges place restrictions on the use of transfer credit.
- MATH 2930 is almost impossible to replace because very few universities have a course that matches it. Try replacing MATH 2940 instead. The two courses can be taken in either order.

¹ The Mathematics Department will approve an introductory statistics course only if it is a satisfactory equivalent to MATH 1710 (*Statistical Theory and Application to the Real World*). Statistics courses taken from social science departments (such as psychology or sociology) must be approved by the corresponding social science department at Cornell.

² The burden is on the student to provide sufficient information for the course to be evaluated, including a detailed course description or syllabus (i.e., topics covered) and the textbook that will be used for the course. If this information is not available through the university’s web site, the student is expected to contact the school to request it.

First-Year Calculus

The standard prerequisite for freshman-level calculus is three years of high school mathematics (including trigonometry and logarithms) or a precalculus course (such as MATH 1000 in the fall, BTRY 1150 in the spring, or MATH 1009 in the summer). None of these courses carry credit toward graduation in the Arts College.

Students with one semester of advanced placement (p. 2) or transfer credit (p. 3) are advised to take a second semester of calculus immediately rather than postponing it. The material is fresher in mind, and the instructor will give more review in the fall than in the spring.

Calculus I: Derivatives

- MATH 1106: *Calculus for the Life and Social Sciences*
- MATH 1110: *Calculus I*

MATH 1106 is a one-semester introduction to calculus using examples from biology and the social sciences; it is taught at a somewhat more elementary level than MATH 1110, and the material emphasized in the two courses is different. MATH 1110 is recommended for students who plan to take more calculus. Students who do very well in MATH 1106 *may* continue with MATH 1120, but some extra study will be necessary between semesters.

Calculus II: Integrals

- MATH 1120: *Calculus II*
- MATH 1220: *Honors Calculus II*

MATH 1120 and 1220 cover essentially the same topics, but MATH 1220 does so in greater depth and at a somewhat more theoretical level. MATH 1120 is a good choice for students who need a standard second-semester calculus course and may or may not continue with more advanced mathematics courses. MATH 1220 provides a more thorough introduction to the foundations of calculus, especially with regard to certain important topics such as infinite series, and provides better preparation for MATH 2210 than does MATH 1120.

- MATH 1910: *Calculus for Engineers*

MATH 1910 is the first course in a sequence designed for engineers that assumes familiarity with differential calculus as taught in MATH 1110. Students not in an engineering program who take MATH 1910 may decide to continue with MATH 2130 or 2210 rather than 1920, but MATH 1910 is the best preparation for MATH 1920.

Building a Suitable Calculus Program

One or two semesters of calculus may be sufficient to satisfy college requirements, but many majors require some advanced calculus and/or linear algebra (p. 5). Students should consult their advisors and keep major prerequisites in mind when planning a suitable program. The following are general recommendations.

- Students who expect to major in mathematics or a science for which a strong math background is recommended, should take MATH 1110-1120 or 1110-1220 and continue with MATH 2210-2220 or 2230-2240. (MATH 1910 may be substituted for 1120.)
- Students who have an aversion to mathematical theory might be happier with MATH 1910-1920-2930-2940, MATH 1110-1120-2130, or MATH 1110-2310.
- MATH 1910-1920-2930-2940 is required for students in the Engineering College and recommended by some advisors in fields strongly related to the mathematical and physical sciences, such as astronomy, computer science, physics, and physical chemistry.
- MATH 1110-1120-2130 is a good choice for students who need to master the basic techniques of calculus but whose majors will not require a substantial amount of mathematics, i.e., chemistry and economics majors.
- MATH 1110-2310 is an option for students who need some linear algebra but not a full year of calculus.

Advanced Calculus and Linear Algebra

The standard prerequisite for most advanced calculus and linear algebra courses is two semesters of calculus. The exception is MATH 2310, which requires only one semester of calculus. (See p. 4, which includes suggestions for building a suitable calculus program.)

MATH 2210-2220: Linear Algebra and Multivariable Calculus

MATH 2210 is primarily a linear algebra course, but it also provides an introduction to linear ordinary differential equations. Some of the linear algebra in MATH 2210 is used to develop multivariable and vector calculus in MATH 2220. MATH 2210-2220 is taught at a higher theoretical level than MATH 1110-1120. For example, in 2210 certain abstract concepts such as vector spaces are introduced, theorems are carefully stated, and many of these theorems are proved. MATH 2210 does not provide adequate preparation for MATH 2240.

MATH 2230-2240: Theoretical Linear Algebra and Calculus

MATH 2230-2240 is “integrated” in the sense that both linear algebra and multivariable calculus are taught in each semester, rather than covered in separate semesters (as in 2210-2220). MATH 2230-2240 is taught at a higher level of mathematical sophistication than MATH 2210-2220, particularly the portion dealing with vector calculus. Students who have been extremely successful in their previous calculus courses are encouraged to try this sequence. Those who find MATH 2230 too challenging may drop down to MATH 2210 at the beginning of the term or continue with MATH 2220 instead of 2240.

MATH 1920-2930-2940: Engineering Mathematics

MATH 1920 covers multivariable calculus, MATH 2930 is a course in ordinary and partial differential equations, and MATH 2940 is a linear algebra course. The defining characteristic of this sequence is its rapid and utilitarian coverage of a wide variety of mathematical topics important in engineering and the physical sciences. Although MATH 1910-1920-2930-2940 covers more topics than other programs, the courses in the sequence cover those topics in somewhat lesser depth and with less attention to theoretical background, particularly when compared to MATH 2210-2220 and MATH 2230-2240. MATH 2930 and 2940 are independent of each other; MATH 1920 is the prerequisite for both. MATH 1920 and 2940 are sufficient prerequisites for most higher-level math courses. In fact, some engineering programs do not require 2930.

MATH 2130: Calculus III and MATH 2310: Linear Algebra with Applications

MATH 2130 is a course with many different topics, including differential equations and multivariable calculus, and MATH 2310 is an applied linear algebra course (less theoretical than 2210) for students who do not expect to take more advanced math courses. Students who complete MATH 1120 with a grade of less than B+ should consider taking 2130 rather than 2210. The only prerequisite for MATH 2310 is MATH 1110, but it is also a good option for students who have taken MATH 2130 and want to learn some linear algebra.

Prerequisites for the Mathematics Major

Students are admitted to the major after successfully completing a semester each of multivariable calculus and linear algebra, which will also fulfill the MQR distribution requirement. The department recommends:

- MATH 2210-2220 or 2230-2240 with grades of B– or better.

Alternative prerequisites are:

- MATH 1920 and 2940 with grades of B– or better;
- MATH 2130 and 2310 with grades of B+ or better.

A 3- or 4-credit computer programming course with a grade of C– or better is also required for acceptance to the major. Eligible courses include: CS 1110, 1112, 1113, 1114, and 2110.

Introductory Statistics

Cornell offers a variety of courses in statistics, but four courses (see table below) are most comparable to the AP statistics curriculum. They have no prerequisites, they are all open to freshmen, and they can be applied to the Arts & Sciences MQR distribution requirement (p. 7), the CALS quantitative literacy requirement (p. 9), and the mathematics requirement for the biology major (p. 10). Students should consult their faculty advisors and/or major departments for help in selecting an appropriate course.

<i>Cornell courses that are comparable to the AP statistics curriculum</i>			
Course	Title	Term(s)	Administering College
MATH 1710	Statistical Theory and Application to the Real World	fall, spring, summer	Arts and Sciences (Only Arts students may pre-enroll.)
AEM 2100	Introductory Statistics	spring	Agriculture and Life Sciences
ILRST 2100/ STSCI 2100	Introductory Statistics	fall, spring, summer	ILR
PAM 2100	Introduction to Statistics	fall, spring	Human Ecology

What Sets MATH 1710 Apart

- Solid coverage of many basic techniques without emphasizing a particular discipline.
- Somewhat greater emphasis on probability and the logic behind basic techniques.
- Extensive use of the statistical software DataDesk.

Advanced Placement Credit

- Students who receive a score of 4 or 5 on the CEEB Statistics exam (excluding engineering students) receive credit for one semester of statistics and placement out of the courses included in the table above.
- Students who receive AP credit for statistics will forfeit that credit if they take any of the courses included in the table above or receive transfer credit for an equivalent course.

Transfer Credit

The Mathematics Department will approve an introductory statistics course only if it is a satisfactory equivalent to MATH 1710. (See p. 3 for instructions.) Statistics courses taken from social science departments (like psychology or sociology) must be approved by the corresponding social science department at Cornell.

More Applied or In-Depth Courses

Students can take any of the following applied (specialized) courses without losing AP credit:

- BTRY 3010: Biological Statistics I
- PSYCH 3500: Statistics and Research Design
- SOC 3010: Evaluating Statistical Evidence (limited to Arts & Sciences students)

Students who have had some calculus and are more interested in the mathematical background of statistics, including probability, may take any of the following without loss of AP credit:

- MATH 2710: A Second Course in Statistics
- MATH 4710-4720: Basic Probability and Statistics
- BTRY 4080-4090: Theory of Probability and Statistics
- ECON 3190: Introduction to Statistics and Probability

Mathematics for the Arts & Sciences Student: Mathematics and Quantitative Reasoning Requirement

Students in the College of Arts & Sciences are required to take four courses from the Physical & Biological Sciences (PBS) group and the Mathematics & Quantitative Reasoning (MQR) group, with at least two from PBS and at least one from MQR. Students may choose two MQR courses provided they have no significant overlap. For example, students may *not* choose two beginning courses in statistics.

Restrictions on Advanced Placement and Transfer Credit

- Students may not apply AP credit (p. 2) to any distribution requirement.
- Students may not apply transfer credit (p. 3) to any distribution requirement unless they transferred to Cornell from another institution. In the latter case, courses taken at the student's previous institution (not summer school) may be approved for transfer and distribution credit by the appropriate department at Cornell.

Eligible Cornell Courses

A search of the Courses of Study catalog (cuinfo.cornell.edu/Academic/Courses/CoSearch.php) with "(MQR)" in the Course Title field will return a list of Arts & Sciences courses eligible to fulfill the MQR requirement.

Sample Two-Semester Programs

Students with a major or majors in mind should take major prerequisites into consideration. Those who expect to major in mathematics, a science, or some other field that requires mastery of the basic techniques of calculus should take at least

- two semesters of calculus: MATH 1110-1120, MATH 1110-1220, or MATH 1910-1920 (See p. 4.)

This is usually *not* the best choice for students who expect to take no more than two semesters of mathematics. A broader view of the subject can be gained from

- one semester of calculus and one non-calculus mathematics course:
 - finite mathematics: MATH 1105 *Finite Mathematics for the Life and Social Sciences*
 - introductory statistics: MATH 1710 *Statistical Theory and Application to the Real World*
AEM 2100 *Introductory Statistics*
BTRY 3010 *Biological Statistics I*
ILRST 2100 *Introductory Statistics* (also STSCI 2100)
PAM 2100 *Introduction to Statistics*
 - other alternatives to calculus: MATH 1300 *Mathematical Explorations*
MATH 1340 *Mathematics and Politics*
MATH 1350 *The Art of Secret Writing*

Other options for fulfilling the MQR requirement include:

- two non-calculus mathematic courses (from the lists above);
- one semester of calculus and a computer programming course:
 - CS 1110 *Introduction to Computing Using Java*
 - CS 1112 *Introduction to Computing Using Matlab*
 - CS 1113 *Computing Using Java: Honors*
 - CS 1114 *Introduction to Computing Using Matlab and Robotics*
 - CS 2110 *Object-Oriented Programming and Data Structures*
- computer programming and a non-calculus mathematics course (from the lists above).

It is also possible to fulfill the MQR requirement while taking no mathematics courses at all.

Mathematics for the Engineering Student

The engineering calculus sequence MATH 1910-1920-2930-2940 is required for most students in the Engineering College and the CALS biological and environmental engineering programs, but some engineering programs do not require MATH 2930. (Students should consult the Engineering Undergraduate Handbook for a complete list of requirements for their chosen major.)

MATH 2930 and 2940 can be taken in either order because MATH 2930 is *not* a prerequisite for 2940. However, MATH 2930 *is* a prerequisite or corequisite for PHYS 2214 and 2217. Students who expect to take either of these physics courses will most likely need to take MATH 2930 before MATH 2940.

Previous Calculus Experience

Entering students are expected to have taken a good first course in calculus. MATH 1910 is essentially a second-semester calculus course, and MATH 1920 is a third-semester calculus course. Students who have not taken any calculus are strongly advised to take either MATH 1110 during the 6-week summer session at Cornell or an equivalent course at another university *before* their freshman year.

Advanced Placement

Students in the College of Engineering or the CALS biological or environmental engineering program with an AP Calculus BC score of 4 or 5 are eligible to receive 4 credits³, place out of MATH 1910, and take MATH 1920. For students entering in the fall who have not taken a calculus placement exam or who wish to improve their AP score, a placement exam will be announced during orientation at the academic briefings.

Minimum Grades

Students who fail to receive at least a C– in MATH 1910, 1920, 2930, or 2940 must repeat the course immediately *before* taking the next course in the sequence. Doubling up is *not* recommended. A better strategy is to take a course over the summer to catch up.

Getting Ahead or Getting Back on Track

Students are strongly discouraged from taking two courses in the engineering sequence simultaneously. These courses move rapidly and are challenging and time-consuming, even for students who have already been exposed to some of the material. Examinations in these courses are given simultaneously, so students enrolled in two must take a make-up exam for one of the courses. The deck is stacked against them, and often their performance suffers. The following options are available to students who wish to get ahead or get back on track after repeating a course:

- MATH 1910 and 1920 are offered during the 6-week summer session at Cornell. Either course may be taken during the summer before or after the freshman year.
- MATH 2930 and 2940 are offered during the 8-week summer session at Cornell. Either course may be taken during the summer before or after the sophomore year.
- The Mathematics Department routinely awards transfer credit⁴ (p. 3) for MATH 1910, 1920, and 2940. Unfortunately, very few universities offer an introductory differential equations course like MATH 2930, which covers both ordinary and partial differential equations. MATH 2930 spends about one-third of the semester on Fourier series and PDEs (heat, wave, and Laplace). A substitute course must do the same.

³ Engineering students receive 4 credits instead of 8 credits because Calculus I is not part of their curriculum.

⁴ A 3-credit course may be used to replace one of the 4-credit math courses, but the student must make up the 4th credit in some way. Students in this situation should contact the Engineering Advising Office to learn their options.

Mathematics for the CALS Student: The Quantitative Literacy Requirement

Students in the College of Agriculture and Life Sciences have the following options for completing the quantitative literacy requirement:

- Earn a score of 4 or 5 on the AP Calculus exam.
- Transfer an approved calculus or statistics course with a C or better.
- Take an approved 3- or 4-credit math or statistics course at Cornell.

Advanced Placement

Students who have had at least a semester of calculus but did not take a calculus placement exam and students who wish to improve their existing AP score may take one of the following placement exams during fall orientation. Students may use the higher of two placement recommendations.

<i>Calculus Placement Exams Offered at Cornell During Fall 2009 Orientation</i>			
Test	Date & Time	Location	Details
Engineering Math Advanced Standing Exam	Sunday, August 23, 10:15 AM	Announced in July letter to new CALS students	Optional for engineering majors. Determines placement in the engineering math sequence. For information, email the BEE Department (bls19@cornell.edu).
Mathematics Department AP Exam	Sunday, August 23, 10:15 AM	228 Malott Hall (Bache Aud.)	Optional for non-engineering majors. Covers essentially the same material as the CEEB Calculus curriculum. No sign-up necessary.

Transfer Credit

The Mathematics Department will review all calculus courses and any statistics course taken in a mathematics or statistics department. (See p. 3 for details.) Statistics courses taken in a social science department (such as psychology or sociology) must be reviewed by the corresponding social science department at Cornell.

Cornell Math Courses

Any course offered by the Mathematics Department except MATH 1000, 1009, or 1890 may be used to satisfy the quantitative literacy requirement. The following courses are good options for CALS students who need to complete an approved math course at Cornell:

- MATH 1105: *Finite Mathematics for the Life and Social Sciences*
- MATH 1106: *Calculus for the Life and Social Sciences*
- MATH 1110: *Calculus I*
- MATH 1710: *Statistical Theory and Application in the Real World*

MATH 1110 is recommended for students who will take at least two semesters of calculus. Students who need only *one* semester of calculus may prefer MATH 1106.

Cornell Statistics Courses

Cornell offers several introductory statistics courses. (See p. 6.) MATH 1710 is a popular choice for many students, but only Arts students may pre-enroll. A list of statistics courses that will satisfy the quantitative literacy requirement can be found on the CALS web site at www.cals.cornell.edu/cals/current/registrar/current-students/cals-graduation/math-requirement.cfm.

Mathematics for the Biology Major or Pre-Med Student

A biologist or medical professional must be able to think mathematically (analyze graphs, interpret quantitative information, use clear logical patterns). An early decision to get a strong mathematical background, particularly in the core areas of calculus, probability and statistics, linear algebra (vectors, matrices, systems of equations), and computer programming, will multiply a student's career options.

The Formal Requirement for the Biology Major

Biology majors are required to take one semester of calculus plus a second math or statistics course. Advanced placement credit for calculus (p. 2) can be applied to this requirement. Sample programs include:

- two semesters of calculus, such as MATH 1110-1120 or MATH 1110-1220;
- one semester of calculus plus a course in finite mathematics, such as MATH 1105-1106;
- one semester of calculus plus an introductory statistics course (p. 6).

Medical School Admissions Requirements

College work in mathematics is required by some medical schools and recommended by almost all. A very few medical schools require one year of calculus. Also, a very few require one semester of statistics. See the book *Medical School Admissions Requirements* or individual medical schools' web pages to verify premedical requirements.

Calculus and Further Study

Students who may take more than one year of mathematics should definitely start with two semesters of calculus. (See p. 4.) The following options provide a good introduction to the core mathematical areas most useful in the biological sciences. (Courses under Option 2 are a bit more challenging.)

	Option 1	Option 2
■ one year of calculus:	MATH 1110-1120	MATH 1110-1220
■ advanced calculus:	MATH 2130	MATH 2220
■ linear algebra:	MATH 2310	MATH 2210
■ probability and statistics:	MATH 1710	MATH 4710-4720
■ computer programming:	CS 1110, 1112, 1113, or 1114	

Of course, much more is possible and in some cases necessary.

2008-2009 Freshman- and Sophomore-Level Courses

MATH 1000: Calculus Preparation

Fall. 2 transcript credits only; cannot be used toward graduation. Prerequisite: permission of instructor. Interested students must complete a questionnaire at 310 Malott Hall to request admittance to the course. Priority will be given to students who need the course to prepare for MATH 1106 or 1110.

Introduces a wide variety of topics of algebra and trigonometry that have applications in various disciplines. Emphasis is on the development of linear, polynomial, rational, trigonometric, exponential, and logarithmic functions. Students will have a better understanding of the behavior of these functions in their application to calculus because of the strong emphasis on graphing. Application of these mathematical ideas is addressed in problem-solving activities.

MATH 1005: Academic Support for MATH 1105

MATH 1006: Academic Support for MATH 1106

MATH 1011: Academic Support for MATH 1110

MATH 1012: Academic Support for MATH 1120

1005, fall; 1006, spring; 1011, fall, spring; 1012, fall, spring.
1 credit each.

Reviews material presented in MATH 1105/1106/1110/1120 lectures, provides problem-solving techniques and tips as well as prelim review. Provides further instruction for students who need reinforcement. Not a substitute for MATH 1105/1106/1110/1120 lectures or recitations.

MATH 1009: Precalculus Mathematics

Summer. 3 transcript credits; cannot be used toward graduation.

Designed to prepare students for MATH 1110. Reviews algebra, trigonometry, logarithms, and exponentials.

MATH 1105: Finite Math for the Life and Social Sciences

Fall. 3 credits. Prerequisite: three years of high school mathematics, including trigonometry and logarithms.

Introduction to linear algebra, probability, and Markov chains that develops the parts of the theory most relevant for applications. Specific topics include: equations of lines, the method of least squares, solutions of linear systems, matrices; basic concepts of probability, permutations, combinations, binomial distribution, mean and variance, and the normal approximation to the binomial distribution. Examples from biology and the social sciences are used.

MATH 1106: Calculus for the Life and Social Sciences

Spring. 3 credits. Prerequisite: three years of high school mathematics (including trigonometry and logarithms) or MATH 1000, MATH 1009, or BTRY 1150. For students planning to take MATH 1120, MATH 1110 rather than 1106 is recommended.

Introduction to differential and integral calculus, partial derivatives, elementary differential equations. Examples from biology and the social sciences are used.

MATH 1110: Calculus I

Fall, spring, summer. 4 credits. Prerequisite: three years of high school mathematics (including trigonometry and logarithms) or MATH 1000, MATH 1009, or BTRY 1150.

Topics include functions and graphs, limits and continuity, differentiation and integration of algebraic, trigonometric, inverse trig, logarithmic, and exponential functions; applications of differentiation, including graphing, max-min problems, tangent line approximation, implicit differentiation, and applications to the sciences; the mean value theorem; and antiderivatives, definite and indefinite integrals, the fundamental theorem of calculus, substitution in integration, the area under a curve. MATH 1110 can serve as a one-semester introduction to calculus or as part of a two-semester sequence in which it is followed by MATH 1120 or 1220.

MATH 1120: Calculus II

Fall, spring. 4 credits. Prerequisite: MATH 1110 with a grade of C or better or excellent performance in MATH 1106. Those who do well in MATH 1110 and expect to major in mathematics or a strongly mathematics-related field should take 1220 instead of 1120.

Focuses on integration: applications, including volumes and arc length; techniques of integration, approximate integration with error estimates, improper integrals, differential equations (separation of variables, initial conditions, systems, some applications). Also covers infinite sequences and series: definition and tests for convergence, power series, Taylor series with remainder, and parametric equations.

MATH 1220: Honors Calculus II

Fall. 4 credits. Prerequisite: one semester of calculus with high performance or permission of department. Students planning to continue with MATH 2130 are advised to take 1120 instead of this course.

Takes a more theoretical approach to calculus than MATH 1120. Topics include differentiation and integration of elementary transcendental functions, techniques of integration, applications, polar coordinates, infinite series, and complex numbers, as well as an introduction to proving theorems.

MATH 1300: Mathematical Explorations

Fall. 3 credits.

For students who wish to experience how mathematical ideas naturally evolve. The course emphasizes ideas and imagination as opposed to techniques and calculations. The homework involves students in actively investigating mathematical ideas. Topics vary depending on the instructor. Some assessment is done through writing assignments.

MATH 1340: Mathematics and Politics

Spring. 3 credits.

We apply mathematical reasoning to some problems arising in the social sciences. We discuss game theory and its applications to political and historical conflicts. Power indices are introduced and used to analyze some political institutions. The problem of finding a fair election procedure to choose among three or more alternatives is analyzed.

MATH 1350: The Art of Secret Writing

Fall, summer. 3 credits. Prerequisite: three years of high school mathematics.

Examines classical and modern methods of message encryption, decryption, and cryptanalysis. Mathematical tools are developed to describe these methods (modular arithmetic, probability, matrix arithmetic, number theory), and some of the fascinating history of the methods and people involved is presented.

MATH 1600: Totally Awesome Mathematics

Spring. 2 credits. Prerequisite: one semester calculus.

Mathematics is a broad and varied field that extends far beyond calculus and the high school curriculum. This course will introduce exciting mathematical topics to stretch your imagination and give you a feel for the great variety of problems that mathematicians study. Each week a different lecturer will present a new topic and fun problems for discussion. Topics will vary from year to year, but may include the following: encryption and number theory, non-Euclidean geometry, knots and surfaces, combinatorics of polyhedra, the Heisenberg Uncertainty Principle and signal processing, unsolvable problems and noncomputable functions, card shuffling and probability, symmetry and solutions of polynomial equations.

MATH 1710: Statistical Theory and Application to the Real World

Fall, spring, summer. 4 credits. Prerequisite: high school mathematics. No previous familiarity with computers is presumed. No credit if taken after ECON 3190, 3200, 3210.

Introductory statistics course discussing techniques for analyzing data occurring in the real world and the mathematical and philosophical justification for these techniques. Topics include population and sample distributions, central limit theorem, statistical theories of point estimation, confidence intervals, testing hypotheses, the linear model, and the least squares estimator. The course concludes with a discussion of tests and estimates for regression and analysis of variance (if time permits). The computer is used to demonstrate some aspects of the theory, such as sampling distributions and the Central Limit Theorem. In the lab portion of the course, students learn and use computer-based methods for implementing statistical methodology presented in lectures.

MATH 1910: Calculus for Engineers

Fall, spring, summer. 4 credits. Prerequisite: three years of high school mathematics including trigonometry and logarithms and at least one course in differential and integral calculus.

Essentially a second course in calculus. Topics include techniques of integration, finding areas and volumes by integration, exponential growth, partial fractions, infinite sequences and series, and power series.

MATH 1920: Multivariable Calculus for Engineers

Fall, spring, summer. 4 credits. Prerequisite: MATH 1910.

Introduction to multivariable calculus. Topics include partial derivatives, double and triple integrals, line integrals, vector fields, Green's theorem, Stokes' theorem, and the divergence theorem.

MATH 2130: Calculus III

Fall, spring. 4 credits. Prerequisite: MATH 1120, 1220, or 1910.

Designed for students who wish to master the basic techniques of calculus, but whose major will not require a substantial amount of mathematics. Topics include vectors and vector-valued functions; multivariable and vector calculus including multiple and line integrals; first- and second-order differential equations with applications; systems of differential equations; and elementary partial differential equations. The course may emphasize different topics in the syllabus in different semesters, such as Green's theorem, Stokes' theorem, and the divergence theorem.

MATH 2210: Linear Algebra

Fall, spring. 4 credits. Prerequisite: two semesters of calculus with high performance or permission of the department. Recommended for students who plan to major in mathematics or a related field. For a more applied version of this course, see MATH 2310.

Topics include vector algebra, linear transformations, matrices, determinants, orthogonality, eigenvalues, and eigenvectors. Applications are made to linear differential equations.

MATH 2220: Multivariable Calculus

Fall, spring. 4 credits. Prerequisite: MATH 2210. Recommended for students who plan to major in mathematics or a related field.

Differential and integral calculus of functions in several variables, line and surface integrals, and the theorems of Green, Stokes, and Gauss.

MATH 2230: Theoretical Linear Algebra and Calculus

Fall. 4 credits. Prerequisite: two semesters of calculus with a grade of A- or better, or permission of instructor.

MATH 2230-2240 provides an integrated treatment of linear algebra and multivariable calculus designed for students who have been highly successful in their previous calculus courses. The material is presented at a higher theoretical level than in 2210-2220. Topics in 2230 include vectors, matrices, and linear transformations; differential calculus of functions of several variables; inverse and implicit function theorems; quadratic forms, extrema, and manifolds; multiple and iterated integrals.

MATH 2240: Theoretical Linear Algebra and Calculus

Spring. 4 credits. Prerequisite: MATH 2230.

Topics include vector fields; line integrals; differential forms and exterior derivative; work, flux, and density forms; integration of forms over parametrized domains; and Green's, Stokes', and divergence theorems.

MATH 2310: Linear Algebra with Applications

Fall, spring. 3 credits. Prerequisite: MATH 1110 or equivalent. Students who plan to major in mathematics should take MATH 2210 or 2940.

Introduction to linear algebra for students who wish to focus on the practical applications of the subject. A wide range of applications are discussed, and computer software may be used. The main topics are systems of linear equations, matrices, determinants, vector spaces, orthogonality, and eigenvalues. Typical applications are population models, input/output models, least squares, and difference equations.

MATH 2710: A Second Course in Statistics

Spring. 4 credits. Prerequisite: two semesters of calculus (MATH 1110-1120 or equivalent), or permission of instructor.

Recommended: an introductory statistics course, such as AP statistics, MATH 1710, ILRST 2100 or similar.

Designed for students who wish to build on their knowledge of basic statistics, to obtain a more modern and advanced perspective on the field. The treatment will be elementary and accessible to students of the sciences and other fields, but a good working knowledge of calculus is assumed. An extended review of probability and random variables will be given first. Statistical inference topics to be discussed include estimation, testing hypotheses, nonparametric methods, multiple regression, and the analysis of variance. Both classical and Bayesian statistical methods are developed in an integrated presentation. Computer exercises will supplement the theory. With some effort, students with no prior knowledge of statistics should be able to master the course.

MATH 2810: Deductive Logic (also PHIL 3310)

Fall. 4 credits. Prerequisite: PHIL 2310 or permission of instructor.

The syntax and model-theory of classical propositional logic and classical predicate logic, including proofs of the soundness and completeness of natural deduction formalizations of these logics, with some attention to related material.

MATH 2930: Differential Equations for Engineers

Fall, spring, summer. 4 credits. Prerequisite: MATH 1920. Taking MATH 2930 and 2940 simultaneously is not recommended.

Introduction to ordinary and partial differential equations. Topics include first order equations (separable, linear, homogeneous, exact); mathematical modeling (e.g., population growth, terminal velocity); qualitative methods (slope fields, phase plots, equilibria and stability); numerical methods; second order equations (method of undetermined coefficients, application to oscillations and resonance, boundary value problems and eigenvalues); Fourier series; linear partial differential equations (heat flow, waves, Laplace equation); linear systems of ordinary differential equations.

MATH 2940: Linear Algebra for Engineers

Fall, spring, summer. 4 credits. Prerequisite: MATH 1920. Taking MATH 2930 and 2940 simultaneously is not recommended.

Linear algebra and its applications. Topics include matrices, determinants, vector spaces, eigenvalues and eigenvectors, orthogonality and inner product spaces; applications include brief introductions to difference equations, Markov chains, and systems of linear ordinary differential equations. May include computer use in solving problems.