The Quantitative/Formal Reasoning (QFR) requirement is intended to help students become adept at reasoning mathematically and abstractly. The ability to apply a formal method to reach conclusions, use numbers comfortably, and employ the research tools necessary to analyze data lessens barriers to carrying out professional and economic roles. The hallmarks of a QFR course are the representation of facts in a language of mathematical symbols and the use of formal rules to obtain a determinate answer. Primary evaluation in these courses is based on multistep mathematical, statistical, or logical inference (as opposed to descriptive answers).

Prior to senior year, all students must satisfactorily complete ONE QFR course. Students requiring extra assistance (as assessed during First Days) are normally placed into Mathematics 100/101/102, which is to be taken before fulfilling the QFR requirement.

ASTR 111 (F) Introduction to Astrophysics (QFR)

The science of astronomy spans vast scales of space and time, from individual atoms to entire galaxies and from the universe's beginning to the future fate of our Sun. In this course, we will survey some of the main ideas in modern astrophysics, with an emphasis on the physics of stars and galaxies. ASTR 111 is the first course in the Astrophysics and Astronomy major sequences. It is also appropriate for students planning to major in one of the other sciences or mathematics and for others who would like a quantitative introduction that emphasizes the relationship of contemporary physics to astronomy. Topics include gravity and orbits, radiation laws and stellar spectra, physical characteristics of the Sun and other stars, star formation and evolution, black holes, galaxies, the expanding universe, and the Big Bang. Students will also use telescopes to observe stars, nebulae, planets, and galaxies and to make daytime observations of the Sun.

Class Format: lecture/discussion, observing sessions, and five labs per semester
Requirements/Evaluation: weekly problem sets, two hour tests, a final exam, lab reports, and an observing portfolio
Prerequisites: a year of high school Physics, concurrent college Physics, or permission of instructor, and MATH 140 or equivalent
Enrollment Limit: 28
Enrollment Preferences: potential Astronomy majors
Expected Class Size: 15
Grading: yes pass/fail option, yes fifth course option
Distributions: (D3) (QFR)
Quantitative/Formal Reasoning Notes: The course requires regular problem sets and quantitative assignments. The course will emphasize how physical equations explain the observed properties of the universe.

Fall 2019
LEC Section: 01    TR 11:20 am - 12:35 pm     Anne Jaskot
LAB Section: 02    M 1:00 pm - 4:00 pm     Kevin Flaherty
LAB Section: 03    R 1:00 pm - 4:00 pm     Kevin Flaherty

ASTR 211 (S) Astronomical Observing and Data Analysis (QFR)

How do astronomers make scientific measurements for objects that are light-years away from Earth? This course will introduce the basics of telescopes and observations and will give students hands-on training in the techniques astronomers use to obtain, process, and analyze scientific data. We will discuss observation planning, CCD detectors, signal statistics, image processing, and photometric and spectroscopic observations. We will begin by focusing on ground-based optical observations and will move on to non-optical observations, both electromagnetic (e.g., radio waves, X-rays) and non-electromagnetic (e.g., gravitational waves, neutrinos). Throughout the course, students will use computational techniques to work with real astronomical data, taken with our 24" telescope and from data archives.

Class Format: lecture/discussion, computer lab work, and observing
Requirements/Evaluation: weekly problem sets, lab work, and observing projects
Prerequisites: MATH 150 or 151; prior experience with Unix and computer programming is helpful, but not required
Enrollment Limit: 14
Expected Class Size: 8

Grading: no pass/fail option, no fifth course option

Distributions: (D3) (QFR)

Quantitative/Formal Reasoning Notes: The course requires regular problem sets. Labs require computer programming and statistical and graphical analyses of data.

Spring 2020
LEC Section: 01 MR 1:10 pm - 2:25 pm  Anne Jaskot, Kevin Flaherty
LAB Section: 02 M 7:00 pm - 9:40 pm  Anne Jaskot, Kevin Flaherty

BIMO 321 (F)(S) Biochemistry I: Structure and Function of Biological Molecules (QFR)

Cross-listings: CHEM 321  BIMO 321  BIOL 321

Primary Cross-listing

This course introduces the basic concepts of biochemistry with an emphasis on the structure and function of biological macromolecules. Specifically, the structure of proteins and nucleic acids are examined in detail in order to determine how their chemical properties and their biological behavior result from those structures. Other topics covered include catalysis, enzyme kinetics, mechanism and regulation; the molecular organization of biomembranes; and the flow of information from nucleic acids to proteins. In addition, the principles and applications of the methods used to characterize macromolecules in solution and the interactions between macromolecules are discussed. The laboratory provides a hands-on opportunity to study macromolecules and to learn the fundamental experimental techniques of biochemistry including electrophoresis, chromatography, and principles of enzymatic assays.

Class Format: lecture, three hours per week; laboratory, four hours per week

Requirements/Evaluation: evaluation is based on quizzes, a midterm exam, a final exam, problem sets and performance in the laboratories including lab reports

Prerequisites: BIOL 101 and CHEM 251/255 and CHEM 155/256

Enrollment Limit: 16/lab

Enrollment Preferences: junior and senior Biology and Chemistry majors and BIMO concentrators

Expected Class Size: 16/lab

Grading: no pass/fail option, yes fifth course option

Unit Notes: does not satisfy the distribution requirement for the Biology major

Distributions: (D3) (QFR)

This course is cross-listed and the prefixes carry the following divisional credit:
CHEM 321 (D3) BIMO 321 (D3) BIOL 321 (D3)

Attributes: BIGP Related Courses  BIMO Required Courses

Fall 2019
LEC Section: 01 MWF 10:00 am - 10:50 am  Bob Rawle
LAB Section: 02 M 1:00 pm - 5:00 pm  Bob Rawle
LAB Section: 03 T 1:00 pm - 5:00 pm
LAB Section: 04 W 1:00 pm - 5:00 pm

Spring 2020
LEC Section: 01 MWF 9:00 am - 9:50 am  Katie M. Hart
LAB Section: 02 M 1:00 pm - 5:00 pm  Katie M. Hart
LAB Section: 03 T 8:00 am - 12:00 pm

BIMO 322 (S) Biochemistry II: Metabolism (QFR)
Cross-listings: BIOL 322  CHEM 322  BIMO 322

Primary Cross-listing

This lecture course provides an in-depth presentation of the complex metabolic reactions which are central to life. Emphasis is placed on the biological flow of energy including alternative modes of energy generation (aerobic, anaerobic, photosynthetic); the regulation and integration of the metabolic pathways including compartmentalization and the transport of metabolites; and biochemical reaction mechanisms including the structures and mechanisms of coenzymes. This comprehensive study also includes the biosynthesis and catabolism of small molecules (carbohydrates, lipids, amino acids, and nucleotides). Laboratory experiments introduce the principles and procedures used to study enzymatic reactions, bioenergetics, and metabolic pathways.

Class Format: lecture, three hours per week; laboratory, three hours per week

Requirements/Evaluation: several exams and performance in the laboratories including lab reports that emphasize conceptual and quantitative and/or graphic analysis of the

Prerequisites: BIOL 101 and CHEM 251/255 or permission of instructor

Enrollment Limit: 64

Enrollment Preferences: junior and senior Biology and Chemistry majors and BIMO concentrators

Expected Class Size: 64

Grading: no pass/fail option, no fifth course option

Unit Notes: does not satisfy the distribution requirement for the Biology major; cannot be counted towards the Biology major in addition to BIOL 222

Distributions: (D3) (QFR)

This course is cross-listed and the prefixes carry the following divisional credit:

BIOL 322 (D3) CHEM 322 (D3) BIMO 322 (D3)

Attributes: BIGP Related Courses  BIMO Required Courses

Spring 2020

LEC Section: 01    TBA     Steven J. Swoap
LAB Section: 02    T 1:00 pm - 4:00 pm     Janis E. Bravo
LAB Section: 03    W 1:00 pm - 4:00 pm     Janis E. Bravo
LAB Section: 04    R 1:00 pm - 4:00 pm     Cynthia K. Holland

BIOL 202 (F) Genetics (QFR)

Genetics, classically defined as the study of heredity, has evolved into a discipline whose limits are continually expanded by innovative molecular technologies. This course covers the experimental basis for our current understanding of the inheritance, structures, and functions of genes. It introduces approaches used by contemporary geneticists and molecular biologists to explore questions in areas of biology ranging from evolution to medicine. The laboratory part of the course provides an experimental introduction to modern genetic analysis. Laboratory experiments include linkage analysis, bacterial transformation with plasmids and DNA restriction mapping.

Class Format: lecture/laboratory, six hours per week

Requirements/Evaluation: evaluation will be based on bi-weekly problem sets, weekly laboratory exercises and laboratory reports, and examinations

Prerequisites: BIOL 101 and 102

Enrollment Limit: none

Expected Class Size: 84

Grading: no pass/fail option, no fifth course option

Unit Notes: does not satisfy the distribution requirement for the Biology major

Distributions: (D3) (QFR)

Attributes: BIGP Recommended Courses  BIMO Required Courses

Fall 2019
BIOL 203  (F)  Ecology  (QFR)
Cross-listings: BIOL 203  ENVI 203

Primary Cross-listing
This course combines lectures with field and indoor laboratory exercises to explore factors that determine the distribution and abundance of plants and animals in natural systems. The course begins with an overall view of global patterns and then builds from the population to the ecosystem level. An emphasis is given to basic ecological principles and relates them to current environmental issues. Selected topics include population dynamics (competition, predation, mutualism); community interactions (succession, food chains and diversity) and ecosystem function (biogeochemical cycles, energy flow).

Class Format: lecture/laboratory, six hours per week
Requirements/Evaluation: evaluation will be based on problem sets, lab reports, hour exams, and a final exam
Prerequisites: BIOL 101 and 102, or ENVI 101 or 102, or permission of instructor
Enrollment Limit: none
Expected Class Size: 35
Grading: no pass/fail option, no fifth course option
Unit Notes: satisfies the distribution requirement for the Biology major
Distributions: (D3)  (QFR)
This course is cross-listed and the prefixes carry the following divisional credit:
BIOL 203 (D3) ENVI 203 (D3)
Attributes: ENVI Natural World Electives  EVST Environmental Science  EVST Living Systems Courses

BIOL 222  (S)  Essentials of Biochemistry  (QFR)
This course will explore the biochemistry of cellular processes and contextualize these processes in healthy and diseased states. Lecture topics in this one semester course will include the structure and function of proteins (enzymes and non-enzymatic proteins), lipids, and carbohydrates. Lectures will also survey the major metabolic pathways (carbohydrates, lipids, and amino acids) with particular attention to enzyme regulation and the integration of metabolism in different tissues and under different metabolic conditions. In the discussion/laboratory component of the course a combination of primary literature, hypothesis-driven exercises, problem solving, and bench work will be used to illustrate how particular techniques and experimental approaches are used in biochemical fields.

Class Format: lecture/discussion/laboratory, six hours per week
Requirements/Evaluation: regular quizzes, final exam, writing assignments (including problem sets), and lab assignments
Prerequisites: BIOL 101 and CHEM 156; not open to students who have taken BIOL 321 or BIOL 322
Enrollment Limit: 24
Enrollment Preferences: seniors who need to fulfill the biochemistry requirement for premedical school
Expected Class Size: 24
Grading: no pass/fail option, no fifth course option
Unit Notes: does not satisfy the distribution requirement for the Biology major; cannot be counted towards the biology major in addition to either BIOL
321 or BIOL 322; cannot be counted towards the BIMO concentration

**Distributions:** (D3) (QFR)

**Quantitative/Formal Reasoning Notes:** The laboratory program is quantitative covering data analyses, numerical transformations, graphical displays.

### Spring 2020

**LEC Section:** 01  TR 9:55 am - 11:10 am  Daniel V. Lynch
**LAB Section:** 02  W 1:00 pm - 4:00 pm  Daniel V. Lynch
**LAB Section:** 03  R 1:00 pm - 4:00 pm  Daniel V. Lynch

**BIOL 302 (F) Communities and Ecosystems (QFR)**

**Cross-listings:** ENVI 312 BIOL 302

**Primary Cross-listing**

An advanced ecology course that examines how species interact with each other and their environment and how communities are assembled. This course emphasizes phenomena that emerge in complex ecological systems, building on the fundamental concepts of population biology, community ecology, and ecosystem science. This foundation will be used to understand specific topics relevant to conservation including invasibility and the functional significance of diversity for ecosystem stability and processes. Lectures and labs will explore how to characterize the emergent properties of communities and ecosystems, and how theoretical, comparative, and experimental approaches are used to understand their structure and function. The lab component of this course will emphasize hypothesis-oriented field experiments as well as "big-data" analyses using existing data sets. The laboratory component of the course will culminate with a self-designed independent or group project.

**Class Format:** lecture/laboratory, six hours a week

**Requirements/Evaluation:** evaluation will be based on lab reports, a midterm exam, a term project presentation, and a final project paper

**Prerequisites:** BIOL/ENVI 203 or 220

**Enrollment Limit:** 28

**Enrollment Preferences:** Biology majors and Environmental Studies majors and concentrators

**Expected Class Size:** 24

**Grading:** yes pass/fail option, yes fifth course option

**Unit Notes:** satisfies the distribution requirement for the Biology major

**Distributions:** (D3) (QFR)

**This course is cross-listed and the prefixes carry the following divisional credit:**

ENVI 312 (D3) BIOL 302 (D3)

**Attributes:** ENVI Natural World Electives EVST Living Systems Courses EXPE Experiential Education Courses

### Fall 2019

**LEC Section:** 01  TR 9:55 am - 11:10 am  Manuel A. Morales
**LAB Section:** 02  T 1:00 pm - 4:00 pm  Manuel A. Morales
**LAB Section:** 03  W 1:00 pm - 4:00 pm  Manuel A. Morales

**BIOL 305 (S) Evolution (QFR)**

This course offers a critical analysis of contemporary concepts in biological evolution. We focus on the relation of evolutionary mechanisms (e.g., selection, drift, and migration) to long term evolutionary patterns (e.g., evolutionary innovations, origin of major groups, and the emergence of diversity). Topics include micro-evolutionary models, natural selection and adaptation, sexual selection, speciation, the inference of evolutionary history among others.

**Class Format:** lecture/discussion/laboratory, six hours per week

**Requirements/Evaluation:** evaluation will be based on independent research project, problem sets, participation in discussions and exams

**Prerequisites:** BIOL 202

**Enrollment Limit:** 24
Enrollment Preferences: Seniors and biology majors

Expected Class Size: 24

Grading: yes pass/fail option, yes fifth course option

Unit Notes: satisfies the distribution requirement for the Biology major

Distributions: (D3) (QFR)

Attributes: BIGP Recommended Courses  BIMO Interdepartmental Electives  COGS Related Courses

Spring 2020

LEC Section: 01    MWF 10:00 am - 10:50 am     Luana S. Maroja
LAB Section: 02    T 1:00 pm - 4:00 pm     Luana S. Maroja
LAB Section: 03    R 1:00 pm - 4:00 pm     Luana S. Maroja

BIOL 321  (F)(S)  Biochemistry I: Structure and Function of Biological Molecules  (QFR)

Cross-listings:  CHEM 321  BIMO 321  BIOL 321

Secondary Cross-listing

This course introduces the basic concepts of biochemistry with an emphasis on the structure and function of biological macromolecules. Specifically, the structure of proteins and nucleic acids are examined in detail in order to determine how their chemical properties and their biological behavior result from those structures. Other topics covered include catalysis, enzyme kinetics, mechanism and regulation; the molecular organization of biomembranes; and the flow of information from nucleic acids to proteins. In addition, the principles and applications of the methods used to characterize macromolecules in solution and the interactions between macromolecules are discussed. The laboratory provides a hands-on opportunity to study macromolecules and to learn the fundamental experimental techniques of biochemistry including electrophoresis, chromatography, and principles of enzymatic assays.

Class Format: lecture, three hours per week; laboratory, four hours per week

Requirements/Evaluation: evaluation is based on quizzes, a midterm exam, a final exam, problem sets and performance in the laboratories including lab reports

Prerequisites: BIOL 101 and CHEM 251/255 and CHEM 155/256

Enrollment Limit: 16/lab

Enrollment Preferences: junior and senior Biology and Chemistry majors and BIMO concentrators

Expected Class Size: 16/lab

Grading: no pass/fail option, yes fifth course option

Unit Notes: does not satisfy the distribution requirement for the Biology major

Distributions: (D3) (QFR)

This course is cross-listed and the prefixes carry the following divisional credit:

CHEM 321 (D3)  BIMO 321 (D3)  BIOL 321 (D3)

Attributes: BIGP Related Courses  BIMO Required Courses

Fall 2019

LEC Section: 01    MWF 10:00 am - 10:50 am     Bob Rawle
LAB Section: 02    M 1:00 pm - 5:00 pm     Bob Rawle
LAB Section: 03    T 1:00 pm - 5:00 pm
LAB Section: 04    W 1:00 pm - 5:00 pm

Spring 2020

LEC Section: 01    MWF 9:00 am - 9:50 am     Katie M. Hart
LAB Section: 02    M 1:00 pm - 5:00 pm     Katie M. Hart
LAB Section: 03    T 8:00 am - 12:00 pm
BIOL 322 (S) Biochemistry II: Metabolism (QFR)

Cross-listings: BIOL 322 CHEM 322 BIMO 322

Secondary Cross-listing

This lecture course provides an in-depth presentation of the complex metabolic reactions which are central to life. Emphasis is placed on the biological flow of energy including alternative modes of energy generation (aerobic, anaerobic, photosynthetic); the regulation and integration of the metabolic pathways including compartmentalization and the transport of metabolites; and biochemical reaction mechanisms including the structures and mechanisms of coenzymes. This comprehensive study also includes the biosynthesis and catabolism of small molecules (carbohydrates, lipids, amino acids, and nucleotides). Laboratory experiments introduce the principles and procedures used to study enzymatic reactions, bioenergetics, and metabolic pathways.

Class Format: lecture, three hours per week; laboratory, three hours per week

Requirements/Evaluation: several exams and performance in the laboratories including lab reports that emphasize conceptual and quantitative and/or graphic analysis of the

Prerequisites: BIOL 101 and CHEM 251/255 or permission of instructor

Enrollment Limit: 64

Enrollment Preferences: junior and senior Biology and Chemistry majors and BIMO concentrators

Expected Class Size: 64

Grading: no pass/fail option, no fifth course option

Unit Notes: does not satisfy the distribution requirement for the Biology major; cannot be counted towards the Biology major in addition to BIOL 222

Distributions: (D3) (QFR)

This course is cross-listed and the prefixes carry the following divisional credit:

BIOL 322 (D3) CHEM 322 (D3) BIMO 322 (D3)

Attributes: BIGP Related Courses BIMO Required Courses

Spring 2020

LEC Section: 01 TBA Steven J. Swoap
LAB Section: 02 T 1:00 pm - 4:00 pm Janis E. Bravo
LAB Section: 03 W 1:00 pm - 4:00 pm Janis E. Bravo
LAB Section: 04 R 1:00 pm - 4:00 pm Cynthia K. Holland

CHEM 151 (F) Introductory Chemistry (QFR)

This course provides an introduction to chemistry for those students with little or no high school chemistry. Students will be introduced to concepts fundamental to studying matter at the molecular level. Principal topics include introductions to the nature of atoms and molecules, stoichiometry, solubility rules and equilibria, gas laws, chemical equilibrium, acid-base reactions, periodic relationships, chemical bonding, molecular structure, intermolecular forces, oxidation-reduction reactions, and related applications. Laboratory work comprises a system of qualitative analysis and quantitative techniques. The course provides preparation for further study of organic chemistry, biochemistry, physical and inorganic chemistry and is intended for students who are anticipating professional study in chemistry, in related sciences, or in one of the health professions, as well as for those students who are interested in exploring the fundamental ideas of chemistry as part of their general education.

Class Format: lecture, three times per week; laboratory, four hours per week

Requirements/Evaluation: frequent electronic and quantitative written weekly problem set assignments, laboratory work and reports, quizzes, two tests, and a final exam

Extra Info: information about the Chemistry Placement Test can be found at http://chemistry.williams.edu/placement/

Extra Info 2: students who have studied chemistry for one or more years are directed to CHEM 153 or 155

Prerequisites: all students planning to enroll are required to take the online Chemistry Placement Test prior to registering for the course (and incoming first year students are required to meet with a faculty member during First Days)

Enrollment Limit: 16/lab
**Enrollment Preferences:** incoming first year students are required to meet with a faculty member during First Days

**Expected Class Size:** 48

**Grading:** no pass/fail option, no fifth course option

**Unit Notes:** CHEM 151 may be taken concurrently with MATH 102—see under Mathematics; CHEM 151 or its equivalent is a prerequisite to CHEM 156; one of CHEM 151 or 153 or 155 required for the BIMO concentration

**Distributions:** (D3) (QFR)

**Attributes:** BIMO Required Courses

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**CHEM 153 (F) Concepts of Chemistry (QFR)**

This course broadens and deepens the foundation in chemistry of students who have had typically one year of chemistry at the high school level. Most students begin study of chemistry at Williams with this course. Familiarity with stoichiometry, basic concepts of equilibria, and the model of an atom is expected. Principal topics for this course include kinetic theory of gases, modern atomic theory, molecular structure and bonding, states of matter, chemical equilibrium (acid-base and solubility), and an introduction to atomic and molecular spectroscopies. Laboratory work includes synthesis, qualitative and quantitative chemical analysis, and molecular modeling. The course is of interest to students who anticipate professional study in chemistry, related sciences, or one of the health professions, as well as to those who want to explore the fundamental ideas of chemistry as part of their general education.

**Class Format:** lecture, three hours per week; laboratory, four hours per week

**Requirements/Evaluation:** quantitative weekly problem set assignments, laboratory work and reports, hour tests, and a final exam

**Extra Info:** information about the Chemistry Placement Test can be found at http://chemistry.williams.edu/placement/

**Prerequisites:** all students are required to take the online Chemistry Placement Test prior to registering for the course (and incoming first year students are required to meet with a faculty member during First Days)

**Enrollment Limit:** 16/lab

**Enrollment Preferences:** incoming first year students also must meet with a faculty member during First Days

**Expected Class Size:** 70

**Grading:** no pass/fail option, no fifth course option

**Unit Notes:** one of CHEM 151 or 153 or 155 required for the BIMO concentration

**Distributions:** (D3) (QFR)

**Attributes:** BIMO Required Courses

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**CHEM 155 (F) Principles of Modern Chemistry (QFR)**

This course is designed for students with strong preparation in secondary school chemistry, including a laboratory experience, such as provided by an Advanced Placement chemistry course (or equivalent) with a corresponding score of 5 of the AP Chemistry Exam (or a 7 on the IB Exam, or equivalent). Topics include chemical thermodynamics, kinetics, structure and bonding, coordination chemistry, electrochemistry and spectroscopy and
their application to fields such as materials science, industrial, environmental, biological, and medicinal chemistry. Laboratory work includes synthesis, characterization, and reactivity of coordination complexes, electrochemical analysis, materials chemistry, qualitative analysis, and molecular modeling. This course is of interest for students who are anticipating professional study in chemistry, related sciences, or one of the health professions, as well as for students who want to explore the fundamental ideas of chemistry as part of their general education.

Class Format: lecture, three hours per week; laboratory, four hours per week

Requirements/Evaluation: weekly problem sets, laboratory work and reports, an hour test, and a final exam

Extra Info: information about the Chemistry Placement Test can be found at http://chemistry.williams.edu/placement/

Prerequisites: students planning to enroll are required to take the Chemistry Placement Survey prior to registering; incoming first year students are required to meet with faculty during First Days; for more information go to http://chemistry.williams.edu/placement/

Enrollment Limit: 16/lab

Enrollment Preferences: CHEM 151 is an introductory course for students with no or little chemistry background. Students who have studied chemistry for one or more years are directed to CHEM 153 or 155

Expected Class Size: 36

Grading: no pass/fail option, no fifth course option

Unit Notes: CHEM 151 may be taken concurrently with MATH 102—see under Mathematics; CHEM 151 or its equivalent is a prerequisite to CHEM 156; one of CHEM 151 or 153 or 155 required for the BIMO concentration

Distributions: (D3) (QFR)

Attributes: BIMO Required Courses

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**CHEM 151 (S) Organic Chemistry: Introductory Level (QFR)**

This course provides the necessary background in organic chemistry for students who are planning advanced study or a career in chemistry, the biological sciences, or the health professions. It initiates the systematic study of the common classes of organic compounds with emphasis on theories of structure and reactivity. The fundamentals of molecular modeling as applied to organic molecules are presented. Specific topics include basic organic structure and bonding, isomerism, stereochemistry, molecular energetics, the theory and interpretation of infrared and nuclear magnetic spectroscopy, substitution and elimination reactions, and the addition reactions of alkenes and alkynes. The coordinated laboratory work includes purification and separation techniques, structure-reactivity studies, organic synthesis, IR and NMR spectroscopy, and the identification of unknown compounds.

Class Format: lecture, three hours per week; laboratory, four hours per week

Requirements/Evaluation: evaluation will be based on quantitative problem sets, laboratory performance, including written lab reports, three midterm exams, and a final exam

Prerequisites: CHEM 151 or 153 or 155 or placement exam or permission of instructor

Enrollment Limit: 16/lab

Expected Class Size: 120

Grading: no pass/fail option, no fifth course option

Distributions: (D3) (QFR)

Attributes: BIMO Required Courses

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Spring 2020

LEC Section: 01 MWF 8:00 am - 8:50 am Sarah L. Goh

LEC Section: 02 MWF 9:00 am - 9:50 am Ben W. Thuronyi
CHEM 321  (F)(S)  Biochemistry I: Structure and Function of Biological Molecules  (QFR)

Cross-listings: CHEM 321  BIMO 321  BIOL 321

Secondary Cross-listing
This course introduces the basic concepts of biochemistry with an emphasis on the structure and function of biological macromolecules. Specifically, the structure of proteins and nucleic acids are examined in detail in order to determine how their chemical properties and their biological behavior result from those structures. Other topics covered include catalysis, enzyme kinetics, mechanism and regulation; the molecular organization of biomembranes; and the flow of information from nucleic acids to proteins. In addition, the principles and applications of the methods used to characterize macromolecules in solution and the interactions between macromolecules are discussed. The laboratory provides a hands-on opportunity to study macromolecules and to learn the fundamental experimental techniques of biochemistry including electrophoresis, chromatography, and principles of enzymatic assays.

Class Format: lecture, three hours per week; laboratory, four hours per week

Requirements/Evaluation: evaluation is based on quizzes, a midterm exam, a final exam, problem sets and performance in the laboratories including lab reports

Prerequisites: BIOL 101 and CHEM 251/255 and CHEM 155/256

Enrollment Limit: 16/lab

Enrollment Preferences: junior and senior Biology and Chemistry majors and BIMO concentrators

Expected Class Size: 16/lab

Grading: no pass/fail option, yes fifth course option

Unit Notes: does not satisfy the distribution requirement for the Biology major

Distributions: (D3)  (QFR)

This course is cross-listed and the prefixes carry the following divisional credit:
CHEM 321 (D3) BIMO 321 (D3) BIOL 321 (D3)

Attributes: BIGP Related Courses  BIMO Required Courses

Fall 2019
LEC Section: 01  MWF 10:00 am - 10:50 am  Bob Rawle
LAB Section: 02  M 1:00 pm - 5:00 pm  Bob Rawle
LAB Section: 03  T 1:00 pm - 5:00 pm
LAB Section: 04  W 1:00 pm - 5:00 pm

Spring 2020
LEC Section: 01  MWF 9:00 am - 9:50 am  Katie M. Hart
LAB Section: 02  M 1:00 pm - 5:00 pm  Katie M. Hart
LAB Section: 03  T 8:00 am - 12:00 pm

CHEM 322  (S)  Biochemistry II: Metabolism  (QFR)

Cross-listings: BIOL 322  CHEM 322  BIMO 322

Secondary Cross-listing
This lecture course provides an in-depth presentation of the complex metabolic reactions which are central to life. Emphasis is placed on the biological flow of energy including alternative modes of energy generation (aerobic, anaerobic, photosynthetic); the regulation and integration of the metabolic pathways including compartmentalization and the transport of metabolites; and biochemical reaction mechanisms including the structures and mechanisms of coenzymes. This comprehensive study also includes the biosynthesis and catabolism of small molecules (carbohydrates, lipids, amino acids, and nucleotides). Laboratory experiments introduce the principles and procedures used to study enzymatic reactions, bioenergetics, and metabolic pathways.

**Class Format:** lecture, three hours per week; laboratory, three hours per week

**Requirements/Evaluation:** several exams and performance in the laboratories including lab reports that emphasize conceptual and quantitative and/or graphic analysis of the

**Prerequisites:** BIOL 101 and CHEM 251/255 or permission of instructor

**Enrollment Limit:** 64

**Enrollment Preferences:** junior and senior Biology and Chemistry majors and BIMO concentrators

**Expected Class Size:** 64

**Grading:** no pass/fail option, no fifth course option

**Unit Notes:** does not satisfy the distribution requirement for the Biology major; cannot be counted towards the Biology major in addition to BIOL 222

**Distributions:** (D3) (QFR)

**This course is cross-listed and the prefixes carry the following divisional credit:**

BIOL 322 (D3) CHEM 322 (D3) BIMO 322 (D3)

**Attributes:** BIGP Related Courses BIMO Required Courses

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**CSCI 103 (F) Electronic Textiles (QFR)**

Digital data is being infused throughout the entire physical world, escaping the computer monitor and spreading to other devices and appliances, including the human body. Electronic textiles, or eTextiles, is one of the next steps toward making everything interactive and this course aims to introduce learners to the first steps of developing their own wearable interactive technology devices. After completing a series of introductory eTextiles projects to gain practice in necessary sewing, circuitry, and programming skills, students will propose and design their own eTextiles projects, eventually implementing them with sewable Arduino components, and other found electronic components as needed. The scope of the project will depend on the individual's prior background, but can include everything from a sweatshirt with light-up turn signals for bicycling, to a wall banner that displays the current air quality of the room, to a stuffed animal that plays a tune when the lights go on, to whatever project you can conceivably accomplish with sewable Arduino inputs, outputs, and development board in a semester context. This class will introduce students to introductory computer programming, circuitry, and sewing with the goal of creating novel wearable artifacts that interact with the world.

**Class Format:** lecture interspersed with hands-on activities in a computer lab

**Requirements/Evaluation:** weekly homework assignments and a final project

**Prerequisites:** none

**Enrollment Limit:** 20

**Enrollment Preferences:** students who have not previously taken a CSCI course

**Expected Class Size:** 20

**Grading:** yes pass/fail option, yes fifth course option

**Materials/Lab Fee:** a fee of $85 will be added to term bill to cover Lilypad Arduino components (Protosnap Plus Kit, battery holders switched and not-switched, sets of LEDs, temperature sensor, vibe board, tri-color LED), alligator test leads, and fabric scissors

**Distributions:** (D3) (QFR)

**Quantitative/Formal Reasoning Notes:** The course will teach students the basics of computer programming through projects in which
quantitative/formal reasoning skills are practiced and evaluated.

Fall 2019
LEC Section: 01    TR 9:55 am - 11:10 am     Iris Howley

CSCI 134 (F)(S) Introduction to Computer Science (QFR)
This course introduces students to the science of computation by exploring the representation and manipulation of data and algorithms. We organize and transform information in order to solve problems using algorithms written in a modern object-oriented language. Topics include organization of data using objects and classes, and the description of processes using conditional control, iteration, methods and classes. We also begin the study of abstraction, self-reference, reuse, and performance analysis. While the choice of programming language and application area will vary in different offerings, the skills students develop will transfer equally well to more advanced study in many areas. In particular, this course is designed to provide the programming skills needed for further study in computer science and is expected to satisfy introductory programming requirements in other departments.

Class Format: lecture/laboratory
Requirements/Evaluation: weekly assignments, programming projects, and examinations
Prerequisites: none, except for the standard prerequisites for a (QFR) course; previous programming experience is not required
Enrollment Limit: 90
Enrollment Preferences: If the course is over-enrolled, enrollment will be determined by lottery
Expected Class Size: 90
Grading: yes pass/fail option, yes fifth course option
Unit Notes: students with prior experience with object-oriented programming should discuss appropriate course placement with members of the department
Distributions: (D3) (QFR)
Attributes: BIGP Recommended Courses COGS Interdepartmental Electives

Fall 2019
LEC Section: 01    MWF 9:00 am - 9:50 am     Thomas P. Murtagh
LEC Section: 02    Cancelled
LEC Section: 03    MWF 11:00 am - 11:50 am     Jeannie R Albrecht
LAB Section: 04    M 1:00 pm - 4:00 pm     Thomas P. Murtagh
LAB Section: 05    M 7:00 pm - 10:00 pm     Thomas P. Murtagh
LAB Section: 06    T 1:00 pm - 4:00 pm     Thomas P. Murtagh
LAB Section: 07    M 1:00 pm - 4:00 pm     Jeannie R Albrecht
LAB Section: 08    T 1:00 pm - 4:00 pm     Jeannie R Albrecht

Spring 2020
LEC Section: 01    MWF 8:00 am - 8:50 am     Andrea Danyluk
LEC Section: 02    MWF 9:00 am - 9:50 am     Shikha Singh
LEC Section: 03    MWF 11:00 am - 11:50 am     Iris Howley
LAB Section: 04    M 1:00 pm - 2:30 pm     Iris Howley
LAB Section: 05    M 2:30 pm - 4:00 pm     Iris Howley
LAB Section: 06    M 1:00 pm - 2:30 pm     Andrea Danyluk
LAB Section: 07    M 2:30 pm - 4:00 pm     Andrea Danyluk
LAB Section: 08    T 1:00 pm - 2:30 pm     Shikha Singh
LAB Section: 09    T 2:30 pm - 4:00 pm     Shikha Singh
This course builds on the programming skills acquired in Computer Science 134. It couples work on program design, analysis, and verification with an introduction to the study of data structures. Data structures capture common ways in which to store and manipulate data, and they are important in the construction of sophisticated computer programs. Students are introduced to some of the most important and frequently used data structures: lists, stacks, queues, trees, hash tables, graphs, and files. Students will be expected to write several programs, ranging from very short programs to more elaborate systems. Emphasis will be placed on the development of clear, modular programs that are easy to read, debug, verify, analyze, and modify.

Class Format: lecture/laboratory

Requirements/Evaluation: evaluation will be based on programming assignments, homework and/or examinations

Prerequisites: CSCI 134 or equivalent; fulfilling the Discrete Mathematics Proficiency requirement is recommended, but not required

Enrollment Limit: 60

Enrollment Preferences: If the course is over-enrolled, enrollment will be determined by lottery

Expected Class Size: 60

Grading: yes pass/fail option, yes fifth course option

Distributions: (D3) (QFR)

Attributes: BIGP Recommended Courses

Fall 2019

LEC Section: 01 MWF 9:00 am - 9:50 am William J. Lenhart
LEC Section: 02 MWF 10:00 am - 10:50 am Samuel McCauley
LAB Section: 03 W 12:00 pm - 2:00 pm William J. Lenhart
LAB Section: 04 W 2:00 pm - 4:00 pm William J. Lenhart
LAB Section: 05 W 12:00 pm - 2:00 pm Samuel McCauley
LAB Section: 06 W 2:00 pm - 4:00 pm Samuel McCauley

Spring 2020

LEC Section: 01 MWF 9:00 am - 9:50 am Daniel W. Barowy
LEC Section: 02 MWF 10:00 am - 10:50 am Bill K. Jannen
LAB Section: 03 W 12:00 pm - 2:00 pm Daniel W. Barowy
LAB Section: 04 W 2:00 pm - 4:00 pm Daniel W. Barowy
LAB Section: 05 W 12:00 pm - 2:00 pm Bill K. Jannen
LAB Section: 06 W 2:00 pm - 4:00 pm Bill K. Jannen

This course studies the basic instruction set architecture and organization of a modern computer. It provides a programmer's view of how computer systems execute programs, store information, and communicate. Over the semester the student learns the fundamentals of translating higher level languages into assembly language, and the interpretation of machine languages by hardware. At the same time, a model of computer hardware organization is developed from the gate level upward.

Class Format: lecture/laboratory

Requirements/Evaluation: evaluation will be based primarily on projects, and one or more exams

Prerequisites: CSCI 134, or both experience in programming and permission of instructor

Enrollment Limit: 12 per lab

Enrollment Preferences: current or expected Computer Science majors

Expected Class Size: 12 per lab

Grading: no pass/fail option, no fifth course option

Distributions: (D3) (QFR)
This course investigates methods for designing efficient and reliable algorithms. By carefully analyzing the structure of a problem within a mathematical framework, it is often possible to dramatically decrease the computational resources needed to find a solution. In addition, analysis provides a method for verifying the correctness of an algorithm and accurately estimating its running time and space requirements. We will study several algorithm design strategies that build on data structures and programming techniques introduced in Computer Science 136. These include induction, divide-and-conquer, dynamic programming, and greedy algorithms. Additional topics of study include algorithms on graphs and strategies for handling potentially intractable problems.

Class Format: lecture

Requirements/Evaluation: evaluation will be based on problem sets and programming assignments, and midterm and final examinations

Prerequisites: CSCI 136 and fulfillment of the Discrete Mathematics Proficiency requirement

Enrollment Limit: 24/sect

Enrollment Preferences: current or expected Computer Science majors

Expected Class Size: 24/sect

Grading: no pass/fail option, no fifth course option

Distributions: (D3) (QFR)

Attributes: BIGP Recommended Courses

This course will provide an overview of Computational Biology, the application of computational, mathematical, statistical, and physical problem-solving techniques to interpret the rapidly expanding amount of biological data. Topics covered will include database searching, DNA sequence alignment, clustering, RNA structure prediction, protein structural alignment, methods of analyzing gene expression, networks, and genome assembly using techniques such as string matching, dynamic programming, hidden Markov models, and expectation-maximization.

Class Format: lab three hours per week plus weekly tutorial meeting

Requirements/Evaluation: evaluation will be based on weekly Python programming assignments, problem sets, a few quizzes and a final project

Prerequisites: programming experience (e.g., CSCI 136), mathematics (PHYS/MATH 210 or MATH 150), and physical science (PHYS 142 or 151, or CHEM 151 or 153 or 155), or permission of instructor
Enrollment Limit: 10
Enrollment Preferences: based on seniority
Expected Class Size: 8
Grading: no pass/fail option, no fifth course option
Distributions: (D3) (QFR)

This course is cross-listed and the prefixes carry the following divisional credit:
PHYS 315 (D3) CSCI 315 (D3)

Attributes: BIGP Recommended Courses

Spring 2020
TUT Section: T1 TBA Daniel P. Aalberts
LAB Section: T2 M 1:10 pm - 3:50 pm Daniel P. Aalberts

CSCI 326 (S) Software Methods (QFR)
Sophisticated software systems play a prominent role in many aspects of our lives, and while programming can be a very creative and exciting process, building a reliable software system of any size is no easy feat. Moreover, the ultimate outcome of any programming endeavor is likely to be incomplete, unreliable, and unmaintainable unless principled methods for software construction are followed. This course explores those methods. Specific topics include: software processes; specifying requirements and verifying correctness; abstractions; design principles; software architectures; concurrent and scalable systems design; testing and debugging; and performance evaluation.

Class Format: lecture/lab
Requirements/Evaluation: homework, programming assignments, group work, presentations, exams
Prerequisites: CSCI 136, and at least one of CSCI 237, 256, or 334
Enrollment Limit: 24
Enrollment Preferences: current or expected Computer Science majors
Expected Class Size: 24
Grading: no pass/fail option, no fifth course option
Distributions: (D3) (QFR)

Spring 2020
LEC Section: 01 TR 9:55 am - 11:10 am Stephen N. Freund
LAB Section: 02 R 1:10 pm - 3:50 pm Stephen N. Freund

CSCI 331 (F) Introduction to Computer Security (QFR)
This class explores common vulnerabilities in computer systems, how attackers exploit them, and how systems engineers design defenses to mitigate them. The goal is to be able to recognize potential vulnerabilities in one's own software and to practice defensive design. Hands-on experience writing C/C++ code to inspect and modify the low-level operation of running programs is emphasized. Finally, regular reading and writing assignments round out the course to help students understand the cultural and historical background of the computer security "arms race."

Class Format: lecture
Requirements/Evaluation: assignments, midterm exam, and final exam
Prerequisites: CSCI 136 and CSCI 237
Enrollment Limit: 24
Enrollment Preferences: upper-level students
Expected Class Size: 24
Grading: no pass/fail option, no fifth course option
Distributions: (D3) (QFR)
CSCI 333  (S) Storage Systems  (QFR)
This course will examine topics in the design, implementation, and evaluation of storage systems. Topics include the memory hierarchy; ways that data is organized (both logically and physically); storage hardware and its influence on storage software designs; data structures; performance models; and system measurement/evaluation. Readings will be taken from recent technical literature, and an emphasis will be placed on identifying and evaluating design trade-offs.

Class Format: lecture/lab

Requirements/Evaluation: problem sets, programming assignments, and midterm and final examinations

Prerequisites: CSCI 136; CSCI 237 or permission of instructor

Enrollment Limit: 24

Enrollment Preferences: current Computer Science majors, students with research experience or interest

Expected Class Size: 24

Grading: no pass/fail option, no fifth course option

Distributions: (D3) (QFR)

Quantitative/Formal Reasoning Notes: This course will have students develop quantitative/formal reasoning skills through problem sets and programming assignments.

CSCI 334  (F)(S) Principles of Programming Languages  (QFR)
This course examines the concepts and structures governing the design and implementation of programming languages. It presents an introduction to the concepts behind compilers and run-time representations of programming languages; features of programming languages supporting abstraction and polymorphism; and the procedural, functional, object-oriented, and concurrent programming paradigms. Programs will be required in languages illustrating each of these paradigms.

Class Format: lecture

Requirements/Evaluation: evaluation will be based on weekly problem sets and programming assignments, a midterm examination and a final examination

Prerequisites: CSCI 136

Enrollment Limit: 30

Enrollment Preferences: current or expected Computer Science majors

Expected Class Size: 30

Grading: no pass/fail option, no fifth course option

Distributions: (D3) (QFR)

CSCI 338  (F) Parallel Processing  (QFR)
This course explores different parallel programming paradigms used for writing applications on today's parallel computer systems. The course will introduce concurrency (i.e. multiple simultaneous computations) and the synchronization primitives that allow for the creation of correct concurrent applications. It will examine how a variety of systems organize parallel processing resources and enable users to write parallel programs for these
systems. Covered programming paradigms will include multiprogramming with processes, message passing, threading in shared memory multiprocessors, vector processing, graphics processor programming, transactions, MapReduce, and other forms of programming for the cloud. Class discussion is based on assigned readings. Assignments provide students the opportunity to develop proficiency in writing software using different parallel programming paradigms.

**Class Format:** lecture/laboratory

**Requirements/Evaluation:** homework assignments, programming projects, and exams

**Prerequisites:** CSCI 136 or equivalent programming experience, and CSCI 237, or permission of instructor

**Enrollment Limit:** 24

**Enrollment Preferences:** current or expected Computer Science majors

**Expected Class Size:** 24

**Grading:** no pass/fail option, no fifth course option

**Distributions:** (D3) (QFR)

**Quantitative/Formal Reasoning Notes:** The course will consist of substantial problem sets and programming assignments in which quantitative/formal reasoning skills are practiced and evaluated.

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**Fall 2019**

LEC Section: 01  MR 1:10 pm - 2:25 pm  Kelly A. Shaw

**CSCI 339 (S) Distributed Systems (QFR)**

This course studies the key design principles of distributed systems, which are collections of independent networked computers that function as single coherent systems. Covered topics include communication protocols, processes and threads, naming, synchronization, consistency and replication, fault tolerance, and security. Students also examine some specific real-world distributed systems case studies, including Google and Amazon. Class discussion is based on readings from the textbook and research papers. The goals of this course are to understand how large-scale computational systems are built, and to provide students with the tools necessary to evaluate new technologies after the course ends.

**Class Format:** lecture/laboratory

**Requirements/Evaluation:** evaluation will be based on homework assignments, programming projects, and exams

**Prerequisites:** CSCI 136 or equivalent programming experience, and CSCI 237, or permission of instructor

**Enrollment Limit:** 24

**Enrollment Preferences:** current or expected Computer Science majors

**Expected Class Size:** 24

**Grading:** no pass/fail option, no fifth course option

**Distributions:** (D3) (QFR)

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**Spring 2020**

LEC Section: 01  MR 1:10 pm - 2:25 pm  Jeannie R Albrecht

**CSCI 343 (F) Application Development with Functional Programming (QFR)**

This course will enrich the participants on how functional programming can reduce unintended complexity and create code bases that are simpler to maintain and reason about. Functional programming is a paradigm, which focuses on values and pure functions rather than mutable objects and imperative statements. Since good code design is intersubjective, we need to be open-minded and continuously reflect upon the decisions we make. Together we will reflect on the design choices made and the dilemmas that will arise. We will learn that there are often multiple solutions, each often having their benefits and drawbacks. By gaining experience, we will acquire empirical knowledge, intuition and sensors for avoiding unintended complexity, creating appropriate abstractions and a sustainable code base. Class will consist of a lot of live coding, code-reviews and a dialog on how we can improve our architectural design and knowledge. Topics include code quality, readability, maintainability, collaboration, version control system (git), global state, dependencies, pure functions, persistent data structures, data consistency, single source of truth (SSOT), reactive programming, web development, functional programming and comparison with object oriented programming, designing for testability, documentation, state management, atomic updates, concurrency, dynamic types, DSLs, lisp and REPL. The concepts are not limited to a specific programming language.
We will use Clojure and ClojureScript to realize the ideas in the specific project. Hence, also rigorous abilities in lisp, repl workflow and Clojure/ClojureScript will be an outcome of the course. For each week there will be a video talk from programming conferences that will serve as inspiration and give us the opportunity to reflect. The videos will be posted when the course starts.

**Class Format:** lecture

**Requirements/Evaluation:** a semester-long programming project, and midterm and final presentations

**Prerequisites:** CSCI 136, and at least one of CSCI 237, 256, or 334

**Enrollment Limit:** 24

**Enrollment Preferences:** current or expected Computer Science majors

**Expected Class Size:** 24

**Grading:** no pass/fail option, no fifth course option

**Distributions:** (D3) (QFR)

**Quantitative/Formal Reasoning Notes:** The course will involve a programming project that emphasizes quantitative/formal reasoning skills.

Fall 2019

LEC Section: 01  TF 1:10 pm - 2:25 pm  Tomas Ekholm

CSCI 356  (F)  Advanced Algorithms  (QFR)

This course explores advanced concepts in algorithm design, algorithm analysis and data structures. Areas of focus will include algorithmic complexity, randomized and approximation algorithms, geometric algorithms, and advanced data structures. Topics will include combinatorial algorithms for packing, and covering problems, algorithms for proximity and visibility problems, linear programming algorithms, approximation schemes, hardness of approximation, search, and hashing.

**Class Format:** This class will follow the meeting structure of a tutorial, with groups of three or four

**Requirements/Evaluation:** evaluation is based on weekly problem sets, several small programming projects, weekly paper summaries, and a small, final project

**Prerequisites:** CSCI 256; CSCI 361 is recommended but not required

**Enrollment Limit:** 10

**Enrollment Preferences:** current or expected Computer Science majors

**Expected Class Size:** 10

**Grading:** no pass/fail option, no fifth course option

**Distributions:** (D3) (QFR)

Fall 2019

TUT Section: T1  TBA  William J. Lenhart

CSCI 358  (S)  Applied Algorithms  (QFR)

This course is about bridging the gap between theoretical running time and writing fast code in practice. The course is divided into two basic topics. The first is algorithmic: we will discuss some of the most useful tools in a coder's toolkit. This includes topics like randomization (hashing, filters, approximate counters), linear and convex programming, similarity search, and cache-efficient algorithms. Our goal is to talk about why these efficient algorithms make seemingly difficult problems solvable in practice. The second topic is applications: we will discuss how to implement algorithms in an efficient way that takes advantage of modern hardware. Specific topics covered will include blocking, loop unrolling, pipelining, as well as strategies for performance analysis. Projects and assessments will include both basic theoretical aspects (understanding why the algorithms we discuss actually work), and practical aspects (implementing the algorithms we discuss to solve important problems, and optimizing the code so it runs as quickly as possible).

**Class Format:** Lecture

**Requirements/Evaluation:** primary evaluation is a course-long project and written final exam, in addition to shorter programming assignments and problem sets
Prerequisites: CSCI 256 or permission of instructor

Enrollment Limit: 24

Enrollment Preferences: current or expected Computer Science majors

Expected Class Size: 24

Grading: no pass/fail option, no fifth course option

Distributions: (D3) (QFR)

Quantitative/Formal Reasoning Notes: The course will consist of programming assignments and problem sets in which quantitative/formal reasoning skills are practiced and evaluated.

Spring 2020

LEC Section: 01    TR 11:20 am - 12:35 pm     Samuel McCauley

CSCI 361  (F)(S)  Theory of Computation  (QFR)

Cross-listings: CSCI 361 MATH 361

Primary Cross-listing

This course introduces a formal framework for investigating both the computability and complexity of problems. We study several models of computation including finite automata, regular languages, context-free grammars, and Turing machines. These models provide a mathematical basis for the study of computability theory--the examination of what problems can be solved and what problems cannot be solved--and the study of complexity theory--the examination of how efficiently problems can be solved. Topics include the halting problem and the P versus NP problem.

Class Format: lecture

Requirements/Evaluation: evaluation will be based on problem sets, a midterm examination, and a final examination

Prerequisites: CSCI 256 or both a 300-level MATH course and permission of instructor

Enrollment Limit: 30

Enrollment Preferences: current or expected Computer Science majors

Expected Class Size: 30

Grading: no pass/fail option, no fifth course option

Distributions: (D3) (QFR)

This course is cross-listed and the prefixes carry the following divisional credit:

CSCI 361 (D3) MATH 361 (D3)

Attributes: COGS Interdepartmental Electives

Fall 2019

LEC Section: 01    MWF 11:00 am - 11:50 am     Aaron M. Williams

Spring 2020

LEC Section: 01    MWF 12:00 pm - 12:50 pm     Thomas P. Murtagh

CSCI 374  (S)  Machine Learning  (QFR)

This tutorial examines the design, implementation, and analysis of machine learning algorithms. Machine Learning is a branch of Artificial Intelligence that aims to develop algorithms that will improve a system's performance. Improvement might involve acquiring new factual knowledge from data, learning to perform a new task, or learning to perform an old task more efficiently or effectively. This tutorial will cover examples of supervised learning algorithms (including decision tree learning, support vector machines, and neural networks), unsupervised learning algorithms (including k-means and expectation maximization), and possibly reinforcement learning algorithms (such as Q learning and temporal difference learning). It will also introduce methods for the evaluation of learning algorithms, as well as topics in computational learning theory.

Class Format: This class will follow the meeting structure of a tutorial, with groups of three or four

Requirements/Evaluation: evaluation will be based on presentations, problem sets, programming exercises, empirical analyses of algorithms, critical analysis of current literature
**Prerequisites:** CSCI 136 and CSCI 256 or permission of instructor

**Enrollment Limit:** 10

**Enrollment Preferences:** Computer Science majors

**Expected Class Size:** 10

**Grading:** no pass/fail option, no fifth course option

**Distributions:** (D3) (QFR)

**Attributes:** COGS Interdepartmental Electives

Spring 2020

TUT Section: T1  TBA  Andrea Danyluk

**ECON 110  (F)(S) Principles of Microeconomics  (QFR)**

This course is an introduction to the study of the forces of supply and demand that determine prices and the allocation of resources in markets for goods and services, markets for labor, and markets for natural resources. The focus is on how and why markets work, why they may fail to work, and the policy implications of both their successes and failures. The course focuses on developing the basic tools of microeconomic analysis and then applying those tools to topics of popular or policy interest such as minimum wage legislation, pollution control, competition policy, international trade policy, discrimination, tax policy, and the role of government in a market economy.

**Class Format:** lecture/discussion

**Requirements/Evaluation:** problem sets, quizzes, short essays, two midterms (one for Bradburd's sections), final exam

**Extra Info:** this course is required of Economics and Political Economy majors and highly recommended for those non-majors interested in Environmental Studies and Women's, Gender and Sexuality Studies

**Extra Info 2:** Prof. Bradburd's section ONLY; intends to use the issue of environmental protection in general, and climate change in particular, as the vehicle for presenting and applying many, though not all, of the economic concepts and tools developed in the course

**Prerequisites:** none

**Enrollment Limit:** 40

**Expected Class Size:** 40

**Grading:** yes pass/fail option, no fifth course option

**Unit Notes:** the department recommends students follow this course with ECON 120 or with a lower-level elective that has ECON 110 as its prerequisite; students may alternatively proceed directly to ECON 251 after taking this introductory course

**Distributions:** (D2) (QFR)

**Attributes:** POEC Required Courses

Fall 2019

LEC Section: 01  MR 1:10 pm - 2:25 pm  Ralph M. Bradburd
LEC Section: 02  MR 2:35 pm - 3:50 pm  Ralph M. Bradburd
LEC Section: 03  TR 8:30 am - 9:45 am  Susan Godlonton
LEC Section: 04  TR 9:55 am - 11:10 am  Susan Godlonton
LEC Section: 05  TR 11:20 am - 12:35 pm  Owen Thompson
LEC Section: 06  TF 1:10 pm - 2:25 pm  Owen Thompson

Spring 2020

LEC Section: 01  MR 2:35 pm - 3:50 pm  Ralph M. Bradburd
LEC Section: 02  TR 11:20 am - 12:35 pm  Matthew Chao
LEC Section: 03  TF 1:10 pm - 2:25 pm  Matthew Chao

**ECON 120  (F)(S) Principles of Macroeconomics  (QFR)**
This course provides an introduction to the study of the aggregate national economy. It develops the basic theories of macroeconomics and applies them to topics of current interest. Issues to be explored include: the causes of inflation, unemployment, recessions, and depressions; the role of government fiscal and monetary policy in stabilizing the economy; the determinants of long-run economic growth; the long- and short-run effects of taxes, budget deficits, and other government policies on the national economy; the role of financial frictions in amplifying recessions; and the workings of exchange rates and international finance.

Class Format: lecture/discussion

Requirements/Evaluation: problem sets, short essays, midterm, final exam

Prerequisites: ECON 110

Enrollment Limit: 40

Expected Class Size: 40

Grading: yes pass/fail option, yes fifth course option

Distributions: (D2) (QFR)

Attributes: POEC Required Courses

Fall 2019
LEC Section: 01    MWF 8:30 am - 9:45 am    Steven E. Nafziger
LEC Section: 02    MWF 11:00 am - 12:15 pm  Steven E. Nafziger

Spring 2020
LEC Section: 01    TF 1:10 pm - 2:25 pm    Gregory P. Casey
LEC Section: 02    TF 2:35 pm - 3:50 pm    Gregory P. Casey
LEC Section: 03    MR 1:10 pm - 2:25 pm    Sara LaLumia
LEC Section: 04    MR 2:35 pm - 3:50 pm    Sara LaLumia

ECON 213  (S)  Introduction to Environmental and Natural Resource Economics  (QFR)

Cross-listings: ENVI 213 ECON 213

Primary Cross-listing

We'll use economics to learn why we harm the environment and overuse natural resources, and what we can do about it. We'll talk about whether and how we can put a dollar value on nature and ecosystem services. We'll study cost benefit analysis, pollution in general, climate change, natural resources (like fisheries, forests, and fossil fuels), and energy. We will take an economic approach to global sustainability, and study the relationship between the environment and economic growth and trade.

Class Format: lecture

Requirements/Evaluation: problem sets, short essays, paper(s); exam(s) are possible

Prerequisites: ECON 110

Enrollment Limit: 30

Enrollment Preferences: first-year and sophomore students

Expected Class Size: 30

Grading: yes pass/fail option, yes fifth course option

Unit Notes: this course will count toward both the Environmental Studies major and concentration

Distributions: (D2) (QFR)

This course is cross-listed and the prefixes carry the following divisional credit:
ENVI 213 (D2) ECON 213 (D2)

Attributes: ENVI Environmental Policy EVST Social Science/Policy POEC Comparative POEC/Public Policy Courses

Spring 2020
LEC Section: 01    MWF 8:30 am - 9:45 am    Sarah A. Jacobson
ECON 251  (F)(S)  Price and Allocation Theory  (QFR)
A study of the determination of relative prices and their importance in shaping the allocation of resources and the distribution of income. Subjects include: behavior of households in a variety of settings, such as buying goods and services, saving, and labor supply; behavior of firms in various kinds of markets; results of competitive and noncompetitive markets in goods, labor, land, and capital; market failure; government policies as sources of and responses to market failure; welfare criteria; limitations of mainstream analysis.

Class Format: lecture

Requirements/Evaluation:  weekly problem sets, one or more quizzes, one or two midterms, one or two short essays, and a final exam

Prerequisites:  ECON 110 and MATH 130 or its equivalent

Enrollment Limit:  30  

Expected Class Size:  25  

Grading:  yes pass/fail option,  yes fifth course option

Distributions:  (D2)  (QFR)

LEC Section: 01  MWF 8:30 am - 9:45 am  Sarah A. Jacobson
LEC Section: 02  MW 11:00 am - 12:15 pm  Sarah A. Jacobson
LEC Section: 03  TF 1:10 pm - 2:25 pm  Ashok S. Rai
LEC Section: 04  TF 2:35 pm - 3:50 pm  Ashok S. Rai

Spring 2020
LEC Section: 01  TF 1:10 pm - 2:25 pm  Stephen C. Sheppard
LEC Section: 02  TF 2:35 pm - 3:50 pm  Stephen C. Sheppard

ECON 252  (F)(S)  Macroeconomics  (QFR)
A study of aggregate economic activity: output, employment, inflation, and interest rates. The class will develop a theoretical framework for analyzing economic growth and business cycles. The theory will be used to evaluate policies designed to promote growth and stability, and to understand economic developments in the U.S. and abroad. Instructors may use elementary calculus in assigned readings, exams and lectures.

Class Format: lecture/discussion

Requirements/Evaluation:  problem sets and/or written assignments, midterm(s), and a final exam

Prerequisites:  ECON 110 and 120 and MATH 130 or its equivalent

Enrollment Limit:  30  

Expected Class Size:  25  

Grading:  no pass/fail option,  no fifth course option

Distributions:  (D2)  (QFR)

Fall 2019
LEC Section: 01  MW 11:00 am - 12:15 pm  Peter J. Montiel
LEC Section: 02  TF 2:35 pm - 3:50 pm  Peter L. Pedroni

Spring 2020
LEC Section: 01  MWF 8:30 am - 9:45 am  Kenneth N. Kuttner
LEC Section: 02  TF 1:10 pm - 2:25 pm  Peter L. Pedroni
LEC Section: 03  MR 1:10 pm - 2:25 pm  Greg Phelan
LEC Section: 04  MR 2:35 pm - 3:50 pm  Greg Phelan

ECON 255  (F)(S)  Econometrics  (QFR)
An introduction to the theory and practice of applied quantitative economic analysis. This course familiarizes students with the strengths and weaknesses of the basic empirical methods used by economists to evaluate economic theory against economic data. Emphasizes both the statistical foundations of regression techniques and the practical application of those techniques in empirical research. Computer exercises will provide experience in using the empirical methods, but no previous computer experience is expected. Highly recommended for students considering graduate training in economics or public policy.

Class Format: lecture

Requirements/Evaluation: problem sets, two exams, group project, and possible additional assignments

Prerequisites: MATH 130, plus STAT 161, 201 or 202 (or equivalent), plus one course in ECON; STAT 101 will also serve as a prerequisite, but only if taken prior to the fall of 2018

Enrollment Limit: 30

Expected Class Size: 30

Grading: no pass/fail option, no fifth course option

Unit Notes: students may substitute the combination of STAT 201 and 346 for ECON 255

Distributions: (D2) (QFR)

Attributes: EVST Methods Courses PHLH Statistics Courses POEC Required Courses

Fall 2019
LEC Section: 01 MR 1:10 pm - 2:25 pm Kenneth N. Kuttner
LEC Section: 02 W 7:00 pm - 9:40 pm David J. Zimmerman

Spring 2020
LEC Section: 01 TF 1:10 pm - 2:25 pm Matthew Gibson
LEC Section: 02 TF 2:35 pm - 3:50 pm Matthew Gibson
LEC Section: 03 MR 1:10 pm - 2:25 pm Lara D. Shore-Sheppard
LEC Section: 04 W 7:00 pm - 9:40 pm David J. Zimmerman

ECON 345 (S) Growth Diagnostics (QFR)

Cross-listings: ECON 545 ECON 345

Primary Cross-listing

Evidence from across the developing world suggests that the "binding constraints" to economic growth can be remarkably heterogeneous—i.e., the growth potential of stagnating or underperforming economies may be unlocked in a large variety of ways. For instance, pre-reform China had been constrained by poor supply incentives in agriculture, whereas Brazil has been held back by an inadequate supply of credit, South Africa by poor employment incentives in manufacturing, El Salvador by insufficient production incentives in tradables, Zimbabwe by bad governance, and so forth. How can developing-country policymakers determine country-specific constraints like these, thus enabling them to pragmatically pursue a selected set of growth-promoting policies rather than attempting to implement a "laundry list" of reforms that are naively based on "best practice" rules-of-thumb?

This course will serve as a primer on "growth diagnostics," an empirically-driven analytical framework for identifying the most binding constraints to economic growth in a given country at a point in time, thereby allowing policymakers to develop well-targeted reforms for relaxing these constraints while being cognizant of the nation's prevailing economic, political, and social context. The course will first build on the basic theories and empirics of economic growth to elucidate the diagnostic framework and will then employ a wide range of country-specific case studies to demonstrate how the framework can be operationalized for policy making. Throughout the semester, students will be required to work in groups, each representing a given developing or emerging-market economy, in order to build a growth diagnostic for their group's assigned country by the end of the course.

Class Format: seminar

Requirements/Evaluation: extensive class participation, two short (5-page) papers, two 15-page team papers comprising a country growth diagnostic, and a team presentation on the diagnostic

Prerequisites: for undergraduates ECON 251, ECON 252, and either ECON 255 or STAT 346

Enrollment Limit: 19

Enrollment Preferences: CDE fellows and senior Economics majors
Expected Class Size: 19

Grading: no pass/fail option, yes fifth course option

Distributions: (D2) (QFR)

This course is cross-listed and the prefixes carry the following divisional credit:
ECON 545 (D2) ECON 345 (D2)

Quantitative/Formal Reasoning Notes: The course material will be drawn heavily on mathematical and statistical models of economic growth and macroeconomic development, and students will be required to routinely develop mathematical models and/or conduct econometric analysis in their assignments.

Spring 2020

SEM Section: 01 TR 11:20 am - 12:35 pm Quamrul H. Ashraf

ECON 371 (F) Time Series Econometrics and Empirical Methods for Macro (QFR)

Econometric methods in many fields including macro and monetary economics, finance and international growth and development, as well as numerous fields beyond economics, have evolved a distinct set of techniques which are designed to meet the practical challenges posed by the typical empirical questions and available time series data of these fields. The course will begin with an introductory review of concepts of estimation and inference for large data samples in the context of the challenges of multivariate endogeneous systems, and will then focus on associated methods for analysis of short dynamics such as vector autoregressive techniques and methods for analysis of long run dynamics such as cointegration techniques. Students will be introduced to concepts and techniques analytically, but also by intuition, learning by doing, and by computer simulation and illustration. The course is particularly well suited for economics majors wishing to explore advanced empirical methods, or for statistics, mathematics or computer science majors wishing to learn more about the ways in which the subject of their majors interacts with the fields of economics. The method of evaluation will include a term paper. ECON 252 and either STATS 346 or ECON 255 are formal prerequisites, although for students with exceptionally strong math/stats backgrounds these can be waived subject to instructor permission. Credit may not be earned for both ECON 371 and ECON 356.

Class Format: seminar

Requirements/Evaluation: term paper and regular homework assignments

Prerequisites: ECON 252 and either ECON 255 or STATS 346

Enrollment Limit: 19

Enrollment Preferences: students wishing to write an honors thesis, and students with strong MATH/STAT/CSCI backgrounds

Expected Class Size: 19

Grading: no pass/fail option, yes fifth course option

Distributions: (D2) (QFR)

Quantitative/Formal Reasoning Notes: Uses quantitative/formal reasoning intensively in the form of mathematical and statistical arguments, as well as computer programming.

Fall 2019

SEM Section: 01 TF 1:10 pm - 2:25 pm Peter L. Pedroni

ECON 378 (F) Long-Run Perspectives on Economic Growth (QFR)

The world today is marred by vast differences in the standard of living, with about a 30-fold difference in per-capita incomes between the poorest country and the most affluent. What explanations do long-run growth economists have to offer for these differences in levels of prosperity across nations? Are the explanations to be found in underlying differences between countries over the past few decades, the past few centuries, or the past few millennia? If contemporary differences in living standards have "deep" historically-rooted origins, what scope exists for policies to reduce global inequality today? Can we expect global inequality to be reduced gradually over time, through natural processes of economic development, or are they likely to persist unless action is taken to reduce them? This course will present a unified theory of economic growth for thinking about these and related questions. Examples of issues to be covered include: the Neoclassical growth model and its inefficacy for answering questions about development over long time horizons; Malthusian stagnation across societies during the pre-industrial stage of economic development; the importance of the so-called demographic transition and of human capital formation in the course of industrialization; the persistent influence of colonialism,
slavery, and ethnic fragmentation in shaping the quality of contemporary politico-economic institutions; and the long-lasting effects of geography on comparative development, through its impact on the emergence of agriculture in early human societies and its influence in shaping the genetic composition of human populations across the globe.

Class Format: lecture/discussion

Requirements/Evaluation: at least one exam, a research paper and a class presentation

Prerequisites: ECON 251, ECON 252, and either ECON 255 or STAT 346

Enrollment Limit: 25

Enrollment Preferences: junior and senior Economics majors

Expected Class Size: 25

Grading: no pass/fail option, no fifth course option

Distributions: (D2) (QFR)

Attributes: POEC Comparative POEC/Public Policy Courses

Fall 2019
LEC Section: 01    TR 11:20 am - 12:35 pm     Quamrul H. Ashraf

ECON 379  (S)  Program Evaluation for International Development  (QFR)

Cross-listings: ECON 379  ECON 523

Secondary Cross-listing

Development organizations face strict competition for scarce resources. Both public and private organizations are under increasing pressure to use rigorous program evaluation in order to justify funding for their programs and to design more effective programs. This course is an introduction to evaluation methodology and the tools available to development practitioners, drawing on examples from developing countries. It will cover a wide range of evaluation techniques and discuss the advantages and disadvantages of each. The course is a mix of applied econometrics and practical applications covering implementation, analysis, and interpretation. You will learn to be a critical reader of evaluations, and to develop your own plan to evaluate an existing program of your choice.

Class Format: seminar

Requirements/Evaluation: problem sets, midterm exam and one 7- to 10-page essay

Prerequisites: one public economics course or microeconomics course (ECON 504 or ECON 110), and one empirical methods course (POEC 253 or ECON 255, 502, or 503)

Enrollment Limit: 20

Enrollment Preferences: CDE Students, but undergraduates with the prerequisites are welcome

Expected Class Size: 20

Grading: no pass/fail option, yes fifth course option

Distributions: (D2) (QFR)

This course is cross-listed and the prefixes carry the following divisional credit:

ECON 379 (D2) ECON 523 (D2)

Attributes: PHLH Methods in Public Health  POEC Comparative POEC/Public Policy Courses

Spring 2020
SEM Section: 01    MR 2:35 pm - 3:50 pm     Susan Godlonton

ECON 385  (S)  Games and Information  (QFR)

This course is a mathematical introduction to strategic thinking and its applications. Ideas such as Nash equilibrium, commitment, credibility, repeated games, incentives and signaling are discussed. Examples are drawn from economics, politics, history and everyday campus life.

Class Format: lecture/discussion

Requirements/Evaluation: exams, problem sets and a substantial final project that involves modeling a real world situation as a game
Students who have taken MATH 335 cannot receive credit for this class.

**Prerequisites:** ECON 251 and MATH 150, or permission of instructor

**Enrollment Limit:** 25

**Enrollment Preferences:** juniors and seniors

**Expected Class Size:** 25

**Grading:** no pass/fail option, yes fifth course option

**Distributions:** (D2) (QFR)

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**Spring 2020**

**LEC Section:** 01  TR 11:20 am - 12:35 pm  Ashok S. Rai

**ECON 389 (S) Tax Policy in Global Perspective** (QFR)

**Cross-listings:** ECON 389  ECON 514

**Secondary Cross-listing**

Taxes are half of what government does. So if you are interested in what government policy can do to promote efficiency, equity, and economic development, you should be interested in tax policy. Governments must raise tax revenue to finance critical public goods, address other market failures and distributional issues, and to avoid problems with debt and inflation. Taxes typically take up anywhere from ten to fifty percent of a country’s income, they profoundly affect the incentives to undertake all varieties of economic activity, and the government expenditures that they finance have potentially large consequences for human welfare. So the stakes involved in improving tax policy are quite large. This class provides an in-depth exploration of tax policy, from a global and comparative perspective. Because most students in this class will be CDE fellows, we will emphasize tax policy issues, examples, and evidence that are most pertinent to developing countries, but we will also learn something about tax systems in the U.S. and other industrialized nations. Topics addressed in this class include: how basic economic principles can be applied to help one think about the efficiency and equity consequences of tax policies; how personal income taxes, corporate income taxes, and value-added taxes are designed and administered and how they influence the economy; ideas for fundamental reforms of these taxes; theory and evidence in the debate over progressive taxes versus “flat” taxes; how various elements of tax design affect incentives to save and invest; how market failures and administrative problems may influence the optimality of different tax policies; the implications of global capital flows and corporate tax avoidance for the design of tax policy; tax holidays and other special tax incentives for investment; empirical evidence on the influence of taxes on economic growth, foreign direct investment, labor supply, and tax evasion; tax policy towards natural resources such as minerals and oil; case studies of efforts to reform tax administration and reduce tax evasion and corruption; taxes on land and property; taxes on imports and exports; presumptive taxation; and the informal economy and its implications for tax policy.

**Class Format:** seminar

**Requirements/Evaluation:** midterm exam, 4 problem sets, two 8-page essays

**Prerequisites:** one public economics course or microeconomics course (ECON 504 or ECON 110), and one empirical methods course (POEC 253 or ECON 255, 502, or 503); students who have previously taken ECON 351 will not be enrolled

**Enrollment Limit:** 19

**Enrollment Preferences:** CDE students, but undergraduates with the prerequisites are welcome

**Expected Class Size:** 15-19

**Grading:** yes pass/fail option, yes fifth course option

**Distributions:** (D2) (QFR)

This course is cross-listed and the prefixes carry the following divisional credit:

ECON 389 (D2) ECON 514 (D2)

**Attributes:** POEC Comparative POEC/Public Policy Courses  POEC International Political Economy Courses

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**Spring 2020**

**SEM Section:** 01  TR 9:55 am - 11:10 am  William M. Gentry

**ECON 453 (S) Research in Labor Economics and Policy** (QFR)
The labor market plays a crucial role in people's lives worldwide. In industrialized countries, most households contain at least one wage earner, and income from working represents the largest component of total income. Thus analyses of the labor market are fundamentally relevant to both public policy and private decision-making. This seminar will explore the structure and functioning of the labor market using theoretical and empirical tools. Topics to be covered include labor supply and demand, minimum wages, labor market effects of social insurance and welfare programs, the collective bargaining relationship, discrimination, human capital, immigration, wage distribution, and unemployment. As labor economics is an intensely empirical subfield, students will be expected to analyze data as well as study the empirical work of others.

Class Format: seminar

Requirements/Evaluation: a series of short papers and empirical exercises, constructive contributions to class discussion, class presentations, and a 15- to 20-page original empirical research paper (written in stages)

Prerequisites: ECON 251 and ECON 255 or POEC 253

Enrollment Limit: 19

Enrollment Preferences: senior Economics majors

Expected Class Size: 19

Grading: no pass/fail option, no fifth course option

Distributions: (D2) (QFR)

Attributes: POEC Comparative POEC/Public Policy Courses

Spring 2020

SEM Section: 01  TF 1:10 pm - 2:25 pm  Owen Thompson

ECON 459 (S) Economics of Institutions (QFR)

Why are some countries so rich and others so poor? Typical answers to this question have emphasized proximate causes like factor accumulation (i.e., growth in a nation's physical and human capital endowments), technological progress, and demographic change. The institutional approach to this question, however, emphasizes the role of sociopolitical and cultural factors, broadly defined, as a fundamental determinant of its economic prosperity. The central idea is that the added-value of economic activities to society at large is primarily conditioned by the social arrangements within which these activities occur. Specifically, these social arrangements invariably generate a structure of private incentives, which can either promote behavior that is conducive to economic development or lead to the pursuit of private gain at the expense of the common good. As such, the key to economic development in this view is the establishment of a suitable set of institutions and structures of governance in society. This course will survey the rapidly expanding literature on the topic of institutions and economic development, with an emphasis on the latest empirical evidence that has come to bear in the context of both historical and contemporary societies. The purpose of the course will be to expose students to the core ideas and empirical tools employed at the frontier of research in this area of inquiry. The readings will primarily comprise published journal articles and unpublished working papers, and students should expect to apply concepts from across all the core courses in economics.

Class Format: seminar

Requirements/Evaluation: extensive class participation, two 5-page review papers, two class presentations, and one 15- to 20-page empirical research paper (written in stages)

Prerequisites: ECON 251, ECON 252, and either ECON 255 or STAT 346

Enrollment Limit: 19

Enrollment Preferences: senior Economics majors

Expected Class Size: 19

Grading: no pass/fail option, no fifth course option

Distributions: (D2) (QFR)

Spring 2020

SEM Section: 01  TF 2:35 pm - 3:50 pm  Quamrul H. Ashraf

ECON 471 (S) Topics in Advanced Econometrics (QFR)
The course uses both a practical and conceptual/theory based approach, with emphasis on methods of structural identification of dynamics in VARs and cointegration analysis, both in conventional time series and panel time series which contain spatial dimensions. The course will also investigate methods of computer simulation related to these techniques. The course is well suited for students considering empirically oriented honors theses in fields that employ these techniques, such as macro, finance, growth, trade and development, as well as fields outside of economics that use time series data. It is also well suited for students majoring in economics, statistics, computer sciences or mathematics who wish to expand their econometrics training and understanding to a more advanced level.

Class Format: seminar

Requirements/Evaluation: periodic homework assignments, term paper

Prerequisites: ECON 371

Enrollment Limit: 10

Enrollment Preferences: students with strong quantitative backgrounds, and to students intending to write an honors thesis

Expected Class Size: 10

Grading: yes pass/fail option, no fifth course option

Distributions: (D2) (QFR)

Spring 2020

SEM Section: 01 TF 2:35 pm - 3:50 pm Peter L. Pedroni

ECON 472 (F) Macroeconomic Instability and Financial Markets (QFR)

This advanced course in macroeconomics and financial theory attempts to explain the role and the importance of the financial system in the global economy. The course will provide an understanding of why there is financial intermediation, how financial markets differ from other markets, and the equilibrium consequences of financial activities. Rather than separating off the financial world from the rest of the economy, we will study financial equilibrium as a critical element of economic equilibrium. An important topic in the course will be studying how financial market imperfections amplify and propagate shocks to the aggregate economy. The course may cover the following topics: the determination of asset prices in general equilibrium; consequences of limited asset markets for economic efficiency; theoretical foundations of financial contracts and justifications for the existence of financial intermediaries; the roles of financial frictions in magnifying aggregate fluctuations and creating persistence and instability; the role of leverage and financial innovation in fueling financial crises.

Class Format: seminar

Requirements/Evaluation: evaluation will be based on problem sets, exams, and potentially student presentations

Prerequisites: ECON 251 and ECON 252

Enrollment Limit: 19

Enrollment Preferences: Economics majors

Expected Class Size: 15

Grading: no pass/fail option, no fifth course option

Distributions: (D2) (QFR)

Fall 2019

SEM Section: 01 MWF 8:30 am - 9:45 am Greg Phelan

ECON 514 (S) Tax Policy in Global Perspective (QFR)

Cross-listings: ECON 389 ECON 514

Primary Cross-listing

Taxes are half of what government does. So if you are interested in what government policy can do to promote efficiency, equity, and economic development, you should be interested in tax policy. Governments must raise tax revenue to finance critical public goods, address other market failures and distributional issues, and to avoid problems with debt and inflation. Taxes typically take up anywhere from ten to fifty percent of a country’s income, they profoundly affect the incentives to undertake all varieties of economic activity, and the government expenditures that they finance have potentially large consequences for human welfare. So the stakes involved in improving tax policy are quite large. This class provides an in-depth
exploration of tax policy, from a global and comparative perspective. Because most students in this class will be CDE fellows, we will emphasize tax policy issues, examples, and evidence that are most pertinent to developing countries, but we will also learn something about tax systems in the U.S. and other industrialized nations. Topics addressed in this class include: how basic economic principles can be applied to help one think about the efficiency and equity consequences of tax policies; how personal income taxes, corporate income taxes, and value-added taxes are designed and administered and how they influence the economy; ideas for fundamental reforms of these taxes; theory and evidence in the debate over progressive taxes versus "flat" taxes; how various elements of tax design affect incentives to save and invest; how market failures and administrative problems may influence the optimality of different tax policies; the implications of global capital flows and corporate tax avoidance for the design of tax policy; tax holidays and other special tax incentives for investment; empirical evidence on the influence of taxes on economic growth, foreign direct investment, labor supply, and tax evasion; tax policy towards natural resources such as minerals and oil; case studies of efforts to reform tax administration and reduce tax evasion and corruption; taxes on land and property; taxes on imports and exports; presumptive taxation; and the informal economy and its implications for tax policy.

Class Format: seminar

Requirements/Evaluation: midterm exam, 4 problem sets, two 8-page essays

Prerequisites: one public economics course or microeconomics course (ECON 504 or ECON 110), and one empirical methods course (POEC 253 or ECON 255, 502, or 503); students who have previously taken ECON 351 will not be enrolled

Enrollment Limit: 19

Enrollment Preferences: CDE students, but undergraduates with the prerequisites are welcome

Expected Class Size: 15-19

Grading: yes pass/fail option, yes fifth course option

Distributions: (D2) (QFR)

This course is cross-listed and the prefixes carry the following divisional credit:

ECON 389 (D2) ECON 514 (D2)

Attributes: POEC Comparative POEC/Public Policy Courses POEC International Political Economy Courses

Spring 2020

SEM Section: 01 TR 9:55 am - 11:10 am William M. Gentry

ECON 523 (S) Program Evaluation for International Development (QFR)

Cross-listings: ECON 379 ECON 523

Primary Cross-listing

Development organizations face strict competition for scarce resources. Both public and private organizations are under increasing pressure to use rigorous program evaluation in order to justify funding for their programs and to design more effective programs. This course is an introduction to evaluation methodology and the tools available to development practitioners, drawing on examples from developing countries. It will cover a wide range of evaluation techniques and discuss the advantages and disadvantages of each. The course is a mix of applied econometrics and practical applications covering implementation, analysis, and interpretation. You will learn to be a critical reader of evaluations, and to develop your own plan to evaluate an existing program of your choice.

Class Format: seminar

Requirements/Evaluation: problem sets, midterm exam and one 7- to 10-page essay

Prerequisites: one public economics course or microeconomics course (ECON 504 or ECON 110), and one empirical methods course (POEC 253 or ECON 255, 502, or 503)

Enrollment Limit: 20

Enrollment Preferences: CDE Students, but undergraduates with the prerequisites are welcome

Expected Class Size: 20

Grading: no pass/fail option, yes fifth course option

Distributions: (D2) (QFR)

This course is cross-listed and the prefixes carry the following divisional credit:

ECON 379 (D2) ECON 523 (D2)
Evidence from across the developing world suggests that the "binding constraints" to economic growth can be remarkably heterogeneous—i.e., the growth potential of stagnating or underperforming economies may be unlocked in a large variety of ways. For instance, pre-reform China had been constrained by poor supply incentives in agriculture, whereas Brazil has been held back by an inadequate supply of credit, South Africa by poor employment incentives in manufacturing, El Salvador by insufficient production incentives in tradables, Zimbabwe by bad governance, and so forth.

How can developing-country policymakers determine country-specific constraints like these, thus enabling them to pragmatically pursue a selected set of growth-promoting policies rather than attempting to implement a "laundry list" of reforms that are naively based on "best practice" rules-of-thumb? This course will serve as a primer on "growth diagnostics," an empirically-driven analytical framework for identifying the most binding constraints to economic growth in a given country at a point in time, thereby allowing policymakers to develop well-targeted reforms for relaxing these constraints while being cognizant of the nation's prevailing economic, political, and social context. The course will first build on the basic theories and empirics of economic growth to elucidate the diagnostic framework and will then employ a wide range of country-specific case studies to demonstrate how the framework can be operationalized for policy making. Throughout the semester, students will be required to work in groups, each representing a given developing or emerging-market economy, in order to build a growth diagnostic for their group's assigned country by the end of the course.

Class Format: seminar

Requirements/Evaluation: extensive class participation, two short (5-page) papers, two 15-page team papers comprising a country growth diagnostic, and a team presentation on the diagnostic

Prerequisites: for undergraduates ECON 251, ECON 252, and either ECON 255 or STAT 346

Enrollment Limit: 19

Enrollment Preferences: CDE fellows and senior Economics majors

Expected Class Size: 19

Grading: no pass/fail option, no fifth course option

Distributions: (D2) (QFR)

This course is cross-listed and the prefixes carry the following divisional credit:

ECON 545 (D2) ECON 345 (D2)

Quantitative/Formal Reasoning Notes: The course material will be draw heavily on mathematical and statistical models of economic growth and macroeconomic development, and students will be required to routinely develop mathematical models and/or conduct econometric analysis in their assignments.
**Requirements/Evaluation:** evaluation will be based on weekly assignments, two hour tests, and a final project culminating in an oral presentation to the class and a 10-page paper; all of these will be substantially quantitative

**Prerequisites:** high school physics, high school chemistry, and mathematics at the level of MATH 130

**Enrollment Limit:** 20

**Expected Class Size:** 20

**Grading:** yes pass/fail option, yes fifth course option

**Distributions:** (D3) (QFR)

**This course is cross-listed and the prefixes carry the following divisional credit:**

ENVI 108 (D3) PHYS 108 (D3)

**Attributes:** ENVI Natural World Electives

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**Fall 2019**

LEC Section: 01  MR 2:35 pm - 3:50 pm  Kevin M. Jones

**ENVI 203 (F) Ecology (QFR)**

**Cross-listings:** BIOL 203  ENVI 203

**Secondary Cross-listing**

This course combines lectures with field and indoor laboratory exercises to explore factors that determine the distribution and abundance of plants and animals in natural systems. The course begins with an overall view of global patterns and then builds from the population to the ecosystem level. An emphasis is given to basic ecological principles and relates them to current environmental issues. Selected topics include population dynamics (competition, predation, mutualism); community interactions (succession, food chains and diversity) and ecosystem function (biogeochemical cycles, energy flow).

**Class Format:** lecture/laboratory, six hours per week

**Requirements/Evaluation:** evaluation will be based on problem sets, lab reports, hour exams, and a final exam

**Prerequisites:** BIOL 101 and 102, or ENVI 101 or 102, or permission of instructor

**Enrollment Limit:** none

**Expected Class Size:** 35

**Grading:** no pass/fail option, no fifth course option

**Unit Notes:** satisfies the distribution requirement for the Biology major

**Distributions:** (D3) (QFR)

**This course is cross-listed and the prefixes carry the following divisional credit:**

BIOL 203 (D3) ENVI 203 (D3)

**Attributes:** ENVI Natural World Electives  EVST Environmental Science  EVST Living Systems Courses

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**Fall 2019**

LEC Section: 01  MWF 10:00 am - 10:50 am  Ron D. Bassar

LAB Section: 02  T 1:00 pm - 4:00 pm  Ron D. Bassar

LAB Section: 03  W 1:00 pm - 4:00 pm  Ron D. Bassar

**ENVI 213 (S) Introduction to Environmental and Natural Resource Economics (QFR)**

**Cross-listings:** ENVI 213  ECON 213

**Secondary Cross-listing**

We'll use economics to learn why we harm the environment and overuse natural resources, and what we can do about it. We'll talk about whether and how we can put a dollar value on nature and ecosystem services. We'll study cost benefit analysis, pollution in general, climate change, natural resources (like fisheries, forests, and fossil fuels), and energy. We will take an economic approach to global sustainability, and study the relationship
between the environment and economic growth and trade.

Class Format: lecture

Requirements/Evaluation: problem sets, short essays, paper(s); exam(s) are possible

Prerequisites: ECON 110

Enrollment Limit: 30

Enrollment Preferences: first-year and sophomore students

Expected Class Size: 30

Grading: yes pass/fail option, yes fifth course option

Unit Notes: this course will count toward both the Environmental Studies major and concentration

Distributions: (D2) (QFR)

This course is cross-listed and the prefixes carry the following divisional credit:
ENVI 213 (D2) ECON 213 (D2)

Attributes: ENVI Environmental Policy EVST Social Science/Policy POEC Comparative POEC/Public Policy Courses

Spring 2020

LEC Section: 01 MWF 8:30 am - 9:45 am Sarah A. Jacobson

ENVI 312  (F) Communities and Ecosystems (QFR)

Cross-listings: ENVI 312 BIOL 302

Secondary Cross-listing

An advanced ecology course that examines how species interact with each other and their environment and how communities are assembled. This course emphasizes phenomena that emerge in complex ecological systems, building on the fundamental concepts of population biology, community ecology, and ecosystem science. This foundation will be used to understand specific topics relevant to conservation including invasibility and the functional significance of diversity for ecosystem stability and processes. Lectures and labs will explore how to characterize the emergent properties of communities and ecosystems, and how theoretical, comparative, and experimental approaches are used to understand their structure and function. The lab component of this course will emphasize hypothesis-oriented field experiments as well as "big-data" analyses using existing data sets. The laboratory component of the course will culminate with a self-designed independent or group project.

Class Format: lecture/laboratory, six hours a week

Requirements/Evaluation: evaluation will be based on lab reports, a midterm exam, a term project presentation, and a final project paper

Prerequisites: BIOL/ENVI 203 or 220

Enrollment Limit: 28

Enrollment Preferences: Biology majors and Environmental Studies majors and concentrators

Expected Class Size: 24

Grading: yes pass/fail option, yes fifth course option

Unit Notes: satisfies the distribution requirement for the Biology major

Distributions: (D3) (QFR)

This course is cross-listed and the prefixes carry the following divisional credit:
ENVI 312 (D3) BIOL 302 (D3)

Attributes: ENVI Natural World Electives EVST Living Systems Courses EXPE Experiential Education Courses

Fall 2019

LEC Section: 01 TR 9:55 am - 11:10 am Manuel A. Morales

LAB Section: 02 T 1:00 pm - 4:00 pm Manuel A. Morales

LAB Section: 03 W 1:00 pm - 4:00 pm Manuel A. Morales
Can people live safely along the coast? Recent events like SuperStorm Sandy and the Tohoku Tsunami have shown us how the ocean can rise up suddenly and wreak havoc on our lives and coastal infrastructure. Only educated geoscientists can evaluate the risks and define informed strategies to prevent future coastal catastrophes. Currently almost half the global population lives within 100 km of the coast, with a large percent of those living in densely populated cities (e.g., New York, New Orleans, Los Angeles, Shanghai, Hong Kong, Cape Town, Sydney, Mumbai). Despite the growing risks and challenges associated with climate change and rising sea levels, the coastal population continues to grow rapidly. To help ensure these growing populations can live safely along the coast requires a detailed understanding of the processes that shape the coastal zone. These processes act across a variety of scales, from deep-time geologic processes that dictate coastal shape and structure, to decadal-scale processes that determine shoreline position and evolution, to weekly and daily processes such as storms and tides. This course will provide an in-depth look at the forces—wind, waves, storms, and people—that shape the coastal zone, as well as the geologic formations—sandy beaches, rocky cliffs, barrier islands, deltas, and coral reefs—that are acted upon and resist these forces. Coastal dynamics are strongly affected by human interventions, such as seawalls, dredged channels, and sand dune removal, as well as by sea level rise and changes in storm frequency and magnitude associated with climate change. Finally, the course will provide students with a perspective on how the U.S. seeks to manage its coastal zone, focusing on sea level rise and coastal development. This class will include a quantitative lab that will use MATLAB software to model and evaluate various coastal processes. Students will gain a basic understanding of MATLAB functionality, and will be asked to independently apply what they have learned to various data sets provided by the instructor.

Class Format: lecture two times a week with a lab one time per week
Requirements/Evaluation: lab reports, tests, and an independent research project
Prerequisites: GEOS 104, GEOS 210, or permission of instructor
Enrollment Limit: none
Expected Class Size: 10
Grading: yes pass/fail option, yes fifth course option
Distributions: (D3) (QFR)
This course is cross-listed and the prefixes carry the following divisional credit:
MAST 404 (D3) ENVI 404 (D3) GEOS 404 (D3)
Attributes: ENVI Natural World Electives

Spring 2020
LEC Section: 01 MWF 8:30 am - 9:45 am Alex A. Apotsos

GEOS 203 (F) Field Methods and Structural Geology (WS) (QFR)
The structure of the Earth's crust is constantly changing and the rocks making up the crust must deform to accommodate these changes. Rock deformation occurs over many scales ranging from individual mineral grains to mountain belts. This course deals with the geometric description of structures and the large scale forces responsible for crustal deformation. The laboratories introduce students to best practices for geologic field work, the field identification of common minerals and rocks, geologic contacts, geologic maps and cross sections, folds, and faults. Students will develop skill for presenting field data in papers, figures, and oral presentations.
Class Format: lecture/discussion, three hours per week; laboratory, three hours per week
Requirements/Evaluation: short weekly writing assignments, two 10-page papers based on field trips, and a one-hour exam
Prerequisites: any 100-level Geosciences course or permission of instructor
Enrollment Limit: 16
Enrollment Preferences: Geosciences majors or students with a strong interest in geosciences
Expected Class Size: 12
Grading: no pass/fail option, no fifth course option
Materials/Lab Fee: $15 for field supplies
Distributions: (D3) (WS) (QFR)
**Writing Skills Notes:** There will be two 10-page papers, each based on four field trips. Students will submit short field descriptions and figures with captions after each field trip for evaluation by the instructor and peers. The shorter assignments will be incorporated in the field reports. Students will receive from the instructor timely comments on their writing skills, with suggestions for improvement.

**Attributes:** GEOS Group C Electives - Solid Earth

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**Fall 2019**

LEC Section: 01  MW 11:00 am - 12:15 pm  Paul M. Karabinos
LAB Section: 02  M 1:00 pm - 4:00 pm  Paul M. Karabinos

**GEOS 234 (S) Introduction to Materials Science (QFR)**

**Cross-listings:** PHYS 234  GEOS 234

**Secondary Cross-listing**

Materials Science is the study of how the microscopic structure of materials—whether steel, carbon fiber, glass, wood, plastic, or mayonnaise—determines their macroscopic mechanical, thermal, electric, and other properties. Topics of this course include classifying materials; material structure; thermodynamics and phase transformations; material properties and testing; how solids bend, flow, and ultimately break; and how to choose the right material for design applications. Materials Science is a highly interdisciplinary field and as a result the course prerequisites are broad but also flexible. Interested students who are unsure about their preparation are strongly encouraged to contact the instructor.

**Class Format:** lecture (3 hours per week), plus three to four small-group laboratory sessions throughout the semester (to be scheduled with instructor)

**Requirements/Evaluation:** based on weekly problem sets, class participation, and midterm and final exams, all of which have a substantial quantitative component

**Prerequisites:** high school physics and chemistry, preferably at the AP level, and MATH 140 or AP Calculus (BC), and one 200-level PHYS, CHEM, or GEOS course; or permission of instructor

**Enrollment Limit:** 20

**Enrollment Preferences:** based on students' scientific background and seniority

**Expected Class Size:** 10

**Grading:** yes pass/fail option,  yes fifth course option

**Distributions:** (D3) (QFR)

**This course is cross-listed and the prefixes carry the following divisional credit:**

PHYS 234 (D3)  GEOS 234 (D3)

**Attributes:** MTSC Courses

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**Spring 2020**

LEC Section: 01  MR 1:10 pm - 2:25 pm  Katharine E. Jensen

**GEOS 314 (S) Analytical Historical Geology (QFR)**

In this course you will learn to collect, interpret, and analyze deep time paleontological, stratigraphic, and sedimentological records through readings, labs, and projects all coordinated around a week long spring break trip to explore the House Range of Utah. The Cambrian and Ordovician successions of Utah's West Desert offers an outstanding record of one of the most important periods in Earth history, tracking the rise of animal ecosystems and major increases in diversity. The first 6 weeks of class will be spent learning the fundamentals of quantitative methods in paleontology and stratigraphy. Labs will focus on skill building including learning basic coding in R, and learning how to interpret paleontological, sedimentological, and stratigraphic data. We will also read widely on the field locality and on the Cambrian and Ordovician Periods. During the field trip, we will explore the House Range. Students will learn skills including geological mapping, measuring stratigraphic section, finding and identifying fossils, and correlating rock units across basins. We will collect samples and data on the field trip and bring them back to Williams. The second 6 weeks of the course will be spent processing and analyzing the samples and data collected during the field trip, culminating in final projects to be done in small groups. Students will determine what data we will collect in the field. Examples might be trilobite taxonomy and phylogenetic analyses, quantitative biostratigraphic correlation using conodont fossils, reconstructing paleoenvironment based on sedimentological analyses of thin sections, or building a sequence stratigraphic framework for a subset of the field locality.
GEOS 404  (S) Coastal Processes and Geomorphology  (QFR)

Cross-listings: MAST 404  ENVI 404  GEOS 404

Primary Cross-listing

Can people live safely along the coast? Recent events like SuperStorm Sandy and the Tohoku Tsunami have shown us how the ocean can rise up suddenly and wreak havoc on our lives and coastal infrastructure. Only educated geoscientists can evaluate the risks and define informed strategies to prevent future coastal catastrophes. Currently almost half the global population lives within 100 km of the coast, with a large percent of those living in densely populated cities (e.g., New York, New Orleans, Los Angeles, Shanghai, Hong Kong, Cape Town, Sydney, Mumbai). Despite the growing risks and challenges associated with climate change and rising sea levels, the coastal population continues to grow rapidly. To help ensure these growing populations can live safely along the coast requires a detailed understanding of the processes that shape the coastal zone. These processes act across a variety of scales, from deep-time geologic processes that dictate coastal shape and structure, to decadal-scale processes that determine shoreline position and evolution, to weekly and daily processes such as storms and tides. This course will provide an in-depth look at the forces--wind, waves, storms, and people--that shape the coastal zone, as well as the geologic formations--sandy beaches, rocky cliffs, barrier islands, deltas, and coral reefs--that are acted upon and resist these forces. Coastal dynamics are strongly affected by human interventions, such as seawalls, dredged channels, and sand dune removal, as well as by sea level rise and changes in storm frequency and magnitude associated with climate change.

Finally, the course will provide students with a perspective on how the U.S. seeks to manage its coastal zone, focusing on sea level rise and coastal development. This class will include a quantitative lab that will use MATLAB software to model and evaluate various coastal processes. Students will gain a basic understanding of MATLAB functionality, and will be asked to independently apply what they have learned to various data sets provided by the instructor.

Class Format: lecture two times a week with a lab one time per week
Requirements/Evaluation: lab reports, tests, and an independent research project
Prerequisites: GEOS 104, GEOS 210, or permission of instructor
Enrollment Limit: none
Expected Class Size: 10
Grading: yes pass/fail option, yes fifth course option
Distributions: (D3) (QFR)

This course is cross-listed and the prefixes carry the following divisional credit:

MAST 404  (D3) ENVI 404  (D3) GEOS 404  (D3)

Attributes: ENVI Natural World Electives

Spring 2020
MATH 113 (S) The Beauty of Numbers (QFR)
Have you ever wondered what keeps your credit card information safe every time you buy something online? Number theory! Number Theory is one of the oldest branches of mathematics. In this course, we will discover the beauty and usefulness of numbers, from ancient Greece to modern cryptography. We will look for patterns, make conjectures, and learn how to prove these conjectures. Starting with nothing more than basic high school algebra, we will develop the logic and critical thinking skills required to realize and prove mathematical results. Topics to be covered include the meaning and content of proof, prime numbers, divisibility, rationality, modular arithmetic, Fermat's Last Theorem, the Golden ratio, Fibonacci numbers, coding theory, and unique factorization.

Class Format: lecture
Requirements/Evaluation: evaluation will be based primarily on projects, homework assignments, and exams
Prerequisites: MATH 102 (or demonstrated proficiency on a diagnostic test) or permission of instructor
Enrollment Limit: 25
Expected Class Size: 25
Grading: yes pass/fail option, yes fifth course option
Distributions: (D3) (QFR)

Spring 2020
LEC Section: 01 TR 9:55 am - 11:10 am Allison Pacelli

MATH 130 (F)(S) Calculus I (QFR)
Calculus permits the computation of velocities and other instantaneous rates of change by a limiting process called differentiation. The same process also solves "max-min" problems: how to maximize profit or minimize pollution. A second limiting process, called integration, permits the computation of areas and accumulations of income or medicines. The Fundamental Theorem of Calculus provides a useful and surprising link between the two processes. Subtopics include trigonometry, exponential growth, and logarithms.

Class Format: lecture
Requirements/Evaluation: based primarily on exams, homework and quizzes
Prerequisites: MATH 102 (or demonstrated proficiency on a diagnostic test); this is an introductory course for students who have not seen calculus before
Enrollment Limit: 50
Enrollment Preferences: Professor's discretion
Expected Class Size: 30
Grading: yes pass/fail option, yes fifth course option
Unit Notes: students who have previously taken a calculus course may not enroll in MATH 130 without the permission of instructor
Distributions: (D3) (QFR)

Fall 2019
LEC Section: 01 MWF 11:00 am - 11:50 am Allison Pacelli
LEC Section: 02 MWF 12:00 pm - 12:50 pm Allison Pacelli

Spring 2020
LEC Section: 01 MWF 9:00 am - 9:50 am Eva Goedhart

MATH 140 (F)(S) Calculus II (QFR)
Mastery of calculus requires understanding how integration computes areas and business profit and acquiring a stock of techniques. Further methods
solve equations involving derivatives ("differential equations") for population growth or pollution levels. Exponential and logarithmic functions and trigonometric and inverse functions play an important role. This course is the right starting point for students who have seen derivatives, but not necessarily integrals, before.

**Class Format:** lecture

**Requirements/Evaluation:** based primarily on homework, quizzes, and/or exams

**Prerequisites:** MATH 130 or equivalent; students who have received the equivalent of advanced placement of AB 4, BC 3 or higher may not enroll in MATH 140 without the permission of instructor

**Enrollment Limit:** 50

**Expected Class Size:** 30

**Grading:** yes pass/fail option, yes fifth course option

**Unit Notes:** students who have higher advanced placement must enroll in MATH 150 or above

**Distributions:** (D3) (QFR)

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MATH 150  (F)(S)  Multivariable Calculus  (QFR)

Applications of calculus in mathematics, science, economics, psychology, the social sciences, involve several variables. This course extends calculus to several variables: vectors, partial derivatives, multiple integrals. There is also a unit on infinite series, sometimes with applications to differential equations.

**Class Format:** lecture

**Requirements/Evaluation:** based primarily on homework, quizzes, and/or exams

**Prerequisites:** MATH 140 or equivalent, such as satisfactory performance on an Advanced Placement Examination

**Enrollment Limit:** 50

**Expected Class Size:** 50

**Grading:** yes pass/fail option, yes fifth course option

**Unit Notes:** students with the equivalent of advanced placement of AB 4 or above should enroll in MATH 150, students with a BC 3 or higher should enroll in Math 151 when it is being offered, and Math 150 otherwise.

**Distributions:** (D3) (QFR)

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MATH 151  (F)  Multivariable Calculus  (QFR)

Applications of calculus in mathematics, science, economics, psychology, the social sciences, involve several variables. This course extends calculus to several variables: vectors, partial derivatives and multiple integrals. The goal of the course is Stokes Theorem, a deep and profound generalization of the Fundamental Theorem of Calculus. The difference between this course and MATH 150 is that MATH 150 covers infinite series instead of Stokes Theorem. Students with the equivalent of BC 3 or higher should enroll in MATH 151, as well as students who have taken the equivalent of an integral
calculus and who have already been exposed to infinite series. For further clarification as to whether MATH 150 or MATH 151 is appropriate, please consult a member of the math/stat department.

Class Format: lecture

Requirements/Evaluation: based primarily on homework, quizzes, and/or exams

Prerequisites: AP BC 3 or higher or integral calculus with infinite series

Enrollment Limit: 50

Expected Class Size: 50

Grading: yes pass/fail option, yes fifth course option

Unit Notes: MATH 151 satisfies any MATH 150 prerequisite; credit will not be given for both MATH 150 and MATH 151

Distributions: (D3) (QFR)

Fall 2019
LEC Section: 01 MWF 9:00 am - 9:50 am Colin C. Adams
LEC Section: 02 MWF 10:00 am - 10:50 am Colin C. Adams
LEC Section: 03 MWF 11:00 am - 11:50 am Colin C. Adams

MATH 200 (F)(S) Discrete Mathematics (QFR)

Course Description: In contrast to calculus, which is the study of continuous processes, this course examines the structure and properties of finite sets. Topics to be covered include mathematical logic, elementary number theory, mathematical induction, set theory, functions, relations, elementary combinatorics and probability, graphs and trees, and algorithms. Emphasis will be given on the methods and styles of mathematical proofs, in order to prepare the students for more advanced math courses.

Class Format: lecture/discussion

Requirements/Evaluation: evaluation will be based primarily on homework and exams

Prerequisites: MATH 140 or MATH 130 with CSCI 134 or 135; or one year of high school calculus with permission of instructor; students who have taken a 300-level math course should obtain permission of the instructor before enrolling

Enrollment Limit: 40

Expected Class Size: 25

Grading: yes pass/fail option, yes fifth course option

Distributions: (D3) (QFR)

Fall 2019
LEC Section: 01 TR 9:55 am - 11:10 am Josh Carlson
LEC Section: 02 TR 11:20 am - 12:35 pm Josh Carlson

Spring 2020
LEC Section: 01 MWF 10:00 am - 10:50 am Lori A. Pedersen
LEC Section: 02 MWF 11:00 am - 11:50 am Lori A. Pedersen

MATH 210 (S) Mathematical Methods for Scientists (QFR)

Cross-listings: MATH 210 PHYS 210

Secondary Cross-listing

This course covers a variety of mathematical methods used in the sciences, focusing particularly on the solution of ordinary and partial differential equations. In addition to calling attention to certain special equations that arise frequently in the study of waves and diffusion, we develop general techniques such as looking for series solutions and, in the case of nonlinear equations, using phase portraits and linearizing around fixed points. We study some simple numerical techniques for solving differential equations. A series of optional sessions in Mathematica will be offered for students who are not already familiar with this computational tool.

Class Format: lecture, three hours per week
**Requirements/Evaluation:** evaluation will be based on several exams and on weekly problem sets, all of which have a substantial quantitative component

**Prerequisites:** MATH 150 or 151 and familiarity with Newtonian mechanics at the level of PHYS 131

**Enrollment Limit:** 50

**Expected Class Size:** 30

**Grading:** yes pass/fail option, yes fifth course option

**Distributions:** (D3) (QFR)

This course is cross-listed and the prefixes carry the following divisional credit:

MATH 210 (D3) PHYS 210 (D3)

Spring 2020

LEC Section: 01 TR 9:55 am - 11:10 am Daniel P. Aalberts, David R. Tucker-Smith

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MATH 250 (F(S)) Linear Algebra (QFR)

Many social, political, economic, biological, and physical phenomena can be described, at least approximately, by linear relations. In the study of systems of linear equations one may ask: When does a solution exist? When is it unique? How does one find it? How can one interpret it geometrically? This course develops the theoretical structure underlying answers to these and other questions and includes the study of matrices, vector spaces, linear independence and bases, linear transformations, determinants and inner products. Course work is balanced between theoretical and computational, with attention to improving mathematical style and sophistication.

**Class Format:** lecture

**Requirements/Evaluation:** evaluation will be based primarily on homework and exams

**Prerequisites:** MATH 150/151 or MATH 200

**Enrollment Limit:** 45

**Expected Class Size:** 35

**Grading:** yes pass/fail option, yes fifth course option

**Distributions:** (D3) (QFR)

**Attributes:** COGS Related Courses

Fall 2019

LEC Section: 01 TR 9:55 am - 11:10 am Eva Goedhart

LEC Section: 02 TR 11:20 am - 12:35 pm Eva Goedhart

Spring 2020

LEC Section: 01 TR 9:55 am - 11:10 am Haydee M. A. Lindo

LEC Section: 02 TR 11:20 am - 12:35 pm Haydee M. A. Lindo

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MATH 309 (S) Differential Equations (QFR)

Ordinary differential equations (ODE) frequently arise as models of phenomena in the natural and social sciences. This course presents core ideas of ODE from an applied standpoint. Topics covered early in the course include numerical solutions, separation of variables, integrating factors, constant coefficient linear equations, and power series solutions. Later, we focus on nonlinear ODE, for which it is usually impossible to find analytical solutions. Tools from dynamical systems allows us to obtain some information about the behavior of the ODE without explicitly knowing the solution.

**Class Format:** lecture, discussion, interactive activities

**Requirements/Evaluation:** quizzes/exams, problem sets, activities

**Prerequisites:** MATH 150/151 and MATH 250

**Enrollment Limit:** 30

**Enrollment Preferences:** Professor's discretion
Expected Class Size: 30
Grading: no pass/fail option, yes fifth course option
Distributions: (D3) (QFR)

Spring 2020
LEC Section: 01    MR 2:35 pm - 3:50 pm    Julie C. Blackwood

MATH 314 (S) Cryptography (QFR)
An introduction to the techniques and practices used to keep secrets over non-secure lines of communication, including classical cryptosystems, the data encryption standard, the RSA algorithm, discrete logarithms, hash functions, and digital signatures. In addition to the specific material, there will also be an emphasis on strengthening mathematical problem solving skills, technical reading, and mathematical communication.

Class Format: lecture
Requirements/Evaluation: exams, homework, and quizzes
Prerequisites: MATH 250
Enrollment Limit: 30
Enrollment Preferences: graduating seniors and Math majors
Expected Class Size: 30
Grading: yes pass/fail option, yes fifth course option
Distributions: (D3) (QFR)
Quantative/Formal Reasoning Notes: The course will contain mathematical proofs.

Spring 2020
LEC Section: 01    MWF 10:00 am - 10:50 am    Eva Goedhart

MATH 317 (F) Introduction to Operations Research (QFR)
In the first N math classes of your career, you can be misled as to what the world is truly like. How? You're given exact problems and told to find exact solutions. The real world is sadly far more complicated. Frequently we cannot exactly solve problems; moreover, the problems we try to solve are themselves merely approximations to the world! We are forced to develop techniques to approximate not just solutions, but even the statement of the problem. Additionally, we often need the solutions quickly. Operations Research, which was born as a discipline during the tumultuous events of World War II, deals with efficiently finding optimal solutions. In this course we build analytic and programming techniques to efficiently tackle many problems. We will review many algorithms from earlier in your mathematical or CS career, with special attention now given to analyzing their run-time and seeing how they can be improved. The culmination of the course is a development of linear programming and an exploration of what it can do and what are its limitations. For those wishing to take this as a Stats course, the final project must have a substantial stats component approved by the instructor.
Prerequisites: Linear Algebra (MATH 250) and one other 200-level or higher CSCI, MATH or STATS course.
Class Format: lecture
Requirements/Evaluation: homework, exams, projects
Prerequisites: MATH 150, MATH 250 and one other 200-level or higher CSCI, MATH or STATS course
Enrollment Limit: 40
Enrollment Preferences: Computer Science, Mathematics and Statistics majors
Expected Class Size: 25
Grading: yes pass/fail option, yes fifth course option
Unit Notes: http://web.williams.edu/Mathematics/sjmiller/public_html/317/
Distributions: (D3) (QFR)

Fall 2019
LEC Section: 01    MWF 10:00 am - 10:50 am    Steven J. Miller
MATH 325 (F) Set Theory (QFR)
Set theory is the traditional foundational language for all of mathematics. We will be discussing the Zermelo-Fraenkel axioms, including the Axiom of Choice and the Continuum Hypothesis, basic independence results and, if time permits, incompleteness theorems. At one time, these issues tore at the foundations of mathematics. They are still vital for understanding the nature of mathematical truth.

Class Format: lecture
Requirements/Evaluation: exams and homework
Prerequisites: MATH 250
Enrollment Limit: 30
Expected Class Size: 15
Grading: yes pass/fail option, yes fifth course option
Materials/Lab Fee: textbook cost
Distributions: (D3) (QFR)

Fall 2019
LEC Section: 01 TR 9:55 am - 11:10 am Thomas A. Garrity

MATH 328 (S) Combinatorics (QFR)
Combinatorics is a branch of mathematics that focuses on enumerating, examining, and investigating the existence of discrete mathematical structures with certain properties. This course provides an introduction to the fundamental structures and techniques in combinatorics including enumerative methods, generating functions, partition theory, the principle of inclusion and exclusion, and partially ordered sets.

Class Format: interactive activities, lecture, discussion
Requirements/Evaluation: quizzes/exams, homework, activities
Prerequisites: MATH 200 and MATH 250
Enrollment Limit: 30
Enrollment Preferences: discretion of the instructor
Expected Class Size: 25
Grading: no pass/fail option, no fifth course option
Distributions: (D3) (QFR)

Spring 2020
LEC Section: 01 MWF 11:00 am - 12:15 pm Josh Carlson

MATH 338 (F) Intermediate Logic (QFR)
Cross-listings: MATH 338 PHIL 338
Secondary Cross-listing
In this course, we will begin with an in-depth study of the theory of first-order logic. We will first get clear on the formal semantics of first-order logic and various ways of thinking about formal proof: natural deduction systems, semantic tableaux, axiomatic systems and sequent calculi. Our main goal will be to prove things about this logical system rather than to use this system to think about ordinary language arguments. In this way the goal of the course is significantly different from that of Logic and Language (PHIL 203). Students who have take PHIL 203 will have a good background for this class, but students who are generally comfortable with formal systems need not have taken PHIL 203. We will prove soundness and completeness, compactness, the Lowenheim-Skolem theorems, undecidability and other important results about first-order logic. As we go through these results, we will think about the philosophical implications of first-order logic. From there, we will look at extensions of and/or alternatives to first-order logic. Possible additional topics would include: modal logic, the theory of counterfactuals, alternative representations of conditionals, the use of logic in the foundations of arithmetic and Godel's Incompleteness theorems. Student interest will be taken into consideration in deciding what additional topics to cover.
Class Format: Seminar
Requirements/Evaluation: problem sets and exams
Prerequisites: some class in which student has studied formal reasoning
Enrollment Limit: 20
Enrollment Preferences: Philosophy majors; juniors and seniors
Expected Class Size: 15
Grading: yes pass/fail option, yes fifth course option
Distributions: (D3) (QFR)
This course is cross-listed and the prefixes carry the following divisional credit:
MATH 338 (D3) PHIL 338 (D2)
Quantative/Formal Reasoning Notes: This is a class in Formal Logic. PHIL 203 satisfies the QFR requirement. If anything, this class will be significantly more formal.

Fall 2019
SEM Section: 01    MR 1:10 pm - 2:25 pm     Keith E. McPartland

MATH 341  (F)(S) Probability  (QFR)
Cross-listings: MATH 341 STAT 341
Primary Cross-listing
While probability began with a study of games, it has grown to become a discipline with numerous applications throughout mathematics and the sciences. Drawing on gaming examples for motivation, this course will present axiomatic and mathematical aspects of probability. Included will be discussions of random variables, expectation, independence, laws of large numbers, and the Central Limit Theorem. Many interesting and important applications will also be presented, potentially including some from coding theory, number theory and nuclear physics.
Class Format: lecture
Requirements/Evaluation: evaluation will be based primarily on homework, classwork, and exams
Prerequisites: MATH 250 or permission of the instructor
Enrollment Limit: 40
Expected Class Size: 20
Grading: yes pass/fail option, yes fifth course option
Distributions: (D3) (QFR)
This course is cross-listed and the prefixes carry the following divisional credit:
MATH 341 (D3) STAT 341 (D3)

Fall 2019
LEC Section: 01    MWF 11:00 am - 11:50 am     Steven J. Miller
Spring 2020
LEC Section: 01    TF 2:35 pm - 3:50 pm     Mihai  Stoiciu

MATH 350  (F)(S) Real Analysis  (QFR)
Real analysis is the theory behind calculus. It is based on a precise understanding of the real numbers, elementary topology, and limits. Topologically, nice sets are either closed (contain their limit points) or open (complement closed). You also need limits to define continuity, derivatives, integrals, and to understand sequences of functions.
Class Format: lecture/discussion
Requirements/Evaluation: evaluation will be based on homework, classwork, and exams
Prerequisites: MATH 150 or MATH 151 and MATH 250, or permission of instructor
MATH 351 (F) Applied Real Analysis (QFR)
Real analysis or the theory of calculus-derivatives, integrals, continuity, convergence--starts with a deeper understanding of real numbers and limits. Applications in the calculus of variations or “infinite-dimensional calculus” include geodesics, harmonic functions, minimal surfaces, Hamilton's action and Lagrange's equations, optimal economic strategies, non-Euclidean geometry, and general relativity.

Class Format: lecture
Requirements/Evaluation: evaluation will be based primarily on exams, homework and quizzes
Prerequisites: MATH 150 and MATH 250, or permission of instructor
Enrollment Limit: 50
Expected Class Size: 20
Grading: yes pass/fail option, yes fifth course option
Distributions: (D3) (QFR)
Quantitative/Formal Reasoning Notes: Core mathematics major course with daily problem sets.

Fall 2019
LEC Section: 01 MWF 11:00 am - 11:50 am Frank Morgan

MATH 355 (F)(S) Abstract Algebra (QFR)
Algebra gives us tools to solve equations. The integers, the rationals, and the real numbers have special properties which make algebra work according to the circumstances. In this course, we generalize algebraic processes and the sets upon which they operate in order to better understand, theoretically, when equations can and cannot be solved. We define and study abstract algebraic structures such as groups, rings, and fields, as well as the concepts of factor group, quotient ring, homomorphism, isomorphism, and various types of field extensions. This course introduces students to abstract rigorous mathematics.

Class Format: lecture
Requirements/Evaluation: evaluation will be based primarily on problem sets and exams
Prerequisites: MATH 250 or permission of instructor
Enrollment Limit: 30
Expected Class Size: 25
Grading: yes pass/fail option, yes fifth course option
Distributions: (D3) (QFR)

Fall 2019
LEC Section: 01 TR 11:20 am - 12:35 pm Thomas A. Garrity
LEC Section: 02 MWF 10:00 am - 10:50 am Thomas A. Garrity
MATH 361  (F)(S)  Theory of Computation  (QFR)

Cross-listings:  CSCI 361  MATH 361

Secondary Cross-listing

This course introduces a formal framework for investigating both the computability and complexity of problems. We study several models of computation including finite automata, regular languages, context-free grammars, and Turing machines. These models provide a mathematical basis for the study of computability theory—the examination of what problems can be solved and what problems cannot be solved—and the study of complexity theory—the examination of how efficiently problems can be solved. Topics include the halting problem and the P versus NP problem.

Class Format: lecture

Requirements/Evaluation: evaluation will be based on problem sets, a midterm examination, and a final examination

Prerequisites: CSCI 256 or both a 300-level MATH course and permission of instructor

Enrollment Limit: 30

Enrollment Preferences: current or expected Computer Science majors

Expected Class Size: 30

Grading: no pass/fail option, no fifth course option

Distributions: (D3)  (QFR)

This course is cross-listed and the prefixes carry the following divisional credit:

CSCI 361 (D3) MATH 361 (D3)

Attributes: COGS Interdepartmental Electives

Fall 2019
LEC Section: 01    MWF 11:00 am - 11:50 am     Aaron M. Williams

Spring 2020
LEC Section: 01    MWF 12:00 pm - 12:50 pm     Thomas P. Murtagh

MATH 404  (F)  Random Matrix Theory  (QFR)

Initiated by research in multivariate statistics and nuclear physics, the study of random matrices is nowadays an active and exciting area of mathematics, with numerous applications to theoretical physics, number theory, functional analysis, optimal control, and finance. Random Matrix Theory provides understanding of various properties (most notably, statistics of eigenvalues) of matrices with random coefficients. This course will provide an introduction to the basic theory of random matrices, starting with a quick review of Linear Algebra and Probability Theory. We will continue with the study of Wigner matrices and prove the celebrated Wigner's Semicircle Law, which brings together important ideas from analysis and combinatorics. After this, we will turn our attention to Gaussian ensembles and investigate the Gaussian Orthogonal Ensemble (GOE) and the Gaussian Unitary Ensemble (GUE). The last lectures of the course will be dedicated to random Schrödinger operators and their spectral properties (in particular, the phenomenon called Anderson localization). Applications of Random Matrix Theory to theoretical physics, number theory, statistics, and finance will be discussed throughout the semester.

Class Format: lecture

Requirements/Evaluation: homework assignments and exams

Prerequisites: experience with Real Analysis (MATH 350 or MATH 351) and with Probability (MATH 341 or STAT 201)

Enrollment Limit: 40

Enrollment Preferences: Mathematics and Statistics majors

Expected Class Size: 20

Grading: yes pass/fail option, yes fifth course option

Distributions: (D3)  (QFR)

Quantitative/Formal Reasoning Notes: This course expands ideas in probability and statistics from random variables (1x1 random matrices) to nxn random matrices. The students will learn to model complex physical phenomena using random matrices and study them using rigorous mathematical tools and concepts.
MATH 419 (S) Algebraic Number Theory (QFR)

We all know that integers can be factored into prime numbers and that this factorization is essentially unique. In more general settings, it often still makes sense to factor numbers into "primes," but the factorization is not necessarily unique! This surprising fact was the downfall of Lamé's attempted proof of Fermat's Last Theorem in 1847. Although a valid proof was not discovered until over 150 years later, this error gave rise to a new branch of mathematics: algebraic number theory. In this course, we will study factorization and other number-theoretic notions in more abstract algebraic settings, and we will see a beautiful interplay between groups, rings, and fields.

Class Format: lecture/seminar
Requirements/Evaluation: evaluation will be based primarily on homework assignments and exams
Prerequisites: MATH 355, or permission of instructor
Enrollment Limit: 25
Expected Class Size: 20
Grading: yes pass/fail option, yes fifth course option
Distributions: (D3) (QFR)

MATH 422 (F) Algebraic Topology (QFR)

Is a sphere really different from a torus? Can a sphere be continuously deformed to a point? Algebraic Topology concerns itself with the classification and study of topological spaces via algebraic methods. The key question is this: How do we really know when two spaces are different and in what senses can we claim they are the same? Our answer will use several algebraic tools such as groups and their normal subgroups. In this course we will develop several notions of "equality" starting with the existence of homeomorphisms between spaces. We will then explore several weakenings of this notion, such as homotopy equivalence, having isomorphic homology or fundamental groups, and having homeomorphic universal covers.

Class Format: lecture
Requirements/Evaluation: evaluation will be based primarily on homework and exams
Prerequisites: MATH 355 or permission of instructor
Enrollment Limit: 30
Enrollment Preferences: Math majors primarily, and Juniors and Seniors secondarily
Expected Class Size: 15
Grading: no pass/fail option, no fifth course option
Distributions: (D3) (QFR)

MATH 426 (F) Differential Topology (QFR)

Differential topology marries the rubber-like deformations of topology with the computational exactness of calculus. This sub field of mathematics asks and answers questions like "Can you take an integral on the surface of doughnut?" and includes far-reaching applications in relativity and robotics. This tutorial will provide an elementary and intuitive introduction to differential topology. We will begin with the definition of a manifold and end with a generalized understanding of Stokes Theorem.

Class Format: Tutorial
Requirements/Evaluation: weekly homework, weekly presentations, and final paper
Prerequisites: MATH 350 (students who have not taken MATH 250 may enroll only with permission of the instructor)
Enrollment Limit: 10
Enrollment Preferences: seniors, majors
Expected Class Size: 10
Grading: no pass/fail option, no fifth course option
Distributions: (D3) (QFR)
Quantative/Formal Reasoning Notes: There will be weekly math problem sets.

Fall 2019
TUT Section: T1 TBA Haydee M. A. Lindo

MATH 427 (S) Tiling Theory (QFR)
Since humans first used stones and bricks to tile the floors of their domiciles, tiling has been an area of interest. Practitioners include artists, engineers, designers, architects, crystallographers, scientists and mathematicians. This course will be an investigation into the mathematical theory of tiling. The course will focus on tilings of the plane, including topics such as the symmetry groups of tilings, the topology of tilings, the ergodic theory of tilings, the classification of tilings and the aperiodic Penrose tilings. We will also look at tilings in higher dimensions, including "knotted tilings".

Class Format: lecture
Requirements/Evaluation: problem assignments, exams and a presentation/paper
Prerequisites: MATH 250 Linear Algebra and MATH 355 Abstract Algebra
Enrollment Limit: 30
Enrollment Preferences: senior majors, seniors, juniors, sophomores, first-year students (this is a senior seminar, one of which is required for all senior majors, so they have first preference)
Expected Class Size: 20
Grading: no pass/fail option, yes fifth course option
Materials/Lab Fee: cost of book which will be under $50
Distributions: (D3) (QFR)

Spring 2020
LEC Section: 01 TR 9:55 am - 11:10 am Colin C. Adams

MATH 428 (S) Catching Robbers and Spreading Information (QFR)
Cops and robbers is a widely studied game played on graphs that has connections to searching algorithms on networks. The cop number of a graph is the smallest number of cops needed to guarantee that the cops can catch a robber in the graph. Similar combinatorial games such as "zero forcing" can be used to model the spread of information. The idea of "throttling" is to spread the information (or catch the robber) as efficiently as possible. This course will survey some of the main results about cops and robbers and the cop number. We will also explore recent research on throttling for cops and robbers, zero forcing, and other variants.

Class Format: interactive activities, lecture, discussion
Requirements/Evaluation: problem sets, investigation journal, final presentation
Prerequisites: MATH 200 and MATH 355
Enrollment Limit: 25
Enrollment Preferences: seniors
Expected Class Size: 20
Grading: yes pass/fail option, no fifth course option
Distributions: (D3) (QFR)
Quantative/Formal Reasoning Notes: The course will involve mathematical proofs.
MATH 482 (F) Homological Algebra (QFR)

Though a relatively young subfield of mathematics, Homological Algebra has earned its place by supplying powerful tools to solve questions in the much older fields of Commutative Algebra, Algebraic Geometry and Representation Theory. This class will introduce theorems and tools of Homological Algebra, grounding its results in applications to polynomial rings and their quotients. We will focus on some early groundbreaking results and learn some of Homological Algebra’s most-used constructions. Possible topics include tensor products, chain complexes, homology, Ext, Tor and Hilbert’s Syzygy Theorem.

Class Format: lecture

Requirements/Evaluation: evaluation will be based primarily on homework and exams

Prerequisites: MATH 355

Enrollment Limit: 20

Enrollment Preferences: junior and senior math majors

Expected Class Size: 12

Grading: no pass/fail option, yes fifth course option

Unit Notes: this course is not a senior seminar, so it does not fulfill the senior seminar requirement for the Math major

Distributions: (D3) (QFR)

MATH 484 (S) Galois Theory (QFR)

Some equations—such as $x^5 - 1 = 0$—are easy to solve. Others—such as $x^5 - x - 1 = 0$—are very hard, if not impossible (using standard mathematical operations). Galois discovered a deep connection between field theory and group theory that led to a criterion for checking whether or not a given polynomial can be easily solved. His discovery also led to many other breakthroughs, for example proving the impossibility of squaring the circle or trisecting a typical angle using compass and straightedge. From these not-so-humble beginnings, Galois theory has become a fundamental concept in modern mathematics, from topology to number theory. In this course we will develop the theory and explore its applications to other areas of math.

Class Format: lecture

Requirements/Evaluation: evaluation will be based primarily on written homeworks, oral presentations, and exams

Prerequisites: MATH 355

Enrollment Limit: 15

Enrollment Preferences: discretion of the instructor

Expected Class Size: 10

Grading: no pass/fail option, yes fifth course option

Unit Notes: this course is not a senior seminar, so it does not fulfill the senior seminar requirement for the Math major

Distributions: (D3) (QFR)

MATH 485 (F) Complex Analysis (QFR)

The calculus of complex-valued functions turns out to have unexpected simplicity and power. As an example of simplicity, every complex-differentiable function is automatically infinitely differentiable. As examples of power, the so-called residue calculus permits the computation of impossible integrals, and conformal mapping reduces physical problems on very general domains to problems on the round disc. The easiest proof of the Fundamental Theorem of Algebra, not to mention the first proof of the Prime Number Theorem, used complex analysis.
**PHIL 338 (F) Intermediate Logic** (QFR)

**Cross-listings:** MATH 338  PHIL 338

**Primary Cross-listing**

In this course, we will begin with an in-depth study of the theory of first-order logic. We will first get clear on the formal semantics of first-order logic and various ways of thinking about formal proof: natural deduction systems, semantic tableaux, axiomatic systems and sequent calculi. Our main goal will be to prove things about this logical system rather than to use this system to think about ordinary language arguments. In this way the goal of the course is significantly different from that of Logic and Language (PHIL 203). Students who take PHIL 203 will have a good background for this class, but students who are generally comfortable with formal systems need not have taken PHIL 203. We will prove soundness and completeness, compactness, the Lowenheim-Skolem theorems, undecidability and other important results about first-order logic. As we go through these results, we will think about the philosophical implications of first-order logic. From there, we will look at extensions of and/or alternatives to first-order logic. Possible additional topics would include: modal logic, the theory of counterfactuals, alternative representations of conditionals, the use of logic in the foundations of arithmetic and Godel's Incompleteness theorems. Student interest will be taken into consideration in deciding what additional topics to cover.

**Class Format:** Seminar

**Requirements/Evaluation:** problem sets and exams

**Prerequisites:** some class in which student has studied formal reasoning

**Enrollment Limit:** 20

**Enrollment Preferences:** Philosophy majors; juniors and seniors

**Expected Class Size:** 15

**Grading:** yes pass/fail option, yes fifth course option

**Distributions:** (D2) (QFR)

**This course is cross-listed and the prefixes carry the following divisional credit:**

MATH 338 (D3) PHIL 338 (D2)

**Quantitative/Formal Reasoning Notes:** This is a class in Formal Logic. PHIL 203 satisfies the QFR requirement. If anything, this class will be significantly more formal.

**Attributes:** Linguistics

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**PHYS 108 (F) Energy Science and Technology** (QFR)

**Cross-listings:** ENVI 108  PHYS 108

**Primary Cross-listing**
Energy use has skyrocketed in the United States and elsewhere in the world, causing significant economic and political shifts, as well as concerns for the environment. This course will address the physics and technology of energy generation, consumption, and conservation. It will cover a wide range of energy sources, including fossil fuels, hydropower, solar energy, wind energy, and nuclear energy. We will discuss energy use in transportation, manufacturing, building heating, and building lighting. Students will learn to compare the efficiencies and environmental impacts of various energy sources and uses.

**Class Format:** lecture twice a week, occasional lab exercises, and a field trip to the college heating plant, all during class hours

**Requirements/Evaluation:** evaluation will be based on weekly assignments, two hour tests, and a final project culminating in an oral presentation to the class and a 10-page paper; all of these will be substantially quantitative

**Prerequisites:** high school physics, high school chemistry, and mathematics at the level of MATH 130

**Enrollment Limit:** 20

**Expected Class Size:** 20

**Grading:** yes pass/fail option, yes fifth course option

**Distributions:** (D3) (QFR)

**This course is cross-listed and the prefixes carry the following divisional credit:**

ENVI 108 (D3) PHYS 108 (D3)

**Attributes:** ENVI Natural World Electives

Fall 2019

LEC Section: 01 MR 2:35 pm - 3:50 pm Kevin M. Jones

**PHYS 109 (F) Sound, Light, and Perception (QFR)**

Light and sound allow us to perceive the world around us, from appreciating music and art to learning the details of atomic structure. Because of their importance in human experience, light and sound have long been the subject of scientific inquiry. How are sound and light related? How do physiology and neural processing allow us to hear and see the world around us? What are the origins of color and musical pitch? This course introduces the science and technology of light and sound to students not majoring in physics. We will start with the origins of sound and light as wave phenomena, and go on to topics including color, the optics of vision, the meaning of musical pitch and tone, and the physical basis of hearing. We will also discuss some recent technological applications of light, such as lasers and optical communications. The class will meet for two 75-minute periods each week for a variable mixture of lecture, discussion, and hands-on, interactive experiments.

**Class Format:** lecture/lab/discussion; each student will attend one lecture plus one conference section weekly

**Requirements/Evaluation:** evaluation will be based on class participation, problem sets, in-class exams, oral presentations, and a final exam, all with a quantitative component

**Extra Info:** Note: Students signing up for the Thursday 2:35 PM conference section must also be available on Thursdays from 1:10-2:25 PM

**Prerequisites:** none

**Enrollment Limit:** 40

**Expected Class Size:** 40

**Grading:** yes pass/fail option, yes fifth course option

**Distributions:** (D3) (QFR)

Fall 2019

LEC Section: 01 MR 1:10 pm - 2:25 pm M 2:35 pm - 3:50 pm Protik K. Majumder

**PHYS 131 (F) Introduction to Mechanics (QFR)**

We focus first on the Newtonian mechanics of point particles: the relationship between velocity, acceleration, and position; the puzzle of circular motion; forces, Newton's laws, and gravitation; energy and momentum; and the physics of vibrations. Then we turn to the basic properties of waves, such as interference and refraction, as exemplified by sound and light waves. We also study the optics of lenses, mirrors and the human eye. This course is not intended for students who have successfully completed an AP physics course in high school.
Class Format: lecture, three hours per week; laboratory, three hours approximately every other week

Requirements/Evaluation: exams, labs, and weekly problem sets, all of which have a substantial quantitative component

Prerequisites: MATH 130; students who scored 4 or 5 on an AP physics exam, or 6 or 7 on the IB Physics HL exam may not take this course and are encouraged to take PHYS 141 instead

Enrollment Limit: 24/lab

Expected Class Size: 60

Grading: yes pass/fail option, yes fifth course option

Unit Notes: PHYS 131 can lead to either PHYS 132 (for students wanting a one-year survey of physics) or PHYS 142 (for students considering a Physics or Astrophysics major)

Distributions: (D3) (QFR)

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**PHYS 132 (S) Electromagnetism and the Physics of Matter (QFR)**

This course is intended as the second half of a one-year survey of physics with some emphasis on applications to medicine. In the first part of the semester we will focus on electromagnetic phenomena. We will introduce the concept of electric and magnetic fields and study in detail the way in which electrical circuits and circuit elements work. The deep connection between electric and magnetic phenomena is highlighted with a discussion of Faraday’s Law of Induction. Following our introduction to electromagnetism we will discuss some of the most central topics in twentieth-century physics, including Einstein’s theory of special relativity and some aspects of quantum theory. We will end with a treatment of nuclear physics, radioactivity, and uses of radiation.

Class Format: lecture, three hours per week; laboratory, three hours approximately every other week; conference section 1 hour approximately every other week

Requirements/Evaluation: evaluation will be based on weekly problem sets, labs, quizzes and exams

Prerequisites: PHYS 131 or 141 or permission of instructor, and MATH 130 (formerly 103)

Enrollment Limit: 22 per lab

Expected Class Size: 60

Grading: yes pass/fail option, yes fifth course option

Distributions: (D3) (QFR)

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Spring 2020

LEC Section: 01 MWF 11:00 am - 11:50 am Graham K. Giovanetti
LAB Section: 02 M 1:00 pm - 4:00 pm Graham K. Giovanetti
LAB Section: 03 T 1:00 pm - 4:00 pm Graham K. Giovanetti

**PHYS 141 (F) Mechanics and Waves (QFR)**

This is the typical first course for a prospective physics major. It covers the same topics as PHYS 131, but with a higher level of mathematical sophistication. It is intended for students with solid backgrounds in the sciences, either from high school or college, who are comfortable with basic calculus.

Class Format: lecture, three hours per week; laboratory, three hours approximately every other week; conference section, one hour approximately every other week

Requirements/Evaluation: weekly problem sets, labs, 2 one-hour tests, and a final exam, all of which have a substantial quantitative component

Prerequisites: high school physics and MATH 130 or equivalent placement

Enrollment Limit: 22 per lab
**PHYS 141 (S)** Foundations of Modern Physics (QFR)

Newtonian Mechanics, spectacular as it is in describing planetary motion and a wide range of other phenomena, only hints at the richness of behaviors seen in the universe. Special relativity, which extends physics into the realm of high speeds and high energies, requires us to rethink our basic notions of space and time. Quantum mechanics successfully describes atoms, molecules, and solids while at the same time calling into question our expectation of what can be predicted by a physical theory. Statistical physics reveals new behaviors that emerge when many particles are present in a system.

This course will survey ideas from each of these three arenas, and can serve either as a terminal course for those seeking to complete a year of physics or as the basis for future advanced study of these topics.

**Class Format:** lecture, two hours weekly; problem-solving conference session, one hour weekly; laboratory, alternating between three hours and one hour approximately every other week (limit 22 per lab, 18 per conference section)

**Requirements/Evaluation:** weekly homework, labs, two hour tests, and a final exam, all of which have a substantial quantitative component

**Prerequisites:** PHYS 141 and MATH 130 (formerly 103), or equivalent; PHYS 131 may substitute for PHYS 141 with the permission of instructor. Students may not take both PHYS 142 and PHYS 151

**Enrollment Limit:** 18 per CON

**Expected Class Size:** 30

**Grading:** yes pass/fail option, yes fifth course option

**Distributions:** (D3) (QFR)

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**PHYS 151 (F) Seminar in Modern Physics (QFR)**

Newtonian Mechanics, spectacular as it is in describing planetary motion and a wide range of other phenomena, only hints at the richness of behaviors seen in the universe. Special relativity has extended physics into the realm of high speeds and high energies and requires us to rethink our basic notions of space and time. Quantum mechanics successfully describes atoms, molecules, and solids while at the same time calling into question our notions of what can be predicted by a physical theory. Statistical physics reveals new behaviors that emerge when many particles are present in a system. This course covers the same basic material as PHYS 142 but in a small seminar format for students with strong prior preparation in physics.

**Class Format:** lecture/discussion, three hours per week; laboratory, 3 hours approximately every other week; conference section 1 hour approximately every other week

**Requirements/Evaluation:** evaluation will be based on class participation, labs, weekly problem sets, an oral presentation, two hour-exams and a final exam, all of which have a substantial quantitative component

**Extra Info:** this is a small seminar designed for first-year students who have placed out of PHYS 141
Prerequisites: placement by the department (see "advanced placement" section in the description about the department). Students may take either PHYS 142 or PHYS 151 but not both

Enrollment Limit: 18

Expected Class Size: 18

Grading: yes pass/fail option, yes fifth course option

Distributions: (D3) (QFR)

Fall 2019

LEC Section: 01  MWF 11:00 am - 11:50 am  Frederick W. Strauch
LAB Section: 02  W 1:00 pm - 4:00 pm  Frederick W. Strauch

PHYS 201  (F)  Electricity and Magnetism  (QFR)
The classical theory of electricity and magnetism is very rich yet it can be written in a remarkably succinct form using Maxwell's equations. This course is an introduction to electricity and magnetism and their mathematical description, connecting electric and magnetic phenomena via the special theory of relativity. Topics include electrostatics, magnetic fields, electromagnetic induction, DC and AC circuits, and the electromagnetic properties of matter. The laboratory component of the course is an introduction to electronics where students will develop skills in building and debugging electrical circuits.

Class Format: lecture, three hours per week; laboratory, three hours per week

Requirements/Evaluation: evaluation will be based on problem sets, labs, two take-home midterms, and a final exam, all of which have a substantial quantitative component

Prerequisites: PHYS 142 OR 151; MATH 150 or 151; with a preference for MATH 151

Enrollment Limit: 20 per lab

Expected Class Size: 25

Grading: yes pass/fail option, yes fifth course option

Distributions: (D3) (QFR)

Fall 2019

LEC Section: 01  MWF 10:00 am - 10:50 am  David R. Tucker-Smith
LAB Section: 02  T 1:00 pm - 4:00 pm  David R. Tucker-Smith
LAB Section: 03  W 1:00 pm - 4:00 pm  David R. Tucker-Smith

PHYS 202  (S)  Vibrations, Waves and Optics  (QFR)
Waves and oscillations characterize many different physical systems, including vibrating strings, springs, water waves, sound waves, electromagnetic waves, and gravitational waves. Quantum mechanics even describes particles with wave functions. Despite these diverse settings waves exhibit several common characteristics, so that the understanding of a few simple systems can provide insight into a wide array of phenomena. In this course we begin with the study of oscillations of simple systems with only a few degrees of freedom. We then move on to study transverse and longitudinal waves in continuous media in order to gain a general description of wave behavior. The rest of the course focuses on electromagnetic waves and in particular on optical examples of wave phenomena. In addition to well known optical effects such as interference and diffraction, we will study a number of modern applications of optics such as short pulse lasers and optical communications. Throughout the course mathematical methods useful for higher-level physics will be introduced.

Class Format: lecture, three hours per week; laboratory, three hours per week

Requirements/Evaluation: evaluation will be based on problem sets, labs, two one-hour tests, and a final exam, all of which have a substantial quantitative component

Prerequisites: PHYS 201; co-requisite: PHYS/MATH 210 or MATH 209 or permission of instructor

Enrollment Limit: none

Expected Class Size: 20
Grading: yes pass/fail option, yes fifth course option

Distributions: (D3) (QFR)

Spring 2020
LEC Section: 01 MWF 10:00 am - 10:50 am Graham K. Giovanetti
LAB Section: 02 T 1:00 pm - 4:00 pm Graham K. Giovanetti
LAB Section: 03 W 1:00 pm - 4:00 pm Graham K. Giovanetti

PHYS 210 (S) Mathematical Methods for Scientists (QFR)
Cross-listings: MATH 210 PHYS 210

Primary Cross-listing
This course covers a variety of mathematical methods used in the sciences, focusing particularly on the solution of ordinary and partial differential equations. In addition to calling attention to certain special equations that arise frequently in the study of waves and diffusion, we develop general techniques such as looking for series solutions and, in the case of nonlinear equations, using phase portraits and linearizing around fixed points. We study some simple numerical techniques for solving differential equations. A series of optional sessions in Mathematica will be offered for students who are not already familiar with this computational tool.

Class Format: lecture, three hours per week
Requirements/Evaluation: evaluation will be based on several exams and on weekly problem sets, all of which have a substantial quantitative component
Prerequisites: MATH 150 or 151 and familiarity with Newtonian mechanics at the level of PHYS 131
Enrollment Limit: 50
Expected Class Size: 30
Grading: yes pass/fail option, yes fifth course option
Distributions: (D3) (QFR)
This course is cross-listed and the prefixes carry the following divisional credit:
MATH 210 (D3) PHYS 210 (D3)

Spring 2020
LEC Section: 01 TR 9:55 am - 11:10 am Daniel P. Aalberts, David R. Tucker-Smith

PHYS 234 (S) Introduction to Materials Science (QFR)
Cross-listings: PHYS 234 GEOS 234

Primary Cross-listing
Materials Science is the study of how the microscopic structure of materials—whether steel, carbon fiber, glass, wood, plastic, or mayonnaise—determines their macroscopic mechanical, thermal, electric, and other properties. Topics of this course include classifying materials; material structure; thermodynamics and phase transformations; material properties and testing; how solids bend, flow, and ultimately break; and how to choose the right material for design applications. Materials Science is a highly interdisciplinary field and as a result the course prerequisites are broad but also flexible. Interested students who are unsure about their preparation are strongly encouraged to contact the instructor.

Class Format: lecture (3 hours per week), plus three to four small-group laboratory sessions throughout the semester (to be scheduled with instructor)
Requirements/Evaluation: based on weekly problem sets, class participation, and midterm and final exams, all of which have a substantial quantitative component
Prerequisites: high school physics and chemistry, preferably at the AP level, and MATH 140 or AP Calculus (BC), and one 200-level PHYS, CHEM, or GEOS course; or permission of instructor
Enrollment Limit: 20
Enrollment Preferences: based on students’ scientific background and seniority
Expected Class Size: 10
Grading: yes pass/fail option, yes fifth course option

Distributions: (D3) (QFR)

This course is cross-listed and the prefixes carry the following divisional credit:

PHYS 234 (D3) GEOS 234 (D3)

Attributes: MTSC Courses

Spring 2020

LEC Section: 01 MR 1:10 pm - 2:25 pm Katharine E. Jensen

**PHYS 301 (F) Quantum Physics (QFR)**

This course serves as a one-semester introduction to the history, formalism, and phenomenology of quantum mechanics. We begin with a discussion of the historical origins of the quantum theory, and the Schroedinger wave equation. The concepts of matter waves and wave-packets are introduced. Solutions to one-dimensional problems will be treated prior to introducing the system which serves as a hallmark of the success of quantum theory, the three-dimensional hydrogen atom. In the second half of the course, we will develop the important connection between the underlying mathematical formalism and the physical predictions of the quantum theory and introduce the Heisenberg formalism. We then go on to apply this knowledge to several important problems within the realm of atomic and nuclear physics concentrating on applications involving angular momentum and spins.

Class Format: lecture, three hours per week; laboratory, three hours per week

Requirements/Evaluation: evaluation will be based on weekly problem sets, labs, a midterm exam, and final exam, all of which have a substantial quantitative component

Prerequisites: PHYS 202 and PHYS/MATH 210 or MATH 209

Enrollment Limit: none

Expected Class Size: 15

Grading: yes pass/fail option, yes fifth course option

Distributions: (D3) (QFR)

Fall 2019

LEC Section: 01 MWF 9:00 am - 9:50 am Charlie Doret
LAB Section: 02 T 1:00 pm - 4:00 pm Charlie Doret
LAB Section: 03 W 1:00 pm - 4:00 pm Charlie Doret

**PHYS 302 (S) Stat Mechanics & Thermodynamics (QFR)**

Macroscopic objects are made up of huge numbers of fundamental particles interacting in simple ways--obeying the Schrödinger equation, Newton's and Coulomb's Laws--and these objects can be described by macroscopic properties like temperature, pressure, magnetization, heat capacity, conductivity, etc. In this course we will develop the tools of statistical physics, which will allow us to predict the cooperative phenomena that emerge in large ensembles of interacting particles. We will apply those tools to a wide variety of physical questions, including the behavior of gases, polymers, heat engines, biological and astrophysical systems, magnets, and electrons in solids.

Class Format: lecture/discussion, three hours per week; laboratory, three hours per week

Requirements/Evaluation: evaluation will be based on weekly problem sets, exams, and labs, all of which have a substantial quantitative component

Prerequisites: required: PHYS 201, PHYS/MATH 210 or MATH 209; recommended: PHYS 202, PHYS 301

Enrollment Limit: 24

Expected Class Size: 15

Grading: yes pass/fail option, yes fifth course option

Distributions: (D3) (QFR)

Attributes: BIGP Related Courses

Spring 2020
PHYS 314  (S)  Controlling Quanta  (QFR)
This course will explore modern developments in the control of individual quantum systems. Topics covered will include basic physical theories of atoms coupled to photons, underlying mathematical tools (including Lie algebras and groups), and computational methods to simulate and analyze quantum systems. Applications to quantum computing, teleportation, and experimental metaphysics (Bell's inequality) will also be discussed.

Class Format: tutorial
Requirements/Evaluation: tutorial preparation and participation, weekly problem sets/papers, and a final project
Extra Info: may not be taken on a pass/fail basis; not available for the fifth course option
Prerequisites: PHYS/MATH 210 or MATH 209 or MATH 250
Enrollment Limit: 10
Enrollment Preferences: sophomores and junior Physics majors
Expected Class Size: 10
Grading: no pass/fail option, no fifth course option
Distributions: (D3) (QFR)

Spring 2020
TUT Section: T1  TBA  Frederick W. Strauch

PHYS 315  (S)  Computational Biology  (QFR)
Primary Cross-listing
This course will provide an overview of Computational Biology, the application of computational, mathematical, statistical, and physical problem-solving techniques to interpret the rapidly expanding amount of biological data. Topics covered will include database searching, DNA sequence alignment, clustering, RNA structure prediction, protein structural alignment, methods of analyzing gene expression, networks, and genome assembly using techniques such as string matching, dynamic programming, hidden Markov models, and expectation-maximization.

Class Format: lab three hours per week plus weekly tutorial meeting
Requirements/Evaluation: evaluation will be based on weekly Python programming assignments, problem sets, a few quizzes and a final project
Prerequisites: programming experience (e.g., CSCI 136), mathematics (PHYS/MATH 210 or MATH 150), and physical science (PHYS 142 or 151, or CHEM 151 or 153 or 155), or permission of instructor
Enrollment Limit: 10
Enrollment Preferences: based on seniority
Expected Class Size: 8
Grading: no pass/fail option, no fifth course option
Distributions: (D3) (QFR)
This course is cross-listed and the prefixes carry the following divisional credit:
PHYS 315 (D3) CSCI 315 (D3)
Attributes: BIGP Recommended Courses
PHYS 321  (F)  Introduction to Particle Physics  (QFR)
The Standard Model of particle physics incorporates special relativity, quantum mechanics, and almost all that we know about elementary particles and their interactions. This course introduces some of the main ideas and phenomena associated with the Standard Model. After a review of relativistic kinematics, we will learn about symmetries in particle physics, Feynman diagrams, and selected applications of quantum electrodynamics, the weak interactions, and quantum chromodynamics. We will conclude with a discussion of spontaneous symmetry breaking and the Higgs mechanism.

Class Format: lecture / seminar, three hours a week
Requirements/Evaluation: weekly problem sets and a final exam
Prerequisites: PHYS 301, which may be taken concurrently, plus permission of instructor
Enrollment Limit: 15
Expected Class Size: 10
Grading: yes pass/fail option, yes fifth course option
Distributions: (D3)  (QFR)

Fall 2019
LEC Section: 01    MW 11:00 am - 12:15 pm     Savan Kharel

PHYS 405  (F)  Electromagnetic Theory  (QFR)
This course builds on the material of Physics 201, and explores the application of Maxwell's Equations to understand a range of topics including electric fields and matter, magnetic materials, light, and radiation. As we explore diverse phenomena, we will learn useful approximation techniques and beautiful mathematical tools. In addition to weekly tutorial meetings, the class will meet once a week as a whole to introduce new material.

Class Format: tutorial, one hour per week; lecture, one hour per week
Requirements/Evaluation: evaluation will be based on weekly problem sets, tutorial participation, presentations, and a final exam or final project, all of which have a substantial quantitative component
Prerequisites: PHYS 202 and PHYS/MATH 210 or MATH 209 or MATH 309
Enrollment Limit: 10/section
Expected Class Size: 16
Grading: no pass/fail option, no fifth course option
Distributions: (D3)  (QFR)

Fall 2019
TUT Section: T1    F 1:10 pm - 2:25 pm     Daniel P. Aalberts

PHYS 418  (S)  Gravity  (QFR)
This course is an introduction Einstein's theory of general relativity. We begin with a review of special relativity, emphasizing geometrical aspects of Minkowski spacetime. Working from the equivalence principle, we then motivate gravity as spacetime curvature, and study in detail the Schwarzschild geometry around a spherically symmetric mass. After this application, we use tensors to develop Einstein's equation, which describes how energy density curves spacetime. With this equation in hand we study the Friedmann-Robertson-Walker geometries for an expanding universe, and finally, we linearize Einstein's equation to develop the theory of gravitational waves.

Class Format: lecture
Requirements/Evaluation: evaluation will be based on weekly problem sets, a midterm exam, and a final exam, all of which have a substantial quantitative component
Prerequisites: PHYS 301 or PHYS 405 or PHYS 411. PLEASE DELETE: "students with strong math backgrounds are invited to consult with the instructor
Enrollment Limit: none
Expected Class Size: 10
Grading: no pass/fail option, yes fifth course option
POEC 253 (F) Empirical Methods in Political Economy (QFR)

This course introduces students to common empirical tools used in policy analysis and implementation. The broad aim is to train students to be discriminating consumers of public policy-relevant research. The emphasis in the course is on intuitive understanding of the central concepts. Through hands-on work with data and critical assessment of existing empirical social scientific research, students will develop the ability to choose and employ the appropriate tool for a particular research problem, and to understand the limitations of the techniques. Topics to be covered include basic principles of probability; random variables and distributions; statistical estimation, inference and hypothesis testing; and modeling using multiple regression, with a particular focus on understanding whether and how relationships between variables can be determined to be causal--an essential requirement for effective policy formation. Throughout the course, the focus will be on public policy applications relevant to the fields of political science, sociology, and public health, as well as to economics.

Class Format: lecture/discussion

Requirements/Evaluation: Problem sets, group project, midterm exam, final exam
Prerequisites: MATH 130 or its equivalent; one course in ECON; not open to students who have taken ECON 255
Enrollment Limit: 25
Enrollment Preferences: Political Economy majors, Environmental Policy majors and sophomores
Expected Class Size: 15
Grading: yes pass/fail option, yes fifth course option
Unit Notes: does not satisfy the econometrics requirement for the Economics major; POEC 253 cannot be substituted for ECON 255, or count as an elective towards the Economics major
Distributions: (D2) (QFR)
Attributes: EVST Methods Courses  PHLH Statistics Courses  POEC Required Courses
STAT 101 (F)(S) Elementary Statistics and Data Analysis (QFR)

It is impossible to be an informed citizen in the world today without an understanding of data and information. Whether opinion polls, unemployment rates, salary differences between men and women, the efficacy of vaccines or consumer webdata, we need to be able to separate the signal from the noise. We will learn the statistical methods used to analyze and interpret data from a wide variety of sources. The goal of the course is to help reach conclusions and make informed decisions based on data.

Class Format: lecture

Requirements/Evaluation: based primarily on performances on quizzes and exams

Prerequisites: MATH 102 (or demonstrated proficiency on a diagnostic test)

Enrollment Limit: 50

Expected Class Size: 40

Grading: no pass/fail option, no fifth course option

Unit Notes: students with calculus background and social science interest should consider STAT 161; students with MATH 150 should enroll in STAT 201; students with a 5 on AP Stats should enroll in STAT 202; students with a 4 on AP Stat should consult the department

Distributions: (D3) (QFR)

Attributes: BIGP Recommended Courses COGS Related Courses PHLH Statistics Courses

Fall 2019

LEC Section: 01 TF 2:35 pm - 3:50 pm Elizabeth M. Upton

Spring 2020

LEC Section: 01 TR 9:55 am - 11:10 am Elizabeth M. Upton

LEC Section: 02 TR 11:20 am - 12:35 pm Elizabeth M. Upton

STAT 161 (F)(S) Introductory Statistics for Social Science (QFR)

This course will cover the basics of modern statistical analysis with a view toward applications in the social sciences and sciences. Topics include exploratory data analysis, elements of probability theory, basic statistical inference, and introduction to statistical modeling. The course focuses on the application of statistics tools to solve problems, to make decisions, and the use of statistical thinking to understand the world.

Class Format: lecture

Prerequisites: MATH 130 (or equivalent); not open to students who have completed STAT 101 or equivalent

Enrollment Limit: 40

Enrollment Preferences: Economics majors, sophomores

Expected Class Size: 40

Grading: no pass/fail option, no fifth course option

Unit Notes: students with MATH 150 should consider STAT 201; students with a 5 on AP Stats should enroll in STAT 202; students with a 4 on AP Stats should consult the department; students without any calculus background should consider STAT 101

Distributions: (D3) (QFR)
Quantitative/Formal Reasoning Notes: It is a quantitative course.

Attributes: PHLH Statistics Courses

Fall 2019
LEC Section: 01 TR 8:30 am - 9:45 am Anna M. Plantinga

Spring 2020
LEC Section: 01 TF 1:10 pm - 2:25 pm Anna M. Plantinga
LEC Section: 02 TF 2:35 pm - 3:50 pm Anna M. Plantinga

STAT 201 (F)(S) Statistics and Data Analysis (QFR)
Statistics can be viewed as the art and science of turning data into information. Real world decision-making, whether in business or science is often based on data and the perceived information it contains. Sherlock Holmes, when prematurely asked the merits of a case by Dr. Watson, snapped back, “Data, data, data! I can’t make bricks without clay.” In this course, we will study the basic methods by which statisticians attempt to extract information from data. These will include many of the standard tools of statistical inference such as hypothesis testing, confidence intervals, and linear regression as well as exploratory and graphical data analysis techniques. This is an accelerated introductory statistics course that involves computational programming and incorporates modern statistical techniques.

Class Format: lecture

Requirements/Evaluation: based primarily on performance on quizzes and exams
Prerequisites: MATH 150 or equivalent; not open to students who have completed STAT 101 or STAT 161 or equivalent
Enrollment Limit: 40
Expected Class Size: 40
Grading: yes pass/fail option, yes fifth course option

Unit Notes: students with a 5 on AP Stats should enroll in STAT 202; students with a 4 on AP Stats should consult the department; students with MATH 130/140 background should consider STAT 161; students with no calc. should consider STAT 101

Distributions: (D3) (QFR)

Attributes: BIGP Recommended Courses COGS Related Courses EVST Methods Courses PHLH Statistics Courses

Fall 2019
LEC Section: 01 TR 9:55 am - 11:10 am Shaoyang Ning
LEC Section: 02 TR 11:20 am - 12:35 pm Shaoyang Ning

Spring 2020
LEC Section: 01 TR 8:30 am - 9:45 am Stewart D. Johnson
LEC Section: 02 TR 9:55 am - 11:10 am Stewart D. Johnson

STAT 202 (F)(S) Introduction to Statistical Modeling (QFR)
Data come from a variety of sources sometimes from planned experiments or designed surveys, but also arise by much less organized means. In this course we’ll explore the kinds of models and predictions that we can make from both kinds of data as well as design aspects of collecting data. We’ll focus on model building, especially multiple regression, and talk about its potential as well as its limits to answer questions about the world. We’ll emphasize applications over theory and analyze real data sets throughout the course.

Class Format: lecture

Requirements/Evaluation: homework, exams and projects
Prerequisites: AP Statistics 5 or STAT 101, 161 or 201 or permission of instructor
Enrollment Limit: 25
Expected Class Size: 20
Grading: no pass/fail option, no fifth course option
**Unit Notes:** students with a 4 on the AP Stats exam should contact the department for proper placement

**Distributions:** (D3) (QFR)

**Attributes:** EVST Methods Courses  PHLH Statistics Courses

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**Fall 2019**

LEC Section: 01    MWF 9:00 am - 9:50 am    Xizhen Cai

LEC Section: 02    MWF 10:00 am - 10:50 am    Xizhen Cai

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**Spring 2020**

LEC Section: 01    MWF 11:00 am - 11:50 am    Xizhen Cai

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**STAT 341 (F)(S) Probability (QFR)**

**Cross-listings:** MATH 341  STAT 341

**Secondary Cross-listing**

While probability began with a study of games, it has grown to become a discipline with numerous applications throughout mathematics and the sciences. Drawing on gaming examples for motivation, this course will present axiomatic and mathematical aspects of probability. Included will be discussions of random variables, expectation, independence, laws of large numbers, and the Central Limit Theorem. Many interesting and important applications will also be presented, potentially including some from coding theory, number theory and nuclear physics.

**Class Format:** lecture

**Requirements/Evaluation:** evaluation will be based primarily on homework, classwork, and exams

**Prerequisites:** MATH 250 or permission of the instructor

**Enrollment Limit:** 40

**Expected Class Size:** 20

**Grading:**  yes pass/fail option,     yes fifth course option

**Distributions:** (D3) (QFR)

This course is cross-listed and the prefixes carry the following divisional credit:

MATH 341 (D3) STAT 341 (D3)

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**Fall 2019**

LEC Section: 01    MWF 11:00 am - 11:50 am    Steven J. Miller

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**Spring 2020**

LEC Section: 01    TF 2:35 pm - 3:50 pm    Mihai Stoiciu

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**STAT 342 (F) Introduction to Stochastic Processes (QFR)**

Stochastic processes are mathematical models for random phenomena evolving in time or space. Examples include the number of people in a queue at time t or the accumulated claims paid by an insurance company in an interval of time t. This course introduces the basic concepts and techniques of stochastic processes used to construct models for a variety of problems of practical interest. The theory of Markov chains will guide our discussion as we cover topics such as martingales, random walks, Poisson process, birth and death processes, and Brownian motion.

**Class Format:** lecture

**Requirements/Evaluation:** primarily on weekly homework, classwork, and exams

**Prerequisites:** STAT 341

**Enrollment Limit:** 30

**Enrollment Preferences:** senior Statistics majors

**Expected Class Size:** 15

**Grading:**  yes pass/fail option,     yes fifth course option

**Distributions:** (D3) (QFR)
Quantitative/Formal Reasoning Notes: This is a statistics class with a focus on mathematical skills and translating real world phenomena into mathematical descriptions.

Fall 2019
LEC Section: 01    TF 1:10 pm - 2:25 pm    Elizabeth M. Upton

STAT 346  (F)(S) Regression and Forecasting (QFR)
This course focuses on the building of empirical models through data in order to predict, explain, and interpret scientific phenomena. Regression modeling is the standard method for analyzing continuous response data and their relationship with explanatory variables. This course provides both theoretical and practical training in statistical modeling with particular emphasis on simple linear and multiple regression, using R to develop and diagnose models. The course covers the theory of multiple regression and diagnostics from a linear algebra perspective with emphasis on the practical application of the methods to real data sets. The data sets will be taken from a wide variety of disciplines.

Class Format: lecture
Requirements/Evaluation: evaluation will be based primarily on performance on exams, homework, and a project
Prerequisites: STAT 201 or 202, and MATH 150 and 250; or permission of instructor
Enrollment Limit: 22
Expected Class Size: 15
Grading: no pass/fail option, no fifth course option
Distributions: (D3) (QFR)
Attributes: EVST Methods Courses

Spring 2020
LEC Section: 01    MWF 8:30 am - 9:45 am    Xizhen  Cai

STAT 360  (S) Statistical Inference (QFR)
How do we estimate unknown parameters and express the uncertainty we have in our estimate? Is there an estimator that works best? Many topics from introductory statistics such as random variables, the central limit theorem, point and interval estimation and hypotheses testing will be revisited and put on a more rigorous mathematical footing. The focus is on maximum likelihood estimators and their properties. Bayesian and computer intensive resampling techniques (e.g., the bootstrap) will also be considered.

Class Format: lecture
Requirements/Evaluation: evaluation will be based on problem sets and exams
Prerequisites: MATH 250, STAT 201 or 202, STAT 341
Enrollment Limit: 30
Enrollment Preferences: Statistics majors
Expected Class Size: 30
Grading: no pass/fail option, yes fifth course option
Distributions: (D3) (QFR)

Spring 2020
LEC Section: 01    MR 2:35 pm - 3:50 pm    Shaoyang Ning

STAT 368  (S) Modern Nonparametric Statistics (QFR)
Many statistical procedures and tools are based on a set of assumptions, such as normality or other parametric models. But, what if some or all of these assumptions are not valid and the adopted models are miss-specified? This question leads to an active and fascinating field in modern statistics
called nonparametric statistics, where few assumptions are made on data's distribution or the model structure to ensure great model flexibility and robustness. In this course, we start with a brief overview of classic rank-based tests (Wilcoxon, K-S test), and focus primarily on modern nonparametric inferential techniques, such as nonparametric density estimation, nonparametric regression, selection of smoothing parameter (cross-validation), bootstrap, randomization-based inference, clustering, and nonparametric Bayes. Throughout the semester we will examine these new methodologies and apply them on simulated and real datasets using R.

Class Format: lecture

Requirements/Evaluation: primarily on performance on exams, homework, and a project

Prerequisites: STAT 201 and STAT 346, or permission of instructor.

Enrollment Limit: 30

Enrollment Preferences: senior Statistics majors

Expected Class Size: 15

Grading: yes pass/fail option, yes fifth course option

Distributions: (D3) (QFR)

Quantitative/Formal Reasoning Notes: This is a statistics class with a focus on mathematical, computational, and data analysis skills as well as appropriate practical application of analysis methods.

Spring 2020

LEC Section: 01 TR 11:20 am - 12:35 pm Shaoyang Ning

STAT 410 (F) Statistical Genetics (QFR)

Genetic studies explore patterns of genetic variation in populations and the effect of genes on diseases or traits. This course provides an introduction to statistical and computational methods for genetic studies. Topics will include Mendelian traits (such as single nucleotide polymorphisms), genome-wide association studies, pathway-based analysis, and methods for population genetics. Students will be introduced to some of the major computational tools for genetic analysis, including PLINK and R/Bioconductor. The necessary background in genetics and biology will be provided alongside the statistical and computational methods.

Class Format: lecture

Requirements/Evaluation: project work, homework, exams, and contribution to discussion

Prerequisites: STAT 346 and STAT 360, or permission of instructor

Enrollment Limit: 14

Enrollment Preferences: Statistics majors, juniors and seniors

Expected Class Size: 10

Grading: no pass/fail option, no fifth course option

Distributions: (D3) (QFR)

Quantitative/Formal Reasoning Notes: This is a statistics class with a focus on mathematical, computational, and data analysis skills as well as appropriate practical application of analysis methods.

Attributes: BIGP Related Courses PHLH Statistics Courses

Fall 2019

LEC Section: 01 TR 11:20 am - 12:35 pm Anna M. Plantinga

STAT 442 (S) Statistical Learning and Data Mining (QFR)

In both science and industry today, the ability to collect and store data can outpace our ability to analyze it. Traditional techniques in statistics are often unable to cope with the size and complexity of today's data bases and data warehouses. New methodologies in Statistics have recently been developed, designed to address these inadequacies, emphasizing visualization, exploration and empirical model building at the expense of traditional hypothesis testing. In this course we will examine these new techniques and apply them to a variety of real data sets.

Class Format: lecture
**ASTR 111 (F) Introduction to Astrophysics** (QFR)

The science of astronomy spans vast scales of space and time, from individual atoms to entire galaxies and from the universe's beginning to the future fate of our Sun. In this course, we will survey some of the main ideas in modern astrophysics, with an emphasis on the physics of stars and galaxies. ASTR 111 is the first course in the Astrophysics and Astronomy major sequences. It is also appropriate for students planning to major in one of the other sciences or mathematics and for others who would like a quantitative introduction that emphasizes the relationship of contemporary physics to astronomy. Topics include gravity and orbits, radiation laws and stellar spectra, physical characteristics of the Sun and other stars, star formation and evolution, black holes, galaxies, the expanding universe, and the Big Bang. Students will also use telescopes to observe stars, nebulae, planets, and galaxies and to make daytime observations of the Sun.

**Class Format:** lecture/discussion, observing sessions, and five labs per semester

**Requirements/Evaluation:** weekly problem sets, two hour tests, a final exam, lab reports, and an observing portfolio

**Prerequisites:** a year of high school Physics, concurrent college Physics, or permission of instructor, and MATH 140 or equivalent

**Enrollment Limit:** 28

**Enrollment Preferences:** potential Astronomy majors

**Expected Class Size:** 15

**Grading:** yes pass/fail option, yes fifth course option

**Distributions:** (D3) (QFR)

**Quantative/Formal Reasoning Notes:** The course requires regular problem sets and quantitative assignments. The course will emphasize how physical equations explain the observed properties of the universe.

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**ASTR 211 (S) Astronomical Observing and Data Analysis** (QFR)

How do astronomers make scientific measurements for objects that are light-years away from Earth? This course will introduce the basics of telescopes and observations and will give students hands-on training in the techniques astronomers use to obtain, process, and analyze scientific data. We will discuss observation planning, CCD detectors, signal statistics, image processing, and photometric and spectroscopic observations. We will begin by focusing on ground-based optical observations and will move on to non-optical observations, both electromagnetic (e.g., radio waves, X-rays) and non-electromagnetic (e.g., gravitational waves, neutrinos). Throughout the course, students will use computational techniques to work with real astronomical data, taken with our 24" telescope and from data archives.

**Class Format:** lecture/discussion, computer lab work, and observing

**Requirements/Evaluation:** weekly problem sets, lab work, and observing projects

**Prerequisites:** MATH 150 or 151; prior experience with Unix and computer programming is helpful, but not required
Enrollment Limit: 14
Expected Class Size: 8
Grading: no pass/fail option, no fifth course option
Distributions: (D3) (QFR)
Quantitative/Formal Reasoning Notes: The course requires regular problem sets. Labs require computer programming and statistical and graphical analyses of data.

Spring 2020
LAB Section: 02 M 7:00 pm - 9:40 pm Anne Jaskot, Kevin Flaherty
LEC Section: 01 MR 1:10 pm - 2:25 pm Anne Jaskot, Kevin Flaherty

BIMO 321 (F)(S) Biochemistry I: Structure and Function of Biological Molecules (QFR)
Cross-listings: CHEM 321 BIMO 321 BIOL 321

Primary Cross-listing
This course introduces the basic concepts of biochemistry with an emphasis on the structure and function of biological macromolecules. Specifically, the structure of proteins and nucleic acids are examined in detail in order to determine how their chemical properties and their biological behavior result from those structures. Other topics covered include catalysis, enzyme kinetics, mechanism and regulation; the molecular organization of biomembranes; and the flow of information from nucleic acids to proteins. In addition, the principles and applications of the methods used to characterize macromolecules in solution and the interactions between macromolecules are discussed. The laboratory provides a hands-on opportunity to study macromolecules and to learn the fundamental experimental techniques of biochemistry including electrophoresis, chromatography, and principles of enzymatic assays.

Class Format: lecture, three hours per week; laboratory, four hours per week
Requirements/Evaluation: evaluation is based on quizzes, a midterm exam, a final exam, problem sets and performance in the laboratories including lab reports
Prerequisites: BIOL 101 and CHEM 251/255 and CHEM 155/256

Enrollment Limit: 16/lab
Enrollment Preferences: junior and senior Biology and Chemistry majors and BIMO concentrators
Expected Class Size: 16/lab
Grading: no pass/fail option, yes fifth course option
Unit Notes: does not satisfy the distribution requirement for the Biology major
Distributions: (D3) (QFR)
This course is cross-listed and the prefixes carry the following divisional credit:
CHEM 321 (D3) BIMO 321 (D3) BIOL 321 (D3)
Attributes: BIGP Related Courses BIMO Required Courses

Fall 2019
LAB Section: 02 M 1:00 pm - 5:00 pm Bob Rawle
LAB Section: 03 T 1:00 pm - 5:00 pm
LAB Section: 04 W 1:00 pm - 5:00 pm
LEC Section: 01 MWF 10:00 am - 10:50 am Bob Rawle

Spring 2020
LAB Section: 03 T 8:00 am - 12:00 pm
LEC Section: 01 MWF 9:00 am - 9:50 am Katie M. Hart
LAB Section: 02 M 1:00 pm - 5:00 pm Katie M. Hart
BIMO 322  (S)  Biochemistry II: Metabolism  (QFR)

Cross-listings: BIOL 322  CHEM 322  BIMO 322

Primary Cross-listing

This lecture course provides an in-depth presentation of the complex metabolic reactions which are central to life. Emphasis is placed on the biological flow of energy including alternative modes of energy generation (aerobic, anaerobic, photosynthetic); the regulation and integration of the metabolic pathways including compartmentalization and the transport of metabolites; and biochemical reaction mechanisms including the structures and mechanisms of coenzymes. This comprehensive study also includes the biosynthesis and catabolism of small molecules (carbohydrates, lipids, amino acids, and nucleotides). Laboratory experiments introduce the principles and procedures used to study enzymatic reactions, bioenergetics, and metabolic pathways.

Class Format: lecture, three hours per week; laboratory, three hours per week

Requirements/Evaluation: several exams and performance in the laboratories including lab reports that emphasize conceptual and quantitative and/or graphic analysis of the

Prerequisites: BIOL 101 and CHEM 251/255 or permission of instructor

Enrollment Limit:  64

Enrollment Preferences: junior and senior Biology and Chemistry majors and BIMO concentrators

Expected Class Size:  64

Grading: no pass/fail option, no fifth course option

Unit Notes: does not satisfy the distribution requirement for the Biology major; cannot be counted towards the Biology major in addition to BIOL 222

Distributions:  (D3)  (QFR)

This course is cross-listed and the prefixes carry the following divisional credit:

BIOL 322 (D3) CHEM 322 (D3) BIMO 322 (D3)

Attributes: BIGP Related Courses  BIMO Required Courses

Spring 2020

LEC Section: 01  TBA  Steven J. Swoap

LAB Section: 03  W 1:00 pm - 4:00 pm  Janis E. Bravo

LAB Section: 02  T 1:00 pm - 4:00 pm  Janis E. Bravo

LAB Section: 04  R 1:00 pm - 4:00 pm  Cynthia K. Holland

BIOL 202  (F)  Genetics  (QFR)

Genetics, classically defined as the study of heredity, has evolved into a discipline whose limits are continually expanded by innovative molecular technologies. This course covers the experimental basis for our current understanding of the inheritance, structures, and functions of genes. It introduces approaches used by contemporary geneticists and molecular biologists to explore questions in areas of biology ranging from evolution to medicine. The laboratory part of the course provides an experimental introduction to modern genetic analysis. Laboratory experiments include linkage analysis, bacterial transformation with plasmids and DNA restriction mapping.

Class Format: lecture/laboratory, six hours per week

Requirements/Evaluation: evaluation will be based on bi-weekly problem sets, weekly laboratory exercises and laboratory reports, and examinations

Prerequisites: BIOL 101 and 102

Enrollment Limit: none

Expected Class Size:  84

Grading: no pass/fail option, no fifth course option

Unit Notes: does not satisfy the distribution requirement for the Biology major

Distributions:  (D3)  (QFR)

Attributes: BIGP Recommended Courses  BIMO Required Courses
Fall 2019
LAB Section: 02  M 1:00 pm - 4:00 pm  Derek Dean
LAB Section: 05  R 1:00 pm - 4:00 pm  Derek Dean
LEC Section: 01  MWF 11:00 am - 11:50 am  David W. Loehlin
LAB Section: 03  T 1:00 pm - 4:00 pm  Derek Dean
LAB Section: 04  W 1:00 pm - 4:00 pm  Derek Dean

BIOL 203  (F)  Ecology  (QFR)

Cross-listings:  BIOL 203  ENVI 203

Primary Cross-listing

This course combines lectures with field and indoor laboratory exercises to explore factors that determine the distribution and abundance of plants and animals in natural systems. The course begins with an overall view of global patterns and then builds from the population to the ecosystem level. An emphasis is given to basic ecological principles and relates them to current environmental issues. Selected topics include population dynamics (competition, predation, mutualism); community interactions (succession, food chains and diversity) and ecosystem function (biogeochemical cycles, energy flow).

Class Format: lecture/laboratory, six hours per week

Requirements/Evaluation:  evaluation will be based on problem sets, lab reports, hour exams, and a final exam

Prerequisites:  BIOL 101 and 102, or ENVI 101 or 102, or permission of instructor

Enrollment Limit:  none

Expected Class Size:  35

Grading:  no pass/fail option,  no fifth course option

Unit Notes:  satisfies the distribution requirement for the Biology major

Distributions:  (D3)  (QFR)

This course is cross-listed and the prefixes carry the following divisional credit:

BIOL 203 (D3)  ENVI 203 (D3)

Attributes:  ENVI Natural World Electives  EVST Environmental Science  EVST Living Systems Courses

Fall 2019
LAB Section: 02  T 1:00 pm - 4:00 pm  Ron D. Bassar
LEC Section: 01  MWF 10:00 am - 10:50 am  Ron D. Bassar
LAB Section: 03  W 1:00 pm - 4:00 pm  Ron D. Bassar

BIOL 222  (S)  Essentials of Biochemistry  (QFR)

This course will explore the biochemistry of cellular processes and contextualize these processes in healthy and diseased states. Lecture topics in this one semester course will include the structure and function of proteins (enzymes and non-enzymatic proteins), lipids, and carbohydrates. Lectures will also survey the major metabolic pathways (carbohydrates, lipids, and amino acids) with particular attention to enzyme regulation and the integration of metabolism in different tissues and under different metabolic conditions. In the discussion/laboratory component of the course a combination of primary literature, hypothesis-driven exercises, problem solving, and bench work will be used to illustrate how particular techniques and experimental approaches are used in biochemical fields.

Class Format: lecture/discussion/laboratory, six hours per week

Requirements/Evaluation:  regular quizzes, final exam, writing assignments (including problem sets), and lab assignments

Prerequisites:  BIOL 101 and CHEM 156; not open to students who have taken BIOL 321 or BIOL 322

Enrollment Limit:  24

Enrollment Preferences:  seniors who need to fulfill the biochemistry requirement for premedical school

Expected Class Size:  24

Grading:  no pass/fail option,  no fifth course option
Unit Notes: does not satisfy the distribution requirement for the Biology major; cannot be counted towards the biology major in addition to either BIOL 321 or BIOL 322; cannot be counted towards the BIMO concentration

Distributions: (D3) (QFR)

Quantitative/Formal Reasoning Notes: The laboratory program is quantitative covering data analyses, numerical transformations, graphical displays.

Spring 2020

LAB Section: 02    W 1:00 pm - 4:00 pm    Daniel V. Lynch
LAB Section: 03    R 1:00 pm - 4:00 pm    Daniel V. Lynch
LEC Section: 01    TR 9:55 am - 11:10 am    Daniel V. Lynch

BIOL 302  (F)  Communities and Ecosystems  (QFR)

Cross-listings: ENVI 312  BIOL 302

Primary Cross-listing

An advanced ecology course that examines how species interact with each other and their environment and how communities are assembled. This course emphasizes phenomena that emerge in complex ecological systems, building on the fundamental concepts of population biology, community ecology, and ecosystem science. This foundation will be used to understand specific topics relevant to conservation including invasibility and the functional significance of diversity for ecosystem stability and processes. Lectures and labs will explore how to characterize the emergent properties of communities and ecosystems, and how theoretical, comparative, and experimental approaches are used to understand their structure and function.

The lab component of this course will emphasize hypothesis-oriented field experiments as well as "big-data" analyses using existing data sets. The laboratory component of the course will culminate with a self-designed independent or group project.

Class Format: lecture/laboratory, six hours a week

Requirements/Evaluation: evaluation will be based on lab reports, a midterm exam, a term project presentation, and a final project paper

Prerequisites: BIOL/ENVI 203 or 220

Enrollment Limit: 28

Enrollment Preferences: Biology majors and Environmental Studies majors and concentrators

Expected Class Size: 24

Grading: yes pass/fail option, yes fifth course option

Unit Notes: satisfies the distribution requirement for the Biology major

Distributions: (D3) (QFR)

This course is cross-listed and the prefixes carry the following divisional credit:
ENVI 312 (D3) BIOL 302 (D3)

Attributes: ENVI Natural World Electives  EVST Living Systems Courses  EXPE Experiential Education Courses

Fall 2019

LEC Section: 01    TR 9:55 am - 11:10 am    Manuel A. Morales
LAB Section: 03    W 1:00 pm - 4:00 pm    Manuel A. Morales
LAB Section: 02    T 1:00 pm - 4:00 pm    Manuel A. Morales

BIOL 305  (S)  Evolution  (QFR)

This course offers a critical analysis of contemporary concepts in biological evolution. We focus on the relation of evolutionary mechanisms (e.g., selection, drift, and migration) to long term evolutionary patterns (e.g., evolutionary innovations, origin of major groups, and the emergence of diversity). Topics include micro-evolutionary models, natural selection and adaptation, sexual selection, speciation, the inference of evolutionary history among others.

Class Format: lecture/discussion/laboratory, six hours per week

Requirements/Evaluation: evaluation will be based on independent research project, problem sets, participation in discussions and exams
**Prerequisites:** BIOL 202

**Enrollment Limit:** 24

**Enrollment Preferences:** Seniors and biology majors

**Expected Class Size:** 24

**Grading:** yes pass/fail option, yes fifth course option

**Unit Notes:** satisfies the distribution requirement for the Biology major

**Distributions:** (D3) (QFR)

**Attributes:** BIGP Recommended Courses  BIMO Interdepartmental Electives  COGS Related Courses

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**Spring 2020**

LAB Section: 02  T 1:00 pm - 4:00 pm  Luana S. Maroja

LAB Section: 03  R 1:00 pm - 4:00 pm  Luana S. Maroja

LEC Section: 01  MWF 10:00 am - 10:50 am  Luana S. Maroja

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**BIOL 321  (F)(S)  Biochemistry I: Structure and Function of Biological Molecules  (QFR)**

**Cross-listings:** CHEM 321  BIMO 321  BIOL 321

**Secondary Cross-listing**

This course introduces the basic concepts of biochemistry with an emphasis on the structure and function of biological macromolecules. Specifically, the structure of proteins and nucleic acids are examined in detail in order to determine how their chemical properties and their biological behavior result from those structures. Other topics covered include catalysis, enzyme kinetics, mechanism and regulation; the molecular organization of biomembranes; and the flow of information from nucleic acids to proteins. In addition, the principles and applications of the methods used to characterize macromolecules in solution and the interactions between macromolecules are discussed. The laboratory provides a hands-on opportunity to study macromolecules and to learn the fundamental experimental techniques of biochemistry including electrophoresis, chromatography, and principles of enzymatic assays.

**Class Format:** lecture, three hours per week; laboratory, four hours per week

**Requirements/Evaluation:** evaluation is based on quizzes, a midterm exam, a final exam, problem sets and performance in the laboratories including lab reports

**Prerequisites:** BIOL 101 and CHEM 251/255 and CHEM 155/256

**Enrollment Limit:** 16/lab

**Enrollment Preferences:** junior and senior Biology and Chemistry majors and BIMO concentrators

**Expected Class Size:** 16/lab

**Grading:** no pass/fail option, yes fifth course option

**Unit Notes:** does not satisfy the distribution requirement for the Biology major

**Distributions:** (D3) (QFR)

**This course is cross-listed and the prefixes carry the following divisional credit:**

CHEM 321 (D3) BIMO 321 (D3) BIOL 321 (D3)

**Attributes:** BIGP Related Courses  BIMO Required Courses

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**Fall 2019**

LAB Section: 04  W 1:00 pm - 5:00 pm

LEC Section: 01  MWF 10:00 am - 10:50 am  Bob Rawle

LAB Section: 02  M 1:00 pm - 5:00 pm  Bob Rawle

LAB Section: 03  T 1:00 pm - 5:00 pm

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**Spring 2020**

LAB Section: 02  M 1:00 pm - 5:00 pm  Katie M. Hart
BIOL 322 (S) Biochemistry II: Metabolism (QFR)

Cross-listings: BIOL 322 CHEM 322 BIMO 322

Secondary Cross-listing

This lecture course provides an in-depth presentation of the complex metabolic reactions which are central to life. Emphasis is placed on the biological flow of energy including alternative modes of energy generation (aerobic, anaerobic, photosynthetic); the regulation and integration of the metabolic pathways including compartmentalization and the transport of metabolites; and biochemical reaction mechanisms including the structures and mechanisms of coenzymes. This comprehensive study also includes the biosynthesis and catabolism of small molecules (carbohydrates, lipids, amino acids, and nucleotides). Laboratory experiments introduce the principles and procedures used to study enzymatic reactions, bioenergetics, and metabolic pathways.

Class Format: lecture, three hours per week; laboratory, three hours per week

Requirements/Evaluation: several exams and performance in the laboratories including lab reports that emphasize conceptual and quantitative and/or graphic analysis of the

Prerequisites: BIOL 101 and CHEM 251/255 or permission of instructor

Enrollment Limit: 64

Enrollment Preferences: junior and senior Biology and Chemistry majors and BIMO concentrators

Expected Class Size: 64

Grading: no pass/fail option, no fifth course option

Unit Notes: does not satisfy the distribution requirement for the Biology major; cannot be counted towards the Biology major in addition to BIOL 222

Distributions: (D3) (QFR)

This course is cross-listed and the prefixes carry the following divisional credit:

BIOL 322 (D3) CHEM 322 (D3) BIMO 322 (D3)

Attributes: BIGP Related Courses  BIMO Required Courses

Spring 2020

LEC Section: 01  TBA  Steven J. Swoap

LAB Section: 03  W 1:00 pm - 4:00 pm  Janis E. Bravo

LAB Section: 04  R 1:00 pm - 4:00 pm  Cynthia K. Holland

LAB Section: 02  T 1:00 pm - 4:00 pm  Janis E. Bravo

CHEM 151 (F) Introductory Chemistry (QFR)

This course provides an introduction to chemistry for those students with little or no high school chemistry. Students will be introduced to concepts fundamental to studying matter at the molecular level. Principal topics include introductions to the nature of atoms and molecules, stoichiometry, solubility rules and equilibria, gas laws, chemical equilibrium, acid-base reactions, periodic relationships, chemical bonding, molecular structure, intermolecular forces, oxidation-reduction reactions, and related applications. Laboratory work comprises a system of qualitative analysis and quantitative techniques. The course provides preparation for further study of organic chemistry, biochemistry, physical and inorganic chemistry and is intended for students who are anticipating professional study in chemistry, in related sciences, or in one of the health professions, as well as for those students who are interested in exploring the fundamental ideas of chemistry as part of their general education.

Class Format: lecture, three times per week; laboratory, four hours per week

Requirements/Evaluation: frequent electronic and quantitative written weekly problem set assignments, laboratory work and reports, quizzes, two tests, and a final exam

Extra Info: information about the Chemistry Placement Test can be found at http://chemistry.williams.edu/placement/

Extra Info 2: students who have studied chemistry for one or more years are directed to CHEM 153 or 155

Prerequisites: all students planning to enroll are required to take the online Chemistry Placement Test prior to registering for the course (and
CHEM 151  (F)  Concepts of Chemistry  (QFR)

This course broadens and deepens the foundation in chemistry of students who have had typically one year of chemistry at the high school level. Most students begin study of chemistry at Williams with this course. Familiarity with stoichiometry, basic concepts of equilibria, and the model of an atom is expected. Principal topics for this course include kinetic theory of gases, modern atomic theory, molecular structure and bonding, states of matter, chemical equilibrium (acid-base and solubility), and an introduction to atomic and molecular spectroscopies. Laboratory work includes synthesis, qualitative and quantitative chemical analysis, and molecular modeling. The course is of interest to students who anticipate professional study in chemistry, related sciences, or one of the health professions, as well as to those who want to explore the fundamental ideas of chemistry as part of their general education.

Class Format: lecture, three hours per week; laboratory, four hours per week

Requirements/Evaluation: quantitative weekly problem set assignments, laboratory work and reports, hour tests, and a final exam

Extra Info: information about the Chemistry Placement Test can be found at http://chemistry.williams.edu/placement/

Prerequisites: all students are required to take the online Chemistry Placement Test prior to registering for the course (and incoming first year students are required to meet with a faculty member during First Days)

Enrollment Limit:  16/lab

Enrollment Preferences:  incoming first year students are required to meet with a faculty member during First Days

Expected Class Size:  70

Grading:  no pass/fail option,  no fifth course option

Unit Notes:  one of CHEM 151 or 153 or 155 required for the BIMO concentration

Distributions:  (D3)  (QFR)

Attributes:  BIMO Required Courses

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CHEM 155  (F)  Principles of Modern Chemistry  (QFR)
This course is designed for students with strong preparation in secondary school chemistry, including a laboratory experience, such as provided by an Advanced Placement chemistry course (or equivalent) with a corresponding score of 5 of the AP Chemistry Exam (or a 7 on the IB Exam, or equivalent). Topics include chemical thermodynamics, kinetics, structure and bonding, coordination chemistry, electrochemistry and spectroscopy and their application to fields such as materials science, industrial, environmental, biological, and medicinal chemistry. Laboratory work includes synthesis, characterization, and reactivity of coordination complexes, electrochemical analysis, materials chemistry, qualitative analysis, and molecular modeling. This course is of interest for students who are anticipating professional study in chemistry, related sciences, or one of the health professions, as well as for students who want to explore the fundamental ideas of chemistry as part of their general education.

Class Format: lecture, three hours per week; laboratory, four hours per week

Requirements/Evaluation: weekly problem sets, laboratory work and reports, an hour test, and a final exam

Extra Info: information about the Chemistry Placement Test can be found at http://chemistry.williams.edu/placement/

Prerequisites: students planning to enroll are required to take the Chemistry Placement Survey prior to registering; incoming first year students are required to meet with faculty during First Days; for more information go to http://chemistry.williams.edu/placement/

Enrollment Limit: 16/lab

Enrollment Preferences: CHEM 151 is an introductory course for students with no or little chemistry background. Students who have studied chemistry for one or more years are directed to CHEM 153 or 155

Expected Class Size: 36

Grading: no pass/fail option, no fifth course option

Unit Notes: CHEM 151 may be taken concurrently with MATH 102—see under Mathematics; CHEM 151 or its equivalent is a prerequisite to CHEM 156; one of CHEM 151 or 153 or 155 required for the BIMO concentration

Distributions: (D3) (QFR)

Attributes: BIMO Required Courses

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CHEM 156 (S) Organic Chemistry: Introductory Level (QFR)

This course provides the necessary background in organic chemistry for students who are planning advanced study or a career in chemistry, the biological sciences, or the health professions. It initiates the systematic study of the common classes of organic compounds with emphasis on theories of structure and reactivity. The fundamentals of molecular modeling as applied to organic molecules are presented. Specific topics include basic organic structure and bonding, isomerism, stereochemistry, molecular energetics, the theory and interpretation of infrared and nuclear magnetic spectroscopy, substitution and elimination reactions, and the addition reactions of alkenes and alkynes. The coordinated laboratory work includes purification and separation techniques, structure-reactivity studies, organic synthesis, IR and NMR spectroscopy, and the identification of unknown compounds.

Class Format: lecture, three hours per week; laboratory, four hours per week

Requirements/Evaluation: evaluation will be based on quantitative problem sets, laboratory performance, including written lab reports, three midterm exams, and a final exam

Prerequisites: CHEM 151 or 153 or 155 or placement exam or permission of instructor

Enrollment Limit: 16/lab

Expected Class Size: 120

Grading: no pass/fail option, no fifth course option

Distributions: (D3) (QFR)

Attributes: BIMO Required Courses

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Fall 2019

LAB Section: 03 T 1:00 pm - 5:00 pm
LEC Section: 01 MWF 8:00 am - 8:50 am Enrique Peacock-López
LAB Section: 04 W 1:00 pm - 5:00 pm
LAB Section: 02 M 1:00 pm - 5:00 pm

Spring 2020
CHEM 321  (F)(S)  Biochemistry I: Structure and Function of Biological Molecules  (QFR)

Cross-listings:  CHEM 321  BIMO 321  BIOL 321

Secondary Cross-listing

This course introduces the basic concepts of biochemistry with an emphasis on the structure and function of biological macromolecules. Specifically, the structure of proteins and nucleic acids are examined in detail in order to determine how their chemical properties and their biological behavior result from those structures. Other topics covered include catalysis, enzyme kinetics, mechanism and regulation; the molecular organization of biomembranes; and the flow of information from nucleic acids to proteins. In addition, the principles and applications of the methods used to characterize macromolecules in solution and the interactions between macromolecules are discussed. The laboratory provides a hands-on opportunity to study macromolecules and to learn the fundamental experimental techniques of biochemistry including electrophoresis, chromatography, and principles of enzymatic assays.

Class Format: lecture, three hours per week; laboratory, four hours per week

Requirements/Evaluation: evaluation is based on quizzes, a midterm exam, a final exam, problem sets and performance in the laboratories including lab reports

Prerequisites: BIOL 101 and CHEM 251/255 and CHEM 155/256

Enrollment Limit: 16/lab

Enrollment Preferences: junior and senior Biology and Chemistry majors and BIMO concentrators

Expected Class Size: 16/lab

Grading: no pass/fail option, yes fifth course option

Unit Notes: does not satisfy the distribution requirement for the Biology major

Distributions:  (D3)  (QFR)

This course is cross-listed and the prefixes carry the following divisional credit:
CHEM 321 (D3)  BIMO 321 (D3)  BIOL 321 (D3)

Attributes: BIGP Related Courses  BIMO Required Courses

Fall 2019
LAB Section: 04  W 1:00 pm - 5:00 pm
LAB Section: 03  T 1:00 pm - 5:00 pm
LEC Section: 01  MWF 10:00 am - 10:50 am  Bob Rawle
LAB Section: 02  M 1:00 pm - 5:00 pm  Bob Rawle

Spring 2020
LAB Section: 02  M 1:00 pm - 5:00 pm  Katie M. Hart
LAB Section: 03  T 8:00 am - 12:00 pm
LEC Section: 01  MWF 9:00 am - 9:50 am  Katie M. Hart

CHEM 322  (S)  Biochemistry II: Metabolism  (QFR)
This lecture course provides an in-depth presentation of the complex metabolic reactions which are central to life. Emphasis is placed on the biological flow of energy including alternative modes of energy generation (aerobic, anaerobic, photosynthetic); the regulation and integration of the metabolic pathways including compartmentalization and the transport of metabolites; and biochemical reaction mechanisms including the structures and mechanisms of coenzymes. This comprehensive study also includes the biosynthesis and catabolism of small molecules (carbohydrates, lipids, amino acids, and nucleotides). Laboratory experiments introduce the principles and procedures used to study enzymatic reactions, bioenergetics, and metabolic pathways.

Class Format: lecture, three hours per week; laboratory, three hours per week

Requirements/Evaluation: several exams and performance in the laboratories including lab reports that emphasize conceptual and quantitative and/or graphic analysis of the

Prerequisites: BIOL 101 and CHEM 251/255 or permission of instructor

Enrollment Limit: 64

Enrollment Preferences: junior and senior Biology and Chemistry majors and BIMO concentrators

Expected Class Size: 64

Grading: no pass/fail option, no fifth course option

Unit Notes: does not satisfy the distribution requirement for the Biology major; cannot be counted towards the Biology major in addition to BIOL 222

Distributions: (D3) (QFR)

This course is cross-listed and the prefixes carry the following divisional credit:
BIOL 322 (D3) CHEM 322 (D3) BIMO 322 (D3)

Attributes: BIGP Related Courses BIMO Required Courses
not-switched, sets of LEDs, temperature sensor, vibe board, tri-color LED), alligator test leads, and fabric scissors

**Distributions:** (D3) (QFR)

**Quantitative/Formal Reasoning Notes:** The course will teach students the basics of computer programming through projects in which quantitative/formal reasoning skills are practiced and evaluated.

Fall 2019

LEC Section: 01 TR 9:55 am - 11:10 am Iris Howley

**CSCI 134 (F)(S) Introduction to Computer Science (QFR)**

This course introduces students to the science of computation by exploring the representation and manipulation of data and algorithms. We organize and transform information in order to solve problems using algorithms written in a modern object-oriented language. Topics include organization of data using objects and classes, and the description of processes using conditional control, iteration, methods and classes. We also begin the study of abstraction, self-reference, reuse, and performance analysis. While the choice of programming language and application area will vary in different offerings, the skills students develop will transfer equally well to more advanced study in many areas. In particular, this course is designed to provide the programming skills needed for further study in computer science and is expected to satisfy introductory programming requirements in other departments.

**Class Format:** lecture/laboratory

**Requirements/Evaluation:** weekly assignments, programming projects, and examinations

**Prerequisites:** none, except for the standard prerequisites for a (QFR) course; previous programming experience is not required

**Enrollment Limit:** 90

**Enrollment Preferences:** If the course is over-enrolled, enrollment will be determined by lottery

**Expected Class Size:** 90

**Grading:** yes pass/fail option, yes fifth course option

**Unit Notes:** students with prior experience with object-oriented programming should discuss appropriate course placement with members of the department

**Distributions:** (D3) (QFR)

**Attributes:** BIGP Recommended Courses COGS Interdepartmental Electives

Fall 2019

LEC Section: 02 Cancelled

LAB Section: 08 T 1:00 pm - 4:00 pm Jeannie R Albrecht

LEC Section: 01 MWF 9:00 am - 9:50 am Thomas P. Murtagh

LAB Section: 06 T 1:00 pm - 4:00 pm Thomas P. Murtagh

LAB Section: 07 M 1:00 pm - 4:00 pm Jeannie R Albrecht

LEC Section: 03 MWF 11:00 am - 11:50 am Jeannie R Albrecht

LAB Section: 04 M 1:00 pm - 4:00 pm Thomas P. Murtagh

LAB Section: 05 M 7:00 pm - 10:00 pm Thomas P. Murtagh

Spring 2020

LEC Section: 01 MWF 8:00 am - 8:50 am Andrea Danyluk

LAB Section: 09 T 2:30 pm - 4:00 pm Shikha Singh

LEC Section: 02 MWF 9:00 am - 9:50 am Shikha Singh

LAB Section: 04 M 1:00 pm - 2:30 pm Iris Howley

LAB Section: 05 M 2:30 pm - 4:00 pm Iris Howley

LEC Section: 03 MWF 11:00 am - 11:50 am Iris Howley

LAB Section: 08 T 1:00 pm - 2:30 pm Shikha Singh
CSCI 136 (F)(S) Data Structures and Advanced Programming (QFR)
This course builds on the programming skills acquired in Computer Science 134. It couples work on program design, analysis, and verification with an introduction to the study of data structures. Data structures capture common ways in which to store and manipulate data, and they are important in the construction of sophisticated computer programs. Students are introduced to some of the most important and frequently used data structures: lists, stacks, queues, trees, hash tables, graphs, and files. Students will be expected to write several programs, ranging from very short programs to more elaborate systems. Emphasis will be placed on the development of clear, modular programs that are easy to read, debug, verify, analyze, and modify.

Class Format: lecture/laboratory
Requirements/Evaluation: evaluation will be based on programming assignments, homework and/or examinations
Prerequisites: CSCI 134 or equivalent; fulfilling the Discrete Mathematics Proficiency requirement is recommended, but not required
Enrollment Limit: 60
Enrollment Preferences: If the course is over-enrolled, enrollment will be determined by lottery
Expected Class Size: 60
Grading: yes pass/fail option, yes fifth course option
Distributions: (D3) (QFR)
Attributes: BIGP Recommended Courses

Fall 2019
LAB Section: 04  W 2:00 pm - 4:00 pm  William J. Lenhart
LAB Section: 05  W 12:00 pm - 2:00 pm  Samuel McCauley
LAB Section: 03  W 12:00 pm - 2:00 pm  William J. Lenhart
LEC Section: 01  MWF 9:00 am - 9:50 am  William J. Lenhart
LAB Section: 06  W 2:00 pm - 4:00 pm  Samuel McCauley
LEC Section: 02  MWF 10:00 am - 10:50 am  Samuel McCauley

Spring 2020
LEC Section: 02  MWF 10:00 am - 10:50 am  Bill K. Jannen
LAB Section: 03  W 12:00 pm - 2:00 pm  Daniel W. Barowy
LAB Section: 04  W 2:00 pm - 4:00 pm  Daniel W. Barowy
LAB Section: 05  W 12:00 pm - 2:00 pm  Bill K. Jannen
LAB Section: 06  W 2:00 pm - 4:00 pm  Bill K. Jannen
LEC Section: 01  MWF 9:00 am - 9:50 am  Daniel W. Barowy

CSCI 237 (F)(S) Computer Organization (QFR)
This course studies the basic instruction set architecture and organization of a modern computer. It provides a programmer's view of how computer systems execute programs, store information, and communicate. Over the semester the student learns the fundamentals of translating higher level languages into assembly language, and the interpretation of machine languages by hardware. At the same time, a model of computer hardware organization is developed from the gate level upward.

Class Format: lecture/laboratory
Requirements/Evaluation: evaluation will be based primarily on projects, and one or more exams
Prerequisites: CSCI 134, or both experience in programming and permission of instructor
Enrollment Limit: 12 per lab
Enrollment Preferences: current or expected Computer Science majors
**Expected Class Size:** 12 per lab

**Grading:** no pass/fail option, no fifth course option

**Distributions:** (D3) (QFR)

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**CSCI 256 (F)(S) Algorithm Design and Analysis** (QFR)

This course investigates methods for designing efficient and reliable algorithms. By carefully analyzing the structure of a problem within a mathematical framework, it is often possible to dramatically decrease the computational resources needed to find a solution. In addition, analysis provides a method for verifying the correctness of an algorithm and accurately estimating its running time and space requirements. We will study several algorithm design strategies that build on data structures and programming techniques introduced in Computer Science 136. These include induction, divide-and-conquer, dynamic programming, and greedy algorithms. Additional topics of study include algorithms on graphs and strategies for handling potentially intractable problems.

**Class Format:** lecture

**Requirements/Evaluation:** evaluation will be based on problem sets and programming assignments, and midterm and final examinations

**Prerequisites:** CSCI 136 and fulfillment of the Discrete Mathematics Proficiency requirement

**Enrollment Limit:** 24/sect

**Enrollment Preferences:** current or expected Computer Science majors

**Expected Class Size:** 24/sect

**Grading:** no pass/fail option, no fifth course option

**Distributions:** (D3) (QFR)

**Attributes:** BIGP Recommended Courses

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**CSCI 315 (S) Computational Biology** (QFR)

**Cross-listings:** PHYS 315, CSCI 315

**Secondary Cross-listing**

This course will provide an overview of Computational Biology, the application of computational, mathematical, statistical, and physical problem-solving techniques to interpret the rapidly expanding amount of biological data. Topics covered will include database searching, DNA sequence alignment, clustering, RNA structure prediction, protein structural alignment, methods of analyzing gene expression, networks, and genome
assembly using techniques such as string matching, dynamic programming, hidden Markov models, and expectation-maximization.

Class Format: lab three hours per week plus weekly tutorial meeting

Requirements/Evaluation: evaluation will be based on weekly Python programming assignments, problem sets, a few quizzes and a final project

Prerequisites: programming experience (e.g., CSCI 136), mathematics (PHYS/MATH 210 or MATH 150), and physical science (PHYS 142 or 151, or CHEM 151 or 153 or 155), or permission of instructor

Enrollment Limit: 10

Enrollment Preferences: based on seniority

Expected Class Size: 8

Grading: no pass/fail option, no fifth course option

Distributions: (D3) (QFR)

This course is cross-listed and the prefixes carry the following divisional credit:

PHYS 315 (D3) CSCI 315 (D3)

Attributes: BIGP Recommended Courses

Spring 2020

LAB Section: T2  M 1:10 pm - 3:50 pm  Daniel P. Aalberts

TUT Section: T1  TBA  Daniel P. Aalberts

CSCI 326 (S) Software Methods (QFR)
Sophisticated software systems play a prominent role in many aspects of our lives, and while programming can be a very creative and exciting process, building a reliable software system of any size is no easy feat. Moreover, the ultimate outcome of any programming endeavor is likely to be incomplete, unreliable, and unmaintainable unless principled methods for software construction are followed. This course explores those methods.

Specific topics include: software processes; specifying requirements and verifying correctness; abstractions; design principles; software architectures; concurrent and scalable systems design; testing and debugging; and performance evaluation.

Class Format: lecture/lab

Requirements/Evaluation: homework, programming assignments, group work, presentations, exams

Prerequisites: CSCI 136, and at least one of CSCI 237, 256, or 334

Enrollment Limit: 24

Enrollment Preferences: current or expected Computer Science majors

Expected Class Size: 24

Grading: no pass/fail option, no fifth course option

Distributions: (D3) (QFR)

Spring 2020

LAB Section: 02  R 1:10 pm - 3:50 pm  Stephen N. Freund

LEC Section: 01  TR 9:55 am - 11:10 am  Stephen N. Freund

CSCI 331 (F) Introduction to Computer Security (QFR)
This class explores common vulnerabilities in computer systems, how attackers exploit them, and how systems engineers design defenses to mitigate them. The goal is to be able to recognize potential vulnerabilities in one's own software and to practice defensive design. Hands-on experience writing C/C++ code to inspect and modify the low-level operation of running programs is emphasized. Finally, regular reading and writing assignments round out the course to help students understand the cultural and historical background of the computer security "arms race."

Class Format: lecture

Requirements/Evaluation: assignments, midterm exam, and final exam

Prerequisites: CSCI 136 and CSCI 237
Enrollment Limit: 24
Enrollment Preferences: upper-level students
Expected Class Size: 24
Grading: no pass/fail option, no fifth course option
Distributions: (D3) (QFR)

Fall 2019
LEC Section: 01    TR 11:20 am - 12:35 pm     Daniel W. Barowy

CSCI 333  (S)  Storage Systems  (QFR)
This course will examine topics in the design, implementation, and evaluation of storage systems. Topics include the memory hierarchy; ways that data is organized (both logically and physically); storage hardware and its influence on storage software designs; data structures; performance models; and system measurement/evaluation. Readings will be taken from recent technical literature, and an emphasis will be placed on identifying and evaluating design trade-offs.

Class Format: lecture/lab
Requirements/Evaluation: problem sets, programming assignments, and midterm and final examinations
Prerequisites: CSCI 136; CSCI 237 or permission of instructor
Enrollment Limit: 24
Enrollment Preferences: current Computer Science majors, students with research experience or interest
Expected Class Size: 24
Grading: no pass/fail option, no fifth course option
Distributions: (D3) (QFR)
Quantative/Formal Reasoning Notes: This course will have students develop quantitative/formal reasoning skills through problem sets and programming assignments.

Spring 2020
LEC Section: 01    MR 2:35 pm - 3:50 pm     Bill K. Jannen

CSCI 334  (F)(S)  Principles of Programming Languages  (QFR)
This course examines the concepts and structures governing the design and implementation of programming languages. It presents an introduction to the concepts behind compilers and run-time representations of programming languages; features of programming languages supporting abstraction and polymorphism; and the procedural, functional, object-oriented, and concurrent programming paradigms. Programs will be required in languages illustrating each of these paradigms.

Class Format: lecture
Requirements/Evaluation: evaluation will be based on weekly problem sets and programming assignments, a midterm examination and a final examination
Prerequisites: CSCI 136
Enrollment Limit: 30
Enrollment Preferences: current or expected Computer Science majors
Expected Class Size: 30
Grading: no pass/fail option, no fifth course option
Distributions: (D3) (QFR)

Fall 2019
LEC Section: 01    TR 9:55 am - 11:10 am     Stephen N. Freund
CSCI 338  (F)  Parallel Processing  (QFR)
This course explores different parallel programming paradigms used for writing applications on today’s parallel computer systems. The course will introduce concurrency (i.e. multiple simultaneous computations) and the synchronization primitives that allow for the creation of correct concurrent applications. It will examine how a variety of systems organize parallel processing resources and enable users to write parallel programs for these systems. Covered programming paradigms will include multiprogramming with processes, message passing, threading in shared memory multiprocessors, vector processing, graphics processor programming, transactions, MapReduce, and other forms of programming for the cloud. Class discussion is based on assigned readings. Assignments provide students the opportunity to develop proficiency in writing software using different parallel programming paradigms.

Class Format: lecture/laboratory
Requirements/Evaluation: homework assignments, programming projects, and exams
Prerequisites: CSCI 136 or equivalent programming experience, and CSCI 237, or permission of instructor
Enrollment Limit: 24
Enrollment Preferences: current or expected Computer Science majors
Expected Class Size: 24
Grading: no pass/fail option, no fifth course option
Distributions: (D3) (QFR)
Quantitative/Formal Reasoning Notes: The course will consist of substantial problem sets and programming assignments in which quantitative/formal reasoning skills are practiced and evaluated.

Fall 2019
LEC Section: 01  MR 1:10 pm - 2:25 pm     Kelly A. Shaw

CSCI 339  (S)  Distributed Systems  (QFR)
This course studies the key design principles of distributed systems, which are collections of independent networked computers that function as single coherent systems. Covered topics include communication protocols, processes and threads, naming, synchronization, consistency and replication, fault tolerance, and security. Students also examine some specific real-world distributed systems case studies, including Google and Amazon. Class discussion is based on readings from the textbook and research papers. The goals of this course are to understand how large-scale computational systems are built, and to provide students with the tools necessary to evaluate new technologies after the course ends.

Class Format: lecture/laboratory
Requirements/Evaluation: evaluation will be based on homework assignments, programming projects, and exams
Prerequisites: CSCI 136 or equivalent programming experience, and CSCI 237, or permission of instructor
Enrollment Limit: 24
Enrollment Preferences: current or expected Computer Science majors
Expected Class Size: 24
Grading: no pass/fail option, no fifth course option
Distributions: (D3) (QFR)

Spring 2020
LEC Section: 01  MR 1:10 pm - 2:25 pm     Jeannie R Albrecht

CSCI 343  (F)  Application Development with Functional Programming  (QFR)
This course will enrich the participants on how functional programming can reduce unintended complexity and create code bases that are simpler to maintain and reason about. Functional programming is a paradigm, which focuses on values and pure functions rather than mutable objects and
imperative statements. Since good code design is intersubjective, we need to be open-minded and continuously reflect upon the decisions we make. Together we will reflect on the design choices made and the dilemmas that will arise. We will learn that there are often multiple solutions, each often having their benefits and drawbacks. By gaining experience, we will acquire empirical knowledge, intuition and sensors for avoiding unintended complexity, creating appropriate abstractions and a sustainable code base. Class will consist of a lot of live coding, code-reviews and a dialog on how we can improve our architectural design and knowledge. Topics include code quality, readability, maintainability, collaboration, version control system (git), global state, dependencies, pure functions, persistent data structures, data consistency, single source of truth (SSOT), reactive programming, web development, functional programming and comparison with object oriented programming, designing for testability, documentation, state management, atomic updates, concurrency, dynamic types, DSLs, lisp and REPL. The concepts are not limited to a specific programming language. We will use Clojure and ClojureScript to realize the ideas in the specific project. Hence, also rigorous abilities in lisp, repl workflow and Clojure/ClojureScript will be an outcome of the course. For each week there will be a video talk from programming conferences that will serve as inspiration and give us the opportunity to reflect. The videos will be posted when the course starts.

**Class Format:** lecture

**Requirements/Evaluation:** a semester-long programming project, and midterm and final presentations

**Prerequisites:** CSCI 136, and at least one of CSCI 237, 256, or 334

**Enrollment Limit:** 24

**Enrollment Preferences:** current or expected Computer Science majors

**Expected Class Size:** 24

**Grading:** no pass/fail option, no fifth course option

**Distributions:** (D3) (QFR)

**Quantative/Formal Reasoning Notes:** The course will involve a programming project that emphasizes quantitative/formal reasoning skills.

Fall 2019

LEC Section: 01  TF 1:10 pm - 2:25 pm  Tomas Ekholm

**CSCI 356 (F) Advanced Algorithms** (QFR)

This course explores advanced concepts in algorithm design, algorithm analysis and data structures. Areas of focus will include algorithmic complexity, randomized and approximation algorithms, geometric algorithms, and advanced data structures. Topics will include combinatorial algorithms for packing, and covering problems, algorithms for proximity and visibility problems, linear programming algorithms, approximation schemes, hardness of approximation, search, and hashing.

**Class Format:** This class will follow the meeting structure of a tutorial, with groups of three or four

**Requirements/Evaluation:** evaluation is based on weekly problem sets, several small programming projects, weekly paper summaries, and a small, final project

**Prerequisites:** CSCI 256; CSCI 361 is recommended but not required

**Enrollment Limit:** 10

**Enrollment Preferences:** current or expected Computer Science majors

**Expected Class Size:** 10

**Grading:** no pass/fail option, no fifth course option

**Distributions:** (D3) (QFR)

Fall 2019

TUT Section: T1  TBA  William J. Lenhart

**CSCI 358 (S) Applied Algorithms** (QFR)

This course is about bridging the gap between theoretical running time and writing fast code in practice. The course is divided into two basic topics. The first is algorithmic: we will discuss some of the most useful tools in a coder's toolkit. This includes topics like randomization (hashing, filters, approximate counters), linear and convex programming, similarity search, and cache-efficient algorithms. Our goal is to talk about why these efficient algorithms make seemingly difficult problems solvable in practice. The second topic is applications: we will discuss how to implement algorithms in an
efficient way that takes advantage of modern hardware. Specific topics covered will include blocking, loop unrolling, pipelining, as well as strategies for performance analysis. Projects and assessments will include both basic theoretical aspects (understanding why the algorithms we discuss actually work), and practical aspects (implementing the algorithms we discuss to solve important problems, and optimizing the code so it runs as quickly as possible).

**Class Format:** Lecture

**Requirements/Evaluation:** primary evaluation is a course-long project and written final exam, in addition to shorter programming assignments and problem sets

**Prerequisites:** CSCI 256 or permission of instructor

**Enrollment Limit:** 24

**Enrollment Preferences:** current or expected Computer Science majors

**Expected Class Size:** 24

**Grading:** no pass/fail option, no fifth course option

**Distributions:** (D3) (QFR)

**Quantitative/Formal Reasoning Notes:** The course will consist of programming assignments and problem sets in which quantitative/formal reasoning skills are practiced and evaluated.

Spring 2020

LEC Section: 01  TR 11:20 am - 12:35 pm  Samuel McCauley

**CSCI 361 (F)(S) Theory of Computation (QFR)**

**Cross-listings:** CSCI 361  MATH 361

**Primary Cross-listing**

This course introduces a formal framework for investigating both the computability and complexity of problems. We study several models of computation including finite automata, regular languages, context-free grammars, and Turing machines. These models provide a mathematical basis for the study of computability theory--the examination of what problems can be solved and what problems cannot be solved--and the study of complexity theory--the examination of how efficiently problems can be solved. Topics include the halting problem and the P versus NP problem.

**Class Format:** lecture

**Requirements/Evaluation:** evaluation will be based on problem sets, a midterm examination, and a final examination

**Prerequisites:** CSCI 256 or both a 300-level MATH course and permission of instructor

**Enrollment Limit:** 30

**Enrollment Preferences:** current or expected Computer Science majors

**Expected Class Size:** 30

**Grading:** no pass/fail option, no fifth course option

**Distributions:** (D3) (QFR)

**This course is cross-listed and the prefixes carry the following divisional credit:**

CSCI 361 (D3) MATH 361 (D3)

**Attributes:** COGS Interdepartmental Electives

Fall 2019

LEC Section: 01  MWF 11:00 am - 11:50 am  Aaron M. Williams

Spring 2020

LEC Section: 01  MWF 12:00 pm - 12:50 pm  Thomas P. Murtagh

**CSCI 374 (S) Machine Learning (QFR)**

This tutorial examines the design, implementation, and analysis of machine learning algorithms. Machine Learning is a branch of Artificial Intelligence that aims to develop algorithms that will improve a system’s performance. Improvement might involve acquiring new factual knowledge from data,
learning to perform a new task, or learning to perform an old task more efficiently or effectively. This tutorial will cover examples of supervised learning algorithms (including decision tree learning, support vector machines, and neural networks), unsupervised learning algorithms (including k-means and expectation maximization), and possibly reinforcement learning algorithms (such as Q learning and temporal difference learning). It will also introduce methods for the evaluation of learning algorithms, as well as topics in computational learning theory.

**Class Format:** This class will follow the meeting structure of a tutorial, with groups of three or four

**Requirements/Evaluation:** evaluation will be based on presentations, problem sets, programming exercises, empirical analyses of algorithms, critical analysis of current literature

**Prerequisites:** CSCI 136 and CSCI 256 or permission of instructor

**Enrollment Limit:** 10

**Enrollment Preferences:** Computer Science majors

**Expected Class Size:** 10

**Grading:** no pass/fail option, no fifth course option

**Distributions:** (D3) (QFR)

**Attributes:** COGS Interdepartmental Electives

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**ECON 110 (F)(S) Principles of Microeconomics (QFR)**

This course is an introduction to the study of the forces of supply and demand that determine prices and the allocation of resources in markets for goods and services, markets for labor, and markets for natural resources. The focus is on how and why markets work, why they may fail to work, and the policy implications of both their successes and failures. The course focuses on developing the basic tools of microeconomic analysis and then applying those tools to topics of popular or policy interest such as minimum wage legislation, pollution control, competition policy, international trade policy, discrimination, tax policy, and the role of government in a market economy.

**Class Format:** lecture/discussion

**Requirements/Evaluation:** problem sets, quizzes, short essays, two midterms (one for Bradburd's sections), final exam

**Extra Info:** this course is required of Economics and Political Economy majors and highly recommended for those non-majors interested in Environmental Studies and Women's, Gender and Sexuality Studies

**Extra Info 2:** Prof. Bradburd's section ONLY: intends to use the issue of environmental protection in general, and climate change in particular, as the vehicle for presenting and applying many, though not all, of the economic concepts and tools developed in the course

**Prerequisites:** none

**Enrollment Limit:** 40

**Expected Class Size:** 40

**Grading:** yes pass/fail option, no fifth course option

**Unit Notes:** the department recommends students follow this course with ECON 120 or with a lower-level elective that has ECON 110 as its prerequisite; students may alternatively proceed directly to ECON 251 after taking this introductory course

**Distributions:** (D2) (QFR)

**Attributes:** POEC Required Courses

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**Fall 2019**

LEC Section: 03  TR 8:30 am - 9:45 am  Susan Godlonton

LEC Section: 04  TR 9:55 am - 11:10 am  Susan Godlonton

LEC Section: 05  TR 11:20 am - 12:35 pm  Owen Thompson

LEC Section: 01  MR 1:10 pm - 2:25 pm  Ralph M. Bradburd

LEC Section: 02  MR 2:35 pm - 3:50 pm  Ralph M. Bradburd

LEC Section: 06  TF 1:10 pm - 2:25 pm  Owen Thompson
ECON 120  (F)(S)  Principles of Macroeconomics  (QFR)
This course provides an introduction to the study of the aggregate national economy. It develops the basic theories of macroeconomics and applies them to topics of current interest. Issues to be explored include: the causes of inflation, unemployment, recessions, and depressions; the role of government fiscal and monetary policy in stabilizing the economy; the determinants of long-run economic growth; the long- and short-run effects of taxes, budget deficits, and other government policies on the national economy; the role of financial frictions in amplifying recessions; and the workings of exchange rates and international finance.

Class Format: lecture/discussion

Requirements/Evaluation: problem sets, short essays, midterm, final exam

Prerequisites: ECON 110

Enrollment Limit: 40

Expected Class Size: 40

Grading: yes pass/fail option, yes fifth course option

Distributions: (D2) (QFR)

Attributes: POEC Required Courses

ECON 213  (S)  Introduction to Environmental and Natural Resource Economics  (QFR)

Cross-listings: ENVI 213  ECON 213

Primary Cross-listing

We'll use economics to learn why we harm the environment and overuse natural resources, and what we can do about it. We'll talk about whether and how we can put a dollar value on nature and ecosystem services. We'll study cost benefit analysis, pollution in general, climate change, natural resources (like fisheries, forests, and fossil fuels), and energy. We will take an economic approach to global sustainability, and study the relationship between the environment and economic growth and trade.

Class Format: lecture

Requirements/Evaluation: problem sets, short essays, paper(s); exam(s) are possible

Prerequisites: ECON 110

Enrollment Limit: 30

Enrollment Preferences: first-year and sophomore students

Expected Class Size: 30

Grading: yes pass/fail option, yes fifth course option

Unit Notes: this course will count toward both the Environmental Studies major and concentration

Distributions: (D2) (QFR)
This course is cross-listed and the prefixes carry the following divisional credit:
ENVI 213 (D2) ECON 213 (D2)

Attributes: ENVI Environmental Policy  EVST Social Science/Policy  POEC Comparative  POEC/Public Policy Courses

Spring 2020
LEC Section: 01  MWF 8:30 am - 9:45 am  Sarah A. Jacobson

**ECON 251 (F)(S) Price and Allocation Theory (QFR)**
A study of the determination of relative prices and their importance in shaping the allocation of resources and the distribution of income. Subjects include: behavior of households in a variety of settings, such as buying goods and services, saving, and labor supply; behavior of firms in various kinds of markets; results of competitive and noncompetitive markets in goods, labor, land, and capital; market failure; government policies as sources of and responses to market failure; welfare criteria; limitations of mainstream analysis.

**Class Format:** lecture

**Requirements/Evaluation:** weekly problem sets, one or more quizzes, one or two midterms, one or two short essays, and a final exam

**Prerequisites:** ECON 110 and MATH 130 or its equivalent

**Enrollment Limit:** 30

**Expected Class Size:** 25

**Grading:** yes pass/fail option, yes fifth course option

**Distributions:** (D2) (QFR)

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Fall 2019
LEC Section: 01  MWF 8:30 am - 9:45 am  Sarah A. Jacobson
LEC Section: 04  TF 2:35 pm - 3:50 pm  Ashok S. Rai
LEC Section: 03  TF 1:10 pm - 2:25 pm  Ashok S. Rai
LEC Section: 02  MW 11:00 am - 12:15 pm  Sarah A. Jacobson

Spring 2020
LEC Section: 02  TF 2:35 pm - 3:50 pm  Stephen C. Sheppard
LEC Section: 01  TF 1:10 pm - 2:25 pm  Stephen C. Sheppard

**ECON 252 (F)(S) Macroeconomics (QFR)**
A study of aggregate economic activity: output, employment, inflation, and interest rates. The class will develop a theoretical framework for analyzing economic growth and business cycles. The theory will be used to evaluate policies designed to promote growth and stability, and to understand economic developments in the U.S. and abroad. Instructors may use elementary calculus in assigned readings, exams and lectures.

**Class Format:** lecture/discussion

**Requirements/Evaluation:** problem sets and/or written assignments, midterm(s), and a final exam

**Prerequisites:** ECON 110 and 120 and MATH 130 or its equivalent

**Enrollment Limit:** 30

**Expected Class Size:** 25

**Grading:** no pass/fail option, no fifth course option

**Distributions:** (D2) (QFR)

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Fall 2019
LEC Section: 01  MW 11:00 am - 12:15 pm  Peter J. Montiel
LEC Section: 02  TF 2:35 pm - 3:50 pm  Peter L. Pedroni

Spring 2020
ECON 255  (F)(S)  Econometrics  (QFR)
An introduction to the theory and practice of applied quantitative economic analysis. This course familiarizes students with the strengths and weaknesses of the basic empirical methods used by economists to evaluate economic theory against economic data. Emphasizes both the statistical foundations of regression techniques and the practical application of those techniques in empirical research. Computer exercises will provide experience in using the empirical methods, but no previous computer experience is expected. Highly recommended for students considering graduate training in economics or public policy.

Class Format: lecture

Requirements/Evaluation: problem sets, two exams, group project, and possible additional assignments

Prerequisites: MATH 130, plus STAT 161, 201 or 202 (or equivalent), plus one course in ECON; STAT 101 will also serve as a prerequisite, but only if taken prior to the fall of 2018

Enrollment Limit: 30

Expected Class Size: 30

Grading: no pass/fail option, no fifth course option

Unit Notes: students may substitute the combination of STAT 201 and 346 for ECON 255

Distributions: (D2)  (QFR)

Attributes: EVST Methods Courses  PHLH Statistics Courses  POEC Required Courses
**Requirements/Evaluation:** extensive class participation, two short (5-page) papers, two 15-page team papers comprising a country growth diagnostic, and a team presentation on the diagnostic

**Prerequisites:** for undergraduates ECON 251, ECON 252, and either ECON 255 or STAT 346

**Enrollment Limit:** 19

**Enrollment Preferences:** CDE fellows and senior Economics majors

**Expected Class Size:** 19

**Grading:** no pass/fail option, no fifth course option

**Distributions:** (D2) (QFR)

**This course is cross-listed and the prefixes carry the following divisional credit:**
ECON 545 (D2) ECON 345 (D2)

**Quantitative/Formal Reasoning Notes:** The course material will draw heavily on mathematical and statistical models of economic growth and macroeconomic development, and students will be required to routinely develop mathematical models and/or conduct econometric analysis in their assignments.

Spring 2020

SEM Section: 01    TR 11:20 am - 12:35 pm     Quamrul H. Ashraf

**ECON 371 (F) Time Series Econometrics and Empirical Methods for Macro (QFR)**
Econometric methods in many fields including macro and monetary economics, finance and international growth and development, as well as numerous fields beyond economics, have evolved a distinct set of techniques which are designed to meet the practical challenges posed by the typical empirical questions and available time series data of these fields. The course will begin with an introductory review of concepts of estimation and inference for large data samples in the context of the challenges of multivariate endogeneous systems, and will then focus on associated methods for analysis of short dynamics such as vector autoregressive techniques and methods for analysis of long run dynamics such as cointegration techniques. Students will be introduced to concepts and techniques analytically, but also by intuition, learning by doing, and by computer simulation and illustration. The course is particularly well suited for economics majors wishing to explore advanced empirical methods, or for statistics, mathematics or computer science majors wishing to learn more about the ways in which the subject of their majors interacts with the fields of economics. The method of evaluation will include a term paper. ECON 252 and either STATS 346 or ECON 255 are formal prerequisites, although for students with exceptionally strong math/stats backgrounds these can be waived subject to instructor permission. Credit may not be earned for both ECON 371 and ECON 356.

**Class Format:** seminar

**Requirements/Evaluation:** term paper and regular homework assignments

**Prerequisites:** ECON 252 and either ECON 255 or STATS 346

**Enrollment Limit:** 19

**Enrollment Preferences:** students wishing to write an honors thesis, and students with strong MATH/STAT/CSCI backgrounds

**Expected Class Size:** 19

**Grading:** no pass/fail option, yes fifth course option

**Distributions:** (D2) (QFR)

**Quantitative/Formal Reasoning Notes:** Uses quantitative/formal reasoning intensively in the form of mathematical and statistical arguments, as well as computer programming.

Fall 2019

SEM Section: 01    TF 1:10 pm - 2:25 pm     Peter L. Pedroni

**ECON 378 (F) Long-Run Perspectives on Economic Growth (QFR)**
The world today is marred by vast differences in the standard of living, with about a 30-fold difference in per-capita incomes between the poorest country and the most affluent. What explanations do long-run growth economists have to offer for these differences in levels of prosperity across nations? Are the explanations to be found in underlying differences between countries over the past few decades, the past few centuries, or the past
few millennia? If contemporary differences in living standards have "deep" historically-rooted origins, what scope exists for policies to reduce global inequality today? Can we expect global inequality to be reduced gradually over time, through natural processes of economic development, or are they likely to persist unless action is taken to reduce them? This course will present a unified theory of economic growth for thinking about these and related questions. Examples of issues to be covered include: the Neoclassical growth model and its inefficacy for answering questions about development over long time horizons; Malthusian stagnation across societies during the pre-industrial stage of economic development; the importance of the so-called demographic transition and of human capital formation in the course of industrialization; the persistent influence of colonialism, slavery, and ethnic fragmentation in shaping the quality of contemporary politico-economic institutions; and the long-lasting effects of geography on comparative development, through its impact on the emergence of agriculture in early human societies and its influence in shaping the genetic composition of human populations across the globe.

**Class Format:** lecture/discussion

**Requirements/Evaluation:** at least one exam, a research paper and a class presentation

**Prerequisites:** ECON 251, ECON 252, and either ECON 255 or STAT 346

**Enrollment Limit:** 25

**Enrollment Preferences:** junior and senior Economics majors

**Expected Class Size:** 25

**Grading:** no pass/fail option, no fifth course option

**Distributions:** (D2) (QFR)

**Attributes:** POEC Comparative POEC/Public Policy Courses

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Fall 2019

LEC Section: 01 TR 11:20 am - 12:35 pm Quamrul H. Ashraf

**ECON 379 (S) Program Evaluation for International Development** (QFR)

**Cross-listings:** ECON 379 ECON 523

**Secondary Cross-listing**

Development organizations face strict competition for scarce resources. Both public and private organizations are under increasing pressure to use rigorous program evaluation in order to justify funding for their programs and to design more effective programs. This course is an introduction to evaluation methodology and the tools available to development practitioners, drawing on examples from developing countries. It will cover a wide range of evaluation techniques and discuss the advantages and disadvantages of each. The course is a mix of applied econometrics and practical applications covering implementation, analysis, and interpretation. You will learn to be a critical reader of evaluations, and to develop your own plan to evaluate an existing program of your choice.

**Class Format:** seminar

**Requirements/Evaluation:** problem sets, midterm exam and one 7- to 10-page essay

**Prerequisites:** one public economics course or microeconomics course (ECON 504 or ECON 110), and one empirical methods course (POEC 253 or ECON 255, 502, or 503)

**Enrollment Limit:** 20

**Enrollment Preferences:** CDE Students, but undergraduates with the prerequisites are welcome

**Expected Class Size:** 20

**Grading:** no pass/fail option, yes fifth course option

**Distributions:** (D2) (QFR)

This course is cross-listed and the prefixes carry the following divisional credit:

ECON 379 (D2) ECON 523 (D2)

**Attributes:** PHLH Methods in Public Health POEC Comparative POEC/Public Policy Courses

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Spring 2020

SEM Section: 01 MR 2:35 pm - 3:50 pm Susan Godlonton
ECON 385 (S) Games and Information  (QFR)
This course is a mathematical introduction to strategic thinking and its applications. Ideas such as Nash equilibrium, commitment, credibility, repeated games, incentives and signaling are discussed. Examples are drawn from economics, politics, history and everyday campus life.

Class Format: lecture/discussion

Requirements/Evaluation: exams, problem sets and a substantial final project that involves modeling a real world situation as a game

Extra Info: students who have taken MATH 335 cannot receive credit for this class

Prerequisites: ECON 251 and MATH 150, or permission of instructor

Enrollment Limit: 25

Enrollment Preferences: juniors and seniors

Expected Class Size: 25

Grading: no pass/fail option, yes fifth course option

Distributions: (D2) (QFR)

Spring 2020
LEC Section: 01    TR 11:20 am - 12:35 pm    Ashok S. Rai

ECON 389 (S) Tax Policy in Global Perspective  (QFR)

Cross-listings: ECON 389 ECON 514

Secondary Cross-listing

Taxes are half of what government does. So if you are interested in what government policy can do to promote efficiency, equity, and economic development, you should be interested in tax policy. Governments must raise tax revenue to finance critical public goods, address other market failures and distributional issues, and to avoid problems with debt and inflation. Taxes typically take up anywhere from ten to fifty percent of a country's income, they profoundly affect the incentives to undertake all varieties of economic activity, and the government expenditures that they finance have potentially large consequences for human welfare. So the stakes involved in improving tax policy are quite large. This class provides an in-depth exploration of tax policy, from a global and comparative perspective. Because most students in this class will be CDE fellows, we will emphasize tax policy issues, examples, and evidence that are most pertinent to developing countries, but we will also learn something about tax systems in the U.S. and other industrialized nations. Topics addressed in this class include: how basic economic principles can be applied to help one think about the efficiency and equity consequences of tax policies; how personal income taxes, corporate income taxes, and value-added taxes are designed and administered and how they influence the economy; ideas for fundamental reforms of these taxes; theory and evidence in the debate over progressive taxes versus "flat" taxes; how various elements of tax design affect incentives to save and invest; how market failures and administrative problems may influence the optimality of different tax policies; the implications of global capital flows and corporate tax avoidance for the design of tax policy; tax holidays and other special tax incentives for investment; empirical evidence on the influence of taxes on economic growth, foreign direct investment, labor supply, and tax evasion; tax policy towards natural resources such as minerals and oil; case studies of efforts to reform tax administration and reduce tax evasion and corruption; taxes on land and property; taxes on imports and exports; presumptive taxation; and the informal economy and its implications for tax policy.

Class Format: seminar

Requirements/Evaluation: midterm exam, 4 problem sets, two 8-page essays

Prerequisites: one public economics course or microeconomics course (ECON 504 or ECON 110), and one empirical methods course (POEC 253 or ECON 255, 502, or 503); students who have previously taken ECON 351 will not be enrolled

Enrollment Limit: 19

Enrollment Preferences: CDE students, but undergraduates with the prerequisites are welcome

Expected Class Size: 15-19

Grading: yes pass/fail option, yes fifth course option

Distributions: (D2) (QFR)

This course is cross-listed and the prefixes carry the following divisional credit:

ECON 389 (D2) ECON 514 (D2)

Attributes: POEC Comparative POEC/Public Policy Courses  POEC International Political Economy Courses
ECON 453 (S) Research in Labor Economics and Policy (QFR)
The labor market plays a crucial role in people's lives worldwide. In industrialized countries, most households contain at least one wage earner, and income from working represents the largest component of total income. Thus analyses of the labor market are fundamentally relevant to both public policy and private decision-making. This seminar will explore the structure and functioning of the labor market using theoretical and empirical tools. Topics to be covered include labor supply and demand, minimum wages, labor market effects of social insurance and welfare programs, the collective bargaining relationship, discrimination, human capital, immigration, wage distribution, and unemployment. As labor economics is an intensely empirical subfield, students will be expected to analyze data as well as study the empirical work of others.

Class Format: seminar
Requirements/Evaluation: a series of short papers and empirical exercises, constructive contributions to class discussion, class presentations, and a 15- to 20-page original empirical research paper (written in stages)
Prerequisites: ECON 251 and ECON 255 or POEC 253
Enrollment Limit: 19
Enrollment Preferences: senior Economics majors
Expected Class Size: 19
Grading: no pass/fail option, no fifth course option
Distributions: (D2) (QFR)
Attributes: POEC Comparative POEC/Public Policy Courses

ECON 459 (S) Economics of Institutions (QFR)
Why are some countries so rich and others so poor? Typical answers to this question have emphasized proximate causes like factor accumulation (i.e., growth in a nation's physical and human capital endowments), technological progress, and demographic change. The institutional approach to this question, however, emphasizes the role of sociopolitical and cultural factors, broadly defined, as a fundamental determinant of its economic prosperity. The central idea is that the added-value of economic activities to society at large is primarily conditioned by the social arrangements within which these activities occur. Specifically, these social arrangements invariably generate a structure of private incentives, which can either promote behavior that is conducive to economic development or lead to the pursuit of private gain at the expense of the common good. As such, the key to economic development in this view is the establishment of a suitable set of institutions and structures of governance in society. This course will survey the rapidly expanding literature on the topic of institutions and economic development, with an emphasis on the latest empirical evidence that has come to bear in the context of both historical and contemporary societies. The purpose of the course will be to expose students to the core ideas and empirical tools employed at the frontier of research in this area of inquiry. The readings will primarily comprise published journal articles and unpublished working papers, and students should expect to apply concepts from across all the core courses in economics.

Class Format: seminar
Requirements/Evaluation: extensive class participation, two 5-page review papers, two class presentations, and one 15- to 20-page empirical research paper (written in stages)
Prerequisites: ECON 251, ECON 252, and either ECON 255 or STAT 346
Enrollment Limit: 19
Enrollment Preferences: senior Economics majors
Expected Class Size: 19
Grading: no pass/fail option, no fifth course option
Distributions: (D2) (QFR)
ECON 471 (S) Topics in Advanced Econometrics (QFR)
The course uses both a practical and conceptual/theory based approach, with emphasis on methods of structural identification of dynamics in VARs and cointegration analysis, both in conventional time series and panel time series which contain spatial dimensions. The course will also investigate methods of computer simulation related to these techniques. The course is well suited for students considering empirically oriented honors theses in fields that employ these techniques, such as macro, finance, growth, trade and development, as well as fields outside of economics that use time series data. It is also well suited for students majoring in economics, statistics, computer sciences or mathematics who wish to expand their econometrics training and understanding to a more advanced level.

Class Format: seminar
Requirements/Evaluation: periodic homework assignments, term paper
Prerequisites: ECON 371
Enrollment Limit: 10
Enrollment Preferences: students with strong quantitative backgrounds, and to students intending to write an honors thesis
Expected Class Size: 10
Grading: yes pass/fail option, no fifth course option
Distributions: (D2) (QFR)

Spring 2020
SEM Section: 01 TF 2:35 pm - 3:50 pm Peter L. Pedroni
ECON 472 (F) Macroeconomic Instability and Financial Markets (QFR)
This advanced course in macroeconomics and financial theory attempts to explain the role and the importance of the financial system in the global economy. The course will provide an understanding of why there is financial intermediation, how financial markets differ from other markets, and the equilibrium consequences of financial activities. Rather than separating off the financial world from the rest of the economy, we will study financial equilibrium as a critical element of economic equilibrium. An important topic in the course will be studying how financial market imperfections amplify and propagate shocks to the aggregate economy. The course may cover the following topics: the determination of asset prices in general equilibrium; consequences of limited asset markets for economic efficiency; theoretical foundations of financial contracts and justifications for the existence of financial intermediaries; the roles of financial frictions in magnifying aggregate fluctuations and creating persistence and instability; the role of leverage and financial innovation in fueling financial crises.

Class Format: seminar
Requirements/Evaluation: evaluation will be based on problem sets, exams, and potentially student presentations
Prerequisites: ECON 251 and ECON 252
Enrollment Limit: 19
Enrollment Preferences: Economics majors
Expected Class Size: 15
Grading: no pass/fail option, no fifth course option
Distributions: (D2) (QFR)

Fall 2019
SEM Section: 01 MWF 8:30 am - 9:45 am Greg Phelan
ECON 514 (S) Tax Policy in Global Perspective (QFR)
Cross-listings: ECON 389 ECON 514
Primary Cross-listing
Taxes are half of what government does. So if you are interested in what government policy can do to promote efficiency, equity, and economic
development, you should be interested in tax policy. Governments must raise tax revenue to finance critical public goods, address other market failures and distributional issues, and to avoid problems with debt and inflation. Taxes typically take up anywhere from ten to fifty percent of a country’s income, they profoundly affect the incentives to undertake all varieties of economic activity, and the government expenditures that they finance have potentially large consequences for human welfare. So the stakes involved in improving tax policy are quite large. This class provides an in-depth exploration of tax policy, from a global and comparative perspective. Because most students in this class will be CDE fellows, we will emphasize tax policy issues, examples, and evidence that are most pertinent to developing countries, but we will also learn something about tax systems in the U.S. and other industrialized nations. Topics addressed in this class include: how basic economic principles can be applied to help one think about the efficiency and equity consequences of tax policies; how personal income taxes, corporate income taxes, and value-added taxes are designed and administered and how they influence the economy; ideas for fundamental reforms of these taxes; theory and evidence in the debate over progressive taxes versus “flat” taxes; how various elements of tax design affect incentives to save and invest; how market failures and administrative problems may influence the optimality of different tax policies; the implications of global capital flows and corporate tax avoidance for the design of tax policy; tax holidays and other special tax incentives for investment; empirical evidence on the influence of taxes on economic growth, foreign direct investment, labor supply, and tax evasion; tax policy towards natural resources such as minerals and oil; case studies of efforts to reform tax administration and reduce tax evasion and corruption; taxes on land and property; taxes on imports and exports; presumptive taxation; and the informal economy and its implications for tax policy.

Class Format: seminar

Requirements/Evaluation: midterm exam, 4 problem sets, two 8-page essays

Prerequisites: one public economics course or microeconomics course (ECON 504 or ECON 110), and one empirical methods course (POEC 253 or ECON 255, 502, or 503); students who have previously taken ECON 351 will not be enrolled

Enrollment Limit: 19

Enrollment Preferences: CDE students, but undergraduates with the prerequisites are welcome

Expected Class Size: 15-19

Grading: yes pass/fail option, yes fifth course option

Distributions: (D2) (QFR)

This course is cross-listed and the prefixes carry the following divisional credit:
ECON 389 (D2) ECON 514 (D2)

Attributes: POEC Comparative POEC/Public Policy Courses  POEC International Political Economy Courses

Spring 2020

SEM Section: 01 TR 9:55 am - 11:10 am William M. Gentry

ECON 523 (S) Program Evaluation for International Development (QFR)

Cross-listings: ECON 379  ECON 523

Primary Cross-listing

Development organizations face strict competition for scarce resources. Both public and private organizations are under increasing pressure to use rigorous program evaluation in order to justify funding for their programs and to design more effective programs. This course is an introduction to evaluation methodology and the tools available to development practitioners, drawing on examples from developing countries. It will cover a wide range of evaluation techniques and discuss the advantages and disadvantages of each. The course is a mix of applied econometrics and practical applications covering implementation, analysis, and interpretation. You will learn to be a critical reader of evaluations, and to develop your own plan to evaluate an existing program of your choice.

Class Format: seminar

Requirements/Evaluation: problem sets, midterm exam and one 7- to 10-page essay

Prerequisites: one public economics course or microeconomics course (ECON 504 or ECON 110), and one empirical methods course (POEC 253 or ECON 255, 502, or 503)

Enrollment Limit: 20

Enrollment Preferences: CDE Students, but undergraduates with the prerequisites are welcome

Expected Class Size: 20

Grading: no pass/fail option, yes fifth course option
Evidence from across the developing world suggests that the "binding constraints" to economic growth can be remarkably heterogeneous—i.e., the growth potential of stagnating or underperforming economies may be unlocked in a large variety of ways. For instance, pre-reform China had been constrained by poor supply incentives in agriculture, whereas Brazil has been held back by an inadequate supply of credit, South Africa by poor employment incentives in manufacturing, El Salvador by insufficient production incentives in tradables, Zimbabwe by bad governance, and so forth. How can developing-country policymakers determine country-specific constraints like these, thus enabling them to pragmatically pursue a selected set of growth-promoting policies rather than attempting to implement a "laundry list" of reforms that are naively based on "best practice" rules-of-thumb? This course will serve as a primer on "growth diagnostics," an empirically-driven analytical framework for identifying the most binding constraints to economic growth in a given country at a point in time, thereby allowing policymakers to develop well-targeted reforms for relaxing these constraints while being cognizant of the nation's prevailing economic, political, and social context. The course will first build on the basic theories and empirics of economic growth to elucidate the diagnostic framework and will then employ a wide range of country-specific case studies to demonstrate how the framework can be operationalized for policy making. Throughout the semester, students will be required to work in groups, each representing a given developing or emerging-market economy, in order to build a growth diagnostic for their group's assigned country by the end of the course.

Class Format: seminar
Requirements/Evaluation: extensive class participation, two short (5-page) papers, two 15-page team papers comprising a country growth diagnostic, and a team presentation on the diagnostic
Prerequisites: for undergraduates ECON 251, ECON 252, and either ECON 255 or STAT 346
Enrollment Limit: 19
Enrollment Preferences: CDE fellows and senior Economics majors
Expected Class Size: 19
Grading: no pass/fail option, no fifth course option
Distributions: (D2) (QFR)

This course is cross-listed and the prefixes carry the following divisional credit:
ECON 545 (D2) ECON 345 (D2)
Quantitative/Formal Reasoning Notes: The course material will be draw heavily on mathematical and statistical models of economic growth and macroeconomic development, and students will be required to routinely develop mathematical models and/or conduct econometric analysis in their assignments.

Spring 2020
SEM Section: 01 TR 11:20 am - 12:35 pm Quamrul H. Ashraf

ENVI 108 (F) Energy Science and Technology (QFR)
Cross-listings: ENVI 108 PHYS 108
Secondary Cross-listing
Energy use has skyrocketed in the United States and elsewhere in the world, causing significant economic and political shifts, as well as concerns for the environment. This course will address the physics and technology of energy generation, consumption, and conservation. It will cover a wide range
of energy sources, including fossil fuels, hydropower, solar energy, wind energy, and nuclear energy. We will discuss energy use in transportation, manufacturing, building heating, and building lighting. Students will learn to compare the efficiencies and environmental impacts of various energy sources and uses.

**Class Format:** lecture twice a week, occasional lab exercises, and a field trip to the college heating plant, all during class hours

**Requirements/Evaluation:** evaluation will be based on weekly assignments, two hour tests, and a final project culminating in an oral presentation to the class and a 10-page paper; all of these will be substantially quantitative

**Prerequisites:** high school physics, high school chemistry, and mathematics at the level of MATH 130

**Enrollment Limit:** 20

**Expected Class Size:** 20

**Grading:** yes pass/fail option, yes fifth course option

**Distributions:** (D3) (QFR)

**This course is cross-listed and the prefixes carry the following divisional credit:**
ENVI 108 (D3) PHYS 108 (D3)

**Attributes:** ENVI Natural World Electives

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**ENVI 203 (F) Ecology (QFR)**

**Cross-listings:** BIOL 203  ENVI 203

**Secondary Cross-listing**
This course combines lectures with field and indoor laboratory exercises to explore factors that determine the distribution and abundance of plants and animals in natural systems. The course begins with an overall view of global patterns and then builds from the population to the ecosystem level. An emphasis is given to basic ecological principles and relates them to current environmental issues. Selected topics include population dynamics (competition, predation, mutualism); community interactions (succession, food chains and diversity) and ecosystem function (biogeochemical cycles, energy flow).

**Class Format:** lecture/laboratory, six hours per week

**Requirements/Evaluation:** evaluation will be based on problem sets, lab reports, hour exams, and a final exam

**Prerequisites:** BIOL 101 and 102, or ENVI 101 or 102, or permission of instructor

**Enrollment Limit:** none

**Expected Class Size:** 35

**Grading:** no pass/fail option, no fifth course option

**Unit Notes:** satisfies the distribution requirement for the Biology major

**Distributions:** (D3) (QFR)

**This course is cross-listed and the prefixes carry the following divisional credit:**
BIOL 203 (D3) ENVI 203 (D3)

**Attributes:** ENVI Natural World Electives  EVST Environmental Science  EVST Living Systems Courses

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**ENVI 213 (S) Introduction to Environmental and Natural Resource Economics (QFR)**

**Cross-listings:** ENVI 213  ECON 213
Secondary Cross-listing

We'll use economics to learn why we harm the environment and overuse natural resources, and what we can do about it. We'll talk about whether and how we can put a dollar value on nature and ecosystem services. We'll study cost benefit analysis, pollution in general, climate change, natural resources (like fisheries, forests, and fossil fuels), and energy. We will take an economic approach to global sustainability, and study the relationship between the environment and economic growth and trade.

Class Format: lecture

Requirements/Evaluation: problem sets, short essays, paper(s); exam(s) are possible

Prerequisites: ECON 110

Enrollment Limit: 30

Enrollment Preferences: first-year and sophomore students

Expected Class Size: 30

Grading: yes pass/fail option, yes fifth course option

Unit Notes: this course will count toward both the Environmental Studies major and concentration

Distributions: (D2) (QFR)

This course is cross-listed and the prefixes carry the following divisional credit:
ENVI 213 (D2) ECON 213 (D2)

Attributes: ENVI Environmental Policy  EVST Social Science/Policy  POEC Comparative POEC/Public Policy Courses

Spring 2020

LEC Section: 01    MWF 8:30 am - 9:45 am     Sarah A. Jacobson

ENVI 312  (F) Communities and Ecosystems  (QFR)

Cross-listings: ENVI 312  BIOL 302

Secondary Cross-listing

An advanced ecology course that examines how species interact with each other and their environment and how communities are assembled. This course emphasizes phenomena that emerge in complex ecological systems, building on the fundamental concepts of population biology, community ecology, and ecosystem science. This foundation will be used to understand specific topics relevant to conservation including invisibility and the functional significance of diversity for ecosystem stability and processes. Lectures and labs will explore how to characterize the emergent properties of communities and ecosystems, and how theoretical, comparative, and experimental approaches are used to understand their structure and function. The lab component of this course will emphasize hypothesis-oriented field experiments as well as "big-data" analyses using existing data sets. The laboratory component of the course will culminate with a self-designed independent or group project.

Class Format: lecture/laboratory, six hours a week

Requirements/Evaluation: evaluation will be based on lab reports, a midterm exam, a term project presentation, and a final project paper

Prerequisites: BIOL/ENVI 203 or 220

Enrollment Limit: 28

Enrollment Preferences: Biology majors and Environmental Studies majors and concentrators

Expected Class Size: 24

Grading: yes pass/fail option, yes fifth course option

Unit Notes: satisfies the distribution requirement for the Biology major

Distributions: (D3) (QFR)

This course is cross-listed and the prefixes carry the following divisional credit:
ENVI 312 (D3) BIOL 302 (D3)

Attributes: ENVI Natural World Electives  EVST Living Systems Courses  EXPE Experiential Education Courses

Fall 2019

LAB Section: 02    T 1:00 pm - 4:00 pm     Manuel A. Morales
ENVI 404  (S)  Coastal Processes and Geomorphology  (QFR)

Cross-listings:  MAST 404  ENVI 404  GEOS 404

Secondary Cross-listing

Can people live safely along the coast? Recent events like SuperStorm Sandy and the Tohoku Tsunami have shown us how the ocean can rise up suddenly and wreak havoc on our lives and coastal infrastructure. Only educated geoscientists can evaluate the risks and define informed strategies to prevent future coastal catastrophes. Currently almost half the global population lives within 100 km of the coast, with a large percent of those living in densely populated cities (e.g., New York, New Orleans, Los Angeles, Shanghai, Hong Kong, Cape Town, Sydney, Mumbai). Despite the growing risks and challenges associated with climate change and rising sea levels, the coastal population continues to grow rapidly. To help ensure these growing populations can live safely along the coast requires a detailed understanding of the processes that shape the coastal zone. These processes act across a variety of scales, from deep-time geologic processes that dictate coastal shape and structure, to decadal-scale processes that determine shoreline position and evolution, to weekly and daily processes such as storms and tides. This course will provide an in-depth look at the forces—wind, waves, storms, and people—that shape the coastal zone, as well as the geologic formations—sandy beaches, rocky cliffs, barrier islands, deltas, and coral reefs—that are acted upon and resist these forces. Coastal dynamics are strongly affected by human interventions, such as seawalls, dredged channels, and sand dune removal, as well as by sea level rise and changes in storm frequency and magnitude associated with climate change. Finally, the course will provide students with a perspective on how the U.S. seeks to manage its coastal zone, focusing on sea level rise and coastal development. This class will include a quantitative lab that will use MATLAB software to model and evaluate various coastal processes. Students will gain a basic understanding of MATLAB functionality, and will be asked to independently apply what they have learned to various data sets provided by the instructor.

Class Format: lecture two times a week with a lab one time per week
Requirements/Evaluation: lab reports, tests, and an independent research project
Prerequisites: GEOS 104, GEOS 210, or permission of instructor
Enrollment Limit: none
Expected Class Size: 10
Grading: yes pass/fail option, yes fifth course option
Distributions: (D3) (QFR)

This course is cross-listed and the prefixes carry the following divisional credit:
MAST 404 (D3) ENVI 404 (D3) GEOS 404 (D3)
Attributes: ENVI Natural World Electives

Spring 2020
LEC Section: 01    MWF 8:30 am - 9:45 am    Alex A. Apotsos

GEOS 203  (F)  Field Methods and Structural Geology  (WS) (QFR)

The structure of the Earth’s crust is constantly changing and the rocks making up the crust must deform to accommodate these changes. Rock deformation occurs over many scales ranging from individual mineral grains to mountain belts. This course deals with the geometric description of structures and the large scale forces responsible for crustal deformation. The laboratories introduce students to best practices for geologic field work, the field identification of common minerals and rocks, geologic contacts, geologic maps and cross sections, folds, and faults. Students will develop skill for presenting field data in papers, figures, and oral presentations.

Class Format: lecture/discussion, three hours per week; laboratory, three hours per week
Requirements/Evaluation: short weekly writing assignments, two 10-page papers based on field trips, and a one-hour exam
Prerequisites: any 100-level Geosciences course or permission of instructor
Enrollment Limit: 16
Enrollment Preferences: Geosciences majors or students with a strong interest in geosciences
Expected Class Size: 12
Grading: no pass/fail option, no fifth course option

Materials/Lab Fee: $15 for field supplies

Distributions: (D3) (WS) (QFR)

Writing Skills Notes: There will be two 10-page papers, each based on four field trips. Students will submit short field descriptions and figures with captions after each field trip for evaluation by the instructor and peers. The shorter assignments will be incorporated in the field reports. Students will receive from the instructor timely comments on their writing skills, with suggestions for improvement.

Attributes: GEOS Group C Electives - Solid Earth

Fall 2019
LEC Section: 01 MW 11:00 am - 12:15 pm Paul M. Karabinos
LAB Section: 02 M 1:00 pm - 4:00 pm Paul M. Karabinos

GEOS 234 (S) Introduction to Materials Science (QFR)

Cross-listings: PHYS 234 GEOS 234

Secondary Cross-listing
Materials Science is the study of how the microscopic structure of materials—whether steel, carbon fiber, glass, wood, plastic, or mayonnaise—determines their macroscopic mechanical, thermal, electric, and other properties. Topics of this course include classifying materials; material structure; thermodynamics and phase transformations; material properties and testing; how solids bend, flow, and ultimately break; and how to choose the right material for design applications. Materials Science is a highly interdisciplinary field and as a result the course prerequisites are broad but also flexible. Interested students who are unsure about their preparation are strongly encouraged to contact the instructor.

Class Format: lecture (3 hours per week), plus three to four small-group laboratory sessions throughout the semester (to be scheduled with instructor)

Requirements/Evaluation: based on weekly problem sets, class participation, and midterm and final exams, all of which have a substantial quantitative component

Prerequisites: high school physics and chemistry, preferably at the AP level, and MATH 140 or AP Calculus (BC), and one 200-level PHYS, CHEM, or GEOS course; or permission of instructor

Enrollment Limit: 20

Enrollment Preferences: based on students' scientific background and seniority

Expected Class Size: 10

Grading: yes pass/fail option, yes fifth course option

Distributions: (D3) (QFR)

This course is cross-listed and the prefixes carry the following divisional credit:
PHYS 234 (D3) GEOS 234 (D3)

Attributes: MTSC Courses

Spring 2020
LEC Section: 01 MR 1:10 pm - 2:25 pm Katharine E. Jensen

GEOS 314 (S) Analytical Historical Geology (QFR)

In this course you will learn to collect, interpret, and analyze deep time paleontological, stratigraphic, and sedimentological records through readings, labs, and projects all coordinated around a week long spring break trip to explore the House Range of Utah. The Cambrian and Ordovician successions of Utah's West Desert offers an outstanding record of one of the most important periods in Earth history, tracking the rise of animal ecosystems and major increases in diversity. The first 6 weeks of class will be spent learning the fundamentals of quantitative methods in paleontology and stratigraphy. Labs will focus on skill building including learning basic coding in R, and learning how to interpret paleontological, sedimentological, and stratigraphic data. We will also read widely on the field locality and on the Cambrian and Ordovician Periods. During the field trip, we will explore the House Range. Students will learn skills including geological mapping, measuring stratigraphic section, finding and identifying fossils, and correlating rock units across basins. We will collect samples and data on the field trip and bring them back to Williams. The second 6 weeks of the course will be spent processing and analyzing the samples and data collected during the field trip, culminating in final projects to be done in small
groups. Students will determine what data we will collect in the field. Examples might be trilobite taxonomy and phylogenetic analyses, quantitative biostatigraphic correlation using conodont fossils, reconstructing paleoenvironment based on sedimentological analyses of thin sections, or building a sequence stratigraphic framework for a subset of the field locality.

**Class Format:** weekly lectures, paper discussions, and hands-on labs

**Requirements/Evaluation:** short papers and lab assignments, spring break field course participation (REQUIRED), and a final group project

**Prerequisites:** GEOS majors who have taken at least one of the following courses: GEOS 212, GEOS 203, GEOS 324, GEOS 401, GEOS 302, or permission of instructor

**Enrollment Limit:** 10

**Enrollment Preferences:** junior and senior Geosciences majors

**Expected Class Size:** 10

**Grading:** no pass/fail option, no fifth course option

**Distributions:** (D3) (QFR)

**Quantitative/Formal Reasoning Notes:** This course will rely on the programming language R. Students will learn how to code in R, and will use R to analyze large data sets of geological data. The majority of labs, as well as the final project, will rely on R, statistical analyses, and wrangling data.

**Attributes:** GEOS Group B Electives - Sediments + Life

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Spring 2020

SEM Section: 01   MW 11:00 am - 12:15 pm   Phoebe A. Cohen

LAB Section: 02   M 1:00 pm - 4:00 pm   Phoebe A. Cohen

**GEOS 404 (S) Coastal Processes and Geomorphology (QFR)**

**Cross-listings:** MAST 404  ENVI 404  GEOS 404

**Primary Cross-listing**

Can people live safely along the coast? Recent events like SuperStorm Sandy and the Tohoku Tsunami have shown us how the ocean can rise up suddenly and wreak havoc on our lives and coastal infrastructure. Only educated geoscientists can evaluate the risks and define informed strategies to prevent future coastal catastrophes. Currently almost half the global population lives within 100 km of the coast, with a large percent of those living in densely populated cities (e.g., New York, New Orleans, Los Angeles, Shanghai, Hong Kong, Cape Town, Sydney, Mumbai). Despite the growing risks and challenges associated with climate change and rising sea levels, the coastal population continues to grow rapidly. To help ensure these growing populations can live safely along the coast requires a detailed understanding of the processes that shape the coastal zone. These processes act across a variety of scales, from deep-time geologic processes that dictate coastal shape and structure, to decadal-scale processes that determine shoreline position and evolution, to weekly and daily processes such as storms and tides. This course will provide an in-depth look at the forces--wind, waves, storms, and people--that shape the coastal zone, as well as the geologic formations--sandy beaches, rocky cliffs, barrier islands, deltas, and coral reefs--that are acted upon and resist these forces. Coastal dynamics are strongly affected by human interventions, such as seawalls, dredged channels, and sand dune removal, as well as by sea level rise and changes in storm frequency and magnitude associated with climate change. Finally, the course will provide students with a perspective on how the U.S. seeks to manage its coastal zone, focusing on sea level rise and coastal development. This class will include a quantitative lab that will use MATLAB software to model and evaluate various coastal processes. Students will gain a basic understanding of MATLAB functionality, and will be asked to independently apply what they have learned to various data sets provided by the instructor.

**Class Format:** lecture two times a week with a lab one time per week

**Requirements/Evaluation:** lab reports, tests, and an independent research project

**Prerequisites:** GEOS 104, GEOS 210, or permission of instructor

**Enrollment Limit:** none

**Expected Class Size:** 10

**Grading:** yes pass/fail option, yes fifth course option

**Distributions:** (D3) (QFR)

This course is cross-listed and the prefixes carry the following divisional credit:

MAST 404 (D3) ENVI 404 (D3) GEOS 404 (D3)
MATH 113  (S)  The Beauty of Numbers  (QFR)
Have you ever wondered what keeps your credit card information safe everytime you buy something online? Number theory! Number Theory is one of the oldest branches of mathematics. In this course, we will discover the beauty and usefulness of numbers, from ancient Greece to modern cryptography. We will look for patterns, make conjectures, and learn how to prove these conjectures. Starting with nothing more than basic high school algebra, we will develop the logic and critical thinking skills required to realize and prove mathematical results. Topics to be covered include the meaning and content of proof, prime numbers, divisibility, rationality, modular arithmetic, Fermat's Last Theorem, the Golden ratio, Fibonacci numbers, coding theory, and unique factorization.

Class Format: lecture
Requirements/Evaluation: evaluation will be based primarily on projects, homework assignments, and exams
Prerequisites: MATH 102 (or demonstrated proficiency on a diagnostic test) or permission of instructor
Enrollment Limit: 25
Expected Class Size: 25
Grading: yes pass/fail option, yes fifth course option
Distributions: (D3)  (QFR)

MATH 130  (F)(S)  Calculus I  (QFR)
Calculus permits the computation of velocities and other instantaneous rates of change by a limiting process called differentiation. The same process also solves "max-min" problems: how to maximize profit or minimize pollution. A second limiting process, called integration, permits the computation of areas and accumulations of income or medicines. The Fundamental Theorem of Calculus provides a useful and surprising link between the two processes. Subtopics include trigonometry, exponential growth, and logarithms.

Class Format: lecture
Requirements/Evaluation: based primarily on exams, homework and quizzes
Prerequisites: MATH 102 (or demonstrated proficiency on a diagnostic test); this is an introductory course for students who have not seen calculus before
Enrollment Limit: 50
Enrollment Preferences: Professor's discretion
Expected Class Size: 30
Grading: yes pass/fail option, yes fifth course option
Unit Notes: students who have previously taken a calculus course may not enroll in MATH 130 without the permission of instructor
Distributions: (D3)  (QFR)
MATH 140  (F)(S)  Calculus II  (QFR)
Mastery of calculus requires understanding how integration computes areas and business profit and acquiring a stock of techniques. Further methods solve equations involving derivatives (“differential equations”) for population growth or pollution levels. Exponential and logarithmic functions and trigonometric and inverse functions play an important role. This course is the right starting point for students who have seen derivatives, but not necessarily integrals, before.

Class Format: lecture

Requirements/Evaluation: based primarily on homework, quizzes, and/or exams

Prerequisites: MATH 130 or equivalent; students who have received the equivalent of advanced placement of AB 4, BC 3 or higher may not enroll in MATH 140 without the permission of instructor

Enrollment Limit: 50

Expected Class Size: 30

Grading:  yes pass/fail option,  yes fifth course option

Unit Notes: students who have higher advanced placement must enroll in MATH 150 or above

Distributions:  (D3)  (QFR)

Fall 2019
LEC Section: 01  MWF 9:00 am - 9:50 am  Lori A. Pedersen
LEC Section: 02  MWF 10:00 am - 10:50 am  Lori A. Pedersen

Spring 2020
LEC Section: 01  MWF 9:00 am - 9:50 am  Leo Goldmakher

MATH 150  (F)(S)  Multivariable Calculus  (QFR)
Applications of calculus in mathematics, science, economics, psychology, the social sciences, involve several variables. This course extends calculus to several variables: vectors, partial derivatives, multiple integrals. There is also a unit on infinite series, sometimes with applications to differential equations.

Class Format: lecture

Requirements/Evaluation: based primarily on homework, quizzes, and/or exams

Prerequisites: MATH 140 or equivalent, such as satisfactory performance on an Advanced Placement Examination

Enrollment Limit: 50

Expected Class Size: 50

Grading:  yes pass/fail option,  yes fifth course option

Unit Notes: students with the equivalent of advanced placement of AB 4 or above should enroll in MATH 150, students with a BC 3 or higher should enroll in Math 151 when it is being offered, and Math 150 otherwise.

Distributions:  (D3)  (QFR)

Fall 2019
LEC Section: 03  MWF 11:00 am - 11:50 am  Julie C. Blackwood
LEC Section: 02  MWF 10:00 am - 10:50 am  Julie C. Blackwood
LEC Section: 01  MWF 9:00 am - 9:50 am  Julie C. Blackwood

Spring 2020
LEC Section: 01  MWF 10:00 am - 10:50 am  Steven J. Miller
LEC Section: 02  MWF 11:00 am - 11:50 am  Steven J. Miller

MATH 151  (F)  Multivariable Calculus  (QFR)
Applications of calculus in mathematics, science, economics, psychology, the social sciences, involve several variables. This course extends calculus
to several variables: vectors, partial derivatives and multiple integrals. The goal of the course is Stokes Theorem, a deep and profound generalization of the Fundamental Theorem of Calculus. The difference between this course and MATH 150 is that MATH 150 covers infinite series instead of Stokes Theorem. Students with the equivalent of BC 3 or higher should enroll in MATH 151, as well as students who have taken the equivalent of an integral calculus and who have already been exposed to infinite series. For further clarification as to whether MATH 150 or MATH 151 is appropriate, please consult a member of the math/stat department.

**Class Format:** lecture

**Requirements/Evaluation:** based primarily on homework, quizzes, and/or exams

**Prerequisites:** AP BC 3 or higher or integral calculus with infinite series

**Enrollment Limit:** 50

**Expected Class Size:** 50

**Grading:** yes pass/fail option, yes fifth course option

**Unit Notes:** MATH 151 satisfies any MATH 150 prerequisite; credit will not be given for both MATH 150 and MATH 151

**Distributions:** (D3) (QFR)

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### MATH 200 (F)(S) Discrete Mathematics (QFR)

**Course Description:** In contrast to calculus, which is the study of continuous processes, this course examines the structure and properties of finite sets. Topics to be covered include mathematical logic, elementary number theory, mathematical induction, set theory, functions, relations, elementary combinatorics and probability, graphs and trees, and algorithms. Emphasis will be given on the methods and styles of mathematical proofs, in order to prepare the students for more advanced math courses.

**Class Format:** lecture/discussion

**Requirements/Evaluation:** evaluation will be based primarily on homework and exams

**Prerequisites:** MATH 140 or MATH 130 with CSCI 134 or 135; or one year of high school calculus with permission of instructor; students who have taken a 300-level math course should obtain permission of the instructor before enrolling

**Enrollment Limit:** 40

**Expected Class Size:** 25

**Grading:** yes pass/fail option, yes fifth course option

**Distributions:** (D3) (QFR)

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### MATH 210 (S) Mathematical Methods for Scientists (QFR)

**Cross-listings:** MATH 210 PHYS 210

**Secondary Cross-listing**

This course covers a variety of mathematical methods used in the sciences, focusing particularly on the solution of ordinary and partial differential equations. In addition to calling attention to certain special equations that arise frequently in the study of waves and diffusion, we develop general techniques such as looking for series solutions and, in the case of nonlinear equations, using phase portraits and linearizing around fixed points.
study some simple numerical techniques for solving differential equations. A series of optional sessions in Mathematica will be offered for students who are not already familiar with this computational tool.

Class Format: lecture, three hours per week

Requirements/Evaluation: evaluation will be based on several exams and on weekly problem sets, all of which have a substantial quantitative component

Prerequisites: MATH 150 or 151 and familiarity with Newtonian mechanics at the level of PHYS 131

Enrollment Limit: 50

Expected Class Size: 30

Grading: yes pass/fail option, yes fifth course option

Distributions: (D3) (QFR)

This course is cross-listed and the prefixes carry the following divisional credit:

MATH 210 (D3) PHYS 210 (D3)

Spring 2020

LEC Section: 01 TR 9:55 am - 11:10 am Daniel P. Aalberts, David R. Tucker-Smith

MATH 250 (F)(S) Linear Algebra (QFR)

Many social, political, economic, biological, and physical phenomena can be described, at least approximately, by linear relations. In the study of systems of linear equations one may ask: When does a solution exist? When is it unique? How does one find it? How can one interpret it geometrically? This course develops the theoretical structure underlying answers to these and other questions and includes the study of matrices, vector spaces, linear independence and bases, linear transformations, determinants and inner products. Course work is balanced between theoretical and computational, with attention to improving mathematical style and sophistication.

Class Format: lecture

Requirements/Evaluation: evaluation will be based primarily on homework and exams

Prerequisites: MATH 150/151 or MATH 200

Enrollment Limit: 45

Expected Class Size: 35

Grading: yes pass/fail option, yes fifth course option

Distributions: (D3) (QFR)

Attributes: COGS Related Courses

Fall 2019

LEC Section: 01 TR 9:55 am - 11:10 am Eva Goedhart

LEC Section: 02 TR 11:20 am - 12:35 pm Eva Goedhart

Spring 2020

LEC Section: 01 TR 9:55 am - 11:10 am Haydee M. A. Lindo

LEC Section: 02 TR 11:20 am - 12:35 pm Haydee M. A. Lindo

MATH 309 (S) Differential Equations (QFR)

Ordinary differential equations (ODE) frequently arise as models of phenomena in the natural and social sciences. This course presents core ideas of ODE from an applied standpoint. Topics covered early in the course include numerical solutions, separation of variables, integrating factors, constant coefficient linear equations, and power series solutions. Later, we focus on nonlinear ODE, for which it is usually impossible to find analytical solutions. Tools from dynamical systems allows us to obtain some information about the behavior of the ODE without explicitly knowing the solution.

Class Format: lecture, discussion, interactive activities

Requirements/Evaluation: quizzes/exams, problem sets, activities

Prerequisites: MATH 150/151 and MATH 250
Enrollment Limit: 30
Enrollment Preferences: Professor's discretion
Expected Class Size: 30
Grading: no pass/fail option, yes fifth course option
Distributions: (D3) (QFR)

Spring 2020
LEC Section: 01 MR 2:35 pm - 3:50 pm Julie C. Blackwood

MATH 314 (S) Cryptography (QFR)
An introduction to the techniques and practices used to keep secrets over non-secure lines of communication, including classical cryptosystems, the data encryption standard, the RSA algorithm, discrete logarithms, hash functions, and digital signatures. In addition to the specific material, there will also be an emphasis on strengthening mathematical problem solving skills, technical reading, and mathematical communication.

Class Format: lecture
Requirements/Evaluation: exams, homework, and quizzes
Prerequisites: MATH 250

MATH 317 (F) Introduction to Operations Research (QFR)
In the first N math classes of your career, you can be misled as to what the world is truly like. How? You're given exact problems and told to find exact solutions. The real world is sadly far more complicated. Frequently we cannot exactly solve problems; moreover, the problems we try to solve are themselves merely approximations to the world! We are forced to develop techniques to approximate not just solutions, but even the statement of the problem. Additionally, we often need the solutions quickly. Operations Research, which was born as a discipline during the tumultuous events of World War II, deals with efficiently finding optimal solutions. In this course we build analytic and programming techniques to efficiently tackle many problems. We will review many algorithms from earlier in your mathematical or CS career, with special attention now given to analyzing their run-time and seeing how they can be improved. The culmination of the course is a development of linear programming and an exploration of what it can do and what are its limitations. For those wishing to take this as a Stats course, the final project must have a substantial stats component approved by the instructor.

Prerequisites: Linear Algebra (MATH 250) and one other 200-level or higher CSCI, MATH or STATS course.

Class Format: lecture
Requirements/Evaluation: homework, exams, projects

LEC Section: 01 MWF 10:00 am - 10:50 am Eva Goedhart
MATH 325 (F) Set Theory (QFR)
Set theory is the traditional foundational language for all of mathematics. We will be discussing the Zermelo-Fraenkel axioms, including the Axiom of Choice and the Continuum Hypothesis, basic independence results and, if time permits, incompleteness theorems. At one time, these issues tore at the foundations of mathematics. They are still vital for understanding the nature of mathematical truth.

Class Format: lecture
Requirements/Evaluation: exams and homework
Prerequisites: MATH 250
Enrollment Limit: 30
Expected Class Size: 15
Grading: yes pass/fail option, yes fifth course option
Materials/Lab Fee: textbook cost
Distributions: (D3) (QFR)

MATH 328 (S) Combinatorics (QFR)
Combinatorics is a branch of mathematics that focuses on enumerating, examining, and investigating the existence of discrete mathematical structures with certain properties. This course provides an introduction to the fundamental structures and techniques in combinatorics including enumerative methods, generating functions, partition theory, the principle of inclusion and exclusion, and partially ordered sets.

Class Format: interactive activities, lecture, discussion
Requirements/Evaluation: quizzes/exams, homework, activities
Prerequisites: MATH 200 and MATH 250
Enrollment Limit: 30
Enrollment Preferences: discretion of the instructor
Expected Class Size: 25
Grading: no pass/fail option, no fifth course option
Distributions: (D3) (QFR)

MATH 338 (F) Intermediate Logic (QFR)
Cross-listings: MATH 338 PHIL 338
Secondary Cross-listing
In this course, we will begin with an in-depth study of the theory of first-order logic. We will first get clear on the formal semantics of first-order logic and various ways of thinking about formal proof: natural deduction systems, semantic tableaux, axiomatic systems and sequent calculi. Our main goal will be to prove things about this logical system rather than to use this system to think about ordinary language arguments. In this way the goal of the course is significantly different from that of Logic and Language (PHIL 203). Students who have take PHIL 203 will have a good background for this class, but students who are generally comfortable with formal systems need not have taken PHIL 203. We will prove soundness and completeness, compactness, the Lowenheim-Skolem theorems, undecidability and other important results about first-order logic. As we go through these results, we will think about the philosophical implications of first-order logic. From there, we will look at extensions of and/or alternatives to first-order logic.
Possible additional topics would include: modal logic, the theory of counterfactuals, alternative representations of conditionals, the use of logic in the...
foundations of arithmetic and Godel's Incompleteness theorems. Student interest will be taken into consideration in deciding what additional topics to cover.

Class Format: Seminar
Requirements/Evaluation: problem sets and exams
Prerequisites: some class in which student has studied formal reasoning
Enrollment Limit: 20
Enrollment Preferences: Philosophy majors; juniors and seniors
Expected Class Size: 15
Grading: yes pass/fail option, yes fifth course option
Distributions: (D3) (QFR)
This course is cross-listed and the prefixes carry the following divisional credit:
MATH 338 (D3) PHIL 338 (D2)
Quantitative/Formal Reasoning Notes: This is a class in Formal Logic. PHIL 203 satisfies the QFR requirement. If anything, this class will be significantly more formal.

Fall 2019
SEM Section: 01 MR 1:10 pm - 2:25 pm Keith E. McPartland

MATH 341 (F)(S) Probability (QFR)
Cross-listings: MATH 341 STAT 341
Primary Cross-listing
While probability began with a study of games, it has grown to become a discipline with numerous applications throughout mathematics and the sciences. Drawing on gaming examples for motivation, this course will present axiomatic and mathematical aspects of probability. Included will be discussions of random variables, expectation, independence, laws of large numbers, and the Central Limit Theorem. Many interesting and important applications will also be presented, potentially including some from coding theory, number theory and nuclear physics.
Class Format: lecture
Requirements/Evaluation: evaluation will be based primarily on homework, classwork, and exams
Prerequisites: MATH 250 or permission of the instructor
Enrollment Limit: 40
Expected Class Size: 20
Grading: yes pass/fail option, yes fifth course option
Distributions: (D3) (QFR)
This course is cross-listed and the prefixes carry the following divisional credit:
MATH 341 (D3) STAT 341 (D3)

Fall 2019
LEC Section: 01 MWF 11:00 am - 11:50 am Steven J. Miller
Spring 2020
LEC Section: 01 TF 2:35 pm - 3:50 pm Mihai Stoiciu

MATH 350 (F)(S) Real Analysis (QFR)
Real analysis is the theory behind calculus. It is based on a precise understanding of the real numbers, elementary topology, and limits. Topologically, nice sets are either closed (contain their limit points) or open (complement closed). You also need limits to define continuity, derivatives, integrals, and to understand sequences of functions.
Class Format: lecture/discussion
**Real analysis or the theory of calculus-derivatives, integrals, continuity, convergence--starts with a deeper understanding of real numbers and limits. Applications in the calculus of variations or "infinite-dimensional calculus" include geodesics, harmonic functions, minimal surfaces, Hamilton's action and Lagrange's equations, optimal economic strategies, nonEuclidean geometry, and general relativity.**

**MATH 355  (F)(S) Abstract Algebra  (QFR)**

Algebra gives us tools to solve equations. The integers, the rationals, and the real numbers have special properties which make algebra work according to the circumstances. In this course, we generalize algebraic processes and the sets upon which they operate in order to better understand, theoretically, when equations can and cannot be solved. We define and study abstract algebraic structures such as groups, rings, and fields, as well as the concepts of factor group, quotient ring, homomorphism, isomorphism, and various types of field extensions. This course introduces students to abstract rigorous mathematics.

**Fall 2019**
LEC Section: 01  TR 11:20 am - 12:35 pm  Thomas A. Garrity
MATH 361 (F)(S) Theory of Computation (QFR)
Cross-listings: CSCI 361 MATH 361
Secondary Cross-listing
This course introduces a formal framework for investigating both the computability and complexity of problems. We study several models of computation including finite automata, regular languages, context-free grammars, and Turing machines. These models provide a mathematical basis for the study of computability theory—the examination of what problems can be solved and what problems cannot be solved—and the study of complexity theory—the examination of how efficiently problems can be solved. Topics include the halting problem and the P versus NP problem.

Class Format: lecture
Requirements/Evaluation: evaluation will be based on problem sets, a midterm examination, and a final examination
Prerequisites: CSCI 256 or both a 300-level MATH course and permission of instructor
Enrollment Limit: 30
Enrollment Preferences: current or expected Computer Science majors
Expected Class Size: 30
Grading: no pass/fail option, no fifth course option
Distributions: (D3) (QFR)
This course is cross-listed and the prefixes carry the following divisional credit:
CSCI 361 (D3) MATH 361 (D3)
Attributes: COGS Interdepartmental Electives

Fall 2019
LEC Section: 01 MWF 11:00 am - 11:50 am Aaron M. Williams

Spring 2020
LEC Section: 01 MWF 12:00 pm - 12:50 pm Thomas P. Murtagh

MATH 404 (F) Random Matrix Theory (QFR)
Initiated by research in multivariate statistics and nuclear physics, the study of random matrices is nowadays an active and exciting area of mathematics, with numerous applications to theoretical physics, number theory, functional analysis, optimal control, and finance. Random Matrix Theory provides understanding of various properties (most notably, statistics of eigenvalues) of matrices with random coefficients. This course will provide an introduction to the basic theory of random matrices, starting with a quick review of Linear Algebra and Probability Theory. We will continue with the study of Wigner matrices and prove the celebrated Wigner's Semicircle Law, which brings together important ideas from analysis and combinatorics. After this, we will turn our attention to Gaussian ensembles and investigate the Gaussian Orthogonal Ensemble (GOE) and the Gaussian Unitary Ensemble (GUE). The last lectures of the course will be dedicated to random Schrodinger operators and their spectral properties (in particular, the phenomenon called Anderson localization). Applications of Random Matrix Theory to theoretical physics, number theory, statistics, and finance will be discussed throughout the semester.

Class Format: lecture
Requirements/Evaluation: homework assignments and exams
Prerequisites: experience with Real Analysis (MATH 350 or MATH 351) and with Probability (MATH 341 or STAT 201)
Enrollment Limit: 40
Enrollment Preferences: Mathematics and Statistics majors
Expected Class Size: 20
Grading: yes pass/fail option, yes fifth course option
Distributions: (D3) (QFR)
Quantitative/Formal Reasoning Notes: This course expands ideas in probability and statistics from random variables (1x1 random matrices) to nxn
random matrices. The students will learn to model complex physical phenomena using random matrices and study them using rigorous mathematical tools and concepts.

Fall 2019
LEC Section: 01   TF 2:35 pm - 3:50 pm   Mihai  Stoiciu

MATH 419  (S)  Algebraic Number Theory  (QFR)
We all know that integers can be factored into prime numbers and that this factorization is essentially unique. In more general settings, it often still makes sense to factor numbers into “primes,” but the factorization is not necessarily unique! This surprising fact was the downfall of Lamé's attempted proof of Fermat's Last Theorem in 1847. Although a valid proof was not discovered until over 150 years later, this error gave rise to a new branch of mathematics: algebraic number theory. In this course, we will study factorization and other number-theoretic notions in more abstract algebraic settings, and we will see a beautiful interplay between groups, rings, and fields.

Class Format: lecture/seminar
Requirements/Evaluation: evaluation will be based primarily on homework assignments and exams
Prerequisites: MATH 355, or permission of instructor
Enrollment Limit: 25
Expected Class Size: 20
Grading:    yes pass/fail option,    yes fifth course option
Distributions:    (D3)    (QFR)

Spring 2020
LEC Section: 01   TR 11:20 am - 12:35 pm   Allison  Pacelli

MATH 422  (F)  Algebraic Topology  (QFR)
Is a sphere really different from a torus? Can a sphere be continuously deformed to a point? Algebraic Topology concerns itself with the classification and study of topological spaces via algebraic methods. The key question is this: How do we really know when two spaces are different and in what senses can we claim they are the same? Our answer will use several algebraic tools such as groups and their normal subgroups. In this course we will develop several notions of "equality" starting with the existence of homeomorphisms between spaces. We will then explore several weakenings of this notion, such as homotopy equivalence, having isomorphic homology or fundamental groups, and having homeomorphic universal covers.

Class Format: lecture
Requirements/Evaluation: evaluation will be based primarily on homework and exams
Prerequisites: MATH 355 or permission of instructor
Enrollment Limit: 30
Enrollment Preferences: Math majors primarily, and Juniors and Seniors secondarily
Expected Class Size: 15
Grading:    no pass/fail option,    no fifth course option
Distributions:    (D3)    (QFR)

Fall 2019
LEC Section: 01   TR 8:30 am - 9:45 am   Andrew  Bydlon

MATH 426  (F)  Differential Topology  (QFR)
Differential topology marries the rubber-like deformations of topology with the computational exactness of calculus. This sub eld of mathematics asks and answers questions like "Can you take an integral on the surface of doughnut?" and includes far-reaching applications in relativity and robotics. This tutorial will provide an elementary and intuitive introduction to differential topology. We will begin with the definition of a manifold and end with a generalized understanding of Stokes Theorem.
Class Format: Tutorial
Requirements/Evaluation: weekly homework, weekly presentations, and final paper
Prerequisites: MATH 350 (students who have not taken MATH 250 may enroll only with permission of the instructor)
Enrollment Limit: 10
Enrollment Preferences: seniors, majors
Expected Class Size: 10
Grading: no pass/fail option, no fifth course option
Distributions: (D3) (QFR)
Quantitative/Formal Reasoning Notes: There will be weekly math problem sets.

Fall 2019
TUT Section: T1 TBA Haydee M. A. Lindo

MATH 427 (S) Tiling Theory (QFR)
Since humans first used stones and bricks to tile the floors of their domiciles, tiling has been an area of interest. Practitioners include artists, engineers, designers, architects, crystallographers, scientists and mathematicians. This course will be an investigation into the mathematical theory of tiling. The course will focus on tilings of the plane, including topics such as the symmetry groups of tilings, the topology of tilings, the ergodic theory of tilings, the classification of tilings and the aperiodic Penrose tilings. We will also look at tilings in higher dimensions, including "knotted tilings".

Class Format: lecture
Requirements/Evaluation: problem assignments, exams and a presentation/paper
Prerequisites: MATH 250 Linear Algebra and MATH 355 Abstract Algebra
Enrollment Limit: 30
Enrollment Preferences: senior majors, seniors, juniors, sophomores, first-year students (this is a senior seminar, one of which is required for all senior majors, so they have first preference)
Expected Class Size: 20
Grading: no pass/fail option, yes fifth course option
Materials/Lab Fee: cost of book which will be under $50
Distributions: (D3) (QFR)

Spring 2020
LEC Section: 01 TR 9:55 am - 11:10 am Colin C. Adams

MATH 428 (S) Catching Robbers and Spreading Information (QFR)
Cops and robbers is a widely studied game played on graphs that has connections to searching algorithms on networks. The cop number of a graph is the smallest number of cops needed to guarantee that the cops can catch a robber in the graph. Similar combinatorial games such as "zero forcing" can be used to model the spread of information. The idea of "throttling" is to spread the information (or catch the robber) as efficiently as possible. This course will survey some of the main results about cops and robbers and the cop number. We will also explore recent research on throttling for cops and robbers, zero forcing, and other variants.

Class Format: interactive activities, lecture, discussion
Requirements/Evaluation: problem sets, investigation journal, final presentation
Prerequisites: MATH 200 and MATH 355
Enrollment Limit: 25
Enrollment Preferences: seniors
Expected Class Size: 20
Grading: yes pass/fail option, no fifth course option
Math 482 (F) Homological Algebra (QFR)
Though a relatively young subfield of mathematics, Homological Algebra has earned its place by supplying powerful tools to solve questions in the much older fields of Commutative Algebra, Algebraic Geometry and Representation Theory. This class will introduce theorems and tools of Homological Algebra, grounding its results in applications to polynomial rings and their quotients. We will focus on some early groundbreaking results and learn some of Homological Algebra's most-used constructions. Possible topics include tensor products, chain complexes, homology, Ext, Tor and Hilbert's Syzygy Theorem.

Class Format: lecture
Requirements/Evaluation: evaluation will be based primarily on homework and exams
Prerequisites: MATH 355
Enrollment Limit: 20
Enrollment Preferences: junior and senior math majors
Expected Class Size: 12
Grading: no pass/fail option, yes fifth course option
Unit Notes: this course is not a senior seminar, so it does not fulfill the senior seminar requirement for the Math major
Distributions: (D3) (QFR)

Math 484 (S) Galois Theory (QFR)
Some equations--such as $x^5 - 1 = 0$--are easy to solve. Others--such as $x^5 - x - 1 = 0$--are very hard, if not impossible (using standard mathematical operations). Galois discovered a deep connection between field theory and group theory that led to a criterion for checking whether or not a given polynomial can be easily solved. His discovery also led to many other breakthroughs, for example proving the impossibility of squaring the circle or trisecting a typical angle using compass and straightedge. From these not-so-humble beginnings, Galois theory has become a fundamental concept in modern mathematics, from topology to number theory. In this course we will develop the theory and explore its applications to other areas of math.

Class Format: lecture
Requirements/Evaluation: evaluation will be based primarily on written homeworks, oral presentations, and exams
Prerequisites: MATH 355
Enrollment Limit: 15
Enrollment Preferences: discretion of the instructor
Expected Class Size: 10
Grading: no pass/fail option, yes fifth course option
Unit Notes: this course is not a senior seminar, so it does not fulfill the senior seminar requirement for the Math major
Distributions: (D3) (QFR)

Math 485 (F) Complex Analysis (QFR)
The calculus of complex-valued functions turns out to have unexpected simplicity and power. As an example of simplicity, every complex-differentiable function is automatically infinitely differentiable. As examples of power, the so-called residue calculus permits the computation of impossible integrals, and conformal mapping reduces physical problems on very general domains to problems on the round disc. The easiest proof of the Fundamental Theorem of Algebra, not to mention the first proof of the Prime Number Theorem, used complex analysis.

Class Format: lecture

Requirements/Evaluation: evaluation will be based primarily on homework, classwork, and exams

Prerequisites: MATH 350 or MATH 351 or permission of instructor

Enrollment Limit: 40

Expected Class Size: 30

Grading: yes pass/fail option, yes fifth course option

Unit Notes: this course is not a senior seminar, so it does not fulfill the senior seminar requirement for the Math major

Distributions: (D3) (QFR)

Quantitative/Formal Reasoning Notes: Advanced mathematics course with weekly or daily problem sets.

Fall 2019

LEC Section: 01 MWF 11:00 am - 11:50 am Andrew Bydlon

PHIL 338 (F) Intermediate Logic (QFR)

Cross-listings: MATH 338 PHIL 338

Primary Cross-listing

In this course, we will begin with an in-depth study of the theory of first-order logic. We will first get clear on the formal semantics of first-order logic and various ways of thinking about formal proof: natural deduction systems, semantic tableaux, axiomatic systems and sequent calculi. Our main goal will be to prove things about this logical system rather than to use this system to think about ordinary language arguments. In this way the goal of the course is significantly different from that of Logic and Language (PHIL 203). Students who have take PHIL 203 will have a good background for this class, but students who are generally comfortable with formal systems need not have taken PHIL 203. We will prove soundness and completeness, compactness, the Lowenheim-Skolem theorems, undecidability and other important results about first-order logic. As we go through these results, we will think about the philosophical implications of first-order logic. From there, we will look at extensions of and/or alternatives to first-order logic. Possible additional topics would include: modal logic, the theory of counterfactuals, alternative representations of conditionals, the use of logic in the foundations of arithmetic and Godel's Incompleteness theorems. Student interest will be taken into consideration in deciding what additional topics to cover.

Class Format: Seminar

Requirements/Evaluation: problem sets and exams

Prerequisites: some class in which student has studied formal reasoning

Enrollment Limit: 20

Enrollment Preferences: Philosophy majors; juniors and seniors

Expected Class Size: 15

Grading: yes pass/fail option, yes fifth course option

Distributions: (D2) (QFR)

This course is cross-listed and the prefixes carry the following divisional credit:

MATH 338 (D3) PHIL 338 (D2)

Quantitative/Formal Reasoning Notes: This is a class in Formal Logic. PHIL 203 satisfies the QFR requirement. If anything, this class will be significantly more formal.

Attributes: Linguistics

Fall 2019

SEM Section: 01 MR 1:10 pm - 2:25 pm Keith E. McPartland
PHYS 108 (F) Energy Science and Technology (QFR)

Cross-listings: ENVI 108  PHYS 108

Primary Cross-listing

Energy use has skyrocketed in the United States and elsewhere in the world, causing significant economic and political shifts, as well as concerns for the environment. This course will address the physics and technology of energy generation, consumption, and conservation. It will cover a wide range of energy sources, including fossil fuels, hydropower, solar energy, wind energy, and nuclear energy. We will discuss energy use in transportation, manufacturing, building heating, and building lighting. Students will learn to compare the efficiencies and environmental impacts of various energy sources and uses.

Class Format: lecture twice a week, occasional lab exercises, and a field trip to the college heating plant, all during class hours

Requirements/Evaluation: evaluation will be based on weekly assignments, two hour tests, and a final project culminating in an oral presentation to the class and a 10-page paper; all of these will be substantially quantitative

Prerequisites: high school physics, high school chemistry, and mathematics at the level of MATH 130

Enrollment Limit: 20

Expected Class Size: 20

Grading: yes pass/fail option, yes fifth course option

Distributions: (D3)  (QFR)

This course is cross-listed and the prefixes carry the following divisional credit:
ENVI 108 (D3) PHYS 108 (D3)

Attributes: ENVI Natural World Electives

Fall 2019
LEC Section: 01  MR 2:35 pm - 3:50 pm  Kevin M. Jones

PHYS 109 (F) Sound, Light, and Perception (QFR)

Light and sound allow us to perceive the world around us, from appreciating music and art to learning the details of atomic structure. Because of their importance in human experience, light and sound have long been the subject of scientific inquiry. How are sound and light related? How do physiology and neural processing allow us to hear and see the world around us? What are the origins of color and musical pitch? This course introduces the science and technology of light and sound to students not majoring in physics. We will start with the origins of sound and light as wave phenomena, and go on to topics including color, the optics of vision, the meaning of musical pitch and tone, and the physical basis of hearing. We will also discuss some recent technological applications of light, such as lasers and optical communications. The class will meet for two 75-minute periods each week for a variable mixture of lecture, discussion, and hands-on, interactive experiments.

Class Format: lecture/lab/discussion; each student will attend one lecture plus one conference section weekly

Requirements/Evaluation: evaluation will be based on class participation, problem sets, in-class exams, oral presentations, and a final exam, all with a quantitative component

Extra Info: Note: Students signing up for the Thursday 2:35 PM conference section must also be available on Thursdays from 1:10-2:25 PM

Prerequisites: none

Enrollment Limit: 40

Expected Class Size: 40

Grading: yes pass/fail option, yes fifth course option

Distributions: (D3)  (QFR)

Fall 2019
LEC Section: 01  MR 1:10 pm - 2:25 pm M 2:35 pm - 3:50 pm  Protik K. Majumder

PHYS 131 (F) Introduction to Mechanics (QFR)
We focus first on the Newtonian mechanics of point particles: the relationship between velocity, acceleration, and position; the puzzle of circular motion; forces, Newton's laws, and gravitation; energy and momentum; and the physics of vibrations. Then we turn to the basic properties of waves, such as interference and refraction, as exemplified by sound and light waves. We also study the optics of lenses, mirrors and the human eye. This course is not intended for students who have successfully completed an AP physics course in high school.

Class Format: lecture, three hours per week; laboratory, three hours approximately every other week

Requirements/Evaluation: exams, labs, and weekly problem sets, all of which have a substantial quantitative component

Prerequisites: MATH 130; students who scored 4 or 5 on an AP physics exam, or 6 or 7 on the IB Physics HL exam may not take this course and are encouraged to take PHYS 141 instead

Enrollment Limit: 24/lab

Expected Class Size: 60

Grading: yes pass/fail option, yes fifth course option

Unit Notes: PHYS 131 can lead to either PHYS 132 (for students wanting a one-year survey of physics) or PHYS 142 (for students considering a Physics or Astrophysics major)

Distributions: (D3) (QFR)

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PHYS 132  (S) Electromagnetism and the Physics of Matter (QFR)

This course is intended as the second half of a one-year survey of physics with some emphasis on applications to medicine. In the first part of the semester we will focus on electromagnetic phenomena. We will introduce the concept of electric and magnetic fields and study in detail the way in which electrical circuits and circuit elements work. The deep connection between electric and magnetic phenomena is highlighted with a discussion of Faraday's Law of Induction. Following our introduction to electromagnetism we will discuss some of the most central topics in twentieth-century physics, including Einstein's theory of special relativity and some aspects of quantum theory. We will end with a treatment of nuclear physics, radioactivity, and uses of radiation.

Class Format: lecture, three hours per week; laboratory, three hours approximately every other week; conference section 1 hour approximately every other week

Requirements/Evaluation: evaluation will be based on weekly problem sets, labs, quizzes and exams

Prerequisites: PHYS 131 or 141 or permission of instructor, and MATH 130 (formerly 103)

Enrollment Limit: 22 per lab

Expected Class Size: 60

Grading: yes pass/fail option, yes fifth course option

Distributions: (D3) (QFR)

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PHYS 141  (F) Mechanics and Waves (QFR)

This is the typical first course for a prospective physics major. It covers the same topics as PHYS 131, but with a higher level of mathematical sophistication. It is intended for students with solid backgrounds in the sciences, either from high school or college, who are comfortable with basic calculus.

Class Format: lecture, three hours per week; laboratory, three hours approximately every other week; conference section, one hour approximately
every other week

**Requirements/Evaluation:** weekly problem sets, labs, 2 one-hour tests, and a final exam, all of which have a substantial quantitative component

**Prerequisites:** high school physics and MATH 130 or equivalent placement

**Enrollment Limit:** 22 per lab

**Expected Class Size:** 50

**Grading:** yes pass/fail option, yes fifth course option

**Unit Notes:** PHYS 141 can lead to either PHYS 132 (for students wanting a one-year survey of physics) or PHYS 142 (for students considering a Physics or Astrophysics major)

**Distributions:** (D3) (QFR)

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**PHYS 142** *(S)* Foundations of Modern Physics  *(QFR)*

Newtonian Mechanics, spectacular as it is in describing planetary motion and a wide range of other phenomena, only hints at the richness of behaviors seen in the universe. Special relativity, which extends physics into the realm of high speeds and high energies, requires us to rethink our basic notions of space and time. Quantum mechanics successfully describes atoms, molecules, and solids while at the same time calling into question our expectation of what can be predicted by a physical theory. Statistical physics reveals new behaviors that emerge when many particles are present in a system.

This course will survey ideas from each of these three arenas, and can serve either as a terminal course for those seeking to complete a year of physics or as the basis for future advanced study of these topics.

**Class Format:** lecture, two hours weekly; problem-solving conference session, one hour weekly; laboratory, alternating between three hours and one hour approximately every other week (limit 22 per lab, 18 per conference section)

**Requirements/Evaluation:** weekly homework, labs, two hour tests, and a final exam, all of which have a substantial quantitative component

**Prerequisites:** PHYS 141 and MATH 130 (formerly 103), or equivalent; PHYS 131 may substitute for PHYS 141 with the permission of instructor. Students may not take both PHYS 142 and PHYS 151

**Enrollment Limit:** 18 per CON

**Expected Class Size:** 30

**Grading:** yes pass/fail option, yes fifth course option

**Distributions:** (D3) (QFR)

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**PHYS 151** *(F)* Seminar in Modern Physics  *(QFR)*

Newtonian Mechanics, spectacular as it is in describing planetary motion and a wide range of other phenomena, only hints at the richness of behaviors seen in the universe. Special relativity has extended physics into the realm of high speeds and high energies and requires us to rethink our basic notions of space and time. Quantum mechanics successfully describes atoms, molecules, and solids while at the same time calling into question our notions of what can be predicted by a physical theory. Statistical physics reveals new behaviors that emerge when many particles are present in a system. This course covers the same basic material as PHYS 142 but in a small seminar format for students with strong prior preparation in physics.

**Class Format:** lecture/discussion, three hours per week; laboratory, 3 hours approximately every other week; conference section 1 hour
Requirements/Evaluation: evaluation will be based on class participation, labs, weekly problem sets, an oral presentation, two hour-exams and a final exam, all of which have a substantial quantitative component

Extra Info: this is a small seminar designed for first-year students who have placed out of PHYS 141

Prerequisites: placement by the department (see "advanced placement" section in the description about the department). Students may take either PHYS 142 or PHYS 151 but not both

Enrollment Limit: 18

Expected Class Size: 18

Grading: yes pass/fail option, yes fifth course option

Distributions: (D3) (QFR)

Fall 2019

LAB Section: 02 W 1:00 pm - 4:00 pm Frederick W. Strauch
LEC Section: 01 MWF 11:00 am - 11:50 am Frederick W. Strauch

PHYS 201 (F) Electricity and Magnetism (QFR)

The classical theory of electricity and magnetism is very rich yet it can be written in a remarkably succinct form using Maxwell's equations. This course is an introduction to electricity and magnetism and their mathematical description, connecting electric and magnetic phenomena via the special theory of relativity. Topics include electrostatics, magnetic fields, electromagnetic induction, DC and AC circuits, and the electromagnetic properties of matter. The laboratory component of the course is an introduction to electronics where students will develop skills in building and debugging electrical circuits.

Class Format: lecture, three hours per week; laboratory, three hours per week

Requirements/Evaluation: evaluation will be based on problem sets, labs, two take-home midterms, and a final exam, all of which have a substantial quantitative component

Prerequisites: PHYS 142 OR 151; MATH 150 or 151; with a preference for MATH 151

Enrollment Limit: 20 per lab

Expected Class Size: 25

Grading: yes pass/fail option, yes fifth course option

Distributions: (D3) (QFR)

Fall 2019

LAB Section: 03 W 1:00 pm - 4:00 pm David R. Tucker-Smith
LAB Section: 02 T 1:00 pm - 4:00 pm David R. Tucker-Smith
LEC Section: 01 MWF 10:00 am - 10:50 am David R. Tucker-Smith

PHYS 202 (S) Vibrations, Waves and Optics (QFR)

Waves and oscillations characterize many different physical systems, including vibrating strings, springs, water waves, sound waves, electromagnetic waves, and gravitational waves. Quantum mechanics even describes particles with wave functions. Despite these diverse settings waves exhibit several common characteristics, so that the understanding of a few simple systems can provide insight into a wide array of phenomena. In this course we begin with the study of oscillations of simple systems with only a few degrees of freedom. We then move on to study transverse and longitudinal waves in continuous media in order to gain a general description of wave behavior. The rest of the course focuses on electromagnetic waves and in particular on optical examples of wave phenomena. In addition to well known optical effects such as interference and diffraction, we will study a number of modern applications of optics such as short pulse lasers and optical communications. Throughout the course mathematical methods useful for higher-level physics will be introduced.

Class Format: lecture, three hours per week; laboratory, three hours per week

Requirements/Evaluation: evaluation will be based on problem sets, labs, two one-hour tests, and a final exam, all of which have a substantial quantitative component
Prerequisites: PHYS 201; co-requisite: PHYS/MATH 210 or MATH 209 or permission of instructor

Enrollment Limit: none

Expected Class Size: 20

Grading: yes pass/fail option, yes fifth course option

Distributions: (D3) (QFR)

Spring 2020

LAB Section: 03 W 1:00 pm - 4:00 pm Graham K. Giovanetti
LEC Section: 01 MWF 10:00 am - 10:50 am Graham K. Giovanetti
LAB Section: 02 T 1:00 pm - 4:00 pm Graham K. Giovanetti

PHYS 210 (S) Mathematical Methods for Scientists (QFR)

Cross-listings: MATH 210 PHYS 210

Primary Cross-listing

This course covers a variety of mathematical methods used in the sciences, focusing particularly on the solution of ordinary and partial differential equations. In addition to calling attention to certain special equations that arise frequently in the study of waves and diffusion, we develop general techniques such as looking for series solutions and, in the case of nonlinear equations, using phase portraits and linearizing around fixed points. We study some simple numerical techniques for solving differential equations. A series of optional sessions in Mathematica will be offered for students who are not already familiar with this computational tool.

Class Format: lecture, three hours per week

Requirements/Evaluation: evaluation will be based on several exams and on weekly problem sets, all of which have a substantial quantitative component

Prerequisites: MATH 150 or 151 and familiarity with Newtonian mechanics at the level of PHYS 131

Enrollment Limit: 50

Expected Class Size: 30

Grading: yes pass/fail option, yes fifth course option

Distributions: (D3) (QFR)

This course is cross-listed and the prefixes carry the following divisional credit:

MATH 210 (D3) PHYS 210 (D3)

Spring 2020

LEC Section: 01 TR 9:55 am - 11:10 am Daniel P. Aalberts, David R. Tucker-Smith

PHYS 234 (S) Introduction to Materials Science (QFR)

Cross-listings: PHYS 234 GEOS 234

Primary Cross-listing

Materials Science is the study of how the microscopic structure of materials—whether steel, carbon fiber, glass, wood, plastic, or mayonnaise—determines their macroscopic mechanical, thermal, electric, and other properties. Topics of this course include classifying materials; material structure; thermodynamics and phase transformations; material properties and testing; how solids bend, flow, and ultimately break; and how to choose the right material for design applications. Materials Science is a highly interdisciplinary field and as a result the course prerequisites are broad but also flexible. Interested students who are unsure about their preparation are strongly encouraged to contact the instructor.

Class Format: lecture (3 hours per week), plus three to four small-group laboratory sessions throughout the semester (to be scheduled with instructor)

Requirements/Evaluation: based on weekly problem sets, class participation, and midterm and final exams, all of which have a substantial quantitative component

Prerequisites: high school physics and chemistry, preferably at the AP level, and MATH 140 or AP Calculus (BC), and one 200-level PHYS, CHEM, or GEOS course; or permission of instructor
Enrollment Limit: 20

Enrollment Preferences: based on students' scientific background and seniority

Expected Class Size: 10

Grading: yes pass/fail option, yes fifth course option

Distributions: (D3) (QFR)

This course is cross-listed and the prefixes carry the following divisional credit:
PHYS 234 (D3) GEOS 234 (D3)

Attributes: MTSC Courses

Spring 2020

LEC Section: 01 MR 1:10 pm - 2:25 pm Katharine E. Jensen

PHYS 301  (F) Quantum Physics  (QFR)
This course serves as a one-semester introduction to the history, formalism, and phenomenology of quantum mechanics. We begin with a discussion of the historical origins of the quantum theory, and the Schrödinger wave equation. The concepts of matter waves and wave-packets are introduced. Solutions to one-dimensional problems will be treated prior to introducing the system which serves as a hallmark of the success of quantum theory, the three-dimensional hydrogen atom. In the second half of the course, we will develop the important connection between the underlying mathematical formalism and the physical predictions of the quantum theory and introduce the Heisenberg formalism. We then go on to apply this knowledge to several important problems within the realm of atomic and nuclear physics concentrating on applications involving angular momentum and spins.

Class Format: lecture, three hours per week; laboratory, three hours per week

Requirements/Evaluation: evaluation will be based on weekly problem sets, labs, a midterm exam, and final exam, all of which have a substantial quantitative component

Prerequisites: PHYS 202 and PHYS/MATH 210 or MATH 209

Enrollment Limit: none

Expected Class Size: 15

Grading: yes pass/fail option, yes fifth course option

Distributions: (D3) (QFR)

Fall 2019

LAB Section: 02 T 1:00 pm - 4:00 pm Charlie Doret
LEC Section: 01 MWF 9:00 am - 9:50 am Charlie Doret
LAB Section: 03  W 1:00 pm - 4:00 pm Charlie Doret

PHYS 302  (S) Stat Mechanics & Thermodynamics  (QFR)
Macroscopic objects are made up of huge numbers of fundamental particles interacting in simple ways--obeying the Schrödinger equation, Newton's and Coulomb's Laws--and these objects can be described by macroscopic properties like temperature, pressure, magnetization, heat capacity, conductivity, etc. In this course we will develop the tools of statistical physics, which will allow us to predict the cooperative phenomena that emerge in large ensembles of interacting particles. We will apply those tools to a wide variety of physical questions, including the behavior of gases, polymers, heat engines, biological and astrophysical systems, magnets, and electrons in solids.

Class Format: lecture/discussion, three hours per week; laboratory, three hours per week

Requirements/Evaluation: evaluation will be based on weekly problem sets, exams, and labs, all of which have a substantial quantitative component

Prerequisites: required: PHYS 201, PHYS/MATH 210 or MATH 209; recommended: PHYS 202, PHYS 301

Enrollment Limit: 24

Expected Class Size: 15

Grading: yes pass/fail option, yes fifth course option

Distributions: (D3) (QFR)
PHYS 314 (S) Controlling Quanta (QFR)
This course will explore modern developments in the control of individual quantum systems. Topics covered will include basic physical theories of atoms coupled to photons, underlying mathematical tools (including Lie algebras and groups), and computational methods to simulate and analyze quantum systems. Applications to quantum computing, teleportation, and experimental metaphysics (Bell's inequality) will also be discussed.

Class Format: tutorial
Requirements/Evaluation: tutorial preparation and participation, weekly problem sets/papers, and a final project
Extra Info: may not be taken on a pass/fail basis; not available for the fifth course option
Prerequisites: PHYS/MATH 210 or MATH 209 or MATH 250
Enrollment Limit: 10
Enrollment Preferences: sophomores and junior Physics majors
Expected Class Size: 10
Grading: no pass/fail option, no fifth course option
Distributions: (D3) (QFR)

Spring 2020
TUT Section: T1 TBA Frederick W. Strauch

PHYS 315 (S) Computational Biology (QFR)
Cross-listings: PHYS 315 CSCI 315
Primary Cross-listing
This course will provide an overview of Computational Biology, the application of computational, mathematical, statistical, and physical problem-solving techniques to interpret the rapidly expanding amount of biological data. Topics covered will include database searching, DNA sequence alignment, clustering, RNA structure prediction, protein structural alignment, methods of analyzing gene expression, networks, and genome assembly using techniques such as string matching, dynamic programming, hidden Markov models, and expectation-maximization.

Class Format: lab three hours per week plus weekly tutorial meeting
Requirements/Evaluation: evaluation will be based on weekly Python programming assignments, problem sets, a few quizzes and a final project
Prerequisites: programming experience (e.g., CSCI 136), mathematics (PHYS/MATH 210 or MATH 150), and physical science (PHYS 142 or 151, or CHEM 151 or 153 or 155), or permission of instructor
Enrollment Limit: 10
Enrollment Preferences: based on seniority
Expected Class Size: 8
Grading: no pass/fail option, no fifth course option
Distributions: (D3) (QFR)
This course is cross-listed and the prefixes carry the following divisional credit:
PHYS 315 (D3) CSCI 315 (D3)
Attributes: BIGP Recommended Courses
PHYS 321  (F)  Introduction to Particle Physics  (QFR)
The Standard Model of particle physics incorporates special relativity, quantum mechanics, and almost all that we know about elementary particles and their interactions. This course introduces some of the main ideas and phenomena associated with the Standard Model. After a review of relativistic kinematics, we will learn about symmetries in particle physics, Feynman diagrams, and selected applications of quantum electrodynamics, the weak interactions, and quantum chromodynamics. We will conclude with a discussion of spontaneous symmetry breaking and the Higgs mechanism.

Class Format: lecture / seminar, three hours a week
Requirements/Evaluation:  weekly problem sets and a final exam
Prerequisites:  PHYS 301, which may be taken concurrently, plus permission of instructor
Enrollment Limit:  15
Expected Class Size:  10
Grading:  yes pass/fail option,  yes fifth course option
Distributions:  (D3)  (QFR)

PHYS 405  (F)  Electromagnetic Theory  (QFR)
This course builds on the material of Physics 201, and explores the application of Maxwell's Equations to understand a range of topics including electric fields and matter, magnetic materials, light, and radiation. As we explore diverse phenomena, we will learn useful approximation techniques and beautiful mathematical tools. In addition to weekly tutorial meetings, the class will meet once a week as a whole to introduce new material.

Class Format: tutorial, one hour per week; lecture, one hour per week
Requirements/Evaluation:  evaluation will be based on weekly problem sets, tutorial participation, presentations, and a final exam or final project, all of which have a substantial quantitative component
Prerequisites:  PHYS 202 and PHYS/MATH 210 or MATH 209 or MATH 309
Enrollment Limit:  10/section
Expected Class Size:  16
Grading:  no pass/fail option,  no fifth course option
Distributions:  (D3)  (QFR)

PHYS 418  (S)  Gravity  (QFR)
This course is an introduction Einstein's theory of general relativity. We begin with a review of special relativity, emphasizing geometrical aspects of Minkowski spacetime. Working from the equivalence principle, we then motivate gravity as spacetime curvature, and study in detail the Schwarzschild geometry around a spherically symmetric mass. After this application, we use tensors to develop Einstein's equation, which describes how energy density curves spacetime. With this equation in hand we study the Friedmann-Robertson-Walker geometries for an expanding universe, and finally, we linearize Einstein's equation to develop the theory of gravitational waves.

Class Format: lecture
Requirements/Evaluation:  evaluation will be based on weekly problem sets, a midterm exam, and a final exam, all of which have a substantial quantitative component
Prerequisites:  PHYS 301 or PHYS 405 or PHYS 411.  PLEASE DELETE: "students with strong math backgrounds are invited to consult with the
Enrollment Limit: none
Expected Class Size: 10
Grading: no pass/fail option, yes fifth course option
Distributions: (D3) (QFR)

Spring 2020
LEC Section: 01 MWF 9:00 am - 9:50 am David R. Tucker-Smith

POEC 253 (F) Empirical Methods in Political Economy (QFR)
This course introduces students to common empirical tools used in policy analysis and implementation. The broad aim is to train students to be discriminating consumers of public policy-relevant research. The emphasis in the course is on intuitive understanding of the central concepts. Through hands-on work with data and critical assessment of existing empirical social scientific research, students will develop the ability to choose and employ the appropriate tool for a particular research problem, and to understand the limitations of the techniques. Topics to be covered include basic principles of probability; random variables and distributions; statistical estimation, inference and hypothesis testing; and modeling using multiple regression, with a particular focus on understanding whether and how relationships between variables can be determined to be causal--an essential requirement for effective policy formation. Throughout the course, the focus will be on public policy applications relevant to the fields of political science, sociology, and public health, as well as to economics.
Class Format: lecture/discussion
Requirements/Evaluation: Problem sets, group project, midterm exam, final exam
Prerequisites: MATH 130 or its equivalent; one course in ECON; not open to students who have taken ECON 255
Enrollment Limit: 25
Enrollment Preferences: Political Economy majors, Environmental Policy majors and sophomores
Expected Class Size: 15
Grading: yes pass/fail option, yes fifth course option
Unit Notes: does not satisfy the econometrics requirement for the Economics major; POEC 253 cannot be substituted for ECON 255, or count as an elective towards the Economics major
Distributions: (D2) (QFR)
Attributes: EVST Methods Courses PHLH Statistics Courses POEC Required Courses

Fall 2019
LEC Section: 01 TF 2:35 pm - 3:50 pm Anand V. Swamy

PSYC 201 (F)(S) Experimentation and Statistics (QFR)
An introduction to the basic principles of research in psychology. We focus on how to design and execute experiments, analyze and interpret results, and write research reports. Students conduct a series of research studies in different areas of psychology that illustrate basic designs and methods of analysis.
Class Format: lecture/lab
Requirements/Evaluation: papers, exams, and problem sets
Extra Info: two sections; must register for the lab and lecture with the same instructor
Prerequisites: PSYC 101; not open to first-year students except with permission of instructor
Enrollment Limit: 16
Enrollment Preferences: Psychology majors
Grading: no pass/fail option, yes fifth course option
Distributions: (D2) (QFR)
Attributes: COGS Related Courses PHLH Statistics Courses
STAT 101  (F)(S)  Elementary Statistics and Data Analysis  (QFR)
It is impossible to be an informed citizen in the world today without an understanding of data and information. Whether opinion polls, unemployment rates, salary differences between men and women, the efficacy of vaccines or consumer webdata, we need to be able to separate the signal from the noise. We will learn the statistical methods used to analyze and interpret data from a wide variety of sources. The goal of the course is to help reach conclusions and make informed decisions based on data.

Class Format: lecture
Requirements/Evaluation: based primarily on performances on quizzes and exams
Prerequisites: MATH 102 (or demonstrated proficiency on a diagnostic test)
Enrollment Limit:  50
Expected Class Size:  40
Grading:  no pass/fail option,  no fifth course option
Unit Notes:  students with calculus background and social science interest should consider STAT 161; students with MATH 150 should enroll in STAT 201; students with a 5 on AP Stats should enroll in STAT 202; students with a 4 on AP Stat should consult the department
Distributions:  (D3)  (QFR)
Attributes:  BIGP Recommended Courses  COGS Related Courses  PHLH Statistics Courses

STAT 161  (F)(S)  Introductory Statistics for Social Science  (QFR)
This course will cover the basics of modern statistical analysis with a view toward applications in the social sciences and sciences. Topics include exploratory data analysis, elements of probability theory, basic statistical inference, and introduction to statistical modeling. The course focuses on the application of statistics tools to solve problems, to make decisions, and the use of statistical thinking to understand the world.

Class Format: lecture
Prerequisites:  MATH 130 (or equivalent); not open to students who have completed STAT 101 or equivalent
Enrollment Limit:  40
Enrollment Preferences:  Economics majors, sophomores
**Expected Class Size:** 40

**Grading:** no pass/fail option, no fifth course option

**Unit Notes:** students with MATH 150 should consider STAT 201; students with a 5 on AP Stats should enroll in STAT 202; students with a 4 on AP Stats should consult the department; students without any calculus background should consider STAT 101

**Distributions:** (D3) (QFR)

**Quantitative/Formal Reasoning Notes:** It is a quantitative course.

**Attributes:** PHLH Statistics Courses

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**Fall 2019**
LEC Section: 01    TR 8:30 am - 9:45 am    Anna M. Plantinga

**Spring 2020**
LEC Section: 01    TF 1:10 pm - 2:25 pm    Anna M. Plantinga
LEC Section: 02    TF 2:35 pm - 3:50 pm    Anna M. Plantinga

**STAT 201  (F)(S)  Statistics and Data Analysis  (QFR)**
Statistics can be viewed as the art and science of turning data into information. Real world decision-making, whether in business or science is often based on data and the perceived information it contains. Sherlock Holmes, when prematurely asked the merits of a case by Dr. Watson, snapped back, "Data, data, data! I can't make bricks without clay." In this course, we will study the basic methods by which statisticians attempt to extract information from data. These will include many of the standard tools of statistical inference such as hypothesis testing, confidence intervals, and linear regression as well as exploratory and graphical data analysis techniques. This is an accelerated introductory statistics course that involves computational programming and incorporates modern statistical techniques.

**Class Format:** lecture

**Requirements/Evaluation:** based primarily on performance on quizzes and exams

**Prerequisites:** MATH 150 or equivalent; not open to students who have completed STAT 101 or STAT 161 or equivalent

**Enrollment Limit:** 40

**Expected Class Size:** 40

**Grading:** yes pass/fail option, yes fifth course option

**Unit Notes:** students with a 5 on AP Stats should enroll in STAT 202; students with a 4 on AP Stats should consult the department; students with MATH 130/140 background should consider STAT 161; students with no calc. should consider STAT 101

**Distributions:** (D3) (QFR)

**Attributes:** BIGP Recommended Courses  COGS Related Courses  EVST Methods Courses  PHLH Statistics Courses

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**Fall 2019**
LEC Section: 01    TR 9:55 am - 11:10 am    Shaoyang Ning
LEC Section: 02    TR 11:20 am - 12:35 pm    Shaoyang Ning

**Spring 2020**
LEC Section: 01    TR 8:30 am - 9:45 am    Stewart D. Johnson
LEC Section: 02    TR 9:55 am - 11:10 am    Stewart D. Johnson

**STAT 202  (F)(S)  Introduction to Statistical Modeling  (QFR)**
Data come from a variety of sources sometimes from planned experiments or designed surveys, but also arise by much less organized means. In this course we'll explore the kinds of models and predictions that we can make from both kinds of data as well as design aspects of collecting data. We'll focus on model building, especially multiple regression, and talk about its potential as well as its limits to answer questions about the world. We'll emphasize applications over theory and analyze real data sets throughout the course.

**Class Format:** lecture

**Requirements/Evaluation:** homework, exams and projects
Prerequisites: AP Statistics 5 or STAT 101, 161 or 201 or permission of instructor

Enrollment Limit: 25

Expected Class Size: 20

Grading: no pass/fail option, no fifth course option

Unit Notes: students with a 4 on the AP Stats exam should contact the department for proper placement

Distributions: (D3) (QFR)

Attributes: EVST Methods Courses PHLH Statistics Courses

Fall 2019
LEC Section: 01 MWF 9:00 am - 9:50 am Xizhen Cai
LEC Section: 02 MWF 10:00 am - 10:50 am Xizhen Cai

Spring 2020
LEC Section: 01 MWF 11:00 am - 11:50 am Xizhen Cai

STAT 341 (F)(S) Probability (QFR)

Cross-listings: MATH 341 STAT 341

Secondary Cross-listing

While probability began with a study of games, it has grown to become a discipline with numerous applications throughout mathematics and the sciences. Drawing on gaming examples for motivation, this course will present axiomatic and mathematical aspects of probability. Included will be discussions of random variables, expectation, independence, laws of large numbers, and the Central Limit Theorem. Many interesting and important applications will also be presented, potentially including some from coding theory, number theory and nuclear physics.

Class Format: lecture

Requirements/Evaluation: evaluation will be based primarily on homework, classwork, and exams

Prerequisites: MATH 250 or permission of the instructor

Enrollment Limit: 40

Expected Class Size: 20

Grading: yes pass/fail option, yes fifth course option

Distributions: (D3) (QFR)

This course is cross-listed and the prefixes carry the following divisional credit:
MATH 341 (D3) STAT 341 (D3)

Fall 2019
LEC Section: 01 MWF 11:00 am - 11:50 am Steven J. Miller

Spring 2020
LEC Section: 01 TF 2:35 pm - 3:50 pm Mihai Stoiciu

STAT 342 (F) Introduction to Stochastic Processes (QFR)

Stochastic processes are mathematical models for random phenomena evolving in time or space. Examples include the number of people in a queue at time t or the accumulated claims paid by an insurance company in an interval of time t. This course introduces the basic concepts and techniques of stochastic processes used to construct models for a variety of problems of practical interest. The theory of Markov chains will guide our discussion as we cover topics such as martingales, random walks, Poisson process, birth and death processes, and Brownian motion.

Class Format: lecture

Requirements/Evaluation: primarily on weekly homework, classwork, and exams

Prerequisites: STAT 341

Enrollment Limit: 30
Enrollment Preferences: senior Statistics majors

Expected Class Size: 15

Grading: yes pass/fail option, yes fifth course option

Distributions: (D3) (QFR)

Quantitative/Formal Reasoning Notes: This is a statistics class with a focus on mathematical skills and translating real world phenomena into mathematical descriptions.

Fall 2019

LEC Section: 01   TF 1:10 pm - 2:25 pm   Elizabeth M. Upton

STAT 346  (F)(S) Regression and Forecasting  (QFR)
This course focuses on the building of empirical models through data in order to predict, explain, and interpret scientific phenomena. Regression modeling is the standard method for analyzing continuous response data and their relationship with explanatory variables. This course provides both theoretical and practical training in statistical modeling with particular emphasis on simple linear and multiple regression, using R to develop and diagnose models. The course covers the theory of multiple regression and diagnostics from a linear algebra perspective with emphasis on the practical application of the methods to real data sets. The data sets will be taken from a wide variety of disciplines.

Class Format: lecture

Requirements/Evaluation: evaluation will be based primarily on performance on exams, homework, and a project

Prerequisites: STAT 201 or 202, and MATH 150 and 250; or permission of instructor

Enrollment Limit: 22

Expected Class Size: 15

Grading: no pass/fail option, no fifth course option

Distributions: (D3) (QFR)

Attributes: EVST Methods Courses

Fall 2019

LEC Section: 01   MWF 8:30 am - 9:45 am   Richard D. De Veaux

Spring 2020

LEC Section: 01   MWF 8:30 am - 9:45 am   Xizhen Cai

STAT 360  (S) Statistical Inference  (QFR)
How do we estimate unknown parameters and express the uncertainty we have in our estimate? Is there an estimator that works best? Many topics from introductory statistics such as random variables, the central limit theorem, point and interval estimation and hypotheses testing will be revisited and put on a more rigorous mathematical footing. The focus is on maximum likelihood estimators and their properties. Bayesian and computer intensive resampling techniques (e.g., the bootstrap) will also be considered.

Class Format: lecture

Requirements/Evaluation: evaluation will be based on problem sets and exams

Prerequisites: MATH 250, STAT 201 or 202, STAT 341

Enrollment Limit: 30

Enrollment Preferences: Statistics majors

Expected Class Size: 30

Grading: no pass/fail option, yes fifth course option

Distributions: (D3) (QFR)

Spring 2020
STAT 368 (S) Modern Nonparametric Statistics (QFR)

Many statistical procedures and tools are based on a set of assumptions, such as normality or other parametric models. But, what if some or all of these assumptions are not valid and the adopted models are miss-specified? This question leads to an active and fascinating field in modern statistics called nonparametric statistics, where few assumptions are made on data’s distribution or the model structure to ensure great model flexibility and robustness. In this course, we start with a brief overview of classic rank-based tests (Wilcoxon, K-S test), and focus primarily on modern nonparametric inferential techniques, such as nonparametric density estimation, nonparametric regression, selection of smoothing parameter (cross-validation), bootstrap, randomization-based inference, clustering, and nonparametric Bayes. Throughout the semester we will examine these new methodologies and apply them on simulated and real datasets using R.

Class Format: lecture

Requirements/Evaluation: primarily on performance on exams, homework, and a project

Prerequisites: STAT 201 and STAT 346, or permission of instructor.

Enrollment Limit: 30

Enrollment Preferences: senior Statistics majors

Expected Class Size: 15

Grading: yes pass/fail option, yes fifth course option

Distributions: (D3) (QFR)

Quantative/Formal Reasoning Notes: This is a statistics class with a focus on mathematical, computational, and data analysis skills as well as appropriate practical application of analysis methods.

Spring 2020

LEC Section: 01    TR 11:20 am - 12:35 pm    Shaoyang Ning

STAT 410 (F) Statistical Genetics (QFR)

Genetic studies explore patterns of genetic variation in populations and the effect of genes on diseases or traits. This course provides an introduction to statistical and computational methods for genetic studies. Topics will include Mendelian traits (such as single nucleotide polymorphisms), genome-wide association studies, pathway-based analysis, and methods for population genetics. Students will be introduced to some of the major computational tools for genetic analysis, including PLINK and R/Bioconductor. The necessary background in genetics and biology will be provided alongside the statistical and computational methods.

Class Format: lecture

Requirements/Evaluation: project work, homework, exams, and contribution to discussion

Prerequisites: STAT 346 and STAT 360, or permission of instructor

Enrollment Limit: 14

Enrollment Preferences: Statistics majors, juniors and seniors

Expected Class Size: 10

Grading: no pass/fail option, no fifth course option

Distributions: (D3) (QFR)

Quantative/Formal Reasoning Notes: This is a statistics class with a focus on mathematical, computational, and data analysis skills as well as appropriate practical application of analysis methods.

Attributes: BIGP Related Courses  PHLH Statistics Courses

Fall 2019

LEC Section: 01    TR 11:20 am - 12:35 pm    Anna M. Plantinga

STAT 442 (S) Statistical Learning and Data Mining (QFR)
In both science and industry today, the ability to collect and store data can outpace our ability to analyze it. Traditional techniques in statistics are often unable to cope with the size and complexity of today's data bases and data warehouses. New methodologies in Statistics have recently been developed, designed to address these inadequacies, emphasizing visualization, exploration and empirical model building at the expense of traditional hypothesis testing. In this course we will examine these new techniques and apply them to a variety of real data sets.

**Class Format:** lecture

**Requirements/Evaluation:** evaluation will be based primarily on homeworks and projects

**Prerequisites:** STAT 346 or permission of instructor

**Enrollment Limit:** 14

**Enrollment Preferences:** seniors and Statistics Majors

**Expected Class Size:** 10

**Grading:** no pass/fail option, no fifth course option

**Distributions:** (D3) (QFR)

Spring 2020

LEC Section: 01  MWF 8:30 am - 9:45 am  Richard D. De Veaux

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