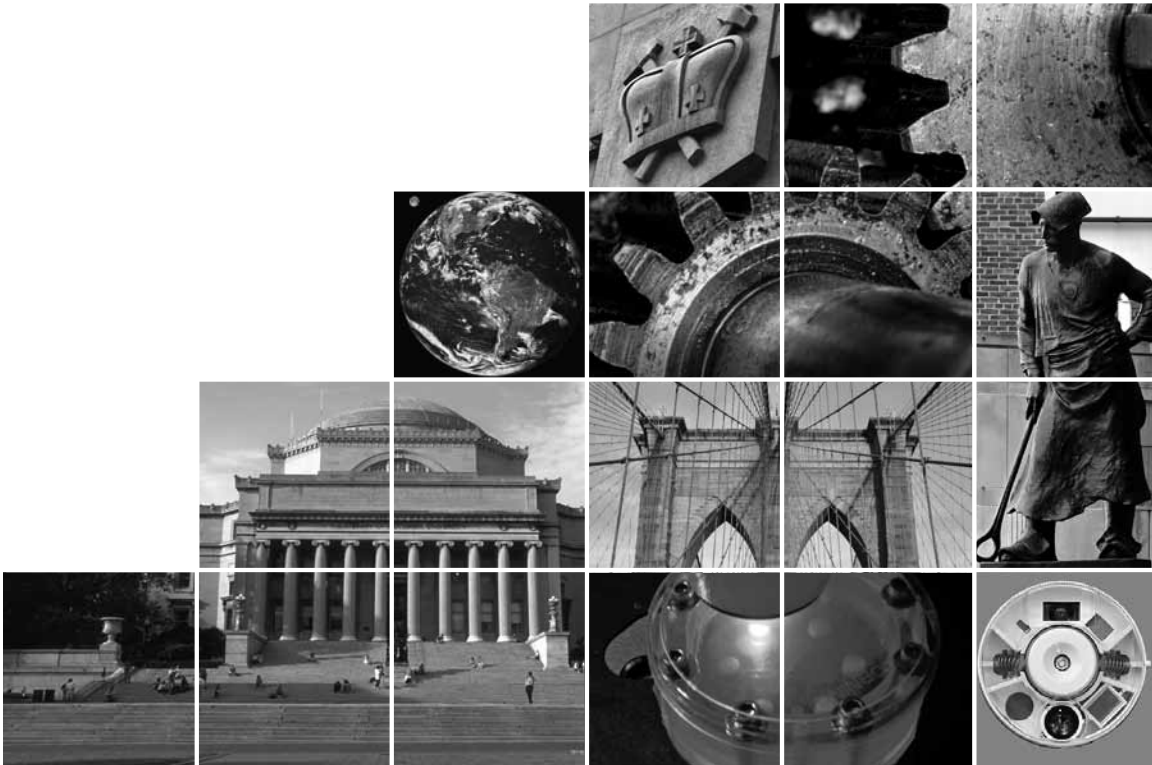




COLUMBIA | ENGINEERING

The Fu Foundation School of Engineering and Applied Science

UNDERGRADUATE RESEARCH INVOLVEMENT PROGRAM 2012-2013



Introduction

At The Fu Foundation School of Engineering and Applied Science at Columbia University, the faculty takes an active role in research, which is funded by both private and government sources. Faculty members view student involvement in research as a part of the educational process and actively encourage it.

Many students at Columbia Engineering are destined for the professional research environment, while others may work in professional capacities in tandem with the research function. It is the purpose of the program and this guide to enable undergraduate students to participate.

Participation in the program is voluntary, although students are advised that the faculty expect students to honor any commitment they may make. This booklet, also available online at www.engineering.columbia.edu/undergraduate-research-involvement-program, is designed to describe the specific opportunities themselves and to lay out the routes of access.

How to Use This Publication

Columbia Engineering faculty members have been asked to list particulars of research opportunities for undergraduate students. This booklet is a compilation of their responses.

A “research opportunity” is similar to—but not quite the same as—a job in research. Some opportunities involve academic credit and require that students register for “independent study” courses. Some positions involve pay, either as a part-time, casual employee of the University, or as a participant in the Federal Work-Study Program. Thus, special work-study eligibility via the Financial Aid Office may be required. Some opportunities extend for one or more academic terms; others continue over the summer. Some may begin only at the start of an academic year, in September. Opportunities may entail different time commitments or time periods of participation. Normally, students are expected to have an overall grade average of at least 3.0.

The duration and other critical factors of the opportunity reflect the needs of the faculty research coordinator and the skills, interests, and capacities of the student participants. As a student grasps new aspects of a project, such as by learning new skills, his/her role in the project may grow and evolve.

Each research opportunity involves areas of expertise and specialization. Thus, the opportunities have been listed both in terms of (1) the specific research area, and (2) the special skills required of the student. Each faculty member in charge of a research area (the “contact”) was asked to specify whether his/her opportunity involved any or all of the following research activities:

- paper study, mathematical projects, library research
- engineering or scientific design
- mechanical or electrical assembly
- computational or computer analysis

They were also asked to specify:

- whether the opportunity entailed academic credit or hourly wages (either through the Federal Work-Study Program or other remuneration)
- the possible duration, whether term-time or summer participation only
- the weekly hour commitment
- any individual qualifications desirable in the applicant, such as minimum GPA, required courses, prior work experience, and computer language fluency

In some cases, respondents did not specify a certain item of information. This omission indicates that the item is not likely to be a requisite or constraint.

Application Procedure

If you are interested in participating in direct research, then your first step is to read through the opportunity descriptions on the following pages. Identify the two or three opportunities that interest you the most, and ask yourself whether or not you meet the basic qualifications. If so, then telephone (or e-mail) the contact listed after the research description to find out if the opportunity is still available. If you do not reach the contact on your first try, please be persistent. Remember, it is likely that you will not be the only applicant for a specific opportunity in the Undergraduate Research Involvement Program and that the contact has the final say as to who is selected for the opportunity.



Department of Applied Physics and Applied Mathematics

Chair: Professor I. Cevdet Noyan, 200 Mudd, 212-854-4457

Opportunities

- structure and properties of nanoparticles
- x-ray and neutron scattering experiments on complex energy materials
- simulation and modeling of nanoparticle structures
- scientific software development
- web development of educational website

Opportunities for motivated sophomore, junior, and senior students, for academic credit or possible remuneration, to participate in the full range of research activities. Experiments are done at National Laboratories (Brookhaven, Argonne, Los Alamos) with opportunities for undergrads to participate. Various possibilities exist depending on the interests of the students, though most involve some use of computers: either data analysis using existing programs or developing new analyses by writing new programs. Students with expertise and an interest in Python programming are especially welcome for numerous scientific software development activities, and also php/SQL for an education website project. Minimum commitment of 8 hours per week is required.

Contact: Professor Simon J. L. Billinge, sb2896@columbia.edu, 1105 Mudd, 212-854-2918

Opportunities

- nanocrystals, nanoscience, and nanotechnology
- laser probe of thin films and thin film processing
- fabrication and properties of nanomaterials

Opportunities for motivated sophomore, junior, and senior students who are willing to commit to at least 6 hours per week, for academic credit or possible remuneration, to participate in the full range of research activities: paper study, mathematical projects, library research, engineering or scientific design, mechanical or electrical assembly, and computational or computer analysis.

Contact: Professor Irving P. Herman, iph1@columbia.edu, 905 CEPSR, 212-854-4950

Opportunities

- applied electrodynamics
- plasma physics and experiments
- space physics, microwave heating, and plasma sources

Opportunities include the following activities: mathematical projects, library research, design and assembly of physics experiments, and computer analysis of physics data. Preference will be given to students interested in and capable of laboratory work. Both academic credit and remunerative positions available. The desired weekly commitment is at least 5 hours. Prerequisite: *APPH E3300: Applied electromagnetism* or equivalent.

Contact: Professor Michael Mauel, mem4@columbia.edu, 213 Mudd, 212-854-4455

Opportunities

- applied electrodynamics
- plasma physics and experiments

Opportunities include the following activities: mathematical projects, library research, design and assembly, and computer analysis. Preference will be given to students interested in and capable of laboratory work. Both academic credit and remunerative positions available. The desired weekly commitment is at least 5 hours. Desired prerequisite: *APPH E3300: Applied electromagnetism* or equivalent.

Contact: Professor Gerald Navratil, navratil@columbia.edu, 209 Mudd, 212-854-4496

Opportunities

- computational physics and mathematics

A commitment of no less than 8 hours per week is expected. Knowledge of C, C++, Python/MATLAB and UNIX is essential.

Contact: Professor Marc Spiegelman, mspieg@ldeo.columbia.edu, 211 Mudd, 212-854-4918

Opportunities

- experimental nanoscience
- nanoscience tool development
- synthesis of new materials

Opportunities for juniors and seniors to participate in research focusing on understanding physics and chemistry at the single molecule level. Experimental work will involve using and developing improvements to an atomic force microscope or scanning tunneling microscope. Students willing to commit to at least 8 hours per week, for academic credit and/or possible wages, should apply. Successful research may extend into the summer. Previous employment, computational literacy, and basic knowledge of chemistry would be highly useful.

Contact: Professor Latha Venkataraman, lv2117@columbia.edu, 212-854-1786;
<http://www.columbia.edu/~lv2117>

Opportunities

- applied mathematics
- wave phenomena in fundamental and applied science

Opportunities for motivated juniors and seniors to participate in a range of activities: library research, paper study, computer simulation, mathematical projects (modeling and analysis). Skills in computer programming would be very useful (e.g., MATLAB) as would basic knowledge of differential equations, dynamical systems, linear algebra, and analysis. A commitment of at least 8 hours per week is required.

Contact: Professor Michael I. Weinstein, miw2103@columbia.edu, 212 Mudd, 212-854-3624; <http://www.columbia.edu/~miw2103>

Opportunities

- machine learning
- biological networks
- systems biology
- computer vision and image analysis

Focus areas include applications of machine learning, statistical inference, and information theory for the inference, analysis, simulation, and organization of biological networks. Students of all years willing to commit to at least 6 hours per week, for academic credit and/or possible wages, should apply. Successful research may extend into the summer. Previous employment, computational literacy (particularly UNIX, MATLAB, Python), and/or mathematical literacy (differential equations, dynamical systems, linear algebra, and/or numerical analysis) would be highly useful.

Contact: Professor Chris Wiggins, chris.wiggins@columbia.edu, 205 Mudd, 212-854-1114; <http://www.columbia.edu/~chw2>

Department of Biomedical Engineering

**Interim Chair: Professor Andreas H. Hielscher, 351 Eng Terrace,
212-854-5080**

Opportunities

- cell mechanics
- tissue mechanics
- tissue engineering
- design of instrumentation for testing soft tissues
- software development for cell, tissue, and joint modeling
- modeling of growth

Student participants are involved in the testing of biological soft tissues for the determination of material and tribological properties, testing of cells for the assessment of their biophysical properties, design of instrumentation for performing such measurements, tissue engineering of cartilage, software development for modeling cells, tissues and joints, and modeling studies of tissue growth.

Contact: Professor Gerard A. Ateshian, ateshian@columbia.edu, 220 Mudd,
212-854-8602

Opportunities

- image analysis and modeling of bone microstructure
- biomedical analysis and computational biomechanics of clinical images
- microcontact printing and bone cell network in mechanotransduction
- 3D single cell mechanics

Opportunities for undergraduate research assistants working on various projects in the laboratory: image analysis and modeling of bone microstructure using micro-computed tomography; biomedical image analysis and computational biomechanics of patients' images; microcontact printing technology, bone cell network and mechanotransduction, single cell 3D biomechanics and real-time signal transduction. Students seeking long-term association are preferred. Possible credit or remuneration, 12 hours per week during academic year and full time during the summer.

Contact: Professor X. Edward Guo, exg1@columbia.edu, 351 Eng Terrace, 212-854-6196

Opportunities

- nanobiotechnology
- engineering applications of molecular motors
- synthetic biology using minimal proteinaceous systems
- science and engineering of non-fouling surfaces

The laboratory pursues engineering at the molecular scale, in particular the design of active nanosystems incorporating biomolecular motors and other enzymes, the study of active self-assembly, and the investigation of protein-resistant polymer coatings. Possible credit or remuneration, 12 hours per week term-time and full time during the summer. Potential summer research project in international partner laboratories.

Contact: Professor Henry Hess, hh2374@columbia.edu, 351 Eng Terrace, 212-854-7749

Opportunities

- biophotonics
- design and testing of instrumentation for optical medical imaging
- software development for medical image reconstruction
- participate in clinical studies on breast cancer, peripheral vascular disease, and others

This laboratory works toward a novel medical imaging modality in which near-infrared light is used to obtain cross-sectional images of various body parts, such as the breast, brain, or limbs. Possible projects include a wide range of topics such as studying light-tissue interactions, setting up clusters for parallel processing, numerically solving large-scale optimization problems with finite-difference and finite-element schemes, designing electro-optical circuits for light amplification and detection, and performing clinical studies concerning rheumatoid arthritis, peripheral vascular disease, breast cancer, and others. Possible credit or remuneration, 12 hours per week term-time and full time during the summer.

Contact: Professor Andreas H. Hielscher, ahh2004@columbia.edu, 351 Eng Terrace, 212-854-5080

Opportunities

- *in vivo* optical imaging and microscopy
- development of laser imaging and CCD camera-based systems
- acquisition of *in vivo* data to investigate neurovascular coupling in the brain
- electrical propagation in the heart, and skin cancer
- data analysis and reconstruction of dynamic optical imaging and microscopy data

Undergraduates joining our lab learn about different high-resolution optical imaging methods. We apply these methods primarily to study the function of the brain *in vivo*, but also have projects relating to dermal and cardiac imaging. Students may wish to gain experience developing imaging systems, applying and learning electronics, optics, data acquisition hardware, and graphical user interface software development. Students may also wish to learn to acquire *in vivo* data and investigate some of the fundamental aspects of brain function such as neurovascular coupling—the way that neurons in the brain communicate with the blood supply. Image processing, computer simulations, and data processing are also major aspects of our work to which students can contribute. Possible credit or remuneration, 12 hours per week term-time and full time during the summer.

Contact: Professor Elizabeth Hillman, eh2245@columbia.edu, 406 CEP SR, 212-854-2788

Opportunities

- cell mechanical characterization and instrumentation
- cell-cell interactions and control of cell behavior
- models of cell mechanotransduction/diseases

Research opportunities available for undergraduates interested in cell mechanics research. The projects' goal is to understand how mechanical stresses and junctional molecules regulate cell adhesion and mechanotransduction. Cell culture experience useful but not necessary. Students learn basic cell culture and microscopy techniques, as well as select molecular techniques depending on the project direction. Instrumentation modification, 10 design, and implementation are available as well. Two research focus tracks are available: (1) development, refinement, and application of cell adhesion assays (instrumentation); and

(2) study of cell-cell interactions and regulation of cell mechanics and adhesion (literature, modeling, and experiments). Possible credit or remuneration, for a commitment of at least 10 hours per week per term, through the academic year and possibly full time during the summer.

Contact: Professor Hayden Huang, hayden.huang@columbia.edu, 351 Eng Terrace

Opportunities

- culturing of cell-seeded three-dimensional scaffolds for orthopedic tissue engineering
- evaluation of functional material/biochemical properties of growing tissue constructs
- studies of orthopedic mechanotransduction-cell response to mechanical forces

Students are involved with multidisciplinary research of the Cellular Engineering Laboratory that is aimed at the study of physical regulation of articular cartilage as well as orthopedic tissue engineering. Students seeking long-term associations are preferred. Possible credit or remuneration, 12 hours per week term-time and full time during the summer.

Contact: Professor Clark T. Hung, cth6@columbia.edu, 351 Eng Terrace, 212-854-6542

Opportunities

- *in vitro* cell culture and molecular biology applied to understanding how bone cells sense and respond to mechanical signals
- evaluation of the response of cells expressing mutant mechanosensing proteins
- microscopic determination of the mechanical behavior of cells
- *in vivo* evaluation of the skeletal response to mechanical loads of mutant mice

The Cell and Molecular Biomechanics Laboratory is focused on determining the molecular mechanism that bone cells use to sense and respond to changes in their mechanical environment. Opportunities for undergraduate research assistants include utilizing techniques from cell and molecular biology to determine the role of specific proteins in mechanosensing. These insights are translated into *in vivo* mouse models with mutations of specific proteins that are, in turn, evaluated in terms of the ability of their bone to adapt to changes in the mechanical demands they are exposed to. Possible credit or remuneration, 12 hours per week during the academic year and full time during the summer.

Contact: Professor Christopher R. Jacobs, crj2111@columbia.edu, 351 Eng Terrace, 212-851-0271

Opportunities

- micro- and nanoscale fabrication of biological systems
- immune engineering
- cell signaling

Contemporary fabrication techniques offer new ways to answer questions in cell signaling and to engineer cell function. Undergraduates will have the opportunity to develop these techniques and apply them to cellular and molecular systems. Skills include microfabrication, protein design and production, advanced fluorescence microscopy, and cell culture. Undergraduates will have the opportunity to learn these skills, and must bring enthusiasm and creativity to these projects. We are particularly interested in students seeking significant, multise semester projects.

Contact: Professor Lance C. Kam, lk2141@columbia.edu, 363 Eng Terrace, 212-854-8611

Opportunities

- medical image analysis: quantification
- 3D cardiac ultrasound imaging: dynamic segmentation
- methods for automated recognition of protein crystals
- nodule detection algorithms in spiral CT lung screening
- longitudinal analysis of medical images and health records
- MRI cardiac tagging for strain measures

Students are sought who are interested in assisting in the testing, performance evaluation, and development of quantitative and qualitative methods of image analysis. Projects include the detection and diagnosis of disease through the modalities of ultrasound, MRI, PET, CT, and digital mammography. Participation requires competence of programming in MATLAB, C, IDL, or Java and an interest to learn underlying algorithms. Students with knowledge of signal processing and applied mathematics are preferred. Projects can provide academic credit and remuneration, 8–12 hours per week during the academic year and full time opportunities in the summer.

Contact: Professor Andrew Laine, laine@columbia.edu, 407 CEPSR, 212-854-6539

Opportunities

- development of novel biomaterials for musculoskeletal tissue regeneration
- study of interactions between cells and biomaterial surfaces
- dental tissue engineering
- research projects: design and custom-built small devices, literature search

Student participants are introduced to various stages of the development of tissue-engineered scaffolds and hybrid matrices for musculoskeletal and dental tissue engineering, focusing on applications at the interface between bone and soft tissue. The student may be involved in the background literature search, in the design of experiments, as well as in data analysis, modeling, and interpretation. An interest in biomaterial design and/or cell-material interaction is expected. Possible credit or work study, 10–12 hours per week term-time or full time during the summer.

Contact: Professor Helen H. Lu, hllu@columbia.edu, 351 Eng Terrace, 212-854-4071

Opportunities

- researching the molecular pathophysiology of traumatic brain injury
- development of the necessary instrumentation to simulate brain injury
- tissue culture of rat brain tissue
- electrophysiological measurements and signal processing
- studying brain injury biomechanics

Matriculating students with a minimum 3.0 GPA are invited to apply for research opportunities to explore the molecular, cellular, and functional consequences of traumatic brain injury. These opportunities span the full gamut of projects from instrumentation development and assembly, feedback control systems, image analysis, signal processing, tissue culture, application of biomechanics, etc. Experience in any of the above-mentioned fields is beneficial but not a prerequisite; however, an enthusiasm to reduce the societal impact of head injury is required. Students seeking long-term associations are preferred. Possible credit or remuneration, 12 hours per week term-time and full time during the summer.

Contact: Professor Barclay Morrison, bm2119@columbia.edu, 363 Eng Terrace, 212-854-6277

Opportunities

- neurocomputational modeling of visual cortex
- computational vision
- analysis of spatiotemporal and spectral imagery

Student participants are involved in development and evaluation of biomimetic models of perceptual organization and object recognition. An interest in learning-related aspects of neuroscience and computer vision is expected. Good programming skills required (e.g., MATLAB, C, C++, Java). Background in linear algebra and introduction to probability theory would also be helpful (but not required). Possible credit or remuneration, 12 hours per week term-time and full time during the summer.

Contact: Professor Paul Sajda, ps629@columbia.edu, 404 CEPSR, 212-854-5279

Opportunities

- MEMS devices to improve the health of people in developing countries
- microscale tissue engineering

Undergraduate students work closely with a graduate student on an independent project. Our laboratory has two areas of focus: (1) developing new low-cost and portable diagnostic devices to improve global health (such as protein sensors); and (2) using molecular and microtechnology-based approaches to study and control how tissues form (such as blood vessels, including work with stem cells). Possible credit or remuneration, with a commitment of 10 hours per week term-time and full time during the summer.

Contact: Professor Samuel Sia, ss2735@columbia.edu, 363 Eng Terrace, 212-854-7549

Opportunities

- tissue engineering of human grafts
- studies of human stem cells
- advanced biomaterials and bioreactors

Opportunities for undergraduate research assistants to work on biophysical regulation of stem cells (adult and embryonic), tissue engineering of functional grafts (cardiac “patch,” orthopedic tissues, vascular beds). Both experimental and modeling studies are available. Laboratory skills and experience with cell culture are a great plus. Work for credit during the semester. The weekly commitment is 10 hours or more.

Contact: Professor Gordana Vunjak-Novakovic, gv2131@columbia.edu,
622 West 168th Street (Vanderbilt Clinic), Room 12-234, 212-305-2304

Department of Chemical Engineering

Chair: Professor Sanat K. Kumar, 801 Mudd, 212-854-4453

Opportunities

- engineering of protein molecules using recombinant DNA technology
- protein purification and protein analysis
- engineering of metabolic networks

Research in this laboratory involves experimental studies in protein engineering. Molecular biology tools and techniques are used including genetic engineering, electrophoresis, chromatography, and assay development. Academic credit and work study are available. Students should be prepared to commit at least 8 hours per week in exchange for academic credit.

Contact: Professor Scott Banta, sbanta@columbia.edu, 820 Mudd, 212-854-7531

Opportunities

- advanced materials research: behavior of macromolecules in solution; adsorption and self-assembly of macromolecules and nanoparticles; characterization of materials for pharmaceutical applications

These projects all involve experimental studies and require at least 6 hours per week commitment. Opportunities are available to study new/unique synthetic materials, mainly macromolecular (i.e., polymeric), for potential applications as advanced coatings, sensors, and thin films. Other projects address characterizing materials used in drug manufacture, packaging, and delivery. Participants learn experimental methods and are responsible for systematic application of the methods, data reduction, and reporting of results. Projects can be undertaken for academic credit or may involve sponsored internships.

- computing: computer simulation of molecular systems; data analysis; software development; web page development

Projects are available to exploit computing skills for materials research, teaching, or Internet applications. Participants normally enroll for academic credit, but work study and internships may be available. Familiarity with Windows- and/or UNIX-based operating systems is necessary, and depending on the project, knowledge of computing languages/software packages (e.g., Fortran, C, Mathcad, IDL) and/or web-development tools (e.g., html) is also necessary.

Contact: Professor Chris Durning, cjd2@columbia.edu, 801 Mudd, 212-854-8161

Opportunities

- nanoparticle-polymer hybrids-matrix free nanocomposites
- magnetic nanoparticles for drug delivery
- solid phase synthesis of branched polymers-surface modification
- kinetics of polymer interfacial reactions

These activities include experimental laboratory work such as polymer synthesis, analysis of soft material surfaces and properties, construction of novel instrumentation for characterizing polymeric materials, as well as some theoretical calculations of polymer properties. Students should be prepared to commit 6–8 hours per week to attain academic credit.

Contact: Professor Jeff Koberstein, jk1191@columbia.edu, 801 Mudd, 212-854-3120

Opportunities

- study of transport phenomena in microfluidic flow of blood
- modeling and simulation of cell capture in microfluidic arrays

The laboratory can host three undergraduate students at most at any one time; students seeking long-term associations are preferred. One opportunity involves closely connected experimental and modeling work associated with microfluidics, including its application to the development of a blood-processing device (artificial kidney) and to “process intensification,” an effort of the chemical industry to devise smaller, more environmentally friendly chemical plants. A second opportunity involves computational flow dynamics (CFD), being used to simulate the capture of rare cells in microfluidic devices to diagnose pregnancy and certain diseases. This effort carries the possibility of a summer internship with a collaborating California company. Any academic credit and/or wages are normally available only after a probationary period that may be as long as an academic year. The weekly time commitment is at least 10 hours. Students must have a GPA of 3.3 or higher and some record of previous employment.

Contact: Professor Edward Leonard, leonard@columbia.edu, 801 Mudd, 212-854-4448, (laboratory: 1033 Mudd, 212-854-3007); <http://www.columbia.edu/~leonard/>; or Professor Michael Hill, mhill@columbia.edu, 801 Mudd, 212-854-1095

Opportunities

- atmospheric chemistry and physics
- air pollution
- climate

Research in this laboratory involves experimental and modeling studies in atmospheric chemistry and climate. Opportunities exist for independent projects or projects in support of doctoral research. Students should be prepared to commit at least 8 hours per week. Academic credit and work study are available.

Contact: Professor V. Faye McNeill, vfm2103@columbia.edu, 816 Mudd, 212-854-2869; <http://www.columbia.edu/~vfm2103>

Opportunities

- biology of the cell and applications: fusion and crossing of cell membrane barriers; viral defense and drug delivery strategies; cell healing; intracellular trafficking; the immune system; force production and mechanosensing by cells
- usage and development of image analysis software applied to complex cellular processes; analysis of cell-generated force maps on the cell environment
- computer projects: developing interactive web-based learning interfaces; JavaScript modules for dynamic graphic visualization; website development

Activities entail a weekly time commitment of 4 hours or more. Both academic credit and remunerative positions available. Term-time and summer positions available.

Contact: Professor Ben O'Shaughnessy, bo8@columbia.edu, 1006 Mudd, 212-854-3203

Opportunities

- carbon capture, utilization, and storage
- study of novel liquid-like nanoparticle organic hybrid materials (NOHMs) for energy and environmental technologies
- synthesis of liquid fuels from wastes and biomass
- investigation of electrostatic charging phenomenon in multiphase flows

Research in this laboratory involves both experimental and modeling studies in catalytic and non-catalytic reactions related to energy and environmental systems. Undergraduate researchers are generally paired with graduate students on specific projects. However, independent research projects may be available for summer interns. The weekly time commitment is at least 10 hours.

Contact: Professor A.-H. Alissa Park, ap2622@columbia.edu, 1038A Mudd, 212-854-8989; <http://www.columbia.edu/~ap2622>

Opportunities

- electrochemistry, with applications in fuel cells, corrosion or metallization of electronic, magnetical, or mechanical devices

This opportunity involves primarily experimental work in support of doctoral research projects. The work provides exposure to basic electrochemical experiments and may involve some optical and electronic microscopy. Some opportunities may exist for enhancing the group's software infrastructure. Students should be prepared to commit approximately 6–8 hours per week in exchange for academic credit (*CHEN E3900: Undergraduate research project*). Work-study opportunities may exist.

Contact: Professor Alan West, acw17@columbia.edu, 801 Mudd, 212-854-4453

Department of Civil Engineering and Engineering Mechanics

Chair: Professor Raimondo Betti, 610 Mudd, 212-854-6388

Opportunities

- deterioration of cable-suspension bridge wires

This project has as its objective the understanding of the deterioration and fracture mechanism in high-strength, low-carbon steel wires that are used in cable suspension bridges. Laboratory tests on wires are conducted to determine the corrosion rate and the location of crack initiation. For academic credit, a minimum commitment of 5–10 hours per week is required.

- structural damage identification

This project focuses on the determination of computer algorithms for the automatic detection of damaged areas in structural systems. These algorithms use the structural response to some known excitations to provide mathematical and physical models that are capable of reproducing the dynamic behavior of the real structure. In this study, computer simulations on numerical and experimental tests are performed. For academic credit, a minimum commitment of 5–10 hours per week is required.

Contact: Professor Raimondo Betti, betti@civil.columbia.edu, 640 Mudd, 212-854-6388

Opportunities

- risk assessment and risk management of infrastructure

This project aims to assess the risk to the civil infrastructure (buildings, bridges, lifelines, etc.) arising from hazards in major metropolitan areas, both natural (earthquake, wind, landslides, etc.) and man-made (climate change, accidents, terrorism). Once the risk is assessed, the objective is to introduce innovative ways to mitigate the catastrophic consequences of the various hazards. The approach followed to address this problem is a multidisciplinary one, combining knowledge and techniques from the natural sciences, engineering, urban planning, economics, finance, and psychology.

- scientific and aesthetic analysis of large-scale structures

This project aims to analyze a series of large-scale structures (including bridges, buildings, and roof structures) from both a scientific and an aesthetic point of view. The social significance of the structures is also considered. The concept of structural art is studied, and emphasis is given to symbolic and historic structures.

- characterization of microstructure of heterogeneous materials

This project aims to develop methodologies to accurately quantify and describe the uncertain microstructure of two-phase materials. Applications in a wide range of materials, including concrete, cellular aluminum, graphite-epoxy fibrous composites, etc.

- reliability of fatigue-sensitive structures, including aircraft and ships

This project aims to develop techniques to assess the reliability of structures that are sensitive to fatigue. Methodologies are developed to estimate the deterioration of their reliability as a function of time and to introduce optimum nonperiodic inspection schedules. Emphasis is placed on aircraft and ships.

- simulation of stochastic processes and fields

This project aims to develop methodologies to digitally simulate stochastic processes and fields that can be used to model random actions on structures (e.g., earthquakes, wind, blast) or uncertain material and soil properties.

- stochastic finite element methods

This project aims at developing stochastic finite element methodologies for the analysis of structural systems with uncertainties in their system properties and external excitation. Emphasis is given in developing variability response functions for various quantities in linear and nonlinear problems.

Contact: Professor George Deodatis, deodatis@civil.columbia.edu, 630 Mudd, 212-854-9728

Opportunities

- structural dynamics
- structural identification
- active control

Laboratory assistant positions, either for academic credit or on a volunteer basis to participate in research projects involving dynamic testing using the medium-scale seismic shake table in the Carleton Laboratory. Research projects include structural system identification, damage detection, and adaptive control. Activities include test-model design and fabrication, dynamic response computer simulation, data acquisition, and library research. Some experience in MATLAB, dynamics/vibrations is desirable.

Contact: Professor Andrew Smyth, smyth@civil.columbia.edu, 636 Mudd, 212-854-3369

Opportunities

- computational fracture mechanics

Students work on computer simulations and algorithm development involving advanced finite element techniques to model fracture and multiphase materials. This requires basic knowledge in finite element methods. For academic credit, a minimum commitment of 5–10 hours per week.

- intensive computations on parallel supercomputers

Students employ supercomputers at Columbia University to model very large problems in elasticity, e.g., models of an entire building with millions of unknowns, using finite element codes. For academic credit, a minimum commitment of 5–10 hours per week.

- damage-induced corrosion (in collaboration with Professor Betti)

Students study and develop corrosion models from experiments to characterize the rate and direction of the damage. Models are then implemented in computer simulations of damaged structures. Literature research is also expected. For academic credit, a minimum commitment of 5–10 hours per week.

- structural health monitoring (in collaboration with Professor Smyth)

The project involves experimental testing and calibration of numerical models to detect damage (cracks and holes) in structures. For academic credit, a minimum commitment of 5–10 hours per week.

- contact mechanics

This project involves mathematical formulation of simple contact problems in mechanics and their solution with various numerical techniques. For academic credit, a minimum commitment of 5–10 hours per week.

Contact: Professor Haim Waisman, hw2286@columbia.edu, 610 Mudd, 212-851-0408

Opportunities

- rheological tests of warm mix asphalt

This project tests the use of some additives to improve the flowability of asphalt materials so they can be produced at lower temperatures and thereby reduce energy consumption and gas emissions. This concept also explores other technologies such as fiber-reinforced asphalt, recycled asphalt, and rubberized asphalt. Laboratory assistant positions for academic credit are available for material testing and modeling. The weekly time commitment is 10 hours. Students should have basic training in laboratory testing and fundamental knowledge of solid mechanics.

- long-term performance of polymer materials

When polymer materials serve under certain aging or weathering conditions, the mechanical properties will significantly change. This project tests the long-term performance with some short-span tests in the Carleton Laboratory. Laboratory assistant positions for academic credit are available for material testing and modeling. The weekly time commitment is 8 hours. Students should have basic training in laboratory testing and fundamental knowledge of solid mechanics.

- fracture characterization of multilayered materials

Multilayered materials have been used in engineering practice for structure and material reinforcement, protective coating, thermal insulation, and infrastructure maintenance and rehabilitation. However, fractures are often found in the weak layers. This project studies the fracture pattern and predicts the fracture behavior of multilayered materials. Laboratory assistant positions for academic credit are available for material testing and fracture modeling. The weekly time commitment is 8 hours. Students should have basic training in laboratory testing and fundamental knowledge of solid mechanics.

Contact: Professor Huiming Yin, yin@civil.columbia.edu, 634 Mudd, 212-851-1648

Department of Computer Science

Chair: Professor Julia Hirschberg, 450 CSB, 212-939-7005

Opportunities

- mobile robotics
- computer vision
- tactile sensing
- 3D modeling

Activities include working on software and hardware projects in the Columbia Robotics Lab. Some current projects include automated 3D site modeling of outdoor structures, graphical simulation of multifingered grasping, 3D reconstruction of objects, and medical robotics. Research positions carry academic credit and may extend into summer and/or have remuneration. Weekly commitment is about 10 hours. Students should be able to work independently; have completed *COMS W3137: Data structures and algorithms*; and have had some experience with either computer vision, robotics, or graphics. Details on research in the Columbia Robotics Lab can be found at <http://www.cs.columbia.edu/robotics>.

Contact: Professor Peter Allen, allen@cs.columbia.edu, 619 CEPSR, 212-939-7093

Opportunities

- computer architecture
- design and programming of system-on-chip platforms
- wireless sensor networks
- combinatorial optimization algorithms
- computer-aided design for embedded systems and integrated circuits

Opportunity to work on graduate-level research projects. These include: hardware-software co-design of energy-efficient accelerators for critical algorithms and their integration into a system-on-chip, design of networks-on-chip, embedded software programming of wireless sensor networks, and software development of prototype computer-aided design (CAD) tools for integrated circuits and embedded systems. Projects can be done for academic credit, and continuation over the summer is possible. Projects may be done independently or as part of a larger team. Based on the particular type of project, one or more of the following prerequisites are necessary: proficiency in data structures and at least one high-level programming language (C, C++, Java), Linux programming, knowledge of digital hardware design and computer organization, fundamentals of digital integrated circuits design, and knowledge of a hardware description language (VHDL, Verilog).

Contact: Professor Luca Carloni, luca@cs.columbia.edu, 466 CSB, 212-939-7043

Opportunities

- algorithmic game theory and economics
- computational complexity and theory

Activities include paper study and research-oriented projects of topics in algorithmic game theory and complexity theory, possibly for academic credit and/or remuneration. Projects include the study of applications, both theoretical and practical, of game theory and mathematical economics in computer science. Solid math background is required.

Contact: Professor Xi Chen, xichen@cs.columbia.edu, 503 CSB, 212-939-7136;
<http://www.cs.columbia.edu/~xichen>

Opportunities

- embedded system development
- device driver development
- domain-specific languages
- compilers
- computer-aided design tools

Projects include embedded system design and development, device driver development, design and implementation of domain-specific languages and their compilers, and development and implementation of algorithms for synthesizing hardware and software from the real-time language Esterel. Projects are ongoing and can be done for academic credit either during the term or over the summer. Knowledge of C/C++, operating systems, digital hardware design, optimization algorithms, and compilers is desirable. Projects may be done independently or as part of a larger team.

Contact: Professor Stephen Edwards, sedwards@cs.columbia.edu, 462 CSB, 212-939-7019

Opportunities

- augmented reality and virtual reality
- collaborative, mobile, and wearable computing
- tracked, see-through/hear-through head-worn displays
- knowledge-based generation of multimedia presentations
- personal health management user interfaces
- multimodal user interfaces
- information visualization
- computer games
- 3D GUI design

These opportunities involve the design and implementation of 3D and 2D computer graphics and user interface software for indoor and outdoor users, using a range of displays and interaction devices: head-worn, handheld (from smartphones to UMPCs), desktop, and wall-sized. Multidisciplinary projects potentially involve interaction with faculty in other departments, schools, and institutions, including Anesthesiology, Architecture, Biomedical Informatics, Electrical Engineering, Journalism, Music, and NewYork-Presbyterian Hospital. Research positions provide academic credit or remuneration and are offered during fall, spring, and summer. Weekly commitment is about 10 hours, and the prerequisites are completion of one of: *COMS W4160: Computer graphics*, *COMS W4170: User interface design*, *COMS W4172: 3D user interfaces and augmented reality*, *COMS E6174: Interaction design*, or equivalent experience/courses; and software design and development expertise.

Contact: Professor Steven Feiner, feiner@cs.columbia.edu, 609 CEPSR, 212-939-7083

Opportunities

- database systems
- Web search
- distributed information retrieval

Programming and research-oriented projects to develop search tools for the Internet. Academic credit and continuation over the summer possible. Weekly commitment is 10 hours. Prerequisites: *COMS W3137: Data structures and algorithms*; *COMS W4111: Introduction to*

database systems; and programming experience in Java, C, C++, Python, or Perl.

Contact: Professor Luis Gravano, gravano@cs.columbia.edu;
<http://www.cs.columbia.edu/~gravano/>

Opportunities

- deceptive speech across cultures
- text-to-scene generation
- spoken dialogue systems
- tools for Low Resource Languages
- entrainment in Supreme Court proceedings

Data analysis and computational modeling, human subjects design and execution, machine learning experiments, providing academic credit during fall, spring, and summer. Commitment of 9–12 hours per week is expected. *COMS W3137: Data structures and algorithms* is required. *COMS W4705: Natural language processing*, *COMS W4771: Machine learning*, and *COMS W4706: Spoken language processing* are useful, either taken or concurrent. See project descriptions at <http://www.cs.columbia.edu/speech/projects.cgi>.

Contact: Professor Julia Hirschberg, julia@cs.columbia.edu, 705 CEPSR, 212-939-7114

Opportunities

- social computing and collaborative filtering for genomics and other scientific research
- tradeoffs between privacy preservation, regulatory localization, green computing, and other societal issues
- MMORPG gaming concepts for engaging software development processes and software engineering education
- better approaches to maintaining the reliability of complex software systems
- novel techniques for finding and fixing security vulnerabilities
- building and operating reliable software for the smart grid, green buildings, and other cyber-physical systems

Individual and team research and development projects, possibly some user studies. Preference is for students interested in participating for multiple consecutive semesters, potentially including summer(s). Prerequisites: *COMS W3157* or equivalent programming experience in Java or C/C++. Recommended co-requisites: any one or more of *COMS W4111: Introduction to databases*, *COMS W4156: Advanced software engineering*, *COMS W4444: Programming and problem solving* are desirable, but not necessary. Non-majors are very welcome, particularly students with background in the life sciences, social sciences, or statistics. Time commitment approximately 12 hours per week for a 3-point project. However, projects are graded based on results rather than effort, so prospective project students must have strong time management and organizational skills. Most work will be conducted in the Programming Systems Lab, located in 6LE1 CEPSR; some work can be conducted remotely. Initial projects are only for academic credit, but a particularly spectacular project could lead to a paid part-time position for a later semester (and/or summer).

Contact: Professor Gail Kaiser, kaiser@cs.columbia.edu; or
Jonathan Bell, jbell@cs.columbia.edu, <http://www.psl.cs.columbia.edu>

Opportunities

- video understanding: segmentation, indexing, and cross-referencing of movies, sitcoms, newscasts, documentaries, YouTube videos, etc.
- video virality and video evolution in large depositories

- synthesis of video summaries, in both video and natural language form
- derivation and improvement of video tags, and their semantics and ontologies
- analysis of human gestures and their relationship to video semantics
- design and improvement of semantic-based video browsers
- performance evaluation of algorithms for all of the above

Activities include paper study, library research, systems design, computer analysis, and mathematical modeling. Research positions carry academic credit; some limited work study for pay is also available. Both are available year-round. Weekly commitment is about 10 hours. Students must be able to work independently, must have completed *COMS W3137: Data structures and algorithms*, and must be proficient in C, C++, Java, or Python. Completion of *COMS W4701: Artificial intelligence* and/or *COMS W4731: Computer vision* and/or *COMS W4735: Visual interfaces to computers* is desirable but not necessary.

Contact: Professor John Kender, jrk@cs.columbia.edu, 622 CEPSPR, 212-939-7115

Opportunities

- computer and network security
- denial of service
- worms and viruses
- access control
- cryptographic protocol design and evaluation
- wireless security
- systems aspects of security

Software design and implementation, paper study, application projects, and/or library research providing academic credit during fall, spring, and summer. Commitment of 9–12 hours per week is expected. *COMS W3137: Data structures and algorithms* is required; *COMS W4180: Network security*, *COMS W4118: Operating systems*, and *COMS W4119: Computer networks* are desirable. One or more of the following languages are required: C, C++, Java.

Contact: Professor Angelos D. Keromytis, angelos@cs.columbia.edu, 515 CSB, 212-939-7095; <http://nsl.cs.columbia.edu/projects/projects.html>

Opportunities

- computer architecture
- hardware/software interaction
- parallel hardware and software systems
- on-chip communication networks

Research projects involve measurement, design, simulation, and analysis of computer architectures. We have specific studies under way in the areas of reconfigurable hardware design and programming of heterogeneous, asymmetric multicores. Software-oriented projects are available. Ideally, students would have taken (or be taking) a hardware-oriented course (*COMS W4824* or *EECS W4340*) or an advanced programming class (*COMS W3157*). Strong programming skills (either hardware or software) are required.

Contact: Professor Martha Kim, martha@cs.columbia.edu, 469 CSB, 212-939-7094

Opportunities

- cryptography

Activities include paper study, theoretical research, or cryptographic implementation. Research positions carry academic credit. Some limited paid positions may also be available. Weekly commitment of 6–12 hours is required. Students must be able to work independently, must have completed *COMS W4261: Introduction to cryptography*, and must be able to understand and write formal definitions and proofs. Theoretical projects additionally require completion of *COMS W3261: CS Theory*, and preferably also *COMS W4236: Introduction to computational complexity*. Implementation projects additionally require proficiency in at least one of C, C++, Java.

Contact: Professor Tal Malkin, tal@cs.columbia.edu, 514 CSB, 212-939-7097

Opportunities

- natural language generation
- machine translation
- question answering on the web
- statistical processing for natural language
- text summarization

Programming projects involving development of tools for natural language generation and statistical analysis. Academic credit and continuation over the summer possible. Weekly commitment is 10 hours. Prerequisites: *COMS W4701: Artificial intelligence*; LISP and C. Preferred: *COMS W4705: Natural language processing*.

Contact: Professor Kathleen McKeown, kathy@cs.columbia.edu, 722 CEPSR, 212-939-7118

Opportunities

- operating systems
- mobile computing
- network, Internet, and thin-client computing
- virtualization
- iPhone and Android applications

Software design and implementation, paper study, application projects, and/or library research providing academic credit during fall, spring, and summer. Commitment of 9–12 hours per week is required. *COMS W3137: Data structures and algorithms* is required; *COMS W4118: Operating systems* and/or *CSEE W4119: Computer networks* is desirable. One or more of the following languages are required: C, C++, Java.

Contact: Professor Jason Nieh, nieh@cs.columbia.edu, 518 CSB, 212-939-7160

Opportunities

- computer-aided design tools for digital systems
- asynchronous digital circuits: design and simulation
- fault-tolerance/error-correction
- optimization algorithms

Research possibilities include (1) software CAD (computer-aided design) tools for digital systems, and (2) digital circuit design and simulation. The focus of this research is on clockless or asynchronous digital circuits, which support scalable system design, low-

power, and tolerance of variability. Opportunity to work on graduate-level research projects. Commitment of 10–12 hours per week is required. Continuation over the summer is possible, with 20–40 hours per week. Prerequisites: (1) basic digital logic and computer organization (*CSEE W3827: Fundamentals of computer systems*, or equivalent), and (2) advanced digital logic (*CSEE W4823: Advanced logic design*, or equivalent background). Additional background is desirable, but is not required, in either VLSI or hardware design (*ELEN E4321: Digital VLSI circuits*, *EECS W4340: Computer hardware design*, or equivalent) or in computer-aided design (*CSEE E6861: CAD of digital systems*).

Contact: Professor Steven Nowick, nowick@cs.columbia.edu, 508 CSB, 212-939-7056

Opportunities

- computational genetics
- systems biology
- comparative genomics
- bioinformatics

Computational biology is a young field aimed at understanding life sciences by computerized analysis of high throughput experimental data. Opportunities are available for talented students with strong interests in this interdisciplinary field. Quantitative thinking is required, and for different projects either programming skills or background biomedical sciences are required. Depending on the project and candidate, academic credit or pay is possible. Specific projects are focused on personalized medicine, inference of genetics of ancestral human populations, reverse engineering of cellular information processing, and cancer genomics.

Contact: Professor Itsik Pe'er, itsik@cs.columbia.edu, 505 CSB, 212-939-7135;
<http://www.cs.columbia.edu/~itsik/Contact.htm>

Opportunities

- Internet multimedia protocols and applications
- wireless and ad hoc network applications
- web applications

Design, simulation, and implementation providing academic credit (also summer) in exchange for a 5-hour weekly commitment. Satisfactory completion of *COMS W3157: Advanced programming* or equivalent is required. *CSEE W4119: Computer networks* is desirable. Excellent background is required in one or more of the following languages: C, C++, Java, PHP, Tcl/Tk.

Contact: Professor Henning Schulzrinne, hgs@cs.columbia.edu, 723 CEPSR, 212-939-7042

Opportunities

- computational complexity theory
- computational learning theory

Activities include paper study and computer experiments with learning algorithms and simulations, possibly for academic credit and/or remuneration. Strong math and theoretical computer science background (including 4000-level course work), good programming skills, and/or strong familiarity with mathematical software packages such as Maple, Mathematica, etc., are required.

Contact: Professor Rocco Servedio, rocco@cs.columbia.edu, 517 CSB, 212-939-7065

Opportunities

- computer architecture
- security

A unique opportunity to work in a fun and challenging environment in the Computer Architecture and Security Technologies Lab. Research activities include paper study, understanding hardware, software design and development, and application analysis for academic credit and/or remuneration. Projects may be individual or pair projects. Some of these projects are multidisciplinary and potentially may involve interaction with other faculty and labs in CS. Roughly 10-hour weekly commitment. Prerequisites: strong problem-solving skills, good GPA, eagerness to learn, and good programming skills.

Contact: Professor Simha Sethumadhavan, simha@cs.columbia.edu, 465 CSB, 212-939-7062; <http://www.cs.columbia.edu/~simha>

Opportunities

- computer and network security
- intrusion detection
- insider and masquerade attack detection
- private network trace synthesis
- embedded system security
- clean-slate design of secure computer systems

Software design and implementation, paper study, application projects, and/or library research providing academic credit during fall, spring, and summer. Commitment of 9–12 hours per week is expected. *COMS W3137: Data structures and algorithms* is required; *COMS W4180: Network security*, *COMS W4771: Machine learning*, and *CSEE W4119: Computer networks* are desirable. One or more of the following languages are required: C, C++, Java.

Contact: Professor Salvatore J. Stolfo, sal@cs.columbia.edu, 606 CEPSR, 212-939-7080; <http://www.cs.columbia.edu/ids>; <http://www.cs.columbia.edu/~sal>

Opportunities

- iphone/android/facebook app programming
- web applications
- software development tools
- study of open-source software
- study of mobile or web applications
- operating systems

Research activities include software design and implementation, paper study, and data analytics. Research positions provide academic credit or remuneration and are offered year-round. Research outcome may include open-source software release, iphone/android/facebook apps, and research publications at top conferences. Commitment of 9–12 hours per week is required. Solid programming skills in any programming language are a big plus. One or more of the following languages/frameworks are required: C, C++, Java, Javascript, PHP, CakePHP, Python, Django, Ruby, Ruby on Rails. Top students will receive funding for the project.

Contact: Professor Junfeng Yang, junfeng@cs.columbia.edu, 460 CSB, 212-939-7012; <http://rsc.cs.columbia.edu>

Earth and Environmental Engineering

Henry Krumb School of Mines

Interim Chair: Professor Paul Duby, 918 Mudd, 212-854-2905

Opportunities

- environmental catalysis: reactor design and analysis
- combustion phenomena and processes: alternative fuels and air pollution
- waste to energy and biomass gasification

Activities range from experimental data acquisition to literature surveys and theoretical modeling. This group's main objective is to understand the underlying principles and mechanisms of the above processes to improve efficiencies, minimize environmental impact, and find alternative approaches. The work may be eligible for credit or work study and requires about 10 hours per week.

Contact: Professor Marco J. Castaldi, mc2352@columbia.edu, 926-B Mudd, 212-854-6390

Opportunities

- enhanced global sanitation and resource recovery from wastewater
- design and application of bioprocess technologies for addressing global water, sanitation and hygiene (WASH)
- wastewater treatment and climate change
- mathematical modeling of microbial communities
- impact of microbial interactions on environmental and public health

The environmental genomics and biotechnology labs offer excellent opportunities to work on independent as well as graduate student projects. Activities include development of water, sanitation and hygiene (WASH) approaches to serve the communities worldwide that are in most need for these services but do not have adequate resources to do so. Our group adopts a fundamental approach using environmental engineering and microbiological techniques to address this issue. Activities of students involved include designing and operating lab-scale and pilot-scale reactors systems to solve pressing WASH needs, cultivation and maintenance of mixed and pure bacterial cultures and communities, characterizing the identity, abundance, and activity of these communities by using state-of-the-art molecular techniques, modeling the interactions within the communities using mathematical models, and examining the environmental and public health impacts of select microbial activities. Students working on these positions can receive either academic credit or work-study remuneration. Research activities may extend into summer. Minimum weekly commitment to earn academic credit is 10 hours.

Contact: Professor Kartik Chandran, kc2288@columbia.edu, 212-854-9027; <http://www.columbia.edu/~kc2288>

Opportunities

- morphogenesis: why fruits/vegetables have distinct appearances; how to explain the patterns found in various animals, cells, tissues; how to create bio-inspired components in engineering
- energy: how to harvest electricity from ambient and otherwise-wasted thermal and mechanical sources for enhanced energy efficiency and sustainability; how to protect systems from hazards and attacks by absorbing harmful energy; how to create a

nanoscale thermal machine and electric machine

- environment: how to overcome the bottleneck of carbon sequestration; how to selectively capture carbon dioxide from air
- proteins/cells: how do the proteins interact with each other and respond to external stimuli? how to simulate whole cell behavior in a multiscale approach
- nanoindentation: how to measure the mechanical properties of small material structures in quick and efficient ways; what are the properties of advanced materials and biosystems?

The micro/nano/biomechanics group offers excellent opportunities to work on independent as well as graduate student projects. The opportunities may provide academic credit or be work-study eligible. Details on research can be found at <http://www.columbia.edu/~xc2107>

Contact: Professor Xi Chen, xichen@columbia.edu, 212-854-3787

Opportunities

- removal of heavy metals and organic contaminants from sediments
- lowering energy use and carbon dioxide emissions by fuel-assisted electrolytic metal extraction
- recovery of heavy metals by recycling of industrial wastes

Paper study, mathematical projects, library research, computer analysis, and electrochemical research activities for academic credit or remuneration, either term-time or summer for junior and senior students. The weekly time commitment is 10 hours during the semester and 30 hours during the summer.

Contact: Professor Paul Duby, pdf1@columbia.edu, 905 Mudd, 212-854-2928

Opportunities

- carbon dioxide sequestration as mineral carbonate
- carbon dioxide extraction from the air

Our goal is to develop industrial processes for carbon dioxide capture and subsequent disposal. For disposal, the carbon dioxide is reacted with readily available magnesium-rich mineral silicates to form thermodynamically stable carbonates. For capture, we are working on capturing the carbon dioxide directly from the air for subsequent disposal. A commitment of a minimum of 5 hours a week is expected, either for credit or remuneration. Projects range from paper studies and library research to numerical modeling. There is also an opportunity for experimental projects. Preconditions tend to be few but vary with the work plan. They might include computer skills, some expertise in geology, chemistry, or fluid mechanics.

The following are examples of possible projects: (1) paper study and literature search to generate a map of worldwide resources of peridotite rock for chemically binding carbon dioxide; and (2) development of numerical and experimental tools for studying carbon dioxide extraction from the air.

Contact: Professor Klaus S. Lackner, kl2010@columbia.edu, 1045 Mudd, 212-854-0304

Opportunities

- prediction of flood, hurricane, and drought risk using climate forecasts
 - a. U.S. (Sacramento, Colorado, East Coast) and international (Brazil, Africa, Central Asia) applications
 - b. water hazards, impacts, and response

- energy and water demand forecasting, systems operation, and risk management
 - a. options for New York City
 - b. environmental regulation, ecological objectives, and the systems approach to option evaluation
- nonlinear dynamics and chaos
 - a. data-based prediction and system identification
 - b. numerical models of interacting nonlinear oscillators with examples from climate and water systems
 - c. statistical identification of predictability from time series
 - d. experiments for complex planetary systems to explore the occurrence, sustenance, and self-regulation of life and climate on Earth
- sustainable management of the environment
 - a. solutions for regional planning and development
 - b. competition, stakeholder perspectives, and the role of science in informed public and private sector decisions

A number of interrelated projects focus on exploring the function of water-dependent natural systems at scales ranging from river basins to hemispheres, and hours to millennia. The goal is to develop an empirical understanding of how this apparently fragile system works, how patterns emerge and lead to catastrophe (hazard or life), and how we can use this knowledge to better manage resource use and the environment by introducing this information to appropriate social institutions. The student is exposed to numerical and statistical modeling; integration of economics, environmental analysis, and mechanistic modeling; and elicitation of social factors as design objectives; and develops computer skills (GIS, high- and low-level languages). The opportunities provide academic credit and work-study wages, and require up to 12 hours weekly.

Contact: Professor Upmanu Lall, ula2@columbia.edu, 840 Mudd, 212-854-8905

Opportunities

- carbon capture, utilization, and storage
- study of novel liquid-like nanoparticle organic hybrid materials (NOHMs) for energy and environmental technologies
- synthesis of liquid fuels from wastes and biomass
- investigation of electrostatic charging phenomenon in multiphase flows

Research in this laboratory involves both experimental and modeling studies in catalytic and non-catalytic reactions related to energy and environmental systems. Undergraduate researchers are generally paired with graduate students on specific projects. However, independent research projects may be available for summer interns. The weekly time commitment is at least 10 hours.

Contact: Professor A.-H. Alissa Park, ap2622@columbia.edu, 1038A Mudd, 212-854-8989; <http://www.columbia.edu/~ap2622>

Opportunities

- interactions of green surfactants/polymers/proteins in solution and at interfaces
- sustainable mineral resource recovery: fundamental and applied research, new reagents, and new technology
- nanotoxicity: effect of morphology and coatings of nanoparticles on their (bio)chemical activity
- environmental engineering (effluent recycling and soil remediation, fate and role of nanoparticles in the environment)
- interfacial phenomena applied to mineral surfaces, nanomaterials, bioimplants
- nanogels as new smart materials for tissue engineering: design of nanogel-cell interactions to control cytotoxicity and cell growth
- improved performance of surfactants and polymers in cosmetics and health care products

Activities include mechanical assembly, measurements of materials properties, spectral measurements, computational analysis, and minor experiments. The opportunities may provide academic credit or be work-study eligible. The weekly commitment is 10 hours.

Contact: Professor Ponisseril Somasundaran, ps24@columbia.edu, 905 Mudd, 212-854-2926

Opportunities

- characterization of mine waste for CO₂ sequestration (paper study involves collection of mine waste properties in U.S. for suitability as a source of magnesium silicates to be used in CO₂ sequestration processes)
- rehabilitation and reuse of mined land: study of economics of alternative reclamation processes and end use of land for sustainable economic or ecological value
- statistical study of largest regional earthquakes. Student researchers conduct global database search for identification of regional extremal earthquakes and help processing data for regional forecasting experiments
- study of clean energy from coal, hydrogen production, fuel cells, carbon dioxide sequestration technologies
- model development for analyzing various alternatives in the design of zero-emission power plants.

This task requires strong programming skills (C++, Visual C++) and basic understanding of inorganic chemistry. Paper study, library research, plus analysis and design providing possible academic credit and work-study wages, requiring 8 hours weekly.

Contact: Professor Tuncel Yegulalp, yegulalp@columbia.edu, 926 Mudd, 212-854-2984

Department of Electrical Engineering

Chair: Professor Keren Bergman, 1305 Mudd, 212-854-2280

Opportunities

- biological sequence analysis
- mining of publicly available biomolecular data
- biomolecular interaction inference

Opportunities for senior students who are willing to commit at least 10 hours per week for academic credit. Qualifications include a minimum GPA of 3.5, programming expertise, and some formal course work in molecular biology.

Contact: Professor Dimitris Anastassiou, anastas@ee.columbia.edu, 719 CEPSR, 212-854-3113

Opportunities

- optical interconnection networks for performance computing systems
- bit-parallel wavelength division multiplexed optical data links
- optical packet routing control

Research projects in the Lightwave Systems and Networks Laboratory involve the design and construction of fiber-optic modules, high-speed optical data testing, and application-specific electronic circuitry packaged to interface with the photonic devices. Participating students learn all aspects of experimental work in fiber optics as well as system-level design aimed toward the application of photonic packet switching to high-performance computing. Participating students are normally in their junior or senior year. For a minimum commitment of 10 hours per week, students can receive academic credit.

Contact: Professor Keren Bergman, bergman@ee.columbia.edu, 1305 Mudd, 212-854-2280

Opportunities

- multimedia retrieval and visual search
- video analysis and object detection
- machine learning

Research and application development projects are available in the Digital Video and Multimedia Laboratory (<http://www.ee.columbia.edu/dvmm>). There are opportunities for individual studies as well as participation in ongoing research projects. Background in image processing, computer vision, machine learning, and basic programming skills (e.g., MATLAB, C) are required.

Contact: Professor Shih-Fu Chang, sfchang@ee.columbia.edu, 212-854-6894

Opportunities

- music signal analysis, similarity, and retrieval
- speech analysis, modification, and recognition
- modeling sound understanding in listeners

Signal modeling/analysis and application development projects are available in

the Laboratory for Recognition and Organization of Speech and Audio (<http://labrosa.ee.columbia.edu>). There are opportunities for individual studies as well as participation in ongoing research projects. A signals and systems background (e.g., *ELEN E3801*) and basic programming skills (e.g., MATLAB) are required. Projects are normally for academic credit and require a commitment of 8–10 hours per week.

Contact: Professor Dan Ellis, dpwe@ee.columbia.edu, 718 CEPSR

Opportunities

- experimental research in quantum communication and quantum computation
- photonic chips and networks
- electro-optic devices

Research projects in the Laboratory for Quantum Photonics focus on the design, fabrication, and implementation of photonic networks for quantum information processing and quantum metrology. Students participate in cutting-edge research that applies modern principles of quantum optics in solid-state systems. Students should have some exposure to optics and preferably also quantum mechanics. Students can receive academic credit.

Contact: Professor Dirk Englund, englund@columbia.edu, 815 CEPSR, 212-851-5958

Opportunities

- design and implementation of autonomous sensor nodes
- design of high-speed analog or RF integrated circuits in advanced CMOS technologies
- experimental characterization of devices and custom integrated circuits and systems
- VLSI for analog computation, analog or RF signal processing, and wireless or optical communications
- development of design and simulation software (CAD tools) for design productivity improvement

There are several opportunities to set up projects that involve the design and implementation of novel hardware ideas. Students can also participate in ongoing research, including integrated circuit design, circuit simulation, construction of breadboard models of novel circuit concepts, and/or experimental verification of fabricated circuits. Qualifications include a strong GPA and course work in electronics and circuits; familiarity with VLSI CAD tools is a requirement for some projects. For a commitment of 10 hours per week, students can receive academic credit. Summer projects are available.

Contact: Professor Peter Kinget, kinget@ee.columbia.edu, 818 CEPSR, 212-854-0309; http://www.cisl.columbia.edu/kinget_group/involvement.html

Opportunities

- development of a passive millimeter-wave imaging system
- electro-magnetics of millimeter-wave IC packaging

Contact: Professor Harish Krishnaswamy, harish@ee.columbia.edu, 1025 CEPSR, 212-854-8196

Opportunities

- organic thin film optoelectronic device fabrication and characterization
- analog/digital system interface design, construction, and testing
- laboratory course project development

Research generally involves design, fabrication, packaging, or characterization projects using organic thin film optoelectronic devices. Fabrication is typically performed in the clean room and the group's facilities under the supervision of a graduate student mentor. Opportunities include projects for credit during the school year, work-study, and paid summer positions.

Contact: Professor Ioannis (John) Kymissis, johnkym@ee.columbia.edu, 1013 CEPSR, 212-854-4023

Opportunities

- neural coding and spike processing in sensory systems
- modeling the olfactory system and the visual system of the fruit fly
- massively parallel neural computation

Programming projects involving the development of models of brain circuits and architectures. Academic credit and continuation over the summer possible. Weekly commitment is 10 hours. Prerequisites: *BMEB E4020* and excellent knowledge of MATLAB.

Contact: Professor Aurel A. Lazar, aurel@ee.columbia.edu, 819 CEPSR, 212-854-1747

Opportunities

- new nanofabrication methods and techniques
- semiconductor lasers and optoelectronic devices
- computer-aided design of optoelectronic circuits
- electronic instrumentation and design and testing
- ultrafast lasers and their use
- use of atom resolved probes of semiconductor or energy materials surfaces

Analysis, software design, laser testing, and assembly activities, for either academic credit or remuneration through work study. Students should anticipate a weekly commitment of 8–10 hours during the academic year and 20–30 hours during the summer. Qualifications include a GPA of 3.5; knowledge of C or C++ is required for programming projects.

Contact: Professor Richard Osgood, osgood@columbia.edu, 1324 Mudd, 212-854-4462

Opportunities

- neural network control of plasma instabilities
- studies of anomalous particle and thermal transport in plasmas

Opportunities in design and construction of diagnostic hardware and software, maintenance of lab equipment, plus mechanical and electrical assembly and computational analysis. The minimum time commitment is 8 hours per week, either as a work-study employee or for academic credit. Knowledge of Fortran or C is required.

Contact: Professor Amiya K. Sen, amiya@ee.columbia.edu, 909 CEPSR, 212-854-3124

Opportunities

Our laboratory in Columbia's Northwest Corner Building is exploring nanoscale CMOS integrated circuits for new applications in the life sciences as well as exploring novel devices based on biological materials and new solid-state materials.

- graphene-based devices and circuits
- membrane-based biological devices

- magnetic materials for power converters
- single-molecule sensors and systems
- neural interfaces

Research projects could include circuit and layout design of integrated circuits, protein purification, cell cultures, nucleic acid diagnostics, solid-state device fabrication. Opportunities include projects for credit during the school year and paid summer positions. Given the broad and multidisciplinary nature of the work in my group, we would entertain students from most Engineering departments, in particular Electrical Engineering, Biomedical Engineering, Chemical Engineering, or Mechanical Engineering, as well as students in the College, Biological Sciences, Chemistry, or Physics.

Contact: Professor Ken Shepard, shepard@ee.columbia.edu, 1019 CEPSR, 212-854-2529

Opportunities

- efficient, accurate, and scalable recognition using random embeddings
- help prototype algorithms and build interactive demo system for recognizing human faces and other objects of interest

Technical core of project draws on new results on efficient subspace query, sparse signal representation, and sparse error correction. Opportunity to learn about some of the fascinating mathematical structures that underlie everyday signals such as face images, and how to exploit them to solve practical problems. Students will collaborate with graduate students to build and test a real-time, interactive demo system. Weekly commitment of ~10 hours per week during the academic year (for academic credit) and ~30 hours per week during the summer should be anticipated. In addition to a love of math and course in linear algebra, skills required include familiarity/experience programming in C or C++ and MATLAB. GPU programming experience and courses in signal processing (e.g., DSP, Image Processing) are desirable but not necessary.

Contact: Professor John Wright, johnwright@ee.columbia.edu, 716 CEPSR, 212-854-3105

Opportunities

- wireless networking
- mobile and vehicular networking
- design, implementation, and evaluation of networking algorithms

Research projects involve design, analysis, and implementation of protocols for wireless and mobile networks. The protocols support efficient distributed operation in a mobile environment over an unreliable wireless channel. For examples of past projects, see enhants.ee.columbia.edu. Requirements: course work in algorithms, good programming skills, and preferably a networking-oriented course (e.g., *CSEE W4119* or *ELEN E4720*). For a commitment of 10 hours per week, students can receive academic credit. Summer projects are also available.

Contact: Professor Gil Zussman, gil@ee.columbia.edu, 811 CEPSR, 212-854-8670

Department of Industrial Engineering and Operations Research

Chair: Professor Clifford Stein, 313 Mudd, 212-854-2941

Opportunities

- calibration of derivative pricing models with market data
- numerical methods for pricing and hedging of financial derivatives
- stochastic simulation for portfolio risk management

Recent projects in Financial Engineering have included: (1) risk analysis of exchange-traded funds; (2) finite-difference methods for solving free boundary problems arising from option trading, exercise of American options, and timing of asset sale; (3) option pricing and hedging under stochastic volatility and jumps; and (4) variance reduction method for simulation with application to risk estimation. Appropriate background: programming (e.g., C, C++, or MATLAB), probability and statistics (*IEOR E3600* or equivalent), stochastic models (*IEOR E3106* or *E4106*), and simulation (*IEOR E4404* or *E4703*).

Contact: Professor Tim Leung, tl2497@columbia.edu, 308A Mudd, 212-854-9539;
<http://www.columbia.edu/~tl2497>

Opportunities

- stochastic models in operations research
 - a. stochastic simulation models of stochastic systems
 - b. evaluate analytical approximations
 - c. numerical algorithms for solving stochastic models

Recent projects have included: (1) studying congestion associated with inspecting shipping containers; (2) studying approximations for performance measures of queueing models of telephone call centers, including customer abandonment; (3) studying methods for determining staffing requirements in service systems with time-varying demand; and (4) studying new methods for numerically inverting transforms, with application to calculating system performance characteristics. Appropriate background: programming (e.g., C, C++, MATLAB), probability and statistics (*IEOR E3600* or equivalent), stochastic models (*IEOR E3106* or *E4106*), and simulation (*IEOR E4404*).

Contact: Professor Ward Whitt, ww2040@columbia.edu, 304 Mudd, 212-854-7255

For more opportunities, please visit the IEOR faculty bios at
<http://www.ieor.columbia.edu/directory/faculty.html>.

Materials Science and Engineering

In Charge: Professor James Im, 200 Mudd, 212-854-4457

Opportunities

- creation of novel atomic-scale magnetic materials
- measurement of ultrafast (~100 ps) magnetization dynamics
- measurement of magnetization and magneto-transport properties
- computer simulation of physical properties of materials

Opportunities could include laboratory, literature, or computational work. Projects can be tailored to the strengths and/or interests of the student. Enthusiasm and self-motivation are a plus. Academic credit may be available. Minimum 8 hours per week commitment is required.

Contact: Professor William Bailey, web54@columbia.edu, 1140 Mudd, 212-854-3090

Opportunities

- structure and properties of nanoparticles
- x-ray and neutron scattering experiments on complex energy materials
- simulation and modeling of nanoparticle structures
- scientific software development
- web development of educational website

Opportunities for motivated sophomore, junior, and senior students, for academic credit or possible remuneration, to participate in the full range of research activities. Experiments are done at National Laboratories (Brookhaven, Argonne, Los Alamos) with opportunities for undergrads to participate. Various possibilities exist depending on the interests of the students, though most involve some use of computers: either data analysis using existing programs or developing new analyses by writing new programs. Students with expertise and an interest in Python programming are especially welcome for numerous scientific software development activities, and also php/SQL for an education website project. Minimum commitment of 8 hours per week is required.

Contact: Professor Simon J. L. Billinge, sb2896@columbia.edu, 1105 Mudd, 212-854-2918

Opportunities

- nanoparticles
- self-assembly thin films, electronic oxides, microstructures
- solid interfaces and grain boundaries—electron microscopy
- superconductors

Activities include paper study, mechanical and electrical assembly, and computational analysis, and may be done in exchange for academic credit; work-study and summer participations are possible. Students should have experience with lab tools and instruments. Weekly commitment of 8 hours required, as is completion of *MSAE E3103: Elements of materials science*.

Contact: Professor Siu-Wai Chan, sc174@columbia.edu, 1136 Mudd, 212-854-8519;
<http://www.columbia.edu/cu/matsci>

Opportunities

- electrodeposition of metals and alloys
- corrosion and embrittlement of bridge steel wires
- dew point hot corrosion of steel tubes in boiler

Paper study, mathematical projects, library research, computer analysis, and electrochemical research activities for academic credit or remuneration, either term-time or summer for junior and senior students. The weekly time commitment is 10 hours during the semester and 30 hours during the summer.

Contact: Professor Paul Duby, pfd1@columbia.edu, 905 Mudd, 212-854-2928

Opportunities

- nanocrystals, nanoscience, and nanotechnology
- laser probe of thin films and thin film processing
- fabrication and properties of nanomaterials

Opportunities for motivated sophomore, junior, and senior students who are willing to commit to at least 6 hours per week, for academic credit or possible remuneration, to participate in the full range of research activities: paper study, mathematical projects, library research, engineering or scientific design, mechanical or electrical assembly, and computational or computer analysis.

Contact: Professor Irving P. Herman, iph1@columbia.edu, 905 CEPSR, 212-854-4950

Opportunities

- mechanical response of small domains such as on-chip structures in microelectronics
- measurement of stress and strain in engineering components in all size scales
- analytical and numerical modeling of the mechanical response of thin films and nanostructures

Possibility of working in the National Laboratories (Los Alamos, Argonne, Lawrence Berkeley, and Brookhaven) for short periods of time during breaks. Projects can be tailored to the strengths and/or interests of the student. Enthusiasm and self-motivation are requirements. Academic credit may be available. Minimum commitment of 8 hours per week is required.

Contact: Professor I. Cevdet Noyan, icn2@columbia.edu, 1120 Mudd, 212-854-8919

Opportunities

- surface phenomena for dispersion/deposition/coating; surface modification for improved materials
- processing of advanced materials (nanocomposites, high-performance ceramics, implants)
- microbial interactions with solid surfaces (teeth, minerals, proteins)

Activities include mechanical or electrical assembly, computational and computer analysis, and minor experiments. The opportunities may provide academic credit or be work-study eligible. The weekly commitment is 10 hours.

Contact: Professor Ponisseril Somasundaran, ps24@columbia.edu, 905 Mudd, 212-854-2926

Department of Mechanical Engineering

Chair: Professor Gerard A. Ateshian, 220 Mudd, 212-854-8602

Opportunities

- cell mechanics
- tissue mechanics
- tissue engineering
- design of instrumentation for testing soft tissues
- software development for cell, tissue, and joint modeling
- modeling of growth

Student participants are involved in the testing of biological soft tissues for the determination of material and tribological properties, testing of cells for the assessment of their biophysical properties, design of instrumentation for performing such measurements, tissue engineering of cartilage, software development for modeling cells, tissues and joints, and modeling studies of tissue growth.

Contact: Professor Gerard A. Ateshian, ateshian@columbia.edu, 220 Mudd, 212-854-8602

Opportunities

- nanoelectromechanical systems (NEMS)
- carbon nanotubes: synthesis, device fabrication, and applications
- nanotechnology for solar energy and fuel cells
- nanofabrication for biological applications

Activities include a variety of experimental work, including nanofabrication, materials synthesis, and electronic/mechanical testing, in the four areas listed above. A commitment of 10 hours per week term-time and 20–35 hours per week during the summer is expected. Students interact with graduate students, faculty, and staff. The opportunity may provide academic credit (*MECE E3900*) or hourly wages during the summer.

Contact: Professor James Hone, jh2228@columbia.edu, 240 Mudd, 212-854-6244

Opportunities

- nanoporous metals with applications to sensing and actuation
- mechanical properties of nanocrystalline thin films
- fracture and deformation phenomena

Opportunities exist to be involved with laboratory work to develop novel nanostructured materials for use in active devices as well as to understand the mechanics of material deformation and failure at the micrometer and nanometer length scales. Students can participate for academic credit or for financial remuneration. Minimum time requirement is 10 hours per week during the academic year and more during the summer.

Contact: Professor Jeffrey Kysar, jk2079@columbia.edu, 244 Mudd, 212-854-7432

Opportunities

- superresolution live cell imaging
- dynamics of molecular motors in living cells
- modeling of molecular motors

The Single Molecule Dynamics Laboratory is focused on understanding mechanics of molecular motors in biology. Two major research areas are (1) superresolution live cell imaging of dynamics of molecular motors, and (2) computational modeling and simulation of molecular motors to understand the underlying mechanics. Possible credit or remuneration, 12 hours weekly commitment during the academic year, and 20–35 hours per week during the summer.

Contact: Professor Jung-Chi Liao, jliao@columbia.edu, 228 Mudd, 212-851-0782; <http://www.me.columbia.edu/liaolab>

Opportunities

- data visualization for energy using software and sensing
- programming cell phones for data gathering/monitoring/payments
- developing algorithms for spatial planning

These opportunities involve one or more of analysis, computer programming, database management, data visualization, and library research. They may carry academic credit and/or remuneration, possibly through the Federal Work-Study Program. The weekly time commitment is 10 hours per week term-time and 20–35 hours in the summer. Long-term involvement of at least two semesters and a summer is desirable.

Contact: Professor Vijay Modi, modi@columbia.edu, 220 Mudd, 212-854-2956

Opportunities

- material characterization of soft biological tissue
- biochemical analysis of soft tissue
- fabrication and design of mechanical testing instrumentation and fixtures

Opportunities exist for juniors and seniors to participate in experimental biomechanics research. Research projects include material characterization, engineering design, and biochemical analysis. During the semester, a commitment of 10 hours per week is required for academic credit. During the summer, paid opportunities are available for full- or part-time work.

Contact: Professor Kristin Myers, kmm2233@columbia.edu, 220 Mudd, 212-854-2957

Opportunities

- computer simulation of friction and lubrication in multiphase systems
- measurement of wear and fatigue of materials under sliding and rolling contact
- surface and materials characterization

Research work in the Energy and Tribology Laboratory may encompass literature review, numerical and/or analytical analysis, experimental setup and/or testing, and reporting of research findings through technical presentations or reports. These opportunities are eligible for academic credit or remuneration. The minimal time commitment required is approximately 10 hours per week during the fall and spring semesters, and more during the summer. A long-term engagement (i.e., multiple semesters plus summer work) is preferred.

Contact: Professor Elon J. Terrell, eterrell@columbia.edu, 220C Mudd, 212-854-0407; <http://terrell.wikischolars.columbia.edu>

Opportunities

- photonic crystal nanostructures for optics
- nanoelectromechanical devices for photonics and electronics
- nonlinear and nonclassical optics in nanostructures
- silicon nanophotonics
- metamaterials nanofabrication
- nanostructures for photovoltaics and energy

Significant opportunities for motivated junior and senior students who are willing to commit 10 hours per week, for academic credit (*MECE E3901: Honors tutorial*) or possible remuneration. Research projects include numerical computations, engineering design, nanofabrication, experimental characterization, and physical measurements. Students interact with our team of faculty, staff, and graduate students.

Contact: Professor Chee Wei Wong, cww2104@columbia.edu, 220 Mudd, 212-854-4275;
<http://www.columbia.edu/cu/nanohv>

Opportunities

- laser micromachining and laser shock processing
- laser forming
- nontraditional manufacturing

Paper study, analytical and experimental work, and computer analysis. A minimum time commitment is 10 hours per week, more in the summer, which may entail academic credit and/or work-study eligibility.

Contact: Professor Y. Lawrence Yao, yly1@columbia.edu, 248 Mudd, 212-854-2887;
<http://www.columbia.edu/mrl>