A PROPOSAL FOR UNDERGRADUATE ACADEMIC PROGRAMS LEADING TO THE B.S. IN NANOSCALE SCIENCE AND B.S. IN NANOSCALE ENGINEERING

Submitted to

THE UNIVERSITY AT ALBANY UNIVERSITY SENATE

By

THE COLLEGE OF NANOSCALE SCIENCE AND ENGINEERING UNIVERSITY AT ALBANY, STATE UNIVERSITY OF NEW YORK

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# Table of Contents

## I. Introduction
- Preamble ............................................................................................................... 3
- Executive Summary ............................................................................................ 3

## II. Program Summary
- Mission .............................................................................................................. 4
  - II.1.A Mission Statement for B.S. Program in Nanoscale Science .......... 5
  - II.1.B Mission Statement for B.S. Program in Nanoscale Engineering .... 5
- Rationale for the Proposed Programs and Institutional Context .............. 6
- Learning Outcomes and Assessment .............................................................. 9
  - II.3.1 Learning Outcomes for B.S. Program in Nanoscale Science ...... 9
  - II.3.2 Learning Outcomes for B.S. Program in Nanoscale Engineering .. 11
  - II.3.3 Assessment Practice and Methodology ............................................. 12
- Admission .......................................................................................................... 13
- CNSE Undergraduate Committee on Admissions and Academic Standing .. 14
- Curriculum Outline .......................................................................................... 15
  - II.6.1 Program Components and Rubrics .................................................. 15
  - II.6.2 Program Requirements ...................................................................... 16
    - II.5.2.1 Requirements for B.S. in Nanoscale Science ......................... 16
    - II.5.2.2 Requirements for B.S. in Nanoscale Engineering .......... 17
  - General Education Requirements ................................................................. 17
  - II.6.4 Nanoscale Science Major Academic Pathway (MAP) and Courses .. 19
    - II.6.4.1 Nanoscale Science MAP ......................................................... 19
    - II.6.4.2 Proposed Nanoscale Science Course Matrix ...................... 20
  - Nanoscale Engineering MAP and Courses ............................................... 22
    - II.6.5.1 Nanoscale Engineering MAP ............................................... 22
    - II.6.5.2 Proposed Nanoscale Engineering Course Matrix ............... 23
    - II.6.5.3 Accreditation Plans for the Nanoscale Engineering Program ... 24
  - Honors Program, Honors College, and Minor in Nanotechnology ........ 25
  - Student Advising and Career Development .............................................. 26

## III. Enrollment .................................................................................................... 27

## IV. Impact of the Programs on Other SUNY Institutions ............................. 27

## V. Faculty ........................................................................................................... 29

## VI. Appendices
- Nanoscale Science Course Catalogue Descriptions ...................................... 34
I. INTRODUCTION

I.1. Preamble

As outlined in the outcomes of the University at Albany (UAlbany) 2006 Strategic Compact Planning,\(^1\) and the recommendations of the UAlbany Board of Visitors (BOV),\(^2\) and in accordance with the UAlbany College of Nanoscale Science and Engineering (CNSE) Faculty Charter and Bylaws, the CNSE Curriculum Committee's ad hoc Sub-Committee on Undergraduate Curriculum formally resolved on May 7, 2007 to draft a proposal for two undergraduate curricula for baccalaureate degrees in nanoscale science and nanoscale engineering. The Sub-Committee also formally resolved to initiate the process for the CNSE Curriculum Committee to formally advance these curricula for review and approval of the two baccalaureate degrees per the policies and guidelines of the College of Nanoscale Science and Engineering, the University at Albany University Senate, the University at Albany, the State University of New York, and the New York State Education Department. The following document outlines both curricula, as unanimously approved by the CNSE Curriculum Committee and the CNSE Faculty Council on October 5, 2007. The document was forwarded to the CNSE Assistant Vice President for Academic Affairs, who completed his review on November 5, 2007, and advanced the proposal to the Vice President of CNSE, who completed his review on January 8, 2008. The document containing both curriculum proposals, as presented in what follows in a unified format to facilitate review and evaluation, is being submitted to the University at Albany University Senate for assessment and action.

I.2. Executive Summary

The College of Nanoscale Science and Engineering (CNSE) of the University at Albany (UAlbany) proposes two academic curricula leading, respectively, to the degrees of Bachelor of Science in Nanoscale Science and Bachelor of Science in Nanoscale Engineering. The curricula proposed are intended to attract and retain at UAlbany a significant portion of the undergraduate student population that is presently inaccessible to SUNY and most of the private institutions of learning in New York State. This inaccessibility is driven by the lack of the interdisciplinary nanoscale science and nanoscale engineering degrees that are sought by this rapidly growing sector of the university clientele, as documented almost invariably by each study, blueprint, report, and analysis published by every governmental body, corporate organization, academic entity, think tank, and cross-organizational panel across the globe--including the National Science Foundation, which forecasts the need for more than two million nanotechnology educated professionals at all employment levels in the U.S. by 2014, with another five million nanotechnology jobs being required worldwide in support fields and disciplines.

Each curriculum represents a 132-credit program designed for completion in eight academic semesters and is consistent with the SUNY General Education Program requirements, as implemented at UAlbany.

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\(^1\) The outcomes of the UAlbany 2006 Strategic Compact Planning Process, as endorsed by the UAlbany University Senate and adopted by the University President, included approval of the concept of undergraduate degrees in nanoscale science and nanoscale engineering and authorized two CNSE nanoscale engineering faculty lines to assist in the development of the two curriculum proposals.

\(^2\) “BOARD OF VISITORS: Report of Observations and Recommendations,” the University at Albany, June 2006. The BOV called for the creation of the baccalaureate degrees in Nanoscale Science and Nanoscale Engineering and stated in its report: “...the development of an undergraduate program in nanoscience engineering would...build undergraduate quality, and at the same time help to strengthen the enrollment of math and science students.”
Each curriculum comprises a cutting-edge, inherently interdisciplinary, academic program centered on scholarly excellence, educational quality, and technical and pedagogical innovation. The outcome is a unique undergraduate experience that taps into CNSE’s global academic leadership in nanoscale science and engineering to attract and educate a diverse and talented pool of qualified scientists and engineers at the baccalaureate level, and position UAlbany to further cement its role as a competitive and valuable educational resource to the State University of New York and the State of New York.

The blueprint of each curriculum is comprised of four basic components: a “Foundational Principles” component, a “Core Competency” component, a “Concentration” component and a “Capstone Research/Design” component. The first two components are designed to integrate the dissemination of fundamental, cross-disciplinary, nanoscale science and engineering principles with the cultivation of the critical skill set necessary for advanced undergraduate coursework and interdisciplinary research. The remaining two components expand on these foundational skills to develop the topical expertise, technical depth, and independent research abilities that are essential to a well-rounded undergraduate educational experience. The combination of these instructional tools ensures two customizable and coherent undergraduate degree programs that train the student’s intellect how to explore, discover, and innovate, while ensuring its proficiency in a specific nanoscale discipline.

The two baccalaureate curricula in nanoscale science and nanoscale engineering exploit the unparalleled academic, professional, and infrastructural resources of the College of Nanoscale Science and Engineering and its $4B Albany NanoTech research and development (R&D) and education complex. By leveraging CNSE’s one-of-a-kind physical infrastructure, world-class interdisciplinary faculty, and extensive public-private partnerships, the proposed undergraduate curricula will hold a scholarly profile and pedagogical impact that are singularly distinct from and highly complementary to current academic offerings at the remaining SUNY campuses and other New York State institutions of higher learning. The curricula will also serve as an effective tool in the attraction of the highest quality undergraduate students from around the world to UAlbany, thus further advancing its stature as a top flight research university. Furthermore, the proposal outlines appropriate academic pathways in both B.S. degree programs for students electing to participate in CNSE’s Honors Program and/or UAlbany’s Honors College. In what follows, relevant admission criteria based on pertinent secondary education preparation are described, along with the underlying undergraduate advisement philosophy and resulting administrative and programmatic structures that ensure student success while maximizing academic options throughout the student’s undergraduate career at the University at Albany.

II. PROGRAM SUMMARY

II.1. Mission

The proposed CNSE undergraduate curricula in nanoscale science and nanoscience engineering are designed to provide UAlbany’s undergraduate students with a well-rounded education of the highest quality—one that endows the student’s intellect with the analytical tools necessary to explore, discover, and innovate; while cementing the student’s basic proficiency and fundamental knowledge in the science or engineering of nanotechnology. As such, the curricula proposed represent a true embodiment of the UAlbany Mission Statement and its commitment to:

“...the teaching of students, to their growth in knowledge, and to that reinforcement of character, through co-curricular experiences, which enables them to develop emotionally, physically, and socially even as they mature intellectually...”
The relevance of the CNSE undergraduate curricula to the approved mission of the institution, and their tight coupling to its on-going planning process, including its Middle States re-accreditation reviews and overall campus enrollment planning, are best captured by the institutional strategic goals below.

“…provide a distinctive, student-centered undergraduate learning experience which will be highly competitive as the result of its intellectual coherence, rigor and engagement of students with faculty in the process of inquiry and discovery…”

“…assuring inclusiveness and ease of access to its educational programs, and by actively supporting the application of its teaching and research to the needs of society…”

“…establish and stabilize enrollment.....with a student body reflective of the rich diversity required for a quality education, and with an academic profile comparable to the most selective of this nation's public research universities...”

By building on the scholarly reputation and educational resources of the UAlbany CNSE--ranked in May 2007 as the world's number one college for nanotechnology and microtechnology in the Annual College Ranking by Small Times magazine--the proposed undergraduate curricula are designed to further advance the UAlbany academic mission in the burgeoning field of nanotechnology and its key interdisciplinary science and engineering fields. Accordingly, the mission statements for the two curricula are:

II.1.A Mission Statement for the Academic Program Leading to the B.S. in Nanoscale Science

The curriculum is dedicated to providing quality undergraduate education in the interdisciplinary field of nanoscale science. The program will impart to its students the broad-based, basic and applied, scientific understanding of atomic scale phenomena, behaviors, and properties of matter that is necessary to achieve deliberate control over nanometer-scale atomic and molecular architectures and systems. The program will also enable a quantitative mastery of the fundamental nature of nanoscale interactions, one that can be effectively used to characterize and measure the behavior and structure of nanometer scale assemblies and systems. This degree program as a whole will offer an academically rigorous preparation for students intending to pursue scientific, technical, or professional careers in nanotechnology enabled fields or graduate studies in nanoscale science or nanoscale engineering, as well as other physical sciences such as materials science, physics, and chemistry.

II.1.B Mission Statement for the Academic Program Leading to the B.S. in Nanoscale Engineering

The curriculum is dedicated to providing quality undergraduate education in the interdisciplinary field of nanoscale engineering. The CNSE nanoscale engineering undergraduates will be prepared to creatively solve nanoscale engineering problems through the use of rigorous analytical, computational, modeling, and experimental tools that are based on foundational physical or biological sciences and mathematics, nanoscale materials, and applied engineering concepts. The program will also enable its students to propose, formulate and execute original, cutting-edge nanoscale engineering research in CNSE’s globally unique R&D complex. Students completing CNSE’s B.S. program in Nanoscale Engineering will be well-equipped to solve challenging problems in nanoscale engineering and applied sciences, as well as other physical and biological engineering sciences, and will be uniquely educated to pursue opportunities in emerging high technology industries--including nanoelectronics, nanomedicine, health sciences, and sustainable energy--or competitive graduate degrees in current and emerging engineering fields.

3 “Memorandum of Understanding Between the University at Albany and the State University of New York,” submitted June 2006 and approved November 2006.
II.2 Rationale for the Proposed Programs and Institutional Context

The natural evolution of disciplined human exploration in the 21st century has led to the emergence of nanotechnology as the primary enabler for discovery, innovation, and education in science and engineering. The essence of nanotechnology is the ability to manage and control the formation and assembly of individual building blocks of matter at the molecular level, atom by atom, to form macro-scale physical, biological, and chemical systems with customized properties and precise functionalities. As such, nanotechnology has literally transformed and reshaped traditional science and engineering disciplines: chemistry, physics, electrical engineering, mechanical engineering, materials science and engineering, molecular biology, and computer science. As such, nanoscale science and engineering—the confluence of physics, chemistry, biology, computer science, and engineering—represents a revolution in science and technology. While unanimity is rarely achieved on any stage, the belief that nanotechnology will revolutionize human life is, by almost all measures, well documented and universally accepted by the academic and industrial science and engineering communities:

“Advances in nanoscience and nanotechnology promise to have major implications for health, wealth, and peace in the upcoming decades... Over the next 10 to 20 years, nanotechnology will fundamentally transform science, technology, and society.”

The importance of nanoscale know-how to the U.S. research and pedagogical agendas is best captured in the multi-billion dollar National Nanotechnology Initiative (NNI), signed into law by the U.S. President in 2004, which proclaims nanotechnology as “leading to the next industrial revolution.” The NNI also calls for the creation of the “laboratory and human resource infrastructure in universities and in the education of nanotechnology professionals” to prepare future generations of U.S. citizens to compete in the “innovation economy” of the 21st century. These conclusions are echoed by the U.S. Commission on National Security/21st Century in its Report entitled Roadmap for National Security: Imperative for Change. The report states that: “We also face an unprecedented opportunity. The world is entering an era of dramatic progress in bioscience and materials science as well as information technology and scientific instrumentation. Brought together and accelerated by nanoscience, these rapidly developing research fields will transform our understanding of the world and our capacity to manipulate it.”

In response to the resulting rapid changes and emerging needs in the research and instructional landscapes, the UAlbany President recommended and the SUNY Board of Trustees (BOT) unanimously approved in April 2004 the creation of the College of Nanoscale Science and Engineering (CNSE) as a UAlbany academic unit. The SUNY BOT action was followed by the implementation of an open dialogue and extensive collaborative process between the UAlbany University Senate and CNSE faculty that affirmed an overarching and mutual commitment to a unified UAlbany faculty governance structure, and established the standards for the various degrees of autonomous CNSE faculty governance in the areas of graduate curricula, academic standing and appeal, continuing appointment and promotion, and research. The resulting CNSE Faculty Bylaws and CNSE Faculty Council Charter were endorsed by the UAlbany University Senate and CNSE Faculty Council in December 2004, and approved by the UAlbany President shortly thereafter.

4 See, for example, “Science as a Solution: An Innovation Agenda for the New President” (the Association of American Universities (March 2008); and M.C. Roco and W.S. Bainbridge (eds.), “Societal Implications of Nanoscience and Nanotechnology” (Dordrecht: Kluwer Academic Press, 2001)


6 UAlbany University Senate Resolution Number 0405-01R (December 6, 2004).
As stated in the SUNY BOT resolution, the overarching mission of CNSE is to “enable the discovery and dissemination of fundamental knowledge in the emerging interdisciplinary fields of nanotechnology and provide the citizens of New York with a comprehensive education of the highest quality.” In accordance with its vision and mission, CNSE has developed a multi-phase, long-term strategic plan that reshapes the traditional departmental structure into four constellations of scholarly excellence in research and development, education, technology deployment, and economic outreach. Conceived as catalysts that encourage and stimulate cross-disciplinary educational and research initiatives, these “think tanks” embody the fundamental intellectual underpinnings of nanotechnology and can be summarized as:

**Nanoscience:** The observation, identification, description, discovery, experimental investigation, and theoretical interpretation of nanoscale phenomena.

**Nanoengineering:** The application of nanoscience principles to practical applications, such as the atomic scale design, manufacture, and operation of efficient and functional structures, machines, processes, and systems.

**Nanoeconomics:** The formulation, study, and analysis of the economic and business principles underlying the development and deployment of nanoscale know-how, products, and systems.

**Nanobioscience:** The application of nanoscale scientific concepts and principles to the study of biological, biomedical, and medical procedures, practices, structures, systems, and organisms.

In accordance with its strategic plan, CNSE created three of its four constellations, namely, nanoscience, nanoengineering and nanoeconomics in September 2004. Concurrently, CNSE established its first graduate curriculum, leading to the degrees of Doctor of Philosophy and Masters of Sciences in NanoScience and NanoEngineering. This step was followed by the creation of its fourth constellation of excellence in nanobioscience in June 2006. Furthermore, in December 2006, CNSE completed the appropriate internal (UAAlbany and SUNY) and external (SED) review and approval process necessary to establish two separate graduate curricula, one in nanoscience and the other in nanoengineering. The successful conclusion of the review process enabled CNSE to offer two separate sets of Ph.D. and M.S. degrees, one in nanoscale science, the other in nanoscale engineering, as well as to implement a dual cross-disciplinary M.S. program in Nanotechnology Management (Nano-MBA) in partnership with the UAAlbany School of Business. These degrees are designed to prepare students to be leaders in the various interdisciplinary fields of nanotechnology, in accordance with the national science and engineering roadmap for competitiveness in the global economy of the 21st century:

“An adequately trained scientific workforce is essential for creating and transforming the industries that will realize the benefits of nanotechnology”

Among the many areas of intellectual strength and scholarly excellence of the CNSE, one of the most visible has been nanoelectronics. Nanoelectronics and nanotechnology involve the tiny engines and brains that drive millions of products and services. Computers, digital cameras and cell phones all work due to the manipulation and control of materials at the nanometer level – and the CNSE offers a unique environment for research and education involving these advanced device structures. As device dimensions continue to shrink, the demands placed on the students going into this field will be significant, although the potential benefits are undeniable:

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“If we are successful in developing nanoelectronic devices and nanofabrication techniques for manufacturing them in huge volumes at very low cost, the impact on society will be enormous.”

Additional assets of research prominence and educational innovation abound within the CNSE, with each asset providing a unique set of technical challenges and innovation opportunities. In particular, clean efficient energy is a scientific challenge and global goal to help reduce mankind’s footprint on the environment. Many technologies have potential to meet this need such as: new generations of advanced photovoltaics or solar cells based on thin film nanocrystalline materials which offer higher efficiencies; advanced fuel cells and advanced hydrogen storage technology require research and development in nano-materials and manufacturing. The impact of nanotechnology in the development of these and other future energy platforms has been recognized by the DOE’s Under Secretary for Science R.L. Orbach:

“Breakthroughs in the effective use of renewable energy through improved energy conversion, transmission, and storage are key to overcoming our nation’s reliance on imported fossil fuels and attaining energy independence in the long term. The study and design of materials at the nanoscale has the potential to address these significant challenges…”

Another growing area of excellence within the CNSE lies at the intersection of the biological and physical sciences. Nanomedicine is an emerging research area that has been born out of molecular nanotechnology, which focuses on the ability to create materials and devices with molecular precision. Nanomedicine employs the knowledge base of molecular nanotechnology to deliver new systems to address medical problems. In turn this will maintain and improve human health and have profound implications for the medical profession in the areas of disease elimination, diagnosis, and treatment of medical conditions. The impact of nanomedicine in preserving and improving human health has been recognized by the National Institute of Health nanomedicine roadmap:

“Researchers have developed powerful tools to extensively categorize the parts of cells in vivid detail, and we know a great deal about how these intracellular structures operate. Yet, scientists have still not been able to answer questions such as, "How many?" "How big?" and "How fast?" These questions must be addressed in order to build "nano" structures or "nano" machines that are compatible with living tissues and can safely operate inside the body. Once these questions are answered, we will design better diagnostic tools and engineer structures for more specific treatments of disease and repair of tissues.”

The single most important step in the successful capitalization on the tremendous potential of nanotechnology and its various disciplines involves the development and implementation of innovative instructional and training programs to prepare qualified scientists and engineers at all academic levels, from K-12 through graduate education. As pointed out earlier, this assessment is supported by practically every study, blueprint, report, and analysis published by every governmental body, corporate organization, academic entity, think tank, and cross-organizational panel across the globe—including the National Science Foundation, which forecasts the need for more than two million nanotechnology educated professionals at all employment levels in the U.S. by 2014, with another five million nanotechnology jobs being required worldwide in support fields and disciplines.

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8 R. Doering, op. cit., p. 87.
As outlined in the National Nanotechnology Initiative roadmap, the outcomes of the UA\textit{b}any 2006 Strategic Compact Planning and the recommendations of the UA\textit{b}any Board of Visitors (BOV)\textsuperscript{11,12} and in accordance with its strategic plan, the CNSE is proposing two undergraduate curricula leading to baccalaureate degrees in nanoscale science and nanoscale engineering. The two degrees are synergistic and complementary in scope and objectives, and build on each other’s strengths to maximize return on investment and ensure paramount effectiveness in advancing the university’s educational mission and overarching goals. This move will ensure that UA\textit{b}any and its CNSE retain their global academic prominence within the highly competitive arena of nanotechnology, and continue to be highly responsive to the increasingly diversified needs and interests of UA\textit{b}any’s ever expanding student clientele.

\section*{II.3 Learning Outcomes and Assessment}

The two customizable and coherent undergraduate degree proposals are designed to educate the student to explore, discover, and innovate, while ensuring his or her proficiency in one of the two fundamental pillars of nanotechnology. As such, CNSE is committed to make certain that the proposed baccalaureate programs meet or exceed the standards of scholarly excellence and academic quality required to graduate scientists, engineers, and professionals who can successfully navigate careers in nanotechnology and, in turn, deliver the innovations that are the lifeline of modern-day academic institutions, global corporations, and the business world.

To meet these stringent targets of “intellectual coherence, rigor and engagement,” CNSE has developed a comprehensive and integrated set of basic learning outcomes that must be met by students to qualify for graduation. Each set of learning outcomes has been customized to reflect the specific goals and objectives of the corresponding degree in nanoscale science or nanoscale engineering, while accounting for the natural overlap which results from the interdisciplinary nature, complementary pedagogical principles, and unified performance metrics of the two disciplines.

The learning outcomes are coupled to a unified, multi-phase, performance evaluation and learning assessment methodology to track and measure student progress towards educational goals and degree requirements throughout the student’s undergraduate career in the CNSE. This assessment methodology is designed to begin with entering UA\textit{b}any freshmen who are interested in nanoscale science or nanoscale engineering to analyze and measure their aptitude and ability to pursue B.S. degrees in nanoscale science or nanoscale engineering and offer them accurate guidance and pertinent advice in terms of appropriateness of such paths versus other opportunities for undergraduate study at UA\textit{b}any.

\subsection*{II.3.1 Learning Outcomes for B.S. Program in Nanoscale Science (NSCI)}

The learning outcomes are designed to ensure that the CNSE NSCI graduates demonstrate the technical and professional proficiencies necessary to enable the identification, description, discovery, experimental investigation, and theoretical interpretation of nanoscale phenomenon and, as a result, become highly successful scientists, educators, and leaders in the global “innovation economy” of the 21\textsuperscript{st} century.

\textsuperscript{11} The outcomes of the UA\textit{b}any 2006 Strategic Compact Planning Process, as endorsed by the University Senate and University President, included approval of the concept of undergraduate degrees in nanoscale science and engineering and authorized two CNSE faculty lines to assist in the development of the two curriculum proposals.

\textsuperscript{12} “BOARD OF VISITORS: Report of Observations and Recommendations,” UA\textit{b}any, June 2006. The BOV called for the creation of the baccalaureate degrees in Nanoscale Science and Nanoscale Engineering and stated in its report: “...the development of an undergraduate program in nanoscience engineering would...build undergraduate quality, and at the same time help to strengthen the enrollment of math and science students.”
Nanoscale Science Outcome 1
CNSE NSCI graduates will exhibit basic knowledge of mathematics, particularly statistics, linear algebra, multivariate calculus, and differential equations, and the foundational principles of nanoscale science necessary for knowledge development and theoretical and experimental problem-solving in nanoscale systems and architectures.

Nanoscale Science Outcome 2
CNSE NSCI graduates will possess the analytical abilities and scientific know-how to systematically design, conduct, and complete successful experimental procedures and applied tasks, including the skill set to analyze and interpret data from a variety of sources (experiment, simulation, etc).

Nanoscale Science Outcome 3
CNSE NSCI graduates will have the ability to analyze, construct or conceive a theoretical or practical nanoscale system, component, or process necessary to elucidate the fundamental nanoscale properties of a given atomic level phenomenon or architecture to meet desired target specifications within realistic and practical constraints. The latter are those that would typically be encountered in the real world of applied nanoscale research and development.

Nanoscale Science Outcome 4
CNSE NSCI graduates will be able to comprehend the cross-disciplinary nature of a nanoscale problem (technical and/or non-technical aspects) when appropriate and, as a result, be capable of functioning and contributing as successful team members within inter-disciplinary R&D organizations.

Nanoscale Science Outcome 5
CNSE NSCI graduates will have the knowledge to identify, analyze, deconstruct, and solve well-defined, open-ended, or poorly-defined research problems in nanoscale science.

Nanoscale Science Outcome 6
CNSE NSCI graduates will have a clear understanding of their professional, societal, and ethical responsibilities as scientists, researchers, educators, and responsible members of society at large.

Nanoscale Science Outcome 7
CNSE NSCI graduates will demonstrate clear and effective communication skills, both oral and written, in technical and non-technical environments.

Nanoscale Science Outcome 8
CNSE NSCI graduates will have the broad “well-rounded” education profile necessary to understand, appreciate, and direct the impact of nanoscale science phenomena, innovations, and applications at the local, regional, and global economic, environmental, technological, and societal levels. This comprehensive education will be achieved through an appropriate integration of the UAlbany General Education requirements with the CNSE NSCI curriculum requisites.

Nanoscale Science Outcome 9
CNSE NSCI graduates will acquire an embedded recognition of the need for, and responsive ability to engage in life-long, self-motivated learning.

Nanoscale Science Outcome 10
CNSE NSCI graduates will exhibit pertinent and timely knowledge of contemporary issues, discoveries, and events that are related to nanoscale science, nanoscale engineering and nanotechnology and their potential impact on industry, business, and society.
Nanoscale Science Outcome 11
CNSE NSCI graduates will possess the techniques, skills, and modern engineering tools necessary for effective nanoscale science research.

II.3.2 Learning Outcomes for B.S. program in Nanoscale Engineering (NENG)

The learning outcomes are designed to ensure that the CNSE NENG graduates display the technical and professional proficiencies necessary for the successful and effective application of nanoscience principles to practical applications, such as the atomic scale design, manufacture, and operation of efficient and functional structures, machines, processes, and systems and, as a result, become highly successful engineers, educators, and leaders in the global “innovation economy” of the 21st century.

Nanoscale Engineering Outcome 1
CNSE NENG graduates will exhibit applied knowledge of mathematics, particularly statistics, linear algebra, multivariate calculus, and differential equations, and the practical principles of nanoscale science and engineering essential for solving real life problems in atomic scale design, manufacture, and operation of efficient and functional structures, machines, and processes.

Nanoscale Engineering Outcome 2
CNSE NENG graduates will possess the analytical abilities and engineering know-how to systematically design, conduct, and complete successful experimental procedures and applied tasks, including the skill set to analyze and interpret data from a variety of sources (experiment, simulation, etc).

Nanoscale Engineering Outcome 3
CNSE NENG graduates will have the ability to analyze, construct or conceive a functional nanoscale system, component, or process that exploits basic and applied nanoscale principles to elucidate the observed behavior and measured properties of a given phenomenon or architecture to meet desired target specifications within realistic and practical constraints. The latter are those that would typically be encountered in real-world nanoscale engineering problems and may include performance, time (scheduling), funding, manufacturability, environmental, societal, and other constraints.

Nanoscale Engineering Outcome 4
CNSE NENG graduates will be able to comprehend the cross-disciplinary nature of a nanoscale problem (technical and/or non-technical aspects) when appropriate and, as a result, be capable of functioning and contributing as successful team members within inter-disciplinary R&D organizations.

Nanoscale Engineering Outcome 5
CNSE NENG graduates will exhibit the ability to identify, formulate and solve both well-defined, open-ended, or poorly-defined practical problems in nanoscale engineering.

Nanoscale Engineering Outcome 6
CNSE NENG graduates will have a clear understanding of their professional, societal, and ethical responsibilities as engineers, researchers, educators, and responsible members of society at large.

Nanoscale Engineering Outcome 7
CNSE NENG graduates will demonstrate clear and effective communication skills, both oral and written, in technical and non-technical environments.

Nanoscale Engineering Outcome 8
CNSE NENG graduates will possess the broad “well-rounded” education profile necessary to understand, appreciate, and direct the impact of nanoscale engineering phenomena, products, and processes at the
local, regional, and global economic, environmental, technological, and societal levels. This comprehensive education will be achieved through an appropriate integration of the UAlbany General Education requirements with the CNSE NSCI curriculum requisites.

**Nanoscale Engineering Outcome 9**: CNSE NENG graduates will acquire an embedded recognition of the need for, and responsive ability to engage in life-long, self-motivated learning.

**Nanoscale Engineering Outcome 10**: CNSE NENG graduates will exhibit pertinent and timely know-how for contemporary issues, discoveries, and events that are related to nanoscale science, nanoscale engineering and nanotechnology and their potential impact on industry, business, and society.

**Nanoscale Engineering Outcome 11**: CNSE NENG graduates will possess the techniques, skills, and modern R&D tools necessary for successful careers in nanoscale engineering fields.

**II.3.3 Assessment Practice and Methodology**

A systematic, broad-based, and multi-pronged approach will be employed to assess student’s progress towards and achievement of the learning outcomes outlined in Sections II.3.1 and II.3.2. This approach employs three primary metrics: course-embedded assessment; student-peer assessment; and capstone experience-driven assessment. These metrics are defined using the four pedagogical pillars and rubrics of each undergraduate degree, as described in Section II.5.1.

**II.3.3.1 Course-embedded Assessment Metric**

This metric employs the well-documented quantitative (grading) system typically applied in individual lecture and laboratory courses. In addition to the conventional oral and written examinations and out-of-class assignments, this approach will also employ novel in-class student response strategies. In particular, the use of real-time electronic tools, such as wireless ‘clickers,’ to provide a live form of student response and feedback will offer an additional assessment tool for both introductory and advanced lecture courses. This approach has proved very effective in first-year student instruction within CNSE’s graduate programs in nanoscale science and nanoscale engineering. The in-class electronic response system and on-demand application methodologies are already available in the classroom infrastructure of the CNSE Albany NanoTech Complex and are readily deployable for the undergraduate programs proposed.

**II.3.3.2 Student-peer Assessment Metric**

A student-peer assessment metric will also be implemented beginning with the fifth and throughout the eighth semester of the undergraduate curricula proposed. It consists of an undergraduate student peer-review and feedback approach that uses systematic oral and poster presentations by individual students or teams of students. This approach is in line with basic components of both proposed undergraduate programs targeting the development of the critical communication skills necessary for success. A similar graduate student peer-based assessment is a prominent feature of the current CNSE graduate programs. It has proven to be an effective tool in fostering a collaborative, interdisciplinary environment, while providing critical feedback for student skill development. The specific format of the undergraduate student-peer assessment is expected to be venue dependent, including individual feedback for oral presentations, written critiques for poster presentations, and a variation of the in-class student response system for large-audience student presentations.

**II.3.3.3 Capstone Experience – A Research Project-Based Assessment Metric**

As noted in Section II.5.1 below, a basic pillar of the undergraduate curricula proposed is the Capstone Undergraduate Research/Design experience. This multi-semester, research-based, rubric also serves as a critical assessment tool to gauge student’s scholarly and research achievements and progress in meeting the learning outcomes outlined in Sections II.3.3.1 and II.3.3.2. The assessment methodology for the
Capstone Experience focuses on the direct evaluation of student performance by the faculty mentor/advisor (as well as faculty committees as appropriate) regarding the student’s scientific, technical, and conceptual (analytical) knowledge in nanoscale science and nanoscale engineering, the student’s oral and written communication skills and ability to work well within a team environment, and the student’s mastery of literature searches, technical writing, and report preparation. In addition, since each Capstone Experience will include a public presentation, multiple opportunities for peer-assessment and broader faculty evaluation will be leveraged to calibrate student performance and for achievement of the overall nanoscale science and nanoscale engineering program mission and goals.

II.4 Admission

The process for admission to the proposed undergraduate programs for both freshmen and transfer applicants will follow the standard UAlbany application procedures for restricted undergraduate applicants. Applicable admission requirements are outlined below for the three potential scenarios of restricted applications, namely, Freshman, Advanced Standing, and Transfer. It should be noted that only undergraduate students formally admitted to the programs in nanoscale science or nanoscale engineering are eligible to enroll in Foundational Principles Courses, Core Competency Courses, Technical Concentration Courses or Capstone Research/Design Courses in nanoscale science or nanoscale engineering (see Section II.5.2 Program Requirements).

II.4.1 Restricted Admission with Freshman Status

At the beginning of each Fall Semester, qualified UAlbany freshmen who demonstrate documented scholarly excellence and academic interest in nanoscale science or nanoscale engineering could be offered an opportunity for direct freshman admission to the CNSE undergraduate programs proposed. Decisions regarding direct freshman admission to CNSE will be made by the CNSE Vice President based on a recommendation from the CNSE Undergraduate Committee on Admissions and Academic Standing (see Section II.5). The committee recommendation will be based on a thorough review of the student’s secondary school performance as reflected in high school grade point average (HSGPA), school-based tests such as Regents exams, scores on the SAT or ACT national exams, overall graduating class rank, letters of recommendation, and potentially a personal interview. The standard eligibility for consideration will be a minimum HSGPA of 87.5% and a minimum SAT of 1,320 (1600 scale) and/or a minimum ACT of 25. Exceptions to the standard eligibility may be made based on individual achievement and/or unique skills or experience. Students selected for Direct Freshmen Admission in nanoscale science or nanoscale engineering will be required to document their intent to declare their majors accordingly. The overarching goal of Direct Freshmen Admission to CNSE undergraduate programs is the identification of outstanding and singularly prepared students who are poised for success in the fields of nanoscale science or engineering. It is expected that these students will rapidly excel and perform in accordance with the highest academic standards at UAlbany. Students must meet University at Albany requirements for good academic standing to retain their enrollment in the CNSE undergraduate programs.

II.4.2 Restricted Admission with Advanced Standing Status

Undergraduate students at UAlbany who are not formally enrolled in the CNSE undergraduate programs are offered an opportunity for direct admission to CNSE after completing 24 credits of qualified science or engineering coursework at UAlbany. Decisions regarding Advance Standing Admission to CNSE will be made by the CNSE Vice President based on a recommendation from the CNSE Undergraduate Committee on Admissions and Academic Standing following a review of the student’s UAlbany transcript, relevant technical or research performance, and secondary school performance (using the criteria described in Section II.4.1). The standard eligibility for consideration will include a minimum...
UAlbany GPA of 3.5 in relevant coursework. Exceptions to standard eligibility may be made based on individual achievement, unique skills, or experience. The goal of Admission with Advanced Standing is the identification of outstanding students who have demonstrated the ability to excel at the university level and a scholarly aptitude for the fields of nanoscale science or nanoscale engineering. Although all applications will be considered, completion of the program within a four-year residency at the University at Albany will remain a top priority. Advanced Standing students who do not satisfy standard eligibility for admission with advanced standing to CNSE undergraduate programs may contact CNSE for individual consideration. Some students may be granted conditional status, with admission to the program contingent upon satisfactory completion of a specific academic contract.

II.4.3. Restricted Admission of Transfers with Advanced Standing

UAlbany students who are admitted as “Transfer” students are offered an opportunity for direct admission to CNSE if they have completed 24 credits of qualified science or engineering coursework at their former institution(s). Decisions regarding Transfer with Advanced Standing admission to CNSE will be made by the CNSE Vice President based on a recommendation from the CNSE Undergraduate Committee on Admissions and Academic Standing following a review of the student’s college or university transcript, relevant technical or research performance, and secondary school performance (using the criteria described in Section II.4.1). The standard eligibility for consideration will include a minimum college or university GPA of 3.5 in relevant coursework. Exceptions to the standard eligibility may be made based on individual achievement and/or unique skills or experience. The goal of Restricted Admission of Transfers with Advanced Standing to CNSE undergraduate programs is the identification of outstanding transfer students that have demonstrated the ability to excel at the university level and an aptitude for the fields of nanoscale science or engineering. Although all applications will be considered, completion of the program within a time period that does not exceed the four-year residency at UAlbany will remain a top priority. Transfers with Advanced Standing students who do not satisfy standard eligibility for admission with advanced standing to CNSE undergraduate programs may contact CNSE for individual consideration. Some students may be granted conditional status, with admission to the program contingent upon satisfactory completion of a specific academic contract.

II.5 CNSE Undergraduate Committee on Admissions and Academic Standing

CNSE will maintain a formal Undergraduate Committee on Admissions and Academic Standing. In addition to the implementation of the admissions process as outlined in Section II.4, the committee is responsible for reviewing the following matters brought to its attention, and making a recommendation to the Vice President for disposition of those matters. The process and deliberations will follow established University policies and protocol for due process. The Committee will consist of the chair, three teaching faculty, and the Director of Student Services (or designee). The Committee tasks include:

II.5.1 Appeals of Admission Decisions

The Committee will review appeals to denial of admission to the CNSE programs. The Committee will review all evidence brought forward by the prospective student and will make a recommendation to the Vice President. The Vice President will make the final decision, which will be communicated to the student via the Office of Student Services. The process and deliberations will follow established University policies and protocol for due process.

II.5.2 Grade Grievances
The committee will investigate and deliberate on cases brought by students who consider that they were aggrieved by the grading process. The committee will review the evidence and make a recommendation for disposition of the grievance to the Vice President. The Vice President will make the final decision, which will be communicated to the student via the Office of Student Services. The process and deliberations will follow established University policies and protocol for due process.

II.5.3 Honors Program

The Committee will review appeals of students petitioning for reinstatement to the CNSE honors programs. Such review may include, but not be limited to, students’ written appeals and consultations with the students’ instructors, the CNSE honors program director, and Assistant Vice President of Academic Affairs, as appropriate. Upon completion of the review the Committee will make a recommendation to the Vice President. The Vice President will make the final decision, which will be communicated to the student via the Office of Student Services. The process and deliberations will follow established University policies and protocol for due process.

II.5.4 Removal from and reinstatement to CNSE Major

The College of Nanoscale Science and Engineering proposes to follow the University Policy on academic dismissal. CNSE does wish to accept its responsibility for reinstatement decisions to the major by establishing a parallel appellate route for students seeking reinstatement to UAlbany after being academically dismissed. The dismissed student would follow the normal procedure for appealing the academic dismissal but would also file an appeal with CNSE’s Committee on Admissions and Academic Standing. The review of this appeal would include, but not be limited to, the student’s written appeal and documentation, consultations with the student’s instructors and advisor, and the CNSE Associate Vice President for Academic Affairs, as appropriate. The committee will review the appeal and make a recommendation to the Vice President. The Vice President will make the final decision, which will be communicated to the student via the Office of Student Services. The process and deliberations will follow established University policies and protocols for due process.

II.6 Curriculum Outline

II.6.1 Program Components and Rubrics

Building on the innovation and success of CNSE’s groundbreaking graduate programs in nanoscale science and nanoscale engineering, the proposed undergraduate academic programs are each comprised of four building blocks designed to preserve both the inherent flexibility required for a true interdisciplinary undergraduate degree and the academic rigor and scholarly excellence demanded by the fields of nanoscale science and nanoscale engineering.

II.6.1.1 Foundational Principles of Nanoscale Science or Nanoscale Engineering:
The course and laboratory contents of the Foundational Principles components of the two degrees proposed are designed to provide the core nanoscale science or nanoscale engineering principles and intellectual “skill sets” required to ensure elementary understanding and basic knowledge of the disciplines of nanoscale science or nanoscale engineering.

II.6.1.2 Core Competencies in Nanoscale Science or Nanoscale Engineering:
The course and laboratory contents of the Core Competency components of the two degrees proposed are intended to impart the sophisticated capabilities required for advanced, in-depth, study in nanoscale science or nanoscale engineering.
II.6.1.3 Concentrations in Nanoscale Science or Nanoscale Engineering:
This component of each degree is comprised of specialized undergraduate coursework or individually-directed independent study in a specific nanoscale science or nanoscale engineering concentration area. Combined with upper level elective courses, this component of each degree permits a high degree of interdisciplinary instructional customization.

II.6.1.4 Capstone Undergraduate Research/Design in Nanoscale Science or Nanoscale Engineering:
This component of each degree entails 3 semesters of individually-directed independent research that will serve as an on-site internship within a true research environment that is conducive to innovation and discovery.

Taken as a whole, the four components of each degree merge and integrate basic and advanced course and laboratory work with customized skills training and individually-directed independent research. This combination of pedagogical tools ensures two customizable and coherent undergraduate degree programs and teaches the student how to explore, discover, and innovate, in addition to being well proficient in a specific nanoscale discipline. Additionally, it is proposed that a series of Nanotechnology Survey Courses be offered to program participants and UAlbany students, at large, to introduce critical concepts and approaches in nanoscale science and nanoscale engineering and stimulate undergraduate discourse in related topics including societal, economic, and cultural impacts of nanotechnology.

From an implementation perspective, it is recommended that the University establish two new course rubrics, NSCI and NENG, to be associated with Nanoscale Science and Nanoscale Engineering undergraduate academic offerings, respectively. These rubrics may or may not be expanded to include current or future CNSE graduate course offerings. In addition, for the initial implementation of the Nanoscale Science and Nanoscale Engineering undergraduate degree programs it is recommended to cross-list the ‘Foundational Principles’ courses as a reflection of the highly interdisciplinary nature of both programs.

II.6.2 Program Requirements

Both nanoscale science and nanoscale engineering undergraduate academic programs require the completion of 102 credits of major-specific coursework, in addition to 30 credits of general education requirements. Although larger than the typical course loads associated with traditional science programs, these requirements are standard for undergraduate engineering programs at SUNY research center campuses.

II.6.2.1 Requirements for the B.S. in Nanoscale Science: The B.S. program in Nanoscale Science requires the completion of the following:

- ‘Foundational Principles’ Courses. Twenty (20) credits of NSCI 110, NSCI 112, NSCI 120, NSCI 122, and NSCI 124 (or NSCI 124T). NSCI 122 and NSCI 124 may be replaced by NSCI 130 and NSCI 132 for students pursuing a nanobioscience concentration.

- ‘Core Competencies’ Courses. Twenty-one (21) credits of NSCI 220 (or NSCI 220T), NSCI 230 (or NSCI 230T), NSCI 300, NSCI 305, NSCI 350, NSCI 360, and NSCI 410.

- ‘Concentrations’ Courses. Twelve (12) credits of nanoscale science concentration courses and nine (9) credits of 400-level Nanoscale Science topical elective courses.
‘Capstone Undergraduate Research/Design’ Courses. Nine (9) credits of NSCI 390, NSCI 490, NSCI 492 (or NSCI 493).

In addition, students in the nanoscale science program must complete:
- Six (6) credits of nanotechnology survey courses;
- Six (6) credits of 200-level Nanoscale Science and Technology Skills electives;
- One (1) credit of a senior seminar courses (NSCI 498 or equivalent); and
- Eighteen (18) credits of the following courses in mathematics (or their equivalent): AMAT 112 (or AMAT 118T), AMAT 113 (or AMAT 119T), AMAT 214 (or AMAT 214T), AMAT 220, and AMAT 314.

II.6.2.2 Requirements for the B.S. in Nanoscale Engineering: The B.S. program in Nanoscale Engineering requires the completion of the following:

- ‘Foundational Principles’ Courses. Twenty (20) credits of NENG 110, NENG 112, NENG 120, NENG 122, NENG 124. NENG 124 may be replaced by NENG 130.
- ‘Core Competencies’ Courses. Twenty-seven (27) credits of NENG 301, NENG 302, NENG 303, NENG 304, NENG 405, NENG 406, NENG 407 and NENG 408.
- ‘Concentrations’ Courses. Nine (9) credits of Nanoscale Engineering Concentration courses from each concentration area and six (6) credits of 400-level Nanoscale Engineering or Science topical elective courses.
- ‘Capstone Undergraduate Research/Design’ Courses. Nine (9) credits of NENG 390, NENG 490, NENG 492 (or NENG 493).

In addition, students in the Nanoscale Engineering program must complete:
- Six (6) credits of Nanotechnology Survey courses;
- Nine (9) credits of 200-level Nanoscale Engineering Design and Skills electives;
- One (1) credit of a senior seminar courses (NENG 498 or equivalent); and
- Fifteen (15) credits of the following courses in mathematics (or their equivalent): AMAT 112 (or AMAT 118T), AMAT 113 (or AMAT 119T), AMAT 214 (or AMAT 214T), and AMAT 311.

II.6.3 General Education Requirements

The General Education Program at the University at Albany consists of a minimum of 30 credits of coursework in the following areas: disciplinary perspectives, cultural and historical perspectives, and communication and reasoning competencies. The General Education Program is summarized in Table I below.

The Natural Science General Education requirements are satisfied by NSCI/NENG “Foundational Principles” courses and the Nanotechnology Survey Courses (NENG/NSCI 101 and 120). Furthermore, the Mathematics and Statistics General Education Requirements are satisfied by the required mathematics courses. Also, the Social Science lower-level writing requirements are satisfied by NENG/NSCI 102 and 103. Likewise, 400-level “Senior Undergraduate Capstone” courses will satisfy General Education requirements for Information Literacy, Oral Discourse, and Upper-level Writing. As noted in the University at Albany Undergraduate Bulletin, students may not use the same course to fulfill both the Arts and the Humanities categories. Otherwise, if a course fulfills more than one category, students may use the course to fulfill all of those categories. Although such “double counting” may reduce the number of
credits needed to fulfill General Education requirements to graduate from the University, each student must have satisfactorily completed a minimum of thirty (30) graduation credits in courses designated as General Education requirements.

If a course fulfilling a General Education category also meets a major requirement, there is no prohibition against counting the course toward General Education and the major. CNSE majors will be advised to make appropriate use of double-counting General Education courses for those categories not currently met through waiver by appropriate NYS Regents test scores (cf. American history and foreign language), Advanced Placement credit (cf. calculus, foreign language, social science, American history, European history), or other college-level coursework earned in high school. CNSE has prepared an advising chart to assist its students in appropriate General Education course selection to maximize their educational experience.

**Table I. General Education Requirements for undergraduate students in nanoscale science or nanoscale engineering.**

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Disciplinary Perspectives</strong></td>
<td>(min. 3 crs)</td>
</tr>
<tr>
<td>Arts</td>
<td>(min. 3 crs)</td>
</tr>
<tr>
<td>Humanities</td>
<td>(min. 6 crs)</td>
</tr>
<tr>
<td>Natural Sciences</td>
<td>(min. 6 crs)</td>
</tr>
<tr>
<td>Social Sciences</td>
<td></td>
</tr>
<tr>
<td><strong>Cultural and Historical Perspectives</strong></td>
<td>(min. 3 crs)</td>
</tr>
<tr>
<td>U.S. Historical Perspective</td>
<td>(min. 3 crs)</td>
</tr>
<tr>
<td>Europe</td>
<td>(min. 3 crs)</td>
</tr>
<tr>
<td>Regions beyond Europe</td>
<td>(min. 3 crs)</td>
</tr>
<tr>
<td>Global and Cross-Cultural Studies</td>
<td>(min. 3 crs)</td>
</tr>
<tr>
<td>U.S. Diversity and Pluralism</td>
<td>(min. 3 crs)</td>
</tr>
<tr>
<td><strong>Communication &amp; Reasoning Competencies</strong></td>
<td>(min. 1 course)</td>
</tr>
<tr>
<td>Information Literacy</td>
<td>(min. 1 course)</td>
</tr>
<tr>
<td>Oral Discourse</td>
<td></td>
</tr>
<tr>
<td><strong>Written Discourse</strong></td>
<td>(min. 1 course)</td>
</tr>
<tr>
<td>Lower-level Writing</td>
<td>(min. 1 course)</td>
</tr>
<tr>
<td>Upper-level Writing</td>
<td></td>
</tr>
<tr>
<td><strong>Mathematics and Statistics</strong></td>
<td></td>
</tr>
<tr>
<td>One semester of collegiate study, or the equivalent, of mathematics at or above the level of pre-calculus and/or probability, statistics, and data analysis</td>
<td></td>
</tr>
<tr>
<td><strong>Foreign Language</strong></td>
<td></td>
</tr>
<tr>
<td>Two semesters of collegiate study, or the equivalent, of a foreign language</td>
<td></td>
</tr>
</tbody>
</table>
### Table II. B.S. in Nanoscale Science Semester-by-Semester Major Academic Pathway (MAP)

<table>
<thead>
<tr>
<th>Year</th>
<th>Fall</th>
<th>Credits</th>
<th>Spring</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>NSCI/NENG 110 – Chemical Principles of Nanoscale Sci and Eng(^1)</td>
<td>4</td>
<td>NSCI/NENG 112 – Chemical Principles of Nanoscale Sci and Eng II(^1)</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>AMAT 112 or 118T – Calculus I</td>
<td>4</td>
<td>AMAT 113 or 119T – Calculus II</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>NSCI/NENG 120 – Physical Principles of Nanoscale Sci and Eng(^1)</td>
<td>4</td>
<td>NSCI/NENG 122 – Physical Principles of Nanoscale Sci and Eng II(^1)</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>NSCI 101 – Nanotechnology Survey(^3)</td>
<td>3</td>
<td>NSCI/NENG 102 – Societal Impacts of Nanotechnology(^2,3)</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>GE* (optional, if not taken, will be made up in future semesters)</td>
<td>3</td>
<td>GE (optional, if not taken will be made up in future semesters)</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15-18</td>
<td></td>
<td>15-18</td>
</tr>
<tr>
<td></td>
<td>NSCI 20x – Science and Eng. Skills elective</td>
<td>2</td>
<td>AMAT 220 – Linear Algebra</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>AMAT 214 or 214T – Calculus of Several Variables</td>
<td>4</td>
<td>NSCI 220 or 220T – Structure of Matter</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>GE or liberal arts and sciences elective</td>
<td>3</td>
<td>NSCI 20x – Science and Tech. Skills elective</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>GE or liberal arts and sciences elective</td>
<td>3</td>
<td>NSCI 20x – Science and Tech. Skills elective</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>GE or liberal arts and sciences elective</td>
<td>3</td>
<td>GE or liberal arts and sciences elective</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>16</td>
<td></td>
<td>16</td>
</tr>
<tr>
<td>3</td>
<td>AMAT 314 – Analysis for Applications I</td>
<td>3</td>
<td>NSCI 3XX – Technical Concentration Course</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>NSCI 3XX – Technical Concentration Course</td>
<td>3</td>
<td>NSCI 360 – Nanoscale Molecular Materials and Soft Matter</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>NSCI 350 – Intro to Quantum Theory for Nanoscale Systems</td>
<td>3</td>
<td>NSCI 305 – Integrated NanoLaboratory II</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>NSCI 300 – Integrated NanoLaboratory I</td>
<td>3</td>
<td>NSCI 390 – Capstone Research I: Intro and Literature Review(^4)</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>GE or liberal arts and sciences elective</td>
<td>3</td>
<td>GE or liberal arts and sciences elective</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>GE or liberal arts and sciences elective</td>
<td>3</td>
<td>GE or liberal arts and science elective (only if not taken in Semester #1)</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>18</td>
<td></td>
<td>15-18</td>
</tr>
<tr>
<td>4</td>
<td>NSCI 410 – Quantum Origins of Material Behavior</td>
<td>3</td>
<td>NSCI 4XX – Technical Concentration Course</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>NSCI 4XX – Technical Concentration Course</td>
<td>3</td>
<td>NSCI 4XX – Elective</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>NSCI 4XX – Elective</td>
<td>3</td>
<td>NSCI 4XX – Elective</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>NSCI 490 – Capstone Research II: Team Research and Project Review</td>
<td>3</td>
<td>NSCI 492 or 493 – Capstone Research III: Team Research and Final Report II(^5,6)</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>NSCI 498 – Seminar</td>
<td>1</td>
<td>GE or liberal arts and sciences elective</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>GE or liberal arts and sciences elective</td>
<td>3</td>
<td>GE or liberal arts and science elective (only if not taken in Semester #2)</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>16</td>
<td></td>
<td>15-18</td>
</tr>
</tbody>
</table>

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\(^1\) Satisfies the GE natural science requirement  
\(^2\) May be applied towards GE Social Sciences requirement  
\(^3\) Satisfies GE lower level writing requirement  
\(^4\) Satisfies GE information literacy requirement  
\(^5\) Satisfies GE upper level writing requirement  
\(^6\) Satisfies GE oral discourse requirement
II.6.4.2 *Proposed Nanoscale Science Course Matrix*

Table III lists the proposed nanoscale science courses by category. Full catalogue descriptions are given in Appendix VI.1. Initially, it is proposed to establish three nanoscale science concentration areas. These areas are expected to evolve both in the number of concentration areas and the courses available for each concentration with the evolution of the nanoscale science academic roadmap. In this initial implementation of the nanoscale science and nanoscale engineering undergraduate degree programs, it is recommended that the ‘*Foundational Principles*’ courses be cross-listed as a reflection of the highly interdisciplinary nature of both programs.

Table III. *Proposed nanoscale science courses by category. Full catalogue descriptions are given in Appendix VI.1.*

<table>
<thead>
<tr>
<th>NSCI Nanotechnology Survey Courses</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSCI 101 Nanotechnology Survey</td>
<td>3</td>
</tr>
<tr>
<td>NSCI 102 Societal Impacts of Nanotechnology</td>
<td>3</td>
</tr>
<tr>
<td>NSCI 103 Economic Impacts of Nanotechnology</td>
<td>3</td>
</tr>
<tr>
<td>NSCI 104 Disruptive Nanotechnologies</td>
<td>3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Foundational Principles of Nanoscale Science</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>NSCI 110 Chemical Principles of Nanoscale Science and Engineering I</td>
<td>4</td>
</tr>
<tr>
<td>NSCI 112 Chemical Principles of Nanoscale Science and Engineering II</td>
<td>4</td>
</tr>
<tr>
<td>NSCI 120 Physical Principles of Nanoscale Science and Engineering I</td>
<td>4</td>
</tr>
<tr>
<td>NSCI 122 Physical Principles of Nanoscale Science and Engineering II</td>
<td>4</td>
</tr>
<tr>
<td>NSCI 124 Physical Principles of Nanoscale Science and Engineering III</td>
<td>4</td>
</tr>
<tr>
<td>NSCI 124T Physical Principles of Nanoscale Science and Engineering III (Honors)</td>
<td>4</td>
</tr>
<tr>
<td>NSCI 130 Biological Principles of Nanoscale Science and Engineering I</td>
<td>4</td>
</tr>
<tr>
<td>NSCI 132 Biological Principles of Nanoscale Science and Engineering II</td>
<td>4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NSCI Science and Technology Skills Courses</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>NSCI 201 Computer Control of Instrumentation</td>
<td>2</td>
</tr>
<tr>
<td>NSCI 202 Introduction to Nanoscale Engineering Design and Manufacturing</td>
<td>2</td>
</tr>
<tr>
<td>NSCI 203 Advanced Circuits Laboratory</td>
<td>2</td>
</tr>
<tr>
<td>NSCI 204 Finite Element Modeling</td>
<td>2</td>
</tr>
<tr>
<td>NSCI 205 Numerical Simulation</td>
<td>2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Core Competencies for Nanoscale Science</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>NSCI 220 Structure of Matter</td>
<td>3</td>
</tr>
<tr>
<td>NSCI 220T Structure of Matter (Honors)</td>
<td>3</td>
</tr>
<tr>
<td>NSCI 230 Thermodynamics &amp; Statistical Mechanics for Nanoscale Systems</td>
<td>3</td>
</tr>
<tr>
<td>NSCI 300 Integrated NanoLaboratory I</td>
<td>3</td>
</tr>
<tr>
<td>NSCI 305 Integrated NanoLaboratory II</td>
<td>3</td>
</tr>
<tr>
<td>NSCI 350 Introduction to Quantum Theory for Nanoscale Systems</td>
<td>3</td>
</tr>
<tr>
<td>NSCI 360 Nanoscale Molecular Materials and Soft Matter</td>
<td>3</td>
</tr>
<tr>
<td>NSCI 410 Quantum Origins of Material Behavior</td>
<td>3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NSCI Technical Concentration Courses</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nanoelectronics</strong></td>
<td></td>
</tr>
<tr>
<td>NSCI 310 Nanoscale Surfaces and Interfaces</td>
<td>3</td>
</tr>
<tr>
<td>NSCI 320 Advanced Physical/Chemical Concepts for Nanoscale Science</td>
<td>3</td>
</tr>
<tr>
<td>NSCI 420 Electronic Properties of Nanomaterials</td>
<td>3</td>
</tr>
</tbody>
</table>
NSCI 421 Nanoscale Electronic Devices 3
NSCI 422 Concepts in Molecular Electronics 3
NSCI 423 Magnetic and Spintronic Materials and Devices 3
NSCI 424 Optoelectronic Materials and Devices 3

**Nanostructured Materials**
NSCI 310 Nanoscale Surfaces and Interfaces 3
NSCI 320 Advanced Physical/Chemical Concepts for Nanoscale Science 3
NSCI 430 Nanoscale Physical Properties in Reduced Dimensions 3
NSCI 431 Growth of Nanostructured Materials 3
NSCI 432 Particle Induced Chemistry 3
NSCI 433 Properties of Nanoscale Composite Structures 3
NSCI 434 Nanostructural Characterization Techniques 3

**Nanobioscience**
NSCI 240 Biochemical Principles for Nanoscale Science 3
NSCI 330 Energetics and Kinetics in Nanobiological Systems 3
NSCI 440 Biological Architectures for Nanotechnology Applications 3
NSCI 441 Nanobiology for Nanotechnology Applications 3
NSCI 442 Nanoscale Bio-Inorganic Interfaces 3
NSCI 443 Biological Routes for Nanomaterials Synthesis 3

**Capstone Undergraduate Research in Nanoscale Science**
NSCI 390 Capstone Research I: Introduction and Literature Review 3
NSCI 490 Capstone Research II: Team Research and Project Review 3
NSCI 492 Capstone Research III: Team Research and Final Report 3
NSCI 493 Capstone Research III: Team Research and Final Report (Honors) 3

**Current Topics Courses**
NSCI 498 Current Topics in Nanoscale Science and Engineering 1-6

**Independent Study and Research Course**
CNSE 397 Independent Study and Research 1-6
### Table IV. B.S. in Nanoscale Engineering Semester-by-Semester Major Academic Pathway (MAP)

<table>
<thead>
<tr>
<th>Year</th>
<th>Fall</th>
<th>Spring</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>NENG/NSCI 110 – Chemical Principles of Nanoscale Sci &amp; Eng</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AMAT 112 or 118T – Calculus I</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NENG/NSCI 101 – Nanotechnology Survey</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GE or liberal arts and sciences elective</td>
<td>3</td>
</tr>
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<td></td>
<td></td>
<td>GE or liberal arts and sciences elective* (optional, must be made up in semester #6)</td>
<td>3</td>
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<tr>
<td></td>
<td>4</td>
<td>NENG/NSCI 112 – Chemical Principles of Nanoscale Sci and Eng II</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AMAT 113 or 119T – Calculus II</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NENG/NSCI 102 – Societal Impacts of Nanotechnology</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GE or liberal arts and sciences elective</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>17</td>
<td>GE or liberal arts and sciences elective</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>NENG/NSCI 120 – Physical Principles of Nanoscale Sci and Eng</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AMAT 214 or 214T – Calculus of Several Variables</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NENG 201 or 201T – Nanoengineering Design</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GE or liberal arts and sciences elective</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>NENG 203 or 203T – Nanoengineering Electronics</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GE or liberal arts and sciences elective</td>
<td>3</td>
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<td>GE or liberal arts and sciences elective</td>
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<td>GE or liberal arts and sciences elective</td>
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<td></td>
<td>GE or liberal arts and sciences elective</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NENG 201 – Thermodynamics &amp; Kinetics of Nanomaterials</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NENG 203 – Mechanics of Nanomaterials</td>
<td>3</td>
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<tr>
<td></td>
<td></td>
<td>GE or liberal arts and sciences elective</td>
<td>3</td>
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<td>GE or liberal arts and sciences elective</td>
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<td>GE or liberal arts and sciences elective</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GE or liberal arts and sciences elective* (If not completed in Semester #1)</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>15-18</td>
<td>GE or liberal arts and sciences elective</td>
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<td>GE or liberal arts and sciences elective</td>
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<td>GE or liberal arts and sciences elective</td>
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<td>GE or liberal arts and sciences elective</td>
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<td></td>
<td>GE or liberal arts and sciences elective</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NENG 405 – Micro and Nano Mat. Processing Technology</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NENG 406 – Fundamentals of Nanoelectronics</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NENG 4xx – Concentration Elective</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NENG/NSCI 4xx – Elective</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NENG 490 – Capstone Research II: Team Research and Project Review</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NENG 407 – Thin Film and Nanomaterials Characterization</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NENG 408 – Industrial Nanomanufacturing</td>
<td>3</td>
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<tr>
<td></td>
<td></td>
<td>NENG 4xx – Concentration Elective</td>
<td>3</td>
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<tr>
<td></td>
<td></td>
<td>NENG/NSCI 4xx – Elective</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NENG 492 or 493 – Capstone Research III: Team Research and Final Report</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NENG 498 – Seminar</td>
<td>1</td>
</tr>
</tbody>
</table>

1. May be applied towards GE natural science requirement
2. Satisfies GE lower level writing requirement
3. Satisfies GE social science requirement
4. Satisfies GE information literacy requirement
5. Satisfies GE oral discourse requirement
6. Satisfies GE upper level writing
II.6.5.2 Proposed Nanoscale Engineering Courses Matrix by Category

Table V lists proposed nanoscale engineering Courses by category. Full catalogue descriptions are given in Appendix VI.2. Initially, it is proposed to establish five nanoscale engineering concentration areas. These areas are expected to evolve both in the number of concentration areas and the courses available for each concentration with the evolution of the nanoscale engineering academic roadmap. In this initial implementation of the nanoscale science and nanoscale engineering undergraduate degree programs, it is recommended that the ‘Foundational Principles’ courses be cross-listed as a reflection of the highly interdisciplinary nature of both programs.

Table V. Proposed nanoscale science courses by category. Full catalogue descriptions are given in Appendix VI.2.

<table>
<thead>
<tr>
<th>NENG Nanotechnology Survey Courses</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>NENG 101</td>
<td>Nanotechnology Survey</td>
</tr>
<tr>
<td>NENG 102</td>
<td>Societal Impacts of Nanotechnology</td>
</tr>
<tr>
<td>NENG 103</td>
<td>Economic Impacts of Nanotechnology</td>
</tr>
<tr>
<td>NENG 104</td>
<td>Disruptive Nanotechnologies</td>
</tr>
</tbody>
</table>

Foundational Principles of Nanoscale Engineering

| NENG 110  | Chemical Principles of Nanoscale Science and Engineering I | 4 |
| NENG 112  | Chemical Principles of Nanoscale Science and Engineering II | 4 |
| NENG 120  | Physical Principles of Nanoscale Science and Engineering I | 4 |
| NENG 122  | Physical Principles of Nanoscale Science and Engineering II | 4 |
| NENG 130  | Biological Principles of Nanoscale Science and Engineering I | 4 |

NENG Engineering and Design

| NENG 201  | Introduction to Nanoengineering Design and Manufacturing | 3 |
| NENG 201T | Introduction to Nanoengineering Design and Manufacturing (Honors) | 3 |
| NENG 202  | Introduction to Computer Programming for Engineers | 3 |
| NENG 202T | Introduction to Computer Programming for Engineers (Honors) | 3 |
| NENG 203  | Introduction to Nanoengineering Electronics | 3 |
| NENG 203T | Introduction to Nanoengineering Electronics (Honors) | 3 |

Core Competencies for Nanoscale Engineering

| NENG 301  | Thermodynamics and Kinetics of Nanomaterials | 3 |
| NENG 302  | Electronic, Optical and Magnetic Properties of Nanomaterials | 3 |
| NENG 303  | Mechanics of Nanomaterials | 3 |
| NENG 304  | Fluid Mechanics and Transport Processes | 3 |
| NENG 405  | Micro and Nanomaterials Processing Technology | 4 |
| NENG 406  | Fundamentals of Nanoelectronics | 4 |
| NENG 407  | Thin Film and Nanomaterials Characterization | 4 |
| NENG 408  | Industrial Nanomanufacturing | 3 |

Nanoscale Engineering Concentration Electives

Nanoelectronics

| NENG 411  | Nanoelectronic IC Fabrication Processes | 3 |
| NENG 412  | Micro and Nano Devices and Circuits | 3 |
| NENG 413  | Nanoscale Optical and Optoelectronic Devices | 3 |
| NENG 414  | Applications of Fields and Waves to Nanoscale Systems | 3 |
NENG 415  Nanoelectronic Devices  3

**Nanoscale Engineering for Energy & Environment Applications**
NENG 421  Introduction to Solar Cell Nanotechnology  3
NENG 422  Introduction to Fuel Cell Nanotechnology  3
NENG 423  Renewable & Alternate Energy Nanotechnologies  3
NENG 424  Nanoscale Chemical and Biological Sensors  3

**NanoSystems Engineering**
NENG 431  Advanced Materials Processing for NEMS/MEMS  4
NENG 432  Interfacial Engineering in Nanobiological Systems  3
NENG 433  NEMS/MEMS for Chemical and Biological Sensors  3
NENG 434  BioMEMS and BioNEMS  3
NENG 435  Nanobiological Systems  3

**Nanoscale Lithography**
NENG 441  Nanoscale patterning  3
NENG 442  Light Optics for Nanoengineering  3
NENG 443  Charged Particle Optics for Nanoengineering  3
NENG 444  Electron Beam Pattern Generation  3

**Emerging Materials and Device Engineering**
NENG 451  Nanophotonics  3
NENG 452  Magnetic Nanostructures  3
NENG 453  Organic Semiconductors  3
NENG 454  Analysis of Thin Film and Interfaces  3
NENG 455  Nanoscale Polymer Science & Engineering  3
NENG 456  Nanoscale Interfacial Engineering  3
NENG 457  Modeling of Nanomaterials and Systems  3

**Capstone Undergraduate Research in Nanoscale Engineering**
NENG 390  Capstone Research I: Introduction and Literature Review  3
NENG 490  Capstone Research II: Team Research and Project Review  3
NENG 492  Capstone Research III: Team Research and Final Report  3
NENG 493  Capstone Research III: Team Research and Final Report (Honors)  3

**Current Topics Courses**
NENG 498  Current Topics in Nanoscale Science and Engineering  1-6

**Independent Study and Research Course**
NNSE 397  Independent Study and Research  1-6

II.6.5.3 Plans for Accreditation of the Proposed B.S. in Nanoscale Engineering

Although specific criteria to provide an accreditation pathway for baccalaureate programs in Nanoscale Engineering are in the process of development and formalization, CNSE fully intends to work closely with the Engineering Accreditation Commission (EAC), the State Education Department, the State University of New York, and other accreditation bodies as appropriate, to implement a proper accreditation process for the newly developed undergraduate program in nanoscale engineering. CNSE
will work diligently to develop and implement vigorous academic and scholarly criteria to meet the requirements of the EAC.

II.6.6  Honors Program, Honors College, and Nanotechnology Minor

II.6.6.1  Nanoscale Science and Nanoscale Engineering Honors Programs

Students may apply in the spring of the sophomore year to the honors program in either nanoscale science or nanoscale engineering. Applications will be available from the CNSE Student Services Office. The student must have an earned overall GPA of 3.25, with a GPA of 3.50 for all courses attended in the major at time of admission to the honors program. In addition, all applicants to the honors program must provide as part of the completed application a written statement of purpose which explains the reasons and motivation for wanting to undertake the honors program.

Honors Students’ progress in the program will be reviewed every semester by the CNSE Student Services Office in consultation with the Honors Program Director and the CNSE Assistant Vice President for Academic Affairs. Students falling below 3.50 overall and/or 3.25 in the major will be given a written warning. The warned student will have one semester in which to raise the GPA to the standard. If the student falls below the standard a second time, s/he will be removed from the honors program pending an appeal. The appellate procedure for a student who believes they should remain in the program is to submit a written appeal to the honors director, who will review the appeal with the Assistant Vice President for Academic Affairs. The student’s instructors and advisor may be consulted as part of the appeal process. A recommendation to continue or remove the student from the honors program will be made to the Vice President of CNSE by the Honors Director. The student will be informed of the decision within ten days of submitting the appeal. If the appeal is granted, the student must meet the standard the next semester in either full-time or part-time study or the student will be dropped from the program with no further appeal. If the appeal is denied, the student is removed from the honors program, and is returned to the original nanoscale science or nanoscale engineering program.

When a student who is admitted to the honors program completes all requirements listed below, earns an overall GPA of 3.25 and a major GPA of 3.50, presents an acceptable honors project or thesis (CNSE 493) then, upon recommendation of the project advisor and honors director to the Vice President, the Vice President will direct that the student graduate with “Honors in Nanoscale Science” or “Honors in Nanoscale Engineering” and that the appropriate designation be placed on the student’s transcript. Students admitted to the honors program will follow the standard curriculum in nanoscale science outlined earlier, but will substitute the following honors courses in the curriculum: NSCI 124H for NSCI 124; NSCI 220H for NSCI 220; NSCI 230H for NSCI 230; and the capstone course NSCI 493 for NSCI 492. Similarly, students admitted to the honors program will follow the standard curriculum in nanoscale engineering outlined above, but will substitute the following honors courses in the curriculum: NENG 201H for NENG 201; NENG 202H for NENG 202; NENG 203H for NENG 203; and the capstone course NENG 493 for NENG 492.

II.6.6.2  Honors College Requirements

UAlbany undergraduate students who are enrolled in the proposed B.S. programs in nanoscale science or nanoscale engineering have the option and could be encouraged to participate in the UAlbany Honors College program, depending on specific interest and particular educational pathway.

To meet the UAlbany Honors College requisite of successful completion of six Honors College courses during the first two years of enrollment, it is proposed that two sets of three courses each be offered
within, respectively, the nanoscale science and nanoscale engineering curricula, as outlined below. These sets would be combined with the UAlbany Honors College courses that are offered through the Department of Mathematics, namely, AMAT 118H, AMAT 119H, and AMAT 214H to fulfill the six course requirements.

NSCI 124H. Physical Principles of Nanoscale Science and Engineering III

NSCI 220H. Structure of Matter

NSCI 230H. Thermodynamics and Statistical Mechanics for Nanoscale Systems

NENG 201H. Introduction to Nanoengineering Design and Manufacturing

NENG 202H. Introduction to Computer Programming for Engineers

NENG 203H. Introduction to Nanoengineering Electronics

During their subsequent two years of enrollment in the Honors College, nanoscale science and nanoscale engineering students could satisfy their Honors College requirements through the Capstone Undergraduate Research/Design Project.

II.6.6.3 **Minor in Nanotechnology**

In the event students enrolled in the nanoscale science or nanoscale engineering baccalaureate programs desire, instead, to pursue other majors and degree options, a provision has been established to provide these students the option to select and complete a minor in nanotechnology. By allowing students opting for other majors to apply 18-24 credits of their completed NSCI or NENG coursework to the Nanotechnology Minor, this provision will enable a smoother programmatic transition as students will not be required to restart coursework for a new minor. This is a restricted minor and students may list it on their record only with permission from the CNSE Office of Student Services.

Minor in Nanotechnology: 18-24 credits of coursework in the College of Nanoscale Science and Engineering (at least nine credits of which must be in coursework at or above the 300-level or in courses requiring one or more prerequisites) from courses with an NSCI or NENG prefix. This is a restricted minor and a student may list it on their record only with permission from the CNSE Office of Student Services.

II.6.7 **Student Advising and Career Development**

A comprehensive and proactive advisement program, coupled to a flexible assessment system (see Section II.3. Learning Outcomes and Assessment), is essential to ensuring top academic quality and scholarly excellence of the CNSE undergraduate programs while best serving the educational and career interests of its student participants. Upon enrollment into the proposed CNSE undergraduate programs, students will be immediately assigned a CNSE academic advisor who is a member of the CNSE teaching faculty for consultation and scheduling of coursework. All administrative and programmatic actions with regards to student matters will be coordinated through the CNSE Office of Student Services. The office is headed by the CNSE Assistant Vice President for Student Affairs and Director of Student Services, who reports directly to the CNSE Vice President to ensure that all student related affairs are handled at the highest levels of awareness and consideration.
Periodic communication and evaluation of progress will be implemented for each student and will center on individual advisor/student interactions to ensure timely completion of the program of study. Students will meet with their academic advisors regularly to review progress, solicit guidance, and identify opportunities for advancement. Upon completion of the equivalent of 4 semesters of residency within the CNSE undergraduate programs, each student will be assigned a research advisor for coordination of research involvement leading to the Capstone Undergraduate Research/Design Project. As part of this research training, undergraduate students will be required as early as possible to participate in and contribute to scientific papers, technical reports, and presentations at national and international conferences, seminars, and symposia. Furthermore, undergraduate students enrolled in the nanoscale science and nanoscale engineering programs will be strongly encouraged to participate in onsite and offsite private sector and government laboratory fellowship and internship programs to develop their technical expertise, team participation skills, and professional networking abilities. Throughout the advisement process, the CNSE academic and research advisors will coordinate their actions with the head of the appropriate CNSE constellation to ensure the availability of the faculty resources and infrastructure assets necessary to support the student’s academic and research paths. This coordination will also involve the CNSE Office of Student Services and the appropriate UAlbany offices and services, as needed. Naturally, every student will have access to UAlbany’s student support services for advisement needs outside the purview of the academic and research advisors or the CNSE Office for Student Services.

III. **ENROLLMENT**

CNSE is committed to academically rigorous undergraduate programs serving a diverse student clientele from New York State and beyond. As such, the undergraduate nanoscale science and nanoscale engineering curricula proposed will be deployed in a manner that maintains the scholarly excellence, educational quality, and technical and pedagogical innovation necessary to attract and educate a talented pool of qualified scientists and engineers at the baccalaureate level. Accordingly, enrollments are planned to increase gradually in accordance with the establishment of the critical mass of intellectual assets and physical infrastructure necessary to ensure full academic and instructional resource management and logistical support for every student enrolled in the programs.

Therefore, an undergraduate enrollment of 20 students for each degree will be targeted for the first year of full implementation of the curricula (tentatively planned for Fall 2009). As an ongoing expansion of the instructional and laboratory capacity at the CNSE’s Albany NanoTech is completed in 2009, and a comprehensive marketing and outreach strategy to qualified high school and two-year institutions is fully executed, enrollments targets will ramp up as per the schedule presented in Table VI. It should be noted that the student populations in the individual programs are not intended to represent a fixed ratio, and are expected to vary based on student interest and the yearly pool of potential applicants.

<table>
<thead>
<tr>
<th>Table VI. Targeted enrollments in the proposed CNSE undergraduate nanoscale science and nanoscale engineering programs.*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Targeted Enrollment</strong> <strong>Fall</strong> <strong>Fall</strong> <strong>Fall</strong> <strong>Fall</strong> <strong>Fall</strong> <strong>Fall</strong></td>
</tr>
<tr>
<td><strong>Enrollment</strong></td>
</tr>
<tr>
<td>Nanoscale Engineering</td>
</tr>
<tr>
<td>Nanoscale Science</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>
* Student populations in the individual programs are not intended to represent a fixed ratio, and are expected to vary based on student interest and the yearly pool of potential applicants.
** Although full program implementation is tentatively planned for Fall 2009, partial instructional activities could be initiated in Spring 2009 depending on the evolution of the internal and external degree review process.

**IV. IMPACT OF THE PROPOSED PROGRAMS ON OTHER SUNY INSTITUTIONS**

The CNSE undergraduate curricula are intended to attract and retain the large numbers of qualified undergraduate students who are presently inaccessible to SUNY and the private institutions of higher learning in New York State. This inaccessibility is driven by the lack of the interdisciplinary nanoscale science and nanoscale engineering degrees that are sought by this rapidly growing sector of the university clientele, as documented almost invariably by each study, blueprint, report, and analysis published by every governmental body, corporate organization, academic entity, think tank, and cross-organizational panel across the globe—including the National Science Foundation, which forecasts the need for more than two million nanotechnology educated professionals at all employment levels in the U.S. by 2014, with another five million nanotechnology jobs being required worldwide in support fields and disciplines. As such, the curricula proposed offer unique educational opportunities that are designed to create a highly qualified pool of future scientists, engineers, researchers, and educators in the emerging fields of nanoscale science and nanoscale engineering, while helping train and retrain pertinent sectors of the high technology workforce in New York State.

In particular, a key component of the CNSE undergraduate educational strategy is to address the severe shortage in the availability of qualified pool of engineers in New York and the U.S., particularly in the emerging discipline of nanoscale engineering. As pointed out by Dr. Shirley Ann Jackson, current president of the Rensselaer Polytechnic Institute, in her article entitled “We Can’t Build a Future without Engineers,”11 “Just when demand for engineers is reaching a critical high, we have fewer bright young people entering the profession.” Dr. Jackson went on to state that: “…for more than a century, engineering has driven our technological advances and economic development. If we do not take steps to fill the pipeline with new engineers, the supply of these critical professionals will diminish and the U.S. will lose its competitive edge.”

In this context, no similar educational program is currently being offered at any other institution of higher learning in New York, including the SUNY system. Instead, a very small number of undergraduate courses dedicated to nanoscale science or nanoscale engineering is currently being offered at other SUNY campuses (See Appendix VI.3). Consequently, the potential negative impacts that might have otherwise resulted from duplication of programs offered at other SUNY colleges or universities are non-existent in this case. To the contrary, it is projected that the undergraduate degrees proposed will have significant positive direct consequences and beneficial ripple effects at a number of SUNY institutions, from two-year colleges to university centers.

From a strategic perspective, the establishment of world-class undergraduate programs in nanoscale science and nanoscale engineering will further advance the standing and reputation of SUNY as a top flight university system. Additionally, the programs will act as an effective pipeline for the graduation of exceptional scientists and engineers who could serve as highly qualified candidates for a wide array of science, engineering, and technology graduate programs at SUNY research centers. Conversely, the proposed programs will provide an attractive and desirable platform for SUNY community college

11 S.A. Jackson, We Can’t Build a Future Without Engineers (Times Union, October 22, 2001) p. A7.
students who seek more advanced educational and training opportunities in the burgeoning fields of nanoscale science and nanoscale engineering. From a programmatic perspective, the undergraduate curricula proposed do effectively complement the SUNY community colleges currently offering or contemplating the implementation of 2-year degree programs related to or building on nanotechnology. A prime example is the Semiconductor Manufacturing Technology program at Hudson Valley Community College (HEGIS # 5310). The proposed undergraduate programs at CNSE will serve as an excellent option for talented HVCC students in this program desiring to pursue a four-year degree in the various fields of nanotechnology.

Furthermore, the two programs proposed will provide an effective pathway for the UAlbany CNSE to continue building and expanding its long standing educational partnerships with the premier science and engineering programs at the other three SUNY university centers, particularly at the University at Stony Brook and the University at Binghamton.

V. FACULTY

The UAlbany CNSE has implemented an aggressive outreach and recruitment program for the development and expansion of its critical mass of teaching faculty and instructors across its four founding Constellations, namely, Nanoscience, Nanoengineering, Nanobioscience, and Nanoeconomics. The resulting core team of professors and educators will serve as an efficient resource for undergraduate course instruction, mentoring, academic advisement, and research oversight. Faculty responsibilities with respect to undergraduate student advisement are specified in Section II.5.7. A listing of current CNSE teaching faculty and instructors who will be participating in the undergraduate degree programs is presented below, along with their primary CNSE constellation affiliation.

Bakhru, Hassaram
   Head, Nanoscience Constellation; Chair, CNSE Faculty Council; Professor of Nanoscience
   Research areas: Nanomaterials, solid state physics, ion beam physics, particle solid state interactions

Bergkvist, Magnus
   Assistant Professor of Nanobioscience
   Research areas: Nanobiotechnology, biosensors, molecular biology

Brainard, Robert
   Associate Professor of Nanoscience
   Research areas: Photoresists, small molecule and polymer synthesis, reaction mechanisms

Cady, Nathaniel
   Assistant Professor of Nanobioscience
   Research areas: Nanobiotechnology, biosensors, molecular biology

Carpenter, Michael
   Assistant Professor of Nanoengineering
   Research areas: Chemical & all-optical sensors, quantum dots, Kelvin probe microanalysis, near field scanning optical microscopy

Castracane, James
   Professor and Head, Nanobioscience Constellation; Director, CATN2
   Research areas: MEMS/NEMS, biomedical instrumentation, optoelectronics, interconnects, metrology development

30
Clow, Lawrence  
Instructor  
Research areas: 200 and 300mm silicon wafer processing, 3-D interconnects, anodic and thermo compression bonding

Cupoli, Edward  
Head, Nanoeconomics Constellation; Professor of Nanoeconomics  
Research areas: Economics of nanotechnology, economic forecasting, policy analysis

Denbeaux, Gregory  
Assistant Professor of Nanoengineering  
Research areas: Microscopy, magnetic materials, lithography

Diebold, Alain  
Empire Innovation Professor of Nanoscale Science  
Research Areas: Nanoscale metrology and materials science; materials characterization at the nanoscale; semiconductor metrology and characterization

Dunn, Kathleen  
Assistant Professor of Nanoscience  
Research areas: Electron microscopy, ion microscopy liners, metallization, defects in metals, ultrafine wires

Efstathiadis, Harry  
Instructor  
Research areas: Film depositions, plasma process and residual gas analysis, thin film characterization, microstructure of carbon & silicon amorphous materials, hydrogen bonded systems

Eisenbraun, Eric  
Associate Professor of Nanoscience  
Research areas: Thin films, ALD, CVD, metallization, barriers, interconnects, gate stack, metals

Elter, John  
Empire Innovation Professor of Nanoscale Engineering; Director, Center for Sustainable Ecosystems Technologies  
Research areas: Environmentally-friendly energy alternatives, advanced fuel cells, next generation power sources

Fancher, Michael  
Director of Economic Outreach; Associate Professor of Nanoeconomics  
Research areas: Alternative technology partnership models, regional innovation plans, strategies for industry, government and academic partnerships

Gadre, Anand  
Assistant Professor of Nanobioscience  
Research areas: MEMS, bioMEMS, polymeric LED and biofluidic-transdermal microsystems, microsensors, conducting polymers, rechargeable batteries

Geer, Robert  
Associate Vice President for Academic Affairs; Professor of Nanoscience
Research areas: Nanomechanical and nano-optical metrology, planarization processing, molecular self-assembly, scanning probe microscopy

Groves, Timothy
Empire Innovation Professor of Nanoscale Science; Director, Center for Nanolithography Development
Research areas: Electron beam physics, particle beam optics, nanoscale electron beam lithography

Haldar, Pradeep
Head, Nanoengineering Constellation; Professor of Nanoengineering
Research areas: Advanced photovoltaics, advanced fuel cells, next generation superconductors, advanced power electronics

Hartley, John
Professor of Nanoengineering; Director, Advanced Lithography Center
Research areas: Electron beam lithography, system engineering

Huang, Mengbing
Associate Professor of Nanoscience
Research areas: Rare-earth doped systems for photonic and optoelectronic applications, ion beam interactions with advanced materials

Kaloyeros, Alain
Vice President and Chief Administrative Officer; Professor of Nanoscience
Research areas: Nanoelectronics, nanobiotechnology

LaBella, Vincent
Associate Professor of Nanoscience
Research areas: Spintronics, surface science, ballistic transport

Lee, Ji Ung
Empire Innovation Professor of Nanoscale Engineering
Research areas: Carbon nanotube electronics, amorphous silicon devices, vacuum microelectronics, superconductivity

Levine, Ernest
Professor of Nanoscience
Research areas: Cu and low k BEOL, electromigration, thermal voids

Lifshin, Eric
Professor of Nanoscience; Director, Metrology & Electron Imaging Facilities; Director, Center for Advanced Interconnect Science & Technology (CAIST)
Research areas: Scanning electron microscopy, X-ray microanalysis, materials characterization

Matyi, Richard
Professor of Nanoscience
Research areas: High resolution X-ray diffractometry and reflectometry, ion beam processing and plasma-source ion implantation, molecular beam epitaxy growth

Moore, Richard
Manager of Analytical Facilities; Senior Scientist; Instructor
Research areas: Vacuum technology, surface analysis, nanoscale metrology, spectroscopy and microscopy, materials characterization

Murray, Thomas
Instructor
Research areas: Materials characterization by electron and ion beam methods

Oktyabrsky, Serge
Associate Professor of Nanoscience
Research areas: Compound semiconductors, photonics, electronics

Rane, Manisha
Instructor
Research areas: Synthesis and characterization of magnetic-property nanoparticles, high temperature corrosion studies & thermochemistry, fuel cells

Raynolds, James
Assistant Professor of Nanoscience
Research areas: Spintronics, density functional theory, high-performance computing, photonics

Rodriguez, Miguel
Instructor
Research areas: Electron & ion microscopy, liners, TEM, SEM, FIB, EELS

Ryan, James
Assistant Professor of Nanoscience
Research areas: Interconnect technology, semiconductor technology, radiation hard nanoelectronics

Schultz, Laura
Assistant Professor of Nanoeconomics
Research areas: R&D investment, R&D collaborations, intangible capital

Shahedipour-Sandvik, Fatemeh (Shadi)
Assistant Professor of Nanoengineering
Research areas: Optoelectronics, wide bandgap III-Nitride semiconductor materials and devices, metalorganic chemical vapor deposition technique

Thiel, Bradley
Associate Professor of Nanoscience
Research areas: Low vacuum scanning electron microscopy, critical dimension SEM metrology, ion-solid interactions, protein elastomers

Tokranov, Vadim
Instructor
Research areas: Optoelectronics, molecular beam epitaxy and nanotechnology

Tokranova, Natalya
Instructor
Research areas: MEMS, NEMS, optoelectronics, porous and hybrid materials
**Xie, Yubing**  
Assistant Professor of Nanobioscience  
Research areas: Stem cell biology, chemical and biomolecular engineering, cellular and tissue engineering

**Xu, Bai**  
Assistant Professor of Nanobioscience  
Research areas: MEMS, nanobiotechnology, nanomedicine, 3D interconnects

**Xue, Yongqiang (Alex)**  
Assistant Professor of Nanoscience  
Research areas: Theoretical nanoscience and computational nanotechnology
APPENDIX VI.1
Nanoscale Science Course Catalogue Descriptions

NSCI 101 (=NENG101) Nanotechnology Survey (3)
Introduction to the definitions, principles and applications of nanotechnology. Discussion of emergent
nanoscale properties, atomic and molecular self-assembly and concepts of bottom-up and top-down
processing and fabrication. Introduction to selected nanoscale systems, including quantum dots, carbon
nanotubes, and graphene. Only one of NSCI 101 or NENG 101 may be taken for credit.

NSCI 102 (=NENG102) Societal Impacts of Nanotechnology (3)
Introduction to the societal implications of nanotechnology innovation including public perception of
nanotechnology, public impacts nanomaterials risk assessment, and impacts of nanotechnology on public
health policy and energy/environmental sustainability. Only one of NSCI 102 or NENG 102 may be taken
for credit.

NSCI 103 (=NENG103) Economic Impacts of Nanotechnology (3)
Introduction to the economic impacts of nanotechnology innovation. Basic economic principles will be
presented and discussed in terms of emerging nanotechnologies. Topics will include economics of
nanoelectronics; nanoscale technologies for energy and the environment; and nanobioscience/
nanobioengineering. Only one of NSCI 103 or NENG 103 may be taken for credit.

NSCI 104 (=NENG104) Disruptive Nanotechnologies (3)
Introduction to the concepts of disruptive technologies and specific nanotechnological applications. Case
studies examining key examples of nanoscale science and nanoscale engineering innovation and their
impact on specific technical fields, applications, and product markets. Only one of NSCI 104 or NENG
104 may be taken for credit.

NSCI 110 (=NENG110) Chemical Principles of Nanoscale Science and Engineering I (4)
Fundamental chemical principles for nanoscale materials and systems. Basic chemical concepts of energy,
enthalpy, thermodynamics, and quantum atomic theory are introduced with a focus on application to
nanoscale materials and application architectures. Fundamentals of chemical bonding in nanoscale
materials (covalent, ionic). Only one of NSCI 110 or NENG 110 may be taken for credit. Prerequisites:
Four years of high school science (earth science, biology, chemistry and physics), and mathematics
through pre-calculus, or equivalent.

NSCI 112 (=NENG112) Chemical Principles of Nanoscale Science and Engineering II (4)
Introduces concepts of gas law, phases, equilibrium, and rates of reaction, applicable to nanoscale
systems. Further development of the concepts and nature of chemical bonding. Application of chemical
principles to the structure of matter, molecular materials, and crystals. Only one of NSCI 112 or NENG
112 may be taken for credit. Prerequisite: satisfactory completion of NSCI/NENG 110 or permission of
instructor.

NSCI 120 (=NENG120) Physical Principles of Nanoscale Science and Engineering I (4)
Newtonian mechanics, motion, momentum, work-energy equivalence as applied to nanoscale materials
and systems. Includes static, dynamics, and mechanics of bulk and nanoscale materials. Laboratory
section included. Only one of NSCI 120 or NENG 120 may be taken for credit. Prerequisite: satisfactory
completion of NSCI/NENG 112 or permission of instructor.
NSCI 122 (=NENG122) Physical Principles of Nanoscale Science and Engineering II (4)
Concepts of charge, electrostatic potential, current, and fields relevant to nanoscale materials, devices, and systems. Electrical properties of bulk and nanoscale metals, semiconductors and insulators. RCL circuit behavior. Lorentz force and application to nanoscale systems and materials. Laboratory section included. Only one of NSCI 122 or NENG 122 may be taken for credit. Prerequisite: satisfactory completion NSCI/NENG 120.

NSCI 124 (=NENG124) Physical Principles of Nanoscale Science and Engineering III (4)
Formalism of vibratory phenomena (waves, oscillators, complex response functions) and scattering (including diffraction) as applied to nanoscale materials and systems. Wave nature of matter, DeBroglie hypothesis, fundamental the double slit experiment, electron diffraction, modern physics. Laboratory section included. Only one of NSCI 124, NENG 124, NSCI 124T, or NENG 124T may be taken for credit. Prerequisite: satisfactory completion of NSCI/NENG 120 or NSCI/NENG 122.

NSCI 124T (=NENG124T) Physical Principles of Nanoscale Science and Engineering III (Honors) (4)
Honors version of NSCI/NENG 124. Same topics as NSCI 124 but topics are covered in greater depth. This course is for students with greater than average ability and background in Nanoscale Science. NSCI 124T substitutes for NSCI 124 toward the prerequisite in any course. Only one of NSCI 124, NENG 124, NSCI 124T, or NENG 124T may be taken for credit. Prerequisite: Admission to the CNSE honors program and satisfactory completion of NSCI/NENG 120 or NSCI/NENG 122.

NSCI 130 (=NENG130) Biological Principles of Nanoscale Science and Engineering I (4)
This course will introduce basic concepts in nanobiology. The course will initially focus on fundamental biological principles such as DNA/RNA synthesis and replication, protein synthesis, and cellular structure/function. Only one of NSCI 130 or NENG 130 may be taken for credit. Prerequisite: satisfactory completion of NSCI/NENG 120 or NSCI/NENG 122.

NSCI 132 (=NENG132) Biological Principles of Nanoscale Science and Engineering II (4)
The course will cover topics relating to the interface between nanosystems and biological systems. This will include general information about biomimetic systems and the uses of nanotechnology for biological research. Only one of NSCI 132 or NENG 132 may be taken for credit. Prerequisite: satisfactory completion of NSCI/NENG 130.

NSCI 201 Computer Control of Instrumentation (2)
Introduction to computer-based automation and control for instrumentation. This course will focus on the use of software (e.g., LabView) and interface cards for controlling processing and analytical tools as well as customized configuration of multiple pieces of equipment for integrated experimental data acquisition and analysis. Prerequisites: satisfactory completion of NSCI/NENG 110, NSCI/NENG 112, NSCI/NENG 120, NSCI/NENG 122, AMAT 112 or 118T, and AMAT 113 or 119T, or equivalent.

NSCI 202 Introduction to Nanoscale Engineering Design and Manufacturing (2)
Develops students' competence and self-confidence as nanodesign scientists. Emphasis on the creative design process bolstered by application of physical laws, design software (CAD) and learning to complete projects on schedule and within budget. Lecture topics include idea generation, estimation, concept selection, visual thinking and communication, kinematics of mechanisms, machine elements, design for manufacturing, basic electronics, and professional responsibilities and ethics. Prerequisites: satisfactory completion of NSCI/NENG 110, NSCI/NENG 112, NSCI/NENG 120, NSCI/NENG 122, AMAT 112 or 118T, and AMAT 113 or 119T, or equivalent.
NSCI 203 Advanced Circuits Laboratory (2)
Introductory subject that provides the knowledge necessary for reading schematics and designing, building, analyzing, and testing fundamental analog and digital circuits. Interactive examples and exploring the practical uses of electronics in engineering and experimental science, including signals and measurement fundamentals. Students have the use of state-of-the-art hardware and software for data acquisition, analysis, and control. Prerequisites: satisfactory completion of NSCI/NENG 110, NSCI/NENG 112, NSCI/NENG 120, NSCI/NENG 122, AMAT 112 or 118T, and AMAT 113 or 119T, or equivalent.

NSCI 204 Finite Element Modeling (2)
Introduction to principles of finite element modeling and utilization of standard commercial software packages (MATLAB, Intellisuite, ANSYS) for modeling of mechanical, transport, and electromagnetic response of nanoscale systems. Prerequisites: satisfactory completion of NSCI/NENG 110, NSCI/NENG 112, NSCI/NENG 120, NSCI/NENG 122, AMAT 112 or 118T, and AMAT 113 or 119T, or equivalent.

NSCI 205 Numerical Simulation (2)
Introduction to standard numerical simulation approaches for nanoscale materials, system and devices using custom and commercial packages. Topics will include direct numerical calculation, simulators and field solvers in addition to statistical (Monte Carlo) approaches for materials analysis. Prerequisites: satisfactory completion of NSCI/NENG 110, NSCI/NENG 112, NSCI/NENG 120, NSCI/NENG 122, AMAT 112 or 118T, and AMAT 113 or 119T, or equivalent.

NSCI 220 Structure of Matter (3)
Course focusing on the chemical bonding and symmetry of clusters, crystal lattices, amorphous materials and organized molecular structures. Emphasis will also be placed on various concepts, constructs, and techniques for characterizing nanoscale structures including the structure factor, diffraction, and the radial distribution function. Prerequisites: satisfactory completion of NSCI/NENG 110, NSCI/NENG 112, NSCI/NENG 120, NSCI/NENG 122, AMAT 112 or 118T, and AMAT 113 or 119T, or equivalent.

NSCI 220T Structure of Matter (Honors) (3)
Honors version of NSCI 220. Same topics as NSCI 220 but topics are covered in greater depth. This course is for students with greater than average ability and background in Nanoscale Science. NSCI 220T substitutes for NSCI 220 toward the prerequisite in any course. Only one of NSCI 220 and NSCI 220T may be taken for credit. Prerequisites: admission to the nanoscience honors program and satisfactory completion of NSCI/NENG 110, NSCI/NENG 112, NSCI/NENG 120, NSCI/NENG 122, AMAT 112 or 118T, and AMAT 113 or 119T, or equivalent.

NSCI 230 Thermodynamics and Statistical Mechanics for Nanoscale Systems (3)
Applications of thermodynamics and Statistical Mechanics to nanoscale materials and systems with an emphasis on the laws of thermodynamics, phase equilibria, chemical potential, Gibbs-Duhem relation, Boltzman, Fermi-Dirac, and Bose-Einstein distribution functions, ensemble behavior. Prerequisites: satisfactory completion of NSCI/NENG 110, NSCI/NENG 112, NSCI/NENG 120, NSCI/NENG 122, AMAT 112 or 118T, and AMAT 113 or 119T, or equivalent.

NSCI 230T Thermodynamics and Statistical Mechanics for Nanoscale Systems (Honors) (3)
Honors version of NSCI 230. Same topics as NSCI 220 but topics are covered in greater depth. This course is for students with greater than average ability and background in Nanoscale Science. NSCI 230T substitutes for NSCI 230 toward the prerequisite in any course. Only one of NSCI 230 and NSCI 230T may be taken for credit. Prerequisites: admission to the nanoscience honors program and satisfactory completion of NSCI/NENG 110, NSCI/NENG 112, NSCI/NENG 120, NSCI/NENG 122, AMAT 112 or 118T, and AMAT 113 or 119T, or equivalent.
NSCI 240 Biochemical Principles for Nanoscale Science (3)
This course will cover basic chemical concepts of chemical/biological signaling, surface binding, and selectivity. The course will also focus on chemical interactions at gas, fluid, and solid interfaces for nanobiosystems. Includes laboratory section. Prerequisites: admission to the nanoscience honors program and satisfactory completion of NSCI/NENG 110, NSCI/NENG 112, NSCI/NENG 120, NSCI/NENG 122, AMAT 112 or 118T, and AMAT 113 or 119T, or equivalent.

NSCI 300 Integrated Laboratory I (3)
Advanced laboratory training for undergraduates. This laboratory will promote hands-on use of advanced CNSE processing, characterization, and integration laboratories including selected toolsets for 200mm and 300mm wafer design, fabrication, processing and metrology. Course will focus on operating principles of selected processing, testing, and metrology tools. Prerequisites: satisfactory completion of required NSCI 220 or 220T, NSCI 230 or 230T and AMAT 220.

NSCI 305 Integrated Laboratory II (3)
Advanced laboratory training for undergraduates. This laboratory will promote hands-on use of advanced CNSE processing, characterization, and integration laboratories including selected toolsets for 200mm and 300mm wafer design, fabrication, processing and metrology. Course will focus on integration of processing, fabrication, and metrology tools for construction, analysis, and testing of device structures. Prerequisites: satisfactory completion of NSCI 300 and permission of instructor.

NSCI 310 Nanoscale Surfaces and Interfaces (3)
Structure of surfaces and interfaces at the nanometer length scale. Diffusion, adsorption, chemisorption, and physisorption of atomic and molecular species at surfaces and interfaces. Overview of analytic approaches for surface and interfacial characterization and metrology. Prerequisites: satisfactory completion of NSCI 220, or 220T, and NSCI 230 and NSCI 230T.

NSCI 320 Advanced Physical/Chemical Concepts for Nanoscale Science (3)
Advanced course focusing on physical/chemical concepts and their application to nanoscale materials and systems. Topics will include advanced treatment of energy levels, orbital theory, spectroscopy, phase transformations, kinetics, and diffusion. Prerequisites: satisfactory completion of NSCI 220, or 220T, and NSCI 230 and NSCI 230T.

NSCI 330 Energetics and Kinetics in Nanobiological Systems (3)
For this course, energy transduction, kinetics, and transport for nanobiological systems will be explored at an advanced level. Topics covered will include oxidation/reduction pathways, electron transport, chemical/electrical gradients, energy transduction and basic biochemical kinetics. Prerequisites: satisfactory completion of NSCI 220, or NSCI 220T, and NSCI 230 and NSCI 230T.

NSCI 350 Introduction to Quantum Theory for Nanoscale Systems (3)
Introduction to Solid State Quantum Theory for Nanoscale Systems. Fundamental quantum mechanical formalisms applicable to solid state materials. Solution of Schrödinger equation for period potentials and application to nanoscale phenomena, such as tunneling and localization. Prerequisites: satisfactory completion of NSCI 220, or NSCI 220T, and NSCI 230 and NSCI 230T.

NSCI 360 Nanoscale Molecular Materials and Soft Matter (3)
Structure-property relations and chemistry of synthetic polymers, biological macromolecules, gels, foams, emulsions and colloids. Prerequisites: satisfactory completion of NSCI 300 and NSCI 350.
NSCI 390 Capstone Research I. Introduction and Literature Review (3)
First course in a 3-course series representing and original, substantive, team-based research project to introduce the student to professional-level Nanoscale Science and Engineering research. During this introductory course the student will work with a CNSE research team to investigate and identify a topical research problem of interest to the wide fields of Nanoscale Science and Engineering. Emphasis will be placed on a functional understanding of the current technical, peer-reviewed literature in the area of interest and the drafting of a coherent research plan with relevant proof-of-concept research results. Prerequisite: Permission of instructor and satisfactory completion of NSCI 300 and NSCI 350.

NSCI 410 Quantum Origins of Material Properties (3)
This course will focus on the quantum properties of a variety of materials systems and how these properties govern bulk and nanoscale material characteristics. Topics will focus on discrete energy levels and orbital theory and relation to spectroscopy, material phase transformations and kinetics. Prerequisite: satisfactory completion of NSCI 300, and NSCI 305, and NSCI 360.

NSCI 420 Electronic Properties of Nanomaterials (3)
Electron transport in metals, properties of dielectric materials including insulators and semiconductors. Topics include electron energies in solids, the statistical physics of carrier concentration and motion in crystals, and energy band models in silicon and well as compound semiconductors. Prerequisite: satisfactory completion of NSCI 300, and NSCI 305, and NSCI 360.

NSCI 421 Nanoscale Electronic Devices (3)
This course will focus on nanoscale device and device geometries based on semiconductor materials. Topics include drift and diffusion currents, recombination-generation of carriers, continuity equations, and the p-n junction under equilibrium and bias conditions, and metal-semiconductor Schottky and ohmic contacts. Non-idealities associated with real diodes are introduced. Prerequisite: satisfactory completion of NSCI 300, and NSCI 305, and NSCI 360.

NSCI 422 Concepts in Molecular Electronics (3)
This course will focus on nanoelectronic materials based on individual molecules or nanoscale molecular assemblies. Will examine electronic polymers, carbon nanotubes, molecular wires, and discuss aspects of electronic band structure and carrier densities, and charge transport in 1-dimensional covalently bonded materials. Prerequisite: satisfactory completion of NSCI 300, and NSCI 305, and NSCI 360.

NSCI 423 Magnetic and Spintronic Materials and Devices (3)
Introduction to magnetic materials and nanoscale structures for spintronic manipulation. This course will focus on the fundamental science of magnetism and local electron spin manipulation, transport and coupling. Devices based on the addition of the spin degree of freedom to conventional charge-based electronic devices, such as Spin-FET will be discussed. Prerequisite: satisfactory completion of NSCI 300, and NSCI 305, and NSCI 360.

NSCI 424 Optoelectronic Materials and Devices (3)
Introduction to semiconductor optoelectronic materials for optoelectronic applications. This course will cover topics including design, operating principles and practical device features. Review of relevant semiconductor physics, optical processes in semiconductors, waveguides, and microcavities will be discussed. Operational principals of light emitting diodes and lasers, photodetectors, and solar cells will be introduced. Prerequisite: satisfactory completion of NSCI 300, and NSCI 305, and NSCI 360.
NSCI 430 Nanoscale Physical Properties in Reduced Dimensions (3)
Origin of electrical, optical, and thermomechanical properties in two-, one- and zero dimensional systems, including thin films, graphene, carbon nanotubes, nanowires, and quantum dots. Prerequisite: satisfactory completion of NSCI 300, and NSCI 305, and NSCI 360.

NSCI 431 Growth of Nanostructured Materials (3)
Nucleation and growth in confined systems, growth of carbon nanotubes, plasma and thermally assisted deposition processes, nature of plasmas. Prerequisite: satisfactory completion of NSCI 300, and NSCI 305, and NSCI 360.

NSCI 432 Particle Induced Chemistry (3)
Processing materials with nanometer-scale resolution using energetic particle beams. Topics include EUV lithography, electron beam lithography, and electron- and ion-beam induced etching and deposition from precursors. Prerequisites: satisfactory completion of NSCI 300, and CNSI 305, and NSCI 360.

NSCI 433 Properties of Nanoscale Composite Structures (3)
Introduction to mechanical, electronic, magnetic, and optical properties of nanoscale composite structures. Topics will include multilayer composites, nanoparticle composites, porous media, and biomaterial composites. Prerequisites: satisfactory completion of NSCI 300, and NSCI 305, and NSCI 360.

NSCI 434 Nanostructural Characterization Techniques (3)
Current methods of directly examining the nanostructure of materials. Topics: optical microscopy, scanning electron and focused ion beam microscopy, field ion microscopy, transmission electron microscopy, scanning probe microscopy, and microanalytical surface science methods. Emphasis is on the electron-optical techniques. Prerequisites: satisfactory completion of NSCI 300, and CNSI 305, and NSCI 360.

NSCI 440 Biological Architectures for Nanotechnology Applications (3)
Concepts of structure, function and self-assembly in biological systems and their applications in nanotechnology. Topics include structure and function of biological macromolecules, self-assembly of these molecules, and their use for nanofabrication and other nanoscale applications. Prerequisites: satisfactory completion of NSCI 300, and CNSI 305, and NSCI 360.

NSCI 441 Nanobiology for Nanotechnology Applications (3)
The course will provide an understanding of how structure, functionality, energy transduction and kinetic properties of biological systems can be applied to nanotechnology. Topics will include biosensors, bio-MEMS/NEMS, biomolecular electronics, energy production, or other nanobiological systems. Prerequisites: satisfactory completion of NSCI 300, and CNSI 305, and NSCI 360.

NSCI 442 Nanoscale Bio-Inorganic Interfaces (3)
This course will introduce fundamental concepts for interfacial dynamics in nanobiosystems. Biological and chemical interactions with nanomaterials will be explored, as well as advanced concepts of chemical/biological signaling, surface binding, and selectivity. Biological-inorganic interfaces will be explored including novel approaches for material characterization and integration in nanoscale and microscale devices. Prerequisites: satisfactory completion of NSCI 300, and CNSI 305, and NSCI 360.

NSCI 443 Biological Routes for Nanomaterials Synthesis (3)
Applications of biological synthesis routes for nanomaterials fabrication. Emphasis will be placed on adaptation of genetic and biochemical routes for the production of tailored materials for molecular self-
assembly or nanoscale interfacial engineering. Prerequisites: satisfactory completion of NSCI 300, and CNSI 305, and NSCI 360.

**NSCI 490 Capstone Research II. Team Research and Project Review (3)**
Second course in a 3-course series representing original, substantive, team-based research project to introduce the student to professional-level Nanoscale Science and Engineering research. During this intermediate course the student will report progress of the CNSE research team in the designated project area focusing on the student’s efforts and results. This ‘project review’ will conform to prevailing formats and reporting structures for profession-level industry or government-funded research to introduce the student to professional research management. Emphasis will be placed on implementation of the student’s research plan and reporting of progress or challenges encountered. Prerequisites: satisfactory completion of NSCI 300, and CNSI 305, and NSCI 360.

**NSCI 492 Capstone Research III. Team Research and Final Report (3)**
Third course in a 3-course series representing original, substantive, team-based research project to introduce the student to professional-level Nanoscale Science and Engineering research. During this final course the student will provide a final report on the research project with an emphasis placed on achievement of the initial goals of the study as well as challenges encountered and lessons learned. Prerequisite: permission of instructor.

**NSCI 493 Capstone Research III. Team Research and Final Report (Honors) (3)**
Third course in a 3-course series representing original, substantive, team-based research project to introduce the student to professional-level Nanoscale Science and Engineering research. During this final course the student will provide a final report on the research project with an emphasis placed on achievement of the initial goals of the study as well as challenges encountered and lessons learned. Prerequisite: permission of CNSE Honors Director.

**NSCI 498 Current Topics in Nanoscale Science and Engineering (1-6)**
Seminar course for upper-level undergraduate students. Students will receive individualized instruction regarding literature review on topics relevant to student’s capstone research and concentration areas. Prerequisite: permission of instructor.
APPENDIX VI.2
NANOSCALE ENGINEERING COURSE CATALOGUE DESCRIPTIONS

NENG 101 (=NSCI 101) Nanotechnology Survey (3)
Introduction to the definitions, principles and applications of nanotechnology. Discussion of emergent nanoscale properties, atomic and molecular self-assembly and concepts of bottom-up and top-down processing and fabrication. Introduction to selected nanoscale systems, including quantum dots, carbon nanotubes, and graphene. Only one of NSCI 101 or NENG 101 may be taken for credit.

NENG 102 (=NSCI 102) Societal Impacts of Nanotechnology (3)
Introduction to the societal implications of nanotechnology innovation including public perception of nanotechnology, public impacts nanomaterials risk assessment, and impacts of nanotechnology on public health policy and energy/environmental sustainability. Only one of NSCI 102 or NENG 102 may be taken for credit.

NENG 103 (=NSCI 103) Economic Impacts of Nanotechnology (3)
Introduction to the economic impacts of nanotechnology innovation. Basic economic principles will be presented and discussed in terms of emerging nanotechnologies. Topics will include economics of nanoelectronics; nanoscale technologies for energy and the environment; and nanobioscience/nanobioengineering. Only one of NSCI 103 or NENG 103 may be taken for credit.

NENG 104 (=NSCI 104) Disruptive Nanotechnologies (3)
Introduction to the concepts of disruptive technologies and specific nanotechnological applications. Case studies examining key examples of nanoscale science and nanoscale engineering innovation and their impact on specific technical fields, applications, and product markets. Only one of NSCI 104 or NENG 104 may be taken for credit.

NENG 110 (=NSCI 110) Chemical Principles of Nanoscale Science and Engineering I (4)
Fundamental chemical principles for nanoscale materials and systems. Basic chemical concepts of energy, enthalpy, thermodynamics, and quantum atomic theory are introduced with a focus on application to nanoscale materials and application architectures. Fundamentals of chemical bonding in nanoscale materials (covalent, ionic). Laboratory section included. Only one of NSCI 110 or NENG 110 may be taken for credit. Prerequisites: Four years of high school science (earth science, biology, chemistry and physics), and mathematics through pre-calculus.

NENG 112 (=NSCI 112) Chemical Principles of Nanoscale Science and Engineering II (4)
Introduces concepts of gas law, phases, equilibrium, and rates of reaction, applicable to nanoscale systems. Further development of the concepts and nature of chemical bonding. Application of chemical principles to the structure of matter, molecular materials, and crystals. Laboratory section included. Only one of NSCI 112 or NENG 112 may be taken for credit. Prerequisites: Four years of high school science (earth science, biology, chemistry and physics), and mathematics through pre-calculus.

NENG 120 (=NSCI 120) Physical Principles of Nanoscale Science and Engineering I (4)
Newtonian mechanics, motion, momentum, work-energy equivalence as applied to nanoscale materials and systems. Includes static, dynamics, and mechanics of bulk and nanoscale materials. Laboratory section included. Only one of NSCI 120 or NENG 120 may be taken for credit. Prerequisites: Four years of high school science (earth science, biology, chemistry and physics), and mathematics through pre-calculus.
NENG 122 (=NSCI 122) Physical Principles of Nanoscale Science and Engineering II (4)
Concepts of charge, electrostatic potential, current, and fields relevant to nanoscale materials, devices, and systems. Electrical properties of bulk and nanoscale metals, semiconductors and insulators. RCL circuit behavior. Lorentz force and application to nanoscale systems and materials. Laboratory section included. Only one of NSCI 122 or NENG 122 may be taken for credit. Prerequisite: satisfactory completion of NSCI/NENG 120.

NENG 124 (=NSCI 124) Physical Principles of Nanoscale Science and Engineering III (4)
Formalism of vibratory phenomena (waves, oscillators, complex response functions) and scattering (including diffraction) as applied to nanoscale materials and systems. Wave nature of matter, DeBroglie hypothesis, fundamental the double slit experiment, electron diffraction, modern physics. Laboratory section included. Only one of NSCI 124 or NENG 124 may be taken for credit. Prerequisite: satisfactory completion of NSCI/NENG 122.

NENG 130 (=NSCI 130) Biological Principles of Nanoscale Science and Engineering I (4)
This course will introduce basic concepts in nanobiology. The course will initially focus on fundamental biological principles such as DNA/RNA synthesis and replication, protein synthesis, and cellular structure/function. Only one of NSCI 130 or NENG 130 may be taken for credit. Prerequisites: satisfactory completion of NSCI/NENG 110, NSCI/NENG 112, NSCI/NENG 120 and NSCI/NENG 122.

NENG 132 (=NSCI 132) Biological Principles of Nanoscale Science and Engineering II (4)
The course will cover topics relating to the interface between nanosystems and biological systems. This will include general information about biomimetic systems and the uses of nanotechnology for biological research. Only one of NSCI 132 or NENG 132 may be taken for credit. Prerequisite: satisfactory completion of NSCI/NENG 130.

NENG 201 Introduction to Nanoengineering Design and Manufacturing (3)
Develops students’ competence and self-confidence as nanodesign engineers. Emphasis on the creative design process bolstered by application of physical laws, design software (CAD) and learning to complete projects on schedule and within budget. Synthesis, analysis, design robustness and manufacturability are emphasized. Subject relies on active learning via a major design-and-build project. Lecture topics include idea generation, estimation, concept selection, visual thinking and communication, kinematics of mechanisms, machine elements, design for manufacturing, basic electronics, and professional responsibilities and ethics. Prerequisites: satisfactory completion of NSCI/NENG 110 and NSCI/NENG 120.

NENG 201T Introduction to Nanoengineering Design and Manufacturing (Honors) (3)
Honors version of NENG 201. Same topics as NENG 201 but topics are covered in greater depth. This course is for students with greater than average ability and background in Nanoscale Science. Only one of NENG 201 and NENG 201T may be taken for credit. Prerequisites: admission to the Nanoscale engineering honors program and satisfactory completion of NSCI/NENG 110 and NSCI/NENG 120. NENG 201T substitutes for NENG 201 toward the prerequisite in any course.

NENG 202 Introduction to Computer Programming for Engineers (3)
Program and how to use computational techniques to solve nanoengineering problems. Topics include algorithms, simulation techniques, and use of software libraries. Prerequisites: satisfactory completion of NSCI/NENG 110 and NSCI/NENG 120.

NENG 202T Introduction to Computer Programming for Engineers (Honors) (3)
Honors version of NENG 202. Same topics as NENG 202 but topics are covered in greater depth. This course is for students with greater than average ability and background in Nanoscale Science. Only one
of NENG 202 and NENG 202T may be taken for credit. Prerequisites: admission to the Nanoscale Engineering honors program and satisfactory completion of NSCI/NENG 110 and NSCI/NENG 120. NENG 202T substitutes for NENG 202 toward the prerequisite in any course.

**NENG 203 Introduction to Nanoengineering Electronics (3)**
Introductory subject that provides the knowledge necessary for reading schematics and designing, building, analyzing, and testing fundamental analog and digital circuits. Interactive examples and exploring the practical uses of electronics in engineering and experimental science, including signals and measurement fundamentals. Students have the use of state-of-the-art hardware and software for data acquisition, analysis, and control. Prerequisites: satisfactory completion of NENG 201 or NENG 201T.

**NENG 203T Introduction to Nanoengineering Electronics (Honors) (3)**
Honors version of NENG 203. Same topics as NENG 203 but topics are covered in greater depth. This course is for students with greater than average ability and background in Nanoscale Science. Only one of NENG 203 and NENG 203T may be taken for credit. Prerequisites: admission to the Nanoscale Engineering honors program and satisfactory completion of NENG 201 or NENG 201T. NENG 203T substitutes for NENG 203 toward the prerequisite in any course.

**NENG 301 Thermodynamics and Kinetics of Nanomaterials (3)**
Applies the concepts of reaction rate, stoichiometry and equilibrium to the analysis of materials systems. Use of rate expressions from reaction mechanisms and equilibrium or steady state assumptions. Design of reactions via synthesis of kinetics, transport phenomena, and mass and energy balances. Thermodynamics of multicomponent, multiphase chemical and biological systems. Applications of first, second, and third laws of thermodynamics to open and closed systems. Prerequisites: satisfactory completion of AMAT 311, NENG 122, 202, and 203.

**NENG 302 Electronic, Optical and Magnetic Properties of Nanomaterials (3)**
Describes how the electronic, optical and magnetic properties of materials originate from their electronic and molecular structure and how these properties can be designed for particular applications, for instance in optical fibers, magnetic data storage, solar cells, transistors and other devices. Experimental exploration of the electronic, optical and magnetic properties of materials. Includes hands-on experimentation using spectroscopy, resistivity, impedance and magnetometry measurements, behavior of light in waveguides, and other characterization methods. Investigation of structure-property relationships through practical materials examples. Prerequisites: satisfactory completion of AMAT 311, NENG 122, 202, and 203.

**NENG 303 Mechanics of Nanomaterials (3)**
Introduction to statics and the mechanics of deformable solids. Emphasis on the three basic principles of equilibrium, geometric compatibility, and material behavior. Stress and its relation to force and moment; strain and its relation to displacement; linear elasticity with thermal expansion. Failure modes. Application to simple engineering structures such as rods, shafts, beams, and trusses. Application to biomechanics of natural materials and structures. Introduces mechanical behavior of engineering materials, and the use of materials in mechanical design. Emphasizes the fundamentals of mechanical behavior of materials, as well as design with materials. Major topics: elasticity, plasticity, limit analysis, fatigue, fracture, and creep. Materials selection. Prerequisites: satisfactory completion of AMAT 311, NENG 122, 202, and 203.

**NENG 304 Fluid Mechanics and Transport Processes (3)**
Mechanical energy balances and Bernoulli's equation. Dimensional analysis and dynamic similarity. Introduces boundary-layer theory and turbulence. Principles of heat and mass transfer. Steady and transient conduction and diffusion. Radiative heat transfer. Convective transport of heat and mass in both laminar and turbulent flows. Emphasis on the development of a physical understanding of the underlying phenomena and upon the ability to solve real heat and mass transfer problems of engineering significance. Prerequisites: satisfactory completion of NENG 301, NENG 302, and NENG 303.

NENG 390 Capstone Research I. Introduction and Literature Review (3)
First course in a 3-course series representing and original, substantive, team-based research project to introduce the student to professional-level Nanoscale Science and Engineering research. During this introductory course the student will work with a CNSE research team to investigate and identify a topical research problem of interest to the wide fields of Nanoscale Science and Engineering. Emphasis will be placed on a functional understanding of the current technical, peer-reviewed literature in the area of interest and the drafting of a coherent research plan with relevant proof-of-concept research results. Prerequisites: satisfactory completion of NENG 301, NENG 302, and NENG 303.

NENG 405 Micro and Nano Materials Processing Technology (4)
Introduces the theory and technology of micro/nano fabrication. Lectures and laboratory sessions on basic processing techniques such as vacuum processes, lithography, diffusion, oxidation, and pattern transfer. Students will gain experience with state of the art 300mm process technology as they follow the fabrication of advanced test sites at leading edge ground rules. Emphasis on the interrelationships between material properties and processing, device structure, and the electrical, mechanical, optical, chemical or biological behavior of devices. Prerequisites: satisfactory completion of NENG 304 and NENG 390.

NENG 406 Fundamentals of Nanoelectronics (4)
An introduction to the fundamentals of semiconductor materials and the effects of variations in the material properties on the resulting current-voltage characteristics for two terminal devices, namely resistors and diodes. Topics include electron energies in solids, the statistical physics of carrier concentration and motion in crystals, energy band models, drift and diffusion currents, recombination-generation of carriers, continuity equations, and the p-n junction under equilibrium and bias conditions, and metal-semiconductor Schottky and ohmic contacts. Non-idealities associated with real diodes are introduced. Students will be introduced to manufacturing level device testing through the use of advanced wafer level probes in the CNSE 300mm full flow process facility. Prerequisites: satisfactory completion of NENG 304 and NENG 390.

NENG 407 Thin Film and Nanomaterials Characterization (4)
Current methods of directly examining the nanostructure of materials. Topics: optical microscopy, scanning electron and focused ion beam microscopy, field ion microscopy, transmission electron microscopy, scanning probe microscopy, and microanalytical surface science methods. Emphasis is on the electron-optical techniques. Samples to be examined will be selected from the various steps in the CNSE baseline 300mm advanced test site working at leading edge ground rules. Prerequisites: satisfactory completion of NENG 405 and NENG 406.

NENG 408 Industrial Nanomanufacturing (3)
Materials and manufacturing based on nanoprocess systems. Industrial engineering concepts are introduced and the student prepared to perform basic engineering tasks, including design of workstations, cells and lines. The key in operating a manufacturing facility is to make optimum use of all of the available resources including labor, capital, technology, materials and time. Quality systems will cover metrology and overall systems for industrial and service companies, including DOE, SPC, ISO, QS, TQM. The materials used in Electronic manufacturing will be reviewed including materials and
components that are used to produce chips and systems. DOE will cover statistical methods for determining settings of independent experimental variables, prior to experimentation, in order to make meaningful inferences based upon subsequent measurements or simulations. Prerequisites: satisfactory completion of NENG 405 and NENG 406.

**NENG 411 Nanoelectronic IC Fabrication Processes (3)**
Basic tools and principles of single electronic component construction and some of the problem areas encountered are discussed. Structural and electrical differences between logic, DRAM, flash devices will be given. Fundamental modules of ion implantation, PECVD, LPCVD, RIE behavior, control of profiles, diffusion, Lithography, yield control tactics, deposition, and oxidation kinetics will be covered. Future changes will be given in terms of factors that drive speed of microprocessors. Prerequisite: permission of instructor.

**NENG 412 Micro and Nano Devices and Circuits (3)**
Micro- and nanoelectronic devices modeling, and basic micro- and nanoelectronic circuit analysis and design. Physical electronics of semiconductor junction and MOS devices. Relating terminal behavior to internal physical processes; developing circuit models; and understanding the uses and limitations of different models. Use of incremental and large-signal techniques to analyze and design bipolar and field effect transistor circuits, with examples chosen from digital circuits, single-ended and differential linear amplifiers, and other integrated circuits. Prerequisite: permission of instructor.

**NENG 413 Nanoscale Optical and Optoelectronic Devices (3)**
Introduction to solid-state optoelectronic devices; display devices, laser diodes, photodetectors, and light modulators; optical waveguides and fibers; topics also include design and fabrication of nanoscale optoelectronic components, monolithic and hybrid integration between photonics and electronic components and associated challenges. System application of optoelectronic devices will be discussed. Prerequisite: permission of instructor.

**NENG 414 Applications of Fields and Waves to Nanoscale Systems (3)**
Starting from Maxwell’s Equations, this course explores fundamental properties of quasistatic and dynamic properties of electromagnetic waves including: radiation, diffraction, plane waves in lossless and lossy media, skin effect, flow of electromagnetic power, Poynting’s Theorem, interaction of fields with matter and particles, and applies these concepts to nanoscale systems and devices. Prerequisite: permission of instructor.

**NENG 415 Nanoelectronic Devices (3)**
Focus in on device physics and operation principles. Device and material options for advanced silicon FETs at the nanoscale. Topics identified by the International Technology Roadmap for Semiconductors, emerging research devices section. Non-silicon based devices such as carbon nanotubes, semiconductor nanowires, molecular devices; and non-FET based devices such as single electron transistors (SET), resonant tunneling diodes (RTD), and quantum dots, logic and memory devices. Prerequisite: permission of instructor.

**NENG 421 Introduction to Solar Cell Nanotechnology (3)**
Theory of conventional pn junction and excitonic solar cells. Design, fabrication, and characterization of crystalline silicon, amorphous silicon, CdTe, CIGS, and tandem and organic solar cells. Emerging solar cell concepts such as intermediate band gap and bioinspired solar cells. Emphasis is on the materials science aspects of solar cells research. Module design and economic hurdles that must be overcome for solar cell technology to generate a significant fraction of the world’s electricity. Group project to explore one solar cell approach in depth. Prerequisite: permission of instructor.
NENG 422 Introduction to Fuel Cell Nanotechnology (3)
The course provides an introduction to the basic science and technology of fuel cells. It begins with an overview of the various types of fuel cells and their technologies including hydrogen production and storage. Next, the fundamental principles involved in the design and analysis of fuel cell components and systems are described. Topics include the thermodynamics of fuel cells, namely, cell equilibrium, standard potentials, and Nernst equation; ion conduction and sorption in proton-exchange membranes; mass transport in gas-diffusion layer; and kinetics and catalysis of electrocatalytic reactions of anode and cathode for hydrogen, direct methanol, solid oxide, and molten carbonate fuel cells. The transport and reaction in fuel cells are finally combined to provide their overall design and performance characteristics. Prerequisite: permission of instructor.

NENG 423 Renewable and Alternate Energy Nanotechnologies (3)
An overview of various renewable energy technologies and their current applications. Emphasis will be placed on energy consumption, efficiency, and conservation. Quantification of incident solar energy is covered in detail along with the basic physics of energy conversion. Technologies include passive and active solar thermal, photovoltaics, wind turbines, small-scale hydrodynamic generation, fuel cells, and hydrogen. Topics will include thermoelectrics, batteries, ultracapacitors etc. Prerequisite: permission of instructor.

NENG 424 Nanoscale Chemical and Biological Sensors (3)
Principles of design, operation, and implementation principles of chemical and biological sensors. Focus on the application of fundamental sensing mechanisms and architectures to prevailing and emerging techniques for device design and integration within a specific chemical and/or biological sensing system. Emphasis will be placed on the engineering of the signal transduction mechanism and implications towards design and fabrication. Prerequisite: permission of instructor.

NENG 431 Advanced Materials Processing for NEMS/MEMS (4)
The course will cover advanced topics of good practices in the selection of organic and inorganic materials based on properties, processes and economics for product design. Students fabricate MOS capacitors, nanomechanical cantilevers, and micro/nanofluidic mixers. Prerequisite: permission of instructor.

NENG 432 Interfacial Engineering in Nanobiological Systems (3)
Fundamentals of interfacial dynamics, energy transduction, kinetics, and transport for nanobiological and bioengineered systems. This course will explore how biological systems interact with engineered systems at the nanoscale, including how energy is generated and transduced at the nano-bio interface. Prerequisite: permission of instructor.

NENG 433 NEMS/MEMS for Chemical and Biological Sensors (3)
NEMS/MEMS design, processing, fabrication approaches, and operational principles for chemical and biological sensors. Focus on fabrication strategies and techniques for integrating specific transduction techniques and engineered coatings for chemical and biological applications. Emphasis will be placed on design and fabrication to enable target sensitivity and selectivity. Prerequisite: permission of instructor.

NENG 434 BioMEMS and BioNEMS (3)
Introduction to the cross-disciplinary application of MEMS and NEMS to the biological sciences. Topics include the interaction of living cells/tissues with nanofabricated structures, micro/nanofluidics for the movement and control of solutions, and the development of I/O architectures for efficient readout of bio-reactions. Prerequisite: permission of instructor.
NENG 435 Nanobiological Systems (3)
Introduction to basic concepts in nanobiology and the interface between nano and biological systems. This course will seek to introduce basic nanobiological concepts to non-biologists. The course will initially focus on fundamental biological principles such as DNA/RNA synthesis/replication, protein synthesis, and the biochemistry of basic biomolecules and cells. The course will then discuss nanobiological applications. These include biosensors, bioinformatics, nanobiological materials, and biomimetics. Prerequisite: permission of instructor.

NENG 441 Nanoscale Patterning (3)
The class will follow the transition of a sample pattern from a CAD file to its physical realization for both production manufacturing and research. Topics covered include optical reduction lithography, electron beam lithography, imprint lithography and resist systems. Sources of error and error characterization of pattern placement, size control and pattern fidelity. Practical limits of resolution will be discussed. Prerequisite: permission of instructor.

NENG 442 Light Optics for Nanoengineering (3)
Applied optics for nanoscale patterning and metrology. Paraxial optics, lens makers equation, 3rd order optics, Seidel aberrations, Zernike polynomials, compound systems, numerical aperture, diffraction limit. Specific examples applied to lithography using 193nm immersion and EUV techniques. Optical specifications for patterning and metrology equipment including economic tradeoffs. Techniques for optical resolution enhancement. Prerequisite: permission of instructor.

NENG 443 Charged Particle Optics for Nanoengineering (3)
Applied optics using using charged particles for nanoscale patterning and metrology. Lorentz force law, electrostatic and magneto static lenses. Sources, correction and deflection elements. Geometrical optics based upon relativistic classical mechanics. Quantum based wave optics. Prerequisite: permission of instructor.

NENG 444 Electron Beam Pattern Generation (3)
A comprehensive review of electron beam pattern generator technology including beam generation, control electronics, mechanical subsystems and system software. Special attention will be given to issues that arise when patterning for nanoscale dimensions and accuracy such as proximity effects and throughput limitations. Prerequisite: permission of instructor.

NENG 451 Nanophotonics (3)

NENG 452 Magnetic Nanostructures (3)
Magnetic moments, magnetic exchange and ferromagnetism, types of magnetic order, magnetic anisotropy, domains, domain walls, hysteresis loops, hard and soft magnetic materials, demagnetization factors, and applications of magnetic materials, especially magnetic nanostructures and nanotechnology. Tools include finite-element and micro/nanomagnetic modeling. Design topics include electromagnet and permanent magnet, electronic article surveillance, magnetic inductors, bio-magnetic sensors, and magnetic drug delivery. Prerequisite: permission of instructor.

NENG 453 Organic Semiconductors (3)
The science and engineering of organic semiconductors and their use in electronic and photonic devices. methods for fabricating thin films and devices; relationship between chemical structure and molecular
packing on properties such as band gap, charge carrier mobility and luminescence efficiency; doping; field-effect transistors; light-emitting diodes; lasers; biosensors; photodetectors and photovoltaic cells. Prerequisite: permission of instructor.

NENG 454 Analysis of Thin Films and Interfaces (3)
The science and technology of micro/nanoanalytical techniques, including Auger electron spectroscopy (AES), Rutherford backscattering spectroscopy (RBS), secondary ion mass spectroscopy (SIMS), ion scattering spectroscopy (ISS), and x-ray photoelectron spectroscopy (XPS or ESCA). Generic processes such as sputtering and high-vacuum generation. Prerequisite: permission of instructor.

NENG 455 Nanoscale Polymer Science & Engineering (3)
Overview of engineering analysis and design techniques for nanoscale synthesis of polymers. Treatment of materials properties selection, mechanical characterization, and processing in design of load-bearing and environment-compatible structures. Prerequisite: permission of instructor.

NENG 456 Nanoscale Interfacial Engineering (3)
The dynamic behavior of fluid interfaces. Concepts of interfacial stress, dynamic interfacial properties, and surfactant adsorption applied to surface tension driven flow, interfacial instabilities, the influence of surface-active agents on interfacial hydrodynamics. Prerequisite: permission of instructor.

NENG 457 Modeling of Nanomaterials and Systems (3)

NENG 490 Capstone Research II. Team Research and Project Review (3)
Second course in a 3-course series representing and original, substantive, team-based research project to introduce the student to professional-level Nanoscale Science and Engineering research. During this intermediate course the student will report progress of the CNSE research team in the designated project area focusing on the student’s efforts and results. This ‘project review’ will conform to prevailing formats and reporting structures for profession-level industry or government-funded research to introduce the student to professional research management. Emphasis will be placed on implementation of the student’s research plan and reporting of progress or challenges encountered. Prerequisites: satisfactory completion of NENG 304 and NENG 390.

NENG 492 Capstone Research III. Team Research and Final Report (3)
Third course in a 3-course series representing and original, substantive, team-based research project to introduce the student to professional-level Nanoscale Science and Engineering research. During this final course the student will provide a final report on the research project with an emphasis placed on achievement of the initial goals of the study as well as challenges encountered and lessons learned. Prerequisite: permission of instructor.

NENG 493 Capstone Research III. Team Research and Final Report (Honors) (3)
Third course in a 3-course series representing and original, substantive, team-based research project to introduce the student to professional-level Nanoscale Science and Engineering research. During this final course the student will provide a final report on the research project with an emphasis placed on achievement of the initial goals of the study as well as challenges encountered and lessons learned. Prerequisite: permission of CNSE Honors Director.
NENG 498 Current Topics in Nanoscale Science and Engineering (1-6)
Seminar course for upper-level undergraduate students. Students will receive individualized instruction regarding literature review on topics relevant to student’s capstone research and concentration areas. Prerequisite: permission of instructor.
APPENDIX VI.3
INDEPENDENT STUDY AND RESEARCH COURSE

NNSE 397 Independent Study and Research (1-6)
Independent study or research in an area of nanoscale science or nanoscale engineering designed for the undergraduate student who desires to engage in study of a subject beyond the introductory or survey level, particularly that which builds upon related prior academic achievement and experience. May be repeated, but each registration must be for an approved project. The normal credit load for this course is 3 credits; students desiring more than 3 credits must submit a request including justification to the CNSE Office of Student Services. (1-6 credits as approved). Prerequisite(s): Permission by CNSE Office of Student Services and consent of supervising CNSE instructor. Further information and application requirements may be obtained from the CNSE Office of Student Services.
APPENDIX VI.4
Nanoscale Engineering Courses
Designated as Non-Liberal Arts and Sciences

Based on the definition of Non-Liberal Arts & Sciences courses that I forwarded you last week, and a review of our proposed curriculum we are propose the following CNSE undergraduate courses be designated as Non-Liberal Arts & Science courses:

NENG 405 Micro and Nano Materials Processing Technology
NENG 408 Industrial Nanomanufacturing
NENG 411 Nanoelectronic IC Fabrication
NENG 444 Electron Beam Pattern Generation
APPENDIX VI.5
UNDERGRADUATE “NANO” COURSES AT OTHER SUNY INSTITUTIONS

VI.5.1. Binghamton University, SUNY

MTLE 567 Physical Phenomena in Micro- and Nanotechnology (3)
As size of a device or structure decreases below approximately 100 nm, physical forces begin to dominate the structure's behavior that are different from those encountered in our macroscale world. As the size continues to decrease, still other forces begin to dominate in various size regimes. Known as "scaling" of physical phenomena, this is extremely important in the design, fabrication and operation of devices with microscale or nanoscale geometries. An understanding of these forces is beneficial to avoiding any difficulties they may introduce, as well as enabling innovative, non-traditional means of creating new functional structures. Length-scale dependencies of various forces and length scales typical of many micro-nanodevices are covered. Case studies of various sensors, micromachines and nanotechnologies illustrate the relevance of these scaling phenomena. Prerequisites: graduate standing in engineering or science with undergraduate work in engineering or either physical, chemical or biological sciences.

MTLE 573 Nanotechnology in Small Scale Systems (3)
A survey of basic concepts and examples of nanotechnology in small scale systems, including electronic and optical devices, sensors, micro-electromechanical and materials systems for nanomedicine, etc.

ME 567 Physical Forces at Micro- and Nanoscales (3)
Scaling of physical phenomena at microscale or nanoscale geometries. Electromagnetic forces, fluid mechanics, solid mechanics, optics, thermal transport, capillary forces, van der Waals forces, sensors, MEMS, microfluidics, microactuators. Case studies of micro- and nanodevices to illustrate scaling of physical forces at extremely small scales. Prerequisite: graduate standing or consent of department chair.

VI.5.2 University at Buffalo, SUNY

EE 240 Nanotechnology, Engineering, and Science (3)
Targeted at undergraduate students in the early stages of their education. The major goals and objectives are to provide second year students with knowledge and understanding of nanoelectronics as an important interdisciplinary subject. Through examples, exercises, and educational Java applets the course covers electromagnetic waves and quantum mechanics, including the quantum-mechanical origin of the electrical and optical properties of materials and nanostructures, chemically-directed assembly of nanostructures, biomolecules, traditional and nontraditional methods of nanolithography, and interactions between electronic and optical properties, as well as forefront topics such as organic heterostructures, nanotubes, and quantum computing.

EE 342 Nanotechnology Engineering and Science Lab (1)
The laboratory course consists of ten experiments, divided into two groups: five Scanning Probe Microscope experiments and five experiments devoted to phenomena that form the basis for modern Nanoelectronics and Nanotechnology. A complete set of laboratory experimental modules delivers to students a hands-on experience in this field.

EE 422 Nanomaterials (3)
The recent emergence of fabrication tools and techniques capable of constructing nanometer-sized structures has opened up numerous possibilities for the development of new devices with size domains
ranging from 0.1 - 50 nm. The course introduces basic single-charged electronics, including quantum dots and wires, single-electron transistors (SETs), nanoscale tunnel junctions, and so forth. Giant magnetoresistance (GMR) in multilayered structures are presented with their applications in hard disk heads, random access memory (RAM) and sensors. Discusses optical devices including semiconductor lasers incorporating active regions of quantum wells and self assembled formation of quantum-dot-structures for new generation of semiconductor layers. Finally, devices based on single- and multi-walled carbon nanotubes are presented with emphasis on their unique electronic and mechanical properties that are expected to lead to ground breaking industrial nanodevices. The course also includes discussions on such fabrication techniques as laser-ablation, magnetron and ion beam sputter deposition, epitaxy for layer structures, rubber stamping for nanoscale wire-like patterns, and electroplating into nanoscale porous membranes.

**EE 424 Introduction to Nanoelectronics, Nanostructure Physics, and Applications (3)**
Covers 2-D electron systems, quantum wires and dots, ballistic transport, quantum interference, and single-electron tunneling.

**EE 428 BioMEMS and Lab-on-a-Chip (3)**
Covers various commonly used micro/nanofabrication techniques, microfluidics, various chemical and biochemical applications such as separation, implantable devices, drug delivery, and microsystems for cellular studies and tissue engineering. Discusses recent and future trends in BioMEMS and nanobiosensors. Students will gain a broad perspective in the area of micro/nano systems for biomedical and chemical applications.

**VI.5.3 University at Stony Brook, SUNY**

**BME 213/MEC 213/EST 213 Studies in Nanotechnology (3)**
The emerging field of nanotechnology develops solutions to engineering problems by taking advantage of the unique physical and chemical properties of nanoscale materials. This interdisciplinary, co-taught course introduces materials and nano-fabrication methods with applications to electronics, biomedical, mechanical and environmental engineering. Guest speakers and a semester project involve ethics, toxicology, economic and business implications of nanotechnology. Basic concepts in research and design methodology and characterization techniques will be demonstrated. Course is cross-listed as BME 213, MEC 213, and EST 213 and is required for the Minor in Nanotechnology Studies (NTS).

**BME 318 Nanofabrication in Biomedical Applications (3)**
Theory and applications of nanofabrication. Reviews aspects of nanomachines in nature with special attention to the role of self-lubrication, intracellular or interstitial viscosity, and protein-guided adhesion. Discusses current nanofabricated machines to perform the same tasks and considers the problems of lubrication, compliance, and adhesion. Self-assembly mechanisms of nanofabrication with emphasis on cutting edge discovery to overcome current challenges associated with nanofabricated machines.

**VI.5.4 SUNY Institute for Technology (SUNYIT)**

**ETC 290 Introduction to Nanotechnology (2)**
An introductory course covering fundamentals of nanotechnology, its applications and future challenges. Course content includes an introduction to nanodevices, fabrication, imaging and characterization of nanodevices, nanoelectronics building blocks, nanosensors and nanocomputing.
ETC 392 Microelectromechanical System (MEMS) Based Nanotechnology (2)
Introduces the student to the emerging field of microelectromechanical systems (MEMS) based nanotechnology. Topics will include introduction to nanoscale systems, methods of fabrications and packaging of MEMS, principle of microactuation, visualization and applications of nano and micro systems.

VI.5.5. NYS College of Ceramics at Alfred University

CEMS 438 - Nano-Technology (3)
No description provided in the College of Ceramics course catalog.

CEMS 513 - Nano-Structured Materials (3)
This course provides a basic knowledge of nano-structured materials. The first section deals with fundamentals of the synthesis processes, e.g. gas phase reactions or precipitation reactions. In the second section the various applications and properties of nano-structured materials will be discussed. Examples are quantum dot (lasers), ductile ceramics, solar cells, memory devices, or magnetic refrigeration.