SOUTH DAKOTA MINES

An engineering, science and technology university

NANOSCIENCE AND NANOENGINEERING

Ph.D. Program

HANDBOOK

2020-2021

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Note: This handbook is for informational purposes - it provides more detailed explanations than are available in the SDSMT Catalog, as well as specific NANO policies established by the NANO Ph.D. Advisory Council. This handbook should be used in conjunction with the SDSMT Catalog.

TABLE OF CONTENTS

General information concerning the Graduate School and the Nano Science and Engineering (NANO SE) Ph.D. program is contained in the South Dakota School of Mines and Technology Catalog. Detailed listings of graduate courses, as well as additional information concerning program and university graduate degree requirements, are contained in the catalog. All graduate students should familiarize themselves with pertinent information contained in this catalog.

The following guide relates to specific requirements of the NANO SE Ph.D. program and is intended to supplement catalog information. It should be studied carefully by all Ph.D. students in the Nano Science and Engineering Program. A discussion of the various forms that must be filed is included herein. The procedure for completing a degree program including pertinent forms are in Appendix A.

I. ADMISSION

The Nano Science and Engineering Ph.D. program requires GRE (Graduate Record Examination) scores of all applicants; applicants must take the Verbal, Quantitative, and Analytical parts. The GRE subject test in the individual's undergraduate degree major is encouraged, but not required. Any exception to the GRE requirement should be approved by the Nano Advisory Committee (Nano AC). In addition to the general admission requirements, the Graduate School requires applicants from foreign countries to achieve a satisfactory TOEFL (Test of English as a Foreign Language) score. TWE test is strongly recommended for a student who wants to be considered for a teaching assistantship or other financial aid. All students whose first language is not English may be tested upon arrival and may be required to take one or more remedial English courses. All graduate students are expected to have or to develop a proficiency in both written and oral English. Any student, who is found weak in communications, as evidenced by written reports and/or seminar presentations, may be required to take additional English or speech course work.

A student whose bachelor's degree is in any science or engineering field is eligible for admission to this program. However, the following courses are regarded as minimum pre-requisites to this program.

Chemistry: one year, general
Math: one year calculus, ordinary differential equations, matrix algebra
Computer Science: proficiency in a computer programming language
Physics: one year, calculus based

II. GRADUATE STUDENT ADVISOR

The Nano Science and Engineering PhD program director serves as a temporary faculty advisor to each new graduate student until such a time as the student selects a permanent advisor (also known as Major Professor) to supervise his/her graduate research. The program director will assist all new graduate students with their course registration and provides each student with information pertinent to the Nano SE PhD program.

III. FINANCIAL ASSISTANCE

Financial assistance is available to graduate students through a number of avenues, including graduate fellowships, graduate teaching assistantships (GTA), and graduate research assistantships (GRA). The required applications for all types of financial assistance should be made to the Dean of Graduate Education. Requests may be included in the application package, at the discretion of the applicant.

IV. SELECTION OF RESEARCH TOPIC

Within the first two semesters of graduate studies, all new students not supported by a GRA should make appointments with faculty involved in the NANO SE Ph.D. program to discuss possible research topics. Each student will be matched with a major professor in accordance with his/her interests. The student must file a Program of Study form with the Office of Graduate Education within the first two semesters of study. An Advisory Committee (also known as the student's dissertation committee), consisting of the major professor and four other faculty, will be formed to guide the student progress. The Advisory Committee is appointed by the Dean of Graduate Education in consultation with the student and the student's major professor. At this time, the major professor becomes the student's advisor on all matters pertaining to guiding the students progress.

V. PROGRAM OF STUDY

The degree of Doctor of Philosophy in Nano Science and Engineering is awarded upon completion of course requirements and demonstration of significant scholarly achievement through independent research. A Ph.D. candidate must demonstrate general competence in the subject matter of his/her chosen field. To this end, the student files and pursues a proposed Program of Study, which includes a list of courses that the student intends to take. This Program of Study must be given preliminary approval before the qualifying exam and final approval before the dissertation defense by the student's advisory committee, Nano Science and Engineering Advisory Committee (Nano AC), and the Dean of Graduate Education. The Program of Study must be filed with the Nano Science and Engineering PhD Program director during the first year of residence, and again before the qualifying exam. Below is a summary of the required course of study. Example curricula and schedule of core course offerings can be found in appendix E.

CATEGORY	**CREDITS***
NANO 701 Nano Materials	3
NANO 702 Theory and Applications of Nanoscale Materials	3
NANO 703/703L Instrumentation and Characterization of Nano-Materials	4
NANO 890 Seminar	3
TOTAL NANO Core Credits:	13

Program Major Emphasis: The program major emphasis consists of foundational graduate training at the MS level, and may be fulfilled in part or in full by a previously earned MS degree. Students entering at the BS level are encouraged to select coursework which will provide a framework upon which the PhD can be based. Specific thematic tracks consisting of coursework well-aligned and complementary to ongoing research areas in the Nano SE PhD program are outlined below under Major Emphasis-specific requirements (see also appendix D).

General requirements: 27-37
Minimally 27 credits, according to program major emphasis. May be fulfilled in part by up to 24 credits applied to an MS degree according to SDSMT graduate school policy.

Major Emphasis-specific requirements:

In addition to the NANO core curriculum, students may select courses from the thematic tracks identified below, corresponding to active research areas in the Nano SE PhD program. These course sequences are designed to complement and provide context to ongoing research activities. The thematic tracks consist of 27 credits which, when combined with the 13 core course credits, wholly fulfill the coursework requirements for the Nano SE PhD. The research areas matched to each thematic track and their coursework components are synopsized below:

Nanoelectronic and Photonic Materials: Encompasses the synthesis, characterization and theory of nanostructured electronic and photonic materials and devices. Examples are nanostructured solar cells, nanophotonic or plasmonic materials, devices and structures.

Nano-biotechnology and Nano-imaging: Development of nanotechnologies and methods to influence and or characterize living systems. Examples are live cell, superresolution imaging, electron tomography, cell level and sub-cellular level nano-biotechnologies.

Nano-composites and Applications: Development of multi-component materials with properties exceeding the performance of matrix and nano-phased fillers. Examples are structural, thermal-insulating and optoelectronic organic/inorganic nano-fiber composites.

Nano SE thematic track course sequences:

Approved course numbers and titles (see catalog for full description)		**Nanoelectronic and Photonic Materials**	**Nano-biotechnology and Nano-imaging**	**Nano-composites and Applications**
NANO 704	Crystallography & Struct. Nanomaterials	x	x	x
NANO 709	Scientific Instr. Cont. and Visualization	x	x	x
NANO 714	Fluorescence Spectroscopy	x	x	x
NANO 717	Nanochemistry	x	x	x
NANO 718	Nanomechanics	x	x	x
NANO 705	Nanoelectronics	x		
NANO 706	Nano-biotechnology		x	
NANO 707	Nanocomposites			x
NANO 504	Nanophotonics	x		x
NANO 604	Nanophotonics materials	x		
NANO 708	Nanomaterials for Photovoltaics	x		
NANO 710	Optical Nanoscopy		x	
NANO 712	EM Prop. Of Heterogeneous Materials			x
NANO 713	Nano-biotechnology II		x	
NANO 715	Polymeric Nanomaterials			x
NANO 719	Nanomaterials for Biosensors		x	

Table V.1: Coursework defining each thematic track and approved thematic electives (indicated by "**x**" under each specific track).

Notes: There are 5 courses common to all thematic tracks, NANO 704, NANO 709, NANO 714, NANO 717, and NANO 718. NANO 705, NANO 706 and NANO 707 are considered flagship courses for their respective specializations. Three additional approved elective courses specific to each thematic track are shown in the table. With approval of the faculty advisor: NANO 504 may be substituted for NANO 714; NANO 715 may be substituted for NANO 717; and NANO 711 may be substituted for NANO 709.

Dissertation Research	30-40
TOTAL REQUIRED FOR PhD:	80

In approving a proposed Program of Study, the Nano SE PhD Program Advisory Committee will take into account acceptable graduate-level courses taken at other institutions or other demonstrations of competence in a particular area. The student should summarize this material as directed in Appendix A, and submit this with the Program of Study.

VI. MASTERS DEGREE:

The Nano SE PhD program is designed with the precept that the PhD is the terminal degree for completion of the program. However, under circumstances wherein a student has completed the required coursework, and has obtained a minimum of 30 credit hours, a coursework only MS degree can be earned en route to the PhD. The degree requirements are described below in tables VI.1-3 below. The degree is composed of 5 core courses, NANO 504, 701, 702, 703/703L, and 709; and 12 elective credits selected from NANO 604, 704, 705, 715, 717, 719, and 718 or any other graduate-level course approved by the advisor, and 2 credits of NANO788 (MS Project, which can be substituted by NANO 898D).

Table VI. 1: Summary of the degree program:

MS Nanoscience and Nanoengineering	Credit Hours	Percent
Required courses, all students	18	60%
Required option or specialization, if any	0	0
Electives (approved 500-700 level courses, including, but not restricted to those listed below)	12	40%
Total Required for the Degree Total	30	

Table VI.2: Required Courses:

Prefix	Number	Course Title	Cr. Hrs.
NANO	504	Nanophotonics	3
NANO	701	Nanomaterials	3
NANO	702	Theory and Application of Nanomaterials	3
NANO	703	Instrument. & Charact. of Nanomaterials	4
NANO	709	Scientific Control and Visualization	3
NANO	788	Nano MS Project	2
		Subtotal	18

Table VI.3: Example MS Elective Courses:

Prefix	Number	Course Title	Cr. Hrs.
NANO	604	Nanophotonic Materials	3
NANO	704	Crystallography and Structure of Nanomaterials	3
NANO	705	Nanoelectronics	3
NANO	715	Polymeric Nanomaterials	3
NANO	717	Nano-chemistry	3
NANO	719	Nanomaterials for Biosensors	3
NANO	718	Nanomechanics‡	3
		Subtotal	21

VII. GPA REQUIREMENTS AND COURSE LOAD

A grade of "B" or better in a course will be accepted as evidence of competence in the subject.

All candidates for the Ph.D. must obtain an average grade of "B" or better in the overall course of study in accordance with the Graduate School requirements. Grades below "C" cannot be credited toward advance degree requirements. A full load for each semester is considered to be nine semester credit hours of course work and/or dissertation. After the dissertation committee has been established, a Ph.D. student must register every semester, in accordance with SDSMT regulations.

Once the student has selected a research topic, he/she will be expected to register for NANO 898 (research) for a number of credit hours agreed to by his/her research advisor. The student will be required to register for three 1-credit hour graduate seminars, and is expected to attend regularly and participate.

VIII. QUALIFYING EXAMINATIONS

Prior to the end of the fifth semester of study, the student will sit for a qualifying examination consisting of two parts:

(i) A written examination based on the core Nano SE curriculum will be given at the end of the second year of study. This will be a 2 hour written examination, roughly 1/3 of the emphasis will be devoted to each of the 3 required core courses.

(ii) The student will prepare a written research proposal and complete an oral presentation of that proposal in the presence of the Dissertation Committee. The topic is to be prepared by the student with the guidance of his/her research advisor. The topic of the proposal will usually be related to the student's anticipated dissertation research; however, the student's research advisor may require the student to prepare a proposal on an unrelated topic.

The written proposal should be no longer than 15 double-spaced, typewritten pages of text, plus nomenclature, references, figures, and appendices. It is recommended that the document be organized in the form shown in Appendix B. This written document must be reviewed by two members of the student's dissertation committee before submission to the full committee. The committee members will point out any problems relating to scope and format. However, final approval of the proposal will only come after the subsequent faculty reading and oral exam.

Copies of the final typed proposal must be submitted to the student's dissertation committee for faculty reading. At this time, a date will be set for the oral presentation by the student of his/her dissertation research proposal. This presentation should closely reflect the contents of the written proposal and should last no longer than 30 minutes, without interruptions. Background information is to be limited to no more than 20% of the document; the majority of the presentation should be a detailed description of the student's proposed research program. The originality and potential significance of the proposed research should be emphasized. Following the oral presentation, the student will be expected to respond to questions from the attending faculty.

The purpose of the examinations is to test the students knowledge in the program focus areas, teach the student how to write technical research proposals, test the student's understanding of the relevant literature, test the student's imagination and judgment in a research environment, and test the student's ability to present work in clear, concise written and oral English. Clear and substantial portions of both the written and oral presentations must demonstrate the student's original ideas. The proposal must be for the most part a product of the student, not that of the advisor or Committee. The outcome of this examination procedure will be a Pass, a Conditional Pass (usually requiring a re-write and/or re-submittal of the proposal), or a Fail. An examination may be repeated only once and only at the discretion of the student's dissertation committee.

Passing the qualifying examination shall be considered equivalent to satisfying both the preliminary and comprehensive examination requirements, as described in the graduate school degree requirements in the SDSMT catalog.

Failing the Qualifying examination: Students who fail the written portion of the exam may retake the exam in the following year, with the permission of the advisor. Students must schedule the oral portion of the qualifying examination by the end of the 5th semester of study (*e.g*. mid-term of the 3rd year).

If a student does not complete and pass both parts of the examination by the end of the 5th semester, an evaluation of the student's progress and eligibility for an assistantship will be initiated during the 6th semester. Contingent on the outcome of this evaluation, a recommendation will be made, with the following outcomes:

a) A specific timeline for completion of these exams, not to exceed one year, will be submitted by the student and/or the faculty advisor, and approved by the Nano AC and the Nano PhD Program Director, or

b) The student will be dismissed from the program.

Failure to successfully complete these exams on the second attempt will result in the student being dismissed from the program.

IX. ADMISSION TO CANDIDACY

Provided the student has passed both portions of the qualifying examination, the student may apply to his/her major professor for admission to candidacy on an official certification form available from the Office of Graduate Education. At this time, no less than four months before the scheduled dissertation defense, the student will be considered a PhD candidate.

X. DISSERTATION

Of major importance to the Ph.D. degree are the student's research and the resulting dissertation. The research results are expected to be of publishable quality. The student's research advisor may specifically require publication of one or more peer-reviewed journal articles, equal to or exceeding the Nano PhD program publication requirements. The time necessary to complete the Ph.D. requirements depends largely upon how soon a student initiates research and the degree to which he/she devotes effort to its pursuit. Detailed instructions concerning the dissertation and the time schedule that must be followed during the semester of intended completion of the Ph.D. requirements are given in the Graduate Bulletin.

Information on guidelines for writing and formatting a Doctoral Dissertation are available from the Office of Graduate Education. Student should obtain a free copy of "Instruction for the Preparation of Thesis and Dissertation" from the Graduate Office. All students are expected to follow the guidelines found within the manual. The final version of the dissertation must be submitted by the candidate to each member of his/her dissertation committee no later than TWO weeks before the scheduled dissertation defense.

XI. DEFENSE OF DISSERTATION

The student will be required to give an oral presentation (30-45 minutes), open to the public, on the major findings of his/her research. An oral examination will follow the presentation; conducted by the student's major professor with only the student's dissertation committee in attendance. The student's dissertation committee will question the student to test the quality and completeness of the research.

XII. PUBLICATION REQUIREMENT

Publication in peer-reviewed journals is a pre-requisite to demonstrating achievement at the level of the PhD. It is suggested that each student would be first author on 3 peer reviewed journal articles prior to obtaining the PhD. A minimum of 2 peer-reviewed journal articles are required, with the student being first author on at least 1 published article prior to graduation. Any exception must be approved by the Nano AC.

XIII. GRADUATE COMMITTEE

The graduate committee will be formed according to the rules laid out by the Graduate office. One member of the committee must fulfill the requirements of the graduate office to act as the graduate representative, and therefore must not be a Nano program faculty advisor. A list of Nano program faculty will be provided to the graduate office annually by the Nano AC or on request.

APPENDIX A

PROGRAM OF STUDY FOR PH.D. STUDENTS
GRADUATE ADVISORY COMMITTEE SIGNATURE PAGE

The original program of study is due to the Office of Graduate Education no later than midterm of the second semester of registration as an advanced degree-seeking candidate.

If the program of study is being revised, a new form must be submitted, complete with all approval signatures.

_____ Original _____ Revision

Student Name and ID #: _____ Today's Date: _____
(Print)

Current Ph.D. Department/Program: _____

Specialization/emphasis (if applicable): _____

Undergraduate degree received: _____

State your dissertation research area, as close to the anticipated topic as possible:

_____
_____

Graduate Advisory Committee:

By signing below I agree that the courses listed represent a specific program leading toward graduation.

Major Professor (Print Name & Dept)	**Signature**	**Date**
Graduate Division Representative (Print Name & Dept)	**Signature**	**Date**
Committee Member (Print Name & Dept)	**Signature**	**Date**
Committee Member (Print Name & Dept)	**Signature**	**Date**
Committee Member (Print Name & Dept)	**Signature**	**Date**
Committee Member (Print Name & Dept)	**Signature**	**Date**
Committee Member (Print Name & Dept)	**Signature**	**Date**
Program Coordinator (Print Name & Dept)	**Signature**	**Date**

I certify that the courses listed represent a specific program leading toward graduation. I understand that the course list can be changed at a later date with the approval of my Graduate Advisory Committee.

Submitted for approval by: _____ _____
Signature of Student **Date**

Dean of Graduate Education: _____ _____
Signature of Dean **Date**

(Note: See graduate education website for most recent approved forms: http://www.sdsmt.edu/Academics/Graduate-Education/Grad-Ed-Forms/.)

APPENDIX A

Coursework Schedule

International students not exempted from the Graduate English Proficiency Program must include English 390 in the coursework schedule.

Courses transferring from another program at SDSMT or from another institution must be identified as such with an asterik (*) in front of the course name. Courses transferring from another institution require attachment of transcript copy evidence. Courses transferring from an institution outside the United States must also include a course description from the transferring university.

Required courses include only those course credits which apply toward degree requirement, including 300-400 level courses approved by petition or on waiver by the Graduate Education and Research Committee. Courses not required and not previously approved on waiver should be listed as Others.

All courses should be listed by semester date, in the order of planned completion. (Sem/Yr example Fall 2020, Spring 2021, etc.) (Under Course Name spell out course title completely.)

		Number of Credit Hours		
Sem/Yr	**Course name and number**	**Required Courses**	**Research**	**Others**

(Note: See graduate education website for most recent approved forms: http://www.sdsmt.edu/Academics/Graduate-Education/Grad-Ed-Forms/.)

APPENDIX B:

RECOMMENDED OUTLINE FOR THE WRITTEN PORTION OF THE RESEARCH PROPOSAL

1. Cover page
2. Summary (one page) including:
   - research objectives
   - significance of the proposed research
   - student's original contributions
3. Literature survey (maximum 3 pages), including:
   - the general literature in the field
   - specific literature on the proposed topic
4. Proposed research program (~8 pages, not including figures), including:
   - research objectives
   - expected significance
   - broad design of experiments and/or modeling to be undertaken
   - description of proposed experimental and/or numerical methods
   - relation of the proposed program to the goals of the research cited in the literature survey
5. Extension of the research to future work
6. A clear and concise statement of the student's original contributions
   – schedule for completion of research
7. Nomenclature
8. References
9. Appendices

   A. Copy of the reference most pertinent to the proposed research program
   B. Other relevant materials.

APPENDIX C:

FACULTY AND RESEARCH INTERESTS

Dr. S. Phil Ahrenkiel, Professor Nanoscience and Nanoengineering, PhD University of Colorado Boulder, high resoltution TEM microscopy and diffraction methods, energy and nano materials.

Dr. Robert B. Anderson, Assistant Professor Nanoscience and Nanoengineering, PhD South Dakota School of Mines and Technology; Photonics, optics, super-resolution imaging, computational methods.

Dr. Hao Fong, Professor of Chemistry, PhD University of Akron, Nano-scaled polymer, ceramic and carbon/graphite fibers and their applications.

Dr. Haiping Hong, Research Scientist IV, PhD Hebrew University, Jerusalem, Carbon based Nano-materials, Nano-composites, Nano-fluids, Nano-grease.

Dr. David Salem, Professor of Chemical and Biological Engineering / Materials and Metallurgical Engineering / Nanoscience and Nanoenginering, Director Composites and Polymer Engineering Laboratory; PhD University of Manchester; Polymer Nano-composties and Polymer Physics.

Dr. Steve Smith, Professor Nanoscience and Nanoengineering; PhD University of Michigan, Ann Arbor; Energy and time-resolved nanoscale optical spectroscopy, superresolution bio-imaging, nanophotonics, electronic and photonic properties of nano- and energy-materials.

Dr. Congzhou Wang, Assistant Professor Nanoscience and Nanoengineering; PhD Virginia Commonwealth University; Nano-biotechnology, nano-biomechanics, nanosensors, metal-organic framework (MOF) chemistry and applications.

Dr. Scott Wood, Assistant Professor Nanoscience and Nanoengineering; PhD Clemson University; Bio-Engineering, Nano-Bio-Mechanics of chondrocytes, Mechano-biology.

Dr. Zhengtao Zhu, Associate Professor of Chemistry, PhD SUNY Binghamton, Organic-inorganic nano-composites, Nano imprinting and lithography.

APPENDIX D:

Elective courses:

NANO 401 Introduction to Nanoscience	3
NANO 475/575 Advanced Processing/Nanoengineering of Polymeric Materials	2
NANO 404/504 Nanophotonics	3
NANO 604 Nanophotonic Materials	3
NANO 704 Crystallography and Structure of Nanomaterials	3
NANO 705 Nanoelectronics	3
NANO 706 Nano-Biotechnology	3
NANO 707 Nanocomposites	3
NANO 708 Nanomaterials for Photovoltaics	3
NANO 709 Scientific Instrumentation, control and Visualization	3
NANO 710 Optical Nanoscopy	3
NANO 711 Scientific Instrumentation, control and Visualization II	3
NANO 712 Electromagnetic Properties of Heterogeneous Materials	3
NANO 713 Nano-Biotechnology II	3
NANO 714 Fluorescence Spectroscopy	3
NANO 715 Polymeric Nanomaterials	3
NANO 717 Nanochemistry	3
NANO 718 Nanomechanics	3
NANO 719 Nanomaterials for Biosensors	3
NANO 720 Contemporary Condensed Matter Physics	3
NANO 722 Nano-biomaterials‡	3
NANO 791 Independent study	1 to 3
NANO 792 Topics	1 to 3
NANO 721 Adv. Electricity and Magnetism	3
NANO 743 Statistical Mechanics	3
NANO 777 Quantum Mechanics I	3
NANO 779 Quantum Mechanics II	3

New Course Descriptions (‡not yet in catalog):

NANO 706 Nano-Biotechnology: Foundational course reviewing basics of prokaryote and eukaryote cellular architecture, metabolism and function, and relevant interventions and assays based on nanotechnology. Basic cell culture, select recombinant DNA technology and methods are covered.

NANO 707 Nanocomposites: Advanced concepts relating to the design and analysis of nanocomposite materials. Structure formation at multiple length scales applied to the engineering and processing of composites, including polymer nanocomposites, nanofibers and hierarchical composite structures.

NANO 710 Optical Nanoscopy: Principles of modern optical microscopy with emphasis on state-of-the-art methods, including: confocal, total internal reflection microscopy, superresolution single molecule imaging based on localization, multiphoton microscopy and light sheet volumetric imaging methods.

NANO 711 Scientific Instrumentation, control and Visualization II: Advanced topics in the instrumentation and control of scientific experiments and visualization of the resulting data. Emphasis is placed on the use of modern software such as LabView, Matlab and others of recent interest.

NANO 713 Nano-Biotechnology II: Advanced methods in cellular and genetic manipulation, especially those involving nanotechnology. Gene editing, CRISPR/Cas9 system and applications, select topics in immunology and drug delivery, DNA based nanotechnology (e.g. DNA origami).

NANO 714 Fluorescence Spectroscopy: Basic principals of light absorption and emission from atomic, molecular and condensed matter. Quantum treatment of light matter interaction, practical methods to measure and analyze optical spectra and interpretation in terms of atomic, molecular and nanostructure.

NANO 718 Nanomechanics: Static and dynamic mechanical properties of nano-systems. Analytical methods, normal modes, dispersion and propagation of vibrational waves modified due to nanostructure. Micro/Nano-Electromechanical Machines (MEMS/NEMS), analysis, properties and applications.

NANO 722 Nano-Biomaterials: Course covers the processing, characterization, modeling, and biomedical applications of nanostructured metals, natural/synthetic polymers, composites, macromolecules and surfaces. Emphases will be on biofunctionalizations of nanostructured particles and surfaces, interactions of nanomaterials with biological systems, and toxicity of nanomaterials.

Nano-electronic and photonic materials:			
504	nanophotonics	15 credits	Common
714	fluorescence spectroscopy		
709	computer and visualization		
717	nano-chemistry		
718	nano-Mechanics		
705	nanoelectronics	3 credits	Keystone
704	crystallography	9 credits	Electives
708	photovoltaics		
604	nanophotonic materials		
Nano-biotechnology and nano-imaging:			
504	nanophotonics	15 credits	Common
714	fluorescence spectroscopy		
709	computer and visualization		
717	nano-chemistry		
718	nano-mechanics		
706	nano-bio technology	3 credits	Keystone
710	optical nano-scopy	9 credits	Electives
713	nano-bio technology II		
719	Nanomaterials for Biosensors		
Nano-composites and applications:			
504	nanophotonics	15 credits	Common
714	fluorescence spectroscopy		
709	computer and visualization		
717	nano-chemistry		
718	nano-mechanics		
575	polymer composites	3 credits	Keystone
704	nanocrystallography	9 credits	Electives
712	electromagnetic composites		
715	nano-polymers		
Nano core courses:			
701	nano-materials	13 credits	Core
702	theory and application of nanomaterials		
703	characterization of nanomaterials		
890	nano seminar		
898	nano research	40 credits	

Nano curriculum thematic tracks

Table I: Nano Curriculum showing three thematic tracks, common and core courses and research credits.

APPENDIX E:

SAMPLE CURRICULUM AND PROJECTED COURSE OFFERINGS

Course Offerings Schedule:

FA 17	SP 18	FA 18	SP 19	FA 19	SP 20	FA 20	SP 21	FA 21
Nano 702	Nano 504	Nano 703	Nano 604	Nano 702	Nano 504	Nano 703	Nano 604	Nano 702
Nano 703	Nano 701	Nano 705	Nano 701	Nano 703	Nano 701	Nano 705	Nano 701	Nano 703
elective	Nano 708	Nano 706	Nano 704	Nano 712	Nano 708	Nano 706	Nano 704	Nano 712
Nano 717	Nano 709	Nano 707	Nano 710	Nano 713	Nano 709	Nano 707	Nano 710	Nano 713
elective	Nano 719	Nano 711	Nano 718	Nano 717	Nano 719	Nano 711	Nano 718	Nano 717
	elective	Nano 714	elective	elective	elective	Nano 714	elective	elective
	Nano 890	Nano 715	Nano 890		Nano 890	Nano 715	Nano 890	

Example Curricula:

student entering program with MS (research intensive):

										Credits:
	Nano 702 (3)	Nano 701 (3)	elective (3)							
	Nano 703 (4)	elective (3)								16
seminar		Nano 890 (1)		Nano 890 (1)		Nano 890 (1)				3
research	Nano 898 (2)	Nano 898 (5)	Nano 898 (9)	Nano 898 (8)	Nano 898 (9)	Nano 898 (8)				40
transfer										21
	9	9	9	9	9	9				80

student entering program with MS (coursework intensive):

										Credits:
	Nano 702 (3)	Nano 701 (3)	elective (3)	elective (3)	elective (3)	elective (2)				
	Nano 703 (4)	elective (3)								24
seminar		Nano 890 (1)		Nano 890 (1)		Nano 890 (1)				3
research	Nano 898 (2)	Nano 898 (2)	Nano 898 (6)	Nano 898 (5)	Nano 898 (6)	Nano 898 (6)	Nano 898 (3)			30
transfer										23
	9	9	9	9	9	9	3			80

student entering program at the BS level (research intensive):

										Credits:
	Nano 702 (3)	Nano 701 (3)	elective (3)	elective (3)	elective (3)	elective (3)				
	Nano 703 (4)	elective (3)	elective (3)	elective (3)	elective (3)	elective (3)				37
seminar		Nano 890 (1)		Nano 890 (1)		Nano 890 (1)				3
research	Nano 898 (2)	Nano 898 (2)	Nano 898 (2)	Nano 898 (1)	Nano 898 (3)	Nano 898 (5)	Nano 898 (9)	Nano 898 (9)	Nano 898 (7)	40
transfer										0
	9	9	9	9	9	9	9	9	7	80

Proposed MS[‡]:

						Credits:
	Nano 702 (3)	Nano 701 (3)	Nano 714 (3)	Nano 718 (3)	elective (3)	28
	Nano 703 (4)	Nano 709 (3)	elective (3)	elective (3)		
seminar		Nano 890 (1)		Nano 890 (1)		2
research	Nano 898 (2)	Nano 898 (2)	Nano 898 (3)	Nano 898 (2)		2
	9	9	9	9	4	32

APPENDIX F:

Student Assessment:

Assessment of student progress is a continual process throughout the PhD, the foremost responsibility rests with the faculty advisor, PhD committee and *the students themselves*. By working together, the student, advisor and committee can inform research decisions, build and confirm relevant skills and competencies in the student, and ensure meaningful contributions to the students' area of specialization. Students learn to frame, plan, execute and analyze nanoscience and nanoengineering research by regular consultation, primarily with their advisor, and secondarily with other committee members or outside experts as determined by ongoing evaluation of research. Short term and long term goals are framed, and continually assessed and adjusted as the PhD research program evolves.

A program of study is designed to complement the student's proposed research area, in consultation with the faculty advisor, preferably in the first semester. Adjustments are made as needed within the first two to three years of the program. A written exam covering key concepts covered in the core curriculum is administered no later than the end of the students second year, to assess the demonstration of advanced knowledge covered in the core curriculum. On or before spring semester of the third year, students prepare a written research proposal and defend this to their PhD committee. At that time, the committee will assess the students' knowledge of the relevant literature, as demonstrated in the research proposal and during the proposal defense. The committee will assess the level of specialized knowledge based on the contents of the proposal, which should include preliminary work and likely publication(s) documenting this, or minimally concrete evidence that such publications are forthcoming. Any deviation from these schedules must be approved by the Nano PhD Program Advisory Committee (Nano AC), as outlined in the Nano PhD Program Handbook.

Student participation in professional meetings and campus research symposia will provide an assessment as to the level and quality of the students' research, and are encouraged. Participation in the Nano PhD program Nano Expo is required by all students in the program. This allows the students to develop oral and written communication skills, and is assessed by groups of at least two Faculty and one student judge. The PhD dissertation and defense will assess the level of the students' original contribution, as measured by products including the dissertation and mandatory peer-reviewed publications, per the program publication requirement. The publications, required oral presentations and proposal will also document the students' abilities and accomplishments in utilizing contemporary tools, methods and theory to evaluate the results of their research.

The Ph.D. proposal and proposal defense, and later the PhD dissertation and defense, are evaluated to ensure they address contemporary challenges in nanoscience and nanoengineering or a closely aligned field, and that the student demonstrates cognizance and understanding of the relevant scientific and technical literature. Further, these document that the student has demonstrated significant accomplishments in the relevant methods, tools, and theory pertaining to their chosen research topic, and have attained the appropriate level in written and oral communication to clearly convey their findings. The PhD advisor and committee are charged with assessing the impact of the student's work on the field, and ensuring the student exhibits high professional ethics.

External peer review of student research, based on conference participation (preferably peer-reviewed) and peer-reviewed journal publications are quantifiable metrics which assess student progress during the course of the PhD program, and can be tied to program outcomes. Table one shows the measures by which progress on the program outcomes can be assessed, and their corresponding metrics for success. In addition to the student and advisor paying careful attention to the steady progress towards meeting these metrics, the Nano PhD program administration also tracks these metrics. The Nano AC, which meets monthly, will assess each students progress on a semester basis in order to ensure timely completion of the degree.

APPENDIX F:

OUTCOMES	MEASURES	METRICS
(1) Students demonstrate advanced knowledge of the physics, chemistry and engineering at the nano-scale	Qualifying Exam.	70% overall minimum.
	Cumulative GPA.	Equal or exceed 3.0.
	Publications.	2 Peer-reviewed articles.
(2) Students demonstrate specific knowledge as pertaining to their area of specialization.	Dissertation.	Successfully defended.
	Presentations.	3 seminars minimum.
	Publications.	2 Peer-reviewed articles.
(3) Students will utilize contemporary methods, tools, and theory to perform research in their area of specialization.	Research credits.	Pass/Fail.
	Dissertation.	Successfully defended.
	Publications.	2 Peer-reviewed articles.
(4) Students are cognizant of the scientific literature in their area of specialization, and understand contemporary issues and frontiers.	Presentations.	3 seminars minimum.
	Research proposal.	Successfully defended.
	Dissertation.	Successfully defended.
	Publications.	2 Peer-reviewed articles.
(5) Students will develop a technically sound research plan to address a research problem.	Research proposal.	Successfully defended.
	Dissertation.	Successfully defended.
	Experimental plans.	Approved by advisor.
(6) Students will communicate effectively in written and oral presentations.	Presentations.	3 seminars minimum.
	Research proposal.	Successfully defended.
	Dissertation.	Successfully defended.
(7) Students demonstrate intellectual honesty when working with data and ideas.	Research proposal.	Successfully defended.
	Publications.	2 Peer-reviewed articles.
	Dissertation.	Successfully defended.
(8) Students have made an original contribution to nanoscience or nanoengineering.	Presentations.	3 seminars minimum.
	Publications.	2 Peer-reviewed articles.
	Dissertation.	Successfully defended.

Table 1: Program Outcomes, measures and metrics for assessment of student achievement.

Program and Curriculum Assessment:

The Nano AC will also review curriculum annually, in light of contemporary developments in the fields of nanoscience and nanoengineering, and ensure curriculum is updated accordingly. The following elements for continuous improvement are implemented:

i. Each course syllabi, agenda, and lecture materials will be examined and discussed in committee.

ii. Grade distributions and student surveys will be evaluated to identify any areas which may need improvement.

iii. A self-assessment will be maintained by the Nano AC, in preparation for external reviews, to be completed on a time schedule set by University and SDBOR policy (currently seven years).

iv. A three-year self-study will be completed by the Nano AC, in preparation for the external review on the seventh year.

The above elements, including both internal and external reviews, are a mechanism for continuous improvement, ensuring relevant curriculum and optimal training of Nanoscience and Nanoengineering PhD students.