GRADUATE STUDIES IN ENVIRONMENTAL SCIENCE

Vanderbilt University's Environmental Science option within the Environmental Engineering program of the Department of Civil and Environmental Engineering is administered jointly by the Departments of Civil and Environmental Engineering (School of Engineering) and Earth and Environmental Sciences (College of Arts and Science). Students may pursue work leading to the M.S. and Ph.D. degrees. The option's focus is centered on:

- earth surface and subsurface system dynamics involving the intersection of engineering and geological timescales;
- natural and human-induced environmental hazards and risk assessment; and
- management and restoration of environmental systems involving coupled physical, chemical and biological elements.

These represent important core areas of engineering and earth and environmental sciences research that intersect current, critical national research priorities.

1. Elements

1.1 Expected Knowledge and Skill Areas

To acquire a solid foundation for pursuing work in the areas of excellence above, students choose courses from four knowledge and skill areas that serve as the foundation for study:

- **materials** — the physicochemical nature of solid and fluid earth materials;
- **processes** — physical, chemical and biological processes affecting the transport and fate of materials in environmental systems;
- **systems** — the dynamics of environmental systems wherein processes are coupled over a wide range of spatial and temporal scales; and
- **quantitative foundations** — understanding and modeling uncertainty in environmental systems, notably as this pertains to science and engineering applications.

Focus on these key areas will allow students to be competitive in the academic and professional marketplace on completion of their studies, and provide them with flexibility to respond to current and future high-priority environmental research needs. We describe below (Section 2.3) the process of designing individual student programs of study consistent with these knowledge and skill areas.

1.2 Degrees and Degree Requirements

The degree tracks and associated requirements in the Environmental Science option are:

- M.S. with thesis — 24 credit hours of coursework and acceptance of a written thesis.
- M.S. without thesis — 30 credit hours of coursework (not an option).
- Ph.D. — a minimum of 36 credit hours of coursework, passage of the comprehensive examination, passage of the Ph.D. qualifying examination, and acceptance and defense of
a written dissertation; 72 total credit hours are required, including coursework, transfer credit (when appropriate) and dissertation research.

In addition,

- students will have flexibility in choosing courses from a menu of courses provided to them. An Academic Advisory Committee will work with the students to ensure a balanced program (Section 2.2). See Section 2.3 below for additional recommendations concerning direction and oversight.
- Directed Study research credit hours (up to 3 credit hours for MS degrees, 6 credit hours for Ph.D. degrees) may be included to meet the appropriate required total(s).
- students with a Masters degree from Vanderbilt will typically be allowed to count Vanderbilt graduate credit hours toward the required total(s) subject to the approval of their Academic Advisory Committees. Students entering with a Masters degree from another institution will need to complete a minimum of 24 course credit hours at Vanderbilt.

2. Program Management

2.1 Program Advisory Committee

Day-to-day management of the Environmental Science study option is shared between CEE and EES under the joint leadership of the Director of Graduate Studies for the Environmental Engineering Program in CEE and the Director of Graduate Studies in EES. Oversight of the Environmental Science study option is provided by a Program Advisory Committee composed of the two Directors of Graduate Studies and two members-at-large, one each from CEE and EES appointed for two-year terms by the respective Chairs of these departments. The Chairs of CEE and EES serve as ex-officio members of the Program Advisory Committee.

The responsibilities of the Program Advisory Committee are to: (i) annually review the management, operation and health of the Environmental Science study option, including recruiting efforts, student admission standards and student retention; (ii) review Comprehensive Examination standards and procedures (Section 2.6) and the assignment of courses in the Expected Knowledge and Skill Areas (Sections 2.3 and 2.4); (iii) provide leadership in selecting and developing the focus of the annual Capstone Course (Section 2.5); and (iv) review actions of all Academic Advisory Committees (Section 2.2) and, if necessary, resolve any problems or disagreements concerning these actions. The Director of Graduate Studies in CEE is responsible for convening and chairing the Program Advisory Committee.

2.2 Selection of Academic Advisory Committee and Research Advisor

Each student’s Academic Advisory Committee, chaired by the student’s Research Advisor, is composed of members of the Graduate Faculty, two from CEE and two from EES, appointed by the Directors of Graduate Studies of these departments in consultation with the Chairs and the student. The two Directors of Graduate Studies may serve as ex-officio members of Academic Advisory Committees on which they are not primary members. In addition, the Directors of Graduate Studies provide initial academic guidance to incoming students prior to the selection of their individual Academic Advisory Committees.

The Research Advisor and Academic Advisory Committee for each student are selected no later than the middle of the second semester of study. Some students will identify faculty
members with whom they wish to work prior to initial enrollment, but this arrangement must be agreed to by the faculty members and approved by the Chairs of CEE and EES. Otherwise, students will be encouraged to discuss research opportunities with program faculty during their first semester of study, then propose possible research topics, Advisors, and potential members for the Academic Advisory Committee, to the Directors of Graduate Studies.

Appointment of the Research Advisor and Academic Advisory Committee will then occur as described in the first paragraph above. In each case, the preference of the student and potential faculty Research Advisor are key considerations. The Research Advisor serves as the primary faculty mentor and advocate for the student, and is expected to work with the student to obtain financial support, provided that the student maintains satisfactory progress.

### 2.3 Selection of Coursework for Individual Students and Periodic Review

The Academic Advisory Committee, in consultation with the student, is responsible for designing a program of study, including selection of specific required coursework, for the student. Course selection is based on: (i) the student’s background, including coursework completed; (ii) the student’s intended area of research; and (iii) the need to ensure that the student has a program of study that is consistent with the Expected Knowledge and Skill Areas (Section 1.1) and the Degree Requirements (Section 1.2). Specifically, students are advised to complete:

- at least two courses in each of the Areas 1 and 2 and one course in each of the Areas 3 and 4, with no double counting of courses assigned to more than one Area (denoted by an asterisk; see Appendix);
- the Preparation for Research in Environmental Science course (Section 2.5) in the fall semester of the student’s first year (in addition to the requirements stated above);
- the Capstone Course in the second year (in addition to the requirements stated above); and
- at least two courses from CEE and two from EES.

New students will meet with the two Directors of Graduate Studies to choose courses before the beginning of their first semester. Graduate students are required to meet with the two Directors of Graduate Studies and their advisor every semester during the course registration period to choose courses for the next semester and to review progress towards degree completion. Students must bring updated copies of their Academic Progress Report to each meeting, and send electronic copies to both Directors of Graduate Studies so they can be forwarded to the faculty. Once these tasks are completed, each student will receive a code that will allow them to register for the next semester. Students must register every fall, spring and summer until they graduate. If they have reached the requirement of 72 credit hours then they must register for 0 credit hours of Ph.D. Dissertation Research (ENVE 399).

### 2.4 Selection of Currently Available Courses

A list of currently available courses assigned to the four Expected Knowledge and Skill Areas (Section 1.1) is included as an Appendix. The assignment of courses in this list will be reviewed annually by the Program Advisory Committee (Section 2.1) as the content and emphasis of individual courses naturally evolve, and as the two departments work together to minimize redundancies in existing course offerings and develop new courses that meet the overall programmatic needs.

Courses with numbers of 250-300 are normally assumed to be acceptable as graduate-level courses, with expectations of enrolled graduate students that are beyond those for enrolled undergraduates. Nonetheless, in order to accommodate students with diverse backgrounds
whose training is limited in certain (undergraduate) background material, we can envision that select 200-249 courses could be appropriate as graduate-level courses for certain students in the Environmental Science option. For example, CEE 203 (Fluid Mechanics) could be appropriate as a graduate-level course for students with undergraduate backgrounds in Earth science pursuing graduate research related to transport phenomena in environmental or Earth-crustal systems. Similarly, EES 230 (Sedimentology) could be appropriate as a graduate-level course for students with undergraduate backgrounds in engineering pursuing graduate research related to the transport and fate of contaminants in riverine and estuarine systems. Similar remarks pertain to courses in Mathematics. Select courses at the 200-249 level are therefore also listed (Appendix). Any 200-249 level course that is approved for a student’s program of study under these conditions must involve an arrangement with the instructor wherein the student undertakes and completes significant ancillary work at the graduate level.

It is anticipated that EES and CEE will examine cross-listing of appropriate courses at the advanced undergraduate-graduate levels. We also anticipate that appropriate advanced courses will be added to this list.

### 2.5 Capstone Course and Preparation for Research in Environmental Science

Two courses are required for Ph.D. students. First, a capstone course serves as the signature of the Environmental Science program. All Ph.D. and interested M.S. students who have completed one year of course work enroll in this course. The course focusses on a highly interdisciplinary, highly visible environmental issue of global significance that is embodied in a type case about which our faculty are knowledgeable and have active or potential research interests. It entails a field trip to the type-case site by participating graduate students and faculty and include extensive interactions with experts representing different backgrounds and viewpoints. The course focus will change biannually; for spring 2007 and 2008 it focuses on the proposed High Level Nuclear Waste repository at Yucca Mt., Nevada.

The second course, Preparation for Research in Environmental Science, is attended by students and faculty participating in the Environmental Science program, but is open to all interested individuals. The course focuses on two items: (i) presentation and discussion of current research projects of participating students and faculty, as a mechanism for familiarizing participants with ongoing research and related literature; and (ii) developing skills for preparing winning grant proposals, in general, and in areas of existing research, specifically. Students conduct background research in their areas of interest and present oral and written versions of their grant proposals for critical review.

### 2.6 Comprehensive Examination

Students are required to take the comprehensive examination after completion of no more than four semesters of study. The Academic Advisory Committee, with input and participation from the program faculty, is responsible for developing and administering the comprehensive examination for students pursuing the Environmental Science study option. The comprehensive examination follows the same structure and format as the comprehensive examination for Environmental Engineering, but is tailored to flexibly address the expected qualifications and coursework expected of students pursuing a course of study focused on Environmental Science. The exam will be administered by the Director of Graduate Studies of the department in which the student is matriculated. The DGS will choose two Professors from EES and two Professors from ENVE from whom the student has taken courses to create and grade the exam.
2.6.1 Goals

The goals of the comprehensive exams are for prospective doctoral students to demonstrate basic competency and for faculty to assess student capabilities in areas critical for future professional performance. Students are expected to demonstrate their

1. basic level of competency in fundamentals relevant to specified degree program;
2. ability to carry out research by (i) seeking out new information related to open ended questions, (ii) critically evaluating work by others, (iii) developing and presenting logical arguments and responses to technical questions, (iv) providing creative approaches to problem solving; and,
3. basic fluency in professional written and oral communications skills (in English).

In addition, faculty use the comprehensive exams to assess the student’s

1. depth of knowledge in relevant subject areas;
2. needs for additional education in critical subject areas; and,
3. needs for further improvement in professional written and oral communications skills (in English).

2.6.2 Approach

The comprehensive exam will be a three part exam as follows:

1. Environmental Science Fundamentals – 5 hours (with an additional 0.5 hour break), open book, no computers, given on the first day (Monday) from 8:30 am - 2:00 pm. All problems are to be answered.

   The content of this part will be based on the student’s course work and interests. Topics will be selected by the student’s committee and will be disclosed to the student in advance of the exam

2. Integrated Problems – 4 hours, open book, no computers, given on the second day (Tuesday) from 8:30 am –12:30 pm. Students must answer problem sets written by two faculty members; usually there will be three or four sets to choose from.

3. A critical review of a designated manuscript from the peer reviewed literature. Each student will be assigned one paper to review, through a random selection process from papers provided by the faculty. The analysis should focus on the technical quality of the paper, specifically technical accuracy and the technical merits of the work that is being described. The student will prepare a typed two (2) page written critique of the paper, including discussion of related citations. On the last day (Friday) each student will be required to submit the written analysis and to give a ten (10) minute PowerPoint presentation of their critique (paper copies of the presentation should be provided to the attending faculty) followed by questions from the faculty. A minimum of three (3) faculty members will attend the presentations.
2.6.3 Exam Preparation and Grading

1. Exams will be graded and students will be informed of the results within two weeks from completion of the exam.
2. Part 1 of the exam will be prepared by three faculty members in each area, with input solicited from other faculty. Faculty will work together to develop the integrated problems for Part 2 of the exam and will submit recommended papers for review in Part 3 of the exam.
3. Grading of Part 1 of the exam will be by the three faculty members responsible for developing the exam. Grading of Part 2 will be by the faculty member that provided the question that was answered. Grading of Part 3 will be by those faculty members who attended the presentation.

2.6.4 Policy

It is the policy of the graduate faculty of EES and ENVE to provide students one opportunity to sit for, and pass the comprehensive exam in Environmental Engineering. Following completion of the exam, a performance review of each student’s record is conducted by the student’s Academic Advisory Committee. Based on the student's performance, the committee will select one of four recommended courses of action:

(1) Award the student a "pass";
(2) Award the student a "conditional pass" and require the completion of additional coursework and/or meeting of specified performance objectives within a specified period of time;
(3) Provide the student with a second opportunity to sit for the exam (in whole or in part). Note that the opportunity to sit for the exam a second time will only be provided if warranted by sufficiently satisfactory performance to date. In no case may a student sit for the exam more than two times; and
(4) Terminate the opportunity for the student to pursue the Ph.D. degree in Environmental Engineering at Vanderbilt University. This will be accompanied by termination of financial aid at completion of the current semester and recommendation of completion of graduate studies in environmental engineering through the completion of the Master's degree (thesis or non-thesis option as recommended by the committee).

The following factors are important considerations in the committee’s decision:

(1) The performance of the student on the exam;
(2) The progress the student has made with respect to other degree requirements, especially research;
(3) An evaluation of the student's potential success in pursuing the Ph.D.; and
(4) The professional performance and conduct of the student

Following release of the committee’s recommended course of action, students may request to review their exam by arranging an appointment with the Director of Graduate Studies in their home department.
2.6.5 Expectations and Grading

The comprehensive exam is a very important milestone in the progress of a Ph.D. candidate at Vanderbilt University. Successful completion of this exam is necessary to continue one's graduate studies toward the Ph.D. degree. Successful completion also provides documentation that the student has not only completed required coursework but also has the knowledge and understanding needed for environmental engineering fundamentals and can apply what has been learned. Finally, successful completion of the comprehensive exam enables the student to focus future work on research, publication, and thesis preparation and defense.

What we expect from you:

- We expect you to understand and appreciate the serious of the comprehensive exam and to prepare for it.
- We expect you to complete the exam in a professional way that reflects the significance of the exam.
- We expect you to state all of your assumptions explicitly and to provide definitions and units for all parameters used in developing the solution.
- We expect you to work the problems in a clear, logical stepwise manner and to show all of your work.
- We expect you to respond to the questions clearly and concisely.

A score of 80 (on a basis of 100) is necessary to pass a given Part of the exam. Scores between 80 and 65 will be evaluated on a case-by-case basis. A score below 65 for a particular part constitutes failure for that Part. Failure of any two (2) Parts constitutes failure of the exam.

2.7 Qualifying Examination

The purpose of the qualifying examination is to test the student’s knowledge of the field of specialization, to assess familiarity with the published research in the field, and to determine whether the student possesses those critical and analytic skills needed for a scholarly career.

The examination is conducted by a Ph.D. committee appointed by the Graduate School on advice of the chair or director of graduate studies of the program. The committee consists of not fewer than four members of the Graduate Faculty. If there is a minor, at least one member comes from the student’s minor area, and when the minor is taken within the department of the major, it is expected that a member of the committee will be from another department. If there is no minor, one member of the committee should be from outside the department. The committee must be appointed by the Graduate School no less than two weeks before the time the student expects to take the qualifying examination.

The functions of the Ph.D. committee are (a) to administer the qualifying examination, (b) to approve the dissertation subject, (c) to aid the student and monitor the progress of the dissertation, and (d) to read and approve the dissertation and administer the final oral examination.

The qualifying examination may be administered at any time during the school year and shall be completed within a period of four weeks, and it must be taken no later than the 6th semester after enrollment. Before a qualifying examination can be scheduled, the student must have completed at least 36 hours of graduate work and the language requirement, if any. In exceptional cases where the student has completed a substantial amount of undergraduate coursework at advanced levels, a department or program may petition the Graduate School to waive the
36-hour requirement. In some programs the student may be required to demonstrate basic competence in the discipline through a written preliminary examination prior to the actual qualifying examination.

All departments and other units offering Ph.D. programs must set a maximum time limit within which a student, under normal circumstances, is required to take the qualifying examination. That maximum time limit must not exceed eight semesters (preferably fewer) during which the student is registered, starting with his or her first enrollment as a Ph.D. student.

For the qualifying examination the student must prepare a thesis proposal of approximately twenty pages, to be distributed to the Ph.D. committee no less than one week before the exam. The Graduate School must be notified of the time and place of the qualifying examination at least two weeks in advance. During the exam the student will give a presentation to the Ph.D. committee 20-30 minutes in duration followed by a question and answer session. A student is allowed only two opportunities to pass the qualifying examination. The qualifying examination results form, signed by the committee members and the director of graduate studies for the program, shall be forwarded to the Graduate School immediately after the examination.

When the student has passed the qualifying examination, the Ph.D. committee shall recommend to the Graduate School that the student be admitted to candidacy for the degree.

2.8 Dissertation

A candidate for the Ph.D. degree must present an acceptable dissertation within the major field of study. The dissertation demonstrates that the candidate has technical competence in the field and has done research of an independent character. It must add to or modify what was previously known, or present a significant interpretation of the subject based upon original investigation. The subject of the dissertation must be approved by the student’s faculty adviser and Ph.D. committee.

The dissertation must be completed within four years after a student has been admitted to candidacy for the degree. Upon petition to the Graduate School, a one-year extension of candidacy may be granted. If such a period has expired without successful completion of the dissertation, the student will be removed from the rolls of the Graduate School. Readmission to the Graduate School, and to candidacy, requires application to the Graduate School, with approval of the program faculty. In such cases the student may be required, by the Graduate School or by the Ph.D. committee, to demonstrate competence for readmission by taking a qualifying examination or additional course work.

The candidate submits two or more copies of the completed dissertation to the Ph.D. committee at least two weeks prior to the dissertation defense. The committee reviews the dissertation and conducts the final examination.

Two copies of the approved dissertation, with the original signatures of not less than a majority of the Ph.D. committee, and two copies of an abstract, of not more than three hundred fifty words, signed by the student’s adviser, must be turned in to the Graduate School no later than two weeks before the end of the term in which the student expects to receive the degree, except for the spring term. A candidate who expects to graduate in May must submit the dissertation to the Graduate School no later than April 3. Due dates are listed on the Graduate School Web site. Students who submit their dissertations electronically must convert their documents to a PDF file and must adhere to the same deadlines.

The graduate is required to publish the dissertation by microfilming. This service is handled by the Graduate School on the graduate’s behalf. After microfilming, both copies of the dissertation are bound and presented to the Jean and Alexander Heard Library.

Microfilming does not preclude publication by other methods, but microfilming is
tantamount to publication and a microfilmed dissertation, if not copyrighted, is in the public domain and may not subsequently be copyrighted in its original form. The Graduate School will obtain a copyright for students who wish to have their dissertation copyrighted. Microfilming, binding, and copyright fees must be paid at the time the dissertation is turned in to the Graduate School. The abstract is published in *Dissertation Abstracts*, which publicizes the completion of the dissertation and announces its availability on microfilm.

### 2.9 Final Examination

The candidate must pass his or her dissertation defense at least fourteen days before the end of the term in which the degree is to be conferred, or by April 1 for May graduation. The final oral examination is administered by the student’s Ph.D. committee and is on the dissertation and significant related material; the student is expected to demonstrate an understanding of the larger context in which the dissertation lies. The public is invited to attend the final examination, which is announced in advance in Vanderbilt’s electronic calendar and/or in the *Vanderbilt Register*.

The requirement for the final examination can be waived only on the written approval of the department, the Ph.D. committee, and the Graduate School.

The chair of the Ph.D. committee or the director of graduate studies of the program, after consultation with the candidate, shall notify the Graduate School in advance of the place and time of the examination and the title of the dissertation. This should be done no later than two weeks prior to the examination. The Graduate School then formally notifies the Ph.D. committee and submits the defense notice to Vanderbilt’s electronic calendar. The dissertation defense results form, signed by the committee members and the director of graduate studies for the program, should be forwarded immediately to the Graduate School.

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### 1. Elements

#### 1.1 Expected Knowledge and Skill Areas

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- **materials** — the physicochemical nature of solid and fluid earth materials;
- **processes** — physical, chemical and biological processes affecting the transport and fate of materials in environmental systems;
- **systems** — the dynamics of environmental systems wherein processes are coupled over a wide range of spatial and temporal scales; and
- **quantitative foundations** — understanding and modeling uncertainty in environmental systems, notably as this pertains to science and engineering applications.

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APPENDIX: COURSE DISTRIBUTION IN EXPECTED KNOWLEDGE AND SKILL AREAS

(* Courses assigned to more than one group - may not be double counted; Section 4.3)

Area 1: Materials — the physicochemical nature of solid and fluid Earth materials
(minimum 2 courses)

EES 225 Earth Materials
EES 226 Petrology
EES 230 Sedimentology
*EES 260 Geochemistry
*EES 285 Volcanic Processes
EES 320 Aqueous Geochemistry
EES 390 Structure, Composition, and Properties of Earth Materials
*EES 390 Equilibria & Transformations of Earth Materials
ENVE 271 Environmental Chemistry
*ENVE 273 Environmental Characterization and Analysis
ChemE 311a-311b Advanced Chemical Engineering Thermodynamics
CE 203 Fluid Mechanics

Area 2: Processes — physical, chemical, and biological processes affecting the fate and transport of materials in environmental systems (minimum 2 courses)

*EES 230 Sedimentology
EES 255 Transport Processes in Earth and Environmental Sciences
*EES 260 Geochemistry
EES 261 Geomorphology
*EES 285 Volcanic Processes
*EES 279 Problems in Sedimentology and Paleobiology
EES 335 Magmatic Processes and Construction of Earth’s Crust
*EES 390 Equilibria & Transformations of Earth Materials
EES 390 Earth Fluids
CE 276 Ground Water Hydrology
ENVE 262 Hydrology
ENVE 270 Environmental Thermodynamics, Kinetics, and Mass Transfer
ENVE 272 Biological Unit Processes
ChemE 230 Introductory Transport Phenomena
ChemE 312a Transport Phenomena I
ChemE 312b Transport Phenomena II
ChemE 317 Physiological Transport Phenomena
MechE 325a Advanced Fluid Dynamics I
MechE 325b Advanced Fluid Dynamics II
MechE 348 Convection Heat Transfer
EES 226 Petrology
EES 230 Sedimentology
EES 240 Structural Geology and Rock Mechanics
CE 203 Fluid Mechanics
CE 226 Introduction to Environmental Engineering
Area 3: Systems — the dynamics of environmental systems wherein materials and processes are coupled over a wide range of spatial and temporal scales (minimum 1 course)

EES 272 Early Earth Systems
*EES 279 Problems in Sedimentology and Paleobiology
EES 390 Source to Sink
EES 390 Marine Geosystems
EES 390 Paleoecological Methods
EES 390 Sustainability Science
ENVE 264 Environmental Assessments
ENVE 269 Radiological Aspects of Environmental Engineering
ENVE 275 Environmental Risk Management
ENVE 300 Water Quality Management
ENVE 312 Pollutant Transport in the Environment
EES 220 Life Through Time

Area 4: Quantitative foundations — understanding and modeling uncertainty in environmental systems, notably as this pertains to science and engineering applications (minimum 1 course)

EES 325 Environmental Applications of Geochemical Modeling
EES 390 Statistical Methods in Earth and Environmental Sciences
CE 290 Reliability and Risk Case Studies
CE 307 Finite Element Analysis
CE 310 Probabilistic Methods in Engineering Design
CE 313 Advanced Reliability Methods
CE 259 Geographic Information Systems
BSCI 270: Statistical Methods in Biology
Anth 280 Intro. to GIS and Remote Sensing
ChemE 310a Applied Mathematics in Chemical Engineering I
ChemE 310b Applied Mathematics in Chemical Engineering II
*ENVE 273 Environmental Characterization and Analysis
MechE 275 Introduction to Finite Element Analysis
MechE 343 High-Performance Computing for Engineers
MATH 204 Linear Algebra
MATH 208 Ordinary Differential Equations
MATH 216 Probability and Statistics for Engineering
MATH 218 Introduction to Mathematical Statistics
MATH 218L Statistics Laboratory
MATH 219 Introduction to Applied Statistics
MATH 247 Probability
MATH 248 Mathematical Statistics
MATH 226 Introduction to Numerical Mathematics
MATH 229 Advanced Engineering Mathematics