

YALE UNIVERSITY
School of Engineering & Applied Science



Qualification Procedure for the
Ph.D. Degree in
Engineering & Applied Science

Majors:

Biomedical Engineering
Chemical & Environmental Engineering
Electrical and Computer Engineering
Mechanical Engineering & Materials Science

Revised, July 2024

YALE UNIVERSITY
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Qualification Procedure

Contents

Introduction	i
Preface	1
Part I	
General Requirements	2
Summary of Requirements to Remain in Good Standing	11
Flowcharts	12
Part II	
Department & Track Requirements	17
Biomedical Engineering	18
Chemical & Environmental Engineering	19
Chemical Engineering Track	19
Environmental Engineering Track	20
Electrical and Computer Engineering	21
Mechanical Engineering & Materials Science	22
Integrated Graduate Program in Physical and Engineering Biology	23
Quantum Materials Science and Engineering	24

Dear Graduate Student in the School of Engineering & Applied Science,

Welcome to Yale University, the School of Engineering & Applied Science and the Graduate School. You have completed a rigorous application process and now begin a journey of learning and exploration leading to the Ph.D. degree in Engineering & Applied Science.

We have prepared this Qualification Procedure document for your journey, as there are critical milestones and requirements to be met. This document has two parts. The first is general SEAS and Graduate School processes and procedures. The second is department or track specific information. We urge you to read this document carefully, paying attention to the various requirements and deadlines. The responsibility of meeting these requirements in a timely fashion is ultimately yours. SEAS forms that are to be used at critical milestones can be accessed at <https://seas.yale.edu/graduate-study/forms-and-guides>.

Many people are here to assist you in your journey, including the Departmental Directors of Graduate Studies and the Graduate Registrars. Please feel free to contact us at any time.

Degree requirements for students enrolled in Computer Science are listed in a separate handbook which can be accessed at <http://cpsc.yale.edu/academics/graduate-program>. Degree requirements for students enrolled in Applied Physics can be accessed at <https://appliedphysics.yale.edu/academics/graduate-studies>.

Best of luck with your studies.

Sincerely,

Vincent Wilczynski
Deputy Dean
School of Engineering & Applied Science
July 2024

Preface

A Ph.D. in engineering at Yale is designed to certify two distinct educational attainments: mastery of the subject matter in a particular field of study and the demonstrated ability to make original research contributions to the field.

Graduate students pursuing this degree are required to follow School of Engineering & Applied Science (SEAS) and Graduate School procedures. Some of these procedures are in this booklet and others are in the “Policies and Regulations” of the *Bulletin of the Graduate School of Arts and Sciences* ([A Message from the Dean < Yale University](#)).

The SEAS Qualification Procedure consists of two categories:

Part One: Academic

The faculty will assess the student’s ability to meet the established coursework requirements at the appropriate level and in a reasonable time. This assessment will be carried out in several steps, as described in this document, and is typically completed by the end of the student’s third term at Yale and no later than the end of the fourth term.

Part Two: Research

The student will be required to achieve mastery of the chosen subject area and to perform original research. This part will constitute a vigorous learning experience.

During Part Two, the student is expected to demonstrate the appropriate mastery of his/her subject. When such a stage is reached, the student will be certified as eligible for an M.Phil. degree. The remaining requirements for a Ph.D. will be the preparation and defense of a dissertation.

The Qualification Procedure defines minimum standards in the program of study that students are expected to meet. It will also help students to organize their course of study. The two educational goals of “mastery of the subject” and “originality of research contributions” are relative concepts and can only be judged against the established traditions of the University and the School of Engineering & Applied Science. Thus, the final decision must rest with the School of Engineering & Applied Science.

A student is expected to be in good standing at all times. Central to good standing are academic status and research status. Academic status is based on the required coursework requirements, as described herein. Research status is demonstrated by progress in research activities and meeting research requirements, also as described herein. The latter includes satisfactory completion of two Special Investigations; a position in a funded laboratory for the third term; a Commitment (described below) by the end of the second semester, or, with approval, at the end of the first summer; and satisfactory progress each semester. A student not in good standing will be asked to leave the program. One term of probation may be permitted.

PROCEDURE

1. First-year Registration

Upon arrival, each student attends SEAS Orientation, obtains the latest information on course offerings and schedules, and the names of the three faculty members who have been nominated for his/her First-year Committee. This committee will assist the student in meeting the requirements (see Article 3). The student should confer with the faculty members on the committee and with the instructors of courses he/she is considering taking so as to arrive at a proposed course of study. Once the course of study is finalized, the student submits the online course selections so the departmental Director of Graduate Studies (DGS) can review and formally endorse them. This process is to be completed before the final date for the submission of course schedules to the Graduate School. Students are to use the Special Investigation Form, depending on departmental requirements, copies of which are available online.

2. Appointment of the First-year Committee

Each entering graduate student has been matched with at least one faculty member on the basis of research interest. That faculty member, acting as *provisional* advisor in the first year, will recommend to the DGS two additional faculty members to be appointed to the student's First-year Committee. The provisional advisor will chair that Committee. At any time during the first year, if a student feels that a different Committee would be desirable, its membership can be altered upon approval by the DGS. For all Committees (First-year, etc.), at least one member must be from the student's admitting department. Since the transcript will designate a department, the student's academics and research must be grounded in that field.

Each student has been admitted to one of the four SEAS departments. Occasionally, the match of a student's research interest and a funded laboratory emerge in another department. If a student wishes to change departments, the student must discuss this with both DGSs; request a transfer; and, obtain the approvals of both DGSs and both Chairs, the SEAS Deputy Dean, and the Associate Dean of the Graduate School. All academic and research requirements in the new department must be met.

3. Course Requirements

Course requirements for the Ph.D. are governed by two general principles. First, students take courses to reach the level of competence in their chosen area of specialization needed to do high-quality research. Second, although depth of knowledge in the major field is essential, breadth of knowledge in related areas is just as important for a reasonably well-rounded education.

To realize these two objectives, at least 10 course units are required. Two of the courses must be in an area outside the specific field of study relating to the subject of the dissertation. Courses such as "Dissertation Research," "Master's thesis," or "Seminar" do not count toward the 10-course requirement, but up to two terms of "Special Investigation" are acceptable.

The detailed program of study for each student is worked out in consultation with the student's faculty advisor, who may suggest courses, sometimes in other departments, that should be taken (or audited). Students are expected to take four graduate courses in each term of the first year of residence. The remaining course requirements must be completed by the end of the fourth term at Yale. Course selections are approved by the student's

advisor and the DGS. Although students are free to take any course in the University for which they meet the prerequisites, courses counted toward the 10 course unit minimum must be full-credit graduate courses with clear technical, scientific, or mathematical focus.

Exceptionally well-prepared students may choose to be excused from some of the course requirements, including those of the first year. To invoke this privilege, either the student must take and pass an exam on the subject prepared by the course instructor at the time, or the student must have taken and performed adequately in a similar course in a graduate degree program either at another institution or at Yale. If the course was taken at another institution, it must be judged by the DGS to be comparable in quality to courses offered at Yale. Students are encouraged to request waivers in their first year. Course exoneration cannot be applied to more than three courses and waived courses will not appear on the student's transcript.

Students are to be engaged in full-time study. The requirement for full-time study is interpreted as 12 class hours per week (i.e., four full course units or three full lecture course units plus a Special Investigation). If the student's advisor and the DGS find it advisable, one or more of these courses can be undergraduate courses; these courses, however, are not given credit toward the 10-course unit requirement for the Ph.D. Courses such as "Dissertation Research" count toward the full-time study requirement. In fact, students who have completed courses and are spending most of their time on research register for "Dissertation Research" every semester. Students may register for electives each semester.

Course changes may be permitted with the approval of the DGS. The last day to withdraw from a course or to change a course from credit to audit or from audit to credit is normally during the final week of October in the fall and the final week of March in the spring.

3.1 Course Requirements during the First Year

- A. A number of core courses, as identified by each department, must be taken in the first year except where noted. The list of core courses for each department/program is located in the Department, Track and Program Requirements section of this book.
- B. Research Projects and Special Investigation— Students must engage in individual research beginning with their first term. During the first year, students are required to register for two of the listed project courses ("Special Investigation"). To register for such a course the student should discuss a specific project with the provisional advisor and prepare a brief outline (~100-200 words), using the departmental Special Investigation Form. This form will be turned in during the registration period and kept in the student's file. The student then adds the course to the schedule by submitting the online Individual Study Course form. At the end of each term of Special Investigation, the student will give a presentation to the First-year Committee on his/her research (see Article 4).
- C. Students are expected to obtain Honors grades in at least two term courses, not including Special Investigations, during their first year of study. An extension of one term may be granted on a case-by-case basis at the discretion of the DGS, in consultation with the student's committee.
- D. All students must complete a one-term course, Responsible Conduct of Research, in the first year of study. This course does not count toward the 10-course requirement.

4. First-year Committee Functions

This Committee serves several critical functions. It will advise the student on the selection of particular courses, it will assess the student's preparation, ability, and progress, and document such progress to the DGS using the appropriate Committee Action Form.

It is strongly recommended that regular meetings be scheduled between the student and the members of the Committee. The responsibility for arranging these meetings rests with the student, and any student who finds that meetings with the members of the Committee on a regular basis cannot be arranged should inform the DGS and request that another faculty member be added to the Committee. The importance of having at least one faculty member who is well-acquainted with the student, and willing and able to make a detailed recommendation, cannot be overstated.

At the end of each term during the first year, the provisional advisor will convene a meeting of the First-year Committee with the student. At that meeting, the student will give a presentation on the Special Investigation. The provisional advisor, as chairman of the Committee, will provide a grade and will report in writing to the DGS on the student's overall performance using the Special Investigation Evaluation Form. Subsequently, after obtaining information on the other grades the student received during the term, the chair, in consultation with the other Committee members, will recommend specific actions to the DGS. A positive recommendation is a necessary condition for the student to remain in good standing. The recommendation of the First-year Committee will, in all cases, be subject to review by the DGS and the decision to permit the student to continue with his/her studies without any further conditions will be recorded as the most important phase of the qualifying procedure in the first year. In cases of questionable performance, the DGS decision together with a general evaluation of the student's standing will be communicated to the student personally by the chair of the First-year Committee and confirmed in writing by the DGS.

Any student whose first report is not encouraging will be advised on a further course of action. Any student whose second report is not fully satisfactory will either be asked to leave at the end of the academic year, or may be given the option to return for a second year subject to specific conditions. These conditions will, in all cases, include a date on which the student's progress will be re-evaluated and a final decision concerning future studies in the department will be made. All such cases of negative recommendation of the First-year Committee will be subject to review by the Deputy Dean and departmental DGSs. The decision by this group together with a general evaluation of the student's standing and recommended course of action will be communicated to the student personally by the chair of the First-year Committee and confirmed in writing by the Deputy Dean.

In those special cases in which a final decision is deferred beyond the end of the first year, a "Special Academic Oversight Committee" of three or more faculty members will be appointed to monitor the student's progress vigilantly, always acting in the same spirit as the original First-year Committee.

5. Selection of Research Advisor and Commitment

It is essential that students engage in full-time research at Yale during the summer following their first academic year. This research will be evaluated in terms of independence of thought, depth of solution and demonstrated progress. To this end, the student must find an advisor who is willing to supervise a project that is consonant with the funded research program of that faculty. In most cases the provisional advisor, chairing the First-

year Committee, will do so. Faculty advisors must have an appointment in the Graduate School. Such arrangements should be finalized by April 1, unless an alternate date has been agreed to by the DGS.

This arrangement, the Commitment, implies a mutual agreement between the student and the advisor to embark on a course of study and research leading to a Ph.D. thesis beginning with the first-year summer research project. Both the student and the research advisor should consider the agreement to a Commitment carefully. The Commitment must include a plan for the financial support of the student and his/her work. Yale is able to offer five years of fellowship or stipend and tuition support because of a student's activities in a funded laboratory with a faculty member in the Graduate School. Thus, a student's research must be within the faculty's funded research program and approved by the faculty sponsor. In many cases, the support plan will be based on the granting or renewal of outside research proposals.

The Commitment also includes the names of faculty who have agreed to serve on the student's Research Committee. Assuming the Commitment is made at the end of the first academic year, the student may plan his/her registration for the second year of study, which will include all remaining course requirements, as well as "Preparing for Qualifying Examination".

6. Temporary Commitment

If arrangements for research projects do not develop into a Commitment by the end of the second term, a "Temporary Commitment" for a specified period (usually the summer) must be requested. Such an arrangement still implies a tentative agreement between the student and the advisor to embark on a course of study and research leading to a Ph.D. thesis. It is expected that by the end of the summer between the second and third terms a Temporary Commitment will evolve into a Commitment and the selection of a *permanent* advisor will be finalized. In the unfortunate circumstance that a Commitment is not made by the end of the summer, the student may be asked to withdraw from the program.

7. Teaching Requirement

Teaching experience is regarded as an integral part of the graduate training program at Yale University and all SEAS students are required to serve as a Teaching Fellow for two semesters, typically during year two. Teaching duties normally involve assisting in laboratories or discussion sections and grading papers and are not expected to require more than ten hours per week. SEAS students are not permitted to teach during the first year of study.

After meeting this degree requirement, students may choose to teach for incremental compensation in later years. If the student undertakes work for incremental compensation, it is understood by all parties, and the graduate student explicitly agrees, that the time required for this activity will neither interfere with nor reduce the amount of effort expected to be devoted and actually devoted to his/her academic/dissertation activities and will maintain satisfactory progress toward the degree.

Teaching Fellow assignments will be coordinated during the summer after the first year of study by the DGS of each department, and with the assistance of the Graduate Registrar's Office. Students will be notified of their assignment prior to the beginning of the fall semester.

Graduate students whose native language is not English are required to meet the oral English proficiency standard before they may begin teaching. This standard may be met by either having received a bachelor's degree from an institution where the principal language of instruction is English, or by passing an English test, which is offered three times each year by the Yale Center for Language Study. Students must earn a score of 50 or higher to pass the test.

If a student was admitted to the program having earned a score of less than 26 on the Speaking Section of the Internet-based TOEFL, the student will be required to take an English as a Second Language (ESL) course each semester at Yale until the Graduate School's Oral Proficiency standard has been met. This must be achieved by the end of the third year in order for the student to remain in good standing.

8. Research Committee

The Research Committee must include at least two faculty members in addition to the research advisor, who acts as chair. These faculty members are selected in consultation with the student and the DGS. At least one of the Committee members should be selected from a field outside that of the research group in which the student plans to work. To ensure continuity, at least two should have tenure and at least one should be a full professor. An exception may be requested from the DGS and Deputy Dean. With the approval of the DGS and the Graduate Registrar's Office, a Committee member from outside the University may be added. Any outside Committee member must agree to make every effort to attend required meetings. An outside Committee member cannot also serve as the external reader.

As soon as this Research Committee is appointed, the student should arrange a meeting to discuss the general plan of study and research. Together the student and the Committee will refine the student's research topic.

9. Admission to Candidacy

Admission to candidacy indicates to all involved that the faculty believes that the student is prepared to do original and independent research. To reach this stage the Research Committee will administer an "Area Examination." The purpose of this Area Examination is to ensure that the student has achieved both the breadth and depth of knowledge appropriate to a Yale Ph.D.

During the third academic year, and no later than December 5th, the Area Examination must be passed and a written prospectus submitted. At least 7 days prior to the exam date the student will have circulated a draft of the dissertation prospectus to the Research Committee and will have turned in the Event Scheduling Form to the Graduate Registrar. The examination will be announced publicly by the Graduate Registrar's Office. One part of the Area Examination will consist of a summary by the student of his/her research activity and plans. At the discretion of the research advisor, this part may be open to all who wish to attend and questions may be allowed by any members of the audience and of the committee. The second part is restricted to questioning of the student (either oral or written) by the committee members or any other member of the faculty, in closed session. Area Examinations should be scheduled during the academic year, so that interested faculty and students can attend. Students will be notified promptly of the results of the exam.

Shortly after passing the Area Examination, and always in consultation with all Research Committee members, the student will revise, if necessary, his/her dissertation prospectus

and submit to the Graduate Registrar's Office a signed Committee Action Form that specifies both the result of the examination and whether the prospectus has been approved by the committee. These two requirements must be accomplished during term time so that the faculty assessment may be made in a timely fashion. At the latest, the student is admitted to candidacy in the Graduate School by the end of the third year.

- A student will not be permitted to register for a fourth year unless the Admission to Candidacy has been granted.

A student who does not pass the Area Examination the first time will be given a second opportunity to take it. The second exam must be taken and the results reported to the DGS and Graduate Registrar's Office by March 15.

- If the examination is failed a second time, the student will be asked to leave the program.

Because scheduling the Area Examination may be difficult, it is recommended that the student contact the Research Committee members prior to the start of the fall semester of the third year to insure that a suitable date and time can be secured. Failure to adequately plan is not grounds for an extension of the deadline. Generally, students who do not take the Area Examination prior to the December 5th deadline lose the opportunity to take the exam a second time if the first exam is failed. The DGS, in consultation with the Deputy Dean, may decide if the student will be allowed to take it a second time.

10. Research Progress Reports and Committee Oversight

Each student, his/her faculty advisor and committee are expected to prospectively discuss and achieve agreement on the goals and expectations for each academic year (plus summer, as appropriate). The planned expectations and achievements for each year build to a completed dissertation at the end of a target of five years.

Students are expected to demonstrate steady progress toward the dissertation, except for cases in which permission has been obtained for a leave of absence from the University. To this end, after admission to candidacy, the Graduate School requires annual Dissertation Progress Reports (DPR) each May 1st. Students shall distribute copies of their progress reports to their committees and convene a meeting of the Research Committee to discuss their progress and their plans for the coming year. During the meeting, the student and/or advisor may be asked to leave the room to allow for discussions of the student's progress and plans, and any issues with mentoring that the student feels need to be addressed. The meeting must be documented via the Committee Action Form. After this meeting, the student will submit the on-line DPR; the advisor, and then the departmental DGS, will review and comment on it.

When the research is nearing its completion, but before the thesis writing has commenced, the full Committee will meet with the student and advise the student on the thesis plan. This meeting is intended to assist the student in identifying the significance of the research, and to comment on its presentation in the thesis. This action, to be implemented several months before the submission and presentation of the thesis, is designed to enhance the quality of the thesis and its defense.

The Committee will communicate to the Graduate Registrar's Office in writing, using the appropriate Committee Action Form, the findings of each of these meetings of the full committee with the student.

Any student whose progress is judged to be not satisfactory and who is not in good standing will be warned and informed about further review procedures. In extreme cases, the Research Committee may recommend to the Graduate Registrar's Office that the student be asked to withdraw from the program. Before such a decision is implemented, it must be ratified by the Deputy Dean and departmental DGS.

All students receiving financial support, either from Fellowships or as Assistants in Research, are reminded that such support carries with it definite obligations with respect to the active full-time course of study, and that continuation of support is generally contingent on satisfactory progress and good standing.

11. Seminars

Communicating results and exchanging ideas is an essential part of any Ph.D. program and all successful careers after the degree is obtained. As such, all graduate students are expected to attend their departmental seminars. In addition, each graduate student will present his/her research in a public seminar at Yale (excluding area exams, thesis defenses and presentations associated with course work) at least once during their graduate student career. The individual departments will determine the formats of these seminars. Students will inform the Graduate Registrar's Office of the date and time of the seminar.

12. Dissertation

The dissertation must report original research in an area of engineering or applied science and demonstrate creative thought and scholarly achievement by the student. When the dissertation is completed, it will be read by the Research Committee and one external reader to be selected by the research advisor in consultation with the DGS. The external reader should have no direct interest in the success or failure of the dissertation.

Each reader is required to submit a written report on the dissertation to the Graduate School. A copy of the report will be available to the DGS and the Graduate Registrar.

13. Final Examination

The readers (excluding the outside reader) will constitute the Examination Committee, chaired by the research advisor, to examine the student orally on the subject of the dissertation, and will recommend acceptance or rejection of the thesis. The examination will be based on the final draft of the dissertation, copies of which will be given at least one week in advance to all Committee members and made available to all faculty members by means of an electronic copy provided to the Graduate Registrar's Office. The student will also be responsible for turning in the Event Scheduling Form at this time.

The examination will be announced publicly by the Graduate Registrar's Office at least one week before it is held, and it will be open to all who wish to attend. It will consist of a summary by the student of the research activity, with questions by the Committee and members of the audience. Examinations should normally be scheduled during the academic year, so that interested faculty and students can attend.

In addition to the public examination, the committee members, either separately or collectively, may also wish to schedule a private meeting with the student for the purpose of clarifying specific details or correcting errors in the dissertation. Such a meeting should be scheduled prior to the public examination whenever possible.

The committee will notify the Graduate Registrar's Office in writing of the result of the examination and the recommendation regarding the acceptance of the thesis, using the appropriate Committee Action Form.

14. Submission of Dissertation

The student must submit to the Dissertation Office of the Graduate School all required paperwork specified in the GSAS Dissertation Submission Checklist and an electronic copy of the dissertation (PDF) via the Dissertation Submission web site. The submission date is set by the Graduate School to be prior to the meeting of the Degree Committee at which the petition for degree is to be considered (see Graduate School Bulletin/Calendar for dates).

15. Certification of Fulfillment of Ph.D. Degree Requirement

After the Graduate Registrar's Office has received the Committee Action Form from the Committee Chair certifying that the student has passed the final examination, and a complete set of copies of the readers' reports from the Graduate School, the DGS will notify the faculty in writing that the candidate has completed the departmental requirement for the Ph.D. degree.

If the DGS receives no objection by a significant minority of the faculty within a week from the time the notification has been mailed, the DGS will certify to the Graduate Registrar's Office that the student has satisfied the requirements for the Ph.D. degree, and the Graduate Registrar's Office will notify the University Registrar's Office. Subsequent approval by the Degree Committee is customary but may not be taken for granted, especially in cases in which there is a sharp division amongst the readers. Official approval of the degree is signified by a letter from the Dean of the Graduate School.

16. Timetables and Deadlines

There are several deadlines by which the various aspects of the above procedure must be completed to comply with Graduate School rules, to avoid additional fees, and to ensure that the degree will be awarded at the next Commencement. It is the student's responsibility to inform himself/herself of the appropriate deadlines and to ensure that there is adequate time for the members of the committee to perform their duties. The appropriate information may be obtained from the Graduate Registrar's Office or from the Graduate School.

One important general deadline all students should be aware of is the upper limit of six years set by the Graduate School for the completion of all Ph.D. theses. Notifications of a sixth year of study must be made in writing to the Graduate Registrar's Office by April 15th and should include the anticipated date of the thesis defense. The average time for the completion of the Ph.D. thesis in the School of Engineering & Applied Science is five years of graduate study.

17. Work External to the Degree

If the student undertakes work for incremental compensation, whether at the University or elsewhere, it is understood by all parties, and the graduate student explicitly agrees, that the time required for this activity will neither interfere with nor reduce the amount of effort expected to be devoted and actually devoted to his/her academic/dissertation activities and will maintain satisfactory progress towards the degree. All part-time employment should be agreed upon by the faculty advisor. Part-time employment in excess of 10

hours per week requires permission from the DGS. International students should contact the Office of International Students and Scholars prior to contemplating part-time employment.

When a student takes a course outside the degree, the effort must be considered incremental to the effort devoted to degree-related activities, such as degree courses and research. Non-degree courses should be discussed with the faculty advisor prior to registration.

Students contemplating internships should note that internships are only allowed between June 1st and the start of the fall term. In addition, some internships may require an official Leave of Absence from the University. Students must complete the Graduate School's *Summer Internship Application* at least 2 months prior to the start of an internship; while these are important opportunities, it may take time to process all of the logistics. Please note that Leaves of Absence may result in loss of student status, loss of access to Yale facilities and loss of student health coverage under the Yale Health Plan.

Summary of Requirements to Remain in Good Standing and Milestones*

First year

- 4 classes, departmental core courses and at least one Special Investigation (SI) each semester,
- Research in a lab for the summer
- Oral English proficiency standard (English test) met by the end of August

Students must have earned 2 grades of Honors (excluding SI's) and have a High Pass average by the end of the first year.

Third term

- 1-2 classes
- Research in lab (last term for finding a faculty mentor)
- Committee approval of progress towards degree
- Meet teaching requirement

Fourth term

- 1-2 classes
- Research in lab
- Committee approval of progress towards degree
- Meet teaching requirement

Students must maintain the High Pass average as they finish course work in the second year.

Students not meeting all the course requirements by the end of the fourth term will not be allowed to continue.

Fifth term

- Area Exam by December 5th
- Prospectus approved by December 5th
- Admitted to candidacy by end of fifth term

If a student fails the exam, he/she will be allowed to take it again prior to March 15.

Sixth term

- Retake area exam if the student failed the first time; have prospectus approved and be admitted to candidacy
- Dissertation Research if already admitted to candidacy
- Committee approval of progress towards degree

Students not admitted to candidacy will not be allowed to continue

Continuing

- Committee approval of progress towards degree
- Research in lab

Fifth year

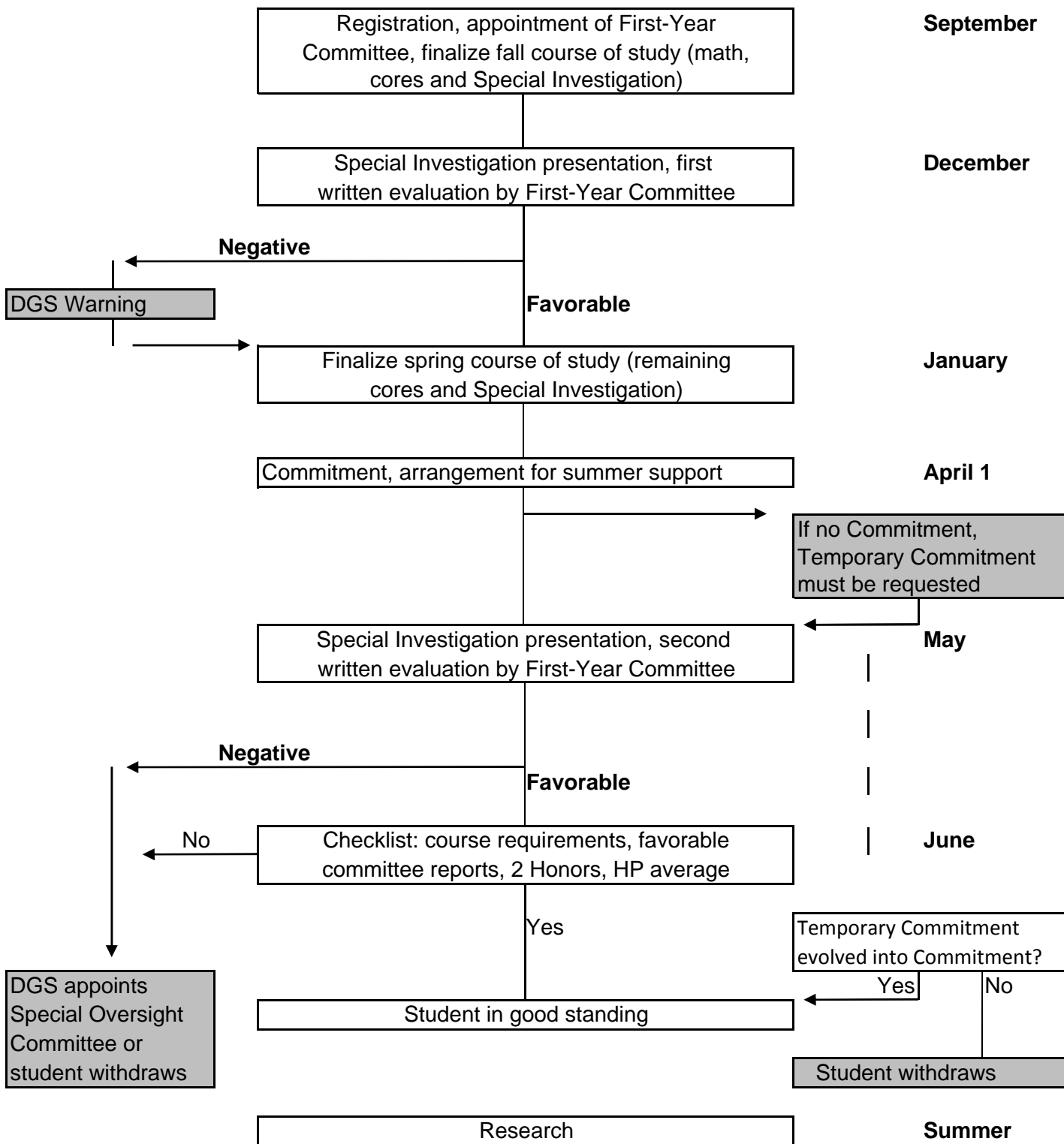
- Guarantee of support ends in June
- Must make a notification for extended registration

Summers: research in lab

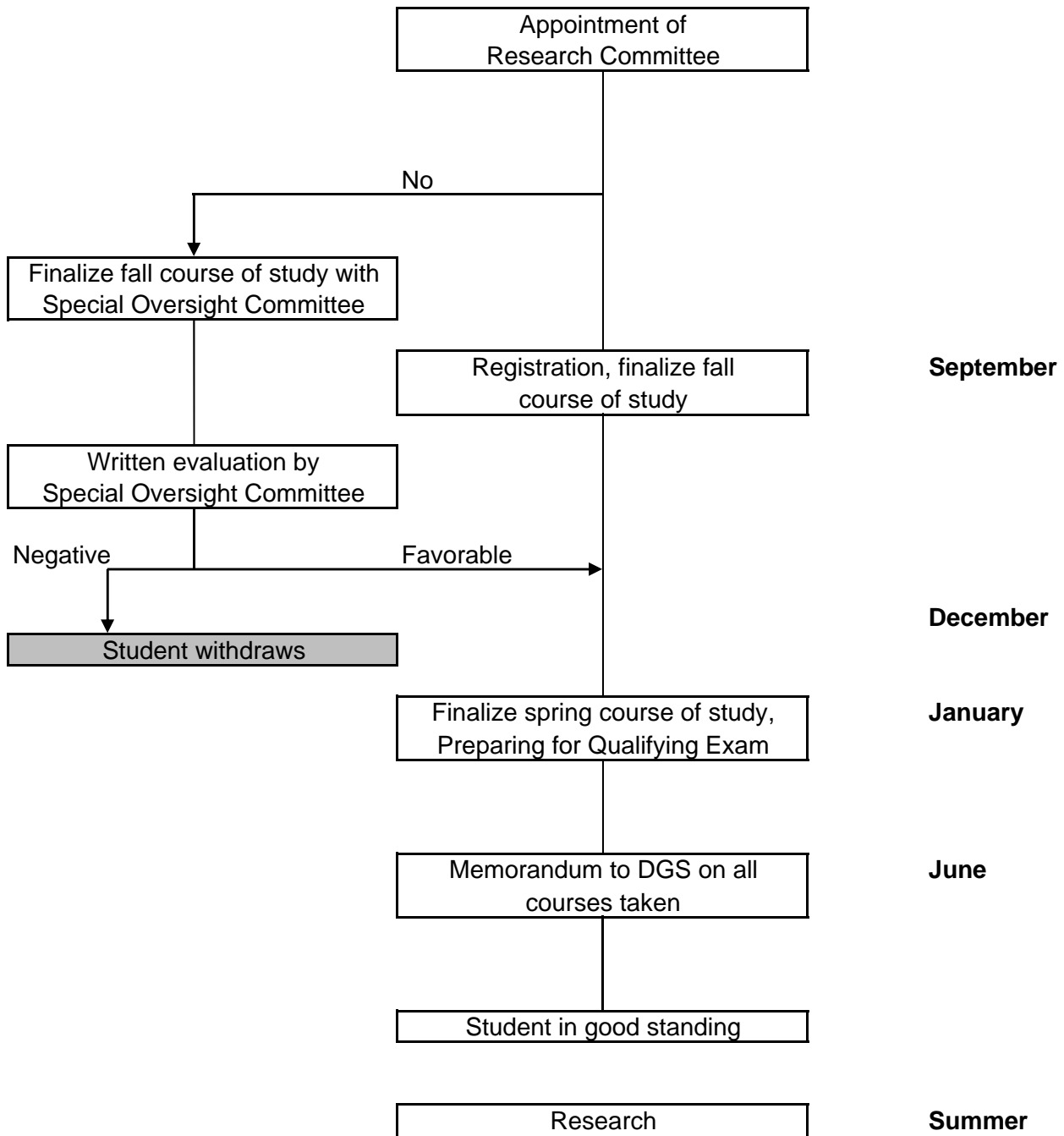
* This summary is presented for convenience. Refer to text for specific requirements.

YEAR 1

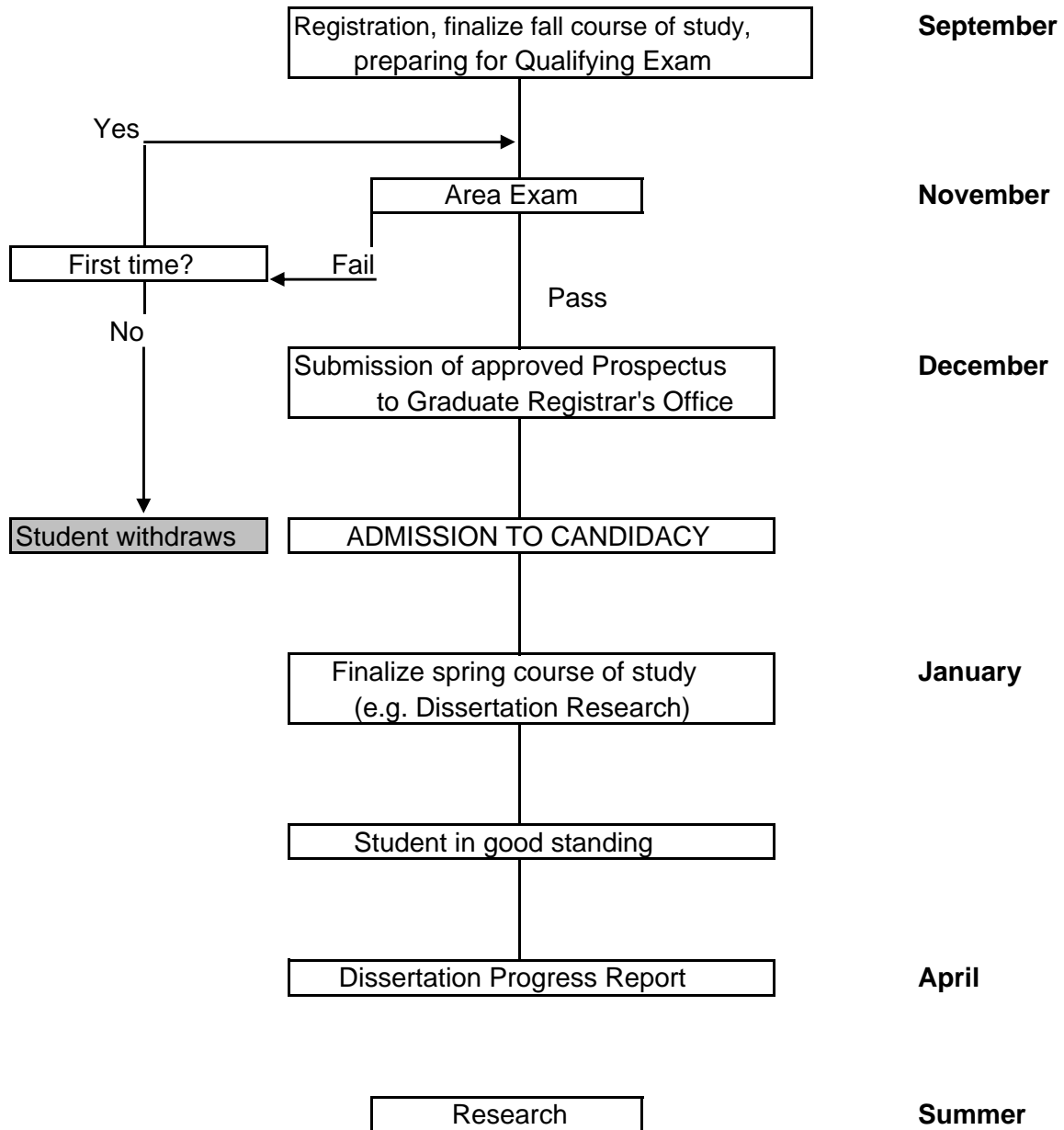
Academic Year and Summer



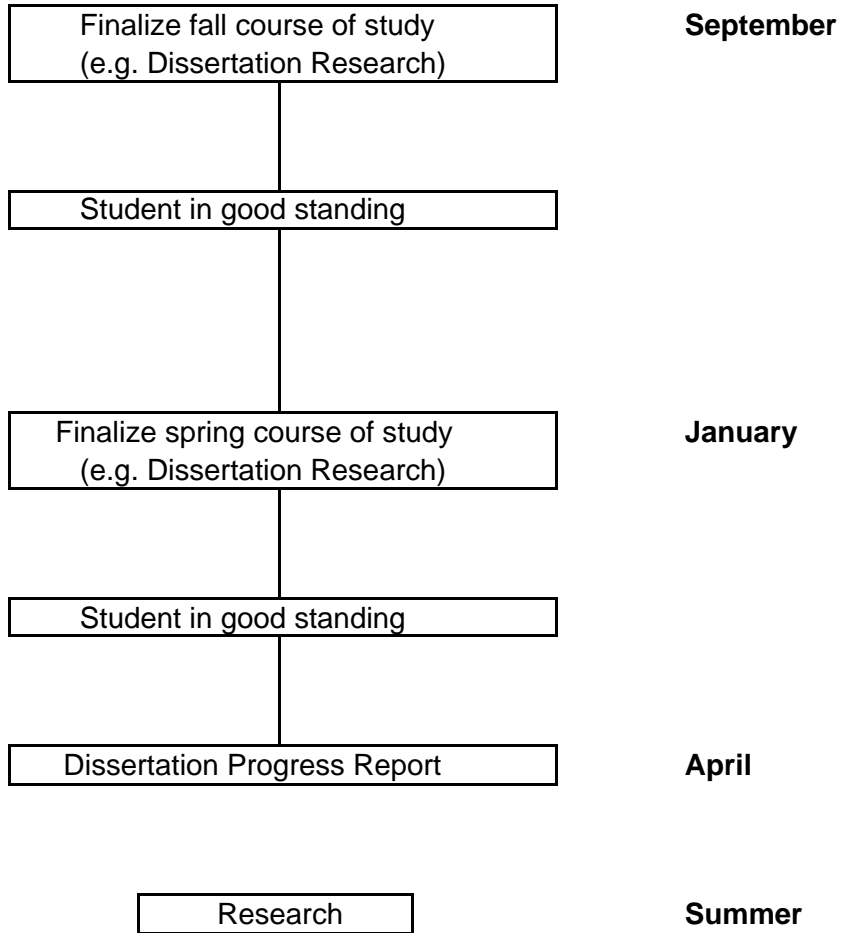
YEAR 2 Academic Year and Summer



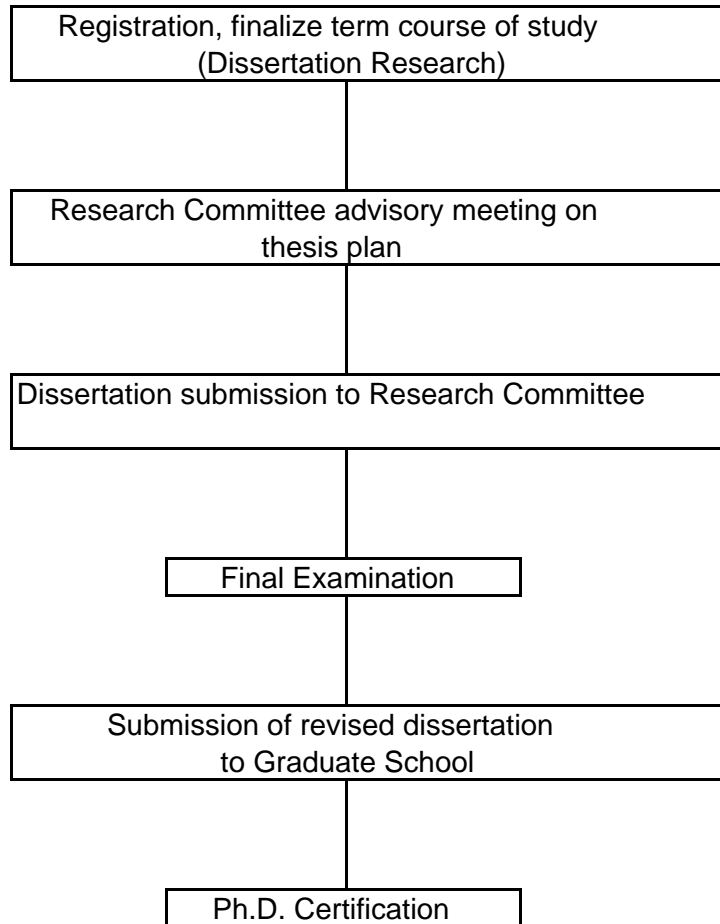
YEAR 3 Academic Year and Summer



YEAR 4
Academic Year and Summer



YEAR 5
Academic Year



Part II

Department & Track Requirements

Department of Biomedical Engineering	18
Department of Chemical & Environmental Engineering	19
Chemical Engineering Track	19
Environmental Engineering Track	20
Department of Electrical and Computer Engineering	21
Department of Mechanical Engineering & Materials Science	22
Integrated Graduate Program in Physical and Engineering Biology	23
Quantum Materials Science and Engineering	24

Department of Biomedical Engineering

Math Requirement

Biomedical Engineering has identified courses that fulfill the department's math requirement that must be taken during the first year. Exceptions will only be granted to students who have demonstrated mastery of the subject by passing an exam given by the instructor of either ENAS 500 or 505, or by obtaining a satisfactory passing grade in an equivalent graduate course at another university following the procedure defined for obtaining course waivers.

The courses that meet the Biomedical Engineering math requirement are:

- ENAS 500: Mathematical Methods I
- ENAS 505: Advanced Engineering Mathematics
- ENAS 549: Biomedical Data Analysis

Students in the PEB program may also meet the math requirement with ENAS 541 or ENAS 561

1. The Core Areas

Competence must be demonstrated in the following areas:

- Physical and Chemical Basis of Bioimaging and Biosensing
- Physiological Systems

2. The Corresponding Graduate Courses

- ENAS 510: Physical and Chemical Basis of Bioimaging and Biosensing
- ENAS 550: Physiological Systems

One of these courses may be taken in the second year.

Students may place out of: ENAS 550: Physiological Systems
 ENAS 500: Mathematical Methods or 505 Advanced Engineering Math
by passing an exam administered by the BME department or course instructor, or by following the standard procedures for obtaining course waivers (see page 2, Article 3).

Additional Requirements

In the first year, all students are expected to present their Special Investigation work at a Department Symposium held on the last day of Reading Period.

BME Seminars are held on Thursdays at 4pm. Attendance at these seminars for graduate students is mandatory.

At least one month before the Area Examination, the student should submit the Research Committee Membership form to the DGS. Subsequently, if there are changes to committee membership, the student should submit an updated form.

In the 4th year, students are expected to present their research work at a BME seminar.

Department of Chemical & Environmental Engineering

Chemical Engineering Track

1. The Core Areas

Competence must be demonstrated in:

- Mathematical Methods
- Plus any two of the three following areas:
- Thermodynamics
 - Chemical Reaction Engineering
 - Energy Mass and Momentum Processes

2. The Corresponding Graduate Courses

- ENAS 500: Mathematical Methods I
- ENAS 521: Classical and Statistical Thermodynamics
- ENAS 602: Chemical Reaction Engineering
- ENAS 603: Energy Mass and Momentum Processes

3. Relevant Text Books and Topics

Classical and Statistical Thermodynamics

- H. B. Callen. (1985). Thermodynamics and an Introduction to Thermostatistics, Wiley
- A. Firoozabadi (1999). Thermodynamics of Hydrocarbon Reservoirs, McGraw Hill
- J. W. Tester and M. Modell. (1997). Thermodynamics and Its Applications, 3rd Ed., Prentice Hall International
- Terrell L. Hill. (1986). An Introduction to Statistical Thermodynamics, Dover Publications
- D.A. McQuarrie. (2000). Statistical Mechanics
- Kenneth George Denbigh. (1981). The Principles of Chemical Equilibrium: With Applications in Chemistry and Chemical Engineering, Cambridge University Press
- M. Scott Shell. (2015). Thermodynamics and Statistical Mechanics – An Integrated Approach, Cambridge University Press
- J. B. Fenn. Engines, Energy and Entropy, Freeman or Global View Publisher

Chemical Reaction Engineering

- C. G. Hill, Jr. (1977). An Introduction to Chemical Engineering Kinetics and Reactor Design, Wiley
- J. A. Dumesic, D. F. Rudd, L. M. Aparacio, J. E. Rekoske, and A. Trevino. (1993). The Microkinetics of Heterogeneous Catalysis, ACS
- K. J. Laidler. (1987). Chemical Kinetics, 3rd Ed., HarperCollins

Energy Mass and Momentum Processes

- R. B. Bird, W. E. Stewart, and E. N. Lightfoot. (2002). Transport Phenomena, 2nd Ed., J. Wiley
- Leal. (1992). Laminar Flow and Convective Transport Processes, Butterworth-Heinemann
- Deen. (1998). Analysis of Transport Phenomena, Oxford
- D.E. Rosner. (2000). Transport Processes in Chemically Reacting Flow Systems, Dover Publications

Environmental Engineering Track

Math Requirement

Environmental Engineering has identified courses that fulfill the department's math requirement that must be taken during the first year. Exceptions will only be granted to students who have demonstrated mastery of the subject by passing an exam given by the instructor of the classes listed below, or by obtaining a satisfactory passing grade in an equivalent graduate course at another university following the procedure defined for obtaining course waivers.

The courses that meet the Environmental Engineering math requirement are:

- ENAS 500: Mathematical Methods I
- ENAS 748: Applied Numerical Methods for Differential Equations
- S&DS 530/ENV 757: Data Exploration and Analysis
- S&DS 563/ENV 758: Multivariate Data Analysis in the Environmental Sciences

1. The Core Areas

- Water Chemistry
- Physical and Chemical Processes in Environmental Engineering
- Biological Processes in Environmental Engineering

2. The Corresponding Graduate Courses

- ENAS 640: Aquatic Chemistry
- ENAS 641: Biological Processes in Environmental Engineering
- ENAS 642: Environmental Physicochemical Processes

3. Relevant Text Books and Topics

Water Chemistry

- F.M.M. Morel, and J.G. Hering. (1993). Principles and Applications of Aquatic Chemistry, Wiley Interscience

Biological Processes

- B.E. Rittmann and P.L. McCarty. (2001). Environmental Biotechnology, McGraw-Hill

Physical and Chemical Processes

- ENAS 642 Class handouts and notes
- D.F. Lawler, and M. Benjamin. "Physical and Chemical Processes", McGraw-Hill (2009, in press).

Students should confirm the departmental seminar schedule with the DGS.

Department of Electrical and Computer Engineering

The department grants the student opportunities to try different research groups. However, a maximum of three research advisors is allowed prior to the dissertation defense.

Courses will be assigned by the advisor in coordination with the research committee, and are subject to approval by the DGS. This applies to all tracks: Microelectronics, System and Signals and Computer Engineering.

Additional Requirements

The presentations of Special Investigation (see Section 4) will be conducted with all first-year students and faculty within the Core Area present. Recommendations will be given by the First-Year Committee together with area faculty.

Microelectronics Track End of Summer Research Exam: In October following the student's first year of summer research, each student will make a presentation on their research progress. It is expected that the presentation will demonstrate an appropriate understanding of the research topic and include positive preliminary results. The exam will be administered and evaluated by the Research Committee and students who do not pass this exam will be advised to leave the program prior to the Area Examination.

Department of Mechanical Engineering & Materials Science

Math Requirement

Mechanical Engineering & Materials Science has identified the courses that fulfill the department's math requirement that must be taken during the first year. Exceptions will only be granted to students who have demonstrated mastery of the subject by passing an exam given by the instructor of the class, or by obtaining a satisfactory passing grade in an equivalent graduate course at another university following the procedure defined for obtaining course waivers.

All students must take 2 semesters of ENAS 700 during the first two years of study; this course does not count toward the ten-course requirement.

The courses that meet the Mechanical Engineering & Materials Science math requirement depend on the student's field of research and are:

- CPSC 553: Unsupervised Learning for Big Data
- ENAS 500: Mathematical Methods I
- PHYS 506: Mathematical Methods of Physics
- ENAS 902: Linear Systems

The Core Areas

Competence must be demonstrated in one of the following five areas: (i) Fluid and Thermal Sciences; (ii) Soft Matter/Complex Fluids; (iii) Materials Science; (iv) Robotics/Mechatronics, or (v) Bioengineering, by selecting appropriate graduate courses after consulting with the graduate advisor and DGS. As a minimum requirement, students must take at least one of the courses listed below in year 1:

- CPSC 559: Building Interactive Machines
- CPSC 570: Artificial Intelligence
- CPSC 572: Intelligent Robotics
- CPSC 573: Intelligent Robotics Laboratory
- CPSC 585: Applied Planning and Optimization
- ENAS 521: Classical and Statistical Thermodynamics
- ENAS 541/PHYS 523: Biological Physics
- ENAS 559: Neuromuscular Biomechanics
- ENAS 606: Polymer Physics
- ENAS 615: Synthesis of Nanomaterials
- ENAS 703: Introduction to Nanomaterials and Nanotechnology
- ENAS 704: Theoretical Fluid Dynamics
- ENAS 708: Fundamentals of Combustion
- ENAS 752: Solidification and Phase Transformations
- ENAS 755: Electronic and Optical Properties of Energy Materials
- ENAS 770: Introduction to Soft Robotics
- ENAS 773: Fundamentals of Robot Modeling and Control
- ENAS 778: Advanced Robotic Mechanisms
- ENAS 787: Forces on the Nanoscale
- ENAS 848/PHYS 528: Soft Condensed Matter Physics
- ENAS 850/PHYS 548: Solid State Physics I
- ENAS 851/PHYS 549: Solid State Physics II
- ENAS 902: Linear Systems (if not used to satisfy math requirement)
- ENAS 994: Mechatronics Laboratory
- PHYS 628: Statistical Physics II

Integrated Graduate Program in Physical and Engineering

Biology (PEB)

The PEB program brings together faculty from the physical, engineering, and biological sciences who carry out collaborative, interdisciplinary research and teaching (peb.yale.edu). PEB students acquire a depth of knowledge in their home department, and also a breadth of knowledge across disciplines through PEB courses and enrichment activities. They become skilled at applying physical and engineering methods and quantitative reasoning to biological problems, at identifying and tackling cutting-edge problems in the life sciences, and become proficient at combining theory and computation with wet lab experiments. In addition, students become comfortable working in an interdisciplinary and collaborative research environment and adept at communicating with scientists from a variety of disciplines and also with non-scientists.

Students applying to the Ph.D. program in Applied Physics, Biomedical Engineering, Chemical & Environmental Engineering and Mechanical Engineering & Materials Science may also apply to be part of the PEB program. Students may also join the PEB after they have matriculated at Yale. After arriving at Yale, students should email peb@yale.edu to express their interest in the PEB and the leadership will review their application materials. Information on course requirements may be found at <http://peb.yale.edu>.

Quantum Materials Science and Engineering

Quantum materials have played a key role in technologies with broad societal impacts (e.g., semiconductors, lasers, LEDs, and medical imaging). Their importance will increase with the growing research on harnessing quantum effects for computation and sensing (e.g., quantum computation and information research programs at leading technology companies). In addition, the role of data science and machine learning methods continue to grow in importance in all fields of science and engineering. The aim of this certificate is to train Ph.D. students in the multidisciplinary field of quantum materials and associated data science methods to allow them to be at the cutting edge of research and engineering on understanding and using quantum matter that can lead to scientific and engineering breakthroughs.

This certificate program is open to Ph.D. students in several graduate-degree granting programs in the Graduate School of Arts and Sciences, including the Departments of Applied Physics, Chemistry, Computer Science, Mechanical Engineering and Materials Science, and Physics. Students can either choose to participate in the certificate program during the application process to the Graduate School, or, if already enrolled in the graduate program of one of the above departments, apply to the certificate program by contacting its directors. Information on course requirements may be found at <https://catalog.yale.edu/gsas/non-degree-granting-programs-councils-research-institutes/quantum-materials-science-engineering/>