Duke UNIVERSITY | MECHANICAL ENGINEERING & MATERIALS SCIENCE

Undergraduate Program Handbook

2020-2021 Academic Year
This handbook is updated every year.
Students and faculty should always use the latest version of the handbook.

HIGHLIGHTS OF IMPORTANT CHANGES

- Fall 2012: Duke Courses Renumbered
- Fall 2013: Only SSH courses in the identified departments on Appendix 8 count toward the SSH requirement. These courses must also identify one of the following codes: ALP, CZ, SS, or FL.
- Fall 2014: EGR 305, even though it is cross-listed with Econ, will NOT count toward the SSH requirement.
- Old course numbers have been removed.
- Fall 2018 EGR101L added to the ME Curriculum and free elective removed. AP and ½ credits are no longer to allowed to satisfy the remaining Free Elective
- Fall 2020 detailed revisions; Math 218 to replace Math 216; Natural Science elective can include Data Science and some Math courses.

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Introduction

This handbook provides detailed information on the undergraduate program in Mechanical Engineering (ME) at Duke University. It covers the program mission, educational objectives, departmental major requirements, and Pratt School requirements. It contains advice and procedural guidelines for a number of student activities, such as research and independent study activities, and study abroad. It provides information for students planning to obtain a certificate in Aerospace Engineering or in Energy and the Environment. It also covers rules and information for students planning a Pratt minor with Electrical and Computer Engineering (ECE) or Energy Engineering. As well as planning a second major in Pratt with Biomedical Engineering (BME).

The undergraduate major in Mechanical Engineering at Duke University is one of the best programs in the United States, and a very popular major in the Pratt School of Engineering. The student population is diverse both geographically and culturally, and is a cross-section of the very best students in the nation and from around the world. The program stresses fundamental understanding and project-based learning in the four primary disciplines that comprise Mechanical Engineering: Dynamics and Control, Fluid and Thermal Sciences, Materials Science, and Mechanics and Design. Exposure in depth and breadth to these areas prepares our students for successful entry into industry and graduate schools.

The program provides firm preparation in the essential engineering topics while allowing wide flexibility for students to pursue their own specialized interests, including hands-on experience, research and independent study, certificates, minors, and second majors in engineering, the sciences and liberal arts, and study abroad.

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Mission

Mechanical engineers are concerned with the optimum use of materials, energy, time, and individual effort to serve societal needs through the design of machines, structures, and devices that employ mechanical, thermal, and electro-dynamic systems, and through better understanding of dynamic processes involving these systems. They have a wide involvement in many industries including aerospace, automotive, energy and power generation, biomechanical and biomedical engineering, construction, electronics, manufacturing, national defense, and transportation systems. Within these industries, the engineer might specialize in the design, analysis, automation, operation, or marketing of systems or services. The individual's contribution may lie anywhere in the spectrum from highly theoretical to eminently practical, and often involves leadership as an engineering manager or organization executive. The department's mission is to prepare our students to serve society in this role in an ethical and conscientious manner.

Because mechanical engineers in industry and research engage in such a great variety of activities, their education is broadly based. Our goal is to graduate mechanical engineers who embody excellence in a broad sense. We expect our graduates to move to industry positions, or on to graduate study, or to carry the attributes of an engineering education into other disciplines. The mechanical engineering program includes mathematics and basic sciences, fundamentals and applications in several engineering sciences, and team-based experience in the process of design, where theory is applied in the context of real needs and limitations, and where judgment must be exercised.

Our mechanical engineering graduates should be able to think critically when solving problems and managing tasks, and communicate effectively in multi-disciplinary professional environments. To be a responsible member of the engineering profession, each graduate must also be aware of social, ethical, environmental and economic factors. Further, be aware of the constraints on engineering activity and understand the importance of these matters in a global context. We aspire to have our graduates exhibit intellectual depth and creativity, uphold high ethical standards, and show a commitment to the betterment of society through service and professional work.

The curriculum capitalizes on the exceptional abilities of our highly select students to cultivate the learning, thinking, and problem-solving abilities needed to adapt, to develop, and to exercise responsible leadership through times of rapid change. The program provides firm preparation in the essential engineering topics while allowing wide flexibility for students to pursue their own specialized interests, and also to broaden their overall range of experiences.

Program Educational Objectives

Our specific Program Educational Objectives are to prepare our graduates to:

- identify and address significant needs and challenges in engineering and society, and effectively communicate solutions;
- advance in professional careers that may encompass a broad range of endeavors, both technical and non-technical;
- exhibit intellectual depth and creativity in employment, advanced education and research;
- uphold high ethical standards and show a commitment to the betterment of society through service and professional work.

Student Learning Outcomes

Our students will have the following capabilities upon completion of their degrees:

- An ability to identify, formulate and solve complex engineering problems by applying principles of engineering, science, and mathematics
- An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety and welfare, as well as global, cultural, social, environmental and economic factors
- An ability to communicate effectively with a range of audiences
- An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgements, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
- An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
- An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgement to draw conclusions
- An ability to acquire and apply new knowledge as needed, using appropriate learning strategies

Additionally, students will have applied principles of engineering, basic science, and mathematics (including multivariate calculus and differential equations) to model, analyze, design, and realize physical systems, components or processes.

Pratt School of Engineering and Mechanical Engineering Major Requirements

As a program accredited by the Engineering Accreditation Commission of ABET (www.abet.org), the Mechanical Engineering curriculum must satisfy minimum requirements in mathematics, sciences, and engineering. In addition, the Pratt School of Engineering has requirements for all engineering students. To meet these constraints, the Department of Mechanical Engineering and Materials Science has developed specific requirements for undergraduate students. Samples of curricula for ME major choices are provided in Tables 1-6. In summary, ME students need to take the following courses.

One Undergraduate Writing Course

Writing 101 is required and taken by all Duke students freshman year.

Digital Computation and Computer Programming

All engineering students must either EGR 103L or COMPSCI 201, if they have adequate prior programming experience.

Engineering Design and Communication

EGR 101L is required of all engineering students during freshman year (exceptions for late transfers).

One Chemistry Course
Students are required to have Chem 101DL, or Chem 110DL, or have AP Credit[1] for Chem 20 or 21 (either score is acceptable for ME majors).

Two Physics Courses

Engineering students must take at least one Physics course post-matriculation, regardless of AP credit. Students with no AP credit will take the following:

- Physics 151L + Physics 152L

Students with a 4 or 5 on the AP[1] Physics C exam(s) earn Physics 25-*Mechanics*; and/or Physics 26-*Electricity & Magnetism*. The following options are available:

- Physics 25 + Physics 26 + any one of the following courses: Physics 153L, 264, 361, or 362
- Physics 25 + Physics 152L

NOTE: Students may not take Physics 151L at Duke and use AP[1] credit for Physics 152L.

Five Mathematics Courses

Students matriculating 2020 and earlier: Math 111L, 112L, 212, 216 or 218, and 353.

Students matriculating 2021 and later: Math 111L, 112L, 218, 212, and 353.
Pratt is transitioning to this math sequence, but the transition may not be complete in the coming year.

<u>AP Credit[1]</u>

AP recommendations are as follows:

No AP: Follow math sequence above and begin with Math 111L
Math 21 AP: Begin with Math 122L in the Fall **or** Math 112L in the Spring
Math 21 AP **and** Math 22 AP: Begin with Math 218, or
Math 21 AP **and** Math 22 AP: Waive AP for MATH 22 and begin with Math 122L

Common questions about mathematics placement are answered at the website:
https://math.duke.edu/undergraduate/course-placement.
Transfer credits examined on an individual basis.

NOTE: If students are advised by the Math department to skip any courses in the Math sequence listed above, *they must replace those courses with additional Math courses approved by the ME DUS. The total number of Math courses taken at Duke plus the number of AP and/or transfer credits must equal 5*. Approved math courses include: Math 230, 238, 333, 342, 361S, 451S, 453, 541.

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[1] *Students who use an AP credit as a prerequisite in order to take a higher-level class are not allowed to waive that AP credit later on and take the equivalent Duke course for credit. For example, PHY 152L is a prerequisite for EGR 224L. Therefore, a student with AP credit for Phy 26 could not take PHY 152L after EGR 224L has been taken.*

ME/Math majors: Students wishing to do a ME/Math second major/minor will need to take:

- Math 111L, 112L, and
- Either **[**212 + 221**] or [**221 + 222**]**, and
- 356, in place of 353

Once students start the ME/Math sequence by taking Math 221, they must complete it. They cannot switch to the regular engineering sequence due to overlapping course content. Consult the math department for additional required courses needed to complete the math major/minor requirements.

Five Social Sciences and Humanities (SSH) Courses

Students in the Pratt School of Engineering are required to have a minimum of 5 courses in the social sciences and humanities. The specific requirements are:

- At least one course must be a social science (SS).
- Other courses must be selected from at least two of the following three areas: arts, literature, and performance (ALP), civilization (CZ), and foreign language (FL).
- At least two courses must be taken from the same *department* with at least one being at 200-level or higher.
- Skill courses cannot be used to fulfill the SSH requirements.
- At most, 2 of these 5 course credits can be met by any combination of 2 from the following options:
    - Advanced Placement (AP) Credit
    - International Placement Credit (IPC)
    - Duke courses only offered on a Satisfactory/Unsatisfactory grading basis.
- A list of Approved SSH Departments is provided in Appendix 8, Table A8
- SSH courses taken in an engineering or science department (e.g., Chemistry) count only if they are cross-listed in an SSH department.
- Some Trinity departments in technology and science, not in social science and humanities, have assigned SS, CZ, or ALP codes for some of their courses as an outreach to Trinity students. For this reason, the Pratt School is now requiring that the SS/H courses be taken only from one of the departments or programs listed in Appendix 8 Table A8.

AP credits do not carry course codes, however in the Pratt School of Engineering, Areas of Knowledge are attributed to AP exams. Some examples include, History (CZ), Psychology (SS), Political Science (SS), AP Language Courses (FL), English (ALP), Economics (SS), Music (ALP). Consult your Dean if you have question about AP credit.

Natural Science or Mathematics Elective for Mechanical Engineering Majors

Students must take an approved Natural Science (NS) elective as part of their requirement for nine math and science courses in the Pratt School of Engineering. Because the requirement is different in each of Pratt's four departments, ME students should be careful to satisfy the Mechanical Engineering requirements. The Natural Science elective is a component of the school's accreditation requirements. Restrictions on this elective are prescribed by each department, and by the accrediting society, which is the American Society of Mechanical Engineers (ASME) for mechanical

engineering. In Mechanical Engineering this requirement can be fulfilled by Appendix 7, Table A7, which lists approved Mathematics and NS electives for ME.

Departments offering certain courses that can satisfy the requirement are Biology, Chemistry, Physics, and Earth and Ocean Sciences. Certain courses in Data Science and in Mathematics can also satisfy this requirement. Chemistry or Physics courses used to satisfy the NS elective cannot also count to fulfill the other Pratt course requirements in those areas. Courses in other departments, e.g. Environmental Science, do not satisfy Pratt NS requirement.

The spirit of the requirement is that students should have broad science exposure at a fundamental level, as opposed to a very narrow topical or application level. Engineering courses never count, regardless of their level. Note that a Trinity NS code does not mean that the course will satisfy the Pratt NS requirement.

In exceptional cases an NS elective not on the list can be approved by the Director of Undergraduate Studies (DUS). Note that the MEMS faculty has stipulated that these exceptional cases must have a clearly stated mathematics or science prerequisite, and both the alternative course and its prerequisites must be at an appropriate level for engineering students.

Some AP courses, e.g. Biology, can fulfill the MEMS NS requirement. Some courses taken for Study Abroad can satisfy the MEMS NS requirement with prior approval of both the MEMS DUS and the DUS of the topically relevant department. Such courses may be approved as equivalent to a Duke course, or as being of appropriate level although there is no Duke equivalent.

ME Required Courses

For students in the Mechanical Engineering major, the following specific courses, or their approved alternatives, are required in addition to the overall school of engineering requirements:

Engineering Courses:

EGR 101L Engineering Design and Communication
EGR 121L Engineering Innovation
EGR 201L Mechanics of Solids
EGR 224L Mechatronics
EGR 244L Dynamics

Mechanical Engineering Courses:

ME 221L Structure and Properties of Materials
ME 331L Thermodynamics
ME 344L Control Systems
ME 424L Mechanical Systems Design
ME 321L Analysis for Design
ME 336L Fluid Mechanics
ME 421L Mechanical Design
ME 431L Heat Transfer

Mechanical Engineering Technical Electives:

A minimum of two upper-level (400-level, or higher) ME electives are required to encourage depth in areas of particular interest. Students are encouraged to consult with their advisors when selecting areas of interest and electives. Students take elective courses to learn advanced knowledge in specific areas of mechanical engineering. A number of ME electives are offered on a regular basis, but the specific courses offered in a given semester depend to a degree on the availability of faculty.

Students should also check ME Special Topics Courses that represent new courses each semester, and should also consider taking 500-level courses that are open to advanced undergraduates and graduate students. Up to two upper-level independent study courses, if supervised by an ME faculty member, can be counted as required ME Electives.

Upper-Level General Electives:

Two upper-level (200-level, or higher) elective credits are required.

- Unrestricted in content, in that they may be courses in either Pratt or Trinity.
- May not be AP credits.
- May be taken abroad with appropriate approval.
- Must be a full credit course, not two half-credit courses

General Elective: One general elective course credit is required, unrestricted in content and level.

- Only this general elective can be taken on the Satisfactory/Unsatisfactory basis.
- AP Credits are not permitted.
- Must be a full credit course, not two half-credit courses.

ROTC Courses and the General and Upper-Level General Electives: Up to two ROTC courses taken in the junior or senior year can be used in any combination in these two free elective categories. ROTC courses are not allowed to fulfill other Pratt or ME requirements.

Mechanical Engineering Curriculum Information

The curriculum outlined to this point is also presented in three other forms, all in this document, and on the website: http://www.mems.duke.edu/undergrad

- Curriculum Flow Chart, Figure 1
- Annotated Check Sheet, Table 1
- Four-year charts that are Appendices 1-5 of this document

The curriculum follows a definite prerequisite structure. Prerequisites and co-requisites are clearly indicated on the Check Sheet and Flow Chart, and implied in the sample four-year curriculum charts in the Appendices. The Flow Chart and Check Sheet are available to download separately at: https://mems.duke.edu/undergrad/degrees/planning.

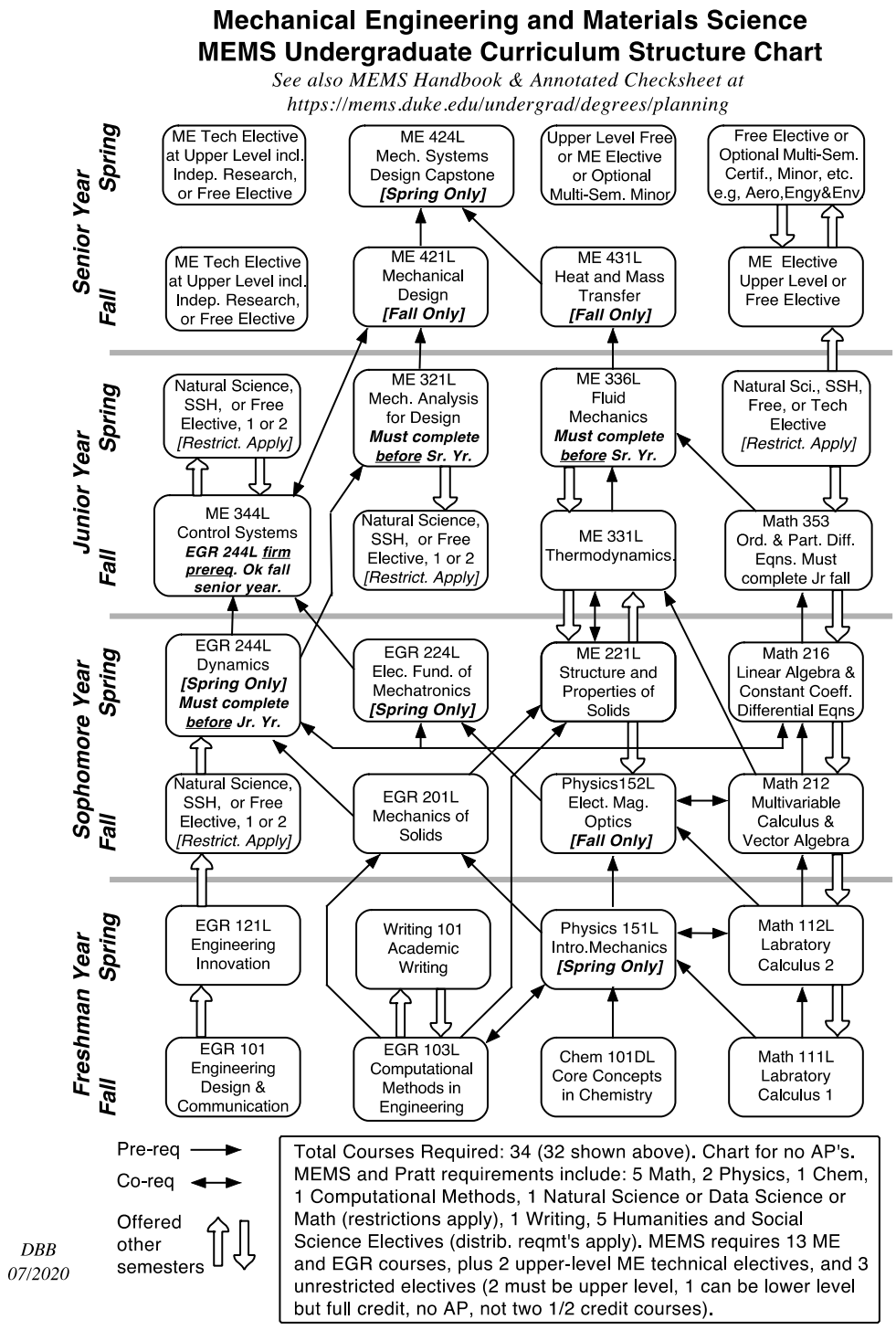

Figure 1 Mechanical Engineering Curriculum Flow Chart

Mechanical Engineering and Materials Science
Annotated Advising Check Sheet

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Name

		Date Taken	Grade	
	Writing			
1.	Writing 101			Required of all Duke 1st-yr students
	Mathematics and Natural Science			
2.	MATH 111L			5 Course Pratt Math Sequence.
3.	MATH 112			If 2 Math AP's, must still take at least 3 Math
4.	MATH 212			courses at Duke.
5.	MATH 216 (Math 218 may substitute w/ approval)			
6.	MATH 353			Complete MATH 353 by fall semester of junior year
7.	CHEM 101DL *[or AP CHEM 20/21 (18/19)]*			
8.	PHY 151L *[or AP PHY 25] Freshman Spring.*			Must take 1 PHY course post-matriculation. If AP
9.	PHY 152L *[or AP PHY 26] Soph. Fall (before EGR 224L)*			credit for BOTH PHY 25 & 26, then take PHY 153L,
10.	Natural Science or Data Science or Math Elective*			or DUS-approved higher level PHY course to satisfy. This WILL NOT also satisfy the NS elective.*
	Engineering			
11.	EGR 101L *take in fall of 1st year, if possible*			Required of all Pratt 1st yr students
12.	EGR 103L *take in 1st year (CS 201 is an option)*			Digital Computation taken by all Pratt 1st yr students
13.	EGR 121L *take in 2nd semester of 1st yr, if possible*			Req'd for MEMS (if not, 3rd ME Tech. Elective Req'd)
14.	EGR 201L *prereq for EGR 244L, EGR 221L, ME 321L*			
15.	EGR 244L** *prereq for ME 336L & other junior courses*			SPRING ONLY – Must complete before junior year!
16.	ME 221L *req'd prereqs: CHEM & EGR 201L*			Must complete before senior year!
17.	EGR 224L*** *prereq for ME 344L*			SPRING ONLY
18.	ME 344L *** *prereq for ME 424*			
19.	ME 331L *prereq for ME 336*			Must complete before senior year
20.	ME 336L *prereq for ME 431L*			Must complete before senior year
21.	ME 321L **** *prereq for ME421L*			Must complete before senior year
22.	ME 421L **** *prereq for ME 424L*			FALL SENIOR YEAR ONLY
23.	ME 431L prereq for *ME 424L*			FALL SENIOR YEAR ONLY
24.	ME 424L **** *Capstone Design*			SPRING SENIOR YEAR ONLY
25.	400-level ME Technical elective 1 § _____			
26.	400-level ME Technical elective 2 § _____			

		Area		
	Humanities and Social Sciences			
27.	_____			Five required. At least one SS and 2 from remaining
28.	_____			Areas of Knowledge (FL, CZ, ALP). For depth, two
29.	_____			must be from the same department, and one of
30.	_____			those must be at the 200 level or higher. Combined
31.	_____			limit of 2 AP's and S/U courses only offered on an S/U basis here. Enter course Area of Knowledge.
	Upper-Level General Electives §§ (Two required)			
32.	_____			No AP's here. Not necessarily engineering. Can also
33.	_____			satisfy certificates, minors, 2nd major requirements.
	General Elective §§§			
34.	_____			Full credit course only. No AP's. No ½ half credit courses allowed here.

* Approved Natural Science courses are found on the MEMS website, see the ME Handbook, including BIO 311, 215L; CHEM 210DL; EOS 201L, 212, 315, 322, 364, 365; PHY 153L, 175, 305; alternatives and higher Math courses require DUS approval. EGR Data & Decision Science approved for the Natural Science Elective.

** Firm Requirement: all ME students must complete EGR 244L Dynamics before rising to junior year.

*** 2-semester Mechatronics sequence. EGR 224L (only taught in Spring) is a firm pre-requisite for ME 344L Control Systems

**** 3-semester Mechanics & Design sequence. ME 321L Mechanical Analysis must be taken junior year as a firm pre-req for ME 421L (Fall only) which is a firm prerequisite for ME 424L Capstone Design (Spring only).

§ Courses must be at 400 level or higher. Independent Study Counts, if ME faculty advisor. Exception: Independent Study ME 393 taken during junior year can count as an upper level ME Technical Elective. Sophomore level independent study does not count. 300 level ME courses taking abroad in JR & SR year count with DUS approval.

§§ HSS electives at the 200-level or higher may be used. Upper level engineering electives can be used, as can additional math and science electives. For each such case enter in this space the course title and course number to indicate level.

§§§ Applies to students entering 2018 and later. Students prior to 2018, who did not take EGR 101L, are allowed two general electives.

Revised Fall 2020 ***DBB***

Table 1: Mechanical Engineering Annotated Check Sheet

Majoring in Mechanical Engineering – Advice, Milestones, and Important Things to Know

Overview

The Mechanical Engineering curriculum provides an in-depth education in four broad primary engineering areas: mechanics, computational methods, and design; dynamics, control, and robotics; thermal and fluid sciences including energy and aerospace; materials science and biomaterials. There are thirteen required engineering courses (having either EGR or ME designations) all with laboratories, plus a requirement of at least two upper level ME electives. Students must also complete the overall Pratt School of Engineering requirements of nine courses in Mathematics and Science. These departmental and school requirements were listed earlier beginning on page 8.

Students considering ME should be aware that the underlying structure of the ME curriculum differs from the curricula in other Pratt engineering departments. In the other departments students typically take a set of common core courses, unique to each department, and then choose from several "tracks" to specialize based on their specific area of interest. The pedagogical philosophy in ME is to provide a broad educational experience and to avoid over-specialization at the undergraduate level. ME students have ample opportunity to pursue their special interests in their choice of ME elective courses. In fact, their broad exposure from required courses can lead to more informed choices for areas of special interest. Our approach provides students with the broad knowledge, in-depth understanding, and versatility to deal with modern engineering systems, which are both complex and require multi-disciplinary skills.

ME Curriculum Structure and Rules

It is important to understand that ME has a *structured* curriculum, meaning that courses are to be taken in a prescribed sequence, with enforcement of prerequisites. This approach allows instructors to assume a certain level of knowledge coming into their courses. Students must understand that it is their professional responsibility to have command of the material in prior courses.

In practice, there is some flexibility in the enforcement of prerequisites. For some course sequences, a pre-requisite course can be treated as a co-requisite, but only if there is a compelling reason in the student's broader educational interest, or particular circumstances. The decision on these special cases is made by the Director of Undergraduate Studies (DUS), or the Associate DUS, who have access to the student's overall situation, and <u>not</u> by the course instructor or the student's academic advisor. Such decisions are always made in consultation with the student's Pratt academic Dean. Students should never deviate from the planned curriculum without formal approval; to do so can jeopardize their opportunity to continue in Mechanical Engineering. If a given student has been allowed an exception due to their circumstance, other students should never infer that a similar exception can apply for them. Furthermore, certain ME prerequisite sequences are "locked" because the courses are designed as a closely-coupled multi-semester sequence where indepth knowledge of the earlier course is assumed; no exceptions are made.

Specifically, the firmly locked sequences are:

- Physics 151L Mechanics (Freshman Spring only) or AP before EGR 244L Dynamics (offered Sophomore Spring; physics mechanics is a prerequisite)
- Physics 152L Electricity and Magnetism (Sophomore Fall only) or AP before EGR 224L Mechatronics (Sophomore or Junior Spring only; physics E&M is a prereq.). EGR 224L can be replaced by the pair of ECE 110L and ECE 280L. ECE 110L and BME 270L can substitute for EGR 224L for BME/ME double majors
- EGR 244L Dynamics (offered spring of Sophomore year only) is firmly required of all majors before advancing to junior year in ME. No exceptions beyond an approved summer course with lab makeup at Duke.
- EGR 224L Mechatronics (offered spring only, Sophomore or Junior year) before ME 344L Control Systems.
- ME 321L Analysis for Design (Fall or Spring Junior year) before ME 421L Mechanical Design (Senior Fall only) is firmly required of all majors before advancing to Senior year in ME.
- ME 421L Mechanical Design before ME 424L Systems Design (Senior Spring only). No exceptions, this is a two term Capstone Design sequence with senior design projects started in fall and finished in spring.

Freshman Year

This first year of college is a time of intellectual and personal growth. Important keys to success are learning to understand material in-depth, and developing good time management and study habits. Engineering is a profession, and this is the time to begin building a mental knowledge base and physical reference library, recognizing that what you learn at each step along the way must be retained, and everything builds on what came before.

During freshmen year, the academic focus is on courses in science and mathematics, and on engineering design. All Pratt freshmen are required to take EGR 101L Engineering Design and Communication. Included in this excellent multi-faceted course is a semester-long design project. Students work in small teams with a mentor to satisfy the needs of customers.

Following this course, Mechanical Engineering requires a hands-on ME-skills-focused design course EGR 121L Engineering Innovation. Pedagogically this course is structured so that every student acquires a broad range of skills to help advance successfully in our curriculum. It includes covers conceptualization, communication, fabrication, and multiple design project challenges, while teaching skills such as Computer Aided Design (CAD) skills, 3-D printing, and much more. This course is an introduction to many aspects of mechanical engineering, and it is taught with a hands-on project-based emphasis.

EGR 121L Engineering Innovation is required for Mechanical Engineering majors, usually taken in spring of freshman year. The course can also be taken sophomore year, if need be, but not thereafter. Students who are unable to take EGR 121L through some circumstance, such as late transfers into ME, must take an additional upper-level ME elective in its place, and must learn SolidWorks CAD on their own prior to taking the junior level course ME 321L Analysis for Design during junior year.

Good activities, beyond academic classes and labs, are student clubs related to engineering, e.g. the Duke Motorsports, Eco-Marathon competition, student chapters of the American Society of Mechanical Engineers (ASME) and the American Institute of Aeronautics and Astronautics (AIAA), and many others. These activities allow freshmen to meet, interact with, and learn from upper-class engineering students, helping them become part of the Pratt community. Keep in mind that it is better to contribute substantially to one or two extra-curricular activities in depth, than to join too many things and be spread too thin.

Freshmen sometimes express interest in early involvement with a research lab, which is certainly possible, but often not preferable to club activities, and should not take priority over course work. Research lab participation is often more rewarding later when a student has more relevant technical background, appropriate skills, and intellectual maturity.

Sophomore Year

Beyond the next courses in Physics and Mathematics, key sophomore courses for Mechanical Engineers are EGR 201L Mechanics of Solids in the fall, which is a prerequisite for the foundational ME courses EGR 244L Dynamics and EGR 224L Mechatronics.

Important: EGR 244L Dynamics and EGR 224L Mechatronics are only offered in the spring, and they are prerequisites for junior level ME courses. Students whose circumstances prevent them from taking either EGR 244L or EGR 224L should consult their Academic Dean and the ME DUS to make an approved alternate plan, before the beginning of their sophomore spring semester; failure to do so can jeopardize future progress in the major. EGR 244L or an equivalent must be completed before rising to junior year.

In some circumstances EGR 224L Mechatronics can be delayed until spring of junior year, but the student must then take ME 344L Control Systems during the fall of senior year. These courses are never taken concurrently because Mechatronics and Controls form a two-semester locked sequence, with the material from Mechatronics assumed for Controls.

Students who are somewhat ahead due to AP credit should consider taking ME 221L Materials, or ME 331L Thermodynamics during sophomore year, or perhaps fulfill the MEMS/Pratt Natural Science requirement, described elsewhere.

Since ME students who study abroad usually do so the first semester of junior year, planning needs to occur during sophomore year; refer to the Study Abroad information beginning on page 22 of this handbook for details and advice.

Junior Year

By the end of junior year students should have completed the ME courses in Thermodynamics, Fluid Mechanics, Analysis for Design, Materials, and usually Control Systems. These ME courses are all offered in both Fall and Spring to provide scheduling flexibility for a variety of needs, including the possibility of a Study Abroad semester (equivalents of some of these courses may be taken abroad with prior approval). Students must have completed all required ME courses except for senior Heat Transfer and the two-semester senior design sequence; the only possible exception being Controls, when Mechatronics is taken during junior spring.

During junior year majors will likely take at least one ME elective. Students who are interested in an in-depth independent study experience can initiate that process by applying to become a Pratt Fellow, starting work in the spring semester, or perhaps by taking Independent Study under the supervision of an ME advisor; a subsequent section discusses this possibility in detail. Important information and advice on independent study is provided in a later section.

During junior year, many ME majors plan their activities for the following summer by arranging for paid internships or summer jobs in a wide variety of companies, institutions and laboratories. Assistance is available through the Duke Career Center. Particularly desirable internships are competitive and often involve an interview process, so it is advisable to start planning during the fall semester.

Senior Year

During fall of senior year, all ME students must take the required courses ME 431L Heat Transfer and ME 421L Mechanical Design. In addition to required courses, technical electives are also taken during senior year, and these are an excellent opportunity to pursue specific interest areas in depth through course selection or independent study.

During spring of senior year all students must take the capstone course ME424L Mechanical Systems Design. The two-semester senior design sequence, ME 421L Mechanical Design and ME 424L System Design, constitutes a very substantial applied hands-on experience spanning more than a semester as they work in small teams; a variety of different projects are represented.

Note that the design courses can only be taken sequentially. Senior design teams are formed and projects are identified and initiated in the fall, and projects are completed in the spring. Design teams comprised of 4 to 6 students undertake a wide variety of projects. The MEMS philosophy for senior capstone design is that projects must be *engineered* and *analyzed* utilizing skills acquired in the student's prior education; these are not just construction projects. Detailed information about senior design, including sample reports, is found on the website:

http://www.mems.duke.edu/undergrad/senior-design.

Students are advised that senior year is often quite busy, even beyond the demands of advanced course work, since it is also the time for planning the future beyond Duke. Graduate school applications, and graduate fellowship applications are typically due in the second half of the fall semester, and proper preparation can take considerable time. Similarly, job interviews take place in both fall and spring semesters, and these often involve travel to potential job sites. Students need to communicate with their instructors about any travel that may impact course attendance, and understand that it is their responsibility (and not the instructor's) to deal with the situation and schedule accordingly.

Fulfilling Requirements for Graduation

During their undergraduate education, ME students should be careful to understand their curriculum requirements, stay on track, and be in touch regularly with their ME Advisor and their specified Pratt Academic Dean. Certain matters are subject to DUS approval, and students should be sure to engage the DUS when needed. The Academic Deans and the Directors of Undergraduate Study work closely together. A definitive review of student completion of major requirements by the DUS and the Deans is undertaken before the second semester of senior year. Prior to graduation, the DUS certifies each

student's record. Approval for second majors, minors, and certificates is the responsibility of the DUS or Coordinator in the appropriate department, and not the responsibility of the ME DUS.

Independent Study and Pratt Fellows Program

MEMS students can take independent study courses for academic credit during junior and senior year, when they can count as upper level ME electives. To count as an ME elective (ME 39x or ME 49x) there is a firm rule that the project must have an advisor on the MEMS faculty, and the project must have substantial upper-level Mechanical Engineering content. If the ME faculty member advising a project agrees, Independent Studies can be taken during the sophomore year, but under an EGR number, without counting as an upper-level ME elective.

The upper-class years are the best time to undertake such activities, since the student has more intellectual maturity and a broader set of engineering skills to bring to the project. Many ME independent studies are research related, although many have a significant design component.

There are several educational benefits to doing an independent study project. Beyond learning new project-related material, such projects typically require the student to draw on knowledge from a range of engineering disciplines, very similar to the work experience of professional engineers. Independent projects typically pose more complex problems than found in a typical course setting, often with several viable solutions. Working with a faculty mentor is also an opportunity to get to know them personally, observe their thinking process and problem solving strategies, and likely see creative approaches being developed. The greatest gain occurs when both the student and the advisor share a strong commitment to the project. There is the added benefit that building a relationship with your advisor will provide a valuable reference for applications to graduate school and for employment.

There are two types of opportunities: ME independent study taken on a semester by semester basis; and the Pratt Fellows program which typically involves a (paid) summer commitment. Each has advantages and disadvantages, depending on the needs of the particular student.

ME Independent work usually takes place during the fall-spring academic year, and may encompass a range of project types ranging from basic research activity to design and development projects. An advantage is more flexibility with regard to project type, and the summer is left free for other activities such as internships, which are often most beneficial in the summer after junior year. A disadvantage can be shorter project duration, so it is best to have the independent study extend over more than one semester, giving adequate time to pursue the project in depth. Students should feel free to approach faculty members, whether or not they already know them, about independent work opportunities in areas of interest. Within a general area, the faculty member is often the best person to define the specific project and set realistic goals.

The Pratt Fellows program involves a competitive selection process, and usually obligates the student to three academic semesters starting in the middle of junior year, plus a nine week paid summer commitment. Students apply to work on specific projects proposed by faculty in descriptive paragraphs. An advantage is that there is time for a very in-depth research experience, which can lead to a very positive experience. Such a strong research experience can be excellent preparation for graduate school. Disadvantages include being unavailable for a summer internship, and that there is a

considerable multi-semester time investment in one activity. On balance, the Pratt Fellows program is an excellent choice for students who wish to assess their interest and aptitude for in-depth research, and are planning to continue their education beyond the BSE degree.

Students are strongly advised to enter any type of independent study with a clear understanding of the overall level of commitment. It is important to have an up-front understanding with the faculty advisor/mentor about the following: project goals and schedule; basis for grading; expected number of hours per week; frequency of meetings; and whether the student will be working directly for the faculty member (usually best), or more for a postdoc or graduate student.

A common problem students experience with independent study projects is time management. Since the independent study is often the largest project the student has undertaken, there is a tendency to underestimate how much time and effort will really be required. Understandably, there is also a tendency to postpone project work due to short term deadlines in other courses. Without careful time management, the result can be a hasty ending to the project without fully achieving goals.

Finally, with regard to research projects, students are advised to consider the difference between working in a research lab as an assistant to a more experienced investigator, and actually doing research - the latter being the primary goal. One is doing research when sufficiently well versed in the activity to make intellectual contributions to the direction and allocation of human and material resources for the research effort. To make such contributions requires intellectual maturity and dedication to the activity.

Graduation with Departmental Distinction (GWDD)

The Graduation with Distinction Award is presented to the Pratt students who, in the opinion of the ME Department and a committee of the faculty, have demonstrated exceptional achievement in the areas of their special interest by conducting independent research and presenting the research project with a distinguished piece of writing and an oral presentation. ME students who have a final grade point average of 3.5 or higher and have taken an ME independent study senior year, or are participating in the Pratt Research Fellow Program, are eligible. Students who have successfully completed the GWDD requirements are individually cited at the Pratt School Graduation Ceremony.

A Mechanical Engineering student can receive Graduation with Departmental Distinction, which is designated on their final transcript, by satisfying the following requirements:

- GPA of at least 3.5 upon graduation
- Completion of an Independent Study during senior year for at least one full semester (preferably more), supervised by an MEMS faculty member (primary or secondary).
- Completion of a graduate level course (500-level or higher) broadly related to the project topic. Pratt Fellows with three in-depth semesters of study are not held to this requirement.
- Preparation of a professional quality paper written in specified format describing the work, to be evaluated by the MEMS Faculty GWDD Committee
- An oral presentation given to the MEMS Faculty GWDD Committee including a Q&A segment. A no-credit course is offered for assistance with the paper and presentation.

Specifically excluded from MEMS GWDD are projects done in groups, unless individual contributions can be clearly delineated, and the GWDD student's work can be identified as equivalent to a stand-alone independent contribution. Also not permitted is work completed prior to senior year, and work conducted off campus as part of a summer job or internship.

Second Major, Minor, and Certificate Programs

Opportunities exist for students with AP credits to combine the ME major with a second major, minor, or certificate, either from another Pratt Department, or from the Trinity College. (A certificate is similar to a minor, but offered for interdisciplinary study.) To do so, the students must meet the same requirements as those for the ME major plus the specific requirements from other departments/programs outlined in the Undergraduate Bulletin:

https://registrar.duke.edu/university-bulletins/undergraduate-instruction

The additional requirements usually consist of 10 courses for a second major, 5 courses for a minor, and 6 courses for a certificate. Some of these courses can be double-counted towards both the ME degree and the second major, minor or certificate in the Trinity College. For example, two courses required for the second major in economics may be counted as two of the five SSH courses required for the ME degree. To reduce the work load for obtaining the second major, minor, or certificate in the Trinity College during the regular academic semesters, students can either take the required Trinity courses as unrestricted electives in the ME curriculum or take them in the summer.

Some mechanical engineering majors complete an engineering certificate, such as the Aerospace Certificate (hosted by the ME department), or other certificates in Pratt, such as Architectural Engineering (hosted by the CEE department), or a university-wide Energy and Environment Certificate. Also available are engineering minors in Electrical & Computer Engineering and in Energy Engineering. A few students complete a second major in BME. Further information can be found by following links from the MEMS departmental website, from the individual websites of other Pratt departments and programs, from the Pratt School of Engineering website, or from the overall Duke University website.

Whether considering a certificate, minor, or second major, students are advised to reflect carefully on their motives and long term objectives, because such decisions place constraints on their overall educational experience. In many cases a better educational outcome can be obtained by judiciously selecting courses in areas of interest beyond the primary major.

For second majors within engineering, students are strongly advised to discuss the requirements, details, and potential issues with the Directors of Undergraduate Study of both departments (see departmental websites for DUS contact information).

Contact Information for Certificates and Minors:

Aerospace Engineering Certificate: Dr. Bliss (dbb@duke.edu)

http://www.mems.duke.edu/undergrad/aerospace-engineering-certificate

Energy and the Environment Certificate: Dr. Knight (jknight@duke.edu)

http://gendell.pratt.duke.edu/academics/undergraduate-certificate

Electrical and Computer Engineering Minor: Dr. Huettel (lisa.huettel@duke.edu)

http://www.ece.duke.edu/undergrad/minor *See also ECE Undergraduate Program Handbook*

Energy Engineering Minor: Dr. Deshusses (marc.deshusses@duke.edu)

http://energy.pratt.duke.edu/

Aerospace Engineering Certificate Program

The Aerospace Engineering Certificate is hosted by MEMS, but open to all Pratt students. The Aerospace Certificate provides undergraduate students with an understanding of fundamental principles in the several disciplines including fluid mechanics and aerodynamics, dynamics and control, structures and materials, thermodynamics and propulsion, plus courses that address specific aerospace technologies for flight and space vehicles. In addition to coursework, the program offers upperclassmen opportunities for independent research for academic credit under the supervision of a faculty member affiliated with the program, either through Independent Projects under faculty supervision, or through the Pratt Fellows Program.

All engineering undergraduates are eligible to participate in the program and qualify for certification. Although MEMS is the host department, there is a concerted effort to engage students from other departments, and to provide flexibility to help majors in other departments meet the program standards while maintaining program focus and quality. Each upper class mechanical engineering student in the Aerospace Certificate Program has the option of being assigned an academic advisor who is affiliated with the program. Successful completion of the Aerospace Certificate Program is noted on the student's academic transcript.

The certificate program focuses on upper class courses. Seven Courses must be completed to earn Aerospace Engineering Certificate and the requirements are described in detail on the ME departmental website: http://www.mems.duke.edu/undergrad/aerospace-engineering-certificate. All students must take:

- ME 472 Aircraft Performance (the *cornerstone* course)
- Choose at least one course from a *restricted list*: Aerospace Structures, Compressible Flow, Aerodynamics, Mobile Powerplants, Engineering Acoustics
- Two additional *supplementary* technical courses broadly related to the Aerospace field are required. Both of which can be counted as the required upper-level ME electives if ME courses. Upper level Independent Study courses with an Aerospace emphasis can qualify as supplementary electives. Relevant technical courses in other areas of Engineering, or in Physics or Mathematics can be used subject to approval by the certificate coordinator. Some upper-level courses taken abroad can be used subject to prior approval.
- One upper-level course (200 level or above) offered by Trinity College is also required related to one of the following subjects: History applicable to the role of technology and science; Public Policy applicable to the use and impact of technology; or Economics applicable to large or international corporate structures. This Trinity course can also be used for part of the Pratt SSH requirement. Some appropriate courses taken abroad can be used subject to prior approval for the certificate, and approval by the appropriate Trinity DUS.

Materials Science Certificate Program

Beginning in the fall semester of 2021 the MEMS Department will host a Certificate in Materials Science. The requirements and course offerings, which are similar in scope to other certificates in the Pratt School of Engineering, are currently in the approval process.

Planning for Study Abroad

A number of ME students take the option to study abroad for a semester. In the vast majority of cases this takes place in the first semester of junior year. Many fewer students go in the second semester of junior year, and a few students go during the spring semester of their sophomore year to the Duke in Berlin program.

Fall junior year is the point where the MEMS curriculum has the most flexibility to accommodate students studying abroad, and at this point it is usually easiest to match courses abroad to MEMS required courses. Courses such as Thermodynamics, Materials, and Fluid Mechanics are fairly common to engineering curricula around the world, and these are often taken early junior year in the MEMS curriculum.

The Office of Global Education holds an information session on an evening in October, and all interested Pratt students, especially sophomores should attend. The session is announced in advance by email to Pratt students, and is held in a convenient location. Students who plan to study abroad should also have an individual meeting with staff from the Global Education Office. There are restrictions on grade point average and academic standing. Considerable advance planning is required, and it helps if the student is at least a little bit ahead due to AP courses.

Initial planning for study abroad should usually include more than one locale, country and university. Final planning should include multiple curricular choices since, unlike most US universities, sometimes courses at foreign universities are suddenly and unexpectedly withdrawn or subject to significant content change without warning.

MEMS students typically take two courses abroad related to the major. The remainder of courses taken abroad fulfill other requirements. No more than two courses can be taken in place of required ME courses. Alternatively, students may take one required course and one course equivalent to an upper level ME technical elective. In special cases, with approval of the Director of Undergraduate Studies (DUS), students may take two required courses plus one upper level ME elective. The latter case might occur when there is an opportunity to study a subject not normally offered at Duke, or a course to help fulfill a certificate requirement that goes beyond the basic ME curriculum. Note that the minimum of two required upper level ME electives cannot both be taken abroad, unless an additional upper level elective is taken at Duke. The approval of the MEMS DUS, not just the student's advisor, is required for all special cases.

The Office of Global Education (https://courseapproval.studyabroad.duke.edu/cgi-bin/study.pl) maintains a list of study abroad courses that have been pre-approved as equivalent to Duke courses. Any courses outside this list must be approved by the MEMS DUS if they are to satisfy requirements of the MEMS curriculum. Courses not related to MEMS requirements must appear either on the pre-approved list, or be pre-approved by the DUS in the appropriate Duke department.

To obtain approval from the DUS for a course not in the Global Education database, the following information is required: course title, descriptive paragraph, a detailed syllabus, the name and author of the required text(s), the year-level of the course at that university (e.g. taken by 3rd year students), and whether the course has a laboratory and, if so, how often it meets. Students are forewarned that while this information is usually fairly easy to obtain from US universities, it is often more challenging when dealing with foreign universities, and so it is important to start gathering this information in advance. The Global Education Office may be helpful if you encounter difficulty obtaining specific information for courses abroad. Please understand that the DUS will be unwilling to search for this information on your behalf, and needs to be presented with a complete package with easy access to all information (electronically or hard copy). Also note that there is no guarantee that a particular university will actually offer the desired courses, or that they are offered in the appropriate semester, so the student must adjust plans accordingly.

A particular problem for Mechanical Engineering students is the approach to teaching Thermodynamics and Fluid Mechanics at some universities abroad. At Duke, like most US universities, these courses are taught as separate entities, with Thermodynamics as a prerequisite for Fluid Mechanics, both taken before the end of junior year. Both are prerequisites for the Heat Transfer course taken senior year. At some foreign universities, the topics are taught in a mixed form, most commonly as a two-semester sequence called "Thermofluids", or sometimes with Fluids and Heat Transfer combined. Courses in such hybridized sequences are never approved as equivalent to Duke's Thermodynamics and Fluids courses. Furthermore, all MEMS students are required to take Heat Transfer at Duke first semester senior year.

Making up Labs after Study Abroad

The majority of ME required courses involve a laboratory component, hence the "L" following the number in the course designation. Often technical courses abroad do not have a laboratory component, or the "lab" is minimal or inadequate. In this common occurrence, the student must make up the lab component of the course upon return to Duke, during the next semester if at all possible. To do so, the student does not register for the Duke course, but rather contacts the instructor and arranges to attend one of the laboratory sections. MEMS faculty are familiar with this arrangement, but the student should contact the MEMS DUS if a problem arises. The student must participate in all laboratory aspects of the course, e.g. working in a lab group, taking and analyzing data, writing lab reports, etc. When the lab period is used for a non-laboratory purpose, such as homework help sessions, test review, testing, etc., then the student is not obligated to attend. At the end of the semester, the course instructor must send an email to the MEMS DUS and the student's Academic Dean stating that the student participated in and passed all aspects of the laboratory portion of the course. The instructor is not required to submit a letter grade. Only when this has occurred will credit for the study abroad course appear on the transcript.

4 + 1 BSE/MS Program (Five-Year Combined Bachelor/Master Degree Program)

The 4+1 Program offers a five-year option that is combines with the Bachelor of Science (B.S.E) and one of several masters level options: the Master of Engineering (M.Eng.); the Master of Engineering Management (MEMP); or the Master of Science (MS) degree in Mechanical Engineering. This program provides an excellent opportunity for students to go well beyond their undergraduate

education including additional course work, an option for an in-depth research experience, or to obtain advanced training in mechanical engineering combined with business-related courses. In addition to completing both degrees in five years, students do not pay the graduate tuition for their graduate courses taken in the senior year.

http://www.pratt.duke.edu/undergrad/degree-programs/bse-masters.

4 + 1 BSE/MS Program degree requires that students fulfill the standard degree requirements for Bachelor of Science plus an additional 30 units of upper level courses suitable for a graduate degree. (In the Graduate School, a 3-hour/week course is counted as 3 units.) Up to 15 graduate course units (5 graduate courses) out of the 30 units can be taken in the senior year, provided that these courses are not used to fulfill the Bachelor degree requirements and they are not Independent Study courses. If you complete two or more courses toward your MS degree before completing your senior year, you can easily complete the remaining graduate courses in one year beyond your BSE.

Students considering combined degree options should always consult the Undergraduate Academic Deans and the Directors of Graduate Study for specific programs to be sure that all requirements and constraints are clearly understood. To complete both Bachelor's and Master's degrees in five years:

- Develop course plans for your senior year and for one graduate year with your academic advisor and obtain Director of Masters Studies (DMS) approval.
- Take the GRE exam in the Fall of your Senior year.
- Apply for admission to the appropriate school during the Fall of your Senior year.

Apply online here (https://pratt.duke.edu/grad/apply), or apply directly to the Pratt School of Engineering for the M.Eng. or MEMP.

Advising

Assignment of ME advisors: Entering students who indicate an interest in Mechanical Engineering as their most likely major will be assigned an ME faculty member as an advisor for their undeclared freshmen year. After declaring ME as their major, the student's advisor can be reassigned, at the request of the student, otherwise the student will retain the same faculty advisor until graduation. In order to declare the major, students complete an online form, including the opportunity to express certain interest areas, go to: https://pratt.duke.edu/undergrad/students/policies/3494
This website can also be used to declare second majors, minors, and certificates.

When possible, the assignment of ME faculty advisors is based upon the interests expressed by the students (e.g., aerospace, energy, materials science, etc.), although the need to balance the number of advisees per faculty is also a consideration. Each ME faculty member advises an average of fifteen students. A student is always welcome to request a change of advisor from the DUS if they desire.

Each semester the student must meet with their faculty advisor in order to be eligible to enroll in classes for the subsequent semester. During the advising meeting, the student should discuss any concerns or problems that he/she is having academically, receive approval of the course schedule for the next semester, and initiate conversations about the field of mechanical engineering that he/she

may be interested in exploring further and/or career options within a particular field of mechanical engineering. The advisor also reviews the student's academic report and maintains a record of the student's current academic plan. The student is responsible for informing the advisor of any changes in the plan. The student should be sure the advisor knows of any special problems, including personal issues or circumstances, that may affect academic performance or be of concern to their well-being.

To schedule an appointment with your advisor, using email is the best approach. During advising for course selection before registration, your advisor may contact you by email or place a sign-up sheet on his/her office door.

The Advisor, the Director of Undergraduate Studies, and the Academic Deans: The Faculty Advisor is the primary contact point for the student, and most routine matters can be handled at that level. The role of the DUS is to set overall academic policy for MEMS, and to deal with special issues unique to individual students, including approvals for academic content of courses taken elsewhere, special circumstances involving modification of prerequisite rules, etc. The Academic Deans serve as a further resource to the student, and work in concert with the DUS on a variety of matters. Students wishing to develop a long term curricular plan should meet with the appropriate academic dean. The academic deans also deal with matters of credit transfer, academic difficulty, disciplinary matters, student wellness, etc.

At the departmental level, students are always welcome to provide the DUS with constructive feedback about the curriculum and their overall educational experience in Mechanical Engineering.

Freshman Advising: In addition to individual meetings with faculty advisors, freshmen interested in ME are invited to an orientation presented by the ME Director of Undergraduate Studies (DUS) in the fall of their first year. The presentation covers the degree requirements, commonly asked questions, and an overview of departmental activities related to the undergraduate experience. The other Pratt departments hold similar sessions.

Career advising: Students can discuss their career plans with their advisors, and with other departmental faculty. In addition, the Duke University Career Center is available for career advising and assistance with job searches for summer internships and/or permanent employment. http://studentaffairs.duke.edu/career

Information on Internships, Employment, and Graduate School Opportunities

Information on internship and employment opportunities is posted on the website of the Duke University Career Center: http://www.studentaffairs.duke.edu/career. Located in Smith Warehouse at 114 S. Buchanan Blvd, Bay 5, the Career Center organizes various career-related activities. These include (a) career advice sessions, (b) industrial interview events, (c) graduate school recruiting events, and (d) workshops and seminars on internship and employment that are specific for engineering. The Career Center provides career advising for STEM undergraduates and hosts career skills workshops and industry programming in those fields and are announced via emails and posted on the TV monitors in the engineering buildings.

In addition to the Career Center, the Director of Industry and Corporate Relations, Kirsten Shaw (kirsten.shaw@duke.edu), can help Pratt students connect with corporations for internship opportunities. For more information, see https://studentaffairs.duke.edu/career/jobs-internships

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When information on internships, employment, and/or graduate school opportunities is sent directly to the ME faculty or the department, the information is distributed to ME students (declared) via emails or posted on the bulletin board outside the ME departmental office in Hudson Hall.

It should be noted that student co-op activities that entail taking a semester off during the academic year are rare among Duke students, although common at some other universities, particularly state schools. The Pratt School of Engineering does not have a co-op program. The vast majority of Duke engineering students complete their degree in four years, and the curriculum is structured on this assumption. Stepping away from this can create significant challenges. Summer internships provide the most common applied industrial exposure for Duke students.

APPENDICES

The following Appendices provide sample tables for the major, a certificate, and second majors, in addition to a list of allowable Natural Science Electives, and a list of allowable SSH departments and programs. All tables assume no AP credit, unless otherwise noted.

APPENDIX 1

Table A1

ME Major

Freshman Year	
Fall Semester	**Spring Semester**
Chemistry 101DL Core Concepts in Chemistry	EGR 121L Engineering Innovation
EGR 103L Computational Methods in Engineering	Math 112L Introductory Calculus II
Math 111L Introductory Calculus I	Physics 151L Introductory Mechanics[1]
EGR 101L Engineering Design and Communication	Writing 101
Sophomore Year	
Fall Semester	**Spring Semester**
EGR 201L Mechanics of Solids	ME 221L Intro to Material Science or Elective[4]
Math 218 Linear Algebra[2]	EGR 224L Mechatronics
Physics 152L Intro Electric, Magnet, Optics[1]	EGR 244L Dynamics
Social Science or Humanities Elective	Math 212 Multivariable Calculus[2]
Junior Year	
Fall Semester	**Spring Semester**
Elective[4] or ME 221L Intro to Material Science (or spring)	ME 336L Fluid Mechanics
Math 353 Ordinary and Partial Differential Eqn[2]	Natural Science Elective[3]
ME 344L Control of Dynamic Systems (or in spring)	ME 321L Analysis for Mechanical Design (or in fall)
Social Science or Humanities Elective	Elective[4]
ME 331L Thermodynamics	Elective[4]
Senior Year	
Fall Semester	**Spring Semester**
ME 421L Mechanical Design	ME 424L Mechanical Systems Design
ME 431L Heat and Mass Transfer	Mechanical Engineering Elective
Mechanical Engineering Elective	Social Science or Humanities Elective
Social Science or Humanities Elective	Elective[4]

1. See also the Physics requirements on pp. 9.

2. Students with ME/Math second-major need to take Math 221/ 222/356 in place of Math 212/218/353. Students who start the Math second major sequence are not allowed to switch back to the engineering sequence shown in Table 1 above.

3. Selected from the Natural Science Electives listed in Appendix Table A7.

4. Two of these 3 Electives must be at the 200-level or above. One can be at any level, but must be a single full-credit course taken at Duke (not an AP)

5. Social Science or Humanities Electives must fulfill requirements as specified on pp. 10 and choose courses from the list of departments allowed by Pratt, see Appendix 8 Table A8

APPENDIX 2

Table A2

ME Major with Aerospace Certificate

Freshman Year	
Fall Semester	**Spring Semester**
Chemistry 101DL Core Concepts in Chemistry	EGR 121L Engineering Innovation
EGR 103L Computational Methods in Engineering	Math 112L Introductory Calculus II
Math 111L Introductory Calculus I	Physics 151L Introductory Mechanics[1]
EGR 101L Engineering Design and Communication	Writing 101
Sophomore Year	
Fall Semester	**Spring Semester**
EGR 201L Mechanics of Solids	ME 221L Intro to Material Science or Elective[4]
Math 218 Linear Algebra[2]	EGR 224L Mechatronics
Physics 152L Intro Electric, Magnet, Optics[1]	EGR 244L Dynamics
Social Science or Humanities Elective[5]	Math 212 Multivariable Calculus[2]
Junior Year	
Fall Semester	**Spring Semester**
Core Aero Elective	ME 336L Fluid Mechanics
Math 353 Ordinary and Partial Differential Eqn[2]	Natural Science Elective[3]
ME 344L Control of Dynamic Systems	ME 321L Analysis for Mechanical Design (or in fall)
Social Science or Humanities Elective[5]	ME 472 Aircraft Performance (Required Course for Aero Cert.)
ME 331L Thermodynamics	Elective[4] or ME 221L Intro to Material Science
Senior Year	
Fall Semester	**Spring Semester**
ME 421L Mechanical Design	ME 424L Mechanical Systems Design
ME 431L Heat and Mass Transfer	Supporting Engineering Elective for Aerospace Certif.
Supporting Engineering Elective for Aerospace Certif.	Social Science or Humanities Elective[5]
Social Science or Humanities Elective[5]	Elective

1. See also the Physics requirements on pp. 9.

2. Students with ME/Math second-major need to take Math 221/ 222/356 in place of Math 212/218/353. Students who start the Math second major sequence are not allowed to switch back to the engineering sequence shown in Table 1 above.

3. Selected from the Natural Science Electives listed in Appendix 7-Table A7.

4. Two of these 3 Electives must be at the 200-level or above. One can be at any level, but must be a single full-credit course taken at Duke (not an AP)

5. Social Science or Humanities Electives must fulfill requirements as specified on pp. 10 and choose courses from the list of departments allowed by Pratt, see Appendix 8-Table A8. One SSH Elective must meet Trinity course requirement for the Aerospace Engineering Certificate, see page 21.

APPENDIX 3

Table A3

ME Major with BME 2nd Major (note 38 courses required)

Freshman Year	
Fall Semester	**Spring Semester**
Chem 101DL Core Concepts in Chemistry	Bio 201L Gateway to Biol: Molecular Biology
EGR 103L Computational Methods in Engineering	Math 112L Introductory Calculus II
Math 111L Introductory Calculus I	Physics 151L Introductory Mechanics[1]
EGR 101L Engineering Design and Communication	EGR 121L Engineering Innovation
	Writing 101
Sophomore Year	
Fall Semester	**Spring Semester**
BME 244L Quant Physiology with Biostat Appl	BME 253L Biomed Electronics and Measurem I **or** ECE 110L Fund Electr and Comput Eng
EGR 201L Mechanics of Solids	ME 221L Structure and Properties of Solids or BME 221L
Chem 210DL Mod Apps Chem Principles **or** Chem 201DL Organic Chemistry	Math 212 Multivariable Calculus
Math 218 Linear Algebra	EGR 244L Dynamics
Physics 152L Intro Electric, Magnet, Optics[1]	Social Science or Humanities Elective
Junior Year	
Fall Semester	**Spring Semester**
BME 260L Modeling Cellul and Molecul Systems	ME 336L Fluid Mechanics
BME 271 Signals and Systems **or** ECE 280L (54L)	BME 354L Biomed Electronics and Measurement II
Math 353 Ordinary and Partial Differential Eqn	BME 302L Fund Biomechanics/Biomaterials
ME 331L Thermodynamics	Life Science Elective[2]
ME 321L Analysis for Design	
Senior Year	
Fall Semester	**Spring Semester**
ME 421L Mechanical Design	ME 424L Mechanical Systems Design[3]
ME 431L Heat and Mass Transfer	Mechanical Engineering Elective
ME 344L Control of Dynamic Systems	Biomech/Biomat Area Elective
Mechanical Engineering Elective	Social Science or Humanities Elective
Social Science or Humanities Elective	Social Science or Humanities Elective

1. See also the Physics requirements on page 9.

2. See BME Handbook, Table 3B, page 33

3. ME 424L with BME project.

APPENDIX 4

Table A4

ME Major with Energy and the Environment Certificate

Freshman Year	
Fall Semester	**Spring Semester**
Chemistry 101DL Core Concepts in Chemistry	EGR 121L Engineering Innovation
EGR 103L Computational Methods in Engineering	Math 112L Introductory Calculus II
Math 111L Introductory Calculus I	Physics 151L Introductory Mechanics[1]
EGR 101L Engineering Design and Communication	Writing 101
Sophomore Year	
Fall Semester	**Spring Semester**
EGR 201L Mechanics of Solids	ME 221L Intro to Material Science or E&E Elective[4]
Math 218 Linear Algebra	EGR 224L Mechatronics
Physics 152L Intro Electric, Magnet, Optics[1]	EGR 244L Dynamics
Social Science or Humanities Elective	Math 212 Multivariable Calculus[2]
ENVIRON 330 Energy and Environment	
Junior Year	
Fall Semester	**Spring Semester**
E&E Elective[4] or ME 221L Intro to Material Science	ME 336L Fluid Mechanics
Math 353 Ordinary and Partial Differential Eqn[2]	Natural Science Elective[3]
ME 344L Control of Dynamic Systems	ME 321L Analysis for Mechanical Design
Social Science or Humanities Elective or E&E Elective[4]	E&E Elective[4] or Social Science or Humanities Elective
ME 331L Thermodynamics	
Senior Year	
Fall Semester	**Spring Semester**
ME 421L Mechanical Design	EGR 424L Energy and Environment Design[7]
ME 431L Heat and Mass Transfer	Mechanical Engineering Elective
Energy Science/Technology Elective[6]	Social Science or Humanities Elective
Social Science or Humanities Elective	E&E Elective[4]

1. See also the Physics requirements on pp. 9.

2. Students with ME/Math second-major need to take Math 221/ 222/356 in place of Math 212/218/353. Students who start the Math second major sequence are not allowed to switch back to the engineering sequence shown in Table 1 above.

3. Selected from the Natural Science Electives listed in Appendix Table A7.

4. Two of these 4 Electives must be at the 200-level or above. Energy and Environment (E&E) Electives may be used to satisfy this Elective requirement.

5. Social Science or Humanities Electives must fulfill requirements as specified on pp. 10 and choose courses from the list of departments allowed by Pratt, see Appendix 8 Table A8. E&E Electives that are from SSH departments could be used toward the SSH requirement. Careful planning could lead to as many as two courses that count in both categories.

6. Chosen to satisfy Mechanical Engineering Elective criteria.

7. EGR 424L Energy and the Environment Design. ME 424 may be substituted if a qualified energy design project is approved by the Certificate Director.

APPENDIX 5

Table A5. ME Major with Energy Engineering Minor

Freshman Year	
Fall Semester	**Spring Semester**
Chemistry 101DL Core Concepts in Chemistry	EGR 121L Engineering Innovation
EGR 103L Computational Methods in Engineering	Math 112L Introductory Calculus II
Math 111L Introductory Calculus I	Physics 151L Introductory Mechanics[1]
Writing 101 or Social Sci or Humanities Elective	Social Science or Humanities Elective or Writing 101
Sophomore Year	
Fall Semester	**Spring Semester**
EGR 201L Mechanics of Solids	ME 221L Intro to Material Science
Math 212 Multivariable Calculus[2]	EGR 224L Mechatronics
Physics 152L Intro Electric, Magnet, Optics[1]	EGR 244L Dynamics
Social Science or Humanities Elective	Math 216 Linear Algebra and Differential Eqn[2]
	Social Science or Humanities Elective
Junior Year	
Fall Semester	**Spring Semester**
ENRGYEGR Elective[4]	ME 336L Fluid Mechanics
Math 353 Ordinary and Partial Differential Eqn[2]	Natural Science Elective[3]
ME 344L Control of Dynamic Systems	ME 321L Analysis for Mechanical Design
ME 461 Energy Engineering and the Environment	ENRGYEGR Elective[4]
ME 331L Thermodynamics	Social Science or Humanities Elective
Senior Year	
Fall Semester	**Spring Semester**
ME 421L Mechanical Design	EGR 490L Energy Design Capstone[6]
ME 431L Heat and Mass Transfer	Mechanical Engineering Elective
Mechanical Engineering Elective	Social Science or Humanities Elective
ENRGYEGR Elective[4]	ENRGYEGR Elective[4]

1. See also the Physics requirements on pp. 9.

2. Students with ME/Math second-major need to take Math 221/ 222/356 in place of Math 212/218/353. Students who start the Math second major sequence are not allowed to switch back to the engineering sequence shown in Table 1 above.

3. Selected from the Natural Science Electives listed in Appendix Table A7.

4. Energy Minor Electives must be chosen to satisfy the current minor distribution requirements. Electives could also count as the Upper-Level Electives and/or Unrestricted Electives, in accordance with ME elective rules.

5. Social Science or Humanities Electives must fulfill requirements as specified on pp. 10 and choose courses from the list of departments allowed by Pratt, see Appendix 8 Table A8.

6. EGR 424L Energy Design Capstone. ME 424L may be substituted if a qualified energy design project is approved by the minor director.

APPENDIX 6

Table A6. ME Major with ECE Minor

ME Major with the Electrical and Computer Engineering Minor

The basic requirements for a minor in ECE *(see also ECE Handbook)* include three courses at the foundational/core level and two upper-level courses. Below are major specific modifications (e.g., courses that are disallowed for the Minor in ECE because students are required to take essentially equivalent courses for their primary major).

ME Major/ECE Minor: Path #1 -- If EGR 224L has been taken, then:

- **Core courses (choose at least one and up to three)[1]:**
  - ECE 230L Microelectronic Devices & Circuits
  - ECE 250L Computer Architecture
  - ECE 270L Electromagnetic Fields
- **Upper-Level Courses:** take a minimum of two upper-level courses[2]. Student may choose to replace up to two (of three) ECE courses with additional upper-level ECE courses to meet the minimum requirement of 5 ECE courses.

1. *An ME major cannot take ECE 110L or ECE 280L, however, EGR 224L will satisfy prerequisites in lieu of ECE 110L and ECE 280L.*
2. *Because the ME major requires courses essentially equivalent to ECE 110L and ECE 280L, a student majoring in ME can choose to reduce the number of ECE core courses taken to fulfill Minor requirements to as few as one, and take additional upper-level courses to meet the minimum requirement of 5 ECE courses.*

ME Major/ECE Minor: Path #2 -- If ECE 110L has been taken, then:

- Student should take ECE 280L in lieu of EGR 224L to satisfy ME major requirement, but ECE 280L will not count toward the ECE minor.
- **Core courses (choose at least two, and up to three):**
  - ECE 110 Fundamentals of ECE
  - ECE 230L Microelectronic Devices and Circuits
  - ECE 250L Computer Architecture
  - ECE 270L Electromagnetic Fields
- **Upper Level Courses**: take a minimum of two upper-level courses[1]. Students may choose to replace one (of three) ECE core courses with an additional upper-level ECE course to meet the minimum requirement of 5 ECE courses.

[1] *Because the ME major requires a course essentially equivalent to ECE 280L, a student majoring in ME can choose to reduce the number of ECE core courses taken to fulfill Minor requirements to as few as two, and take additional upper-level courses to meet the minimum requirements of 5 ECE courses.*

APPENDIX 7

Table A7. MEMS Approved Natural Science Courses for Mechanical Engineering Majors

Higher level courses in these areas are subject to DUS Approval

(Note: A Trinity NS code does NOT apply to the Pratt Natural Science Requirement)

Course No.	Title	Description
MATH 238L C-L EGR 238L	Data Analysis and Decision Science	A mathematically rigorous and broad foundation for key concepts in probability and statistics, as well as the application of probability and statistics to the mathematical modeling of non-deterministic systems. The main motivation of the course is to show how these concepts are fundamental to a variety of current data analysis techniques, and to demonstrate applications of these techniques in situations relevant to all engineering majors.
BIO 20	AP/IB/IPC Credit	Advance Placement, International Baccalaureate, and International Placement credits, with the appropriate score, will receive BIO 20 credit on the Duke transcript.
BIO 201	Gateway to Biology: Molecular Biology	Introduces major concepts in biology through the lens of molecular biology. Molecular mechanisms that comprise the Central Dogma and variants. DNA structure and function, replication, transcription, and translation. Protein synthesis, folding, structure and function. Supporting topics related to the structure of cells, metabolism and energetics. Integration of physical and quantitative principles to molecular biology. Relevance to human diseases and the biotechnology industry. Laboratory includes an introduction to recombinant DNA technology. Prerequisite: Chemistry 101DL, or equivalent.
BIO 202	Genetics and Evolution	Introduction to principles transmission genetics and evolution. Includes Mendelian and non-Mendelian inheritance, quantitative genetics, genetic mapping, evidence for evolution, natural selection, genetic drift, kin selection, speciation, molecular evolution, phylogenetic analysis. Relevance to human family and social structure, evolution of infectious disease, human hereditary disorders, social implications of genetic knowledge.
BIO 311	Systems Biology: An Introduction for the Quantitative Sciences	Introduction to concepts and applications of Systems Biology. Identification of molecular interactions that underlie cellular function using high dimension data acquired through high-throughput approaches. Intended for students with training in quantitative fields (computer science, math, physics, statistics, engineering).
BIO 215L	Intro to Mathematical Modeling in Biology	A first course applying mathematics to biological problems. Topics drawn from cell and molecular biology, molecular evolution, enzyme catalysis, biochemical pathways, ecology, systems biology, and developmental biology. Prerequisite: Mathematics 212 or equivalent.
CHEM 201DL	Organic Chemistry	The structures and reactions of the compounds of carbon and the impact of selected organic compounds on society. Laboratory: techniques of separation, organic reactions and preparations, and systematic identification of compounds by their spectral and chemical properties. Prerequisite: Chemistry 101DL, or 110DL, or 21
CHEM 210DL	Modern App of Chem Principles	Modern applications of chemistry in context of larger scientific theme, e.g. in biology, materials science, or environmental chemistry. Revisits core concepts from CHEM 101L, incorporating additional topics including intermolecular interactions, phases of matter, solutions, quantitative treatment of aqueous equilibria, electron transfer reactions, and inorganic and coordination chemistry. Laboratory illustrates experimental approaches to modern problems in biological, materials, and environmental chemistry, as well as analytical and synthetic techniques. Prerequisite: Chemistry 101L.

EOS 201L	The Solid Earth: Minerals, Rocks & Structural Geology	Description and interpretation of minerals, rocks and geologic structures. Lectures on theoretical aspects, lab on practical applications and use of petrographic microscope. Prereq: Earth & Ocean Sciences 101 or consent of instructor.
EOS 202	Ocean and Atmosphere Dynamics	Introduction to the dynamics of ocean and atmospheric circulations, with particular emphasis on the global climate cycle. Prerequisites: Mathematics 111, Physics 153L or consent of instructor.
EOS 365	Weather and Climate	Introduction to weather and climate. Topics include atmospheric structure, composition, circulation and energy properties; severe weather events such as cyclones, hurricanes, and tornadoes; ozone depletion; natural climate variability; climate change and global warming. Instructor consent required.
PHYS 153L*	Application of Physics: A Modern Perspective	Intended principally for students in engineering and the physical sciences as a continuation of Physics 152L. Topics include: mechanics from a microscopic perspective, the atomic nature of matter, energy, energy quantization, entropy, the kinetic theory of gases, the efficiency of engines, electromagnetic radiation, the photon nature of light, physical optics and interference, waves and particles, applications of wave mechanics. Prerequisites: Physics 52L and Mathematics 212L or the equivalents. ** PHYS 153L only counts in the NS Elective spot when Phys 152L has been taken at Duke – and NOT when AP for Phys 151L and 152L exist. The reqm't of one Physics course at Duke is separate from the NS reqm't.*
PHYS 305	Intro to Astrophysics	Basic principles of astronomy treated quantitatively. Cosmological models, galaxies, stars, interstellar matter, the solar system, and experimental techniques and results. Prereqs: Mathematics 212 and Physics 264L or consent of instructor. Math 218 is strongly recommended.
PHYS 361	Intermediate Mechanics	Newtonian mechanics as the intermediate level. Lagrangian mechanics, linear oscillations, chaos, dynamics of continuous media, motion in noninertial reference frames. Prerequisites: Mathematics 216 or equivalent (may be taken concurrently).
PHYS 363	Thermal Physics	Thermal properties of matter treated using the basic concepts of entropy, temperature, chemical potential, partition function, and free energy. Topics include the laws of thermodynamics, ideal gases, thermal radiation and electrical noise, heat engines, Fermi-Dirac and Bose-Einstein distributions, semiconductor statistics, kinetic theory, and phase transformations. Also taught as Electrical and Computer Engineering 311. Prerequisite: Physics 264L.
PHYS 513	Nonlinear Dynamics	Introduction to the study of temporal patterns in nonequilibrium systems. Theoretical, computational, and experimental insights used to explain phase space, bifurcations, stability theory, universality, attractors, fractals, chaos, and time-series analysis. Each student carries out an individual research project on a topic of nonlinear dynamics and gives a formal presentation of the results. Prerequisites: Computer Science 101, Mathematics 216, and Physics 161L, 162L, or equivalent. Instructor: C-L: Computer Science 524.

Appendix 8
Table A8: Approved Social Science and Humanities Departments and Programs

In recent years there has been a proliferation of non-social science and non-humanities departments (including some engineering departments) applying for and receiving SS, CZ, or ALP Areas of Knowledge codes for some of their courses. These particular codes, therefore, are no longer exclusive to social science and humanities departments as they once were. Given that the five SS/H courses are intended to allow you to explore in breadth and depth disciplines of social sciences and humanities, the Pratt school requires (effective Fall 2013) that SS/H courses must be taken from, or cross-listed with, one of the following departments or programs (see the list of exceptions that follow):

Department/Program	**Subject Code(s)**
African & African American Studies	AAAS
Art, Art History, and Visual Media Studies	ARTHIST, HCVIS, ARTSVIS, VMS
Arts of the Moving Image	AMI
Asian and Middle Eastern Studies	AMES, ARABIC, CHINESE, HEBREW, HINDI, JPN, KOREAN, PERSIAN, SANSKRIT, TIBETAN
Canadian Studies	CANADIAN
Classical Studies	CLST, GREEK, LATIN
Cultural Anthropology	CULANTH
Documentary Studies	DOCST
East Asian Studies	EAS
Economics	ECON
Education	EDUC
English	ENGLISH
Study of Ethics	ETHICS
Evolutionary Anthropology	EVANTH
Germanic Languages and Literature	GERMAN
History	HISTORY
International Comparative Studies	ICS
Islamic Studies	ISLAMST
Jewish Studies	JEWISHST
Latin American Studies	LATAMER
Linguistics	LINGUIST
Literature Program in Global Cultural Studies	LIT
Markets and Management Studies	MMS
Medieval and Renaissance Studies	MEDREN
Music	MUSIC
Philosophy	PHIL
Political Science	POLSCI
Psychology and Neuroscience	PSY
Public Policy Studies	PUBPOL
Religious Studies	RELIGION
Romance Studies	ROMST, CREOLE, FRENCH, ITALIAN, PORTUGUE,

QUECHUA, SPANISH
Slavic and Eurasian Studies.....SES, BALTFIN, POLISH, ROMANIAN, RUSSIAN, SERBCRO, TURKISH, UKRAIN, UZBEK
Sociology.....SOCIOL
Theater Studies.....THEATRST
Women's Studies.....WOMENST

Please note that, as illustrated above, individual departments and programs may constitute one *or more* subject codes.

EXCEPTIONS

EGR 305/ECON 212: Even though EGR 305 is cross-listed with ECON (within the economics department) it cannot be used toward the SS/H requirement.