

## EST&P Applied Studies pre-approved project courses

(that satisfy requirements towards 24 units of project coursework)

DRAFT version 3.2 – March 11, 2019

Please note: Courses may not be offered every year, and space is not guaranteed in any specific class or section. If you wish to petition for a course not on this list to count towards project requirements, please contact your academic advisor. **A project intensive course is defined by a College of Engineering course with at least a minimum of 30% of the course grade is from project work** (individual or group) and faculty review or approval.

Following this Table are individual course descriptions, as of the time this document was written. A list of independent study courses for EST&P and partner departments appears at the end of the document. This is to be used in conjunction with the EST&P Master's Project Approval form (found on Canvas).

Note: Courses in **bold** are offered during Fall 2019.

| Course Number        | Course Title   | Number of Units | Term Typically Offered | Recommended Background |
|----------------------|--|-----------------|------------------------|------------------------|
| <b>39-605</b>        | Engineering Design Projects  | 12              | Fall                   | All                    |
| 39-606               | Engineering Design Projects  | 12              | Spring                 | All                    |
| 39-620               | Basics and Applications of Power Magnetic Devices                                | 12              | Spring                 | MSE, MEG, ECE and CHE  |
| 39-651               | Engineering Optical and Thermal Energy Transport: Energy Efficiency Applications | 12              | Spring                 | MSE, CEE, MEG, and CHE |
| <b>12-706</b>        | Civil Systems Investment Planning and Pricing                                    | 12              | Fall                   | All                    |
| <b>12-712/19-717</b> | Sustainable Engineering Principles   | 12              | Fall                   | All                    |
| 12-714/19-714        | Environmental Life Cycle Assessment  | 12              | Spring                 | All                    |
| 12-718               | Environmental Engineering, Sustainability and Science Project                    | 12              | Spring                 | CEE                    |
| 12-745               | Advanced Infrastructure Systems Project  | 12              | Spring                 | CEE                    |
| 12-761               | Sensing & Data Mining in Smart   | 12              | Spring                 | CEE, ECE               |

|  |   |    |        |   |
|--|---|----|--------|---|
|  | Structures and Systems                        |    |        |   |
| <b>18-500*</b><br>*undergraduate units*                          | ECE Design Experience                         | 12 | Fall   | ECE   |
| <b>18-618/19-638</b>   | Smart Grids                                   | 12 | Fall   | ECE, EPP*<br>*background: power systems fundamentals, linear algebra, dynamic systems, power systems economics, optimization techniques |
| 18-743   | Energy Aware Computing                        | 12 | Fall   | ECE   |
| 24-618   | Computational Analysis of Transport Phenomena | 12 | Spring | MEG   |
| 24-642   | Fuel Cell Systems                             | 12 | Fall   | MEG, MSE, CHE *<br>*Thermodynamics prerequisite   |
| <b>24-643/27-700</b>   | Energy Storage Materials and Systems          | 12 | Fall   | MEG, MSE, CHE, ECE  |
| 24-645   | Air Pollutant Sensor Design and Application   | 12 | Spring | MEG, ECE  |
| <b>24-722</b>  | Energy Systems Modeling                       | 12 | Fall   | MEG, MSE, CHE *<br>*Thermodynamics prerequisite   |
| 24-778   | Mechatronic Design                            | 12 | Spring | MEG, ECE  |
| 19-451*<br>*Only specific terms and under specific circumstances | EPP Projects                                  | 12 | Spring | EPP   |

## Course Descriptions

### 39-605 (Fall) and 39-606 (Spring) Engineering Design Projects

In this project course, students work in multidisciplinary teams to design products or processes. The course is open to juniors, seniors and graduate students from all parts of the campus community. Each project is sponsored by an industry, government or non-profit partner, and is of real commercial interest to that partner. Students work directly with their partner throughout the semester to establish goals and requirements, evaluate their design as it progresses, and produce a final report, presentation, and, if appropriate, a prototype. Design reviews, held twice during the semester, give students a chance to present their preliminary designs and receive feedback and advice. In completing their designs, teams must consider not only the functionality of their designs, but also the look, feel, appearance, and societal impact. Skills built in this course will include: developing the product statement, establishing goals and constraints for the product, project management, and generating and evaluating design alternatives. As some projects may span multiple semesters with new groups of students, careful documentation of project work is emphasized. Students may take this course for either one or two semesters.

### 39-620 Basics and Applications of Power Magnetic Devices

This course will provide a sound background in the fundamentals of soft magnetic materials and the physics required for magnetic component design. Fundamental principles will be applied to practical component level design problems. A final design project will leverage analytical and/or finite element simulations. The course is targeted to masters-level students but will be accessible to advanced undergraduate and PhD level students. Primary learning objectives are: 1) Establish a fundamental knowledge base of the relevant materials science and physics principles that dictate performance of soft magnetic materials. 2) Establish a strong foundation in the fundamentals of applied electromagnetics required for intelligent application of finite element simulations and other analytical models for magnetic component design. 3) Provide students with experience in performing magnetic component design including material selection and component optimization through assigned problems and a final project.

### 39-651 Engineering Optical and Thermal Energy Transport: Energy Efficiency Applications of Optical Coatings

This graduate level course targets to provide students with a sound fundamental understanding of applied optics principles relevant for the design of engineered optical coatings for energy related applications including (1) low emissivity coatings for energy efficient windows, (2) anti-reflection coatings for solar photovoltaics, (3) optical absorber material coatings for concentrating solar power, and (4) thermal barrier coatings. One key focus of the course will be the successful completion of an optical coating design project tailored to the interests of the student which leverages the fundamental principles, design tools, and concepts to be developed. Students will also gain experience with thin film optical modeling packages such as TFCalc, FreeSnell, and Thin Film Cloud and will learn techniques and methodologies for modeling the optical constants of typical materials used in optical coating applications which can be integrated with optical coating design models.

### 12-706 Civil Systems Investment Planning and Pricing

This course introduces students to the fundamental principles and quantitative methods used in engineering systems, and how to communicate results. Its primary audience is first year graduate students in engineering. The course covers economic-based decision making methods, such as decision trees, benefit-cost and cost-effectiveness analysis, and more advanced decision and risk analysis methods like sensitivity analysis, multi-attribute, and simulation. The integration of uncertainty into

formal methods is a fundamental component of the course, and tells us how confident we should be in our answers. The primary applications in this course will deal with infrastructure systems planning and environmental policy.

#### 12-712/19-717 Sustainable Engineering Principles

This course presents an overview of the concept of sustainability, including changing attitudes and values toward technology and the environment through the late twentieth and early twenty-first centuries. Relevant issues in sustainable engineering, including population growth, urbanization, energy, water, food and material resources are discussed. Tools for sustainable engineering are presented, including metrics of sustainability, principles of design for the environment, and use of material and energy balances in sustainable systems. Publicly available data sets and computational models will be explored to assess sustainability. A team-based project is required.

#### 12-714/19-714 Environmental Life Cycle Assessment

Cradle-to-grave analysis of new products, processes and policies is important to avoid undue environmental harm and achieve extended product responsibility. This course provides an overview of approaches and methods for life cycle assessment and for green design of typical products and processes using the ISO 14040 family of standards. This includes goal and scoping definition, inventory analysis, life cycle impact assessment (LCIA), interpretation, and guidance for decision support. Process-based analysis models, input-output and hybrid approaches are presented for life cycle assessment. Example software such as MATLAB, Excel, and Simapro are introduced and used in assignments. A group life cycle assessment project consistent with the principles and tools of sustainability to solve real-world engineering problems is required.

#### 12-718 Environmental Engineering, Sustainability and Science Project

This course integrates and exercises students in a significant sustainable engineering and/or environmental project that is team-based and built upon the knowledge, skills, and technologies learned in the core and specialist courses in the EESS graduate curriculum.

#### 12-745 Advanced Infrastructure Systems Project

This course will integrate and exercise students in a significant AIS system development project that is team-based, related to some area of infrastructure systems, industry driven, and built upon the knowledge, skills, and technologies learned in the core and specialist courses in the AIS program.

#### 12-761 Sensing & Data Mining in Smart Structures and Systems

This course will introduce smart monitoring systems for applications in physical structures and systems. Such monitoring systems enable us to understand the performance of the physical systems and diagnose/prognose their critical status using technologies, such as sensor network and data analytics. Examples include but not limited to structural health monitoring, traffic monitoring, water/air quality sensing, patient monitoring, etc. The goal is for students to understand the overall process from obtaining data to specific application performance in a systematic way. This course is intended for graduate students with prior exposure to probability, statistics, computer programming, and physical science.

#### 18-500 ECE Design Experience\*

\*undergraduate units

The ECE Design Experience is a capstone design course that serves to introduce students to broad-based, practical engineering design and applications through an open-ended design problem. Students will work with a team on a project of their choosing (subject to instructor approval) throughout the

semester culminating with a final project presentation, report, and public demonstration. The projects will need to encompass a minimum of two ECE areas. Throughout the semester, teams will need to give both written and oral project proposals and periodic performance updates. Team-building experiences designed to educate students on group dynamics, resource management, deadline planning, Big-picture implications of engineering applications: societal, human, ethical, and long-term impact will be explored.

#### 18-618/19-638 Smart Grids and Future Electric Energy Systems

This course discusses the transformational changes that modern electrical power industry has been going through for some time now. While most of the standard power systems objectives are still the same, there are new solutions and new problems that need to be addressed and understood. Ever increasing consumption of electrical energy is arguably directly related to green house gases emissions, global warming and pollution in general not to mention diminishing fossil fuels supplies. As a consequence of these concerns, a range of new technologies are used for power generation, monitoring and control resulting into complex engineering systems termed smart grids. There have been many attempts to define Smart Grid in a few sentences but with a limited success unless the audience is fully familiar with the terms and precise meaning of the used language; that is if the audience already knows what a smart grid is. From the engineering perspective, the term "smart grid" defines a self-healing network equipped with dynamic optimization techniques that use real-time measurements to minimize network losses, maintain voltage levels, increase reliability, and improve asset management. Economic and/or social aspects of Smart Grid solutions are much harder to define or even recognize. In this course, we will explore engineering, economic and social aspects of smart grids. From the engineering perspective, new technologies will be explored including renewable energy resources, flexible demand, communications methods, and role of advanced technologies such as FACTS devices and Phasor Measurement Units (PMU). Special attention will be paid to economic and environmental outcomes of the new technologies. Time permitting, relevant industry standards and utility requirements for third party energy producers will be discussed as well.

#### 18-743 Energy Aware Computing

This course provides a comprehensive coverage of topics related to energy aware and green computing. While it is widely recognized that power consumption has become the limiting factor in keeping up with increasing performance trends, static or point solutions for power reduction are beginning to reach their limits. This course is intended to provide an insight into: (i) power and energy consumption modeling and analysis; (ii) energy aware computing, i.e., how various power reduction techniques can be used and orchestrated such that the best performance can be achieved within a given power budget, or the best power efficiency can be obtained under prescribed performance constraints; and (iii) green computing in the context of large scale computing systems or smart grid-aware computing. Recommended: basic VLSI design, basic computer system organization, basic compiler design and OS knowledge. Prerequisites: Senior or Graduate Standing.

#### 24-618 Computational Analysis of Transport Phenomena

In this course, students will develop basic understanding and skill sets to perform simulations of transport phenomena (mass, momentum, and energy transport) for engineering applications using a CAE tool, learn to analyze and compare simulation results with theory or available data, and develop ability to relate numerical predictions to behavior of governing equations and the underlying physical system. First 8 weeks of the course will include lectures and simulation-based homework assignments. During last 7 weeks, teams of students will work on self-proposed projects related to computational analysis of transport phenomena. In the project, students will learn to approach loosely defined problems through design of adequate computational mesh, choice of appropriate numerical scheme and boundary conditions, selection of suitable physical models, efficient

utilization of available computational resources etc. Each team will communicate results of their project through multiple oral presentations and a final written report.

#### 24-642 Fuel Cell Systems

Fuel cells are devices that convert chemical potential energy directly into electrical energy. Existing fuel cell applications range from the small scale, such as portable cell phone chargers, to the large scale, such as MW-scale power plants. Depending on the application, fuel cell systems offer unique advantages and disadvantages compared with competing technologies. For vehicle applications, they offer efficiency and environmental advantages compared with traditional combustion engines. In the first half of the course, the focus is on understanding the thermodynamics and electrochemistry of the various types of fuel cells, such as calculating the open circuit voltage and the sources of voltage loss due to irreversible processes for the main fuel cells types: PEM/SOFC/MCFC. The design and operation of several real fuel cells are then compared against this theoretical background. The second half of the course focuses on the balance-of-plant requirements of fuel cell systems, such as heat exchangers, pumps, fuel processors, compressors, as well as focusing on capital cost estimating. Applying the material learned from the first and second halves of the class into a final project, students will complete an energy economic analysis of a fuel cell system of their choice. Prerequisite- Undergraduate Thermodynamics course 12 units

#### 24-643/27-700 Energy Storage Materials and Systems

Contemporary energy needs require large scale electrochemical energy conversion and storage systems. Batteries are playing a prominent role in portable electronics and electric vehicles. This course introduces principles and mathematical models of electrochemical energy conversion and storage. Students will study thermodynamics, reaction kinetics pertaining to electrochemical reactions, phase transformations relating to batteries. This course includes applications to batteries, fuel cells, supercapacitors

#### 24-645 Air Pollutant Sensor Design and Application

In this course, students will be instructed in the development, testing, and deployment of air quality monitoring networks. Key topics will include: introduction to EPA regulations for air pollutants and the measurements used to monitor compliance with those regulations; operating principles behind standard EPA measurements and emerging sensors; emissions of pollutants; effects of pollutants on human health and climate; sensor calibration and maintenance; data collection, processing, and interpretation. Statistical treatment of data will also be discussed. A major focus of this class will be a team-based project, in which students design, construct, and deploy small, low-cost air pollutant sensors. The course assumes understanding of thermodynamics, basic chemistry, and computer programming.

#### 24-722 Energy System Modeling

This course focuses on the thermodynamic modeling of energy systems with emphasis on energy/availability analysis techniques. These techniques are developed and applied to both established and emerging energy technologies, such as internal combustion engines, gas- and coal-fired power plants, solar and wind energy systems, thermochemical hydrogen production cycles, and fuel cells. The course will also consider the integration of components such as reformers and electrolyzers. Modern computational tools are used throughout the course. The course culminates with a group project that requires developing sophisticated, quantitative models of an integrated energy system. Students are expected to have completed an undergraduate course in thermodynamics comparable to 24-221. (12 units) 4 hrs lec. Pre-requisite: 24-221 or 06-221 or 27-215, or equivalent

### 24-778 Mechatronic Design

Mechatronics is the synergistic integration of mechanical mechanisms, electronics, and computer control to achieve a functional system. Because of the emphasis upon integration, this course will center around laboratory projects in which small teams of students will configure, design, and implement mechatronic systems. Lectures will complement the laboratory experience with operational principles and system design issues associated with the spectrum of mechanical, electrical, and microcontroller components. Class lectures will cover selected topics including mechatronic design methodologies, system modeling, mechanical components, sensor and I/O interfacing, motor control, and microcontroller basics.

### 19-451 EPP Projects\*

\*Only specific terms and under specific circumstances

Interdisciplinary problem-solving projects in which students work as leaders or members of project teams. Problem areas are abstracted from local, state and national situations and involve the interaction of technology and public policy, with different projects being chosen each semester. Oral and written presentations concerning the results of project studies are required.

## **Independent Project Work**

For an EST&P student who desires a project or research-like experience outside a classic classroom structure, he or she must find an **engineering faculty member** who is willing and able to supervise an appropriate sized and scoped project related to energy. Other CMU faculty whose research area is focused on energy may be approved on a case by case exception basis. Project topics are self-defined working in cooperation with an engineering faculty member; they are NOT assigned by the EST&P program. Project course units must be taken for a letter grade to count towards degree requirements and to fulfill the project units for the Applied Studies degree. Any combination of 24 units of 39-660 or equivalent course units will fulfill the project requirement. Summer internship project units, such as those taken for CPT, will also count towards this degree requirement. Ideally the project topic will be related to, and increase preparation for, a student's professional and career goals. The same project course number (such as 39-660) can be taken multiple times (to reflect different topics). Project units can be taken in successive semesters (for continuation of the same project topic).

### **Instructions for one-on-one faculty supervision**

Below are some recommended steps to guide you towards an independent project process. However, they do not guarantee success:

1. Identify a faculty member, with whom you might want to do project work. Sources are: an engineering professor teaching one of your classes, faculty associated with either the EST&P program or the Scott Institute for Energy Innovation, or identifying a topic area that a faculty member has expertise. Website listing of associated EST&P faculty: <http://www.cmu.edu/engineering/estp/about-us/faculty-and-staff.html>
2. Narrow down the list, and contact a few faculty members. This can be before or after class, during their office hours, or a very concise and politely worded email of introduction. Also, before meeting with faculty consider talking with their PhD students to learn about the detailed work going on within their faculty advisor's research group.
3. Discuss areas of common interest, and highlight what skills and background you can offer to the professor's focus area or research projects. Also discuss possible final deliverables for the project work, such as poster, contributions towards a paper, develop a model, etc.

4. After the supervising faculty member agrees to supervise your independent project, scope out the subject area, deliverables, and number of units that reflects this amount of work.
5. The student then fills out the EST&P master's project approval form (or similar type of document from the faculty member's home department), have the supervising faculty member sign it, and then turn it in to the EST&P office for EST&P advisor approval.
6. Once approved, register in SIO for the appropriate number of units (either 39-660 course or a similar corresponding course number in the supervising faculty member's department). The number of units should correlate with the amount of work to be performed. The project work requires a letter grade to be assigned at the end of each semester. The number of units registered for is variable, although it is typically in increments of 3 units: 3, 6, 9 or 12 units.

| Course Number             | Course Title                         | Number of Units                         | Term Typically Offered | Recommended Background |
|---------------------------|--------------------------------------|---|------------------------|------------------------|
| <b>39-660 (preferred)</b> | Masters EST&P Project                | Variable Based on scope of project work | Fall and Spring        | All                    |
| 06-600                    | Masters Chemical Engineering Project | Variable Based on scope of project work | Fall and Spring        | CHE                    |
| 12-792                    | Advanced Independent Study           | Variable Based on scope of project work | Fall and Spring        | CEE                    |
| 18-980                    | M.S. Graduate Project                | Variable Based on scope of project work | Fall and Spring        | ECE                    |
| 19-690                    | M.S. Project                         | Variable Based on scope of project work | Fall and Spring        | EPP                    |
| 24-794                    | Master of Science Project            | Variable Based on scope of project work | Fall and Spring        | MEG                    |
| 27-756                    | Masters Project                      | Variable Based on scope of project work | Fall and Spring        | MSE                    |



## Course Descriptions

### 39-660 Masters EST&P Project

This project course is designed for EST&P students who are working on an independent investigation on a project related to energy with the advice and approval of the program advisor and/or affiliated faculty member. Summary report, presentation or poster on work accomplished must be submitted at completion of semester. Once you have determined a suitable topic area, found an engineering faculty member who has agreed to supervise the project work, send the EST&P project approval form to the EST&P director for enrollment. Variable units. Restricted to EST&P students

### 06-600 Masters Chemical Engineering Project

No course description.

### 12-792 Advanced Independent Study

In-Depth investigation of selected advanced topics not offered in formal courses. By special arrangement upon demand and with approval of the instructor. Prerequisites: Permission of instructor.

### 18-980 M.S. Graduate Project

No course description.

### 19-690 M.S. Project

No course description.

### 24-794 Master of Science Project

This course is designed to be a training opportunity in engineering research and associated professional activity. Content includes a series of investigations under the student's initiative culminating in comprehensive reports, with special emphasis on orderly presentation and effective English composition for Master of Science candidates. Variable hrs. Prerequisite: permission of the instructor.

### 27-756 Masters Project

Individual research project, including laboratory, theoretical, library or design work followed by a written or oral report on the work accomplished.