Industrial and Systems Engineering

Mission Statement

To pursue excellence and national prominence in the areas of manufacturing, operations research, information technology and related fields of industrial and systems engineering through innovative teaching, distinguished research and scholarship, and active professional leadership. Building on its unique strength and national reputation in undergraduate education and industrial research, the department strives for leadership in educational innovation, multidisciplinary research, and industrial partnership. Our ultimate mission is to produce leaders who have learned to think critically and analytically, have the skills and techniques to comprehend and create new knowledge, and are willing to serve and inspire others.

Physical Facilities

The industrial and systems engineering department is located in the Harold S. Mohler Laboratory at 200 West Packer Avenue at the northwest corner of the Lehigh University Asa Packer campus. The Mohler Lab building contains the classrooms, laboratories, and faculty offices of the department. Labs in the Mohler Laboratory building include:

Computational Optimization Research @ Lehigh (COR@L) Lab. The COR@L lab consists of high performance computer workstations, each equipped with state-of-the-art commercial and noncommercial software for large-scale numerical optimization. COR@L is used for both research and instruction.

Enterprise Systems Center Laboratories. The ESC Laboratories contain a variety of computer systems and software in support of agility in Computer Integrated Manufacturing (CIM) and in engineering logistics and distribution problem solving, including: Computer Aided Design (CAD), Computer Aided Engineering (CAE), discrete event simulation, linear and nonlinear optimization, Finite Element Analysis (FEA), facilities design, process design, process control, and analytics software, such as the SAS software suite.

Manufacturing Technology Laboratory (MTL). The MTL contains equipment for instruction and research in manufacturing processes, numerical control (NC), NC part programming, material handling and storage, industrial control systems, and metrology.

Automation and Robotics Laboratory. This lab is located in the MTL, it contains a variety of industrial robots and other automated systems to provide students with hands-on experience in the planning and use of this kind of equipment.

Work Systems Laboratory. This classroom/laboratory affords the opportunity for undergraduate students to analyze and plan human work activities for individual workstations and worker team situations. A full scale manual assembly line is available for study.

ISE Computer Laboratories. Considerable use is made of university computer facilities in ISE coursework. ISE/computing center PC laboratories containing 38 and 16 PCs, respectively, are located in the Mohler Laboratory building.

B.S. in Industrial & Systems Engineering

Industrial & Systems Engineering (ISE) is concerned with the analysis, design, and implementation of integrated systems of people, materials, information, and equipment to accomplish useful work.

Career Opportunities

ISE graduates are sought by nearly all industrial corporations as well as government agencies and other service institutions. Major employers of our graduates include management consulting firms, manufacturing companies, banks, hospitals, railroads, the postal service, and transportation/logistics services. A typical career path of an industrial and systems engineer is to start in an entry level engineering position or as a technical analyst and to progress through various management positions in the firm or institution. Significant numbers of industrial and systems engineers ultimately become chief executive officers, chief operating officers, and chief technology officers in their respective organizations.

Production Systems Career Opportunities

The discipline of industrial & systems engineering is applicable in nearly all industries, whether the industry involves manufacturing of a product or delivery of a service. Job functions performed by ISEs include: systems analysis, cost estimation, capital equipment selection, engineering economy, facilities planning, production planning and scheduling, inventory control, quality control, project management, operations management, engineering management, as well as methods analysis and work measurement. Manufacturing systems engineering (MSE) is a specialty field associated with industrial and systems engineering that emphasizes functions and technologies such as process planning, plant layout design, manufacturing resource planning, production management, production line design, automation, robotics, flexible manufacturing systems, and computer integrated manufacturing.

Information Systems Career Opportunities

The Industrial & Systems Engineering program can also produce graduates who understand the complex facets of modern information systems, and the integration of these systems in industrial, service and financial organizations. The ISE student has an opportunity to focus on three important areas that are key to a successful information systems-oriented career. (1) Information Economics, (2) Quantitative Systems Analysis, and (3) Information Technology. These areas are coupled with general engineering and business background courses. Information economics studies the formulation, structure, and operational dynamics of information-centric systems in the context of industrial organizations, service sector economics, and financial institutions. Quantitative systems analysis studies operations research and computational tools for analyzing complex systems and their information components. Information technology and applications studies computer and communication technologies needed to design and implement information system applications. Topic areas include the applications of information technology in manufacturing and business environments, including electronic commerce, supply chain and enterprise information systems, manufacturing information systems, and financial enterprises.

ISE Curriculum

The ISE curriculum is designed to provide graduates with the skills and knowledge that employers expect of young industrial and systems engineers beginning their professional careers, and to instill the ability for lifetime learning. It includes the basic mathematical, physical, and social sciences, together with the principles and methods of engineering analysis and design that are specific to industrial and systems engineering. These principles and methods include probability and statistics, engineering economy, cost accounting, operations research, computer simulation, work methods and measurement, manufacturing processes, production and inventory control, and information technology.

In the junior year, an ISE student may elect to specialize more in production systems by choosing a course in modern manufacturing methods. Alternatively, a student may elect to specialize more in information systems by choosing a course in computer algorithm design. An ISE student must choose at least one of these courses, but may elect to choose both for a broader preparation for a career.

Specialized ISE electives in the senior year include: advanced optimization models, stochastic models, operations research, operations management, organization planning and control, statistical quality control, database design, web technologies, and data communications technologies. Electives related to manufacturing systems engineering include: industrial robotics, facilities planning and material handling, logistics and supply chain, and production engineering.

Program Educational Objectives

The set of key, over-arching objectives of the Industrial and Systems Engineering program are to prepare our students, within the first several years of the beginning of their careers, to

1. meet the expectations of employers of industrial and systems engineers,
2. pursue advanced study, if desired,
3. be active leaders in their profession and/or community.

Specifically, these general objectives can be met by graduates that

1. recognize and analyze problems, design innovative solutions, and lead their implementation,
2. excel as industrial and systems engineering professionals who are able to operate effectively in a global, culturally diverse society,
3. communicate effectively using written, oral, and electronic media,
4. pursue life-long learning and professional growth as ethical and responsible members of society,
5. form, lead, and participate on multi-disciplinary teams that solve problems in engineering and business.

In each course in the Industrial & Systems Engineering program, a subset of the student outcomes, listed below, are pursued to prepare students to achieve the Industrial and Systems Engineering program's stated objectives. This list of student outcomes articulated by the Engineering Accreditation Commission of ABET, http://www.abet.org , have been adopted by the program and are as follows:

1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics

2. 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

3. an ability to communicate effectively with a range of audiences

4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts

5. 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

6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions

7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies

ISE Major Requirements

The ISE degree requires a minimum of 130 credit hours.

See freshman year requirements on the First Year Courses for Engineering Degrees under the heading of the P.C. Rossin College of Engineering and Applied Science (http://catalog.lehigh.edu/coursesprogramsandcurricula/engineeringandappliedscience/) An HSS course is assumed to be taken in the freshman year in the following semester course plans.

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Sophomore

Fall	Credits	Spring	Credits
ISE 111	3	ISE 121	3
ISE 112	1	MATH 205	3
ISE 131	3	MAT 033 or CSE 004	2-3
ISE 132	1	PHY 021	0-4
MATH 023	4	PHY 022	1
Engineering Elective[3]	3	ECO 001 or HSS Elective[1]	3-4
CSE 003	2		
	17		**12-18**

Junior

Fall	Credits	Spring	Credits	Summer	Credits
ISE 230 or 240	3	ISE 240 or 230	3	ISE 100	0
ISE 224	3	ISE 226	3		
HSS Electives[1]	6-8	HSS Elective[1]	3-4		
Engineering Elective[3]	3	ISE 308 or 305	3		
		Select one of the following	4		
		ISE 172			
		ISE 215 & ISE 216			
	15-17		**16-17**		**0**

Senior

Fall	Credits	Spring	Credits
ISE 251	3	ISE Technical Electives[2]	6
ISE Technical Electives[2]	6	Free Electives	6
Free Elective	3	ISE 254[4]	3
HSS Elective[1]	3-4	ACCT 108	3
	15-16		**18**

Total Credits: 93-103

Notes:

1

HSS elective credit totals must satisfy the college HSS program requirements.

2

ISE Technical Electives include all ISE 300-level courses (except ISE 308 (formerly 305, which is required), ISE 260, the CSE 2XX (except CSE 241 and CSE 252) and 3XX courses, the BIS 3XX courses, and MATH 230. In addition, ISE 215 can be used as a technical elective, if ISE 172 is selected as a core course. Conversely, if ISE 215 and ISE 216 are selected as core courses, ISE 172 can be used as a technical elective. ISE 256 can be used as a technical elective . Of the 4 ISE technical electives that must be taken, at least 2 must be ISE courses.

3

Engineering Elective Course Candidates: Courses of 3 or more credits with course prefixes of BIOE, CHE, CEE, CSE, ECE, MAT, ME, or MECH for which the prerequisites are met. The courses with these prefixes that are excluded from consideration are listed on the following ISE Dept. web page: https://ise.lehigh.edu/content/courses (https://ise.lehigh.edu/content/courses/). The list of excluded courses for an individual ISE major is governed by the catalog in force when admitted to Lehigh. A provisional course offered with one of these prefixes requires departmental approval. Any course meeting these stipulations is denoted "Engineering Elective Requirement" in the ISE program description. A course counts toward meeting only one course requirements category for the ISE program.

4

The senior project course, ISE 254, requires senior standing and can be taken in either the fall or spring semester of the senior year.

5

CSE 007 can be used to replace CSE 003 and CSE 004.

Special Opportunities for ISE students

The following special opportunities are available to majors in industrial and systems engineering:

Nontechnical Minor. Students may choose to pursue a nontechnical minor in an area of the humanities, social sciences, business, or entrepreneurship. Students in the business minor can satisfy the ACCT 108 requirement by completing BUS 275.

Technical Minor. Technical minors such as engineering leadership, materials science, environmental engineering, and computer science are available through departments in the P. C. Rossin College of Engineering and Applied Science. Consult the specific department for more details.

Graduate Courses. Seniors in industrial and systems engineering can petition to take up to two graduate ISE courses (400-level) to satisfy two of their four 300-level elective ISE course requirements. The petitioning senior must have a good scholastic record (generally above a 3.0 GPA).

Senior Thesis Option. Students interested in continuing on to graduate school or performing research are encouraged to take the senior thesis option. In this option a student takes ISE 255 as a free elective to develop the thesis proposal. ISE 255 serves as a prerequisite to ISE 256 in which the thesis is written. ISE 256 may be used as an ISE technical elective.

Technical Minor in Engineering Leadership

The minor in engineering leadership provides students with the background and practice to become more effective leaders. The minor consists of 5 courses that explore different aspects of leadership. Additional details can be found on the Engineering Leadership Minor website (http://lehigh.edu/~inleader/).

Technical Minor in Manufacturing Systems Engineering

The minor in manufacturing systems engineering provides a concentration of courses in the manufacturing and production areas. This minor is not available to students majoring in industrial and systems engineering. It requires 16 credits.

Graduate Programs

The Department of Industrial and Systems Engineering (ISE) offers a Ph.D. degree and a variety of master's degrees that are designed to provide students the knowledge and skills to excel in careers that span industry and academia. The requirements of each program give students flexibility to personalize their program and take advantage of ISE's world-recognized expertise in optimization, applied operations research, statistical modeling and machine learning, data science, quantum computing, and uncertainty quantification.

Additional information on all of our graduate programs can be found below.

M.S. in Optimization (OPT)

The Master of Science (M.S.) degree in Optimization is primarily designed to meet the goals and interests of students whose professional plans include research in an educational, governmental, or industrial environment. Students graduating from the program will have a solid understanding of how to design, analyze, implement, and use optimization algorithms for solving problems arising throughout engineering and data science.

Each student is required to take 12 credit hours of graduate coursework in the area of Optimization, as well as supplement this specific knowledge with broader knowledge obtained by taking 9 additional credit hours of coursework in the Department of Industrial and Systems Engineering (ISE). The student rounds out their degree by taking 9 additional credit hours of relevant coursework from any department at Lehigh University. All coursework must be approved by the ISE Master Program Director. The above total of 30-credit hours of coursework may include project-based courses as well as a masters thesis.

M.S. in Industrial Engineering and Operations Research (IEOR)

The Master of Science (M.S.) degree in Industrial Engineering and Operations Research provides engineering graduates the skills and knowledge to pursue careers in their field of interest while meeting the industrial engineering needs of industry, business, health, and government. Graduates will be motivated to continue learning throughout their career, and gain the knowledge and skills to contribute significantly to society. Students graduating from the program will have great knowledge of, and practice in using, a multitude of tools used throughout industrial engineering and operations research.

Each student is required to take 12-credit hours of graduate coursework in the area of Industrial Engineering and Operations Research, as well as supplement this knowledge with additional broader knowledge obtained by taking 9 additional credit hours of coursework in the Department of Industrial and Systems Engineering (ISE). The student rounds out their degree by taking 9 additional credit hours of relevant coursework from any department at Lehigh University. All coursework must be approved by the ISE Master Program Director. The above total of 30-credit hours of coursework may include project-based courses as well as a masters thesis.

M.S. in Health Systems Engineering

The Master of Science (M.S.) degree in Health Systems Engineering (HSE) produces graduates with strong fundamental skills in industrial and systems engineering and a strong background in health systems and processes. Graduates will be ideally positioned for skilled professional management roles aimed at improving quality, streamlining processes and improving efficiency in health systems. This degree program is designed to prepare graduate students for engineering and management careers in firms engaged in delivering health-related products and services.

Students seeking to enroll to the program should have a bachelor's degree in engineering, mathematics, science, or business. Students should be quantitatively oriented and have completed a calculus based probability and statistics course. A candidate lacking certain background may be required to take background courses.

The program consists of 30 credit hours of course work that may be completed either in-person or online.

Each student is required to take 9-credit hours of graduate coursework in the area of health and an additional 9-credit hours of graduate coursework in the Department of Industrial and Systems Engineering (ISE). The student rounds out their degree by taking 6 additional credit hours of relevant coursework from the College of Engineering and 6 additional credits hours of relevant coursework from any department at Lehigh University. All coursework must be approved by the HSE Master Program Director. The above total of 30 credit hours of coursework may include project-based courses as well as a masters thesis.

M.S. in Financial Engineering

The Masters in Financial Engineering program combines key concepts in financial theory, mathematical finance and engineering decision making to produce professionals instrumental in creating innovative solutions to real financial issues. See separate catalog listing under Interdisciplinary Graduate Study and Research (http://catalog.lehigh.edu/coursesprogramsandcurricula/interdisciplinarygraduatestudyandresearch/analyticalfinance/).

Ph.D. in Industrial and Systems Engineering

The graduate program leading to the doctor of philosophy (Ph.D.) degree is organized to meet the individual goals and interests of graduate students whose professional plans include teaching, consulting, or research in an educational, governmental, or industrial environment. Each doctoral candidate is required to demonstrate: (1) a high level of proficiency in one or more fields of industrial and systems engineering, and (2) a capacity for independent research through the preparation of a dissertation related to his/her field of specialization.

The research directions of the program include mathematical optimization, data science and machine learning, energy and service systems, and high-performance computing. Methodological research thrusts focus on optimization, machine learning, stochastics, and quantum computing. On the applied side, the expertise of our faculty revolves around the operations and analytics of energy, finance, healthcare, mobility & transportation, and supply chain management.

The Lehigh ISE Ph.D. program offers a vibrant perspective on the next generation of data science, providing students with the

knowledge base and research skills that are necessary to mine and analyze high-volume data using state-of-the-art optimization and stochastic modeling techniques.

Students in our program have the opportunity to take a variety of courses covering the spectrum of descriptive, diagnostic, predictive, and prescriptive analytics, in topics such as:

- Convex Analysis & Mathematical Optimization
- Stochastic Models & Statistical Learning
- Continuous & Discrete Optimization
- Optimization Methods in Machine Learning
- Machine Learning & Data Mining
- Reinforcement Learning & Dynamic Programming

A summary of the requirements to obtain the Ph.D. degree offered by Lehigh ISE is the following. Further details, along with rules and procedures particular to the program, can be found on the Department of ISE website.

- Program Requirements. (These requirements remain incomplete until a student passes the Program Review, which in turn cannot be passed until all other Program Requirements have been completed.)
  - Complete a set of core and elective (i.e., non-core) Ph.D.-level courses.
  - Acquire an advisor from among the program faculty members.
  - Pass a Qualifying Examination conducted by a committee of program faculty members.
  - Pass a Performance Review conducted by the program faculty members.
  - Pass a Program Review conducted by the ISE Director of Graduate Studies (DGS) (or, conditionally, the program faculty members).
- Doctoral Research Requirements. (These requirements remain incomplete until a student passes the Dissertation Defense, which in turn cannot be passed until all other Doctoral Research Requirements have been completed and the student submits a dissertation approved by all of the student's doctoral committee members to the RCEAS.)
  - Form a doctoral committee satisfying the RCEAS requirements.
  - Pass a Dissertation Proposal Defense conducted by the doctoral committee.
  - Receive Admission to Candidacy for the Doctorate by the RCEAS.
  - Complete paperwork to indicate passage of the General Examination required by the RCEAS.
  - Accumulate a number of credits as required by the RCEAS.
  - Pass a Dissertation Defense conducted by the doctoral committee.
- Additional Requirements.
  - Submit annual progress reports to the ISE DGS.
  - Any additional Ph.D. degree requirements specified by the RCEAS and Lehigh.

Courses

ISE 100 Industrial Employment 0 Credits
Usually following the junior year, students in the industrial engineering curriculum are required to do a minimum of eight weeks of practical work, preferably in the field they plan to follow after graduation. A report is required. Must have sophomore standing.

ISE 111 Engineering Probability 3 Credits
Random variables, probability models and distributions. Poisson processes. Expected values and variance. Joint distributions, covariance and correlation.
Prerequisites: MATH 022 or MATH 096 or MATH 032 or MATH 052

ISE 112 Computer Graphics 1 Credit
Introduction to interactive graphics and construction of multiview representations in two and three dimensional space. Applications in industrial engineering. Must have sophomore standing in industrial engineering.

ISE 121 Applied Engineering Statistics 3 Credits
The application of statistical techniques to solve industrial problems. Regression and correlation, analysis of variance, quality control, and reliability.
Prerequisites: ISE 111 or MATH 231 or IE 111

ISE 131 Work Systems and Operations Management 3 Credits
Workermachine systems, work flow, assembly lines, logistics and service operations, and project management. Operations analysis, methods engineering, work measurement, lean production, and six sigma. Workplace ergonomics, plant layout design, and work management.
Prerequisites: ISE 111 or MATH 231 or IE 111
Can be taken Concurrently: ISE 111, MATH 231, IE 111

ISE 132 Work Systems Laboratory 1 Credit
Laboratory exercises, case studies, and projects in operations analysis, methods engineering, work measurement, and plant layout design.
Prerequisites: ISE 131 or IE 131
Can be taken Concurrently: ISE 131, IE 131

ISE 172 Algorithms in Systems Engineering 0,4 Credits
Use of computers to solve problems arising in systems engineering. Design and implementation of algorithms for systems modeling, systems design, systems analysis, and systems optimization. Computer systems, basic data structures, the design and implementation of efficient algorithms, and application of algorithms to the design and optimization of complex systems such as those arising in transportation, telecommunications, and manufacturing. Weekly laboratory with exercises and projects.
Prerequisites: CSE 004 or CSE 007 or CSE 017

ISE 215 Fundamentals of Modern Manufacturing 3 Credits
Manufacturing processes and systems. Metal machining and forming, polymer shape processes, powder metallurgy, assembly and electronics manufacturing. Introduction to automation, numerical control, and industrial robots.
Prerequisites: MAT 033

ISE 216 Manufacturing Laboratory 1 Credit
Laboratory exercises and experiments in manufacturing processes and systems.
Prerequisites: ISE 215 or IE 215
Can be taken Concurrently: ISE 215, IE 215

ISE 224 Information Systems Analysis and Design 3 Credits
An introduction to the technological as well as methodological aspects of computer information systems. Content of the course stresses basic knowledge in database systems. Database design and evaluation, query languages and software implementation. Students that take CSE 241 cannot receive credit for this course.

ISE 226 Engineering Economy and Decision Analysis 3 Credits
Economic analysis of engineering projects; interest rate factors, methods of evaluation, depreciation, replacement, breakeven analysis, aftertax analysis. decision-making under certainty and risk.
Prerequisites: ISE 111 or MATH 231 or IE 111

ISE 230 Introduction to Stochastic Models in Operations Research 3 Credits
Formulating, analyzing, and solving mathematical models of real-world problems in systems exhibiting stochastic (random) behavior. Discrete and continuous Markov chains, queueing theory, inventory control, Markov decision process. Applications typically include traffic flow, call centers, communication networks, service systems, and supply chains.
Prerequisites: ISE 111 or IE 111 or MATH 231

ISE 240 Introduction to Deterministic Optimization Models in Operations Research 3 Credits
Formulating, analyzing, and solving mathematical models of real-world problems in systems design and operations. A focus on deterministic optimization models having parameters that are known and fixed. Algorithmic approaches for linear, integer, and nonlinear problems. Solving optimization problems utilizing specialized software.
Prerequisites: MATH 205

ISE 251 Production and Inventory Control 3 Credits
Techniques used in the planning and control of production and inventory systems. Forecasting, inventory models, operations planning, and scheduling.
Prerequisites: ISE 121 and ISE 230 and ISE 240
Can be taken Concurrently: ISE 230, ISE 240

ISE 254 Senior Project 0,3 Credits
The use of industrial and systems engineering techniques to solve a major problem in either a manufacturing or service environment. Problems are sufficiently broad to require the design of a system. Human factors are considered in system design. Laboratory component provides significant industry exposure.
Prerequisites: ISE 226 or ISE 251
Can be taken Concurrently: ISE 226, ISE 251

ISE 255 Senior Thesis I 3 Credits
In-depth study of a research topic in industrial and systems engineering supervised by an Industrial and Systems Engineering department faculty member. Requires completion of a formal research proposal and a public presentation of the proposal at the end of the semester.

ISE 256 Senior Thesis II 3 Credits
Continued in-depth study of a research topic in industrial and systems engineering supervised by an Industrial and Systems Engineering department faculty member. Requires a formal thesis and public presentation of the results.
Prerequisites: ISE 255

ISE 260 (WGSS 260) Algorithms and Social Justice 4 Credits
This course explores how algorithms reflect and magnify social inequality. Topics include race, gender, sexuality, and class in the context of policing and punishment, search engines and social media, and ranking and optimization. Readings, discussions, and assignments are designed to cultivate transdisciplinary competence in the history of science and technology, feminist theory, machine learning, and artificial intelligence, and to encourage peer-to-peer learning across the humanities, social science, and engineering.
Attribute/Distribution: Q

ISE 275 Fundamentals of Web Applications 3 Credits
Introduction to web technologies required to support the development of client side and server side components of Internet based applications. Students will be exposed to the problems of design, implementation, and management by way of assigned readings, class discussion, and project implementation. Term project.
Prerequisites: ISE 224 or IE 224 or CSE 241
Can be taken Concurrently: ISE 224, IE 224, CSE 241

ISE 281 Leadership Project 1-3 Credits
Application of leadership principles through team projects with industry. Written report required.
Repeat Status: Course may be repeated.
Prerequisites: ISE 382 or IE 382

ISE 300 Apprentice Teaching 1-4 Credits

ISE 304 Introduction to Mathematics and Statistics for Industrial Engineering 3 Credits
Random variables, probability functions, expected values, statistical inference, hypothesis testing, regression and correlation, analysis of variance, and introduction to design of experiments. Review of linear algebra and an introduction to quantitative analysis, matrices, concepts associated with systems of linear equations and linear optimization, algebraic and geometric models. Credits for this course cannot be applied to any undergraduate degree offered by the Industrial and Systems Engineering (ISE) Department. Consent of department required.
Prerequisites: MATH 023

ISE 308 Simulation 0,3 Credits
Applications of discrete and continuous simulation techniques in modeling industrial systems. Simulation using a high-level simulation language. Design of simulation experiments. This course is an undergraduate version of ISE 408. A student can receive credit for only one of the following courses: ISE 305, ISE 404, ISE 308, and ISE 408.
Prerequisites: ISE 121

ISE 309 Time Series Analysis 3 Credits
Theory and applications of an approach to process modeling, analysis, prediction, and control based on an ordered sequence of observed data. Single or multiple time series are used to obtain scalar or vector difference/ differential equations describing a variety of physical and economic systems. This course is an undergraduate version of ISE 409. A student cannot receive credit for both ISE 309 and ISE 409.

ISE 310 Design of Experiments 3 Credits
Experimental procedures for sorting out important causal variables, finding optimum conditions, continuously improving processes, and trouble shooting. Applications to laboratory, pilot plant and factory. Must have some statistical background and experimentation in prospect. This course is an undergraduate version of ISE 410. A student cannot receive credit for both ISE 310 and ISE 410.
Prerequisites: ISE 121

ISE 321 Independent Study in Industrial and Systems Engineering 1-3 Credits
Experimental projects in selected fields of industrial engineering, approved by the instructor. A written report is required. Department permission required.
Repeat Status: Course may be repeated.

ISE 324 Industrial Automation and Robotics 3 Credits
Introduction to robotics technology and applications. Robot anatomy, controls, programming, work cell design, sensors, vision systems, using Programmable Logic Controllers. Laboratory exercises. This course is an undergraduate version of ISE 424. A student cannot receive credit for both ISE 324 and ISE 424.
Prerequisites: MATH 205

ISE 327 Facilities Planning and Material Handling 3 Credits
Facilities planning including plant layout design and facility location. Material handling analysis including transport systems, storage systems, and automatic identification and data capture. This course is an undergraduate version of ISE 427. A student can receive credit for only one of the following courses: ISE 319, ISE 327, and ISE 427.
Prerequisites: ISE 131

ISE 332 Product Quality 3 Credits
Introduction to engineering methods for monitoring, control, and improvement of quality. Statistical models of quality measurements, statistical process control, acceptance sampling, and quality management principles. Some laboratory exercises. This course is an undergraduate version of ISE 432. A student cannot receive credit for both ISE 332 and ISE 432.
Prerequisites: ISE 121

ISE 333 Introduction to Systems Engineering and Decision Analysis 3 Credits
Systems Engineering modeling techniques. Architectures for large scale systems design. Includes physical, functional, and operational architectures. Requirements engineering, interface and integration issues, graphical modeling techniques. Additional topics may include: decision analysis techniques for systems, uncertainty analysis, utility functions, multiattribute utility functions and analysis, influence diagrams, risk preference, Analytical Hierarchy and Node Processes in decision making. A student cannot receive credit for both ISE 333 and ISE 356.
Prerequisites: ISE 230 and ISE 240

ISE 334 Operational Excellence 3 Credits
Provides a comprehensive understanding of Operational Excellence within an organization. From defining business strategy and creating measurable initiatives and metrics, students learn various tools, such as Lean and Six Sigma Methodologies, Sales, Operations and Inventory Planning, and Change, and Project Management to optimize the end-to-end value chain. These tools enhance operational and organizational efficiency in complex business environments. This course is an undergraduate version of ISE 434. A student cannot receive credit for both ISE 334 and ISE 434.

ISE 335 Planning and Scheduling in Manufacturing and Services 3 Credits
Models for the planning and scheduling of systems that produce goods or services. Resource allocation techniques utilizing static and dynamic scheduling methods and algorithms. Application areas include manufacturing and assembly systems, transportation system timetabling, project management, supply chains, and workforce scheduling. This course is an undergraduate version of ISE 435. A student can receive credit for only one of the following courses: ISE 335, ISE 435, and ISE 419.

ISE 336 Engineering Project Management 3 Credits
Presents the principles and techniques used in all phases of managing engineering projects that includes the initial phase, planning, execution, control, and closeout. Students develop the analytical skills and awareness necessary for managing engineering projects.

ISE 339 Stochastic Models and Applications 3 Credits
Introduction to stochastic process modeling and analysis techniques and applications. Generalizations of the Poisson process; renewal theory and applications to inventory theory, queuing, and reliability; Brownian motion and stationary processes. This course is an undergraduate version of ISE 439. A student cannot receive credit for both ISE 339 and ISE 439.
Prerequisites: ISE 230

ISE 347 Financial Optimization 3 Credits
Making optimal financial decisions under uncertainty. Financial topics include asset/liability management, option pricing and hedging, risk management and portfolio optimization. Optimization covered includes linear/nonlinear optimization, discrete optimization, dynamic programming and stochastic optimization. Emphasis on use of modeling languages and solvers in financial applications. Requires basic knowledge of linear optimization and probability. This course is an undergraduate version of ISE 447. A student cannot receive credit for both ISE 347 and ISE 447.
Prerequisites: ISE 240

ISE 355 Optimization Algorithms and Software 3 Credits
Basic concepts of large families of optimization algorithms for both continuous and discrete optimization problems. Pros and cons of the various algorithms when applied to specific types of problems; information needed; whether local or global optimality can be expected. Participants practice with corresponding software tools to gain hands-on experience. This course is an undergraduate version of ISE 455. A student cannot receive credit for both ISE 355 and ISE 455.
Prerequisites: ISE 240

ISE 358 Game Theory 3 Credits
A mathematical analysis of how people interact in strategic situations. Applications include strategic pricing, negotiations, voting, contracts and economic incentives, and environmental issues. This course is an undergraduate version of ISE 458. A student cannot receive credit for both ISE 358 and ISE 458.
Prerequisites: MATH 021 or MATH 031 or MATH 051 or MATH 076

ISE 362 Logistics and Supply Chain Management 3 Credits
Modeling and analysis of supply chain design, operations, and management. Analytical framework for logistics and supply chains, demand and supply planning, inventory control and warehouse management, transportation, logistics network design, supply chain coordination, and financial factors. Students complete case studies and a comprehensive final project. This course is an undergraduate version of ISE 462. A student cannot receive credit for both ISE 362 and ISE 462.
Prerequisites: ISE 230 and ISE 240

ISE 364 Introduction to Machine Learning 3 Credits
Techniques of applied machine learning rather than deep theory behind the algorithms and methods. Programming solutions for machine learning problems using a high-level programming language and associated machine learning libraries. Regression, clustering, principal component analysis, Bayesian methods, decision trees, random forests, support vector machines, and neural networks. This course is an undergraduate version of ISE 464. A student cannot receive credit for both ISE 364 and ISE 464.
Prerequisites: CSE 003 or CSE 007 or CSE 017

ISE 365 Applied Data Mining 3 Credits
Introduction to the data mining process including business problem understanding, data understanding and preparation, modeling and evaluation, and model deployment. Emphasis on hands-on data preparation and modeling using techniques from statistics, artificial intelligence, such as regression, decision trees, neural networks, and clustering. A number of application areas are explored. This course is an undergraduate version of ISE 465. A student cannot receive credit for both ISE 365 and ISE 465.
Prerequisites: ISE 121 or ISE 304

ISE 371 Quality and Process Improvement in Healthcare 3 Credits
The dimensions of Healthcare quality and their definitions, quality metrics, accreditation and other benchmarking and evaluation methods. Change management, project planning and team management. Continuous improvement tools including “lean”, “six-sigma”, and “TQM”. This course is an undergraduate version of ISE 471. A student cannot receive credit for both ISE 371 and ISE 471.

ISE 372 Financial Management in Healthcare 3 Credits
Engineering economics in Healthcare; value metrics (net present value, return on investment, etc.), cost-benefit analysis, capital projects and improvements. Accounting methods in Healthcare systems. Reimbursement methods, organizations, and alternatives. Financial strategy, planning, pricing and capital formation in “for”, and “not for” profit settings. This course is an undergraduate version of the graduate level course ISE 472. A student cannot receive credit for both ISE 372 and ISE 472.

ISE 382 Leadership Development 3 Credits
Exploration and critical analysis of theories, principles, and processes of effective leadership. Managing diverse teams, communication, and ethics associated with leadership. Application of knowledge to personal and professional life through projects and team assignments. This course is an undergraduate version of ISE 482. A student cannot receive credit for both ISE 382 and ISE 482.

ISE 401 Convex Analysis 3 Credits
Theory and applications of convex analysis, particularly as it relates to convex optimization and duality theory. Content of the course emphasizes rigorous mathematical analysis as well as geometric and visually intuitive viewpoints of convex objects and optimization problems.

ISE 402 Operations Research Models and Applications 3 Credits
Applied models in operations research, including models in supply chain management, energy, health care, disaster relief, and/or financial optimization. Models, theorems, algorithms, and skills for translating practical problems into mathematical ones.

ISE 403 Research Methods 3 Credits
Skills for conducting doctoral research. Topics include technical reading, technical writing, computing skills, literature review skills, and research ethics.

ISE 406 Fundamentals of Optimization 3 Credits
Introduction to theory and algorithms for linear, discrete, and convex mathematical optimization. Significant portion dedicated to linear optimization theory from both geometric and algebraic perspectives. Basic coverage of discrete optimization, including modeling techniques and algorithmic ideas for solving discrete optimization problems such as branch-and-bound and cutting planes. Basic introduction to convex optimization, including convex sets and functions, duality theory, and optimality conditions.

ISE 407 Numerical Methods and Scientific Computing 3 Credits
Topics in numerical methods, numerical analysis, and scientific computing including floating point arithmetic, conditioning and stability, data structures for scientific computing, analysis of algorithms, and direct and iterative methods for numerical linear algebra. Emphasis on efficient implementations in modern computing languages.

ISE 408 Simulation 0,3 Credits
Applications of discrete and continuous simulation techniques in modeling industrial systems. Simulation using a highlevel simulation language. Design of simulation experiments. This course is a version of ISE 308 for graduate students, with advanced assignments. A student can receive credit for only one of the following courses: ISE 305, ISE 404, ISE 308, and ISE 408.

ISE 409 Time Series Analysis 3 Credits
Theory and applications of an approach to process modeling, analysis, prediction, and control based on an ordered sequence of observed data. Single or multiple time series are used to obtain scalar or vector difference/ differential equations describing a variety of physical and economic systems. This course is a version of ISE 309 for graduate students, with advanced assignments. A student cannot receive credit for both ISE 309 and ISE 409.

ISE 410 Design of Experiments 3 Credits
Experimental procedures for sorting out important causal variables, finding optimum conditions, continuously improving processes, and trouble shooting. Applications to laboratory, pilot plant and factory. Must have some statistical background and experimentation in prospect. This course is a version of ISE 310 for graduate students, with advanced assignments. A student cannot receive credit for both ISE 310 and ISE 410.

ISE 411 Networks and Graphs 3 Credits
This course examines the theory and applications of networks and graphs. Content of the courses stresses the modeling, analysis and computational issues of network and graph algorithms. Complexity theory, trees and arborescences, path algorithms, network flows, matching and assignment, primal-dual algorithms, Eulerian and Hamiltonian walks and various applications of network models.

ISE 412 Quantitative Models of Supply Chain Management 3 Credits
Analytical models for logistics and supply chain coordination. Modeling, analysis, and computational issues of production, transportation, and other planning and decision models. Logistics network configuration, risk pooling, stochastic decision-making, information propagation, supply chain contracting, and electronic commerce implication.

ISE 414 Uncertainty Quantification 3 Credits
In-depth exploration of the principles, methodologies, and practical applications of managing uncertainty in the context of optimization, operations research, data science, and scientific computing.
Prerequisites: ISE 403 and ISE 429

ISE 415 Optimization Under Uncertainty 3 Credits
Modeling, theory, solution algorithms, and applications of optimization models under uncertainty. Topics include stochastic, robust, and distributionally robust optimization techniques, including the mathematics of obtaining their associated deterministic equivalent optimization problems.

ISE 416 Dynamic Programming 3 Credits
This course is concerned with the dynamic programming approach to sequential decision making under uncertainty, exact solution algorithms, and approximate methods adapted to large-scale problems. Value iteration, policy iteration and lambda-policy iteration are introduced and analyzed using fixed-point theory. The linear optimization approach to dynamic programming is introduced. Special policy structures are studied. Algorithms based on sampling and on the use of linear approximation architectures are covered.
Prerequisites: ISE 316 or IE 316

ISE 417 Continuous Optimization 3 Credits
Theoretical principles underlying continuous (nonlinear) optimization problems and the numerical methods that are available to solve them. Topics include the steepest descent method, Newton's method for unconstrained optimization, necessary and sufficient optimality conditions, duality, line search and trust region methods for unconstrained optimization, derivative-free and quasi-Newton techniques, and other numerical methods relevant for solving continuous optimization problems.

ISE 418 Discrete Optimization 3 Credits
Theory, algorithms, and applications of discrete optimization. Focus on mathematical and algorithmic foundations with emphasis on techniques most successful in current software implementations, such as convexification and enumeration. Use of commercial and open source software and frameworks for solving discrete optimization problems will be discussed.

ISE 422 Quantum Computing Optimization 3 Credits
Quantum computers have the potential to efficiently solve optimization problems that are intractable for classical computers. Foundations and basic concepts of quantum computing are discussed. Sample list of topics include: quantum mechanics of qubits; quantum entanglement; quantum circuits, quantum Fourier transform; the Shor factorization algorithm; the Grover search algorithm; elements of quantum linear algebra and quantum tomography; Quantum approximate optimization algorithm and quantum interior point methods.

ISE 424 Industrial Automation and Robotics 3 Credits
Introduction to robotics technology and applications. Robot anatomy, controls, programming, work cell design, sensors, vision systems, using Programmable Logic Controllers. Laboratory exercises. This course is a version of ISE 324 for graduate students, with advanced assignments. A student cannot receive credit for both ISE 324 and ISE 424.

ISE 426 Optimization Models and Applications 3 Credits
Modeling and analysis of operations research problems using techniques from mathematical programming. Linear programming, integer programming, multicriteria optimization, stochastic programming and nonlinear programming using an algebraic modeling language. A student can receive credit for only one of the following courses: ISE 240, ISE 316, and ISE 426.

ISE 427 Facilities Planning and Material Handling 3 Credits
Facilities planning including plant layout design and facility location. Material handling analysis including transport systems, storage systems, and automatic identification and data capture. This course is a version of ISE 327 for graduate students, with advanced assignments. A student can receive credit for only one of the following courses: ISE 316, ISE 327, and ISE 427.

ISE 429 Probability and Stochastic Processes 3 Credits
Mathematical foundations of probability and stochastic processes for modeling and analyzing real-world phenomena. Modeling and analyzing systems that evolve over time, such as queueing systems. Topics include probabilistic models, fundamental theorems of probability, conditional probability, independence, random variables, distribution functions, laws of large numbers, martingales, Markov chains, Poisson processes, and Brownian motion.

ISE 432 Product Quality 3 Credits
Introduction to engineering methods for monitoring, control, and improvement of quality. Statistical models of quality measurements, statistical process control, acceptance sampling, and quality management principles. Some laboratory exercises. This course is a version of ISE 332 for graduate students, with advanced assignments. A student cannot receive credit for both ISE 332 and ISE 432.

ISE 434 Operational Excellence 3 Credits
Provides a comprehensive understanding of Operational Excellence within an organization. From defining business strategy and creating measurable initiatives/metrics, students learn tools, such as Lean and Six Sigma Methodologies, Sales, Operations and Inventory Planning, and Change, and Project Management to optimize the end-to-end value chain. These tools enhance operational and organizational efficiency in complex businesses. This course is a version of ISE 334 for graduate students, with advanced assignments. A student cannot receive credit for both ISE 334 and ISE 434.

ISE 435 Planning and Scheduling in Manufacturing and Services 3 Credits
Models for the planning and scheduling of systems that produce goods or services. Resource allocation techniques utilizing static and dynamic scheduling methods and algorithms. Application areas include manufacturing and assembly systems, transportation system timetabling, project management, supply chains, and workforce scheduling. This course is a version of ISE 335 for graduate students, with advanced assignments. A student can receive credit for only one of the following courses: ISE 335, ISE 419, and ISE 435.

ISE 436 Engineering Project Management 3 Credits
Presents the principles and techniques used in all phases of managing engineering projects that includes the initial phase, planning, execution, control, and closeout. Students develop the analytical skills and awareness necessary for managing engineering projects. This course is a version of ISE 336 for graduate students, with advanced assignments. A student cannot receive credit for both ISE 336 and ISE 436.
Repeat Status: Course may be repeated.

ISE 439 Stochastic Models and Applications 3 Credits
Introduction to stochastic process modeling and analysis techniques and applications. Generalizations of the Poisson process; renewal theory and applications to inventory theory, queuing, and reliability; Brownian motion and stationary processes. This course is a graduate version of ISE 339. A student cannot receive credit for both ISE 339 and ISE 439.

ISE 444 Optimization Methods in Machine Learning 3 Credits
Machine learning models and optimization methods that are used to apply these models in practice. Convex models. Gradient and subgradient methods and their stochastic counterparts. Limits and errors of learning, noise reduction, and nonconvex models. Other techniques and algorithms include acceleration, coordinate descent, alternating-direction methods, first-order constrained convex optimization methods, and second-order methods.

ISE 447 Financial Optimization 3 Credits
Making optimal financial decisions under uncertainty. Financial topics include asset/liability management, option pricing and hedging, risk management and portfolio optimization. Optimization covered includes linear/nonlinear optimization, discrete optimization, dynamic programming and stochastic optimization. Emphasis on use of modeling languages and solvers in financial applications. Requires basic knowledge of linear optimization and probability. This course is a graduate version of ISE 347. A student cannot receive credit for both ISE 347 and ISE 447.
Prerequisites: ISE 426

ISE 455 Optimization Algorithms and Software 3 Credits
Basic concepts of large families of optimization algorithms for both continuous and discrete optimization problems. Pros and cons of the various algorithms when applied to specific types of problems; information needed; whether local or global optimality can be expected. Participants practice with corresponding software tools to gain hands-on experience. This course is a version of ISE 355 for graduate students, with advanced assignments. A student cannot receive credit for both ISE 355 and ISE 455.

ISE 456 Conic Optimization 3 Credits
Modeling, theory, solution algorithms, and applications of conic optimization. Topics include mathematics of conic optimization: second-order cones, semidefinite cones, conic duality, interior-point methods. Applications of conic optimization to combinatorial optimization and other areas of optimization are covered.

ISE 458 Game Theory 3 Credits
A mathematical analysis of how people interact in strategic situations. Applications include strategic pricing, negotiations, voting, contracts and economic incentives, and environmental issues. This course is a version of ISE 358 for graduate students, with advanced assignments. A student cannot receive credit for both ISE 358 and ISE 458.

ISE 462 Logistics and Supply Chain Management 3 Credits
Modeling and analysis of supply chain design, operations, and management. Analytical framework for logistics and supply chains, demand and supply planning, inventory control and warehouse management, transportation, logistics network design, supply chain coordination, and financial factors. Students complete case studies and a comprehensive final project. This course is a version of ISE 362 for graduate students, with advanced assignments. A student cannot receive credit for both ISE 362 and ISE 462.

ISE 464 Introduction to Machine Learning 3 Credits
Techniques of applied machine learning rather than deep theory behind the algorithms and methods. Programming solutions for machine learning problems using a high-level programming language and associated machine learning libraries. Regression, clustering, principal component analysis, Bayesian methods, decision trees, random forests, support vector machines, and neural networks. This course is a version of ISE 364 for graduate students, with advanced assignments. A student cannot receive credit for both ISE 364 and ISE 464.

ISE 465 Applied Data Mining 3 Credits
Introduction to the data mining process including business problem understanding, data understanding and preparation, modeling and evaluation, and model deployment. Emphasis on hands-on data preparation and modeling using techniques from statistics, artificial intelligence, such as regression, decision trees, neural networks, and clustering. A number of application areas are explored. This course is a version of ISE 365 for graduate students, with advanced assignments. A student cannot receive credit for both ISE 365 and ISE 465.

ISE 471 Quality and Process Improvement in Healthcare 3 Credits
The dimensions of Healthcare quality and their definitions, quality metrics, accreditation and other benchmarking and evaluation methods. Change management, project planning and team management. Continuous improvement tools including “lean”, “six-sigma”, and “TQM”. This course is a version of ISE 371 for graduate students, with advanced assignments. A student cannot receive credit for both ISE 371 and ISE 471.

ISE 472 Financial Management in Healthcare 3 Credits
Engineering economics in Healthcare; value metrics (net present value, return on investment, etc.), cost-benefit analysis, capital projects and improvements. Accounting methods in Healthcare systems. Reimbursement methods, organizations, and alternatives. Financial strategy, planning, pricing and capital formation in “for”, and “not for” profit settings. This course is a version of ISE 372 for graduate students, with advanced assignments. A student cannot receive credit for both ISE 372 and ISE 472.

ISE 480 ISE Project 1-3 Credits
Intensive study of an area of industrial and systems engineering with emphasis upon design and application. A written report is required.
Repeat Status: Course may be repeated.

ISE 481 HSE Project 1-3 Credits
Intensive study in health systems engineering with an emphasis upon design and application. Written report is required.
Repeat Status: Course may be repeated.

ISE 482 Leadership Development 3 Credits
Exploration and critical analysis of theories, principles, and processes of effective leadership. Managing diverse teams, communication, and ethics associated with leadership. Application of knowledge to personal and professional life through projects and team assignments. This course is a version of ISE 382 for graduate students, with advanced assignments. A student cannot receive credit for both ISE 382 and ISE 482.

ISE 485 Industrial Engineering Special Topics 1-3 Credits
An intensive study of some field of industrial engineering.
Repeat Status: Course may be repeated.

ISE 486 Operations Research Special Topics 1-3 Credits
An intensive study of some field of operations research.
Repeat Status: Course may be repeated.

ISE 487 Professional Development 0 Credits
Discuss and learn how to implement the tools needed to successfully navigate the employment market, as well as guide students through the process of pursuing a job and internship opportunities.

ISE 489 Readings 1-3 Credits
Intensive readings-based course of some topic in industrial and systems engineering.
Repeat Status: Course may be repeated.

ISE 490 Thesis 1-6 Credits
Thesis course.
Repeat Status: Course may be repeated.

ISE 499 Dissertation 1-15 Credits