# INDUSTRIAL ENGINEERING

## Undergraduate Program Information

Industrial engineers design, develop, install, and improve integrated systems. Integrated systems can involve people, equipment, information, financial resources, software, materials, or energy. Industrial engineers work in a variety of manufacturing, health care, utility, retail, government, and research settings, therefore the tools and methods of the industrial engineer are both varied and broad. Industrial Engineers use knowledge and skills in engineering, mathematics, and physical and social sciences. They also use principles and methods of engineering analysis and design to monitor and improve systems. New Mexico State University's undergraduate degree program in Industrial Engineering prepares students to join the workforce or pursue graduate education while setting the foundation for lifelong learning.

Specifically, within 2-3 years of graduation, graduates of the program will have:

- successfully applied various industrial Engineering techniques in an integrated fashion to solve real-world problems in process design and/or improvement;
- been engaged in a successful career sustained by life-long learning experiences

In addition, the Engineering Accreditation Commission of ABET, Inc. criteria in conjunction with the Institute of Industrial Engineers, requires that:

- baccalaureate degree graduates will be able to demonstrate the ability to design, develop, implement, and improve integrated systems that include people, materials, information, equipment, and energy;
- industrial engineering curricula include in-depth instruction allowing students to accomplish the integration of systems using appropriate analytical, computational, and experimental practices; and
- that faculty teaching in industrial engineering departments shows evidence of understanding professional practice and staying current in their respective professional areas. Program faculty must have a responsibility and sufficient authority to define, revise, implement, and achieve program objectives.

***Master's Accelerated Program:*** The Master's Accelerated Program (MAP) option provides excellent opportunities for academically qualified undergraduate students to begin working on a master's degree during their junior year and senior year. The student must obtain prior approval from the department head before starting the MAP. Note that the MAP is only applicable if the student has not yet completed a bachelor's degree.

**Graduate Program Information**

The Department of Industrial Engineering offers graduate work leading to the degrees of Master of Engineering in Industrial Engineering (MEIE), Master of Science in Industrial Engineering (MSIE), and Doctor of Philosophy (Ph.D.) with a specialization in industrial engineering. Areas of emphasis include

- operations research and simulation analytics,
- manufacturing systems,
- quality and reliability engineering,
- engineering management and systems engineering.

Departmental admission requirements in addition to those of the Graduate School must be considered on an individual basis because of the diversity of backgrounds of applicants in the program. An applicant should meet or correspond directly with the department as a first step in determining his or her specific admission status. Applicants should present mathematics preparation equivalent to 9 credits of calculus for engineers, 3 credits of differential equations, and 3 credits of calculus-based probability and statistics.

The MEIE is a Professional Master's degree targeting a working professional who wants to pursue a Master's degree in Industrial Engineering. The minimum credit-hour requirements for the MEIE degree may be met in the following way:

- 30-semester credits of approved coursework.

The MSIE is a research-oriented degree. The minimum credit-hour requirements for the MSIE degree may be met in any of the following ways:

- 24-semester credits approved course work and 6-semester credits of thesis (I E 599 Master's Thesis) for a total of 30-semester credits or
- 27-semester credits approved course work and 3-semester credits of project (I E 598 Special Research Programs) for a total of 30-semester credits.

Approved coursework must meet all requirements of the Graduate School, represent a consistent master's program in relation to a student's graduate study goals as determined through consultation with the graduate program adviser, and be approved by a program committee of the graduate faculty of the department. Programs in the focus areas of operations research and simulation analytics, manufacturing systems, quality and reliability engineering, or engineering management and systems engineering can be developed with the aid of a faculty advisor.

Departmental facilities and equipment are available to support the research efforts of graduate students, including computer terminals and laboratories. In addition to departmental facilities, supporting facilities such as the Aggie Innovation Space (AIS) and interdisciplinary research clusters are available for research work.

The Ph.D. program is research-oriented with the final product being the dissertation. The general information (https://catalogs.nmsu.edu/nmsu/regulations-policies/) chapter in this catalog describes the Ph.D. degree program. The Ph.D. in Industrial Engineering also includes the following requirements:

- the coursework must include at least 12 credits at the 500 level in a related field,
- 6 credits of 600-level research courses covering two areas, and
- 18 credits of 700-level courses following successful completion of the comprehensive examination.

The department does not have any foreign language or research tool requirements. Interested individuals should correspond directly with the department to determine eligibility for admission.

## Degrees for the Department

### Bachelor Degree(s)

- Industrial Engineering - Bachelor of Science in Industrial Engineering (https://catalogs.nmsu.edu/nmsu/engineering/industrial-

engineering/industrial-engineering-bachelor-science-industrial-engineering/)

## Master Degree(s)

The Master of Science in Industrial Engineering degree is a research-oriented degree. If you are interested in pursuing an advanced degree for a career in the engineering sciences or in preparation for a Ph.D., our MS degree is for you. The Master of Engineering in Industrial Engineering is the coursework-only degree. It is a **Professional Master's degree** targeting a working professional who wants to pursue a Master's degree in Industrial Engineering at New Mexico State University.

- Engineering Management - Master of Engineering in Engineering Management (Online) (https://catalogs.nmsu.edu/global/nmsu-global/engineering-management-meem-online/)
- Industrial Engineering (Systems Engineering) - Master of Engineering in Industrial Engineering (Online) (https://catalogs.nmsu.edu/global/nmsu-global/industrial-engineering-systems-engineering-meie-online/)
- Industrial Engineering - Master of Engineering in Industrial Engineering (https://catalogs.nmsu.edu/nmsu/graduate-school/industrial-engineering-master-engineering/)
- Industrial Engineering - Master of Engineering in Industrial Engineering (Online) (https://catalogs.nmsu.edu/global/nmsu-global/industrial-engineering-meie-online/)
- Industrial Engineering - Master of Science in Industrial Engineering (https://catalogs.nmsu.edu/nmsu/graduate-school/industrial-engineering-master-science-industrial-engineering/)
- Industrial Engineering - Master of Science in Industrial Engineering (Online) (https://catalogs.nmsu.edu/global/nmsu-global/industrial-engineering-msie-online/)

## Doctoral Degree(s)

- Engineering (Industrial Engineering) - Doctor of Philosophy (https://catalogs.nmsu.edu/nmsu/graduate-school/engineering-industrial-engineering-doctor-philosophy/)

# Minors for the Department

- Advanced Manufacturing - Graduate Minor (https://catalogs.nmsu.edu/nmsu/graduate-school/advanced-manufacturing-graduate-minor/)
- Entrepreneurship - Undergraduate Minor (https://catalogs.nmsu.edu/nmsu/engineering/industrial-engineering/entrepreneurship-undergraduate-minor/)
- Lean Manufacturing and Analytics - Undergraduate Minor (https://catalogs.nmsu.edu/nmsu/engineering/industrial-engineering/lean-manufacturing-analytics-ug-minor/)
- Supply Chain and Operations Research Analytics - Undergraduate Minor (https://catalogs.nmsu.edu/nmsu/engineering/industrial-engineering/supply-chain-operations-research-analytics-ug-minor/)
- Systems Engineering - Undergraduate Minor (https://catalogs.nmsu.edu/nmsu/engineering/industrial-engineering/systems-engineering-ug-minor/)

# Graduate Certificates

- Systems Engineering - Graduate Certificate (https://catalogs.nmsu.edu/nmsu/graduate-school/systems-engineering-graduate-certificate/)
- Systems Engineering - Graduate Certificate (Online) (https://catalogs.nmsu.edu/global/nmsu-global/systems-engineering-gr-certificate-online/)

**Hansuk Sohn, Department Head**

***Professors***

***Associate Professors*** Hansuk Sohn (Department Head), John Mullen, Raja Jayaraman

***Assistant Professors*** Chaitanya Mahajan, Venkata Sirimuvva "Siri" Chirala

***Professor of Practices*** Manuel Ivan Rodriguez Borbon, Salvador Rodriguez

***Adjunct Professor*** German Reyes

***Professor Emeritus*** Ed Pines

*H. Sohn, Department Head, Ph.D. (University of Iowa)– Combinatorial optimization, Operations Research applications in logistics, transportation, and health systems; J. Mullen, Ph.D. (Iowa State)– Stochastic processes, quality, improvement, production system design; R. Jayaraman, Ph.D. (Texas Tech)- Digital supply chain, applied Operations Research, healthcare systems engineering; C. Mahajan, Ph.D. (Rochester Institute of Technology)- Additive manufacturing, computer integrated manufacturing, manufacturing systems; V. S. Chirala, Ph.D. (Wayne State)- Robot operating system, autonomous vehicles, multi-objective stochastic programming, machine learning; M. I. Rodriguez Borbon, Ph.D. (NMSU)- Experimental statistics, reliability, degradation analysis, survival analysis, lifecycle analysis; Salvador "Sal" Rodriguez, MS (NMSU)- Conceptual, Developmental and Operational Test & Evaluation, and Project Management; G. Reyes, Ph.D. (NMSU)- computer simulation modeling, including agent-based modeling, system dynamics modeling, and digital twin technology; E. Pines, Ph.D. (Penn State)– Quality and continuous improvement, technology policy;*

# Industrial Engineering Courses

**I E 151. Computational Methods in Industrial Engineering**
**3 Credits (3)**
History, social implications, and application of computers and an introduction to computer programming, word processing, and database management systems. Satisfies General Education computer science requirement. May be repeated up to 3 credits.
**Prerequisite:** MATH 1220G.
**Learning Outcomes**

1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
2. An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.

**I E 200. Special Problems-Sophomore**
**1-3 Credits**
Directed individual projects. May be repeated up to 3 credits.
**Learning Outcomes**

1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
2. An ability to communicate effectively with a range of audiences.

**I E 217. Manufacturing Processes**
**3 Credits (2+3P)**

Introduction to manufacturing and processing, including: casting, forming, and machining. Emphasis on creating products with the appropriate techniques. Crosslisted with: E T 217.
**Prerequisite(s):** A grade of C- or better in either E T 110 or ENGR 110 and C- or better in MATH 1220G.

**Learning Outcomes**

1. Identify the different manufacturing processes and their applications.
2. Use, set up, and calibrate measuring tools.
3. Apply geometric tolerances to engineering drawings.
4. Demonstrate basic knowledge of materials and material properties.
5. Demonstrate basic knowledge of GM codes and their application.
6. Proficiently use CAM packages such as SolidWorks CAM.
7. Identify different tooling, their use, and manufacturing application.

**I E 300. Special Problems-Junior**
**1-3 Credits**
Directed individual projects. May be repeated up to 3 credits.
**Prerequisite:** consent of faculty member.

**Learning Outcomes**

1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
2. An ability to communicate effectively with a range of audiences.

**I E 311. Engineering Data Analysis**
**3 Credits (3)**
Methodology and techniques associated with identifying and analyzing industrial data.
**Prerequisite:** C- or better in MATH 1521G or MATH 1521H or ENGR 190.

**Learning Outcomes**

1. Ability to correctly interpret statistical reports
2. Ability to correctly identify and solve problems involving continuous and discrete probability and random variables.
3. Ability to correctly analyze random samples using methods that include: point estimates, confidence intervals, tests of hypothesis, analysis of variance (ANOVA), and linear regression.

**I E 316. Methods Engineering**
**3 Credits (2+3P)**
Methods analysis and design. Work measurement techniques. Job evaluation and wage incentive methods. May be repeated up to 3 credits.
**Corequisite:** I E 311.

**Learning Outcomes**

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 develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.
5. An ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

**I E 351. Applied Problem Solving in Industrial Engineering**
**3 Credits (3)**
Application of computational techniques to engineering problems including the use of commercial programs in statistics and applied mathematics. Restricted to majors.
**Corequisite:** I E 311.

**Learning Outcomes**

1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
2. An ability to communicate effectively with a range of audiences.
3. An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.

**I E 365. Quality Control**
**3 Credits (3)**
Statistical analysis of quality in manufacturing. Acceptance sampling and control charts.
**Prerequisite:** I E 311 or equivalent.

**Learning Outcomes**

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.

**I E 375. Manufacturing Processes II**
**3 Credits (3)**
Review of basic manufacturing processes. Advanced topics in casting, forming, machining and joining; major process parameters; economics of processes.
**Prerequisite:** I E 217 or E T 217.

**Learning Outcomes**

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 function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
4. An ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

**I E 400. Undergraduate Research**
**1-3 Credits**
Directed individual projects. May be repeated up to 6 credits.

**Learning Outcomes**

1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
2. An ability to communicate effectively with a range of audiences.

**I E 411. Occupational Safety**
**3 Credits (3)**
Practical methods to improve safety in the workplace. Topics include OSHA and other regulations, hazard recognition, assessment and control,

industry standards, risk assessment and safety management. Material is applicable to a variety of workplace settings. This course is intended for College of Engineering students who have completed their lower-division requirements in mathematics, engineering, technology, and basic science. Same as I E 561 with differential assignments. May be repeated up to 3 credits.
**Prerequisite:** Junior standing.
**Learning Outcomes**
1. 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.
2. An ability to communicate effectively with a range of audiences.
3. 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.

**I E 412. Design for Manufacturing and Assembly**
**3 Credits (3)**
Engineering methodology focusing on reducing time-to-market and total production costs by prioritizing both the ease of manufacture for the product's parts and the simplified assembly of those parts into the final product.
**Prerequisite:** (ENGR 217 or I E 217) and I E 316.
**Learning Outcomes**
1. The ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
2. The 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.
3. The 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.
4. The ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.

**I E 413. Engineering Operations Research I**
**3 Credits (3)**
Deterministic operations research modeling including linear and integer programming.
**Prerequisite:** MATH 1521G or MATH 1521H or ENGR 190.
**Corequisite:** MATH 480 or MATH 2415.
**Learning Outcomes**
1. Ability to model optimization problems that can be solved by linear optimization.
2. Ability to solve linear optimization problems
3. Ability to interpret solutions of linear optimization problems in the context of the larger problem.

**I E 423. Engineering Operations Research II**
**3 Credits (3)**
Probabilistic operations research modeling, including queuing systems and their optimization; Markov chains.
**Prerequisite:** I E 311.
**Corequisite:** MATH 392.
**Learning Outcomes**
1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
2. An ability to communicate effectively with a range of audiences.
3. 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.
4. 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.

**I E 424. Manufacturing Systems**
**3 Credits (3)**
Organization and functions of manufacturing planning and control systems including forecasting, MRP, capacity planning, JIT systems, scheduling, and inventory control.
**Prerequisite:** I E 311.
**Learning Outcomes**
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 develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.

**I E 425. Supply Chain Modeling and Analysis**
**3 Credits (3)**
This course introduces supply chain and logistics concepts integrating theory and its application. The course emphasis is on understanding the role of supply chains for competitive advantage, when and how these concepts are applied to improve the distribution of goods and services, as well as in using mathematical programming and optimization methods for their adequate implementation.
**Prerequisite:** MATH 1521G or MATH 1521H or ENGR 190.
**Corequisite:** MATH 2415.
**Learning Outcomes**
1. Define and understand different structures and the importance of the supply chain.
2. Identify the main drivers of supply chain performance and measure them using precise metrics.
3. Integrate production operations management topics in the context of the supply chain.
4. Develop the ability to formulate quantitative decision models for supply chain and logistics management.
5. Study inventory planning decisions, Economic Order Quantity (EOQ), and its variants.

**I E 451. Engineering Economy**
**3 Credits (3)**
Discounted cash flows, economics of project, contract and specifications as related to engineering design.

**Learning Outcomes**

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.

**I E 456. Large Scale Systems Engineering**
**3 Credits (3)**
Systems engineering approaches to large-scale complex technological and societal problems. Concepts of interaction and structural graphs, matrices, delta, and Gantt charts. The hall matrix approach, structural concepts, reachability matrices, and cross impact-analysis, modeling and decision making. May be repeated up to 3 credits.
**Learning Outcomes**

1. Ability to describe the systems engineering standards and best practices
2. Ability to characterize the limitations of the way that current systems engineering is practiced in terms of dealing with lifecycle uncertainty.

**I E 459. Systems Thinking and Decision Making**
**3 Credits (3)**
A general introduction to systems engineering. Topics include General Systems Theory, Systems Thinking and emerging concepts, Systems Dynamics approaches for modelling and analyzing non-linear feedback mechanisms in complex systems, and Complexity science and complex adaptive systems. May be repeated up to 3 credits.
**Learning Outcomes**

1. Ability to understand the complexities of engineering systems, and the implications of change on system behavior
2. Ability to understand the nature of complex systems in respect to people, processes, the environment and development organization
3. Ability to understand Systems Thinking's' role and value within organizations
4. Ability to recognize the advantages, as well as the flaws of our present predominant way of thinking (Cartesian), while looking at the changes that would enable us to deal with complex issues in daily practice (Systems Thinking)
5. Ability to recognize the value and limitations of modeling and simulation as well as how to construct and interpret various models to support decision making.

**I E 460. Evaluation of Engineering Data**
**3 Credits (3)**
Analysis of engineering systems possessing variability, employing regression, analysis of variance, distribution theory, and experimental design methods.
**Prerequisite:** I E 311 or equivalent.
**Learning Outcomes**

1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
2. An ability to communicate effectively with a range of audiences.
3. An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.

**I E 466. Reliability**
**3 Credits (3)**
Application of statistical theory to engineering reliability estimation, reliability improvement, and the analysis of reliability test data.
**Prerequisite:** I E 311 or equivalent.
**Learning Outcomes**

1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
2. An ability to communicate effectively with a range of audiences.
3. An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.

**I E 467. Discrete-Event Simulation Modeling**
**3 Credits (3)**
Basic modeling concepts, organizations of simulations, input data analysis, random variate generation, simulation design and analysis, model validation, output analysis, and management of simulations. Differentiated graduate assignments.
**Prerequisite:** I E 311 or equivalent.
**Learning Outcomes**

1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
2. An ability to communicate effectively with a range of audiences.
3. 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.
4. An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.
5. An ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

**I E 468. Advanced Discrete-Event Simulation Applications**
**3 Credits (3)**
Semester long project involving development and application of advanced simulation skills. May be repeated up to 3 credits.
**Prerequisite:** I E 467.
**Learning Outcomes**

1. Ability to understand the techniques of computer simulation modeling in the context of hierarchy of knowledge about a system and develop the capability to apply the same to study systems through available computer simulation software

**I E 478. Facilities Planning and Design**
**3 Credits (3)**
Plant location methods, total process analysis, process integration, materials handling analysis, and traditional and computerized plant layout methodologies.
**Prerequisite:** I E 316.

**Prerequisite/Corequisite:** I E 424.

**Learning Outcomes**

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.

**I E 490. Selected Topics**

**1-3 Credits**

This course offers an in-depth exploration of specific topics within a given field or discipline. The content may vary each time the course is offered, allowing for flexibility in addressing emerging trends, current issues, or specialized areas of study. May be repeated up to 9 credits.

**Learning Outcomes**

1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
2. An ability to communicate effectively with a range of audiences.
3. 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.
4. 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.

**I E 505. Directed Readings**

**1-3 Credits**

The Directed Readings course provides students with the opportunity to pursue an in-depth exploration of a specific topic or area of interest under the guidance of a faculty mentor. Through independent study and directed readings, students will delve into scholarly literature, research articles, and relevant texts to deepen their understanding of the chosen subject matter. The course allows for a flexible learning experience tailored to the student's academic goals and interests. Students will work closely with their mentor to develop a reading list, set learning objectives, and engage in discussions to enhance their comprehension and critical analysis skills. May be repeated up to 6 credits.

**Learning Outcomes**

1. An ability to demonstrate a comprehensive understanding of the chosen topic or area of interest through in-depth reading and analysis of relevant literature.
2. An ability to develop critical thinking skills by evaluating and synthesizing information from scholarly sources, research articles, and other relevant texts.
3. An ability to effectively communicate their insights, findings, and reflections on the chosen topic through written assignments, discussions, and presentations.
4. An ability to acquire research skills, including the ability to locate, evaluate, and integrate scholarly sources into their analysis and writing.

**I E 511. Survey of Industrial Engineering**

**3 Credits (3)**

A project-based course covering methods of engineering, plant layout, production and inventory control, economic analysis, etc. May be repeated up to 3 credits.

**Learning Outcomes**

1. Ability to apply the various techniques of Industrial Engineering to solve real-life problems

**I E 515. Stochastic Processes Modeling**

**3 Credits (3)**

Introduction to the use of stochastic processes in the modeling of physical and natural systems. Use of generating functions, conditional probability and expectation, Poisson processes, random walk models, Markov chains, branching processes, Markov processes, and queuing processes in an applied setting.

**Learning Outcomes**

1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
2. An ability to communicate effectively with a range of audiences.
3. 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.
4. 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.

**I E 522. Queuing Systems**

**3 Credits (3)**

Elements and classification of queuing systems, single server models, multi-server models, cost analysis and applications.

**Learning Outcomes**

1. Ability to model, analyze, and apply solutions to problems involving queueing systems
2. Ability to read and understand literature in the queueing system analysis field.

**I E 523. Advanced Engineering Economy**

**3 Credits (3)**

Theoretical basis for engineering economy methods, problems of cost estimation, replacement, nonmonetary factors, and feasibility studies. Same as C E 523.

**Learning Outcomes**

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.

**I E 524. Advanced Production and Inventory Control**

**3 Credits (3)**

Organization and functions of manufacturing planning and control systems including forecasting, MRP, capacity planning, JIT systems,

scheduling and inventory control. Same as I E 424 with differentiated assignments.

**Learning Outcomes**

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

**I E 525. Systems Synthesis and Design**
**3 Credits (3)**

Examination of the production management complex in terms of its components and the synthesis of these components into an effective operating unit. Development of input-output models representing the basis structure of all production activities.

**Learning Outcomes**

1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
2. An ability to communicate effectively with a range of audiences.
3. 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.
4. 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.

**I E 530. Environmental Management Seminar**
**1 Credit (1)**

Survey of practical and new developments in hazardous and radioactive waste management provided through a series of guest lectures and reports of ongoing research. Same as C E 530, E E 530, CHME 530.

**Learning Outcomes**

1. An ability to demonstrate a comprehensive understanding of key concepts, principles, and theories related to environmental management, including environmental policy, sustainability, resource conservation, and pollution control.
2. An ability to develop critical thinking and analytical skills by evaluating environmental issues, assessing their impact on ecosystems and human populations, and proposing evidence-based solutions to address complex environmental challenges.
3. An ability to gain an interdisciplinary perspective by exploring environmental management topics from multiple viewpoints, integrating knowledge from fields such as ecology, economics, sociology, and public policy.
4. An ability to develop an awareness of ethical considerations and values relevant to environmental management, including principles of environmental justice, equity, and responsibility towards future generations.

**I E 533. Linear Programming**
**3 Credits (3)**

Linear programming problem formulation, simplex algorithm, theory of linear programming, duality, revised simplex algorithm, and sensitivity analysis.

**Learning Outcomes**

1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
2. An ability to communicate effectively with a range of audiences.
3. 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.
4. 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.

**I E 534. Nonlinear Programming**
**3 Credits (3)**

Theoretical and computational methods to solve optimization problems in engineering, statistics, economics, and operations research. Topics include convexity, optimality conditions, Newton's method, Lagrange multipliers, search algorithms for unconstrained and constrained problems, as well as barrier and penalty methods.

**Learning Outcomes**

1. Ability to model situations which may be solved by nonlinear optimization and to interpret the results in the context of the larger problem
2. Ability to employ several computer tools to correctly solve nonlinear optimization problems.
3. Ability to read and understand literature in the field of nonlinear optimization
4. Ability to select appropriate methods and algorithms from a core representative set of methods and tools to solve nonlinear optimization problems

**I E 535. Discrete Optimization**
**3 Credits (3)**

Combinatorial Optimization problems using both integer programming and graph theoretic approaches. Emphasis on modeling and computational algorithms. May be repeated up to 3 credits.

**Learning Outcomes**

1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
2. An ability to communicate effectively with a range of audiences.
3. 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.
4. 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.

**I E 537. Large Scale Systems Engineering**
**3 Credits (3)**

Systems engineering approaches to large-scale complex technological and societal problems. Concepts of interaction and structural graphs, matrices, delta, and Gantt charts. The hall matrix approach, structural concepts, reachability matrices, and cross impact-analysis, modeling and decision making.

**Learning Outcomes**

1. Ability to describe the systems engineering standards and best practices.
2. Ability to characterize the limitations of the way that current systems engineering is practiced in terms of dealing with lifecycle uncertainty.

**I E 545. Characterizing Time-Dependent Engineering Data**
**3 Credits (3)**

Theory and techniques employed in the characterization of stochastic processes commonly found in engineering applications. Distribution models include exponential, gamma, Weibull, and extreme value. Design and analysis of experiments involving complete and censored data and elevated stress. Analytical techniques include parametric, nonparametric, and graphical approaches with emphasis on modern computer tools. Exact and approximate maximum-likelihood techniques are stressed.

**Learning Outcomes**

1. Ability to characterize a process, based on data that is time-dependent or sequential in nature.

**I E 561. Advanced Safety Engineering**
**3 Credits (3)**

Regulation as well as qualitative, and quantitative methods to achieve and maintain safety in the workplace. Includes liability, worker's compensation, OSHA, hazard control, safety assessment, cost justification, and system analysis.

**Learning Outcomes**

1. 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.
2. An ability to communicate effectively with a range of audiences.
3. 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.

**I E 563. Topics in Engineering Administration**
**3 Credits (3)**

Study of qualitative and quantitative aspects. Consideration given to philosophical, psychological, political and social implications of engineering administrative decisions.

**Learning Outcomes**

1. An ability to demonstrate a comprehensive understanding of key principles, theories, and practices related to engineering administration, including organizational management, leadership, strategic planning, and decision-making processes.
2. An ability to apply management techniques and tools to analyze and solve complex administrative problems commonly encountered in engineering organizations, such as resource allocation, project management, and risk assessment.
3. An ability to develop effective communication skills, including written, oral, and interpersonal communication, to convey technical information, lead teams, and interact with stakeholders in engineering settings.
4. An ability to enhance critical thinking and problem-solving abilities by evaluating case studies, identifying challenges, and proposing innovative solutions to address administrative issues in engineering contexts.
5. An ability to demonstrate an understanding of ethical and professional responsibilities in engineering administration, including considerations of integrity, fairness, and accountability in decision-making and leadership roles.
6. An ability to develop strategic leadership abilities by analyzing case studies, formulating organizational strategies, and articulating visions for future growth and innovation within engineering organizations.

**I E 567. Design and Implementation of Discrete-Event Simulation**
**3 Credits (3)**

Basic modeling concepts, organizations of simulations, input data analysis, random variate generation, simulation design and analysis, model validation, output analysis, and management of simulations. Taught with I E 467 with differentiated assignments for graduate students.

**Learning Outcomes**

1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
2. An ability to communicate effectively with a range of audiences.
3. 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.
4. An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.
5. An ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

**I E 571. Advanced Quality Control**
**3 Credits (3)**

Advanced topics in quality control and design of experiments for improvement of quality.

**Prerequisite:** I E 311 or equivalent.

**Learning Outcomes**

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.

**I E 575. Advanced Manufacturing Processes**
**3 Credits (3)**

Covers major process parameters in casting, forming, machining, and joining. Process economics and selection of processes design and interactions.

**Learning Outcomes**

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 function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.

4. An ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

**I E 590. Selected Topics**
**1-3 Credits**
This course offers an in-depth exploration of specific topics within a given field or discipline. The content may vary each time the course is offered, allowing for flexibility in addressing emerging trends, current issues, or specialized areas of study. May be repeated up to 9 credits.
**Learning Outcomes**
1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
2. An ability to communicate effectively with a range of audiences.
3. 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.
4. 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.

**I E 598. Special Research Programs**
**1-3 Credits (1-3)**
Individual analytical or experimental investigations. May be repeated up to 6 credits.
**Learning Outcomes**
1. An ability to demonstrate the ability to develop a well-defined research question, formulate hypotheses or objectives, and design a research plan or methodology appropriate to address the research question or problem.
2. An ability to conduct a comprehensive literature review related to their research topic, critically evaluating existing scholarship, identifying gaps in the literature, and synthesizing relevant theoretical frameworks or conceptual models.
3. An ability to collect, analyze, and interpret data using appropriate qualitative or quantitative research methods, techniques, and tools, demonstrating proficiency in data management, statistical analysis, and data visualization.
4. An ability to apply critical thinking skills to evaluate research findings, draw conclusions, and generate insights that contribute to knowledge advancement or address practical problems in their field of study.
5. An ability to effectively communicate their research findings, methodologies, and interpretations to both specialized and non-specialized audiences through written reports, oral presentations, and visual aids, demonstrating clarity, coherence, and persuasiveness.
6. An ability to demonstrate an understanding of ethical principles and guidelines governing research conduct, including issues related to research integrity, confidentiality, informed consent, and the responsible conduct of research.
7. An ability to manage their research projects effectively, including setting timelines, allocating resources, and adapting to unforeseen challenges or setbacks, demonstrating skills in organization, time management, and project coordination.

**I E 599. Master's Thesis**
**1-15 Credits**
Thesis. May be repeated up to 88 credits.
**Learning Outcomes**
1. An ability to demonstrate the ability to develop a well-defined research question, formulate hypotheses or objectives, and design a research plan or methodology appropriate to address the research question or problem.
2. An ability to conduct a comprehensive literature review related to their research topic, identifying gaps in the literature, and synthesizing relevant theoretical frameworks or conceptual models.
3. An ability to collect, analyze, and interpret data using appropriate qualitative or quantitative research methods, techniques, and tools, demonstrating proficiency in data management, statistical analysis, and data visualization.
4. An ability to apply critical thinking skills to evaluate research findings, draw conclusions, and generate insights that contribute to knowledge advancement or address practical problems in their field of study.
5. An ability to effectively communicate their research findings, methodologies, and interpretations to both specialized and non-specialized audiences through written reports, oral presentations, and visual aids, demonstrating clarity, coherence, and persuasiveness.
6. An ability to demonstrate an understanding of ethical principles and guidelines governing research conduct, including issues related to research integrity, confidentiality, informed consent, and the responsible conduct of research.
7. An ability to manage their research projects effectively, including setting timelines, allocating resources, and adapting to unforeseen challenges or setbacks, demonstrating skills in organization, time management, and project coordination.

**I E 610. Topics in Operations Research**
**3 Credits (3)**
Selected topics of current interest, to be designated by subtitle. May be repeated up to 6 credits.
**Learning Outcomes**
1. An ability to demonstrate a deep understanding of advanced topics in operations research, including but not limited to optimization theory, stochastic processes, queuing theory, decision analysis, and simulation modeling.
2. An ability to apply mathematical modeling techniques to formulate and solve complex optimization problems arising in real-world contexts, such as production planning, logistics, supply chain management, transportation, and resource allocation.
3. An ability to analyze and interpret optimization solutions generated by mathematical models, identifying optimal solutions, sensitivity analysis, trade-offs, and implications for decision-making under uncertainty or constraints.
4. An ability to develop algorithmic problem-solving skills by implementing and applying optimization algorithms, heuristic methods, and computational techniques to solve large-scale optimization problems efficiently and effectively.
5. An ability to demonstrate proficiency in using operations research software tools and programming languages commonly used in the field, such as linear programming solvers, simulation software, mathematical modeling languages (e.g., Xpress, CPLEX, AMPL, GAMS), and general-purpose programming languages (e.g., Python, MATLAB).
6. An ability to critically evaluate the application of operations research techniques in various industries and domains, assessing the strengths, limitations, and practical considerations of OR models and methodologies in addressing complex decision problems.
7. An ability to effectively communicate the results of their operations research analyses and findings to diverse stakeholders, including

technical and non-technical audiences, through written reports, presentations, and visualizations.

**I E 620. Topics in Computer Modeling**
**3 Credits (3)**
Selected topics of current interest, to be designated by subtitle. May be repeated up to 6 credits.
**Learning Outcomes**

1. An ability to demonstrate an understanding of fundamental principles and techniques used in computer modeling, including conceptual modeling, mathematical modeling, simulation, and computational algorithms.
2. An ability to apply computer modeling tools and software packages to develop, implement, and validate models for solving real-world problems across various domains, such as engineering, science, economics, and social systems.
3. An ability to develop, analyze, and interpret computer models to simulate complex systems, processes, or phenomena, identifying relevant input parameters, defining system boundaries, and evaluating model outputs to draw meaningful conclusions.
4. An ability to acquire proficiency in programming languages and scripting tools commonly used for computer modeling, such as Python, MATLAB, R, or specialized simulation software, enabling them to implement and customize models to address specific requirements.
5. An ability to employ verification and validation techniques to assess the accuracy, reliability, and credibility of computer models, including sensitivity analysis, calibration, uncertainty quantification, and comparison with empirical data or experimental results.
6. An ability to integrate optimization techniques and decision support tools into computer models to optimize system performance, resource allocation, scheduling, or decision-making processes, considering constraints, objectives, and stakeholder preferences.
7. An ability to utilize visualization techniques and graphical representation methods to visualize model outputs, communicate results effectively, and facilitate stakeholders' understanding and interpretation of complex modeling scenarios.
8. An ability to apply critical thinking and problem-solving skills to analyze real-world problems, formulate hypotheses, design experiments, and iteratively refine models based on feedback and empirical observations.

**I E 630. Topics in Engineering Management**
**3 Credits (3)**
Selected topics of current interest, to be designated by subtitle. May be repeated up to 6 credits.
**Learning Outcomes**

1. An ability to demonstrate an understanding of fundamental concepts, theories, and principles in engineering management, including organizational behavior, project management, strategic planning, leadership, and decision-making processes.
2. An ability to apply engineering management techniques and tools to analyze, plan, and optimize engineering projects, processes, and systems, considering factors such as cost, quality, time, risk, and stakeholder requirements.
3. An ability to develop skills in strategic planning and decision-making, identifying organizational goals, formulating strategies, evaluating alternatives, and making informed decisions to achieve desired outcomes in engineering contexts.
4. An ability to acquire proficiency in project management methodologies, tools, and techniques, including project planning, scheduling, budgeting, resource allocation, risk management, and performance monitoring, to successfully execute engineering projects.
5. An ability to recognize the ethical and social responsibilities of engineering managers, considering the impact of engineering projects on society, environment, and stakeholders, and integrating ethical considerations into decision-making processes.
6. An ability to engage in cross-functional collaboration, interacting with professionals from diverse disciplines such as engineering, business, finance, marketing, and operations to address complex engineering management challenges and opportunities.
7. An ability to evaluate and mitigate risks associated with engineering projects and operations, applying risk assessment techniques, developing risk management plans, and implementing proactive measures to minimize potential negative impacts.

**I E 690. Selected Topics**
**1-15 Credits**
This course offers an in-depth exploration of specific topics within a given field or discipline. The content may vary each time the course is offered, allowing for flexibility in addressing emerging trends, current issues, or specialized areas of study. May be repeated up to 99 credits.
**Learning Outcomes**

1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
2. An ability to communicate effectively with a range of audiences.
3. 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.
4. 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.

**I E 700. Doctoral Dissertation**
**15 Credits**
Dissertation. May be repeated up to 88 credits.
**Learning Outcomes**

1. An ability to demonstrate the ability to develop a well-defined research question, formulate hypotheses or objectives, and design a research plan or methodology appropriate to address the research question or problem.
2. An ability to conduct a comprehensive literature review related to their research topic, identifying gaps in the literature, and synthesizing relevant theoretical frameworks or conceptual models.
3. An ability to collect, analyze, and interpret data using appropriate qualitative or quantitative research methods, techniques, and tools, demonstrating proficiency in data management, statistical analysis, and data visualization.
4. An ability to apply critical thinking skills to evaluate research findings, draw conclusions, and generate insights that contribute to knowledge advancement or address practical problems in their field of study.
5. An ability to effectively communicate their research findings, methodologies, and interpretations to both specialized and non-specialized audiences through written reports, oral presentations, and visual aids, demonstrating clarity, coherence, and persuasiveness.

6. An ability to demonstrate an understanding of ethical principles and guidelines governing research conduct, including issues related to research integrity, confidentiality, informed consent, and the responsible conduct of research.
7. An ability to manage their research projects effectively, including setting timelines, allocating resources, and adapting to unforeseen challenges or setbacks, demonstrating skills in organization, time management, and project coordination.

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