

# INDUSTRIAL ENGINEERING (I E)

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## **Any experimental courses offered by I E can be found at:**

registrar.iastate.edu/faculty-staff/courses/explistsings/ (<http://www.registrar.iastate.edu/faculty-staff/courses/explistsings/>)

## **Courses primarily for undergraduates:**

### **I E 101: Industrial Engineering Profession**

Cr. R. F.S.

(1-0) Introduce students to the industrial engineering profession, its scope, industrial engineering tools, and future trends. Offered on a satisfactory-fail basis only.

### **I E 148: Information Engineering**

(2-2) Cr. 3. F.S.

*Prereq: Credit or enrollment in MATH 143*

Development of information solutions for engineering problems. Fundamentals of the software development process. Engineering computations and the human/computer interface. Data models and database development. Program connectivity and network applications.

### **I E 222: Design & Analysis Methods for System Improvements**

(3-0) Cr. 3. S.

*Prereq: I E 248; credit or enrollment in I E 271.*

Study of system improvement methods and strategies. Specific areas of lean system improvements include continuous improvement, setup reduction, workplace organization, and inventory and waste reduction. Methods and strategies to analyze and quantify the impact of changes.

### **I E 248: Engineering System Design, Manufacturing Processes and Specifications**

(2-2) Cr. 3. F.

*Prereq: MATH 166 and PHYS 221. Credit or enrollment in I E 101 and MAT E 273.*

Introduction to metrology, engineering drawings and specifications. Engineering methods for designing and improving systems. Theory, applications, and quality issues related to machining processes.

### **I E 271: Applied Ergonomics and Work Design**

(3-0) Cr. 3. S.

*Prereq: PHYS 221*

Basic concepts of ergonomics and work design. Their impact on worker and work place productivity, and cost. Investigations of work physiology, biomechanics, anthropometry, work sampling, work evaluation methods, and their measurement as they relate to the design of human-machine systems.

### **I E 305: Engineering Economic Analysis**

(3-0) Cr. 3. F.S.SS.

*Prereq: MATH 166*

Economic analysis of engineering decisions under uncertainty. Financial engineering basics including time value of money, cash flow estimation, and asset evaluation. Make versus buy decisions. Comparison of project alternatives accounting for taxation, depreciation, inflation, and risk.

### **I E 312: Optimization**

(3-0) Cr. 3. F.

*Prereq: Credit or enrollment in MATH 267.*

Concepts, optimization and analysis techniques, and applications of operations research. Formulation of mathematical models for systems, concepts, and methods of improving search, linear programming and sensitivity analysis, network models, and integer programming.

### **I E 341: Production Systems**

(3-0) Cr. 3. F.

*Prereq: STAT 231; credit or enrollment in I E 312*

Introduction of key concepts in the design and analysis of production systems. Topics include inventory control, forecasting, material requirement planning, Kanban systems, project planning and scheduling including Critical Path Method (CPM) and Program Evaluation Review Technique (PERT), operations scheduling, and other production systems such as Just-In-Time (JIT), warehousing, and global supply chains.

### **I E 348: Solidification Processes**

(Cross-listed with MAT E). (2-2) Cr. 3. S.

*Prereq: I E 248 and MAT E 273, or MAT E 215*

Theory and applications related to metal casting, welding, polymer processing, powder metallurgy, and composites manufacturing, and related rapid manufacturing processes.

### **I E 361: Statistical Quality Assurance**

(Cross-listed with STAT). (2-2) Cr. 3. F.S.

*Prereq: STAT 231, STAT 301, STAT 326, STAT 401, or STAT 587*

Statistical methods for process improvement. Simple quality assurance principles and tools. Measurement system precision and accuracy assessment. Control charts. Process capability assessment. Experimental design and analysis for process improvement. Significant external project in process improvement.

### **I E 396: Summer Internship**

Cr. R. Repeatable. SS.

*Prereq: Permission of department and Engineering Career Services*

Professional work period of at least 10 weeks during the summer. Students must register for this course prior to commencing work. Offered on a satisfactory-fail basis only.

**I E 398: Cooperative Education (Co-op)**

Cr. R. Repeatable. F.S.

*Prereq: Permission of department and Engineering Career Services*

Professional work period. One semester per academic or calendar year. Students must register for this course before commencing work. Offered on a satisfactory-fail basis only.

**I E 403: Introduction to Sustainable Production Systems**

(Dual-listed with I E 503). (3-0) Cr. 3.

*Prereq: Credit or enrollment I E 341*

Quantitative introduction of sustainability concepts in production planning and inventory control. Review of material recovery (recycling) and product/component recovery (remanufacturing) from productivity perspectives. Sustainability rubrics ranging from design and process to systems. Application to multi-echelon networks subject to forward/backward flow of material and information. Closed-loop supply chains. Comparative study of sustainable vs. traditional models for local and global production systems.

**I E 405: Advanced Engineering Economy for Complex Engineering Projects**

(Dual-listed with I E 505). (3-0) Cr. 3.

*Prereq: MATH 265, MATH 267, STAT 231 and I E 305, or permission by instructor*

Overview of engineering economic valuation and complex engineering projects. Stochastic dynamic programming for project valuation. Modeling and analysis of confounding factors of engineering projects. Integration and synthesis of valuation methodologies to complex projects. Applications to power plants, transmission networks, and satellites.

**I E 413: Stochastic Modeling, Analysis and Simulation**

(4-0) Cr. 4. F.

*Prereq: MATH 265, STAT 231*

Development of probabilistic and simulation models using a simulation language. Introduction to Markov processes and other queuing models. Application to various areas of manufacturing and service systems such as assembly, material handling, and customer queues. Fitting of statistical distributions to data. Utilization of model output towards improved decision-making.

**I E 430: Entrepreneurial Product Engineering**

(Cross-listed with ENGR). Cr. 3. F.Alt. S., offered irregularly.

*Prereq: Junior Classification*

Process of innovative product development in both entrepreneurial and intra-preneurial settings. Define, prototype and validate a product concept based on competitive bench-marking, market positioning and customer requirement evaluation in a target market into a product design that is consistent with defined business goals and strategies. Combination of lecture, discussion, problem solving and case study review.

**I E 432: Industrial Automation**

(2-3) Cr. 3. S.

*Prereq: Phys 222*

Overview of electrical circuit theory and its relationship to industrial control systems. Theory and application of transducers in the form of sensors and actuators, with applications in manufacturing, distribution and mechanical systems. Programmable Logic Controllers (PLC), their programming and use for automation solutions. Introduction of automated identification systems such as Radio Frequency Identification (RFID) and Bar Coding technologies.

**I E 441: Industrial Engineering Design**

(1-6) Cr. 3. F.S.

*Prereq: I E 248, I E 271, I E 361; credit or enrollment in I E 341, I E 413, and I E 448*

A large, open-ended design project related to an enterprise. Application of engineering design principles including problem definition, analysis, synthesis, and evaluation.

**I E 445: Rapid Prototyping and Manufacturing**

(Dual-listed with I E 545). (3-0) Cr. 3.

*Prereq: I E 248 or similar manufacturing engineering course, MATH 265. Undergraduates at Senior Standing if given permission by instructor.*

Introduction to rapid prototyping processes and other rapid manufacturing methodologies. Operating principles and characteristics of current and developing rapid prototyping processes. Use of rapid prototypes in product design, development, and service. Selection of rapid prototyping systems based on rapid methodologies used in manufacturing processes and rapid tooling approaches.

**I E 446: Geometric Variability in Manufacturing**

(Dual-listed with I E 546). (3-0) Cr. 3.

*Prereq: I E 348, or MAT E 216, or ME 324*

Assessment, accommodation, and control of geometric variability in manufacturing processes, specifically composites, metalcasting, welding, machining, powder metallurgy and additive processing. Techniques include the design of the component, tooling, process plan and inspection methodology.

**I E 447: Biomedical Design and Manufacturing**

(Dual-listed with I E 547). (3-0) Cr. 3.

*Prereq: Undergraduate students with three semesters or less before graduation while graduate standing for graduate students*

Exploration of biology, materials, body mechanics, manufacturing, quality control, and ethics and the intersection of these subjects as they relate to biomedical manufacturing.

**I E 448: Manufacturing Systems Engineering**

(3-0) Cr. 3. S.

*Prereq: I E 248, I E 305*

Fixturing and tooling requirements for manufacturing process planning, geometric dimensioning and tolerancing, computer aided inspection, cellular and flexible manufacturing, and facility layout. Lean manufacturing principles and controlled flow production.

**I E 449: Computer Aided Design and Manufacturing**

(Dual-listed with I E 549). (3-0) Cr. 3.

*Prereq: Prereq: I E 248 or similar manufacturing engineering course, MATH 265.*

Representation and interpretation of curves, surfaces and solids. Parametric curves and surfaces and solid modeling. Use of CAD software and CAD/CAM integration. Computer numerical control, CNC programming languages, and process planning.

**I E 450: Technical Sales for Engineers I**

(3-0) Cr. 3. F.

*Prereq: Credit or enrollment in I E 305.*

Sales process methodology, techniques for building professional relationships, sales automation software, prospecting and account development, market analysis and segmentation, responding to RFQ's and RFP's in written and verbal form. Developing technical value propositions and competitive positioning, evaluating organizational decision processes and people, technical marketing strategies, sales closing strategies.

**I E 451: Technical Sales for Engineers II**

(3-0) Cr. 3. S.

*Prereq: I E 450*

Case studies and experiential lessons on the development and application of technical sales strategies. Specific topics include developing pricing and distribution strategies, managing a sales staff and channel, developing sales teams and global sales plans, bid and negotiation strategies, time management skills, and implementing sales automation technologies.

**I E 452: Introduction To Systems Engineering And Analysis**

(Cross-listed with AER E). Cr. 3. SS.

*Prereq: Junior Classification in an Engineering Major*

Principles of systems engineering to include problem statement formulation, stakeholder analysis, requirements definition, system architecture and concept generation, system integration and interface management, verification and validation, and system commissioning and decommissioning operations. Introduction to discrete event simulation processes. Students will work in groups to propose, research, and present findings for a systems engineering topic of current relevance.

**I E 466: Multidisciplinary Engineering Design**

(Cross-listed with A B E, AER E, B M E, CPR E, E E, ENGR, M E, MAT E).

(1-4) Cr. 3. Repeatable. F.S.

*Prereq: Student must be within two semesters of graduation; permission of instructor.*

Application of team design concepts to projects of a multidisciplinary nature. Concurrent treatment of design, manufacturing, and life cycle considerations. Application of design tools such as CAD, CAM, and FEM. Design methodologies, project scheduling, cost estimating, quality control, manufacturing processes. Development of a prototype and appropriate documentation in the form of written reports, oral presentations and computer models and engineering drawings.

**I E 467: Multidisciplinary Engineering Design II**

(Cross-listed with AER E, ENGR, M E, MAT E). (1-4) Cr. 3. Repeatable, maximum of 2 times. Alt. F., offered irregularly. Alt. S., offered irregularly.

*Prereq: Student must be within two semesters of graduation or receive permission of instructor.*

Build and test of a conceptual design. Detail design, manufacturability, test criteria and procedures. Application of design tools such as CAD and CAM and manufacturing techniques such as rapid prototyping. Development and testing of a full-scale prototype with appropriate documentation in the form of design journals, written reports, oral presentations and computer models and engineering drawings.

**I E 468: Large-Scale Complex Engineered Systems (LSCES)**

(Dual-listed with I E 568). (Cross-listed with AER E). (3-0) Cr. 3. S.

*Prereq: senior standing in College of Engineering or permission of AerE 468 instructor*

Introduction to the theoretical foundation and methods associated with the design for large-scale complex engineered systems, including objective function formation, design reliability, value-driven design, product robustness, utility theory, economic factors for the formation of a value function and complexity science as a means of detecting unintended consequences in the product behavior.

**I E 481: e-Commerce Systems Engineering**

(Dual-listed with I E 581). (3-0) Cr. 3.

*Prereq: I E 148*

Design, analysis, and implementation of e-commerce systems. Information infrastructure, enterprise models, enterprise processes, enterprise views. Data structures and algorithms used in e-commerce systems, SQL, exchange protocols, client/server model, web-based views.

**I E 483: Data Mining**

(Dual-listed with I E 583). (3-0) Cr. 3.

*Prereq: I E 148, I E 312, and STAT 231*

Foundations of classification, data clustering and association rule mining. Techniques for data mining, including probabilistic and statistical methods, optimization algorithms and deep learning with neural networks, visualization techniques, and mathematical programming. Advanced topics include web-mining and mining of multimedia data. Case studies from both manufacturing and service industries. A computing project is required.

**I E 487: Big Data Analytics and Optimization**

(Dual-listed with I E 587). Cr. 3. S.

*Prereq: IE 312, Stat 231*

Optimization and statistical learning related to big data problems. Modern modeling for data-driven optimization problems and their applications in big data analytics. Algorithms for optimization and statistical learning and their implementation. Applications in manufacturing sector and service sciences.

**I E 490: Independent Study**

Cr. 1-5. Repeatable.

*Prereq: Senior classification, permission of instructor*

Independent study and work in the areas of industrial engineering design, practice, or research.

**I E 490H: Independent Study: Honors**

Cr. 1-5. Repeatable.

*Prereq: Senior classification, permission of instructor*

Independent study and work in the areas of industrial engineering design, practice, or research.

**Courses primarily for graduate students, open to qualified undergraduates:**

**I E 501: I E Graduate Seminar**

Cr. R. Repeatable.

*Prereq: Enrollment in graduate program in Industrial Engineering. Research presentations by internal and external scholars.*

Principles and practices for research tasks at the M.S. level including proposal writing, presentations, paper preparation, and project management. Offered on a satisfactory-fail basis only.

**I E 503: Introduction to Sustainable Production Systems**

(Dual-listed with I E 403). (3-0) Cr. 3.

*Prereq: Credit or enrollment I E 341*

Quantitative introduction of sustainability concepts in production planning and inventory control. Review of material recovery (recycling) and product/component recovery (remanufacturing) from productivity perspectives. Sustainability rubrics ranging from design and process to systems. Application to multi-echelon networks subject to forward/backward flow of material and information. Closed-loop supply chains. Comparative study of sustainable vs. traditional models for local and global production systems.

**I E 505: Advanced Engineering Economy for Complex Engineering Projects**

(Dual-listed with I E 405). (3-0) Cr. 3.

*Prereq: MATH 265, MATH 267, STAT 231 and I E 305, or permission by instructor*

Overview of engineering economic valuation and complex engineering projects. Stochastic dynamic programming for project valuation. Modeling and analysis of confounding factors of engineering projects. Integration and synthesis of valuation methodologies to complex projects. Applications to power plants, transmission networks, and satellites.

**I E 508: Design and Analysis of Allocation Mechanisms**

(3-0) Cr. 3.

*Prereq: I E 312 or MATH 307*

Market-based allocation mechanisms from quantitative economic systems perspective. Pricing and costing models designed and analyzed with respect to decentralized decision processes, information requirements, and coordination. Financial Engineering Techniques. Case studies and examples from industries such as regulated utilities, semiconductor manufacturers, and financial engineering services.

**I E 510: Network Analysis**

(3-0) Cr. 3.

*Prereq: I E 312*

Formulation and solution of deterministic network flow problems including shortest path, minimum cost flow, and maximum flow. Network and graph formulations of combinatorial problems including assignment, matching, and spanning trees. Solution algorithm design and analysis based on optimality conditions and duality.

**I E 513: Analysis of Stochastic Systems**

(3-0) Cr. 3.

*Prereq: STAT 231*

Introduction to modeling and analysis of manufacturing and service systems subject to uncertainty. Topics include the Poisson process, renewal processes, Markov chains, and Brownian motion. Applications to inventory systems, production system design, production scheduling, reliability, and capacity planning.

**I E 514: Production Scheduling**

(3-0) Cr. 3.

*Prereq: I E 312, I E 341*

Introduction to the theory of machine shop systems. Complexity results for various systems such as job, flow and open shops. Applications of linear programming, integer programming, network analysis. Enumerative methods for machine sequencing. Introduction to stochastic scheduling.

**I E 519: Simulation Modeling and Analysis**

(3-0) Cr. 3.

*Prereq: COM S 311, STAT 401*

Event scheduling, process interaction, and continuous modeling techniques. Probability and statistics related to simulation parameters including run length, inference, design of experiments, variance reduction, and stopping rules. Aspects of simulation languages.

**I E 531: Quality Control and Engineering Statistics**

(Cross-listed with STAT). (3-0) Cr. 3.

*Prereq: STAT 401 or STAT 587; STAT 342 or STAT 447 or STAT 588*

Statistical methods and theory applicable to problems of industrial process monitoring and improvement. Statistical issues in industrial measurement; Shewhart, CUSUM, and other control charts; feedback control; process characterization studies; estimation of product and process characteristics; acceptance sampling, continuous sampling and sequential sampling; economic and decision theoretic arguments in industrial statistics.

**I E 533: Reliability**

(Cross-listed with STAT). (3-0) Cr. 3. Alt. S., offered even-numbered years.

*Prereq: STAT 342 or STAT 432 or STAT 447 or STAT 478 or STAT 578 or STAT 588*

Probabilistic modeling and inference in engineering reliability; lifetime models, product limit estimator, probability plotting, maximum likelihood estimation for censored data, Bayesian methods in reliability, system reliability models, competing risk analysis, acceleration models and analysis of accelerated test data; analysis of recurrence and degradation data; planning studies to obtain reliability data.

**I E 534: Linear Programming**

(3-0) Cr. 3.

*Prereq: I E 312*

Formulation of optimization problems as mathematical models, such as linear programming, integer programming, and multi-objective optimization. Introduction to classic optimization algorithms, such as Simplex and cutting plane algorithms. Basic concepts of duality theory and sensitivity analysis. Using computer solvers to obtain optimal solutions to optimization models.

**I E 537: Reliability and Safety Engineering**

(3-0) Cr. 3.

*Prereq: STAT 231 or STAT 401*

Mathematical basics for dealing with reliability data, theory, and analysis. Bayesian reliability analysis. Engineering ethics in safety evaluations. Case studies of accidents in large technological systems. Fault and event tree analysis.

**I E 541: Inventory Control and Production Planning**

(3-0) Cr. 3.

*Prereq: I E 341*

Economic Order Quantity, dynamic lot sizing, newsboy, base stock, and (Q,r) models. Material Requirements Planning, Just-In-Time (JIT), variability in production systems, push and pull production systems, aggregate and workforce planning, and capacity management. Supply Chain Contracts.

**I E 543: Wind Energy Manufacturing**

(3-0) Cr. 3. Alt. S., offered even-numbered years.

*Prereq: Undergraduate engineering degree or permission of instructor.*

Materials, processes and systems required to produce the major components (blades, towers, nacelles) of megawatt scale wind turbines. Transportation, manufacturing siting and procurement decisions as it relates to these large components in an expanding industry.

**I E 545: Rapid Prototyping and Manufacturing**

(Dual-listed with I E 445). (3-0) Cr. 3.

*Prereq: I E 248 or similar manufacturing engineering course, MATH 265.**Undergraduates at Senior Standing if given permission by instructor.*

Introduction to rapid prototyping processes and other rapid manufacturing methodologies. Operating principles and characteristics of current and developing rapid prototyping processes. Use of rapid prototypes in product design, development, and service. Selection of rapid prototyping systems based on rapid methodologies used in manufacturing processes and rapid tooling approaches.

**I E 546: Geometric Variability in Manufacturing**

(Dual-listed with I E 446). (3-0) Cr. 3.

*Prereq: I E 348, or MAT E 216, or M E 324*

Assessment, accommodation, and control of geometric variability in manufacturing processes, specifically composites, metalcasting, welding, machining, powder metallurgy and additive processing. Techniques include the design of the component, tooling, process plan and inspection methodology.

**I E 547: Biomedical Design and Manufacturing**

(Dual-listed with I E 447). (3-0) Cr. 3.

*Prereq: Undergraduate students with three semesters or less before graduation while graduate standing for graduate students*

Exploration of biology, materials, body mechanics, manufacturing, quality control, and ethics and the intersection of these subjects as they relate to biomedical manufacturing.

**I E 549: Computer Aided Design and Manufacturing**

(Dual-listed with I E 449). (3-0) Cr. 3.

*Prereq: Prereq: I E 248 or similar manufacturing engineering course, MATH 265.*

Representation and interpretation of curves, surfaces and solids. Parametric curves and surfaces and solid modeling. Use of CAD software and CAD/CAM integration. Computer numerical control, CNC programming languages, and process planning.

**I E 560: Engineering Risk Analysis**

(3-0) Cr. 3.

*Prereq: Coursework in basic probability and statistics*

Overview of probabilistic risk analysis, modeling risks, and risk management. Topics include probability, influence diagrams, subjective probability assessment, fault tree analysis, decision making with uncertainty, risk perception, risk communication, and intelligent adversary. Use of Monte Carlo simulation to combine different sources of uncertainty and risk to generate probability distributions over an outcome. Application of probabilistic risk analysis to business investments, engineering systems, critical infrastructure, defense and security, and health systems.

**I E 561: Total Quality Management**

(3-0) Cr. 3.

*Prereq: Course in quality control*

Perspectives for how to analyze and implement total quality management in different organizations, to include manufacturing firms, service industries, the non-profit sector, and government agencies. Topics include the different viewpoints of quality (from the customer, workforce, and process perspective); aligning quality in an organization's goals; performance measurement; quality in supply chain management; and reliability. Some advanced statistical elements of quality control will also be discussed.

**I E 563: Engineering and Systems Management**

(3-0) Cr. 3.

*Prereq: Course in probability and statistics.*

Introduction to engineering management concepts and examples relevant to the engineering manager today. Topics include decision trees and associated probabilities; personnel issues and challenges; working with management, client and the project team; personality types; and documents/forms that are useful for the engineering manager. Case studies, and a group project required.

**I E 564: Decision Analysis**

(3-0) Cr. 3.

*Prereq: Course in probability and statistics.*

Application of normative decision theory to problems with uncertainty and/or multiple objectives. The first decision framework will be a single-objective decision problem with uncertainty that takes into account a decision maker's attitude towards risk. The second decision framework will be a multi-criteria decision problem in which a decision maker has multiple objectives. Topics include utility theory, value of information, sensitivity analysis, value-focused thinking, cost-effectiveness analysis, influence diagrams, and behavioral decision making. Examples will be drawn from business, systems engineering and design, and government.

**I E 565: Systems Engineering and Analysis**

(Cross-listed with AER E, E E). (3-0) Cr. 3.

*Prereq: Coursework in basic statistics*

Introduction to organized multidisciplinary approach to designing and developing systems. Concepts, principles, and practice of systems engineering as applied to large integrated systems. Life cycle costing, scheduling, risk management, functional analysis, conceptual and detail design, test and evaluation, and systems engineering planning and organization. Not available for degrees in industrial engineering.

**I E 566: Applied Systems Engineering**

(3-0) Cr. 3.

*Prereq: I E 565*

Design for reliability, maintainability, usability, supportability, producibility, disposability, and life cycle costs in the context of the systems engineering process. Students will be required to apply the principles of systems engineering to a project including proposal, program plan, systems engineering management plan, and test and evaluation plan. Not available for degrees in industrial engineering.

**I E 568: Large-Scale Complex Engineered Systems (LSCES)**

(Dual-listed with I E 468). (Cross-listed with AER E). (3-0) Cr. 3. S.

*Prereq: senior standing in College of Engineering or permission of AerE 468 instructor*

Introduction to the theoretical foundation and methods associated with the design for large-scale complex engineered systems, including objective function formation, design reliability, value-driven design, product robustness, utility theory, economic factors for the formation of a value function and complexity science as a means of detecting unintended consequences in the product behavior.

**I E 570: Systems Engineering and Project Management**

(3-0) Cr. 3.

*Prereq: Coursework in basic statistics*

Systems view of projects and the processes by which they are implemented. Focuses on qualitative and quantitative tools and techniques of project management. Topics will include organizational structure types; project selection methodologies; simulation and optimization; and earned value management. Case studies will be included, and a group project required.

**I E 571: Occupational Biomechanics**

(3-0) Cr. 3.

*Prereq: E M 274, STAT 231*

Anatomical, physiological, and biomechanical bases of physical ergonomics. Anthropometry, body mechanics, strength of biomaterials, human motor control. Use of bioinstrumentation, passive industrial surveillance techniques and active risk assessment techniques. Acute injury and cumulative trauma disorders. Static and dynamic biomechanical modeling. Emphasis on low back, shoulder and hand/wrist biomechanics.

**I E 572: Design and Evaluation of Human-Computer Interaction**

(3-0) Cr. 3.

*Prereq: I E 271 or graduate classification*

Human factors methods applied to interface requirements, design, prototyping, and evaluation. Concepts related to understanding user characteristics, design principles, usability analysis, methods and techniques for design and evaluation of the interface. The evaluation and design of the information presentation characteristics of a wide variety of interfaces: web sites (e-commerce), mobile applications, and information presentation systems (cockpits, instrumentation, etc.).

**I E 576: Human Factors in Product Design**

(3-0) Cr. 3.

*Prereq: I E 572 or I E 577*

Investigation of the human interface to consumer and industrial systems and products, providing a basis for their design and evaluation. Discussions of human factors in the product design process: modeling the human during product use; usability; human factors methods in product design evaluation; user-device interface; safety, warnings, and instructions for products; considerations for human factors in the design of products for international use.

**I E 577: Human Factors**

(3-0) Cr. 3.

*Prereq: I E 271 or graduate classification*

Physical and psychological factors affecting human performance in systems. Signal detection theory, human reliability modeling, information theory, and performance shaping applied to safety, reliability, productivity, stress reduction, training, and human/equipment interface design. Laboratory assignments related to system design and operation.

**I E 581: e-Commerce Systems Engineering**

(Dual-listed with I E 481). (3-0) Cr. 3.

*Prereq: I E 148*

Design, analysis, and implementation of e-commerce systems. Information infrastructure, enterprise models, enterprise processes, enterprise views. Data structures and algorithms used in e-commerce systems, SQL, exchange protocols, client/server model, web-based views.

**I E 582: Enterprise Modeling and Integration**

(3-0) Cr. 3.

*Prereq: 3 credits in information technology or information systems*

The design and analysis of enterprise models to support information engineering of enterprise-wide systems. Representation of system behavior and structure including process modeling, information modeling, and conceptual modeling. Applications in enterprise application integration, enterprise resource planning systems, product data management systems, and manufacturing execution systems.

**I E 583: Data Mining**

(Dual-listed with I E 483). (3-0) Cr. 3.

*Prereq: I E 148, I E 312, and STAT 231*

Foundations of classification, data clustering and association rule mining. Techniques for data mining, including probabilistic and statistical methods, optimization algorithms and deep learning with neural networks, visualization techniques, and mathematical programming. Advanced topics include web-mining and mining of multimedia data. Case studies from both manufacturing and service industries. A computing project is required.

**I E 585: Requirements and Architecture Engineering**

(3-0) Cr. 3.

*Prereq: 3 credits in information technology or information systems*

Principles and practices for requirements engineering as part of the product development process with emphasis on software systems engineering. Problem definition, problem analysis, requirements analysis, requirements elicitation, validation, specifications. Case studies using requirements engineering methods and techniques.

**I E 587: Big Data Analytics and Optimization**

(Dual-listed with I E 487). Cr. 3. S.

*Prereq: IE 312, Stat 231*

Optimization and statistical learning related to big data problems. Modern modeling for data-driven optimization problems and their applications in big data analytics. Algorithms for optimization and statistical learning and their implementation. Applications in manufacturing sector and service sciences.

**I E 588: Information Systems for Manufacturing**

(3-0) Cr. 3.

*Prereq: I E 148, I E 448*

Design and implementation of systems for the collection, maintenance, and usage of information needed for manufacturing operations, such as process control, quality, process definition, production definitions, inventory, and plant maintenance. Topics include interfacing with multiple data sources, methods to utilize the information to improve the process, system architectures, and maintaining adequate and accurate data for entities internal and external to the enterprise to achieve best manufacturing practices.

**I E 590: Special Topics**

Cr. 1-3. Repeatable.

Advanced study of a research topic in the field of industrial engineering.

**I E 599: Creative Component**

Cr. arr.

Offered on a satisfactory-fail basis only.

**Courses for graduate students:****I E 613: Stochastic Production Systems**

(3-0) Cr. 3.

*Prereq: I E 513*

Modeling techniques to evaluate performance and address issues in design, control, and operation of systems. Markov models of single-stage make-to-order and make-to-stock systems. Approximations for non-Markovian systems. Impact of variability on flow lines. Open and closed queuing networks.

**I E 631: Nonlinear Programming**

(3-0) Cr. 3.

*Prereq: I E 534*

Develop nonlinear models, convex sets and functions, optimality conditions, Lagrangian duality, unconstrained minimization techniques. Constrained minimization techniques covering penalty and barrier functions, sequential quadratic programming, the reduced gradient method, nonlinear control concepts.

**I E 632: Integer Programming**

(3-0) Cr. 3.

*Prereq: I E 534*

Integer programming including cutting planes, branch and bound, and Lagrangian relaxation. Introduction to complexity issues and search-based heuristics.

**I E 633: Stochastic Programming**

(3-0) Cr. 3.

*Prereq: I E 513 or STAT 447, I E 534 or equivalent*

Mathematical programming with uncertain parameters; modeling risk within optimization; multi-stage recourse and probabilistically constrained models; solution and approximation algorithms including Benders decomposition and progressive hedging; and applications to planning, allocation and design problems.

**I E 634: Computational Optimization**

(3-0) Cr. 3.

*Prereq: I E 534 or equivalent.*

Theory, algorithm, and computer implementation of optimization models. Simplex, Benders decomposition, computational complexity, mixed integer linear program, linear program with complementarity constraints, inverse optimization, bilevel discrete optimization. Open source and commercial optimization solvers will be introduced and used.

**I E 642: Simultaneous Engineering in Manufacturing Systems**

(3-0) Cr. 3.

*Prereq: I E 549 or M E 415*

Current engineering methods for the product life cycle process. Feature-based design, computer-aided process planning, and data-driven product engineering.

**I E 671: Research Practicum in Human Factors and Ergonomics**

(3-0) Cr. 3. Repeatable.

*Prereq: I E 571 or I E 577 or IE 572*

Research topic development, literature evaluation, experimental design, use of bioinstrumentation, data collection, basic data interpretation, statistical analysis, manuscript preparation.



**I E 673: Spine Biomechanics**

(3-0) Cr. 3. Repeatable, maximum of 3 times. Alt. F., offered odd-numbered years.

*Prereq: I E 571 or equivalent*

Gross and fine anatomy of spine, mechanism of pain, epidemiology, in vitro testing, psychophysical studies, spine stability models, bioinstrumentation: intradiscal pressure, intra-abdominal pressure and electromyography. Biomechanics of lifting and twisting, effects of vibration, effects of posture/lifting style, lifting belts, physical models, optimization models, mathematical models, muscle models, finite element models, current trends in medical management and rehabilitation, chiropractic.

**I E 681: Cognitive Engineering**

(Cross-listed with HCI). (3-0) Cr. 3.

*Prereq: I E 572 or I E 577 or PSYCH 516 or HCI/PSYCH 521 or equivalent*

Provides an overview of human cognitive capabilities and limitations in the design of products, work places, and large systems. Contexts vary broadly and could range from simple use of mobile devices to an air-traffic control or nuclear plant command center. Course focuses on what we can infer about users' thoughts and feelings based on what we can measure about their performance and physiological state. Covers the challenge of designing automated systems.

**I E 690: Advanced Topics**

Cr. 1-3. Repeatable.

*Prereq: Permission of the instructor*

Advanced topics related to Ph.D. research in industrial engineering under the direction of the instructor.

**I E 697: Engineering Internship**

Cr. R. Repeatable. F.S.SS.

*Prereq: Permission of department*

One Fall OR Spring semester combined with one summer, maximum per academic year. Excludes Fall/Spring combination. Professional work period. Offered satisfactory/fail basis only. (With Instructor Permission). Offered on a satisfactory-fail basis only.

**I E 699: Research**

Cr. arr. Repeatable.