

Computer Aided Design (CAD), ME 530.414, JHU

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COURSE DESCRIPTION:

The course outlines modern solid modeling design, analysis, simulation, and manufacturing of mechanical systems. Theoretical focus is given to fundamental Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM) concepts. These are sustained by numerous practical examples to provide the student with intensive hands-on experience with CAD/CAM. Implementations use the Creo (former Pro/Engineer) design package (PTC Inc.). The course has an intensive schedule covering aspects of solid modeling design, assemblies, mechanism design, dynamics, structural analysis, simulation, and manufacturing spanning an entire range of product development, from creative concept through detailed product definition to prototype development and serviceability. Knowledge acquired will likely reflect in the way that students express and implement engineering ideas.

COURSE OBJECTIVE:

The objective of this course is to prepare the students to utilize powerful digital design, simulation, and manufacturing tools to use in classes, projects, and future work. The materials learned will help engineers to develop a product from the stage of the research and development, into prototype developments, and final commercial product developments.

COURSE MEETING TIMES:

Lectures: One 3 hour session / week (attendance mandatory)
TA Sessions: One 3 hour session / week (voluntary participation)

PREREQUISITE:

Not required

TEXTBOOK & SOFTWARE:

Not required. Online PDF materials are available on the class website. Instructor suggests and assigns reading materials weekly. Students use the University software with open (or VPN) access to a site license management server. CAD Software is installed in the HITS Lab (Krieger 160), and instructions are given to students to install on PCs free of charge.

CLASS PARTICIPATION:

Class attendance is mandatory due to the interactive nature of the class. Student participation in class discussions is imperative. Lessons learned and past experiences provide the entire class with a broader perspective of the topics being discussed. All students are required to participate throughout the semester. As shown below, class participation counts toward the final grade.

Health Related Problems: The Student Health and Wellness Center advises students who have flu symptoms not to attend class and isolate themselves to the extent possible until they have been fever-free for 24 hours, in the interest of minimizing contagion. In this situation students should inform the instructor by email. Students who heed the advice of health professionals will not be penalized academically.

Religious Holidays: Religious holidays are valid reasons to be excused from class. Students who must miss a class because of a religious holiday must inform the instructor as early in the semester as possible in order to be excused from class or to make up any work that is missed.

HOMEWORK:

Weekly homework is assigned and submitted over the class website. Homeworks are due before the next lecture. Making the homework in time is essential for being able to follow the next class. Each student is

expected to complete all homework assignments. Homework assignments are evaluated and graded on a scale of 0 to 100. Homework not submitted will receive a grade of 0. Late homework assignments will be reduced by a 10 point penalty per week late, unless otherwise specified. Working together is permitted and encouraged for homework assignments. However, copying is not permitted and will not prepare the student for the exam.

EXAMINATION:

A 3-hour final exam will be given. The examination will take place in the classroom. A design problem that requires iterations throughout all design stages presented in the class will be assigned. The exam is individual, but OPEN book, notes, software, www, etc. This will be graded on a scale of 0 to 100. The exam is individual.

GRADING:

Final grade is calculated based on the averaged class participation, homework, and final exam grades of each student. The tentative basis for the final grade is:

20% Class Participation (including discussion postings and team presentation)

30% Homework (approx. 12 assignments)

50% Final Exam

Letter grades are normalized over the grades of the entire class using an interval distribution.

ACADEMIC INTEGRITY:

The strength of the University depends on academic and personal integrity. The student must be honest and truthful. Ethical violations include cheating on exams, plagiarism, reuse of assignments, improper use of the Internet and electronic devices, unauthorized collaboration, alteration of graded assignments, forgery and falsification, lying, facilitating academic dishonesty, and unfair competition.

SYLLABUS:

1. Computer Aided Design Overview

- 1.1. Introduction
- 1.2. Design Process Overview
 - 1.2.1. Concept and Motivation of CAD
 - 1.2.2. CAD Terminology
 - 1.2.3. Part Modeling Concept
 - 1.2.4. Assembly Modeling Concept
- 1.3. Kinematic and Dynamic Analysis Process
- 1.4. Structural Analysis Process Overview
- 1.5. Manufacturing Process Concepts
- 1.6. CAD Environment
- 1.7. CAD Packages and Architectures

2. Engineering Graphics

- 2.1. Introduction
- 2.2. Design Information and Visualization
- 2.3. Spatial Visualization
- 2.4. Research and Development Engineering Graphics
- 2.5. Product Development Engineering Graphics
- 2.6. Engineering Representations
 - 2.6.1. Projection Views
 - 2.6.2. Orthographic Representations
 - 2.6.3. Model Sectioning
 - 2.6.4. Design Standards

- 2.7. Descriptive Geometry
 - 2.7.1. Projection of Points, Lines, Planes
 - 2.7.2. Visibility
 - 2.7.3. Multilayer Geometry Concepts
 - 2.7.4. Graphic Entity Standards
- 2.8. Geometric Determination
 - 2.8.1. Systems of Units: SI, English
 - 2.8.2. Size, Shape, and Position
 - 2.8.3. Dimensioning
 - 2.8.4. Geometric Constraints
 - 2.8.5. Geometric References
 - 2.8.6. Standards and Guidelines

3. Basic Part Modeling

- 3.1. Introduction and Definitions
 - 3.1.1. Feature Based Design
 - 3.1.2. Solid Modeling Concepts
 - 3.1.3. Parametric Modeling
 - 3.1.4. Associative Design Concepts
- 3.2. Design Environment
 - 3.2.1. Graphics Environment
 - 3.2.2. Model Architecture
 - 3.2.3. Geometric Visualization
 - 3.2.4. Default Features
- 3.3. Geometric Features
 - 3.3.1. Datums, Placed, Sketched
- 3.4. Three-Dimensional Operations
- 3.5. Sketch Based 3-D Genesis
 - 3.5.1. Geometric Entities
 - 3.5.2. Referencing
 - 3.5.3. Dimensioning and Constraints
 - 3.5.4. Dimensional Relations
- 3.6. Iterative Design Methods
- 3.7. Sketched Features
 - 3.7.1. Extrude Operations
 - 3.7.2. Revolve Operations
- 3.8. Placed Features
 - 3.8.1. Holes, Rounds, Chamfers, Shells, Drafts
- 3.9. Symbolic Representations
 - 3.9.1. Standards
 - 3.9.2. Surface Modeling

4. Static Assembly Modeling

- 4.1. Introduction
- 4.2. Degrees of Freedom
- 4.3. Assembly Constraints
 - 4.3.1. Mate, Align, Insert
 - 4.3.2. Other Constraints
- 4.4. Geometric Relations and Parameters
 - 4.4.1. Theory and Types
 - 4.4.2. Operators, Functions, and Variables
 - 4.4.3. Associative Definitions

- 4.4.4. Graphic Functions
- 4.4.5. Simultaneous Equations
- 4.5. Geometric Instancing
 - 4.5.1. Geometric Model
 - 4.5.2. Dependence Relationship
 - 4.5.3. Assembly Instance
 - 4.5.4. Repeated Assembly Operations
 - 4.5.5. Component Interfaces
- 4.6. Bottom-Up Design Concepts
 - 4.6.1. Component Identification
 - 4.6.2. Relations and Rules
- 4.7. Top-Down Designs
 - 4.7.1. Generation Rules and Constraints
 - 4.7.2. Reference Geometry
- 4.8. View Management
 - 4.8.1. Representation Styles
 - 4.8.2. Cross Sectional Display

5. Allowances and Tolerances

- 5.1. Introduction and Applications
- 5.2. Definitions
- 5.3. Limits and Fits
- 5.4. Preferred Hole/Shaft Fit Standards
- 5.5. Statistical Approach
- 5.6. Geometric Tolerances
- 5.7. Surface Finish Requirements
- 5.8. Gauging and Measuring
- 5.9. Measuring Equipment
- 5.10. Shrinkage and fit allowances

6. Engineering Drawing and Detailing

- 6.1. Introduction
- 6.2. Standards, Formats, Unit Systems
- 6.3. Projection Views
- 6.4. Isometric Representations
- 6.5. Cross Sections
- 6.6. Ordinate Dimensioning
- 6.7. Tolerance Descriptions
- 6.8. Exploded Views, Bills of Materials
- 6.9. Geometric Relations and Associativity

7. Part and Assembly Modeling

- 7.1. Geometric Patterns
 - 7.1.1. Dimensional and Directional Types
 - 7.1.2. Rotary Axial and Dimensional
- 7.2. Sweep and Blend Operations
 - 7.2.1. Three-Dimensional Principles
 - 7.2.2. Trajectory Based Generation
 - 7.2.3. Helical Geometry
 - 7.2.4. Variable Section Sweeps
 - 7.2.5. Combined Sweep-Blend Operations
- 7.3. Iterative Design Concepts

- 7.4. Parent-child relationships
 - 7.4.1. Inheritance
 - 7.4.2. Feature Dependency / Independency
 - 7.4.3. Geometric Suppression
 - 7.4.4. Feature Reordering
 - 7.4.5. Geometric Groups
- 7.5. Feature and Group Operations
 - 7.5.1. Dependent Geometry
 - 7.5.2. Duplication Methods
- 7.6. Iterative Design Tools
- 7.7. Standard Components
 - 7.7.1. Standards and Libraries
 - 7.7.2. Table Driven Geometry
 - 7.7.2.1. Standard and Custom
 - 7.7.2.2. Family Type Geometry
 - 7.7.3. Industry Libraries
- 7.8. Analytic Features
 - 7.8.1. Materials and Mass Properties
 - 7.8.2. Surfaces and Volumes
 - 7.8.3. Mass Products and Moments of Inertia
- 7.9. Flexible Geometry

8. Mechanism Design and Simulation

- 8.1. Introduction to Design and Simulation Process
- 8.2. Model - Analyze - Results Overview
- 8.3. Degrees of Freedom and Constraints
- 8.4. Mechanism Connections
 - 8.4.1. Mechanism Bodies
 - 8.4.2. Constraints and Connection Sets
 - 8.4.3. Motion Axis Connections
 - 8.4.3.1. Pin, Slider, Cylinder, Planar, Ball, Bearing
 - 8.4.4. Connection Sets
 - 8.4.4.1. Slot Connections, Cam-follower, Gears, Belts
 - 8.4.5. Prescribing Motion
 - 8.4.5.1. Drivers: Servo Motors
 - 8.4.5.2. Constant, Ramp, Cosine, Cycloidal, Parabolic, Polynomial
- 8.5. Kinematic Analysis
 - 8.5.1. Initial Configurations
 - 8.5.2. Measure Definitions
 - 8.5.3. Result Evaluations
 - 8.5.4. Animation Display
- 8.6. Dynamic Modeling
 - 8.6.1. Dynamic Entities
 - 8.6.2. Mass Properties
 - 8.6.3. Friction Models: Coulomb and Viscous
 - 8.6.4. Elastic Models
 - 8.6.4.1. Linear and Tensional Springs
 - 8.6.4.2. Impact: Newton Coefficient of Restitution
 - 8.6.5. Drivers
 - 8.6.5.1. Gravity Loads
 - 8.6.5.2. Servo Motors
 - 8.6.5.3. Force/Torque Loads

- 8.6.6. Model Analysis
 - 8.6.6.1. Initial Conditions
 - 8.6.6.2. Force Balance
 - 8.6.6.3. Dynamic

8.7. Model Evaluations

- 8.7.1. Measures
- 8.7.2. Graphic Representations
- 8.7.3. Simulation Display
- 8.7.4. Trajectories, work envelopes

8.8. Mechanism Synthesis

- 8.8.1. Overview
- 8.8.2. Cam Synthesis
- 8.8.3. Gear Generation

9. Structural Simulation and Analysis

9.1. Introduction and Overview

- 9.1.1. Model - Analyze - Results

9.2. Finite / Geometric Element Methods

- 9.2.1. Overview
- 9.2.2. Convergence
- 9.2.3. Systems of Units
- 9.2.4. Types: Models, Elements, Meshes
- 9.2.5. Surface and Volume Regions

9.3. Materials and Material Properties

- 9.3.1. Types
- 9.3.2. Failure Criteria

9.4. Idealized Models

- 9.4.1. Plane Stress and Strain Models
- 9.4.2. Axisymmetric Models
- 9.4.3. Beam, Shell, Mass, Spring Idealizations

9.5. Structural Loads

- 9.5.1. Force and Moments
- 9.5.2. Bearing Loads
- 9.5.3. Centrifugal
- 9.5.4. Gravity Loads
- 9.5.5. Pressure
- 9.5.6. Mechanism Loads

9.6. Structural Constraints

- 9.6.1. Displacement Constraints
- 9.6.2. Planar, Pin, Ball Constraints
- 9.6.3. Mirror and Cyclic Symmetry Constraints
- 9.6.4. Assembly Weld and Fastener Constraints

9.7. Structural Analyses

- 9.7.1. Static, Modal, Large Deformation
- 9.7.2. Contact Analyses
- 9.7.3. Convergence and Adaptivity

9.8. Result Processing and Display

- 9.8.1. Fringe, Vector, Graphs
- 9.8.2. Stress: Principal, von Mises.
- 9.8.3. Animation Displays

10. Feasibility Studies and Design Optimizations

- 10.1. Introduction: Design Studies / Design Specifications
- 10.2. Behavioral Modeling
- 10.3. Measurement Features
 - 10.3.1. Dimensional
 - 10.3.2. Mass Properties, Clearance
- 10.4. Analysis Features
 - 10.4.1. Relation Analysis Features
 - 10.4.2. Motion Analysis Features
 - 10.4.3. Structural Analysis Features
 - 10.4.4. Statistical Design Studies
- 10.5. Studies and Analyses
 - 10.5.1. Sensitivity Study
 - 10.5.2. Feasibility Study
 - 10.5.3. Objective Functions
 - 10.5.4. Design Optimizations

11. Computer Numerical Control Manufacturing (CNC)

- 11.1. Manufacturing Process Overview
- 11.2. CNC Equipment
 - 11.2.1. Multi-axis machining and turning centers
- 11.3. CNC Programming Overview
 - 11.3.1. Coordinate Systems
 - 11.3.2. Numeric Control Codes (NC)
 - 11.3.3. Factory Interface Language (FIL)
 - 11.3.4. G-Code Language
- 11.4. Manufacturing Model Concepts
- 11.5. Types of Operations
- 11.6. Workcell Definitions
- 11.7. Manufacturing Sequences
 - 11.7.1. Manufacturing Parameters
 - 11.7.2. Roughing and Finishing Concepts
- 11.8. NC Simulation
- 11.9. Post Processing
- 11.10. Executing CNC Operations

12. Conclusion

- 12.1. CAD Perspective
- 12.2. Additional Topics for Independent Study
- 12.3. Future Trends