University of Macau
Department of Electromechanical Engineering
MECH308 - Product Design II
Syllabus
2nd Semester 2011/2012
Part A – Course Outline

Compulsory course in Electromechanical Engineering

Course description:

Product Design is a subject that encompasses many branches of sciences, such as structural analyses, mechanical design, project management. Among the many factors that have to considered in product design, this course focuses on the optimisation and material selection processes.

The first part of this course is on the materials selection process. The most common failure phenomena a designer will encounter, such as fatigue and creep, will be introduced first. Performances indices that are useful for selecting the right materials to guard against these failure modes will then be discussed. Topics to be covered also include the relationship between design and material selection, the economics and environmental impact of materials and processes, material substitution, the Pugh method of concept selection, the nature of engineering design, methods for ranking materials for a given design problem, and case studies. The second part of this course will cover design optimisation. The formulation of design problems into models that are adaptable for subsequent processing using common optimisation algorithms will be introduced. Design optimisation problems presented in this course are those that are commonly encountered in practice, such as the optimum design of a structure for achieving maximum strength-to-weight ratio and the most economical use of raw material. Other topics to be covered are linear and non-linear programming, multiobjective optimisation, sensitivity analysis, the steepest decent method, etc.

Students undertaking this course will be required to work on projects involving the optimisation of design prototypes generated in the prerequisite course. Students also have to critique, using their knowledge gained in the Material Selection part of this course, on the reasonableness of the choices of materials in their prototypes.

Prerequisite:

MECH305 - Product Design I

Textbooks:

- Farag MM. Materials and Process Selection for Engineering Design. CRC Press. 2008
- Ashok D. Belegundu and Tirupathi R. Chandrupatla. Optimization Concepts and Applications in Engineering. Prentice Hall. 1999.
- Singiresu S. Rao. Engineering Optimization theory and Practice. John Wiley & Sons. 2009.

References:

- Linus Schrage. Optimization modeling with LINDO. Duxbury. 1997.
- G.V.Shenov. Linear Programming Methods and Applications (2nd ed). New Age International. 1998
- Xin-She Yang. Engineering Optimization : an Introduction with Metaheuristic Applications. John Wiley. 2010
- A. Ravindran, K.M. Ragsdell, G.V. Reklaitis. Engineering Optimization : Methods and Applications. John Wiley & Sons. 2006
- Philip J. Pritchard. MathCAD : a Tool for Engineering Problem Solving. McGraw Hill. 2008

Course objectives:

On completion of this course, students are expected to:

1. Know the most common failure modes in mechanical engineering and how to design against them [a, e]

2. Be able to select the best material(s) to fulfil the functional/economic requirements specified for a given product [a, e]
3. Be able to select a better material (or materials) to substitute for the currently used material of a given product [a,e]
4. Understand the process of formulation of product design problems into mathematical models [a, e]
5. Have an understanding on how to design under given constraints (both economic and technical) [c]
6. Be able to apply the most commonly used mathematical algorithms and software programme(s) for solving a variety of optimisation problems in engineering design [a, e]

Topics covered:

Introduction to Product Design and Development in industry – Feasibility and Concept Selection; System-level Design; Selection of Materials and Processes; Testing and Refinement; Launching and Selling of Products; Production Life Cycle

Common Failure Modes in Mechanical Engineering – Types of Mechanical failures; Fracture and Fracture Mechanics; Ductile and Brittle Fractures; Fatigue; Creep; Corrosion; Radiation Damage

Selection of Materials from the technical point of view – Performance Indices; Selection of Materials for Static Strength; Selection of Materials for Stiffness; Selection of Materials for Toughness; Selection of Materials for Fatigue resistance; Selection of Materials for Creep resistance; Selection of Materials for Corrosion Resistance

Effects of Materials Properties on Design – Designing for Strength; Designing for Stiffness; Fail-Safe Design; Leak-before-Burst Design; Designing against Creep and fatigue

Selection of Materials from the economic and environmental point of view – Impact of cost on material selection; Performance indices based on cost; Impact of different materials on the environment; Methods for ranking materials in terms of environmental impact; Energy content estimation; Relationship between recycling and material selection

Ranking of Materials – Rigid material requirements; soft materials requirements; the weighted-properties method; the limits-on-properties method; Scaling of material requirements for the purpose of ranking materials; Upper-limit properties; Lower-limit properties; Target-value properties

Material Substitution – Materials Audit; Considerations in Materials Substitution; Ranking of Materials for a Given Design; Screening of Alternative Materials; Cost of Performance Method; The Compound Performance Function Method

Introduction to Engineering optimisation – Concept of optimisation; Decision variables; Feasible and infeasible solution and regions; Equality and inequality constraints; Active and inactive constraints; Design space; Objective function; Classification of optimisation problems; Formulation of problems into optimisation models

Linear Programming – Linear programming (LP); Formulation of LP models; Examples of applications of LP in various fields; Simplex tableau; Graphical solution of LP problems; Slack variables; Artificial variables; Basic and non-basic variables; Pivot; Identification of the nature of solution; Duality; Primal problem and dual problem; Shadow price; Sensitivity and post-optimality analyses; Interpretation of slack and artificial variables; Effects of reduction in supplies; Effects of adding new activities to production schedule

Multiobjective Optimisation –Multiobjective optimisation; Efficient points and solutions; Efficient frontiers; Graphical solution for efficient points; Preemptive optimisation; Weighted sums of objective functions; Goal programming; Soft constraints; Deficiency variables; Preemptive goal programming

Mathematical Techniques for Design Optimisation - Unconstrained and constrained optimisation of single and multi-variable functions; Weak and strong local optimum points; Properties of convex multi-variable functions; The Steepest-Descent method; Newton’s method; Constrained optimisation of equality and inequality constraints; The Lagrange multiplier method

The Use of Optimisation Software (LINDO) – The use of LINDO for solving optimisation problems

Topic Outline:

Week No.	No. of hours	Topics
1	4	**Introduction to Design and Development in industry** Feasibility and Concept Selection; System-level Design; Selection of Materials and Processes; Testing and Refinement; Launching and Selling of Products; Production Life Cycle
2	4	**Common Failure Modes in Engineering Components** Types of Mechanical failures; Fracture and Fracture Mechanics; Ductile and Brittle Fractures; Fatigue; Creep; Corrosion; Radiation Damage
3	4	**Selection of Materials for Product Design** Performance Indices; Selection of Materials for Static Strength; Selection of Materials for Stiffness; Selection of Materials for Toughness; Selection of Materials for Fatigue resistance; Selection of Materials for Creep resistance; Selection of Materials for Corrosion Resistance
4	4	**Effects of Materials Properties on Design** Designing for Strength; Designing for Stiffness; Fail-Safe Design; Leak-before-Burst Design; Designing against Creep and fatigue
5	4	**Material Selection on the Basis of Economics and Environmental Impact** Impact of cost on material selection; Performance indices based on cost; Impact of different materials on the environment; Methods for ranking materials in terms of environmental impact; Energy content estimation; Relationship between recycling and material selection
6	4	**Ranking of Materials** Rigid material requirements; soft materials requirements; the weighted-properties method; the limits-on-properties method; Scaling of material requirements for the purpose of ranking materials; Upper-limit properties; Lower-limit properties; Target-value properties
7	4	**Material Substitution** Materials Audit; Considerations in Materials Substitution; Ranking of Materials for a Given Design; Screening of Alternative Materials; Cost of Performance Method; The Compound Performance Function Method
8	4	**Ranking of Materials** Rigid material requirements; soft materials requirements; the weighted-properties method; the limits-on-properties method; Scaling of material requirements for the purpose of ranking materials; Upper-limit properties; Lower-limit properties; Target-value properties
9	4	**Introduction to Engineering Optimisation** Introduction to the concept of optimisation; Decision variables; Feasible regions; Feasible and infeasible points; Constraints; Design space; Objective function; Introduction of the various optimisation models; Basics of formulation of problems into optimisation models; Classification of optimisation problems
10	4	**Linear Programming** Linear programming (LP); Formulation of LP models; Examples of applications of LP in various fields; Simplex tableau; Graphical solution of LP problems; Slack variables; Artificial variables; Basic and non-basic variables; Pivot; Identification of the nature of solution; Duality; Primal problem and dual problem; Shadow price; Sensitivity and post-optimality analyses; Interpretation of slack and artificial variables; Effects of reduction in supplies; Effects of adding new activities to production schedule
11	2	**Introduction to LINDO** Introduction to LINDO; Use of LINDO for solving problems in linear programming, integer programming, mixed programming; multiobjective programming
12	4	**Multiobjective Optimisation** Multiobjective optimisation; Formulation of problems into multiobjective

		optimisation models; Efficient points and solutions; Efficient frontiers; Graphical solution for efficient points; Preemptive optimisation; Weighted sums of objective functions **Computer session:** Use of the software programme LINDO for solving multiobjective optimisation problems
13	4	**Mathematical techniques for design optimisation (Part I)** Unconstrained optimisation of multi-variable functions; Weak and strong local optimum points; Properties of convex multi-variable functions; The Steepest-Descent method; Newton’s method
14	4	**Mathematical techniques for design optimisation (Part II)** Unconstrained and constrained optimisation of single and multi-variable functions; Weak and strong local optimum points; Properties of convex multi-variable functions; The Steepest-Descent method; Newton’s method; Constrained optimisation of equality and inequality constraints; The Lagrange multiplier method

Class/practice schedule:

3-hour lectures and 1-hour practice per week (14 weeks)

Contribution of course to meet the professional component:

This course prepares students to work professionally in the area of **design**

Relationship to EME program objectives and outcomes:

This course primarily contributes to Electromechanical Engineering Program outcomes that develop student abilities to:
(a) An ability to apply knowledge of mathematics and engineering
(c) An ability to design a system, component, or process to meet desired needs within realistic constraints, such as economic, environmental, social, political, ethical, health and safety, manufacturability and sustainability
(e) An ability to identify, formulate, and solve engineering problems;

Course content:

Maths	Engineering Science	Engineering Design and Synthesis	Complementary Studies	Computer Studies	Total 100%
35	30	25	0	10	100

Persons who prepared this description:

Dr. Kin Ho Lo

Part B General Course Information and Policies

2nd Semester 2010/2011

Instructor: Dr. Kin Ho Lo Office: N306
Office Hour: By appointment: every afternoon during weekdays Phone: (853) 8397-4356
Email: KHLO@umac.mo

Time/Venue:

1.30pm-3.30pm. Tuesdays. ILG128
1.30pm-3.30pm. Fridays. ILG128

Assessment:

Final assessment will be determined on the basis of:
Tutorial problems and Homework: 5 %
Mid-term I and Mid – term II: 30%
Group Project on Design Optimisation: 30%
Final Exam (Comprehensive): 35%

Grading System:

The credit is earned by the achievement of a grade from 'A' to 'D'; 'F' carries zero credit.

Grades are awarded according to the following system:

Letter Grades	Grade Points	Percentage
A	4.0 (Excellent)	93-100
A-	3.7 (Very good)	88-92
B+	3.3	83-87
B	3.0 (Good)	78-82
B-	2.7	73-77
C+	2.3	68-72
C	2.0 (Average)	63-67
C-	1.7	58-62
D+	1.3	53-57
D	1.0 (Pass)	50-52
F	0 (Fail)	Below 50

Comment:

The objectives of the lectures are to explain the text material and teach the use of commercially available optimisation software for solving problems that are intractable otherwise. Students who wish to succeed in this course should read the handouts prior to lectures and should do all homework and lab assignments independently.

Homework Policy:

- There will be approximately 3-5 homework assignments
- Due date for each homework is about 2 weeks after its announcement
- Homework will be returned to students in about 10 days after submission

Quizzes/Mid-terms Exams:

Two mid-term exams will be held during the semester

Note:

- Attendance is strongly recommended
- Announcement of homework and dates for examinations will be made during lectures
- No make-up exam will be given unless with justifications (e.g., illness)

Appendix - Rubric for Program Outcomes (a) to (l)

Rubric for (a)	5 (Excellent)	3 (Average)	1 (Poor)
Understand the theoretic background	Students understand theoretic background and the limitations of the respective applications.	Students have some confusion on some background or do not understand theoretic background completely	Students do not understand the background or do not study at all
Use a correct model and formulation correctly	Students choose a model correctly and properly apply correct techniques	Students choose a wrong model sometime, use a wrong formula, or a different technique	Students use a wrong model and wrong formula, or do not know how to model
Compute the problem correctly	Students use correct techniques, analyze the problems, and compute them correctly	Students sometime solve problem mistakenly using wrong techniques	Students do not know how to solve problems or use wrong techniques completely

Rubric for (b)	5 (Excellent)	3 (Average)	1 (Poor)
Conduct experiments	Student successfully completes the experiment, records the data, analyzes the experiment's main topics, and explains the experiment concisely and well.	Student successfully completes the experiment, records the data, and analyzes the experiment's main topics.	Student either does not complete the experiment successfully, or completes it successfully but does not record the correct data.
Design experiments	Student understands what needs to be tested and designs an appropriate experiment that takes into account the limitations of the equipment and measurement accuracy.	Student understands what needs to be tested and designs an appropriate experiment, but may not fully understand the limitations of the measurements.	Student does not understand what needs to be tested and/or does not design an appropriate experiment.

Rubric for (c)	5 (Excellent)	3 (Average)	1 (Poor)
Design capability and design constraints	Student understands very clearly what needs to be designed and the realistic design constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.	Student understands what needs to be designed and the design constraints, but may not fully understand the limitations of the design constraints	Student does not understand what needs to be designed and the design constraints.
Process to meet desired needs	Student understands very clearly the process of the design	Student understands what the needs of the process design, but may not fully understand the limitations of the design constraints	Student does not understand the process.

Rubric for (d)	5 (Excellent)	3 (Average)	1 (Poor)
Ability to work in teams	Performance on teams is excellent with clear evidence of equal distribution of tasks and effort as well as frequent meetings of the team members.	Performance on teams is acceptable with one or more members carrying a larger amount of the effort as well as infrequent meetings of the members or one or more members being absent from several meetings.	Performance on teams is poor to unacceptable with one or two members clearly carrying the majority of the effort as well as inadequate team meeting or one or more members missing the majority of the meetings.
Multi-disciplinary teams	Team consists of members from two or more different engineering/science/business fields (this could contain some members not actually enrolled in the course but interacting as part of a competition, collaboration, etc.)	Team consists of members from two or more concentrations within the Department of Electromechanical Engineering	Team consists of members from the same concentration within the Department of Electromechanical Engineering

Rubric for (e)	5 (Excellent)	3 (Average)	1 (Poor)
Identify applications in engineering systems	Students understand problem and can identify fundamental formulation	Students understand problem but cannot apply formulation.	Students cannot identify correct terms for engineering applications
Modeling, problem formulation and problem solving	Students choose and properly apply the correct techniques	Students model correctly but cannot select proper technique or model incorrectly but solve correctly accordingly	Students at loss as to how to solve a problem

Rubric for (f)	5 (Excellent)	3 (Average)	1 (Poor)
Design	Understand how to critique and analyze design tradeoffs and constraints with respect to safety, liability, and integrity of data, and context of use	Have knowledge of safety, liability, and integrity of data, and context of use but cannot analyze thoroughly	No awareness of importance of safety, liability, and integrity of data, and context of use
Professional Engineering Practice	Understand how to critique and analyze tradeoffs and constraints with respect to research issues of credit and authorship, integrity of data, and informed consent	Have knowledge of credit and authorship, integrity of data, and informed consent but cannot completely identify ownership in practical	No awareness of credit and authorship, integrity of data, and informed consent
Group Relations	Understand how to critique and analyze tradeoffs and constraints with respect to conflict of interest, bribery, professional dissent, authorship, and discrimination	Have partial knowledge of conflict of interest, bribery, professional dissent, authorship, discrimination but cannot apply it in practice correctly	No awareness of conflict of interest, bribery, professional dissent, authorship, and discrimination

Rubric for (g)	5 (Excellent)	3 (Average)	1 (Poor)
Professional Impact	Student's/Team's/Group's document(s)/presentation(s) is/are considered to be of professional quality	Student's/Team's/Group's document(s)/presentation(s) is/are considered acceptable for college level work	Student's/Team's/Group's document(s)/presentation(s) is/are considered unacceptable for college level work
Written Component	Document is nearly error free with sophisticated use of vocabulary, formatted properly, with well developed concise sentences and paragraphs	Document contains some errors with a somewhat colloquial vocabulary, minor formatting issues, with some organizational issues that do not interfere with communication	Document contains many errors, very colloquial vocabulary, with severe organizational issues that interfere with communication. Document would be considered unacceptable.
Oral Component	Presentation is consistent, uniform, clear, direct, complete and captivating with very clear fonts and graphics with an excellent layout that clearly presents the technical content	Presentation is somewhat inconsistent between speakers, occasionally difficult to hear, with an acceptable layout containing acceptable fonts and graphics that adequately presents the technical content	Presentation is very inconsistent between speakers, difficult to hear with a poor layout containing illegible fonts and graphics that poorly presents the technical content. Would be considered unacceptable

Rubric for (h)	5 (Excellent)	3 (Average)	1 (Poor)
Scope of Content	Students will demonstrate material, items, or topics characterized by a sophisticated array of information, insight, and understanding.	Students demonstrate significance reflecting an acceptable degree of perception and thoughts.	Students have limited abilities to relate, incorporate, or demonstrate knowledge of subject with a dynamic breadth.
Impact of Process	Students will employ techniques, designs, ideas, and knowledge demonstrating a profound ability to improve and possess broad applications with a keen a series of actions, changes, or functions	Techniques, designs, ideas, and knowledge present some understanding and ability to demonstrate progression, significance, and influence.	Techniques, designs, ideas, and knowledge present limited progression, significance, and influence

Rubric for (i)	5 (Excellent)	3 (Average)	1 (Poor)
Research/ Gathering Information	Comprehensive collection of information on a subject, including state-of-the-art and background	Collects adequate information on a subject	Collects minimal information on a subject
Analysis/ Evaluation	Detailed analysis accounting for all the information, conclusions are well supported	Some analysis done but somewhat shallow; some supporting evidence	Analysis simply involves restating gathered information; claims not supported by evidence

Rubric for (j)	5 (Excellent)	3 (Average)	1 (Poor)
Relevance to the Present Time	Student displays an understanding of the theoretical or practical impact and an ability to correlate a subject, perception, communication, association and reasoning from a global and societal perspective.	Student is able to display an understanding of current topics and issues with some knowledge regarding their impact in a bigger global and societal sense.	Student has difficulty demonstrating an awareness or familiarity with current topics and issues relevant to most current global and societal affairs.

Rubric for (k)	5 (Excellent)	3 (Average)	1 (Poor)
Use modern hardware tools in engineering practice	Student uses the hardware to measure and/or build engineering systems/designs correctly, and understands the limitations of the hardware.	Student uses the hardware to measure and/or build engineering systems/designs correctly.	Student does not use the hardware correctly.

Rubric for (l)	5 (Excellent)	3 (Average)	1 (Poor)
Use modern computer and software tools in engineering practice	Student uses the computer and software to correctly analyze engineering problems and/or create engineering designs, and understands the limitations of the software.	Student uses the computer and software to correctly analyze engineering problems and/or create engineering designs.	Student does not use the computer and software to correctly create engineering designs and/or does not correctly interpret the results.