University of Macau
Department of Electromechanical Engineering
MECH204 - Mechanics of Materials
Syllabus
2^{nd} Semester 2011/2012
Part A – Course Outline

Compulsory course in Electromechanical Engineering

Course description:

4 credits. This course aims to introduce the fundamental concepts of mechanics of deformable solids to students, with an emphasis on mechanical design. A good knowledge in Mechanics of Materials not only enables the engineer to design reliable components economically, but it will also enable the engineer to assess whether an existing design of a component is reasonable or not. Some of the topics covered in this course are: stresses and strains, constitutive equations, mechanical behaviour of materials, statically indeterminate structures, torsion of circular and non-circular bars, shear force and bending moment diagrams, bending of beams of different cross-sectional shapes, shear stresses in beams of different cross-sectional shapes, transformation of stresses and strains, stresses induced by complex loading conditions, temperature effects and thermal stress, energy principles, failure theories, and buckling of columns. Examples covered in this course are particularly orientated towards design of machine components.

Prerequisite:

MECH102 – Applied Mechanics

Textbooks:

- Ferdinand P. Beer, E. Russell Johnston Jr, John T. DeWolf. Mechanics of Materials (SI ed). McGraw Hill. 2010
- James M. Gere. Mechanics of Materials. Brooks/Cole Thompson Learning. 2005

References:

- Anthony Bedford, Kenneth M. Liechti. Mechanics of Materials. Prentice Hall. 2000
- Andrew Pytel, Jaan Kiusalaas. Mechanics of Materials. Thomson, 2003
- Ansel C. Ugural. Mechanics of Materials. Wiley 2008

Course objectives:

On completion of this course, students are expected to:

- Understand how loading, geometry, and material properties interact to affect the mechanical behaviour of structures [a, e]
- Be able to systemically determine stresses, strains and deformation in different structures (trusses, frames, beams, and columns) under different modes of loading (axial, torsional, flexural, etc.) [a, e]
- Be able to differentiate between statically determinate and indeterminate structures and solve them [a, e]
- Know what is structural stability for slender structural members (column) [a, e]
- Have the ability to design against yielding, brittle fracture, and excessive deformation [a, e]
- Possess the knowledge required for studying advanced courses in structural analysis and mechanical design [a, c]

Topics covered:

Stresses and strains - Normal and shear stresses; Normal and shear strains; Hooke's laws; Tensile and torsion experiments; Fundamental mechanical properties; Introduction to the inadequacy of using Statics alone for design purposes; Safety factor; Simple design problems in mechanical engineering; Stress concentration; Elasticity and plasticity

Axial loading and torsion - Axially loaded prismatic and non-prismatic bars; Normal stresses in axially loaded bars; Calculation of deformations in axially loaded bars; Axial force diagrams; Torsion of circular and non-circular bars; Torsional shear stresses; Comparison between axially loaded bars and torsionally loaded bars; Torsion of thin-walled bars of closed or open cross-sections; Introduction to power transmission machinery

Statically indeterminate structures - Statically indeterminate structures under axial loading conditions; Statically indeterminate structure in torsion; Degree of indeterminacy; Concept of deformation compatibility; Redundant supports; Released structures

Shear force and bending moment diagrams - Shear force; Bending moment; Construction of V and M diagrams; Differential relations relating V and M; Use of V and M diagrams for design purposes

Bending of beams - Pure bending; Flexure formula for elastic beams; Neutral layer; Beam design problems when only normal stresses are considered; Composite beams; Calculation of normal stresses in beams under non-symmetric bending; Core of section

Shear stresses in beams - Transverse bending; Shear formula for rectangular beams; Beam design problems when both normal and shear stresses must be considered; Shear stresses for non-rectangular beams; Shear of beams having open cross-sections; Shear centre

Transformation of stresses and strains - Stress element; Normal and shear stresses in different orientations for the same point; Principal stresses and directions; Maximum shear stresses and their directions; Stress representation with Mohr's circle; Normal and shear strains in different orientations for the same point; Strain representation with Mohr's circle

Combined stresses due to complex loading conditions - Calculation of normal and shear stresses for structure and machine components under complex loading conditions; Identification of critical locations; Stress contours

Failure theories - Maximum normal stress theory; Maximum normal strain theory; Maximum shear stress theory; Maximum strain energy theory; Mohr's theory; Application of these theories to design problems

Temperature effects and thermal stress - Thermal strains; Thermal stresses; Thermal deformation; Temperature change; Calculation of stresses under external loads and temperature change

Stability and buckling - Stability and buckling; Euler columns of different support conditions; Critical buckling load; Columns supporting eccentric loads; Secant formula; Classification of columns into short, intermediate and long columns; Slenderness ratio; The various empirical formulae for short columns and columns of intermediate lengths

Energy principles - Conservation of energy; Work; Strain energy; Conservative system; Potential energy; Reciprocal theorem; Castigliano's theorems; Principle of virtual work for deformable bodies

Topic Outline:

Week No.	No. of hours	Topics
1	5	**Introduction** Review of Statics; Review of tensile and torsion experiments; Review of fundamental mechanical properties like yield point and modulus of elasticity; Introduction to the inadequacy of using Statics alone for design purposes; Introduction to normal and shear stresses; Normal and shear strains; Hooke's laws; Underlying assumptions in Mechanics of Materials such as isotropicity and small deformations; Safety factor; Simple design problems in mechanical engineering; Stress concentration
2	5	**Axially-loaded bars** 2-force bodies; Axially loaded prismatic bars; Axially loaded non-prismatic bars; Normal stresses in axially loaded bars; Calculation of deformations in axially loaded bars; Axial force diagrams
3	2	**Statically indeterminate structures with axial loads** Statically indeterminate structures with axial loads; Concept of deformation compatibility in axial loading conditions; Redundant supports; Released structures
3	3	**Torsion of circular and non-circular bars** Introduction to torsion of circular bars; Standard procedures for solving deformable bodies: equilibrium, deformation and constitutive relations; The implications of bars having circular cross-sections (plane cross-section

		assumption); Warping of cross-section in non-circular bars; Torsional shear stresses; Non-prismatic circular bars in torsion; Statically indeterminate structures in torsion; Comparison with axially loaded bars
4	2	**Statically indeterminate structures in torsion** Statically indeterminate structures with axial loads; Concept of deformation compatibility in torsion; Redundant supports; Released structures
4	3	**Torsion of non-circular bars, torsion of thin-walled bars, and power transmission** Torsion of non-circular bars; Torsion of thin-walled bars of closed or open cross-sections; Introduction to power transmission machinery and related design problems
5	5	**Shear force (V) and bending moment (M) diagrams** Shear force; Bending moment; Construction of V and M diagrams by listing equilibrium equations; Differential relations relating V and M; Use of differential relations for constructing V and M diagrams
6	5	**Normal stresses in beams** Introduction to beams; Pure bending; Flexure formula for elastic beams; Understanding of the underlying assumptions for beams (such as plane cross-section assumption); Neutral layer; Beam design problems when only normal stresses are considered (such as slender beams made of metals that are extensively used in mechanical engineering)
7	3	**Normal stresses in composite beams and non-symmetric bending** Composite beams; Calculation of normal stresses in beams under non-symmetric bending; Core of section
7	2	**Shear stresses in beams with rectangular cross-section** Transverse bending; Shear formula for rectangular beams; Beam design problems when BOTH normal and shear stresses must be considered
8	5	**Shear stresses in non-rectangular beams, shear of beams of open cross-sections** Calculation of shear stresses for non-rectangular beams; Shear of beams having open cross-sections; Shear centre
9	5	**Transformations of stresses** Stress element; Normal and shear stresses in different orientations for the same point; Principal stresses and directions; Maximum shear stresses and their directions; Stress representation with Mohr's circle
10	5	**Transformation of strains** Normal and shear strains in different orientations for the same point; Strain representation with Mohr's circle
11	3	**Structures under complex loading conditions** Calculation of normal and shear stresses for structure and machine components under complex loading conditions; Identification of critical locations; Stress contours
11	2	**Thermal stress** Thermal strains; Thermal stresses; Thermal deformation; Temperature change; Calculation of stresses under external loads and temperature change
12	5	**Failure theories** Maximum normal stress theory; Maximum normal strain theory; Maximum shear stress theory; Maximum strain energy theory; Mohr's theory; Application of these theories to predict structural failure, with an emphasis on design problems of machinery
13	5	**Column and stability** Introduction to the concept of stability and buckling; Introduction to columns and their comparison with beams; Euler columns of different support conditions; Concept of critical buckling load; Limitations of the Euler formula for columns; Columns supporting eccentric loads; Secant formula; Slenderness ratio;

		Limitation of Secant formula for short columns and columns of intermediate lengths; The various empirical formulae for short columns and columns of intermediate lengths
14	5	**Energy methods** Conservation of energy; Work; Conservative system; Strain energy; Potential energy; Reciprocal theorem; Castigliano's theorems; Principle of virtual work for deformable bodies

Class/practice schedule:

4-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 **mechanical 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%
10	55	35	0	0	100

Course coordinator:

Prof. Chi Tat Kwok

Persons who prepared this description:

Dr. Kin Ho Lo, Prof. Chi Tat Kwok, Prof. Vai Kuong Sin, 14 July 2010

Part B General Course Information and Policies

2nd Semester 2010/2011

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

Time/Venue:

8.30am-10.30am. Wednesdays. U103
4.00pm-7.00pm. Thursdays. U103

Assessment:

Final assessment will be determined on the basis of:
Tutorial problems and Homework: 10 %
Mid-term I and Mid – term II: 30%
Final Exam (Comprehensive): 60%

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 real case studies. Students who wish to succeed in this course should read the handouts prior to lectures and should do independently all homework and tutorial assignments.

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.