جامعة الملك عبدالله
للعلوم والتقنية
King Abdullah University of
Science and Technology

Course Syllabus: Computational Solid Mechanics - ME 319A

Division	Physical Science and Engineering Division
Course Number	ME 319A
Course Title	Computational Solid Mechanics
Academic Semester	Spring
Academic Year	2017/2018
Semester Start Date	01/28/2018
Semester End Date	05/24/2018
Class Schedule (Days & Time)	10:30 AM - 12:00 PM | Mon Wed

Instructor(s)

Name	Email	Phone	Office Location	Office Hours
Marco Alfano	Marco.Alfano@kaust.edu.sa			Sun 4.00 PM to 5.00 PM or by appointment

Teaching Assistant(s)

Name	Email

Course Information

Comprehensive Course Description	The main objectives of the course are to provide students with a conceptual understanding and practical implementation of advanced finite element analysis (FEA). Static and dynamic conditions will be addressed and applications to engineering structures at multiple-scale will be considered. Finite element methods and solution procedures for linear and nonlinear analyses will be largely presented using physical arguments. Special focus will be placed on the analysis of failure of advanced engineering materials using computational methods. Models for material failure, *e.g.* cohesive zone models, will be presented in detail. Finite element implementation of interface elements as well as parameters identification strategies will be discussed. The key ideas of continuum damage models will be also given. The homework involves the use of either a general-purpose finite element analysis program or symbolic programming. Applications include finite element analyses, modeling of problems, and interpretation of numerical results. We will go through the following topics: || Differential and variational formulations. Weighted residual, least squares and Ritz analysis methods. General formulation of the FEM and generalized coordinate models. Formulation and calculation of iso-parametric models. Formulation of structural elements. Gauss and Newton-Cotes integration formulas. Stresses recovery and inter-element averaging techniques. Practical considerations. Applications. || Solution of equilibrium equations in static and dynamic analysis. Static condensation and sub-structuring. Direct integration: explicit versus implicit techniques. Stability and accuracy. Error estimators. Mode superposition analysis and time history. Damping. Errors and static correction. Solution methods for frequency and mode shapes. Practical considerations. Applications. || Non-linear analysis. Formulation of the continuum mechanics incremental equations of motions. Total and updated Lagrangian formulations. Solution of nonlinear finite element equations. Formulation of constitutive models. Contact. Advanced techniques for the analysis of damage and fracture of materials and structural interfaces. Practical considerations. Applications. **Course Description from Program Guide*:** Differential and variational formulations. Weighted residual, least squares and Ritz analysis methods. Iso-parametric formulation. Jacobian transformation. Structural elements. Static condensation. Multilevel sub-structuring. Direct integration. Explicit and implicit techniques. Stability and accuracy. Structural vibration and wave propagation. Solution of nonlinear finite element equations. Deformation gradient. Linearization. Total and updated Lagrangian formulations. Formulation of interfacial elements. Implementation of constitutive models for linear and non-linear analysis. Continuum damage mechanics. Interface elements.

Course Description from Program Guide	Variational principles in linear elasticity. Finite element analysis. Error estimation. Convergence. Singularities. Adaptive strategies. Constrained problems. Mixed methods. Stability and convergence. Variational problems in nonlinear elasticity. Consistent linearization. The Newton--Rahpson method. Bifurcation analysis. Adaptive strategies in nonlinear elasticity. Constrained finite deformation problems. Contact and friction. Time integration. Algorithm analysis. Accuracy,stability, and convergence. Operator splitting and product formulas. Coupled problems. Impact and friction. Space-time methods. Inelastic solids. Constitutive updates. Stability and convergence. Consistent linearization. Applications to finite deformation viscoplasticity, viscoelasticity, and Lagrangian modeling of solids.
Goals and Objectives	The course aims to provide the students with an in-depth knowledge as well as the tools needed to independently apply the finite element method to structural problems of practical interest. **Learning outcomes** After completion of the course students will develop the ability to: -idealize a structure or a mechanical component and to develop a structural model; -perform an efficient finite element discretization of the model to be analyzed; -analyze problems under static and dynamic loading conditions, also involving non-linearity of various types (e.g. geometry, material, boundary conditions). -understand the solution algorithm employed in solving the equations of equilibrium in static and dynamic analyses, including non-linear problems; -perform structural analyses using a commercial software and/or in-house developed codes using a suitable computing environment. -apply knowledge of mathematics, science, and engineering; -design a system or a component in order to meet desired needs within realistic constraints (e.g. economic, environmental, social, ethical, health and safety, manufacturability, and sustainability); -use the techniques, skills, and modern engineering tools necessary for engineering practice. **Transversal skills** Students will develop abilities in -problem modeling and solving; -developing work collaborative with colleagues -delivering reports and/or presentations on their work;
Required Knowledge	Prior knowledge in Calculus and Linear algebra, Strength of Materials, Continuum Mechanics, Dynamics, Introduction to programming is an asset.
Reference Texts	-Klaus-Jurgen Bathe, *Finite Element Procedu*res, Xth Edition, Prentice-Hall, NJ, 1996. ISBN 0-13-301458-4. (Main textbook) -Lecture notes and journal papers handed by the instructor and available on-line. Additional resources -Robert D. Cook, David S. Malkus, Michael E. Plesha, Robert J. Witt, *Concepts and applications of finite element analysis*, 4th Edition, John Wiley and Sons, Inc. 2002. ISBN-13: 978-0471356059. -Dunne, N. Petrinic, *Introduction to computational plasticity*, Oxford University Press, 2004. -A. Crisfield, *Non-linear finite element analysis of solids and structures*. John Wiley & Sons, 2000.
Method of evaluation	**20.00**% - Homework /Assignments **30.00**% - Final exam **30.00**% - Exam 1 **20.00**% - Course Project(s)
Nature of the assignments	The reading assignments will be given in the lectures and will refer mainly to the textbook Klaus-Jurgen Bathe, *Finite Element Procedures*, X*th* Edition, Prentice-Hall, NJ, 1996. ISBN 0-13-301458-4. We will discuss specific material in chapters 1, 3, 4, 5, 6, 8-11.

Course Policies	-**General**?– Exams are closed book, closed notes. ? -**Labs and Assignments**. Generally, homework will be assigned on Wednesday and usually will be due by Wednesday (will be collected in class ONLY). -**Collaboration policy**: You may work on homework problems as a group. However, any work submitted for grading must represent work done by the person who will receive credit for the assignment. It is not acceptable for two students to submit identical copies of a homework problem. -**Attendance and Absences**. I do expect your active participation during classes and I strongly encourage the students to attend my office hours. Attendance is very important since some of the material covered in class is not in the textbooks. If you have to miss a class, you are responsible to get all missing notes or materials, regardless of the reason for absence. ?
Additional Information	**Homeworks:** (20% of total grade): Notice that homeworks may include the use of a FEA software product that will be presented during the class. Answers to proposed problems may come from sources other than class notes and you are strongly encouraged to extend your skills by reading the reference textbooks and other sources. **Exams:** One mid-term exam (30% of total grade). Date will be announced during the first month. Final exam is 30% of total grade. Exam questions are mostly taken from homework with modification and/or extensions. You should do well if you have done the homework (seriously, not copied) and understand concepts through individual efforts. **Projects:** (20% of total grade): These are design or analysis problems involving the use of finite element software. Here the students are encouraged to learn certain aspects of the software on their own as an exercise in self-education and life long learning. The project includes a significant research component that will allow students to analyze an engineering problem specific to their own interests. Project presentation is done just before the final exams. **Grades** 20% - Homework /Assignments 20% - Presentation (Project) 30% - Midterm exam 30% - Final exam

Tentative Course Schedule *(Time, topic/emphasis & resources)*		
Week	**Lectures**	**Topic**
1	Mon 01/29/2018	Introduction. Differential and variational formulations. Finite Element Method
1	Wed 01/31/2018	Introduction. Differential and variational formulations. Finite Element Method.
2	Mon 02/05/2018	Generalized coordinates FE models. Practice session.
2	Wed 02/07/2018	Generalized coordinates FE models. Practice session.
3	Mon 02/12/2018	Formulation of isoparametric models. Part 1.
3	Wed 02/14/2018	Formulation of isoparametric models. Part 1.
4	Mon 02/19/2018	Formulation of isoparametric models. Part 2.
4	Wed 02/21/2018	Formulation of isoparametric models. Part 2.
5	Mon 02/26/2018	Formulation of structural elements. Practice session.
5	Wed 02/28/2018	Formulation of structural elements. Practice session.
6	Mon 03/05/2018	Solution of Finite Element equations in static analysis.
6	Wed 03/07/2018	Solution of Finite Element equations in static analysis.
7	Mon 03/12/2018	Summary of presented material and Project Assignment. Midterm Exam
7	Wed 03/14/2018	Summary of presented material and Project Assignment. Midterm Exam
8	Mon 03/19/2018	FEA in structural analysis and vibrations. Part 1.
8	Wed 03/21/2018	FEA in structural analysis and vibrations. Part 1.
9	Mon 03/26/2018	FEA in structural analysis and vibrations. Part 2.
9	Wed 03/28/2018	FEA in structural analysis and vibrations. Part 2
10	Mon 04/02/2018	FEA in structural analysis and vibrations. Part 3. Practice session.
10	Wed 04/04/2018	FEA in structural analysis and vibrations. Part 3. Practice session.
11	Mon 04/09/2018	Selected topics in nonlinear analysis. Part 1.
11	Wed 04/11/2018	Selected topics in nonlinear analysis. Part 1.
12	Mon 04/16/2018	Selected topics in nonlinear analysis. Part 2. Practice session.
12	Wed 04/18/2018	Selected topics in nonlinear analysis. Part 2. Practice session.
13	Mon 04/23/2018	Advanced models for the analysis of damage and fracture. Part 1.
13	Wed 04/25/2018	Advanced models for the analysis of damage and fracture. Part 1.
14	Mon 04/30/2018	Advanced models for the analysis of damage and fracture. Part 2. Practice session.
14	Wed 05/02/2018	Advanced models for the analysis of damage and fracture. Part 2. Practice session.
15	Mon 05/07/2018	Project presentation and review for Final Exam
15	Wed 05/09/2018	Project presentation and review for Final Exam
16	Mon 05/14/2018	
16	Wed 05/16/2018	
17	Mon 05/21/2018	
17	Wed 05/23/2018	

Note

The instructor reserves the right to make changes to this syllabus as necessary.