Finite Elements for Mechanical Applications

1. **Course number and name:** 020ELFES4 Finite Elements for Mechanical Applications

2. **Credits and contact hours:** 4 ECTS credits, 2x1:15 contact hours per week

3. **Name(s) of instructor(s) or course coordinator(s):** Ali AL Shaer

4. **Instructional Materials:** PowerPoint slides

   Textbooks/References:
   - An Introduction to the Finite Element Method; third edition by J.N.Reddy. McGraw Hill. ISBN 978-007-12671-8.
   - Abaqus for Engineers, A Practical Tutorial Book, Ryan lee, BW publications, 1st edition 2019, ISBN-10: 1696288592.
   - Finite Element Analysis; Theory and Application with ANSYS, Saeed Moaveni, Prentice Hall, ISBN 0137850980.

5. **Specific course information**
   a. **Catalog description:**
   The finite element method is a numerical simulation method widely used by engineers and researchers in all technical and scientific fields. The objective of this course is to show the theoretical basis and the numerical implementation of the finite element method on problems from mechanics of materials and heat transfer. Students are brought to deal with the resolution of second order differential equations in one and two dimensions and with one and two variables. The stiffness method and/or weak formulations are used to obtain the finite element model. The applications deal with problems of bars, trusses, beams, heat exchangers, frames, plane stresses and plane strains in elasticity. In addition, symmetric and asymmetric problems are also discussed. This course also allows students to communicate effectively with finite element calculation software (Abaqus) and know how to validate and interpret the results.

   b. **Prerequisites:** Numerical Methods (020MENES1) and Strength of Materials (020RDMES1) or Strength of Materials 1 (020RM1ES2).

   c. **Required** for ME students, **Selected Elective** for EE students.

6. **Educational objectives for the course**
   a. **Specific outcomes of instruction:**
   A student who successfully fulfills the course requirements will have demonstrated an ability to:
   - Discuss the basic concepts in finite elements formulation including direct formulation, minimum potential energy theorem, principle of virtual work and the variational methods.

- Discuss the concepts of one-dimensional elements and shape functions and their properties, and understand the concept of local and natural coordinate systems.
- Study the theoretical development of Euler-Bernoulli beam theory, cubic approximation of displacement, and frame structures.
- Discuss the concepts of single variable problems in two dimensions, boundary value problems, element matrices and vectors, and assembly of element equations.
- Study applications related to conduction and convection heat transfer, plane systems, symmetric and asymmetric structures, and solids mechanics.
- Identify the different steps needed to execute a complete analysis, generate one-, two-, and three-dimensional models, apply boundary conditions, obtain solution, display results using Abaqus software, interpret and judge the results obtained from the analysis performed.

b. PI addressed by the course:

PI	1.3	3.2	6.4	7.1	7.2
Covered	x		x	x	x
Assessed	x	x	x	x	x

7. Brief list of topics to be covered

- **Chapter 1: Introduction:** Need for Finite Element analysis – Mechanical engineering problems – Solutions and Difficulties. (1 Lecture).
- **Chapter 2: Weak Formulation of a Second Order Differential Equations in One Dimension:** Weak formulation – Selection of approximation functions – Finite element models using the principle of virtual work. (4 Lectures).
- **Chapter 3: Applications on Second Order Differential Equations in One Dimension: Finite Element Model:** Linear elastic springs problems – Linear elastic bars problems – One-dimensional heat transfer and fluid mechanics problems – Truss problems with and without constraints. (5 Lectures).
- **Chapter 4: Beams and Frames:** Solution of fourth order differential equation of a beam using Finite Element Model – Frames **-** Mixed Finite elements and problems (Bars, beams, and frames). (4 Lectures).
- **Chapter 5: Second Order Differential Equations in Two Dimensions:** Weak formulation – Coefficient matrix of a triangular element – Coefficient matrix of a rectangular element – Heat transfer problems in two dimensions. (4 Lectures).
- **Chapter 6: Symmetric and Asymmetric Problems:** Symmetric problems – Symmetric loading – Antisymmetric loading – Asymmetric loading. (3 Lectures).
- **Chapter 7: Plane Elasticity Problems:** Differential equations – Weak formulation – Stiffness matrix. (3 Lectures)
- **Applications on Abaqus:** Truss problem – Beam problem – Springs problem -2D Heat Transfer problem – Plane stress problem – Natural Frequency beam problem (4 Lectures).