An Introductory Course on Modelling of Multiphysics Problems

Introductory Course on Multiphysics Modelling

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1 Course objectives

LECTURES: Basic theoretical background

- Partial Differential Equations
- Finite Element Method
- Mathematical modelling of various problems of physics
- Coupling of some problems of physics

EXERCISES: Practical introduction to COMSOL Multiphysics®

- Using models implemented in COMSOL *Application Modes*
- Coupling *Application Modes* of different problems of physics
- Advanced modelling: using *PDE Modes* (*Weak*, *General*, and *Coefficient Form*)

2 Course outline

Introductory lectures:

1. General mathematical preliminaries
2. Fundamentals of Partial Differential Equations (PDEs)
3. Fundamentals of Finite Element Method (FEM)
   - Weighted Residual Methods
   - the equivalence of strong and weak forms
   - Ritz-Galerkin method

- topics related to FEM (procedures, shape functions, etc.)

Single- and multi-physics problems to discuss:

4. Heat transfer
5. Linear elasticity
6. Thermoelasticity (thermo-mechanical coupling)
7. Fluid dynamics (and the basics of aerodynamics)
8. Waves in fluids
9. Acoustics and vibroacoustics (acoustic-structure interaction)
10. Piezoelectricity (electro-mechanical coupling)
11. Wave propagation in anisotropic media
12. Surface Acoustic Waves

3 Problem topics

Theoretical discussion of a typical problem of physics should involve (some of) the following topics:

- the derivation of the governing PDE (fundamental principles and constitutive laws, primary and secondary dependent variables)
- a discussion of boundary conditions (from the physical and mathematical points of view)
- the derivation of the corresponding weak variational formulation
- the Galerkin's approximation by shape functions (definitions and interpretations of coefficient matrices)
- a discussion of analogies and possible couplings to other problems

COMSOL Multiphysics® environment will be used for (some of) the following tasks:

- solving a thematic (single-physics) Boundary Value Problem
- solving a multi-physics problem, that is, one problem of physics coupled to another problem(s)
- learning weak and strong formulations by implementation using some of the COMSOL *PDE Modes* and validating the results by using an adequate *Application Mode*