

An Introductory Course on Modelling of Multiphysics Problems

Introductory Course on Multiphysics Modelling

TOMASZ G. ZIELIŃSKI

`bluebox.ippt.pan.pl/~tzielins/`

**Institute of Fundamental Technological Research
of the Polish Academy of Sciences
Warsaw • Poland**



Objectives of the course

LECTURES: Basic theoretical background

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

Objectives of the course

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)*

Outline of the course

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.)

Outline of the course

Introductory lectures:

- 1 General mathematical preliminaries
- 2 Fundamentals of Partial Differential Equations (PDEs)
- 3 Fundamentals of Finite Element Method (FEM)

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

Topics for a typical problem of physics

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

Topics for a typical problem of physics

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*