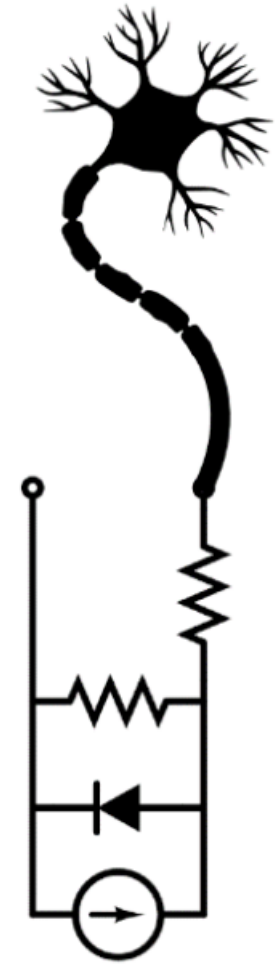
COMSOL Multiphysics Workshop

21. – 22.12. 2020

University of Zagreb, Faculty of Science, Physics department

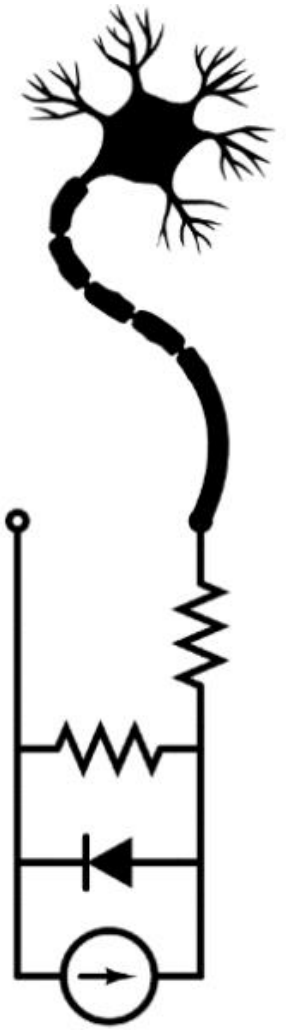
Bijenička cesta 32, Zagreb



Workshop program

Monday, 21.12.2020		
10:00-11:00	**Vedran Đerek** University of Zagreb, Physics department	Introduction to modeling in COMSOL Multiphysics
11:00-12:00		Light trapping in 3D micropyramids – step by step tutorial
12:00-13:00	**Aleksandar Opančar** University of Zagreb, Physics department	Modeling 3D current transport in tissue under stimulation by photocapacitors – status update
14:00-16:00	**Vedran Đerek** University of Zagreb, Physics department	COMSOL Multiphysics 5.6 – AC/DC+Wave Optics packages Hands-on training

Tuesday, 22.12.2020		
10:30-12:30	**Ihor Sahalianov** Linkoping University, Department of Science and Technology, Laboratory of Organic Electronics	Step-by-step: Heat-transfer and diluted species transport
14:00-14:45	**Jacob Yström** COMSOL Inc.	Solving Larger Models in COMSOL Multiphysics® Version 5.6



Uvod u modeliranje programskim paketom

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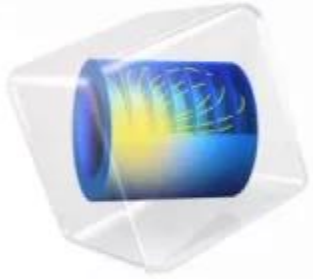


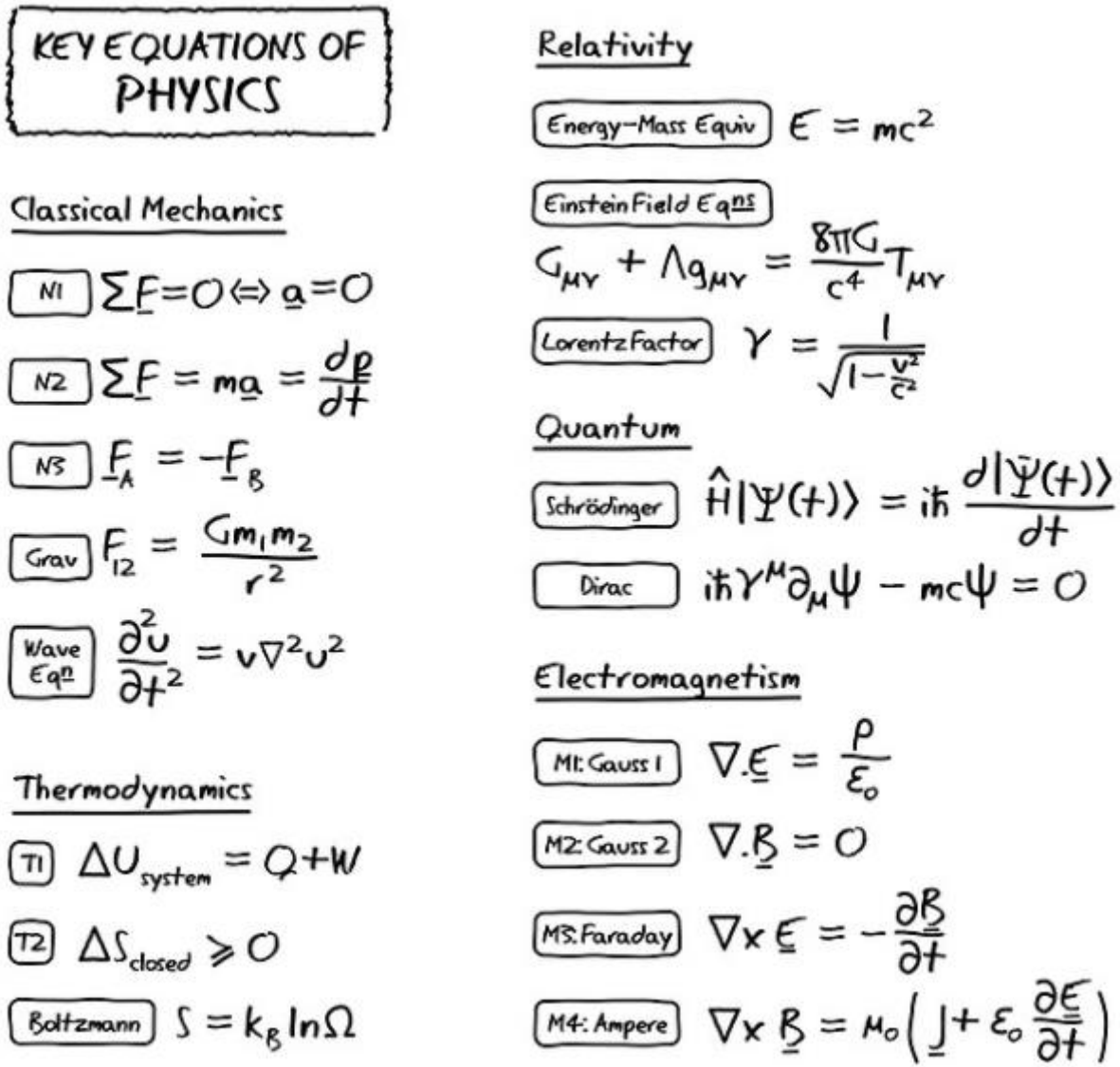
COMSOL Multiphysics Workshop
21-22.12.2020.

Vedran Đerek
vdjere@phy.hr

HrZZ
Croatian Science Foundation

Ova radionica održava se u okviru projekta Hrvatske zaklade za znanost
3DOptoBio UIP-2019-04-1753

Modeliranje realnih kompleksnih fizikalnih sustava



Primijetimo:

- Svako područje opisano jednadžbama
- Za jednostavne probleme moguće analitičko rješenje

Kompleksni problemi:

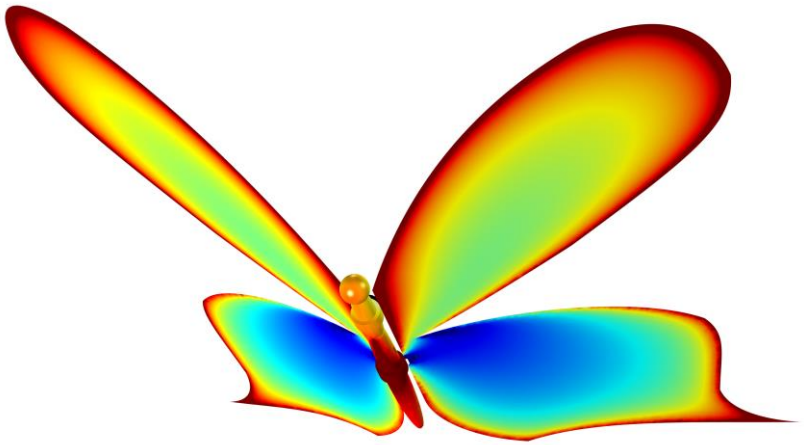
- više područja (multi-fizika)
- realne geometrije i materijali
- problemi optimizacije

Zašto numeričko modeliranje?

- Većina kompleksnijih problema nije rješiva analitički
- Intuiciji **ne možemo** vjerovati za kompleksnije probleme

Numeričko računalno modeliranje nudi

- Rješenja proizvoljne geometrije
- Egzaktna rješenja
- Mogućnost automatizirane optimizacije

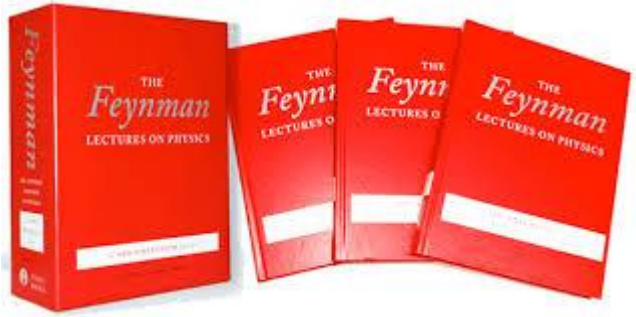


Numeričko modeliranje

Konceptualno jasno – složena primjena

Poteškoće – prvi koraci su zahtjevni!

- Potrebno ekstenzivno tehničko znanje
  - Programiranje
  - Numeričke metode
  - Optimizacija
- Kako postaviti problem?
- Potrebna jaka računala



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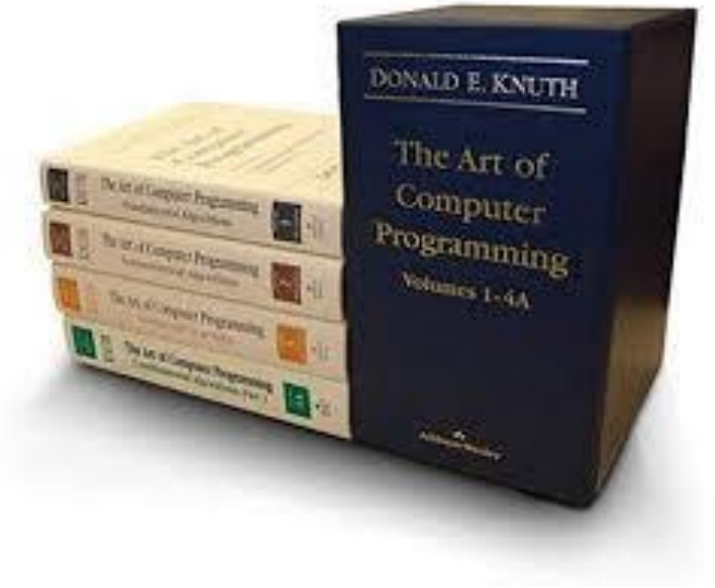


Numeričko modeliranje

Najčešće korištene metode za numeričko rješavanje PDE:

- Metoda konačnih razlika (FDM)
- Metoda konačnih elemenata (FEM)
- Metoda konačnih volumena (FVM)
- Metoda graničnih elemenata (BEM)

FDM

- starija i jednostavnija metoda,
- zahtjeva manje računalne snage
- manje precizna

FEM

- preciznija metoda
- zahtjeva snažnija računala
- osjetljivija na kvalitetu mreže
- općenito prihvaćena u industriji (strojarstvo, akustika, građevina, dinamika fluida, hidraulika, toplina…)

Metoda konačnih elemenata

Zakoni fizike u prostoru i vremenu - parcijalne diferencijalne jednadžbe

- za kompleksne probleme – nisu rješive analitički

Metoda konačnih elemenata

- PDE se aproksimiraju svojom **slabom formulacijom**
  Weak formulations are important tools for the analysis of mathematical equations that permit the transfer of concepts of linear algebra to solve problems in other fields such as partial differential equations. In a weak formulation, an equation is no longer required to hold absolutely (and this is not even well defined) and has instead weak solutions only with respect to certain "test vectors" or "test functions” (Wikipedia)

- Testne funkcije se zadaju na geometriji definiranoj mrežom -> **diskretizacija**
- **Rješenja su aproksimacije početnih PDE**

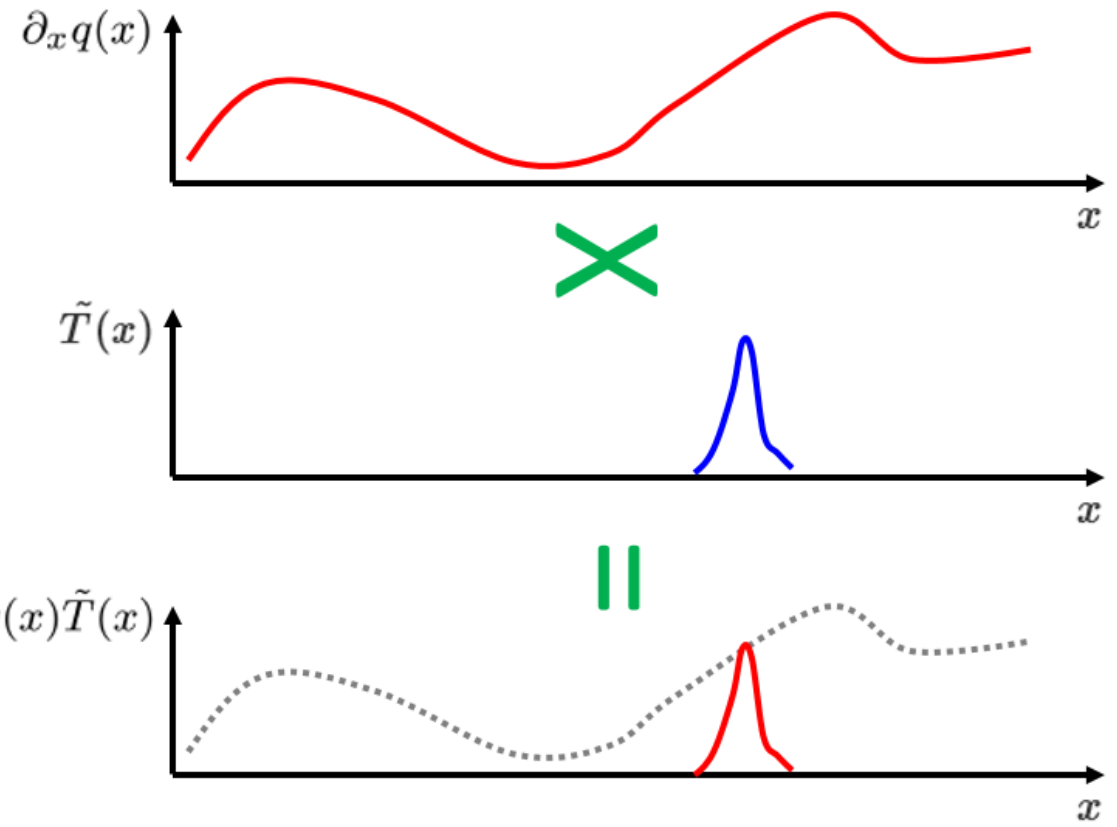
Metoda konačnih elemenata – slaba formulacija

$$q(x) = -\partial_x T(x)$$

$$\partial_x q(x) = 0$$

$$\int_1^5 \partial_x q(x)\, dx = 0$$

$$\int_1^5 \partial_x q(x) \tilde{T}(x)\, dx = 0$$

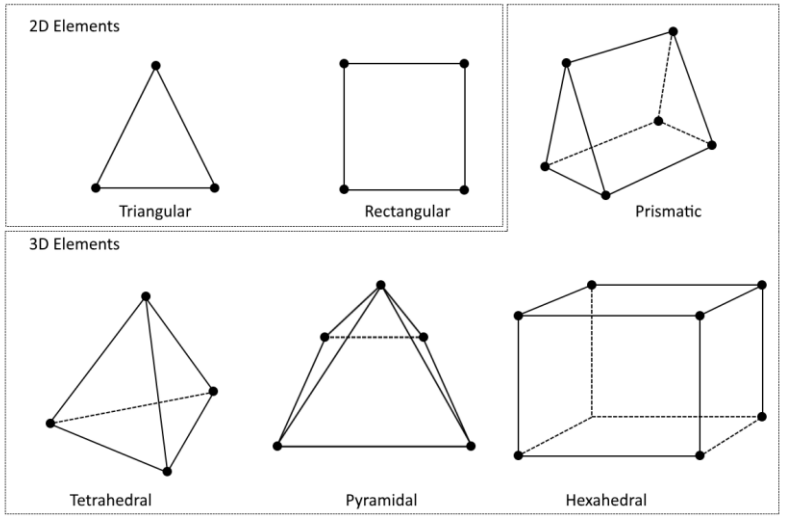


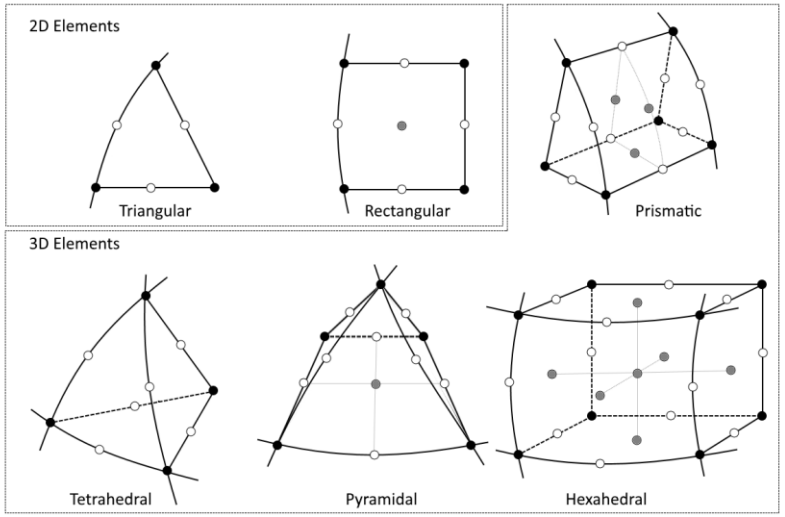
„The main idea of the weak form is to turn the differential equation into an integral equation, so as to lessen the burden on the numerical algorithm in evaluating derivatives."

Numerički je jednostavnije rješavati diskretne integralne jednadžbe

https://www.comsol.com/blogs/brief-introduction-weak-form/

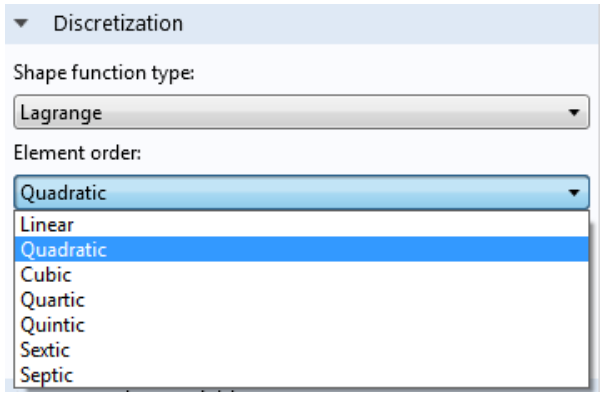
Metoda konačnih elemenata - diskretizacija

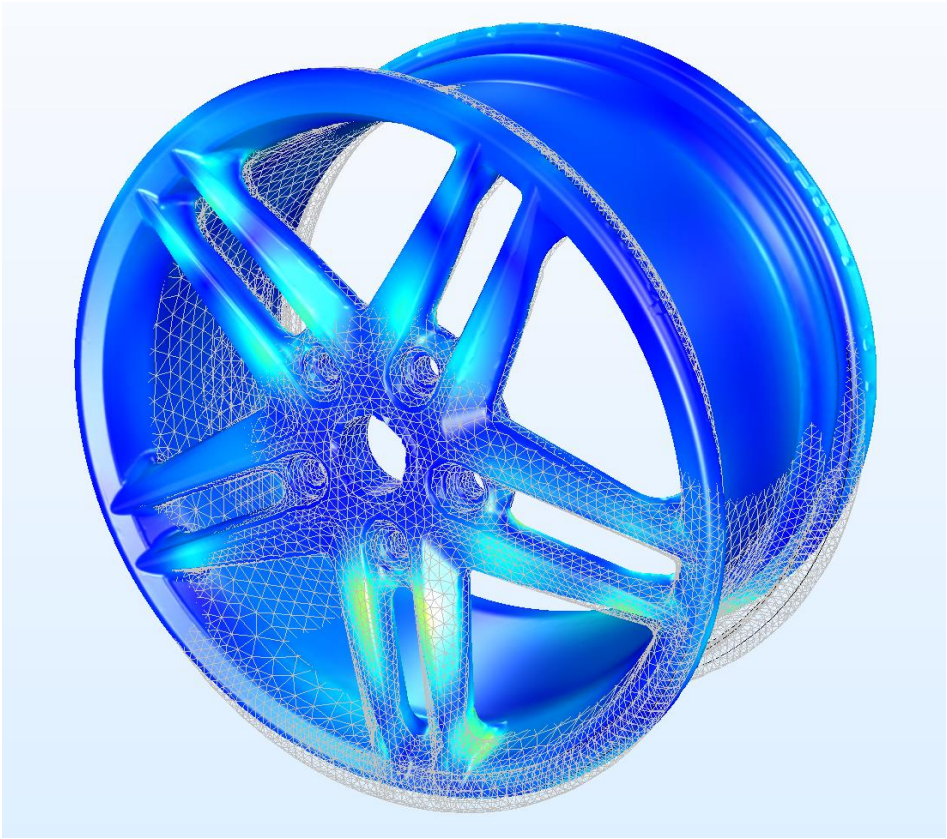




- Funkcije baze (testne funkcije) definirane su između točaka (node) mreže geometrije (1D, 2D, 3D)

- Obični linearna i kvadratična diskretizacija (koriste se i viši redovi)
  - Viši redovi aproksimacije smanjuju potreban broj elemenata mreže, no izračun je sporiji





Jednostavno numeričko modeliranje?

- Mnoštvo softverskih paketa

Lista želja:

- Višenamjenski
- Akademski orijentiran
- **Jednostavan** za korištenje
  - dobar GUI
  - bez programiranja
  - ali uz mogućnost programiranja
  - parametarski dizajn 3D geometrija
  - importiranje 3D geometrija

List of finite element software packages

From Wikipedia, the free encyclopedia

This is a list of software packages that implement the finite element method for solving partial differential equations.

Software	Features	Developer	Version	Released	License
Mathematica[11]	General purpose computation software.	Wolfram Research	12.2 (December 16, 2020; 0 days ago) [±][7]	Regularly	Proprietary
Nastran	Originally developed for NASA, now available commercially from several software companies	MSC NASTRAN, Siemens PLM NX Nastran[12]	2014	2014	Proprietary EULA
Midas Civil	Finite element software for bridge structural modeling, analysis and design	MIDAS IT - MIDAS Information Technology	2020 v3.2	2001-11	Proprietary commercial software
MATLAB Partial Differential Equation Toolbox	MATLAB Toolbox for solving structural, thermal, electromagnetics, and other general PDEs	MathWorks	3.3 (R2019b)	2019-09-11	Proprietary commercial software
LS-DYNA	Best known for explicit dynamics / crash analysis	LSTC - Livermore Software Technology Corporation	R8.0	2015-03	Proprietary commercial software
JCMsuite	Finite element software for the analysis of electromagnetic waves, elasticity and heat conduction	JCMwave GmbH	3.6.1	2017-01-27	Proprietary EULA
Advance Design	BIM software for FEM structural analysis, including international design eurocodes	GRAITEC	2014	2013-09	Proprietary commercial software
StressCheck	Finite element analysis software based on hp-FEM with a focus on solid mechanics applications	ESRD, Inc.	10.5	2019-06-06	Proprietary commercial software
Pam Crash	Best used for explicit dynamics / crash analysis	ESI	15.5.1	2020-03-05	Proprietary commercial software
SESAM (FEM)	Software suite for structural and hydrodynamic analysis of ships and offshore structures	DNV GL		regularly	Proprietary, SaaS
CosmosWorks	Part of SolidWorks	Dassault Systèmes SolidWorks Corp.			Proprietary commercial software
COMSOL Multiphysics	COMSOL Multiphysics Finite Element Analysis Software (formerly FEMLAB)	COMSOL Inc.	5.5	2019-11-14	Proprietary EULA
Autodesk Simulation	Finite Element software of Autodesk	Autodesk			Proprietary commercial software
ADINA	Finite element software for structural, fluid, heat transfer, electromagnetic, and multiphysics problems, including fluid-structure interaction and thermo-mechanical coupling	Adina R&D			Proprietary commercial software
Abaqus	Advanced Franco-USA software from SIMULIA, owned by Dassault Systemes			2019-12	Proprietary commercial software
JMAG	2D and 3D finite element analysis software for electromagnetic field, thermal, structural			2019-06	Proprietary commercial software
GetFEM++	A generic finite element library written in C++ with interfaces for Python, Matlab and Sc			2015-07	LGPL
deal.II	Comprehensive set of tools for finite element codes, scaling from laptops to clusters wi			2018-05-12	LGPL
Agros2D	Multiplatform open source application for the solution of physical problems based on th			2014-03-03	GNU GPL
FEBio	Finite Elements for Biomechanics			April, 2018	Custom
MoFEM JosePH	Mesh Oriented hp-FE code, written in C++			2017-11-16	LGPL
Range Software	Multiphysics Finite Element Analysis Software			2018-04-30	GPL
FreeFEM[13]	FreeFEM is a free and open-source parallel FEA software for multiphysics simulations. C++.			2019-06-06	LGPL
GOMA	GOMA is an open-source, parallel, and scalable multiphysics software package for mo			Aug 28, 2015	GPL Version 2
MFEM	MFEM is a free, lightweight, scalable C++ library for finite element methods that feature generality, and high-performance computing efficiency.			2020-10-30	BSD
MOOSE	Object Oriented FE framework, written in C++			regularly	LGPL
Hermes Project	Modular C/C++ library for rapid development of space- and space-time adaptive hp-FE			2014-03-01	LGPL
CalculiX	It is an Open Source FEA project. The solver uses a partially compatible ABAQUS file f			2019-11-24	GNU GPL
FreeCAD	Parametric 3D modeler with a FEM workbench allowing it to use external solvers like C			12 March 2019	LGPL 2

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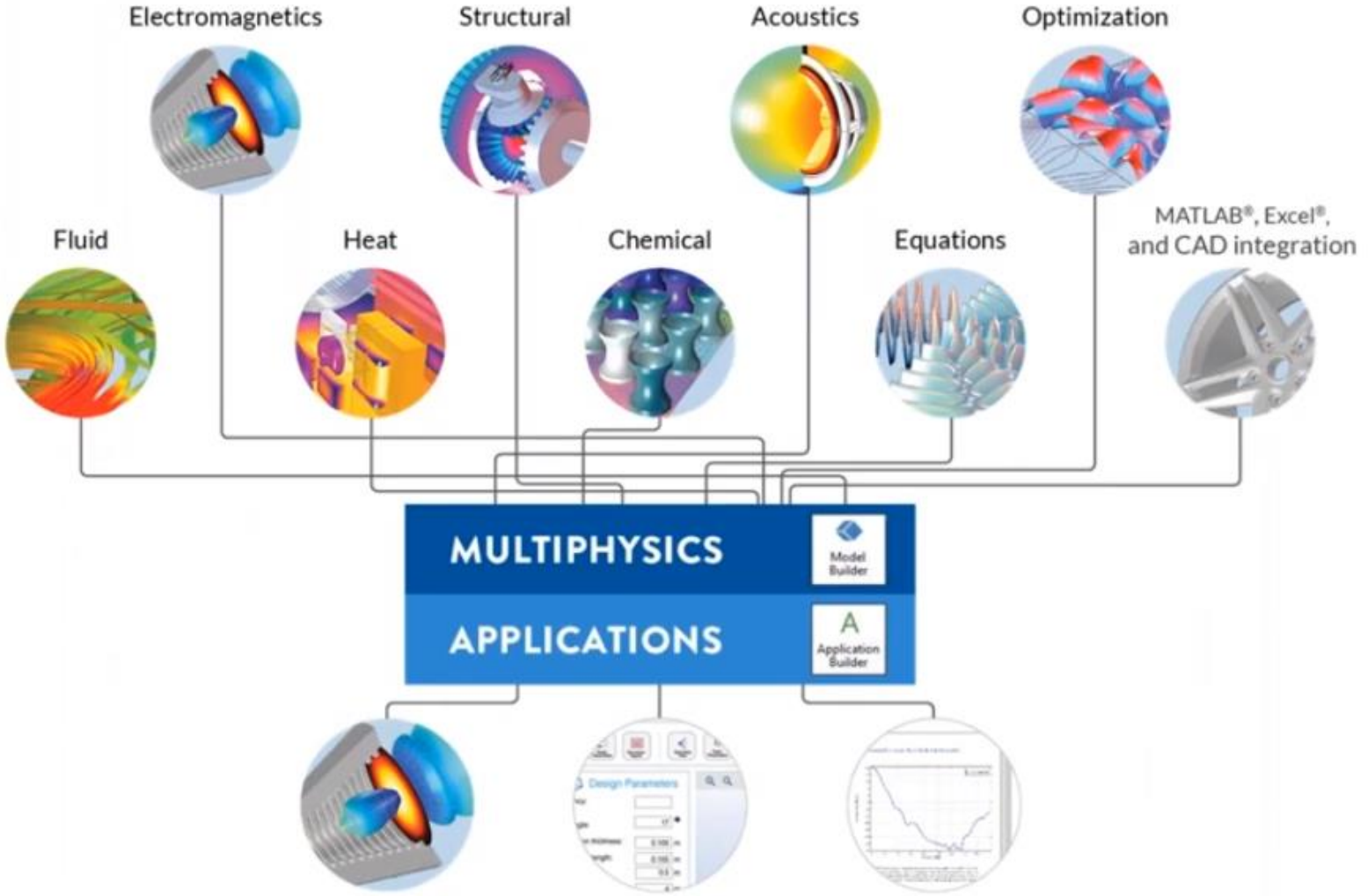

The COMSOL® Software Product Suite

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The platform product. Understand, predict, and optimize physics-based designs and processes with numerical simulation.

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- COMSOL Server™

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- RF Module
- Wave Optics Module
- Ray Optics Module
- Plasma Module
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FLUID & HEAT

- CFD Module
  - Mixer Module
- Polymer Flow Module
- Microfluidics Module
- Porous Media Flow Module
- Subsurface Flow Module
- Pipe Flow Module
- Molecular Flow Module
- Metal Processing Module
- Heat Transfer Module

STRUCTURAL & ACOUSTICS

- Structural Mechanics Module
  - Nonlinear Structural Materials Module
  - Composite Materials Module
  - Geomechanics Module
  - Fatigue Module
  - Rotordynamics Module
- Multibody Dynamics Module
- MEMS Module
- Acoustics Module

CHEMICAL

- Chemical Reaction Engineering Module
- Battery Design Module
- Fuel Cell & Electrolyzer Module
- Electrodeposition Module
- Corrosion Module
- Electrochemistry Module

MULTIPURPOSE

- Optimization Module
- Material Library
- Particle Tracing Module
- Liquid & Gas Properties Module

INTERFACING

- LiveLink™ *for* MATLAB®
- LiveLink™ *for* Simulink®
- LiveLink™ *for* Excel®
- CAD Import Module
- Design Module
- ECAD Import Module
- LiveLink™ *for* SOLIDWORKS®
- LiveLink™ *for* Inventor®
- LiveLink™ *for* AutoCAD®
- LiveLink™ *for* Revit®
- LiveLink™ *for* PTC® Creo® Parametric™
- LiveLink™ *for* PTC® Pro/ENGINEER®
- LiveLink™ *for* Solid Edge®
- File Import *for* CATIA® V5

~35,000.00 HRK (Comsol base+AC/DC+Wave optics)

COMSOL

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COMSOL Multiphysics 5.6

- Integrirani softverski paket za numetičko (multi)fizikalno modeliranje modelom konačnih elemenata

Uvod u COMSOL (knjiga)
- https://cdn.comsol.com/doc/5.6/IntroductionToCOMSOLMultiphysics.pdf

Web dokumentacija
- https://www.comsol.com/documentation

Galerija primjena
- https://www.comsol.com/models

Centar za učenje
- https://www.comsol.com/learning-center

Forum
- https://www.comsol.com/forum

Novosti iz COMSOL-a
- https://www.comsol.com/blogs

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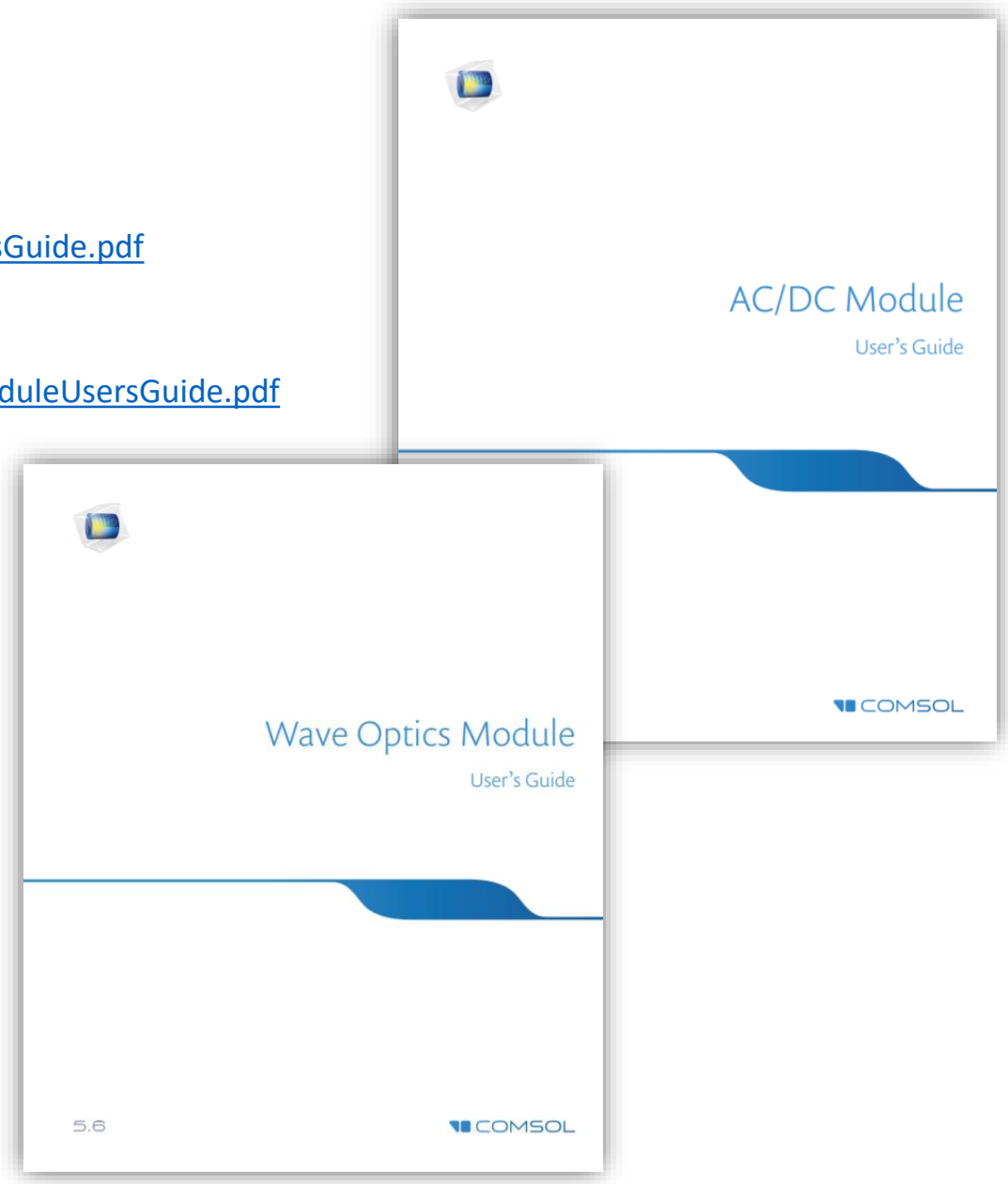
AC/DC Module User Guide

- https://doc.comsol.com/5.6/doc/com.comsol.help.acdc/ACDCModuleUsersGuide.pdf

Wave Optics Module User Guide

- https://doc.comsol.com/5.6/doc/com.comsol.help.woptics/WaveOpticsModuleUsersGuide.pdf



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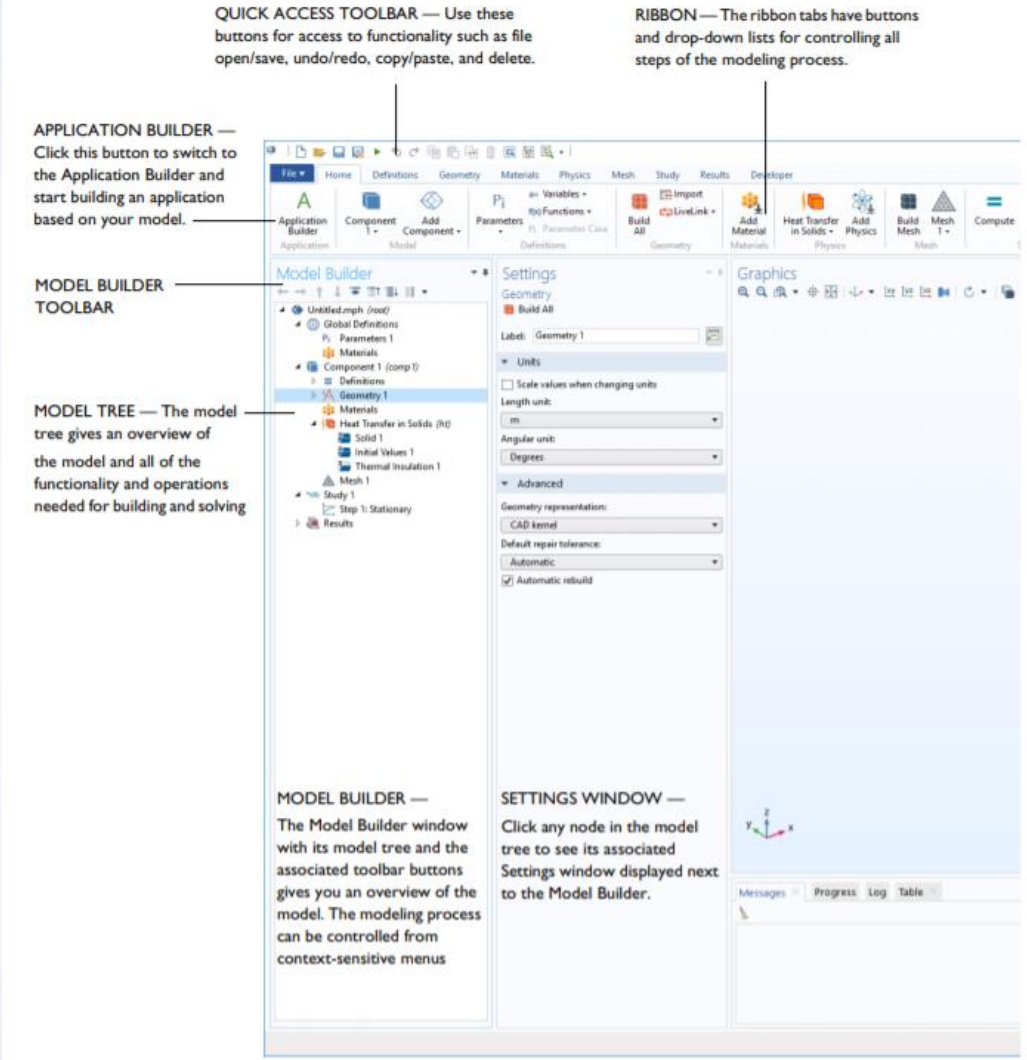

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