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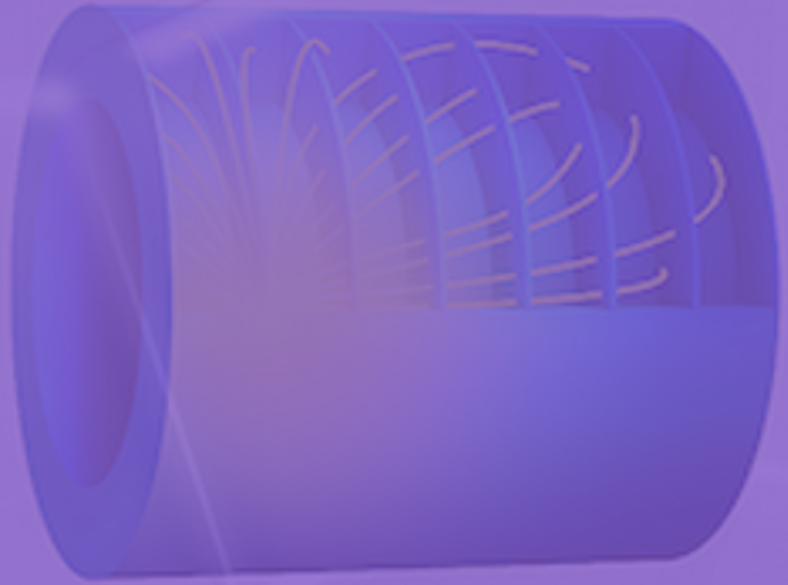
School of Electrical
Engineering

Akufys 2023

Introduction to COMSOL Multiphysics®



28.11.2023

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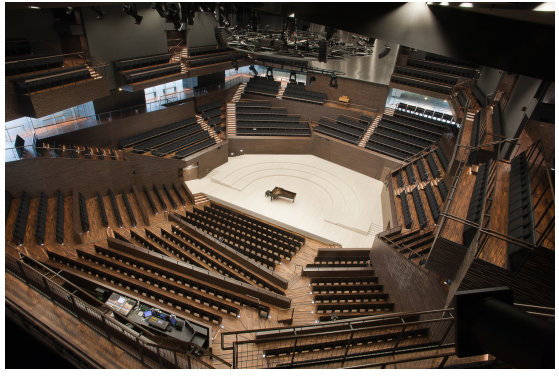
Application: Simulating room acoustics

Predict and fix acoustics (architecture, acoustic treatment etc.)

Auralization of spaces

Virtual acoustics (gaming & virtual reality)



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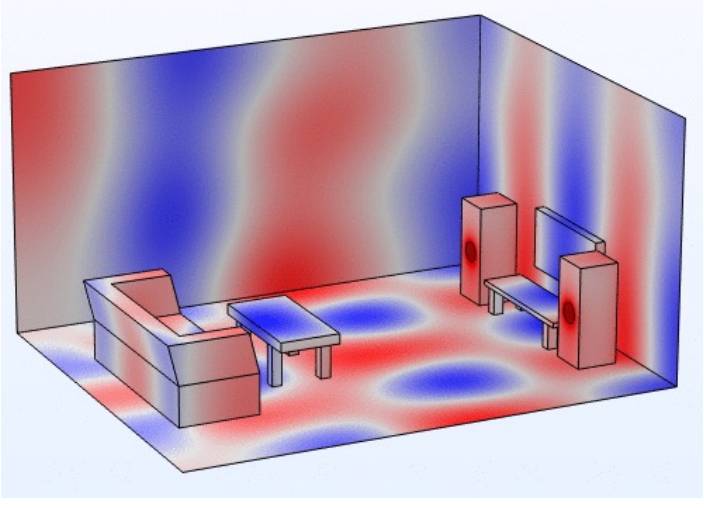
Simulating room acoustics

Two main approaches

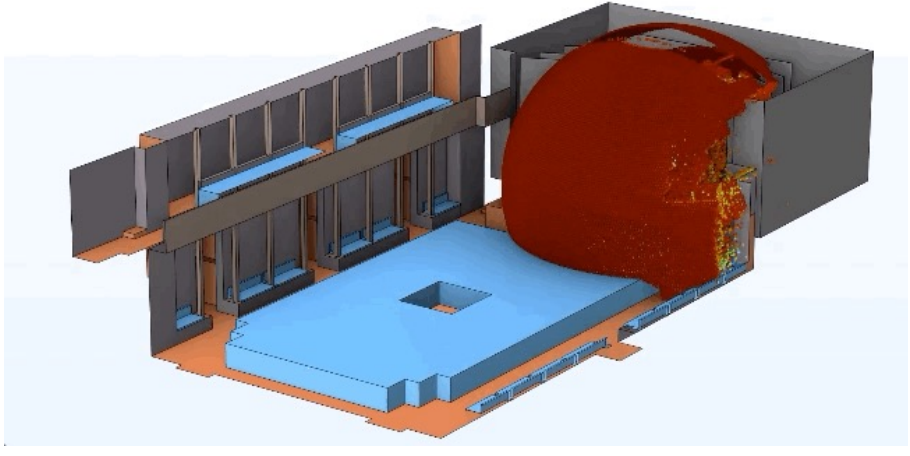
Wave-based modelling

- Low frequency region
- Computationally heavy
- Modal behaviour (mainly)
- Finite/Boundary elements



Geometrical acoustics

- High frequency region
- Computationally light
- Reverberant behaviour
- Ray/particle tracing



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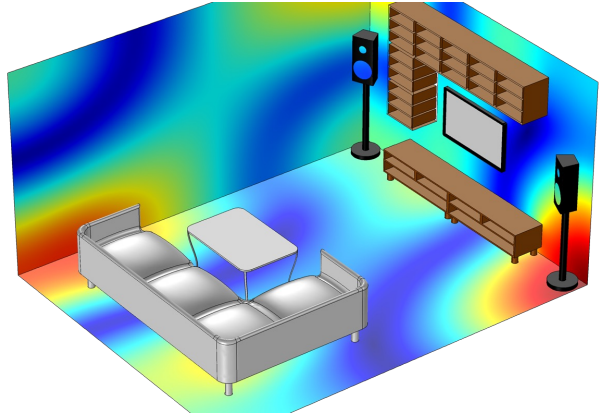
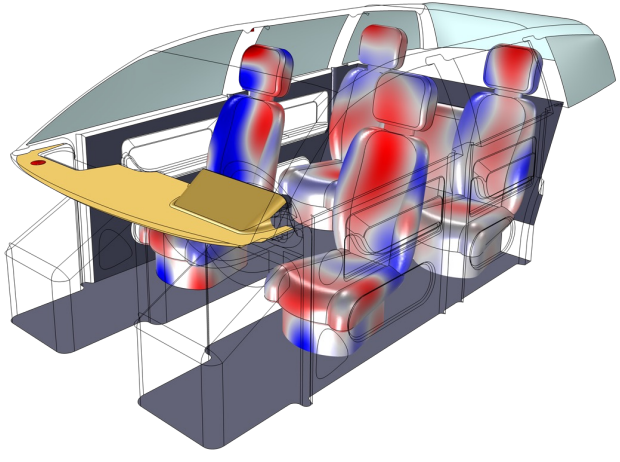
COMSOL Multiphysics® basics

- **Finite Element Analysis (FEA)**: The space domain is discretized into small units called **finite elements** through a process called **meshing.**
- Partial differential equations which describe the physics are converted into a system of algebraic equations.
- It is an **approximation** to the real problem: More elements -> more accurate approximation and solution, but also longer solution time and required memory.
- Particularly useful for complex geometries for which analytical solutions do not exist.
- **''Multiphysics''**: combination of physics, e.g. coupling between acoustics and vibrations for solving the vibro-acoustics problem
- Latest version: COMSOL Multiphysics 6.2 (released November 2023)

Modelling Steps

- Build or import the Geometry
- Specify Material properties
- Select Physics, define boundary conditions and coupling between Physics
- Create the mesh
- Configure study settings and solve
- Post-process and visualize the results





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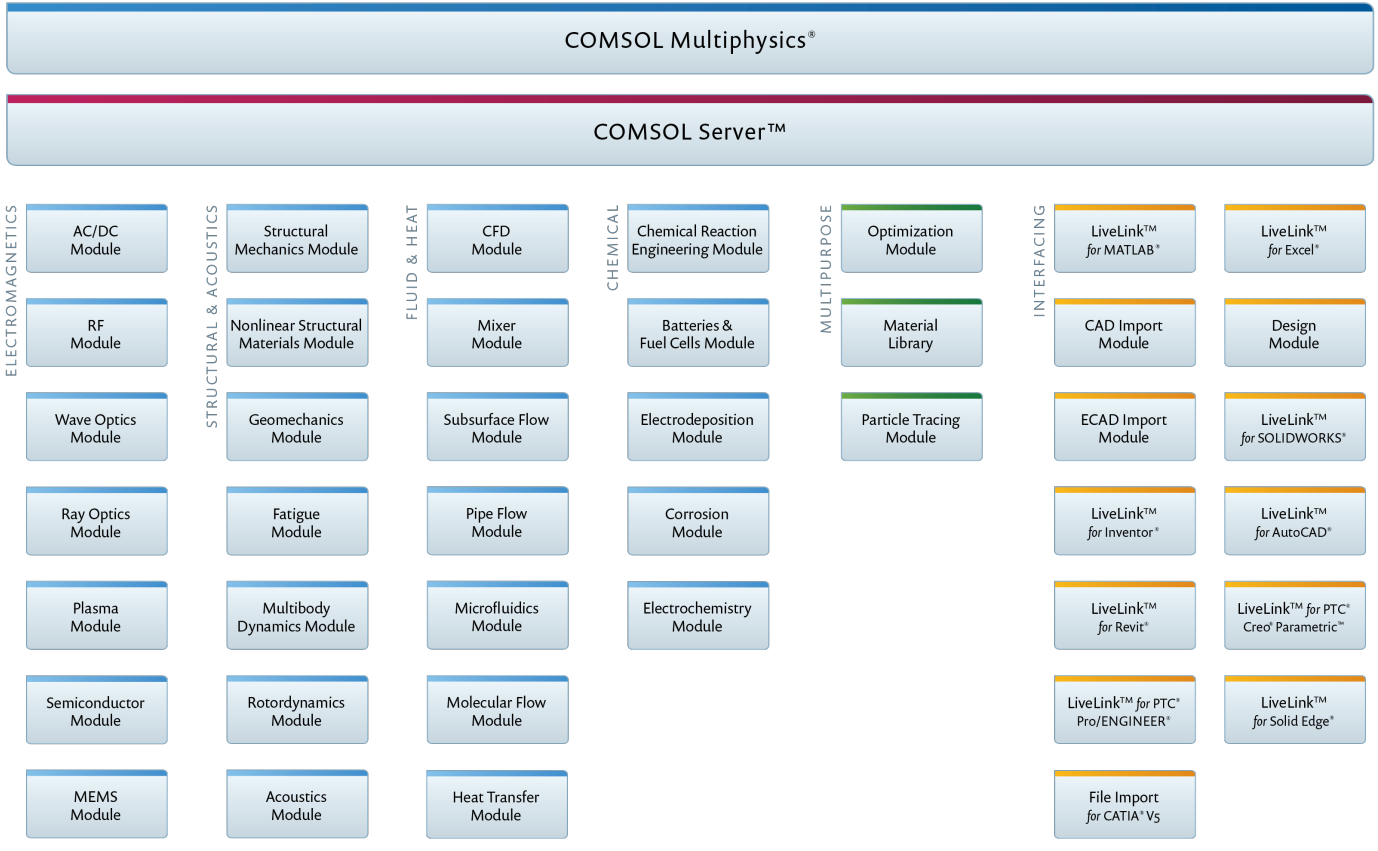
The COMSOL® Product Suite



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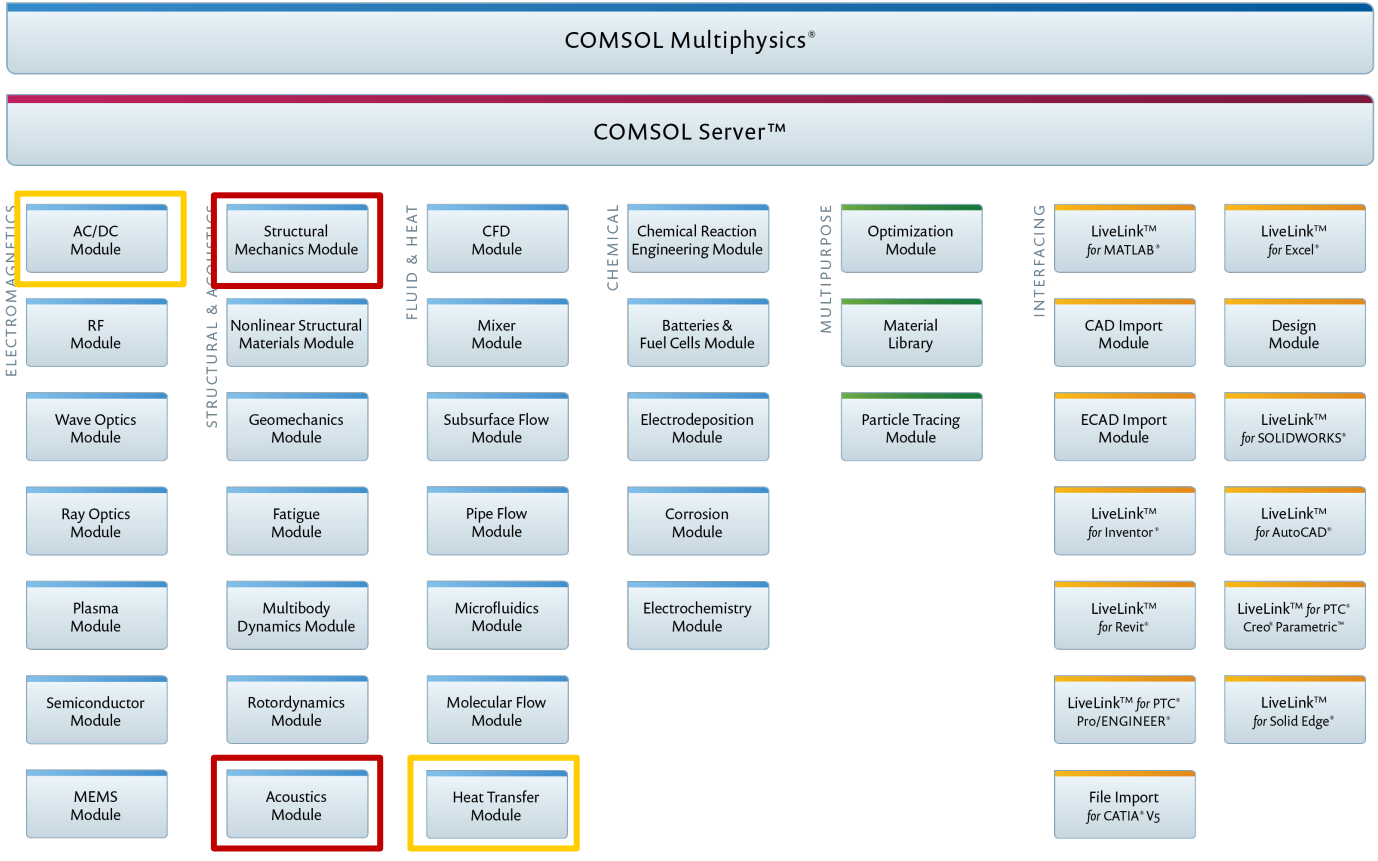
The COMSOL® Product Suite



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Demo: Eigenmodes of a room

- Dimensions: 5 m x 4 m x 2.6 m
- All boundaries are assumed perfectly rigid
- Eigenfrequencies: $f_{i,l,m} = \frac{c}{2}\sqrt{\left(\frac{i}{L_x}\right)^2 + \left(\frac{l}{L_y}\right)^2 + \left(\frac{m}{L_z}\right)^2}$

MODE INDEX	FREQUENCY	MODE INDEX	FREQUENCY
0,0,0	0	0,1,1	78.7
1,0,0	34.3	2,1,0	80.9
0,1,0	42.9	0,2,0	85.8
1,1,0	54.9	1,1,1	85.8
0,0,1	66.0	1,2,0	92.4
2,0,0	68.6	2,0,1	95.2
1,0,1	74.3	3,0,0	103

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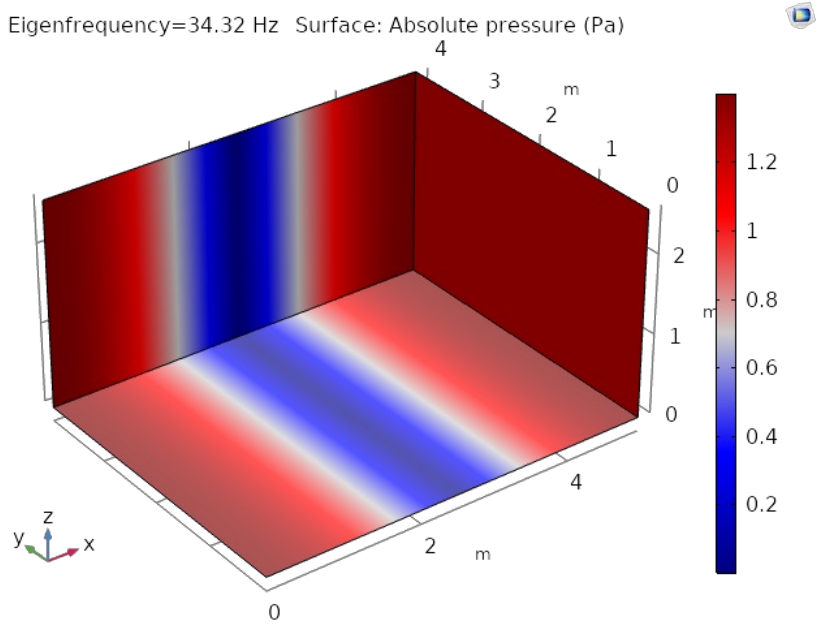
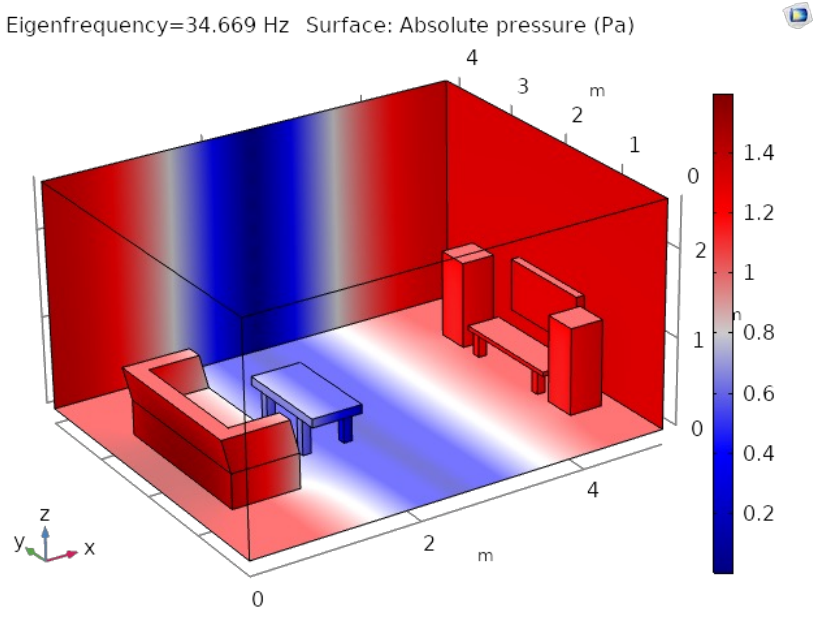
Demo: Eigenmodes of a room

First mode (1,0,0)





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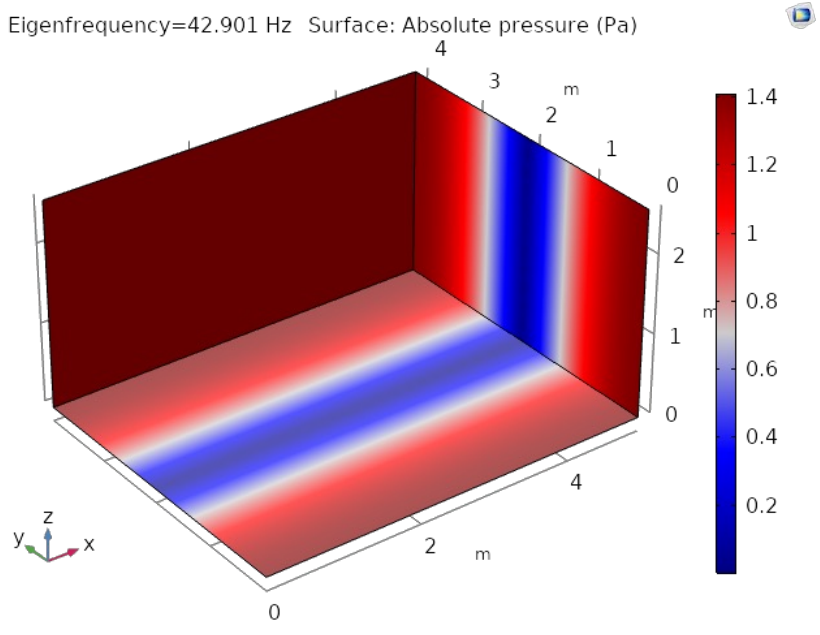
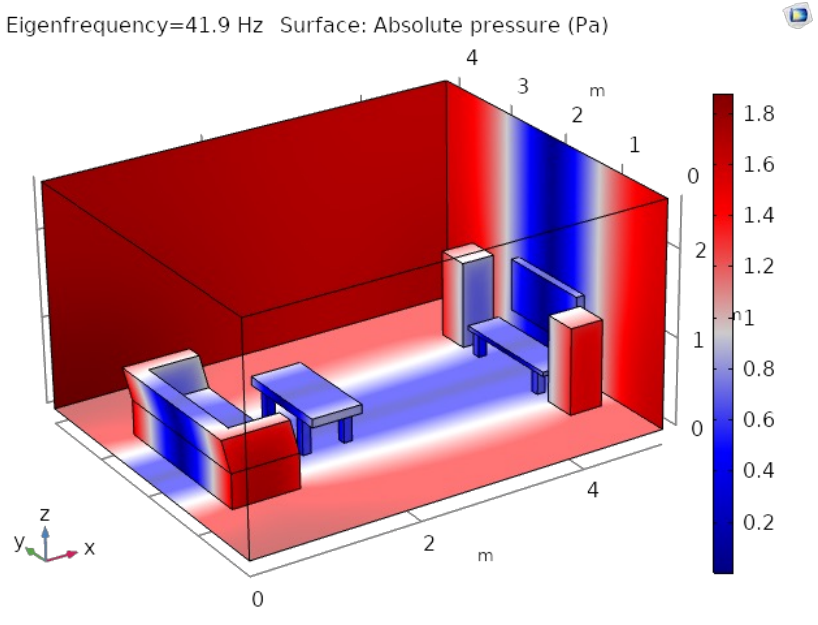
Demo: Eigenmodes of a room

Second mode (0,1,0)





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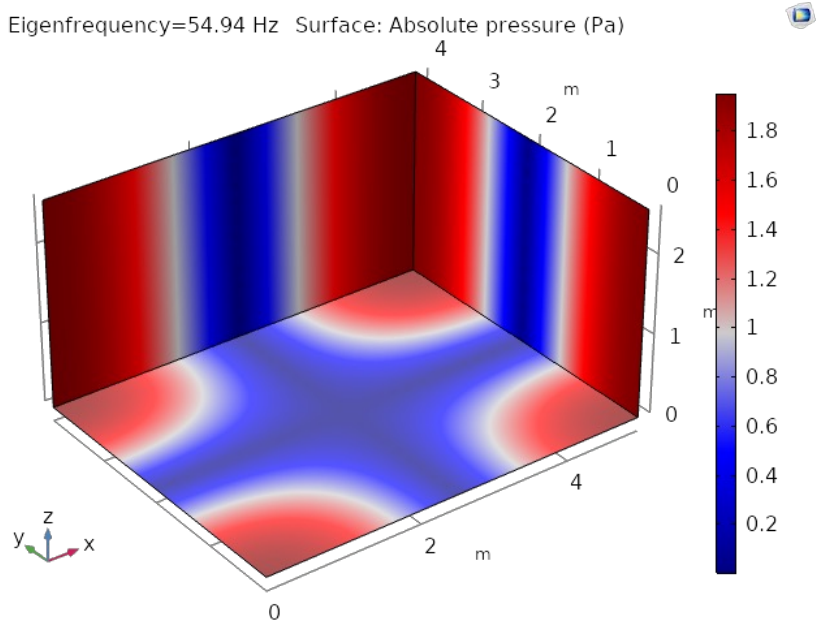
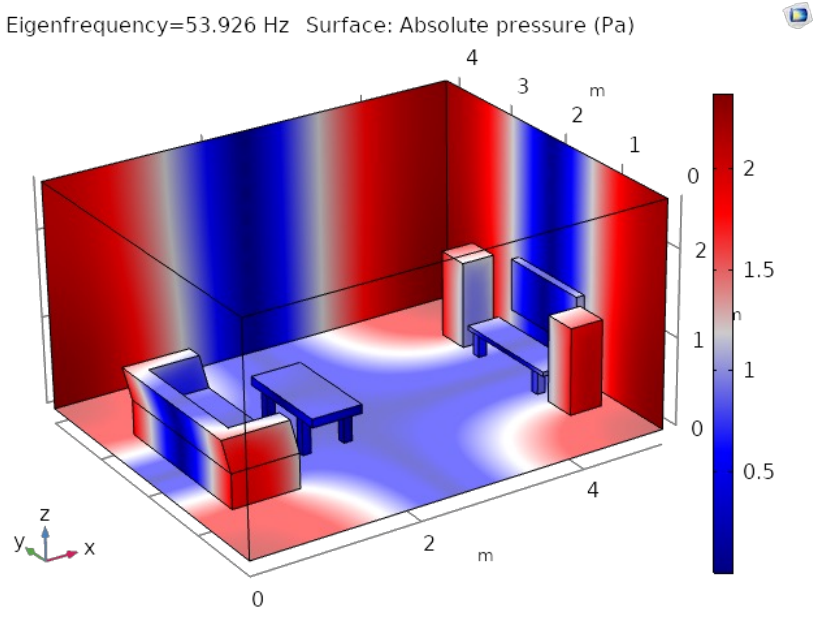
Demo: Eigenmodes of a room

Third mode (1,1,0)





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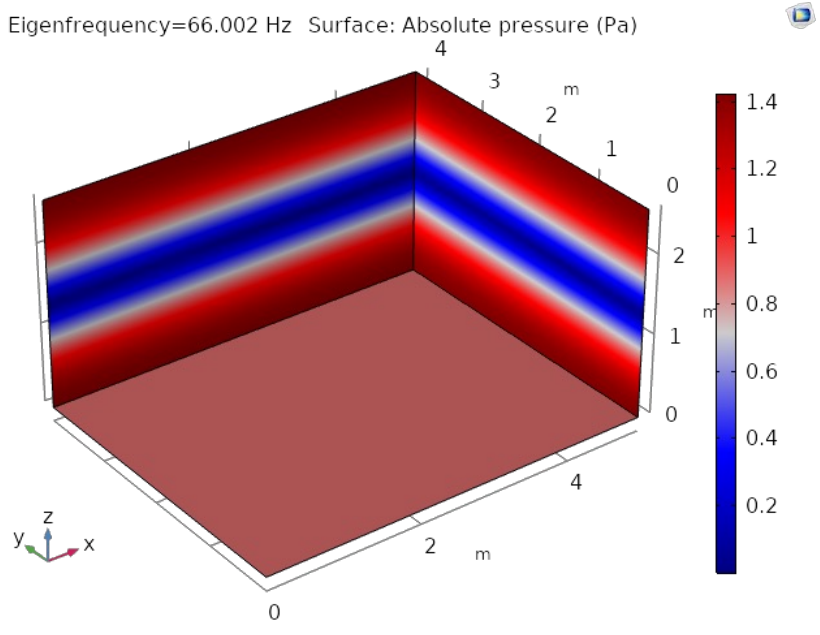
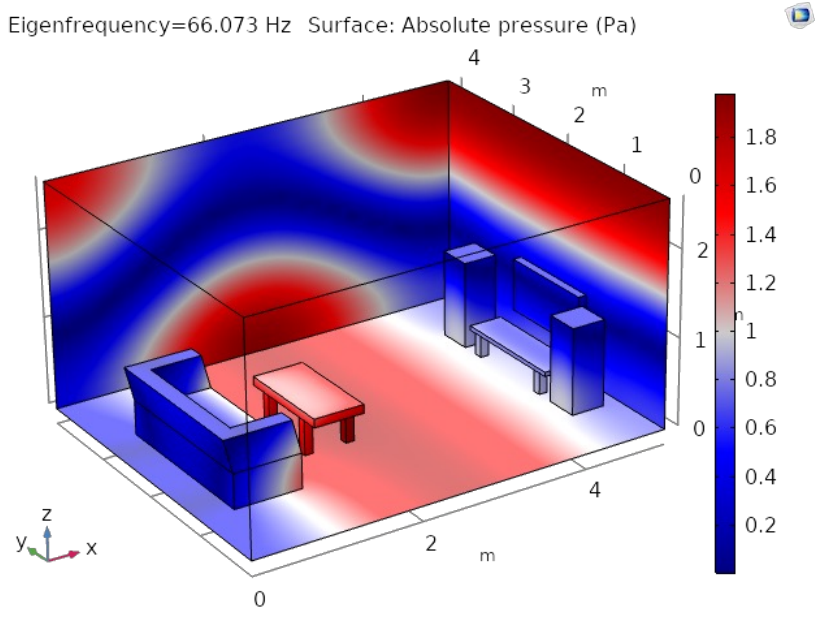
Demo: Eigenmodes of a room

Fourth mode (0,0,1)





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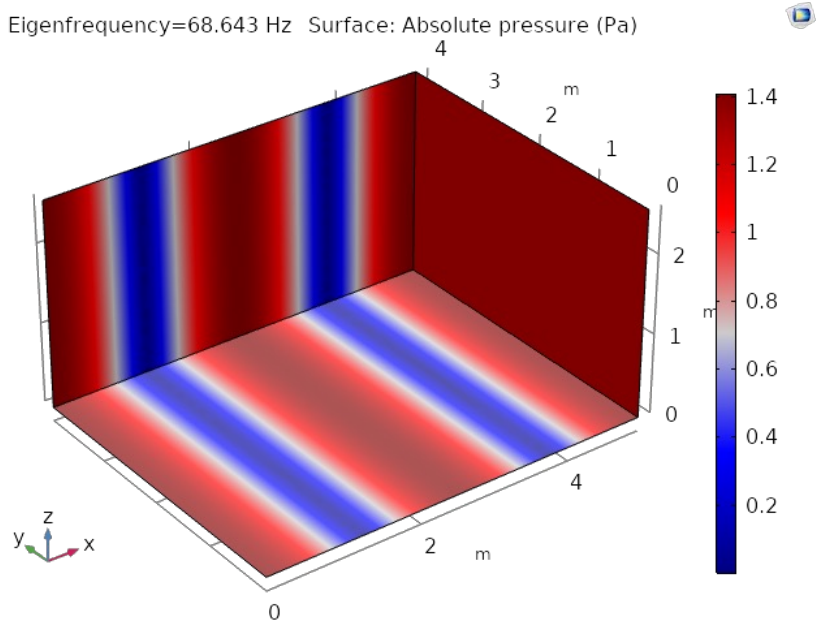
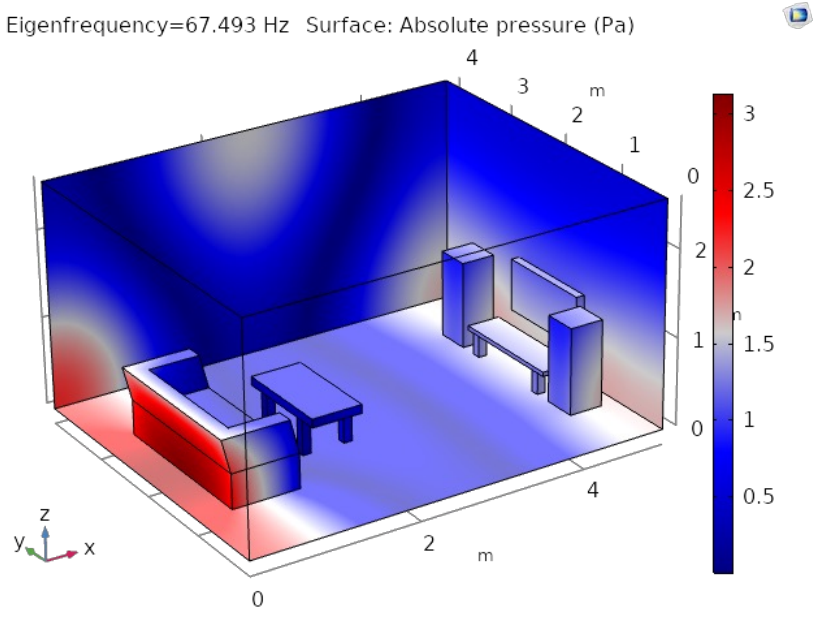
Demo: Eigenmodes of a room

Fifth mode (2,0,0)





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Demo: Eigenmodes of a room

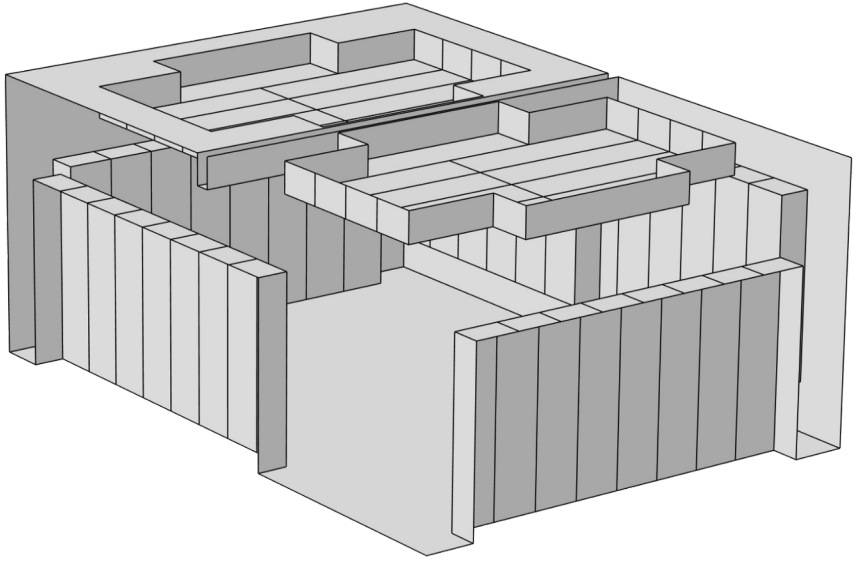
Eigenfrequencies (Hz)

MODE INDEX	Analytical Expression	Empty Room (COMSOL)	Furnished Room (COMSOL)
0,0,0	0	0	0
1,0,0	34.3	34.3	34.7
0,1,0	42.9	42.9	41.9
1,1,0	54.9	54.9	53.9
0,0,1	66	66	66
2,0,0	68.6	68.6	67.4
1,0,1	74.3	74.3	74.9
0,1,1	78.7	78.7	78
2,1,0	80.9	80.9	80.1

Appication ID 63: https://www.comsol.com/model/eigenmodes-of-a-room-63

Homework Assignment

Variable Acoustics Room Arni



Further reading

Room acoustics modelling

- Modeling Room Acoustics with COMSOL Multiphysics
- Modeling Room Acoustics Using a Hybrid Approach

Meshing

- How to Inspect Your Mesh in COMSOL Multiphysics®
- 2 Mesh Adaptation Methods: Enabling More Efficient Computations

ELEC-E5650 - Electroacoustics

- Acoustic radiation
- Vibration analysis
- Acoustic-structure interaction
- Electromagnetics
- Transducer modelling