ETH zürich

# P&S COMSOL® Design Tool
## Lecture Week 3: Introduction to COMSOL

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# Content

- Software & Physics
- Meshing
- Boundary Conditions
- Source
- General Workflow
- Tutorial 3: Young’s Slit Experiments


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# Software & Physics

## Software & Physics

### Simulation Software





### Simulation Method

Finite Element Method (FEM)


Finite Difference Time Domain (FDTD)




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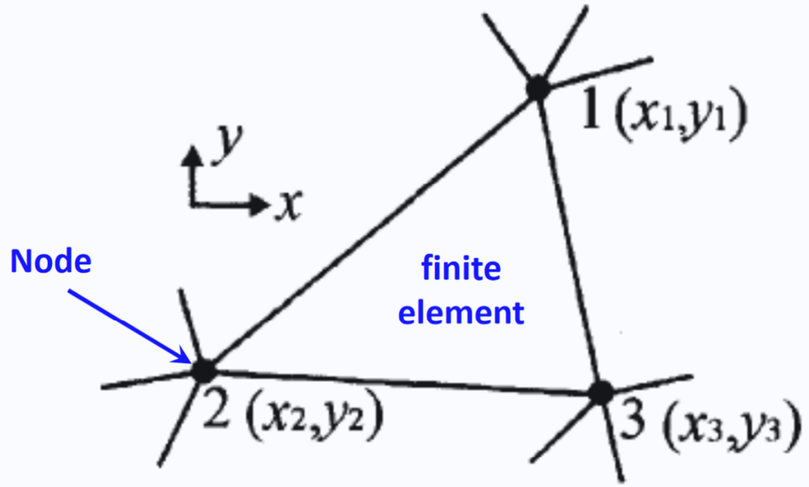
# Software & Physics

## Software & Physics

COMSOL

FEM

1. *Division of space into finite elements*
   - *Local refinement*
   - *Almost perfectly conformal*
2. *Formulation of a boundary value problem*
   - *Field calculated at the node and interpolated at edges*
3. *Elimination of time derivatives (steady state)*




### Advantages of FEM

+ Modeling
+ Accuracy specification
+ Boundary conditions
+ Visualization
+ Material properties

### Disadvantages of FEM

– Data required as input for mesh
– Sometimes large computational power
– Output can vary
– Frequency domain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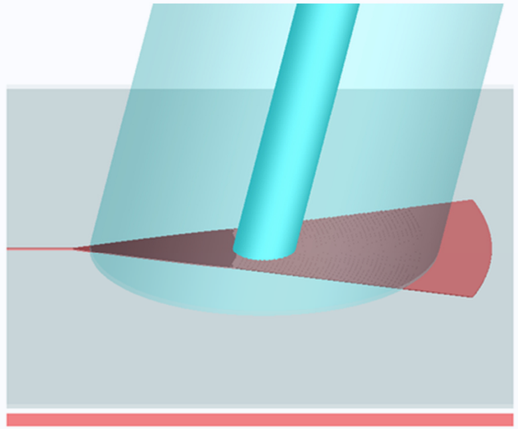
# Software & Physics

## Software & Physics

FDTD

1. *Replace derivative with finite difference, discretize in space and time*
2. *Solve resulting difference equations*
3. *Evaluate magnetic field one time-step in future*
4. *Evaluate electric field one time-step in future*
5. *Repeat the previous two steps*

Advantages of FDTD

+ Intuitive
+ Time-domain technique
+ Animated display of evolving fields
+ Direct usage of $E$- and $H$-Fields

Disadvantages of FDTD

– Rectangular mesh
  – Conformality and refinement
– Material boundaries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# Meshing

## Software & Physics

COMSOL

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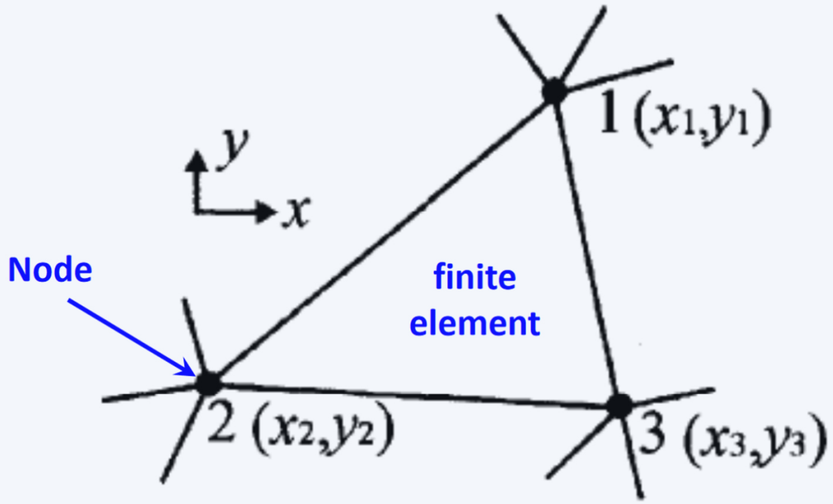
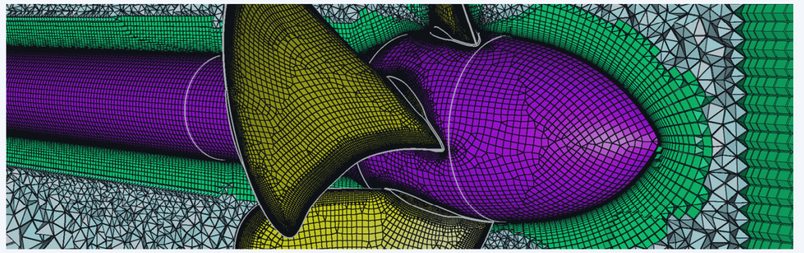
MATLAB

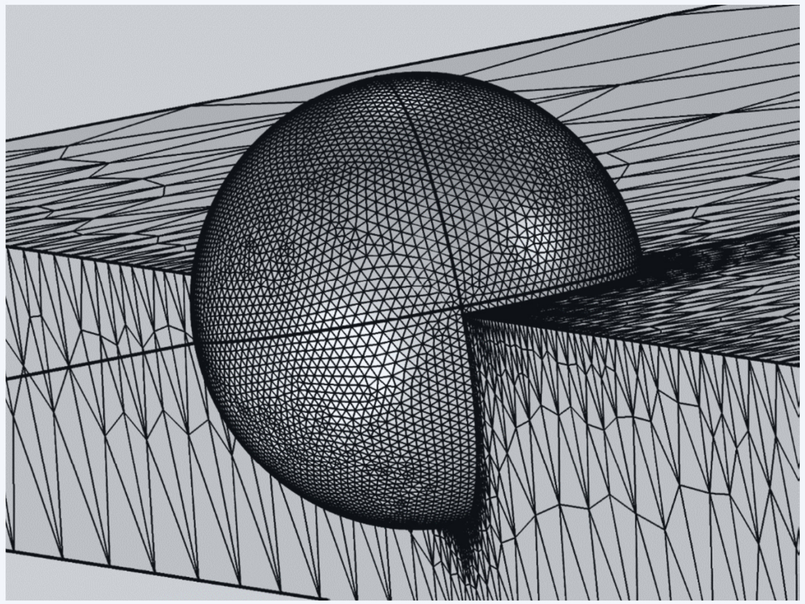
FEM, FDTD, FDFD,
FEM, BEM

Frequency Domain,
Acoustics, Fluids,
Plasma, etc

## Domain & Mesh







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# Meshing

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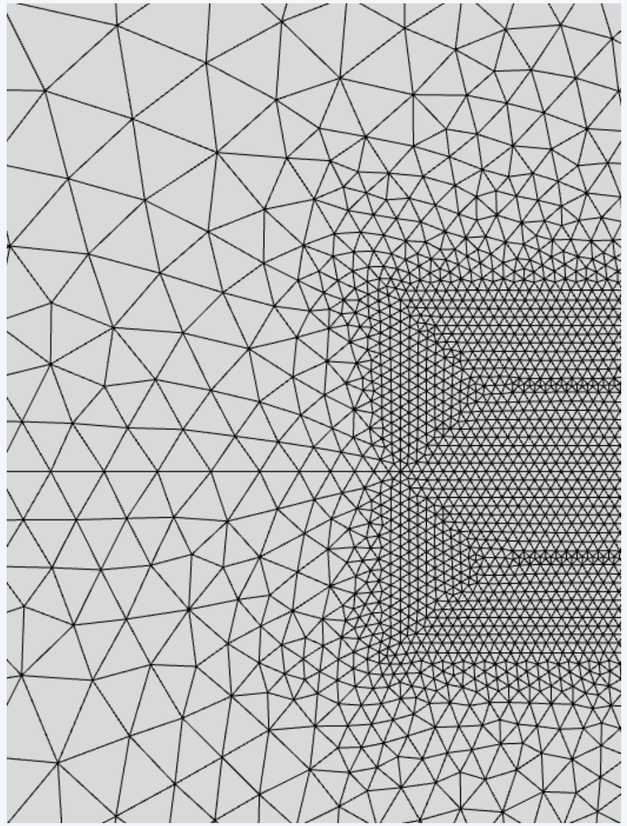
Frequency Domain, Acoustics, Fluids, Plasma, etc

## Domain & Mesh

- Discretization of simulation domain
- Mesh size determines accuracy of solution
  - Too large mesh → wrong results
- Accuracy vs. simulation time
  - Too small mesh → very large simulation time
  - If RAM is too low, data is written onto hard drive → ultra large simulation time





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# Boundary Conditions

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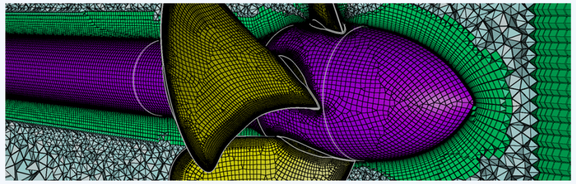
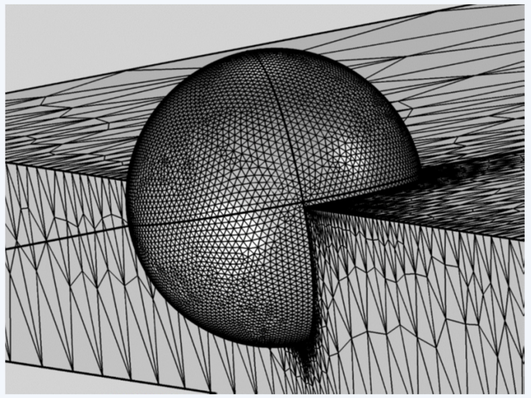
## Domain & Mesh





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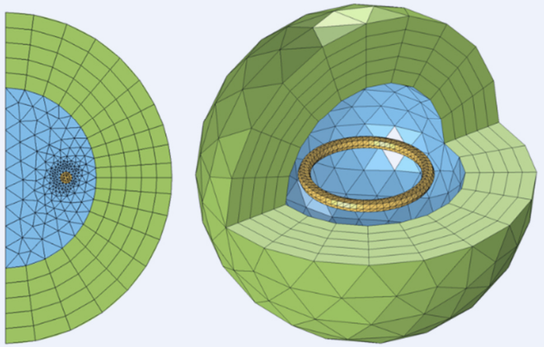

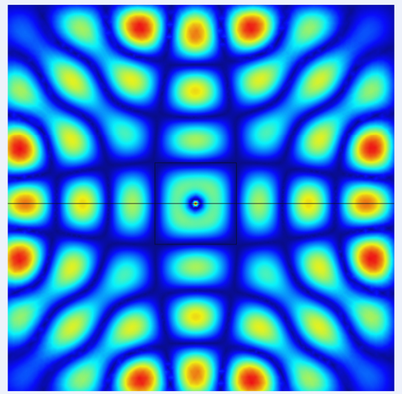

Types of boundary conditions in COMSOL

- Perfect Electric Conductor (PEC)
- Perfect Magnetic Conductor (PMC)
- Scattering Boundary Condition
- Periodic Boundaries Condition (PBC)
- Perfectly Matched Layer (PML)



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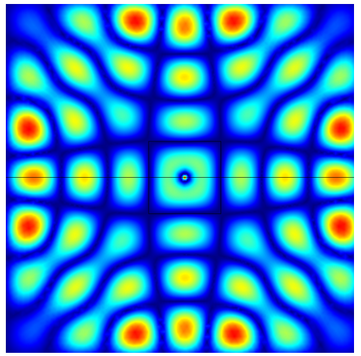
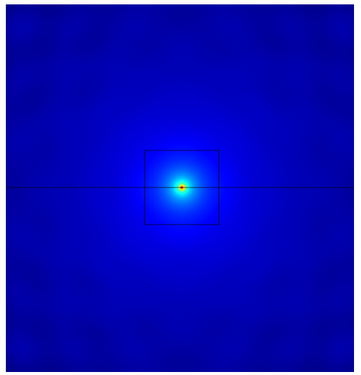
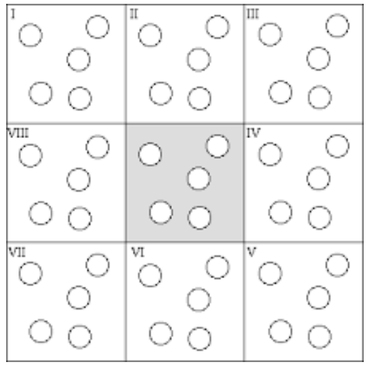
# Boundary Conditions

- **Perfect Electric Conductor (PEC)**
  - Properties
    - Electric field cannot penetrate → reflection of electric field
    - Equivalent to infinite electric conductivity
- **Perfect Magnetic Conductor (PMC)**
  - Properties
    - Magnetic field cannot penetrate → reflection of magnetic field
    - Equivalent to infinite magnetic conductivity
- **Scattering Boundary Condition**
  - Properties
    - Electric field is absorbed → no reflection
- **Periodic Boundary Condition**
  - For repeating structures
  - Use a unit cell for the analysis
  - Simulates systems expanding infinitely in 1D/2D









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# Source

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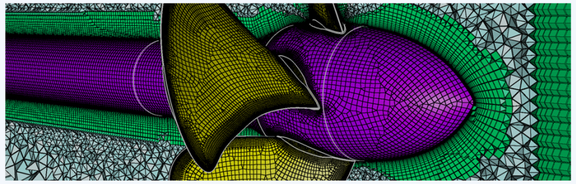
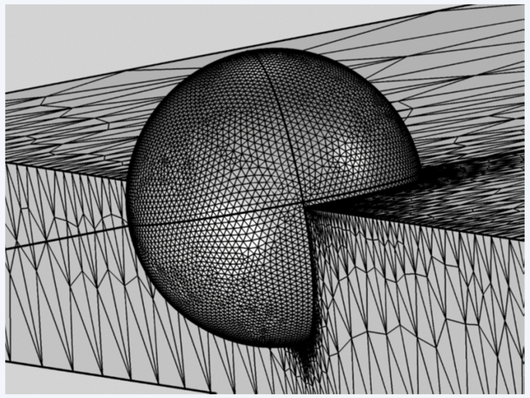
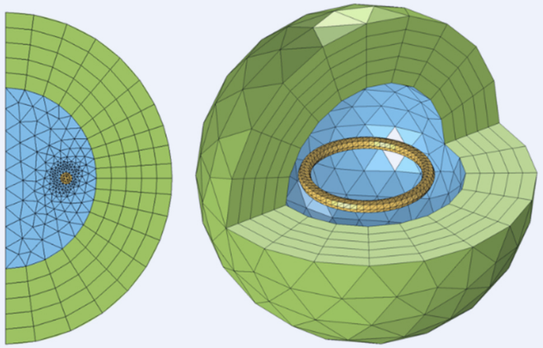
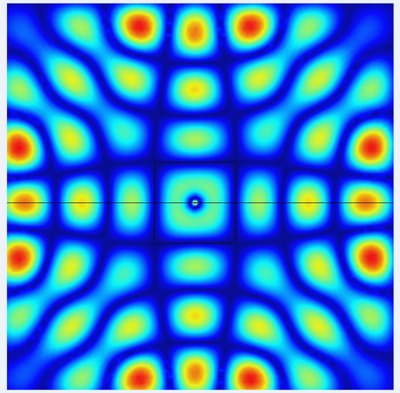




## Bondary Condition





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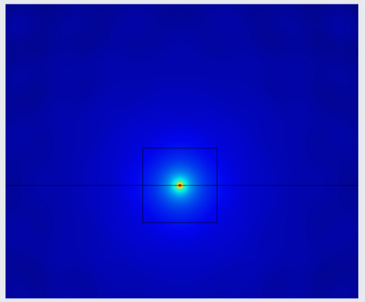

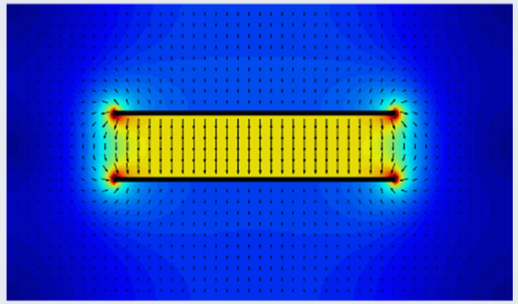

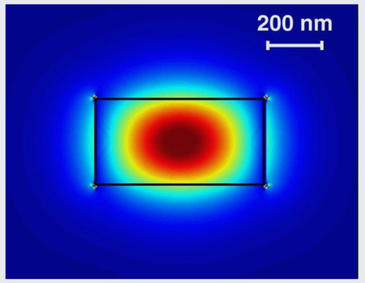




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# General Workflow

- Model Wizard!
- Select Geometry type
  - 2D
- Select Physics
  - Either emw or ewfd → they have the same functionality


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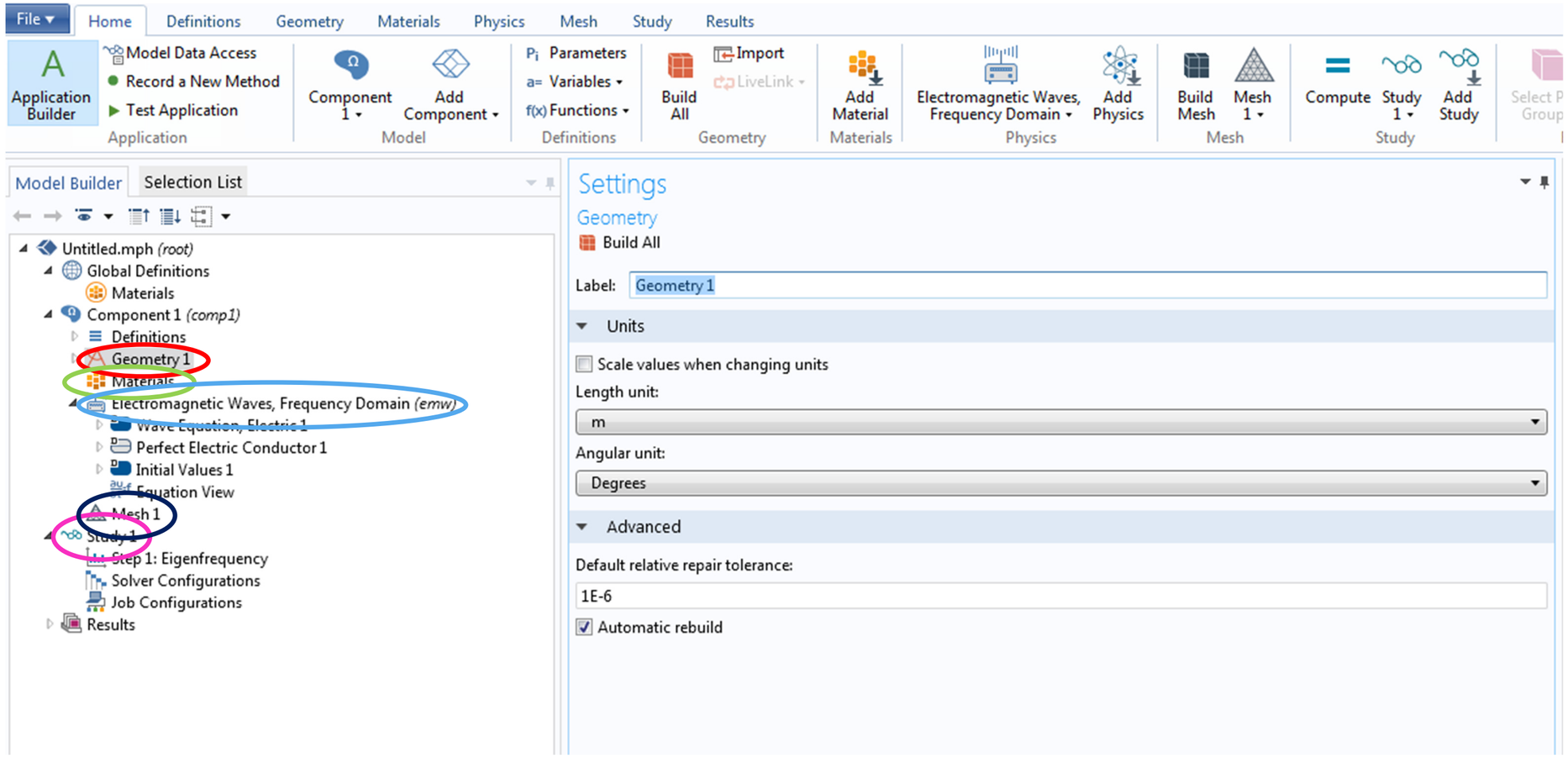



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# Starting COMSOL

- Every Student has access to Linux Server

Connection to Linux Server

1) Download and install Cisco Anyconnect: https://ethz.ch/content/dam/ethz/special-interest/hest/isg-hest-dam/documents/pdf/vpn-de.pdf
   Available for MS,MAC & Linux

2) Connect to ETH network using Ciso Anyconnect

3) Connect to Linux Server
   - Linux & Mac: using terminal type «ssh $username@itet-ief-l0.ethz.ch -X»
   - Windows, Linux, Max: using any remote desktop with xserver capability (e.g. Remmina)

4) Enter Username and Password

5) Start COMSOL
   type: «comsol &» into the terminal


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