

Week 2: QuickField Fundamentals

How to start QuickField and solve a simple problem of electrostatics.

1. Create the problem. Choosing the formulation
2. Draw the geometry by vertices, segments and arcs. Make the problem closed, when needed
3. Assign names to geometry shapes: all blocks, some edges, some vertices
4. Set up the material property, boundary conditions, field sources
5. Achieving optimal accuracy: control the mesh density (manually or automatically)
6. Analyzing the solution: field picture, local values, integral values, XY-plots, tables
7. Remember the field theory: how to calculate the capacitance

Getting started: the QuickField windows

The screenshot displays the QuickField software interface for a postprocessing task. The main window shows a model of a plane capacitor with a green mesh and a pink rectangular region. Overlaid on this is a 'Field picture window' showing a color-coded electric field distribution. To the left, a 'Problem tree' lists the model's components, and a 'Property grid' shows the settings for the selected model. At the bottom, a 'Values' panel displays calculated parameters.

Labels and their corresponding components:

- Main menu**: File, Edit, View, Problem, Contour, Tools, Window, Help
- Main toolbar**: Icons for file operations and viewing.
- Problem tree**: A hierarchical list of the model's components, including Geometry, Data, Block Labels, Edge Labels, Vertex Labels, Library Data, and Links.
- Problem toolbar**: Icons for interacting with the problem tree.
- Property grid**: A table of properties for the selected model.
- Model window**: The main workspace showing the model geometry and mesh.
- Field picture window**: A window showing the calculated field distribution (contour plot).
- Model toolbar**: Icons for interacting with the model window.
- Field picture toolbar**: Icons for interacting with the field picture window.
- Calculator panel**: A panel for performing calculations on the field data.
- Legend panel**: A color scale for the field values, ranging from -1.0 to 1.0 V.

Property grid details:

Properties for PlaneCapacitor.pbm	
General	
Problem Type	Electrostatics
Model Class	Plane-parallel
Z Length (L_z), mm	20
Precision	Normal
Geometry	Planecapacitor.mod
Data	Planecapacitor.des
Library Data	
Coordinates	
Length Unit	Millimeters
Coordinates	Cartesian

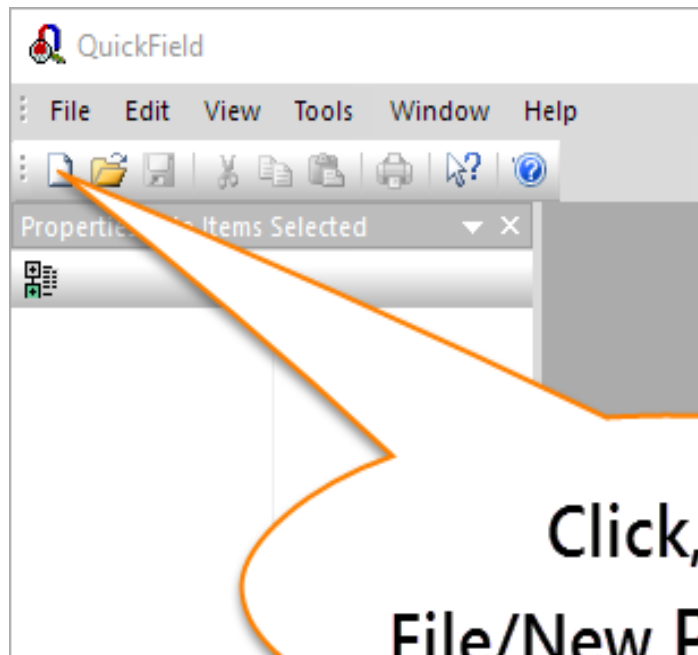
Values panel details:

- $r = 2.7203 \text{ mm}$
- $\theta = -107.1 \text{ deg}$
- Voltage $U = 0.31816 \text{ V}$
- Strength $E = 398.52 \text{ V/m}$
- Strength $E_x = 398.52 \text{ V/m}$
- Strength $E_y = -2.2202 \text{ V/m}$
- Field Gradient
- Displacement $D = 1.4114 \times 10^{-8} \text{ C/m}$
- Displacement $D_x = 1.4114 \times 10^{-8} \text{ C/m}$
- Displacement $D_y = -7.8632 \times 10^{-9} \text{ C/m}$

Getting started: Create a new problem

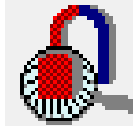
Think twice: Choose the proper problem formulation
(a subset of Maxwell equations)

1. Create the new problem and name it



Click, or
File/New Problem

2. Select the problem formulation



Select the type of analysis and other parameters for the new problem. You can also change the names for the files where the model and material data are stored.

Problem Type:

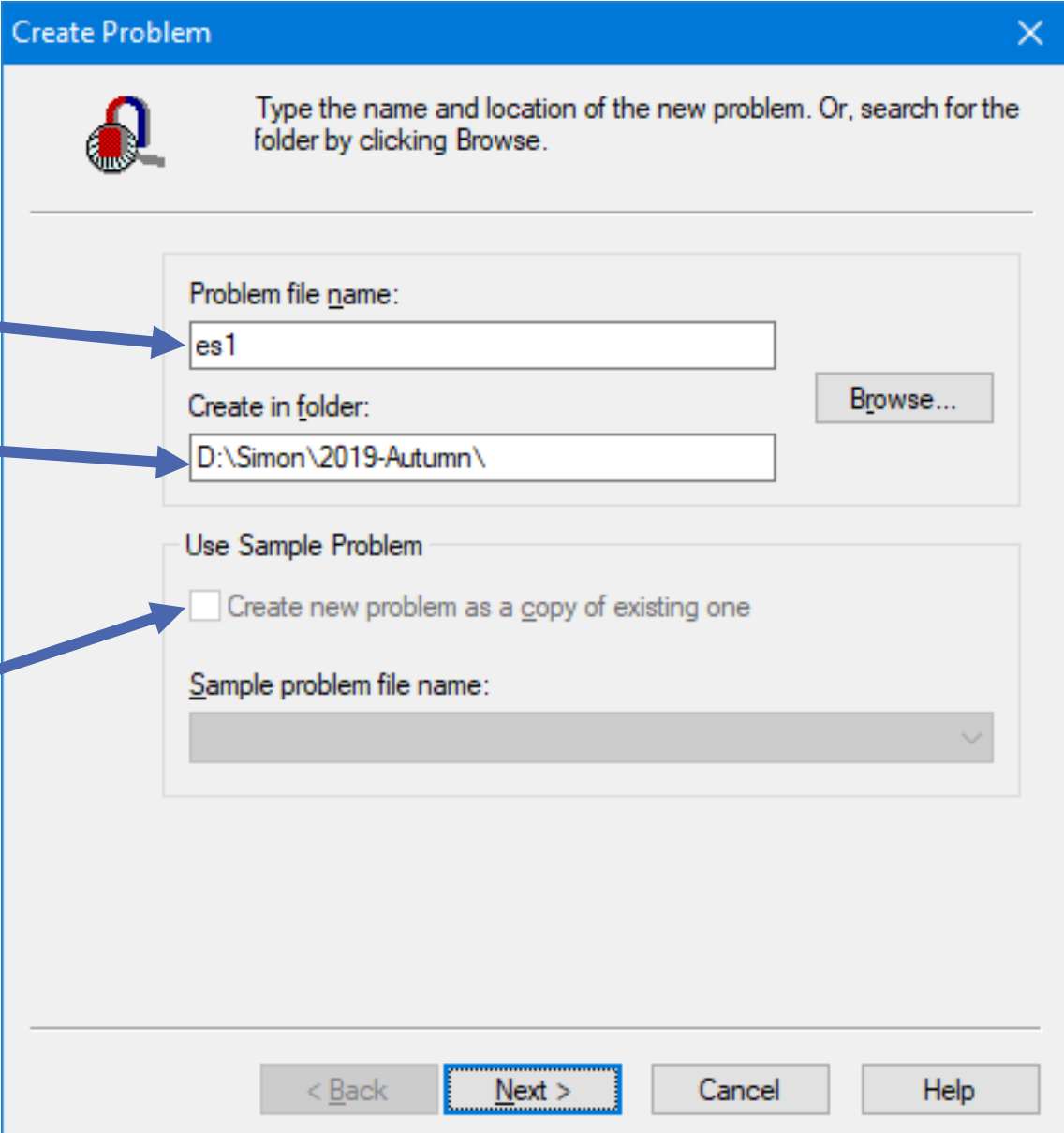
Electrostatics
Electrostatics
Transient Electric
DC Conduction
AC Conduction
Magnetostatics
AC Magnetics
Transient Magnetics
Steady-State Heat Transfer
Transient Heat Transfer
Stress Analysis

The Problem

Problem name

Location

Make a copy?



The screenshot shows the 'Create Problem' dialog box. It has a blue title bar with the text 'Create Problem' and a close button. Below the title bar is a message: 'Type the name and location of the new problem. Or, search for the folder by clicking Browse.' To the left of the message is a small icon of a padlock with a key. The dialog contains three main sections. The first section has a label 'Problem file name:' followed by a text box containing 'es1'. The second section has a label 'Create in folder:' followed by a text box containing 'D:\Simon\2019-Autumn\' and a 'Browse...' button. The third section is titled 'Use Sample Problem' and contains a checkbox labeled 'Create new problem as a copy of existing one' which is currently unchecked. Below this is a label 'Sample problem file name:' followed by a dropdown menu. At the bottom of the dialog are four buttons: '< Back', 'Next >', 'Cancel', and 'Help'. The 'Next >' button is highlighted with a blue border. Three blue arrows point from the text labels on the left to the corresponding fields in the dialog: 'Problem name' points to the 'Problem file name' text box, 'Location' points to the 'Create in folder' text box, and 'Make a copy?' points to the 'Create new problem as a copy of existing one' checkbox.

Create Problem

Type the name and location of the new problem. Or, search for the folder by clicking Browse.

Problem file name:
es1

Create in folder:
D:\Simon\2019-Autumn\ Browse...

Use Sample Problem
☐ Create new problem as a copy of existing one

Sample problem file name:
▼

< Back Next > Cancel Help

Problem Properties

Formulation: Electrostatic field

Geometry class: Plane-parallel 2D problem

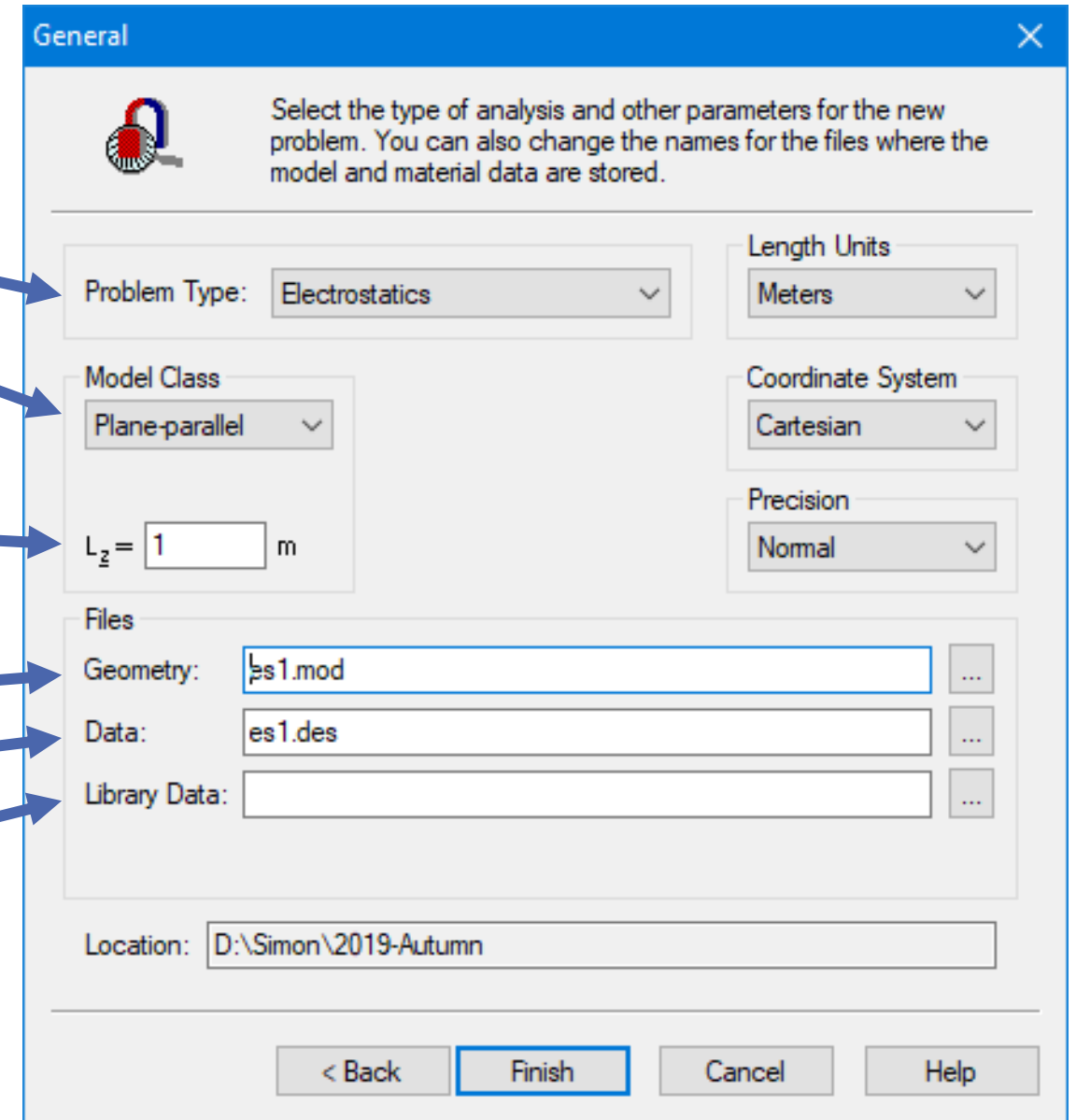
Length in the 3rd dimension (out of plane)

Links to referred files:

Geometry

Data

Background data



The screenshot shows a 'General' dialog box with a blue header and a close button. Below the header is a lock icon and a text box: 'Select the type of analysis and other parameters for the new problem. You can also change the names for the files where the model and material data are stored.'

The dialog contains several sections:

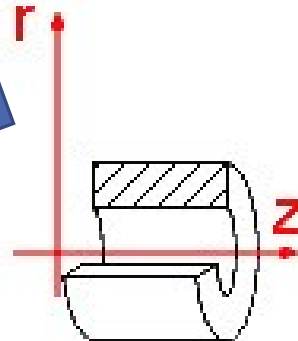
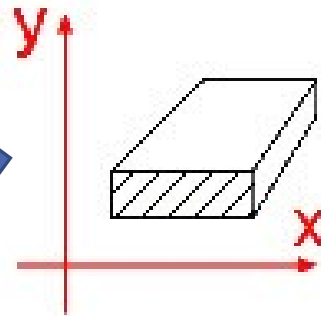
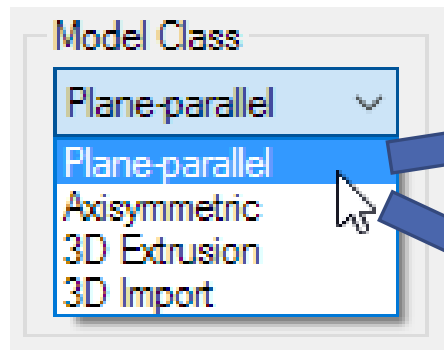
- Problem Type:** A dropdown menu set to 'Electrostatics'.
- Length Units:** A dropdown menu set to 'Meters'.
- Model Class:** A dropdown menu set to 'Plane-parallel'.
- Coordinate System:** A dropdown menu set to 'Cartesian'.
- Precision:** A dropdown menu set to 'Normal'.
- Files:** A section with three text boxes and browse buttons (...):
 - Geometry:** 'es1.mod'
 - Data:** 'es1.des'
 - Library Data:** (empty)
- Location:** A text box containing 'D:\Simon\2019-Autumn'.

At the bottom are four buttons: '< Back', 'Finish' (highlighted with a blue border), 'Cancel', and 'Help'.

Choosing the Model Class

How the 2D geometry extends in 3D world

3. Choose the Model Class: Plane-parallel or Axisymmetric



Plane-parallel:

1. Most of physical values are per 1 meter of axial length (in Z-direction)
2. You may define the axial length of the model. If you do that, QuickField calculates all integral quantities with respect to given Z-length

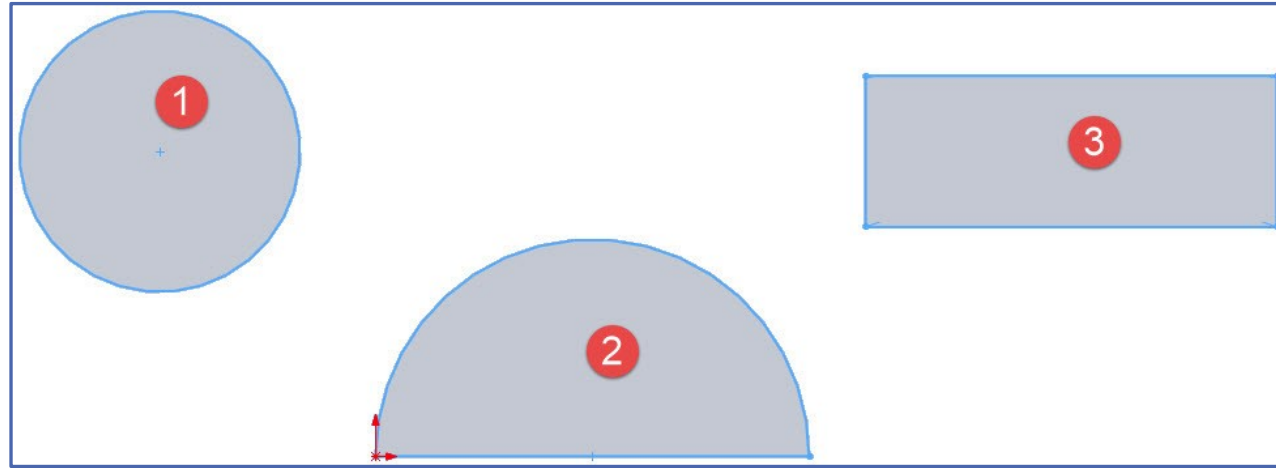
Axisymmetric:

1. With axisymmetric problems the rotation axis is always horizontal coordinate axis OZ
2. You only draw the cross-section of axisymmetric geometry above the rotation axis OZ

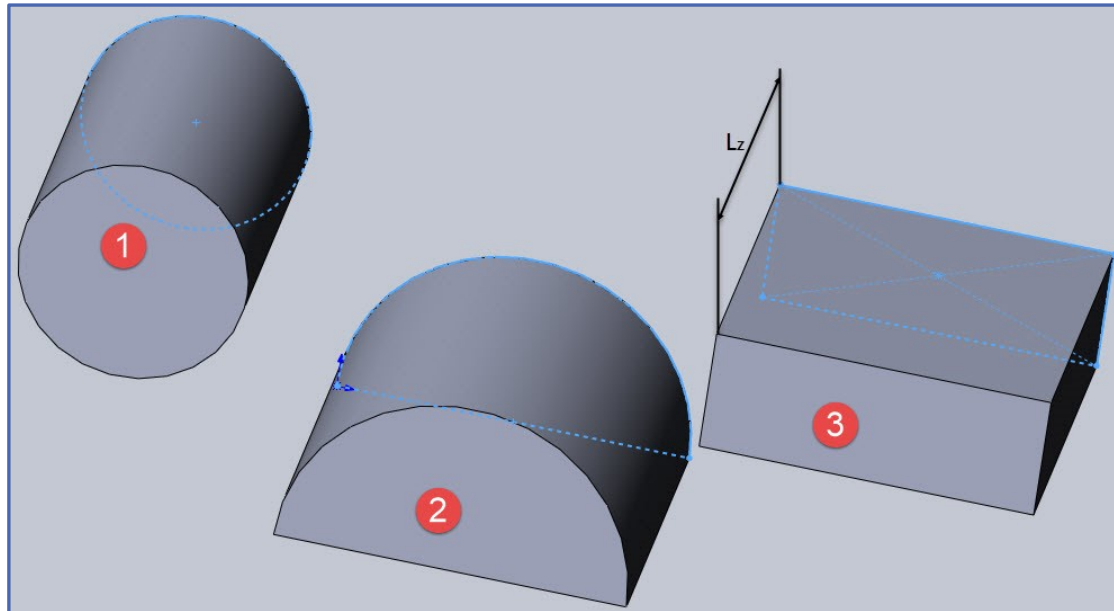
Getting started: Understand model classes

You draw:

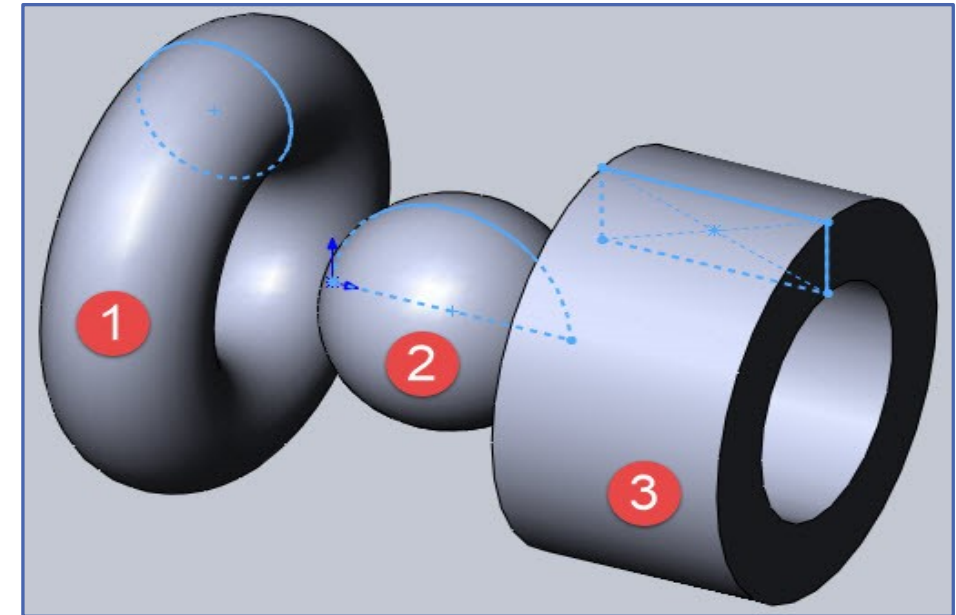
1. Circle
2. Semicircle
3. Rectangle



You get:



Or:



Working with the Model editor

Switch the operation mode:
Select shapes (left side), or
Insert new vertices and edges

Mesh controls:
build mesh
remove mesh
affects on selected blocks
or on the whole model

Scale control:
+ zoom in
- zoom in
zoom to fit

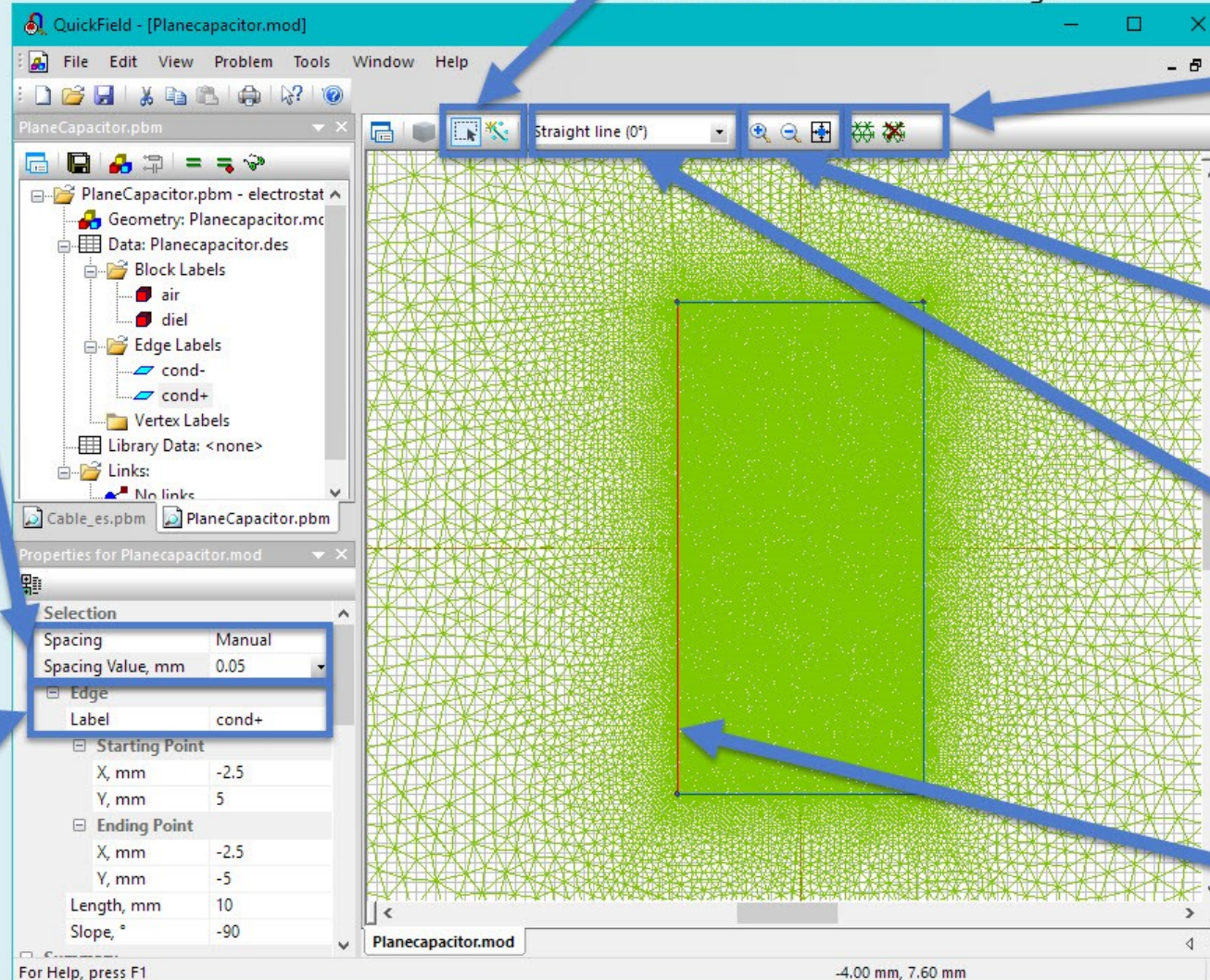
Segment or Arc:
Choose 0 for segments
or non-zero arc angle

Mesh spacing control:

Assign manual spacing
to some vertices of
your choice

Assigning text label to
all blocks,
and
edges and vertices
with boundary
condition

Selected shapes
displayed in red color



Working with the Model editor

To add any geometry shape first switch to Insert mode:
use toolbar button or **INS** key

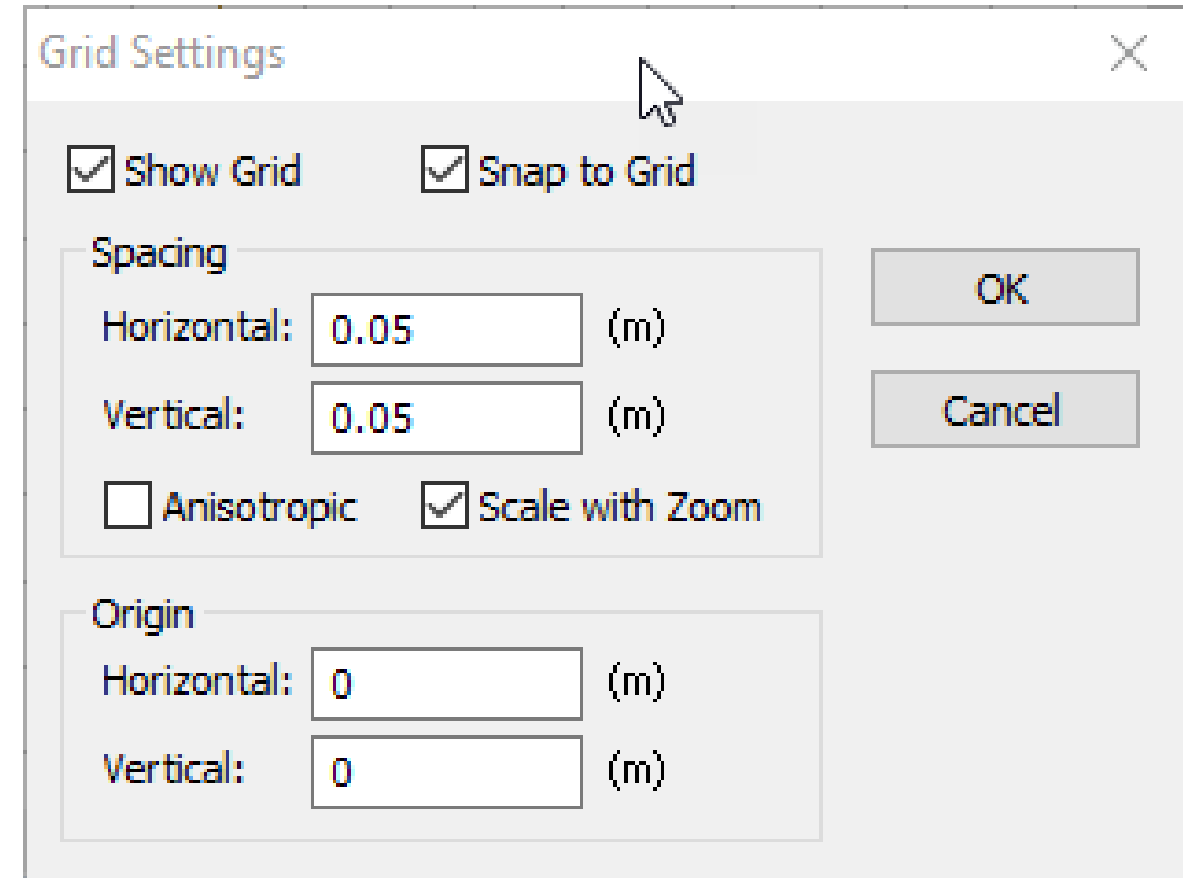
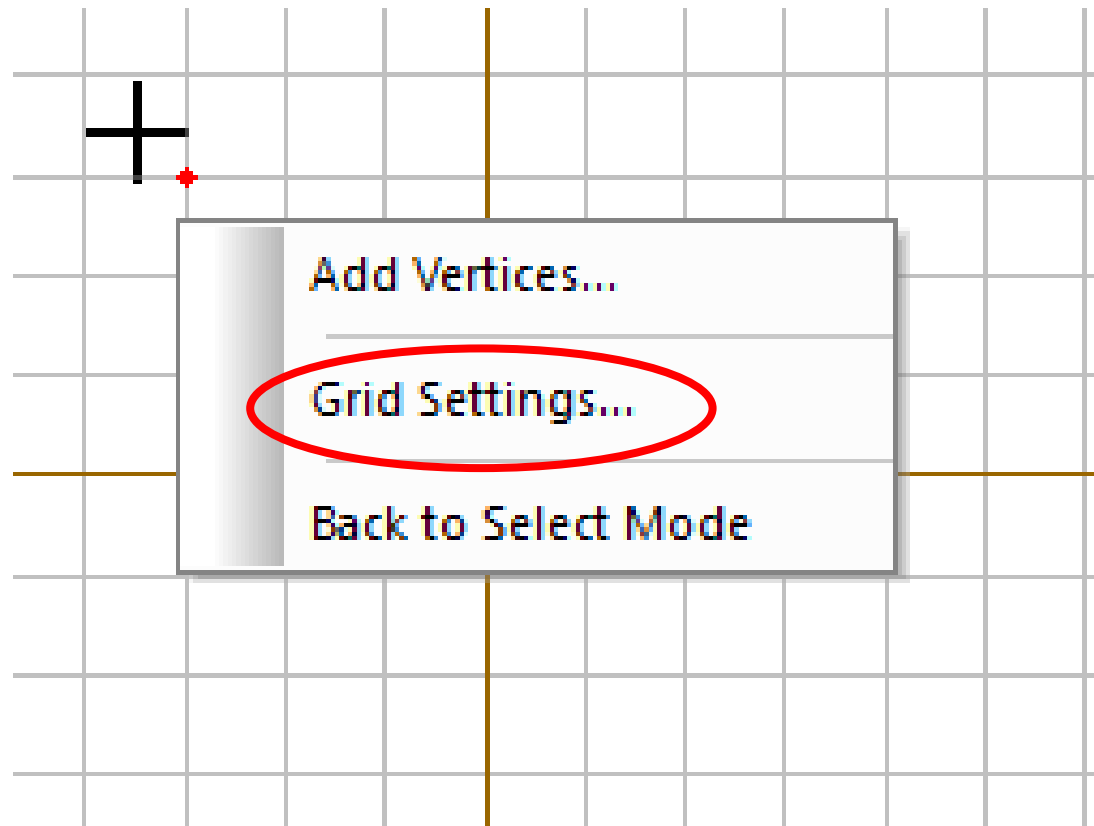
Primitive

How to add

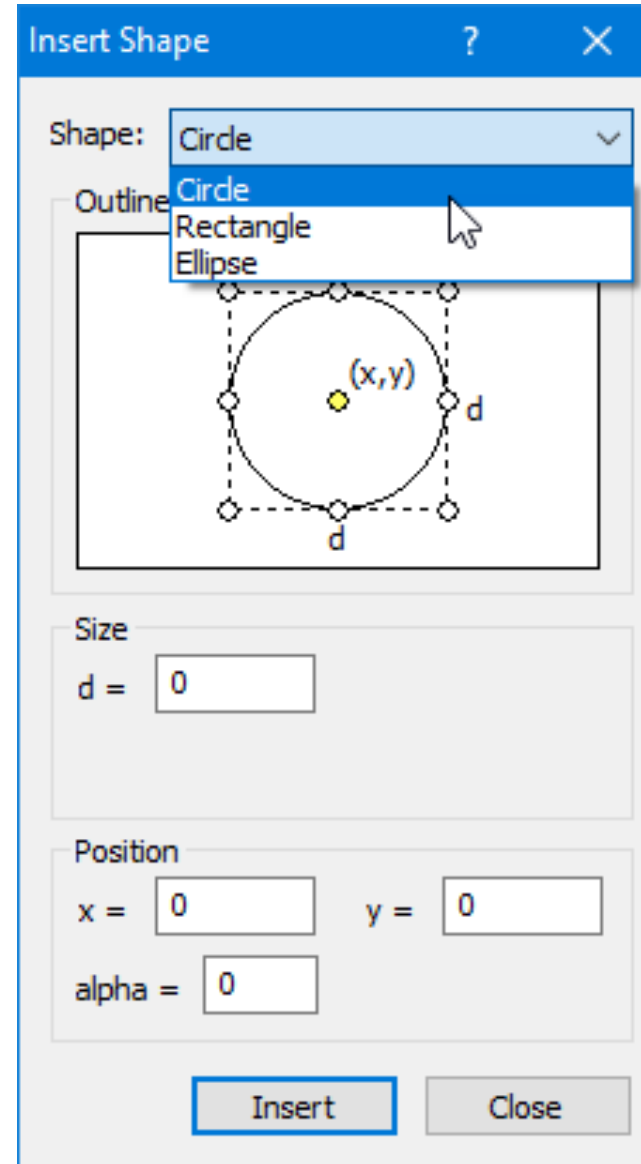
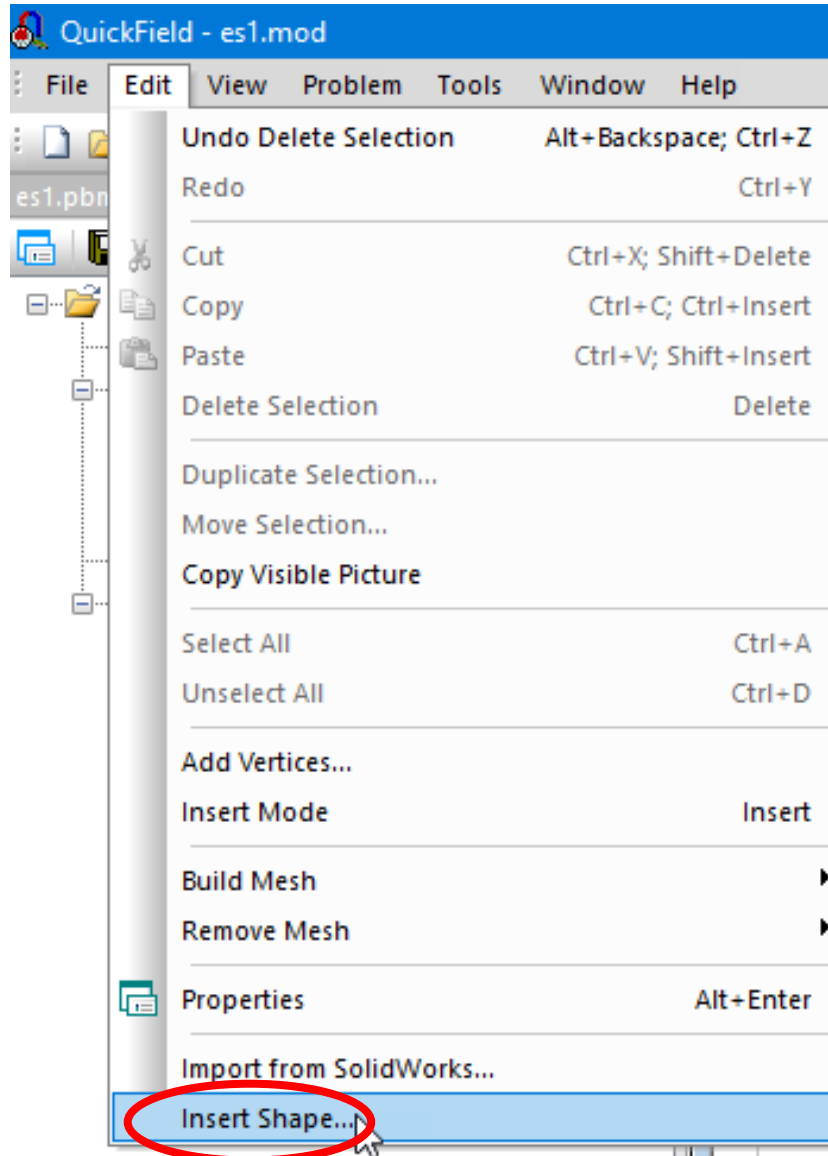
Vertex	Left mouse button (LMB): double click
Line	LMB: Click – Drag – Release
Arc	Choose or enter the central angle, then LMB: Click – Drag – Release
Polygon	Detected automatically

Working with the Model editor

Snap to the background grid



Using the Shape Inserting Tool



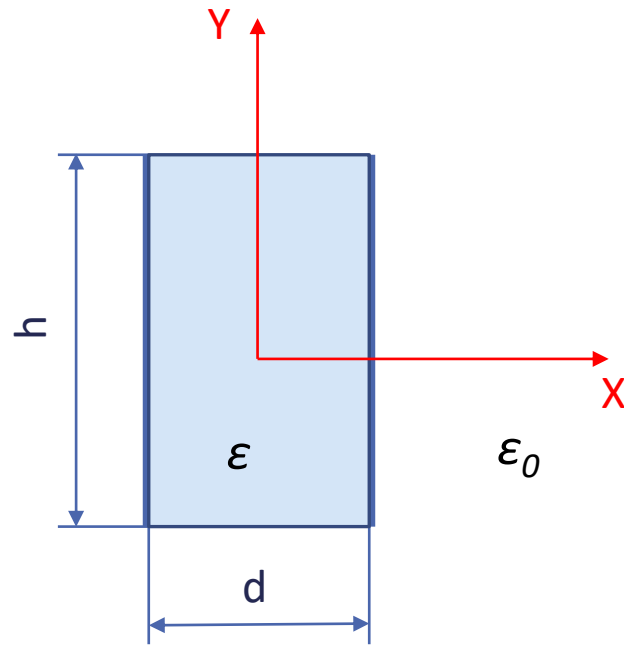
Shape

Sizing

Positioning

Draw the plane capacitor

Our first problem to solve is the plane capacitor.
We want to know its capacitance



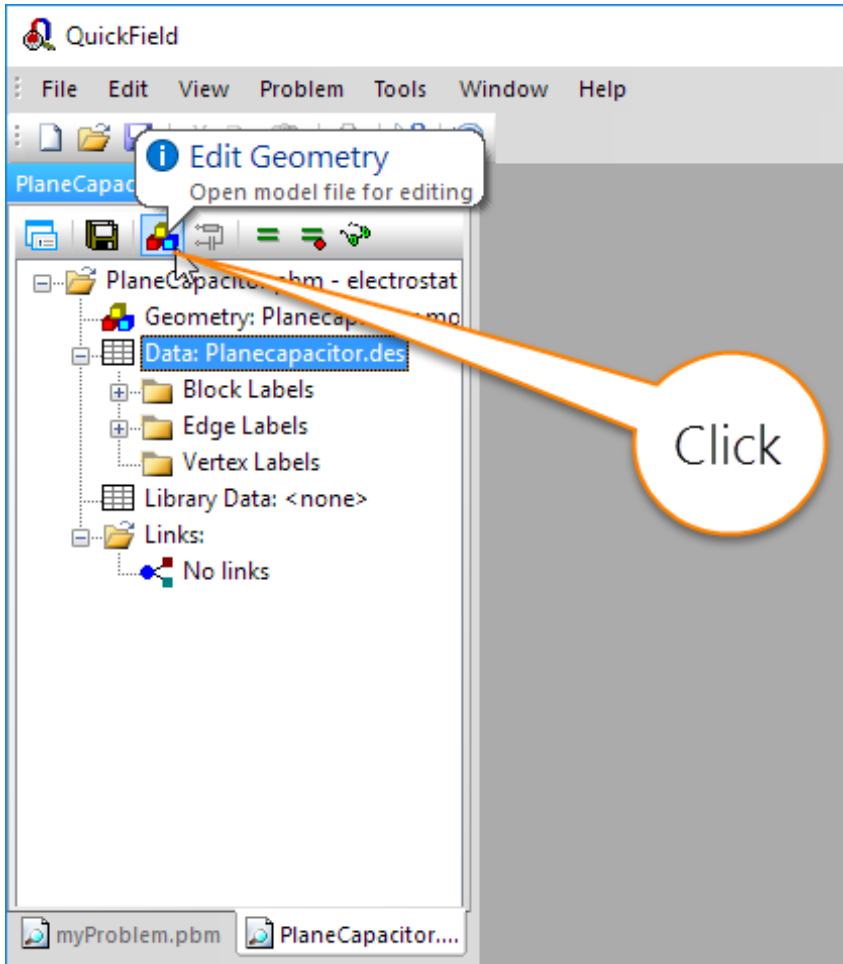
Formulation: Electrostatic field

Geometry class: Plane-parallel 2D problem

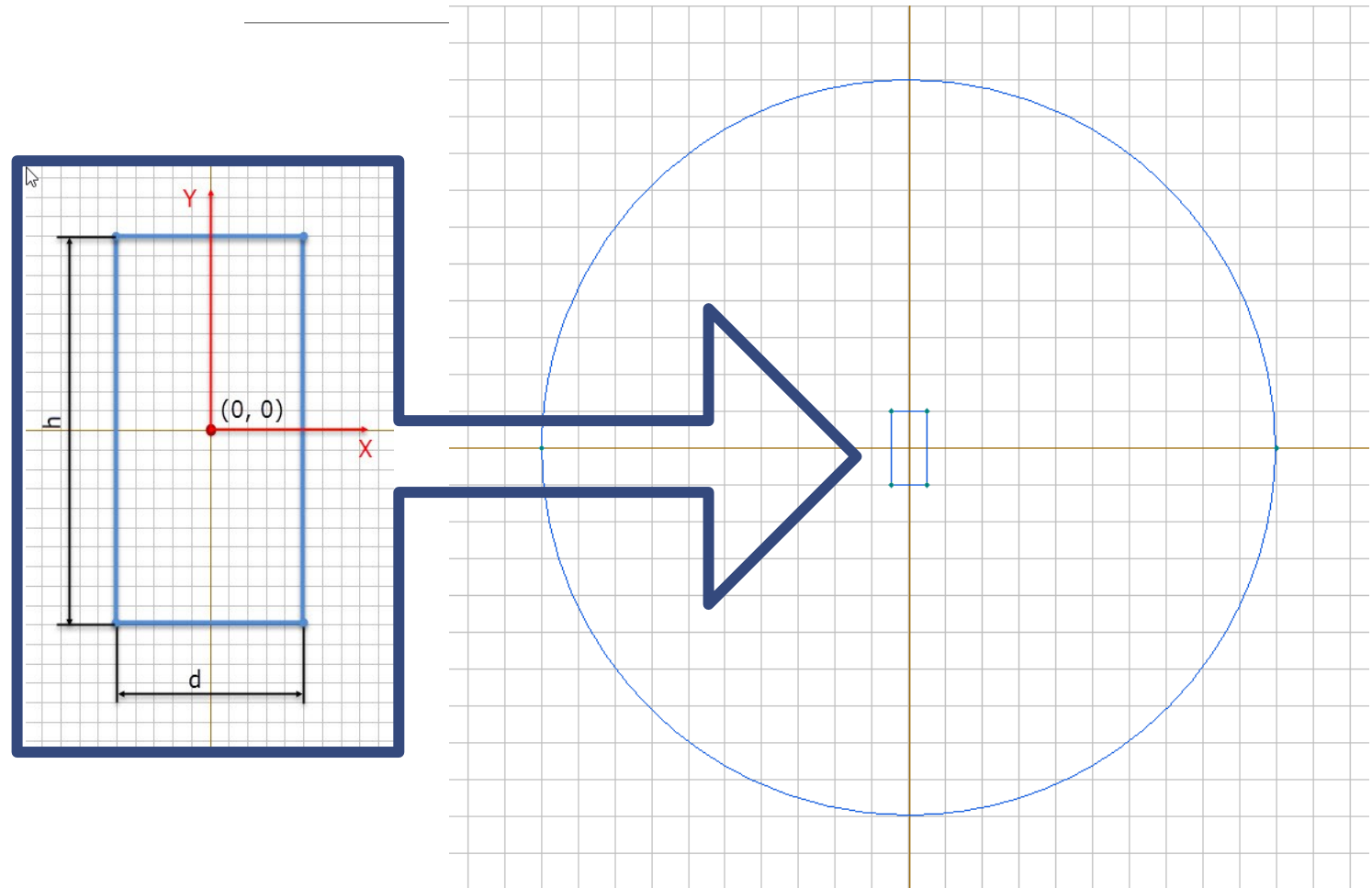
Parameter	Notation	Value
Distance between plates	d	5 mm
Height	h	10 mm
Axial length	Z_L	20 mm
Dielectric permittivity	ϵ	4

Draw the plane capacitor

1. Open the model editor



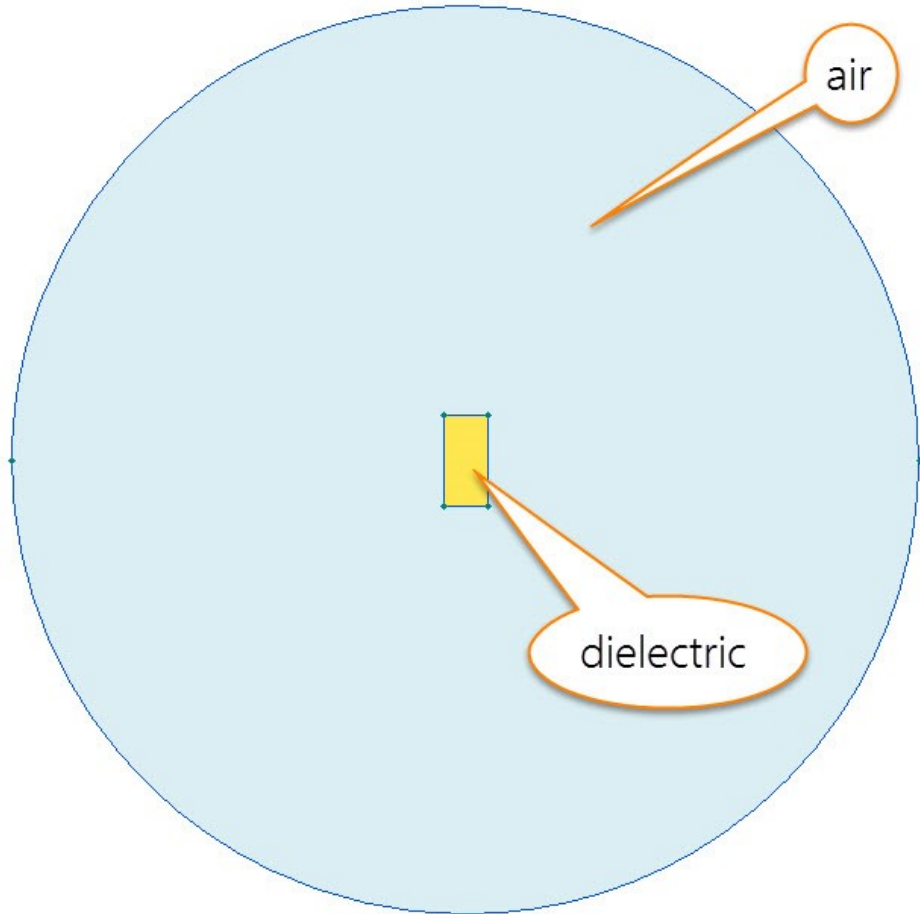
2. Draw the rectangle (capacitor), and the circle (artificial outer boundary)



Making the problem bounded

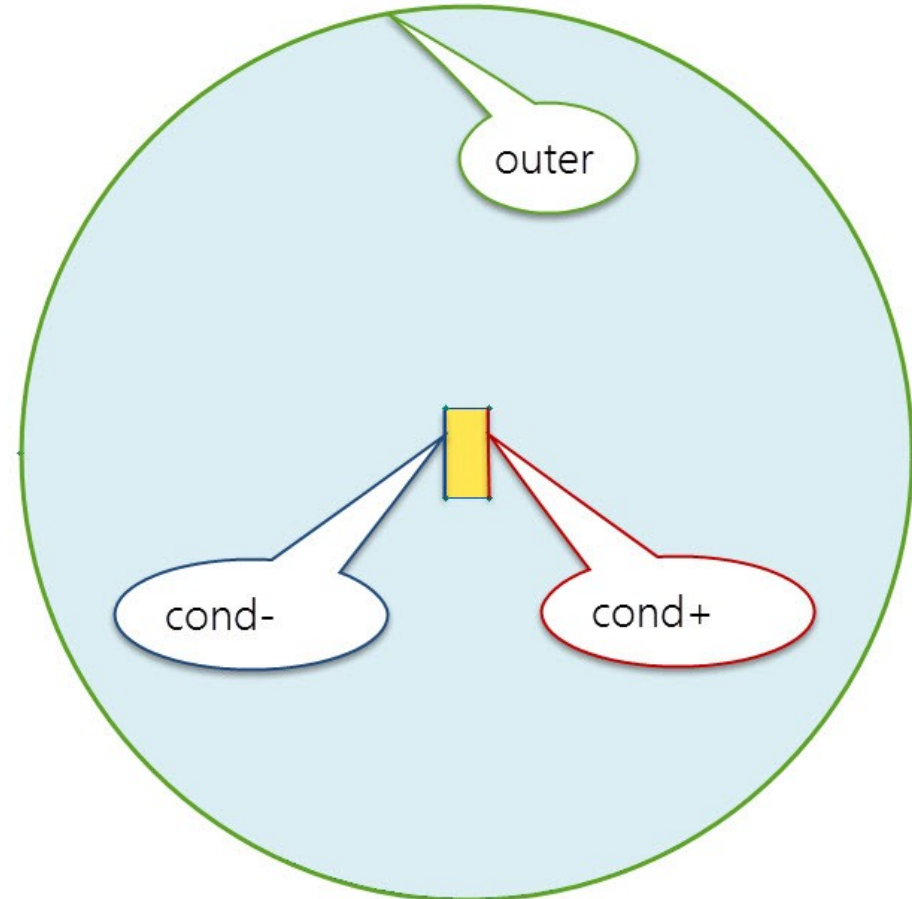
1. Add the artificial outer boundary

Material properties:



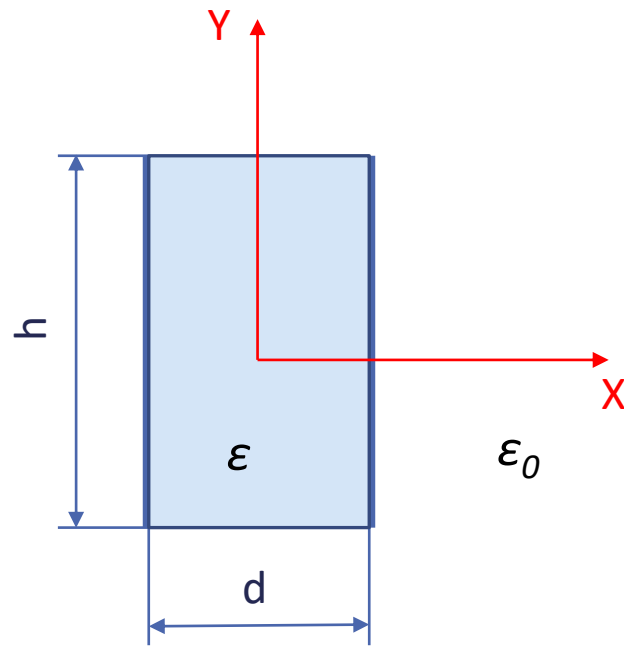
2. Replace the discarded part of the universe with the boundary condition

Boundary conditions:



Draw the plane capacitor (cont.)

1. Draw the capacitor's cross-section



Parameter	Notation	Value
Distance between plates	d	5 mm
Height	h	10 mm
Axial length	z_L	20 mm
Dielectric permittivity	ϵ	4

The simplest way is starting with creating 4 vertices using the **Edit / Add Vertices** command:

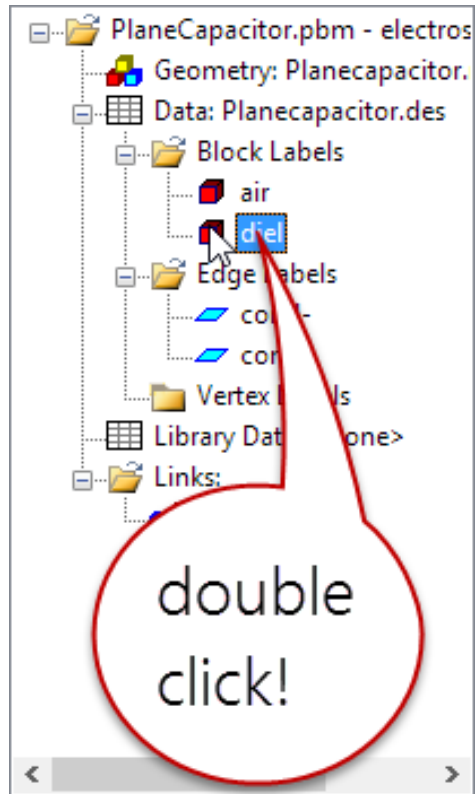
Adding New Vertices ×

$x =$ (mm)

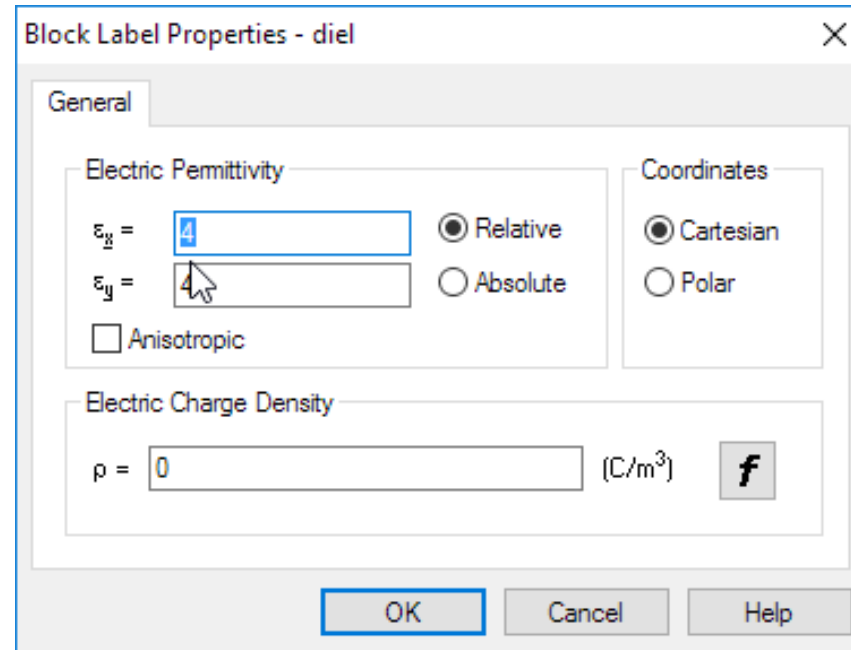
$y =$ (mm)

Now set up the physical data

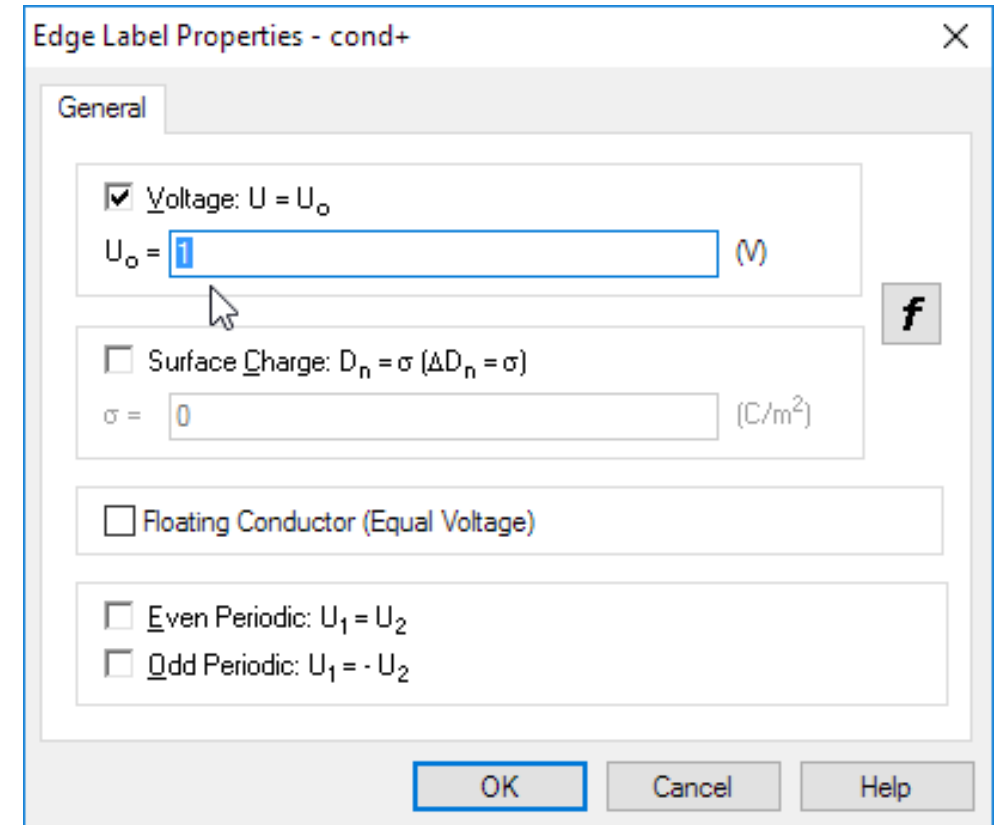
1. Activate label properties



2. Set material property for block labels



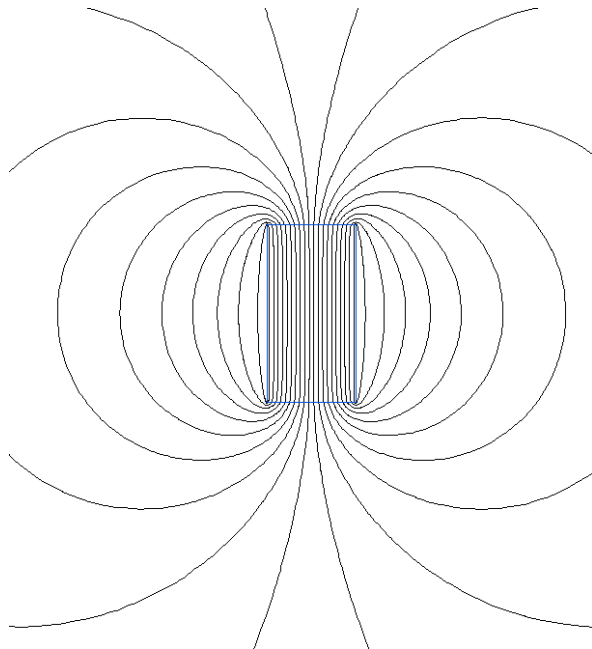
3. Set Dirichlet or Neumann boundary condition



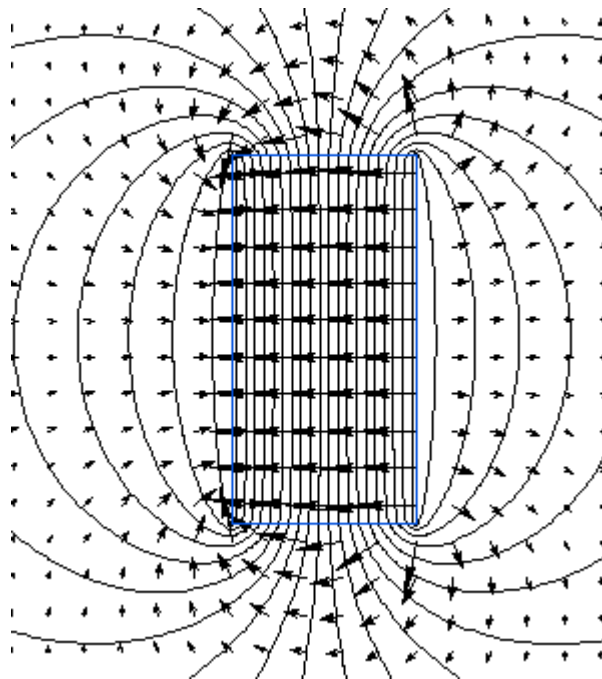
Working with the Field picture

The calculation results may be presented as:

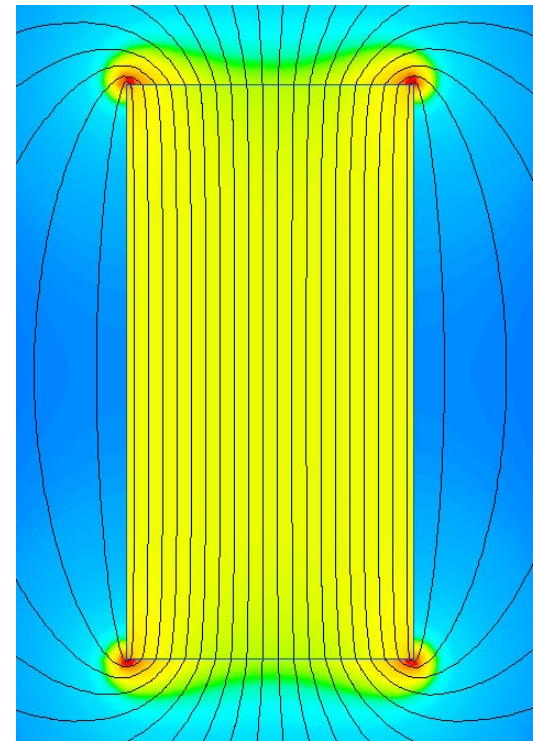
1. Field Lines



2. Vectors

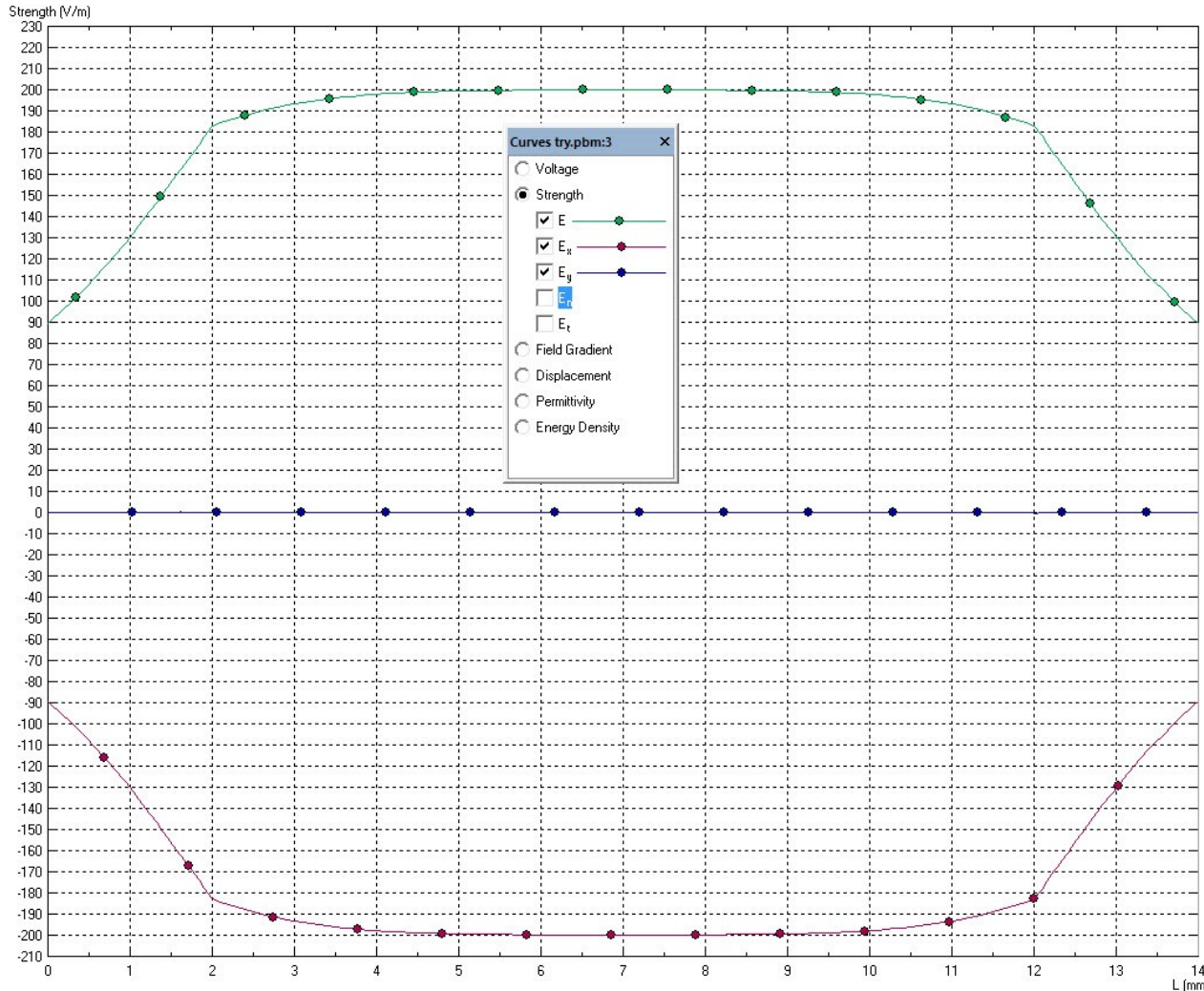


3. Color map



Field postprocessing

4. XY-Plot

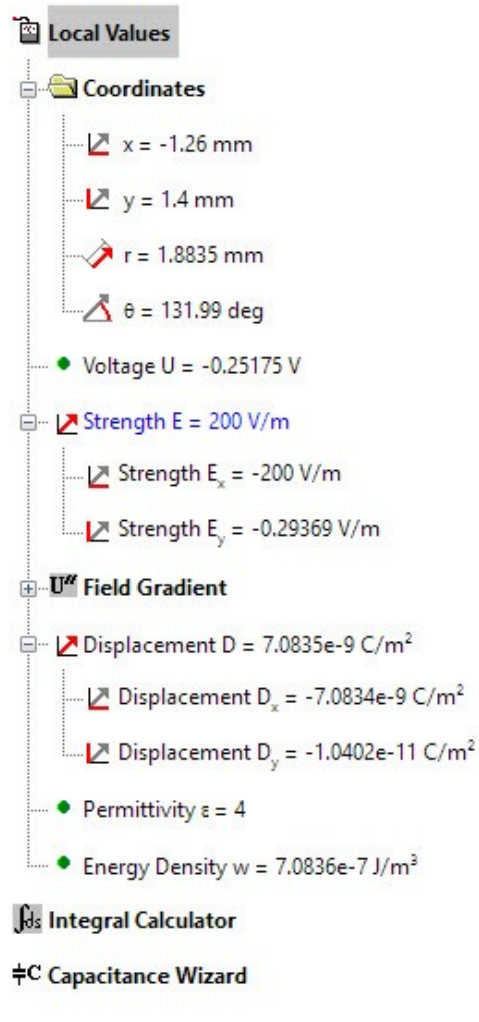


5. Table

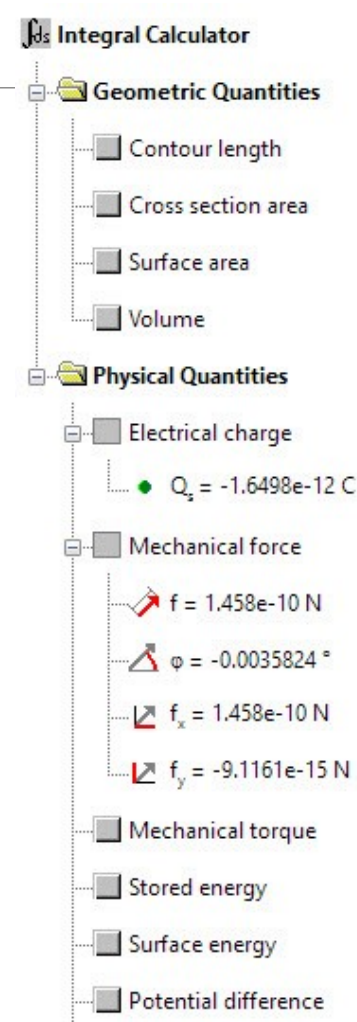
L (mm)	x (mm)	y (mm)	N_x	N_y	U (V)	E (V/m)	E_x (V/m)	E_y (V/m)
0.00000	0.00000	-7.00000	1.00000	-0.00000	2.15068e-4	89.5768	-89.5768	0.0567527
0.700000	0.00000	-6.30000	1.00000	-0.00000	2.23998e-4	116.558	-116.558	-0.134715
1.40000	0.00000	-5.60000	1.00000	-0.00000	-2.86082e-6	150.659	-150.659	0.00779105
2.10000	-4.06576e-16	-4.90000	1.00000	-0.00000	3.42190e-5	184.201	-184.201	0.00230175
2.80000	-4.06576e-16	-4.20000	1.00000	-0.00000	2.76852e-5	191.776	-191.776	0.0111026
3.50000	-4.06576e-16	-3.50000	1.00000	-0.00000	2.01271e-5	196.137	-196.137	0.0101272
4.20000	-4.06576e-16	-2.80000	1.00000	-0.00000	1.38484e-5	198.308	-198.308	0.00771142
4.90000	-4.06576e-16	-2.10000	1.00000	-0.00000	9.36994e-6	199.279	-199.279	0.00197479
5.60000	-4.06576e-16	-1.40000	1.00000	-0.00000	6.25337e-6	199.690	-199.690	0.00353100
6.30000	-4.06576e-16	-0.700000	1.00000	-0.00000	4.31451e-6	199.853	-199.853	0.00233199
7.00000	-4.06576e-16	-9.40395e-33	1.00000	-0.00000	3.31278e-6	199.896	-199.896	9.78339e-4
7.70000	-4.06576e-16	0.700000	1.00000	-0.00000	2.90362e-6	199.853	-199.853	1.87734e-4
8.40000	-4.06576e-16	1.40000	1.00000	-0.00000	3.04931e-6	199.690	-199.690	-0.000603730
9.10000	-4.06576e-16	2.10000	1.00000	-0.00000	3.75649e-6	199.278	-199.278	-0.00144128
9.80000	-3.08998e-16	2.80000	1.00000	-0.00000	5.09622e-6	198.316	-198.316	-0.00238518
10.5000	-8.13152e-17	3.50000	1.00000	-0.00000	7.06330e-6	196.172	-196.172	-0.00316025
11.2000	1.46367e-16	4.20000	1.00000	-0.00000	9.29121e-6	191.784	-191.784	-0.00286609
11.9000	3.74050e-16	4.90000	1.00000	-0.00000	8.43755e-6	184.424	-184.424	0.0218234
12.6000	2.84603e-16	5.60000	1.00000	-0.00000	-1.02829e-4	150.703	-150.703	0.115639
13.3000	1.42302e-16	6.30000	1.00000	-0.00000	1.72624e-4	116.347	-116.347	0.0143037
14.0000	0.00000	7.00000	1.00000	-0.00000	1.23501e-4	89.3916	-89.3915	-0.0773936

Field postprocessing: Get Numbers

6. Local values



7. Integral values



Calculation Capacitance

By Charge and Voltage

$$C = \frac{q}{U}$$

Where:

C is the capacitance,
 q is the total charge of one
conductor,
 U is the potential difference
between conductors

By Energy and Voltage

$$C = \frac{2W}{U^2}$$

Where:

C is the capacitance,
 W is the total energy of electric field,
 U is the potential difference
between conductors

Calculation Capacitance

By Charge and Voltage

By Energy and Voltage

$$C = \epsilon_0 \epsilon \frac{S}{d}$$

$$C = \frac{q}{\Delta U}$$

$$C = \frac{2 W}{U^2}$$

Theory

mm	1000	
ϵ_0	8.8542E-12	F/m
ϵ	4.0000	
d	5	mm
h	10	mm
L	20	mm
S	0.0002	m ²
C	1.4167E-12	F
	1.4167	pF

By Charge and Voltage

Qs	1.6499E-12	C
ΔU	1	V
C	1.6499E-12	F
	1.6499	pF

By Energy and Voltage

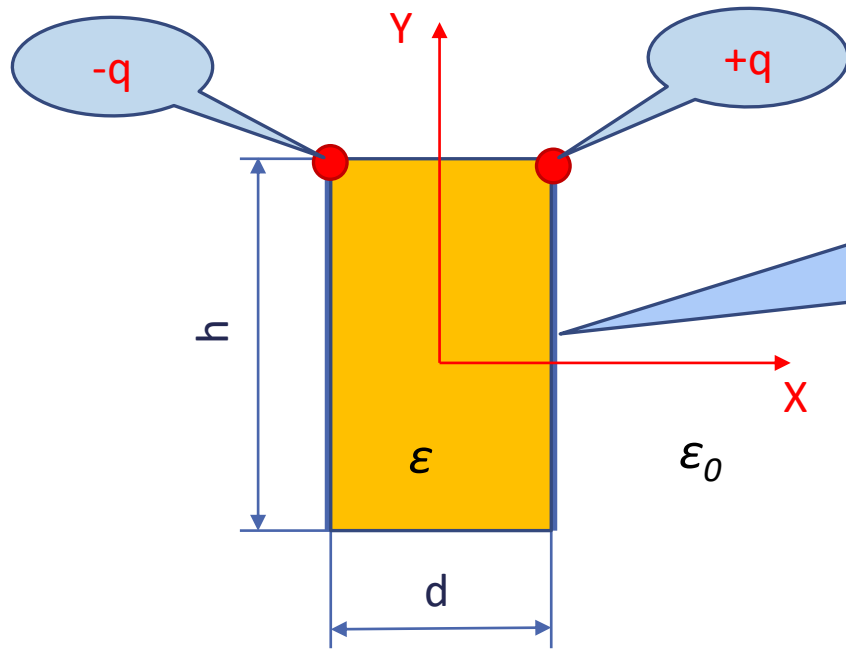
W	8.24E-13	J
C	1.6474E-12	F
	1.6474	pF

What Next?

1. Give the charge, measure the voltage ($q \rightarrow U$)
2. Benefit from problem symmetry.
How to modify boundary conditions?
3. How to know the maximal electric field?
Make the model a bit more realistic.
4. What if we have more than two conductors?
Calculation of the capacitance matrix.
5. How to apply an external field?
A trick with coordinate dependent Dirichlet boundary condition.
6. ELECTROSTATIC SUMMARY:
Equation, boundary conditions, calculated field quantities

Calculation Capacitance

Give the charge, measure voltage



The conductor's potential is equal (as with any conductor), but its value is unknown

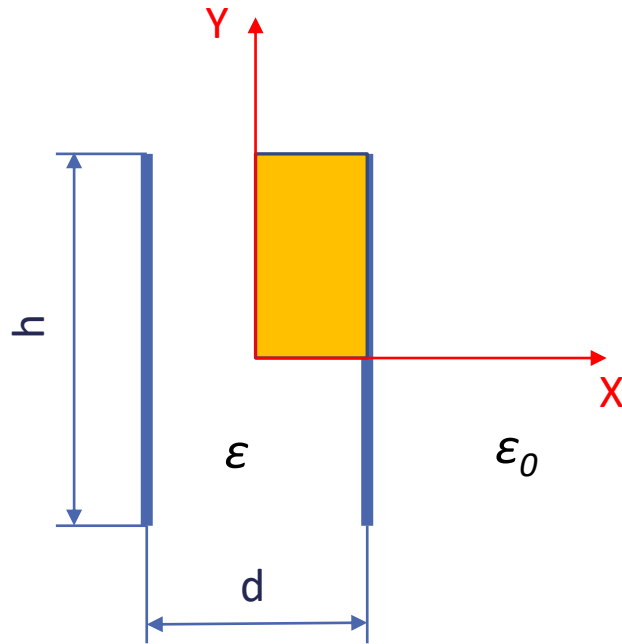
We **assign** the known **charge to any vertex**, belonging to the conductor.

The conductor itself is described as a **floating conductor**. Its potential is subject to calculation

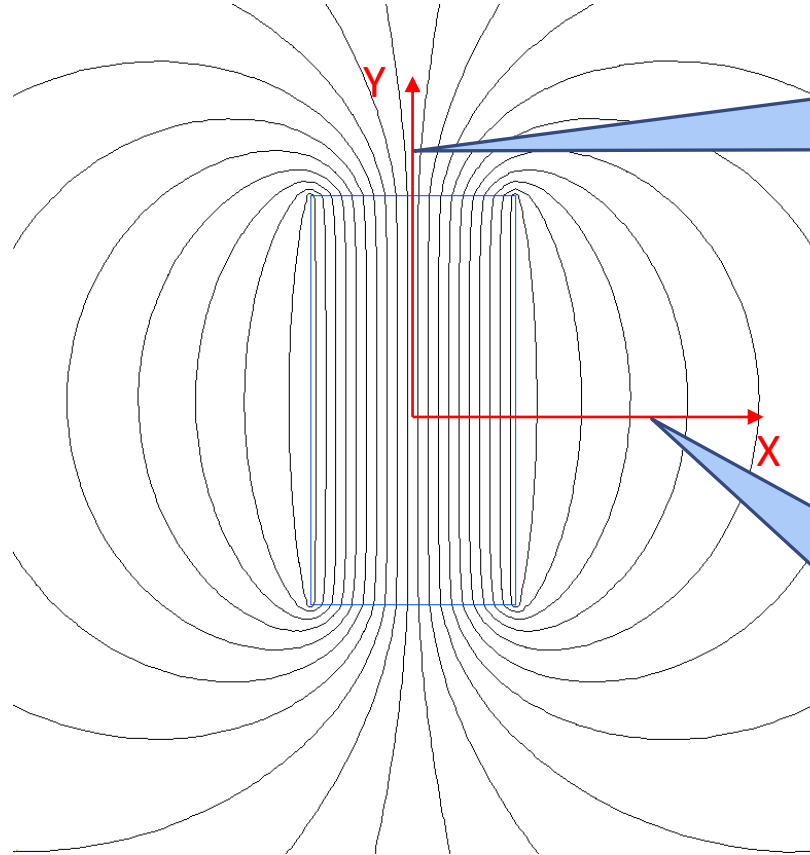
Assigning the charge we have to use the value per 1m of length, no regards of the actual model length Z_L

Calculation Capacitance

Employ the symmetry



Removing a part of geometry,
we have to take into account the removed part
by appropriate boundary condition



Vertical wall is
equipotential:
 $U_{\text{vert}} = 0$
(zero Dirichlet condition)

Horizontal wall is normal to
the equipotential lines:
 $\frac{\partial U}{\partial n} = 0$
(zero Neumann condition)

Using the Capacitance Wizard

Capacitance Calculation Wizard

Completing the Capacitance Wizard

You have successfully calculated capacitance of your conductors.

Voltage $U =$ (V)

Charge $Q =$ (C)

Energy $W =$ (J)

Capacitance

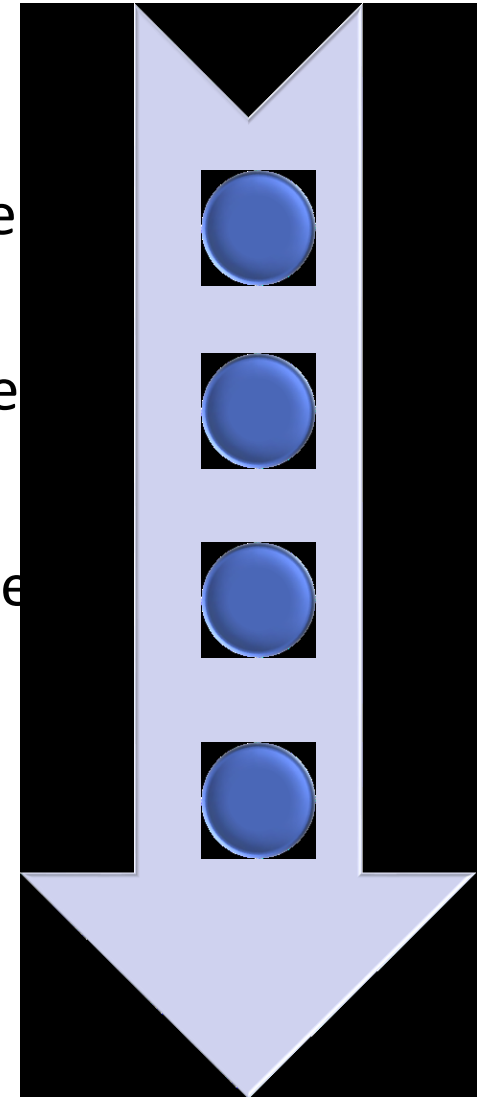
From charge: $C =$ (F)

From energy: $C =$ (F)

< Back Finish Cancel Help

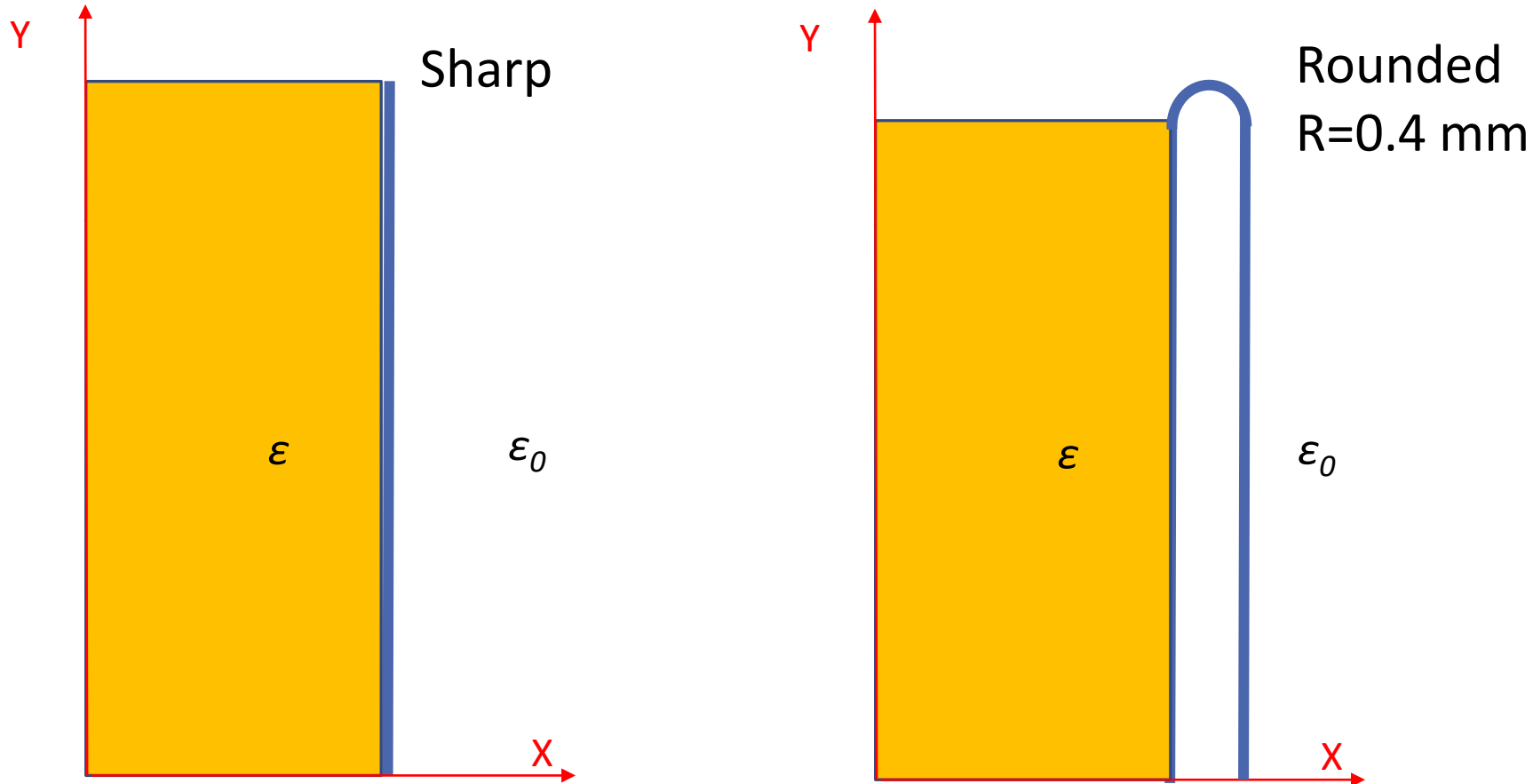
PAGES:

1. Welcome
2. Electrode
3. Charge/Ene
4. Results

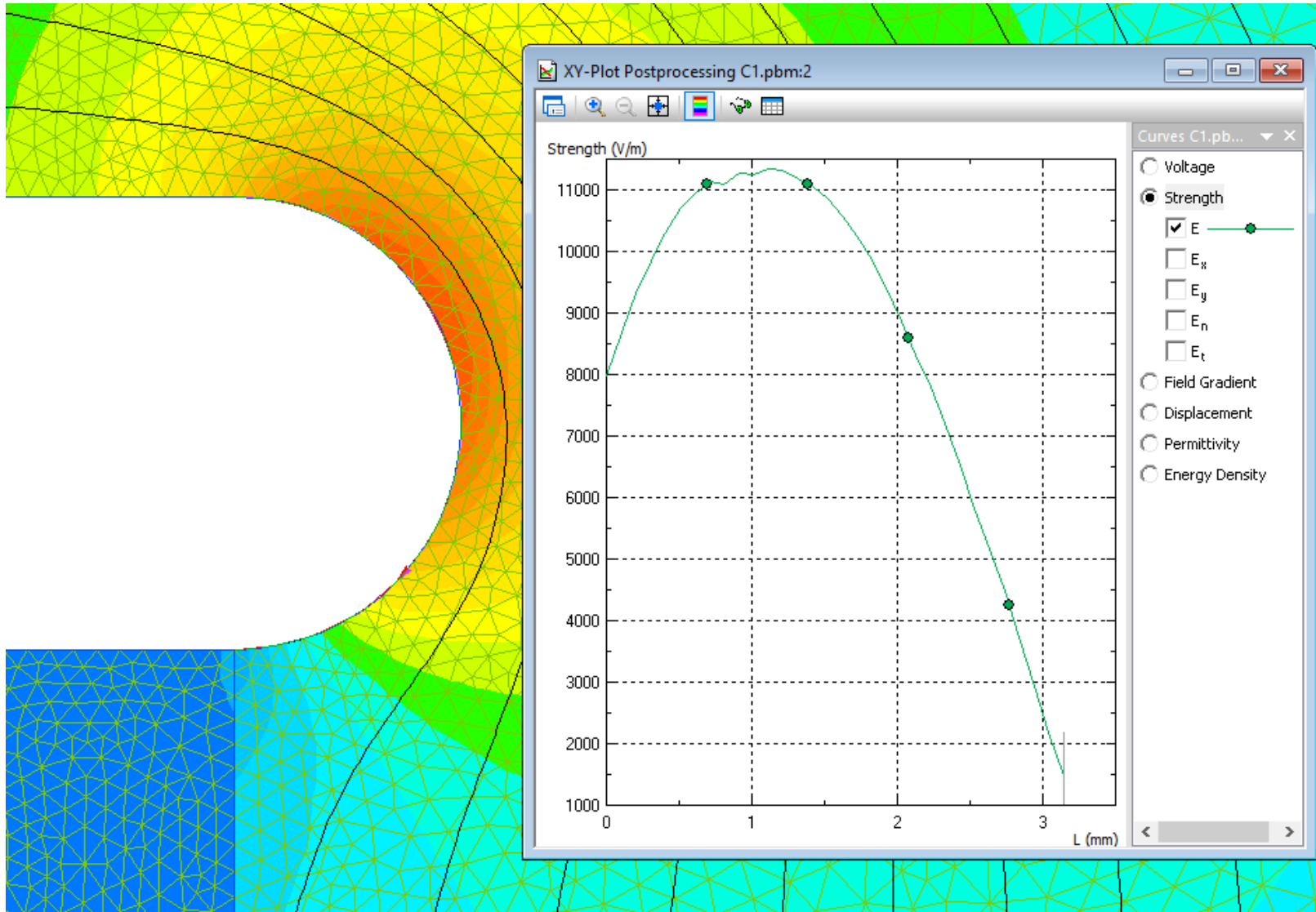


Maximal Electric Field

Field E near the sharp edge is theoretically infinite big



Maximal Electric Field

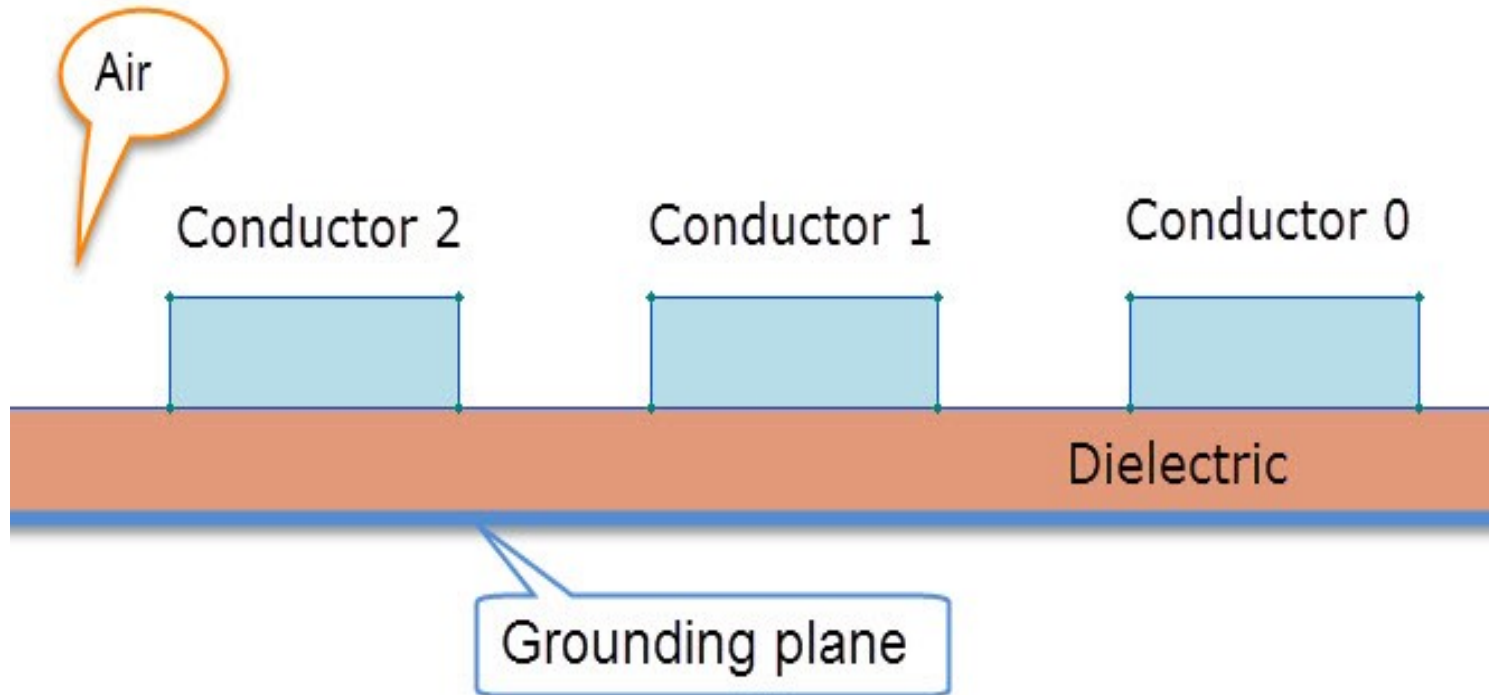


The mesh density near the rounded corner is vitally important for accuracy of **E**-field

Electrostatics: Summary

3. Calculated quantities: Capacitance matrix

What is the capacitance when we have more than one conductor?



Electrostatic induction coefficients

$$\begin{bmatrix} q_0 \\ q_1 \\ q_2 \end{bmatrix} = \begin{bmatrix} \beta_{00} & \beta_{01} & \beta_{02} \\ \beta_{10} & \beta_{11} & \beta_{12} \\ \beta_{20} & \beta_{21} & \beta_{22} \end{bmatrix} \cdot \begin{bmatrix} U_0 \\ U_1 \\ U_2 \end{bmatrix}$$

Electrostatics: Summary

3. Calculated quantities: Capacitance matrix

Two equivalent forms of the capacitance matrix

Electrostatic induction coefficients

$$\begin{bmatrix} q_0 \\ q_1 \\ q_2 \end{bmatrix} = \begin{bmatrix} \beta_{00} & \beta_{01} & \beta_{02} \\ \beta_{10} & \beta_{11} & \beta_{12} \\ \beta_{20} & \beta_{21} & \beta_{22} \end{bmatrix} \cdot \begin{bmatrix} U_0 \\ U_1 \\ U_2 \end{bmatrix}$$

Self- and mutual partial capacitances

$$\begin{bmatrix} q_0 \\ q_1 \\ q_2 \end{bmatrix} = \begin{bmatrix} C_{00} & C_{01} & C_{02} \\ C_{10} & C_{11} & C_{12} \\ C_{20} & C_{21} & C_{22} \end{bmatrix} \cdot \begin{bmatrix} U_0 & U_0 - U_1 & U_0 - U_2 \\ U_1 - U_0 & U_1 & U_1 - U_2 \\ U_2 - U_0 & U_2 - U_1 & U_2 \end{bmatrix}$$

B_{nk} can be negative

C_{nk} is always positive

Capacitance matrix

CMatrix - Capacitance Matrix Calculator

Choose Problem

- 2.pbm
- Elec2.pbm
- Elec2-3.pbm**

Conductor

☒	conductor 1	
☒	conductor 2	Grounded
☒	conductor 3	
☒	ground	Grounded

Info

Close

Calculate

Help

Energy:

Step 0 Energy W = 4.7699e-007

Step 1 Energy W = 4.6897e-007

Step 2 Energy W = 4.6913e-007

Step 3 Energy W = 8.6336e-007

Step 4 Energy W = 8.6338e-007

Step 5 Energy W = 9.3096e-007

Energy:

	0	1	2
0	4.7699e-007	8.6336e-007	8.6338e-007
1		4.6897e-007	9.3096e-007
2			4.6913e-007

Electrostatic induction coefficients

	0	1	2
0	9.5399e-011	-8.2601e-012	-8.2748e-012
1	-8.2601e-012	9.3793e-011	-7.1342e-013
2	-8.2748e-012	-7.1342e-013	9.3826e-011

Self and mutual partial capacitances

	0	1	2
0	7.8864e-011	8.2601e-012	8.2748e-012
1	8.2601e-012	8.482e-011	7.1342e-013
2	8.2748e-012	7.1342e-013	8.4838e-011

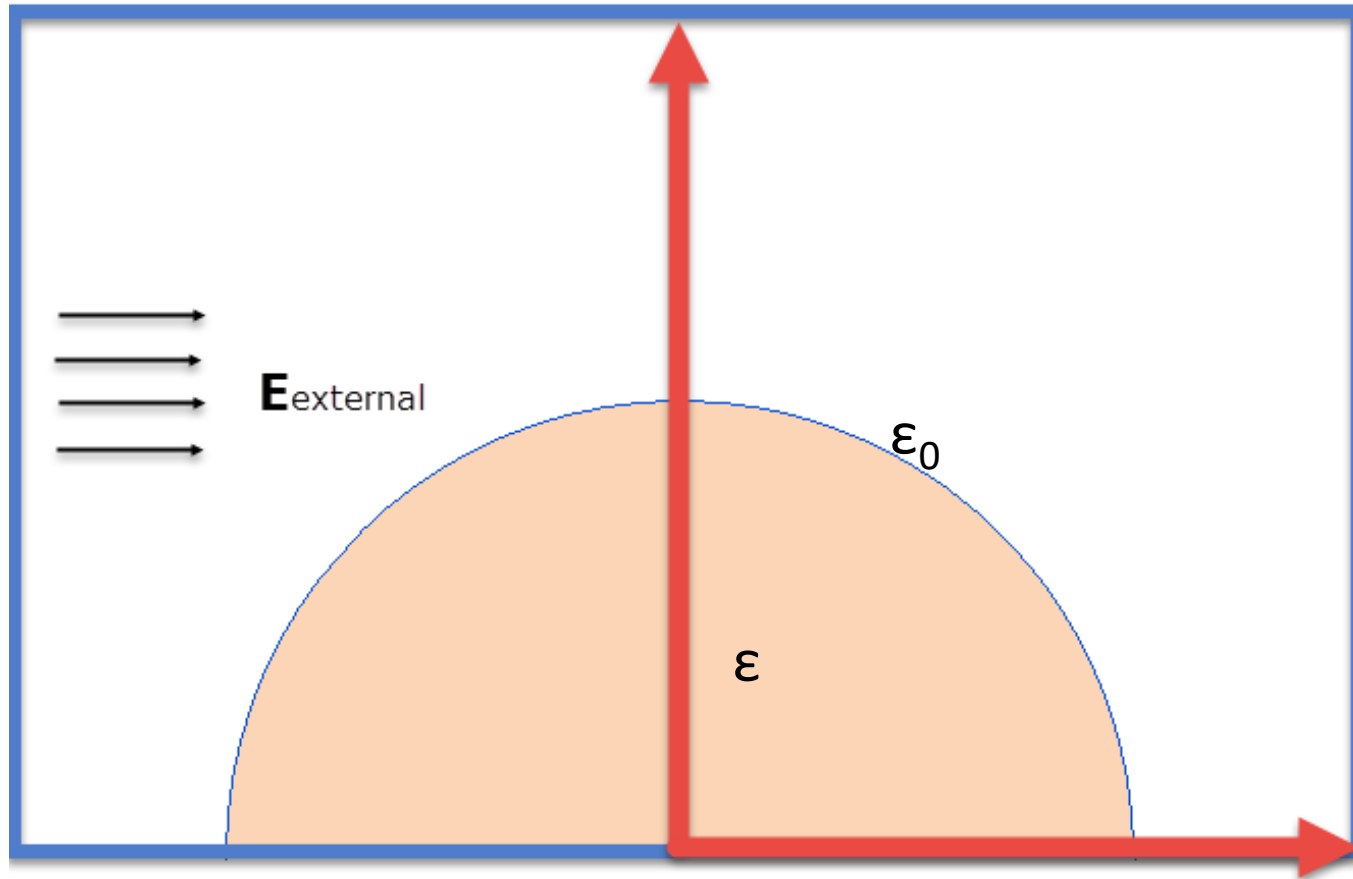
Energy

β_{ij}

C_{ij}

Applying external field by Dirichlet boundary condition

We want to model a dielectric sphere
in an uniform electric field $\mathbf{E} = 5 \text{ V/m}$



$$\mathbf{E} = \text{grad}U \Rightarrow E_z = \frac{\partial U}{\partial z}$$

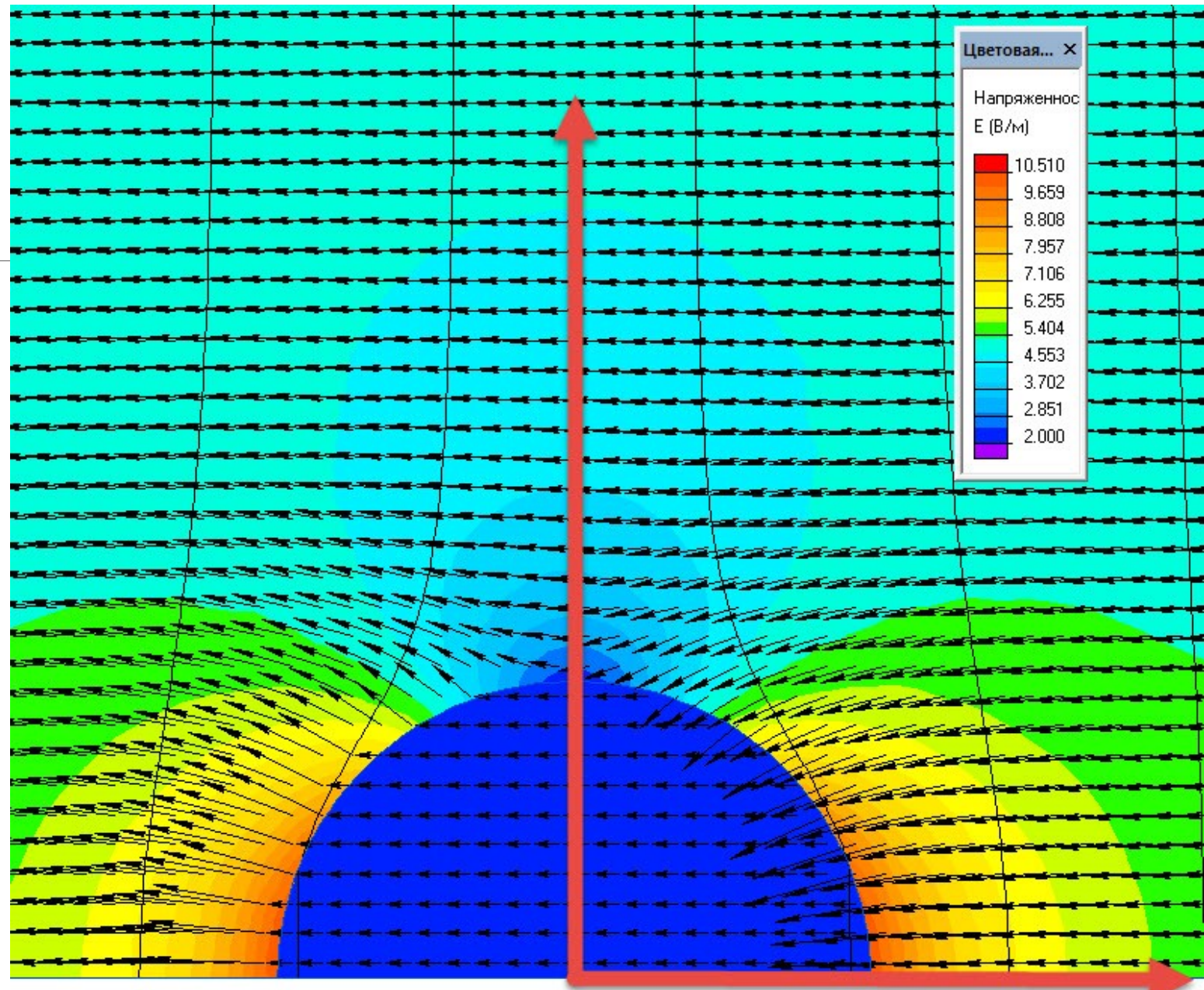
Setting $U=5z$ on the all outer boundary,
we obtain $\mathbf{E}_z = d(5z)/dz = 5 \text{ V/m}$

$U = 5 \cdot z$

Electrostatics: Summary

Analytical solution for the
E-field inside the sphere:

$$E_z = E_0 \frac{3\epsilon_0}{2\epsilon_0 + \epsilon_{sphere}} =$$
$$= 5 \frac{3}{2 + 4} = 2.5 \frac{V}{m}$$



Electrostatics: Summary

1. The Poisson Equation

$$\text{div}(\varepsilon \cdot \text{grad}U) = -\rho$$

Poisson equation
(coordinate independent form)

$$\frac{\partial}{\partial x} \left(\varepsilon_x \frac{\partial U}{\partial x} \right) + \frac{\partial}{\partial y} \left(\varepsilon_y \frac{\partial U}{\partial y} \right) = -\rho$$

In Cartesian coordinates (x, y)

$$\frac{1}{r} \frac{\partial}{\partial r} \left(\varepsilon_r r \frac{\partial U}{\partial r} \right) + \frac{\partial}{\partial z} \left(\varepsilon_z \frac{\partial U}{\partial z} \right) = -\rho$$

In cylindrical coordinates (r, z)

Electrostatics: Summary

2. Boundary Conditions

$$U = U_0(x, y)$$

Dirichlet Condition: the known potential
(may depend on coordinates)

$$D_n = \varepsilon \frac{\partial U}{\partial n} = \sigma(x, y)$$

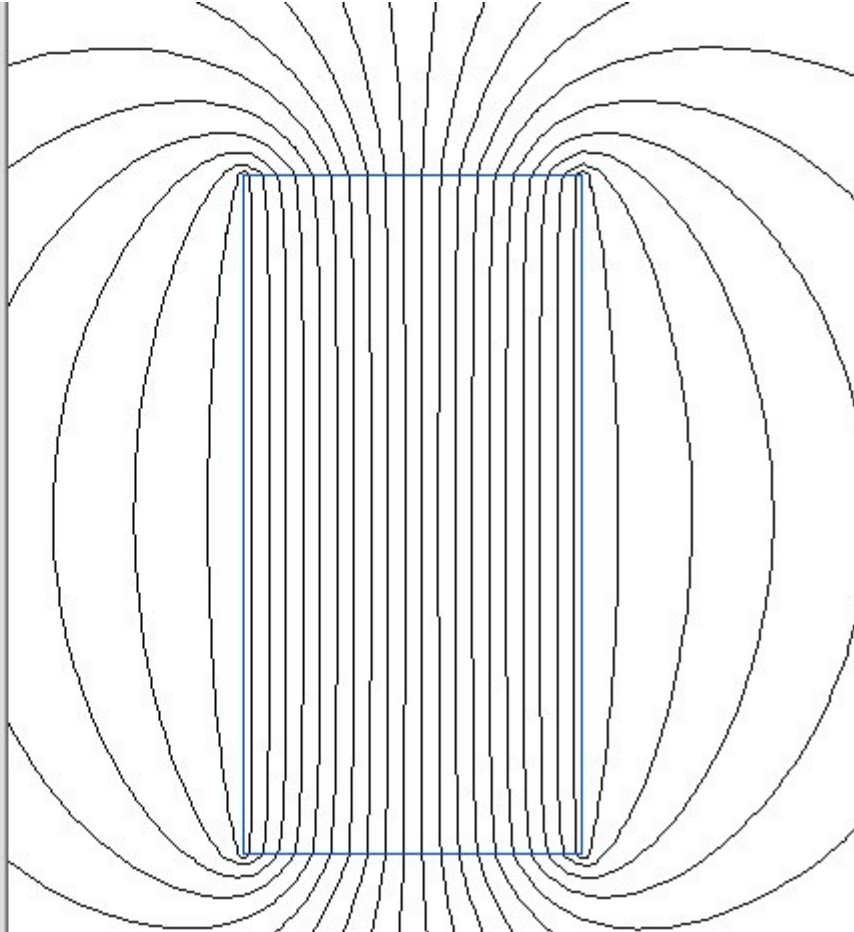
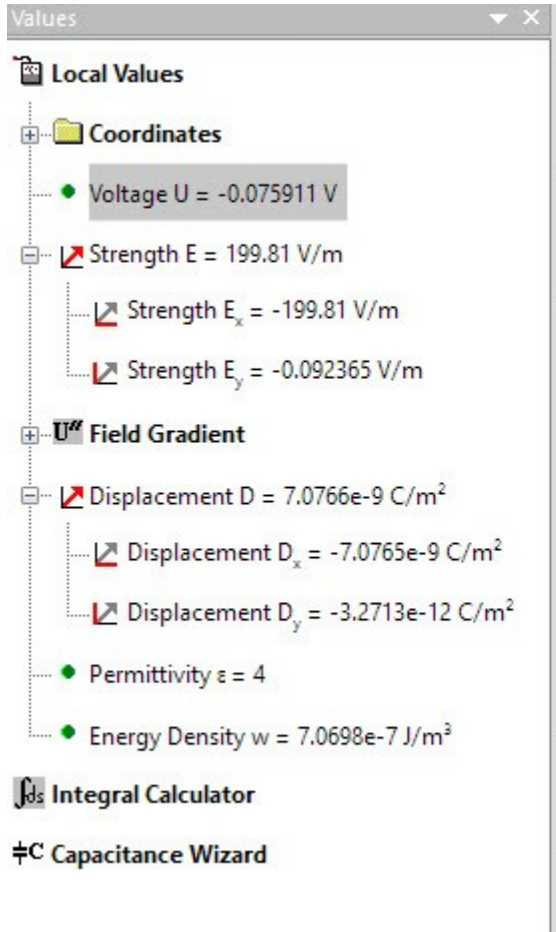
Neumann condition: the known value of
normal potential gradient

$$U = \text{const} = \text{unknown}$$

Floating conductor:
A special type of Dirichlet condition

Electrostatics: Summary

3. Calculated quantities: Locals



Strength $\mathbf{E} = -\text{grad}U$

Displacement $\mathbf{D} = \epsilon\mathbf{E}$

Energy density $w = \frac{\mathbf{D} \cdot \mathbf{E}}{2}$