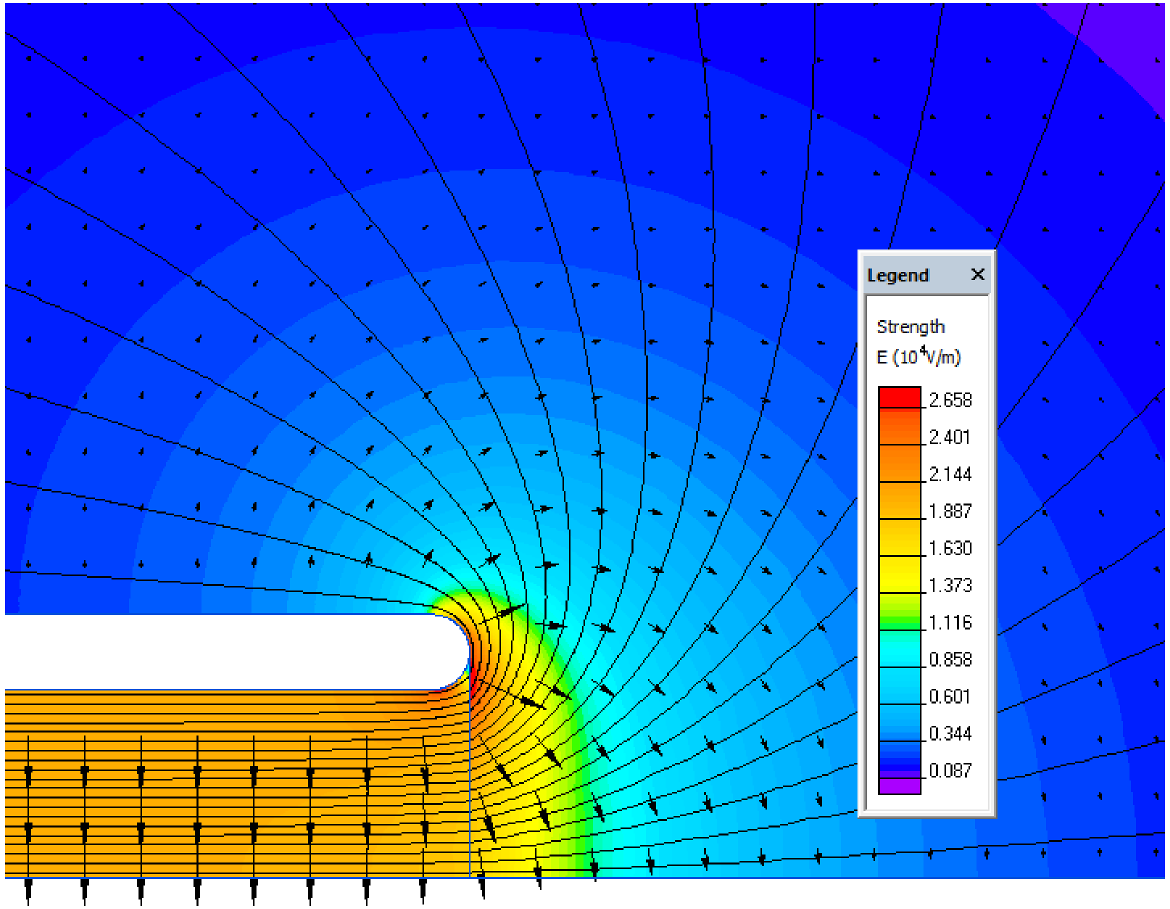
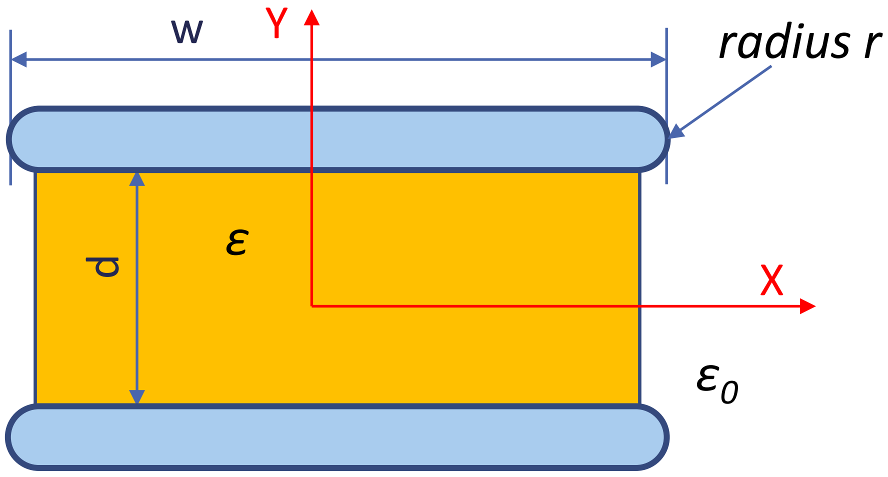
ELECTROSTATICS

How to do your first QuickField project



Plane capacitor

We want to know: the capacitance C, the field $\mathbf{E}_c$ in the center, maximal field E_{max}

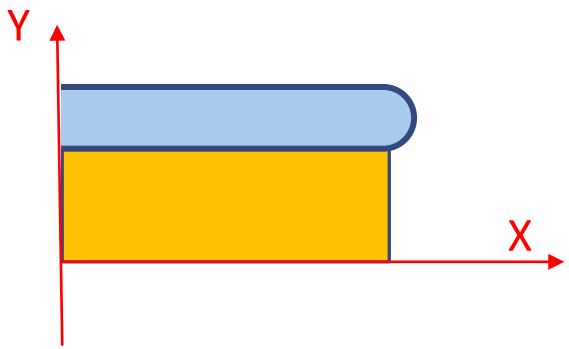


Formulation: Electrostatic field

Geometry class: Plane-parallel 2D problem

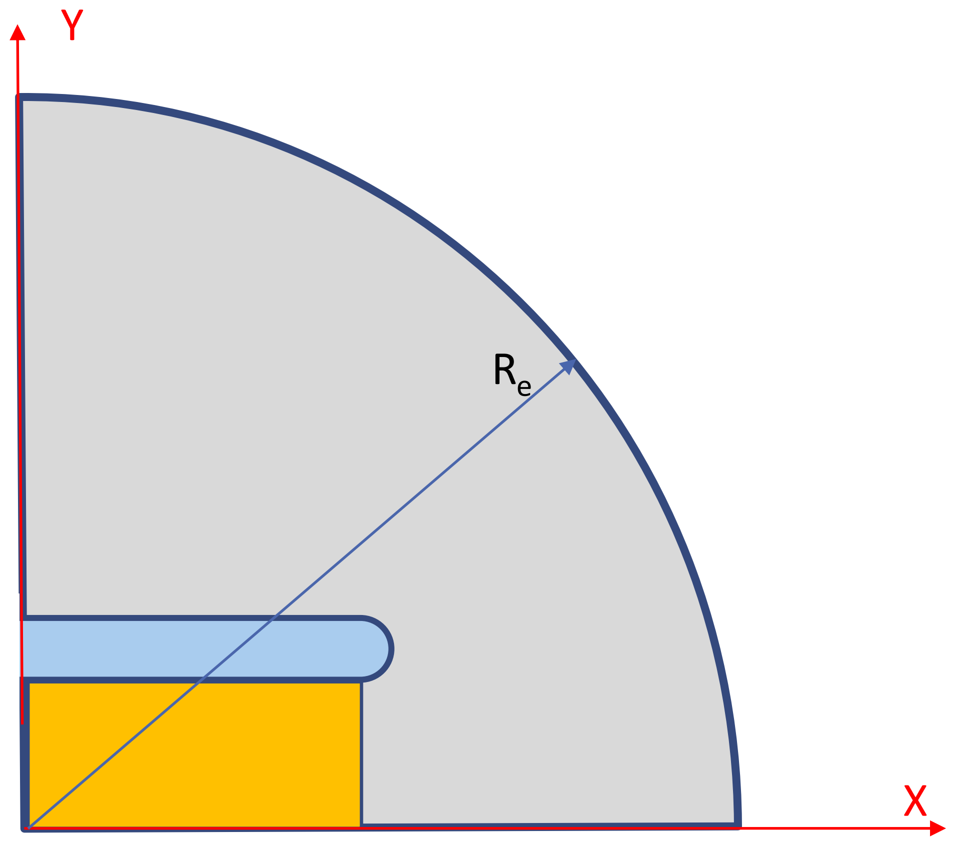
Parameter	Notation
Distance between plates	d
Width	w
Axial length	Z_L
Radius	r
Dielectric permittivity	ε

Due to symmetry we only need ¼ of the model



Setting up the geometry and data

1. Add the artificial outer boundary
2. Replace the discarded part of the universe with the boundary condition
3. Set the material properties



1. Material properties:

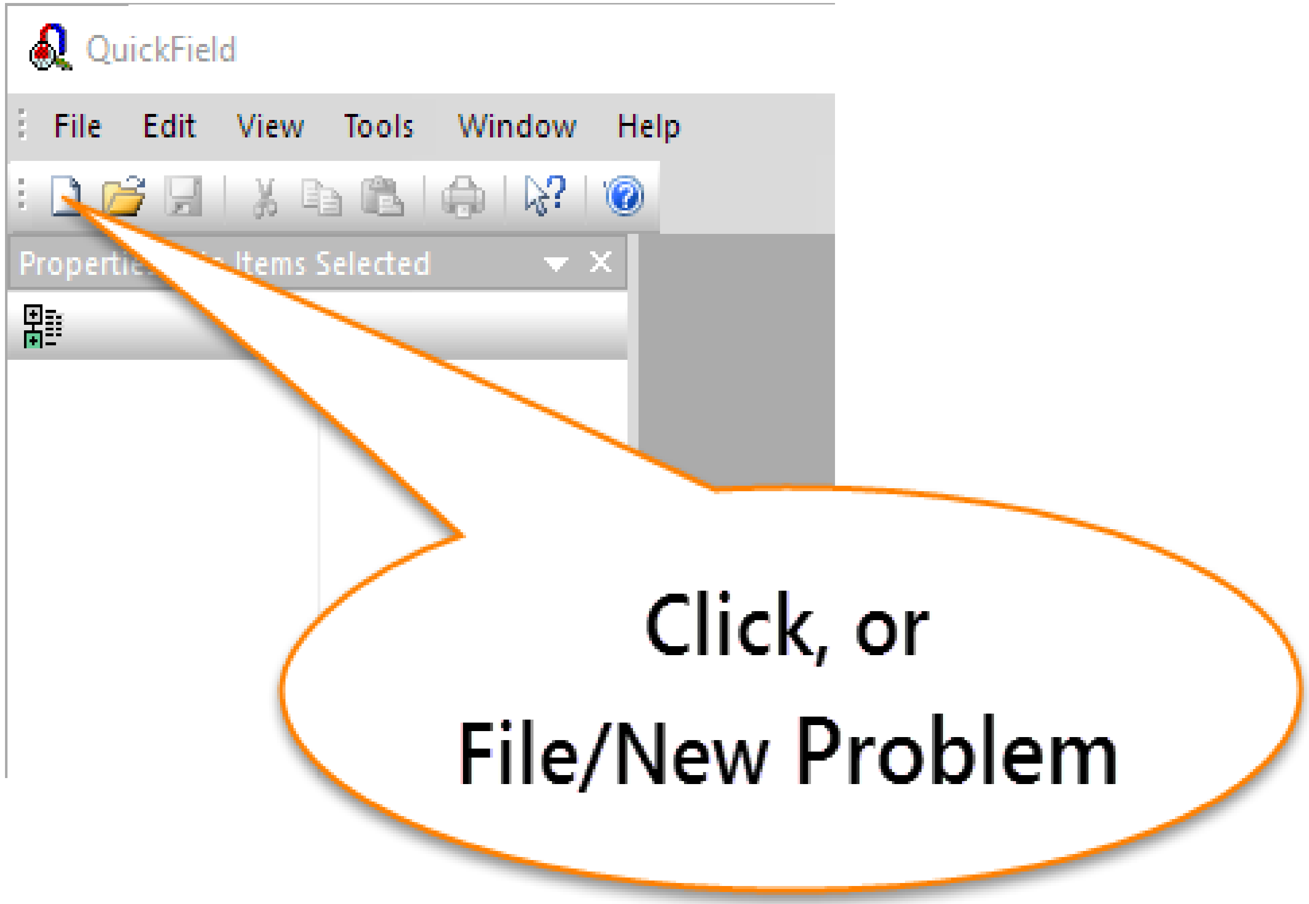
(yellow)	Dielectric	ε
(grey)	Air	ε =1
(blue)	Metal	no ε

2. Boundary conditions:

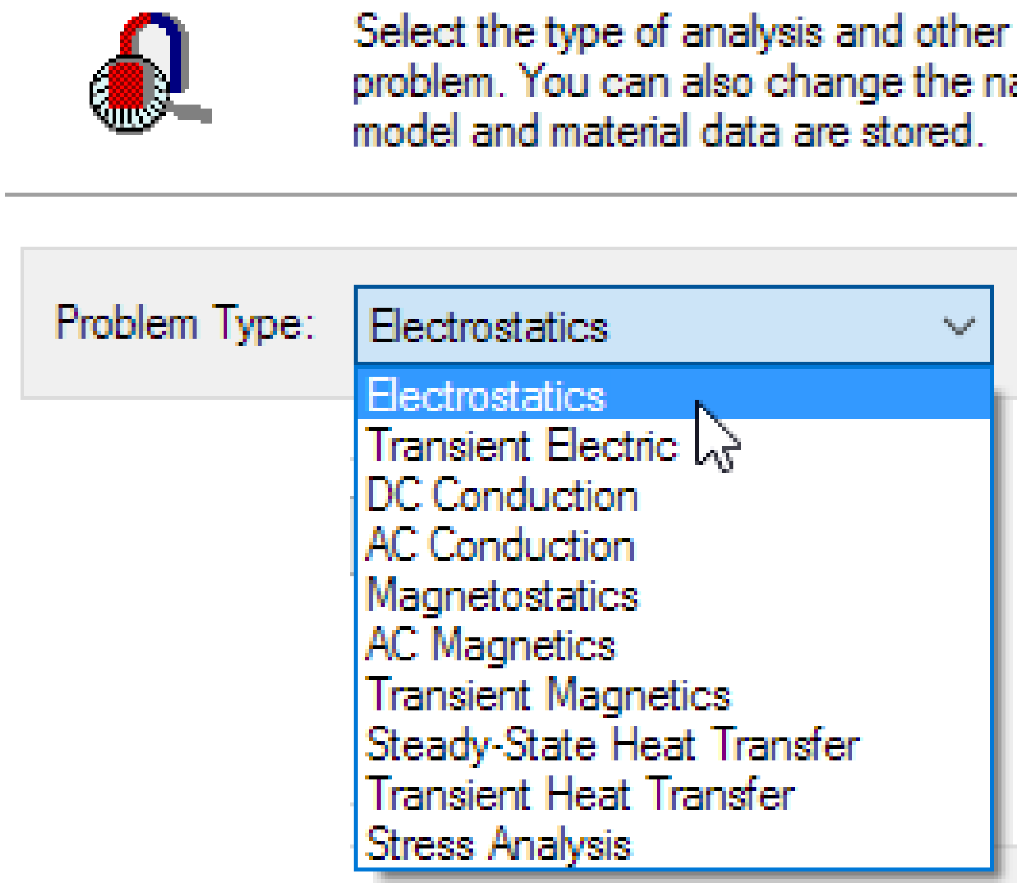
Y-axis	Zero normal field	$\varepsilon \frac{\partial U}{\partial n} = 0$
X-axis	Equipotential U=0	$U = 0$
Far external boundary	No field there. What does it mean?	Either of two above

Getting started: Create a new problem

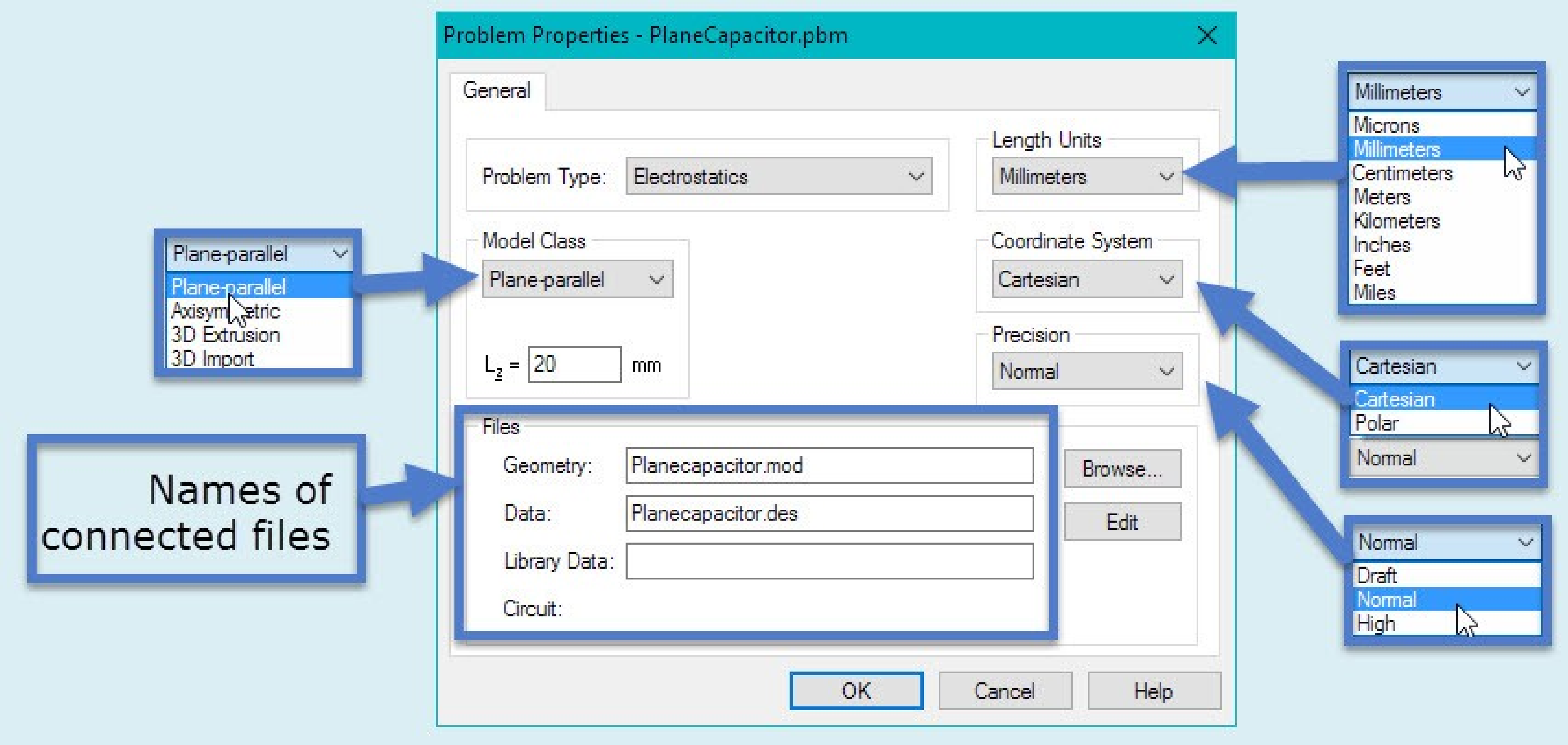
1. Create the new problem and name it



2. Select the problem formulation: Electrostatics



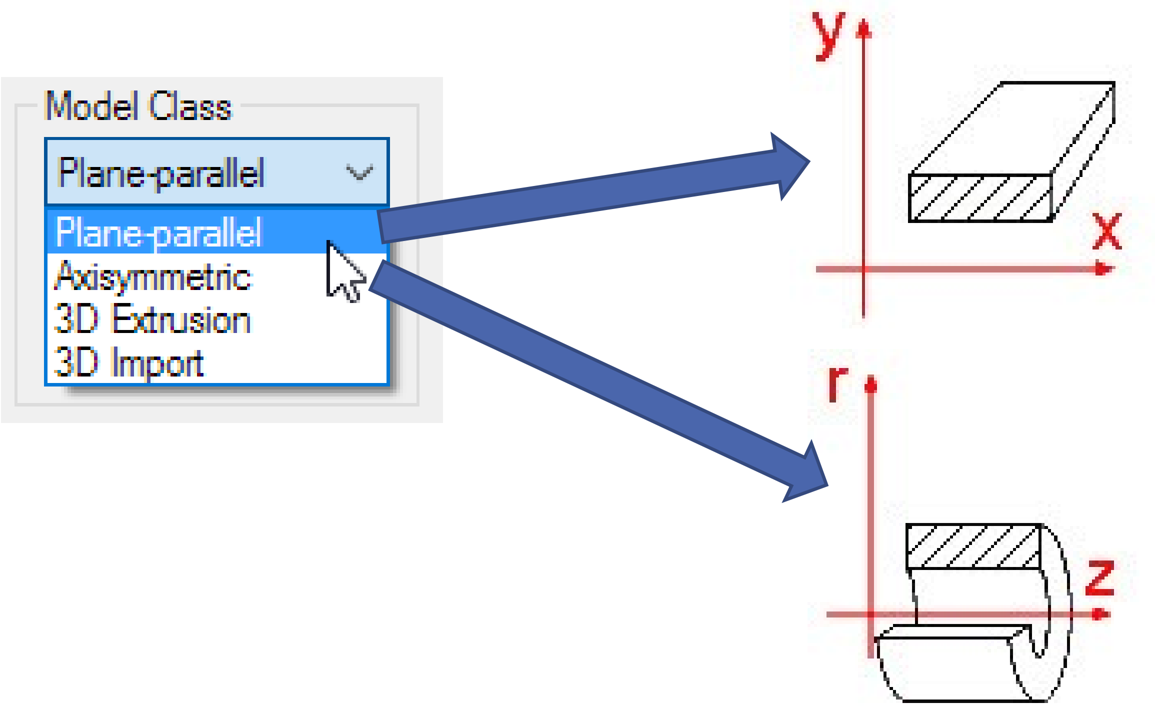
Getting started: Problem properties



Getting started: Understanding model class

How the 2D geometry extends in 3D world

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



Plane-parallel:

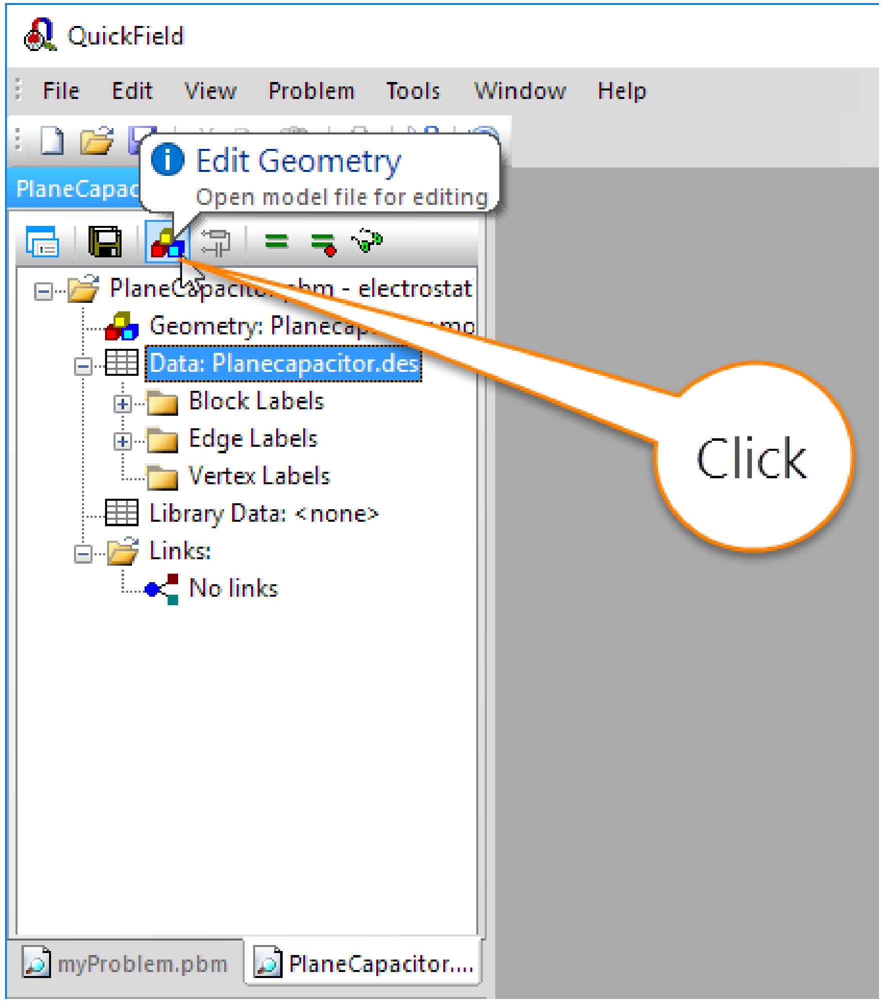
1. Most of physical values are per 1 meter of axial length (in Z-direction)
2. You may define the axial length of the model. If you do that, QuickField calculates all integral quantities with respect to given Z-length

Axisymmetric:

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

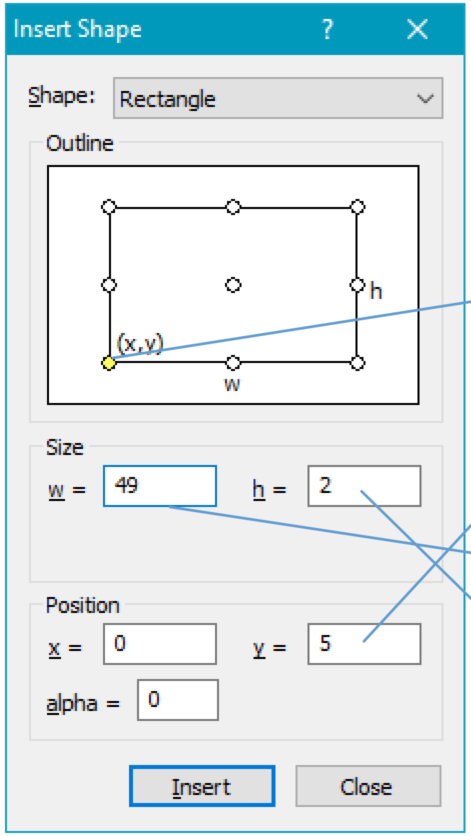
Draw the plane capacitor

1. Open the model editor



2. Draw the rectangle –right half of the upper conductor

Edit / Insert Shape...



Select anchor point

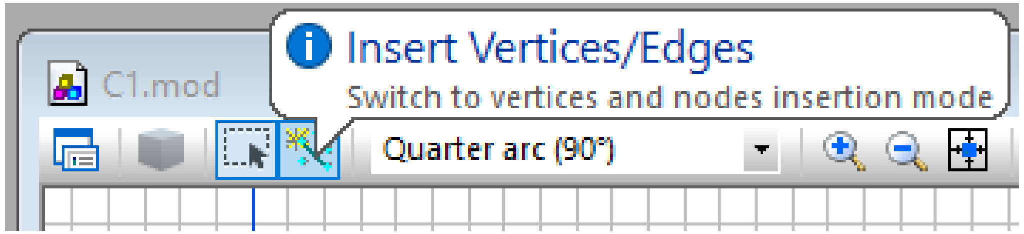
Set anchor point position: y = d/2

width = w/2 - r

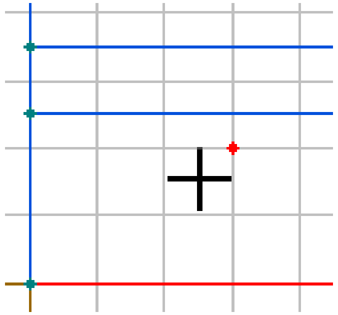
height = 2 r

When drawing: use Snap to grid

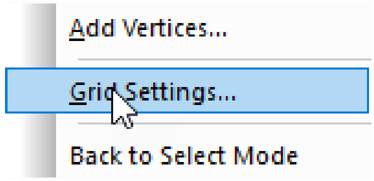
1. To start drawing switch to the [Insert](#) mode: click the toolbar button or press **Ins** key.

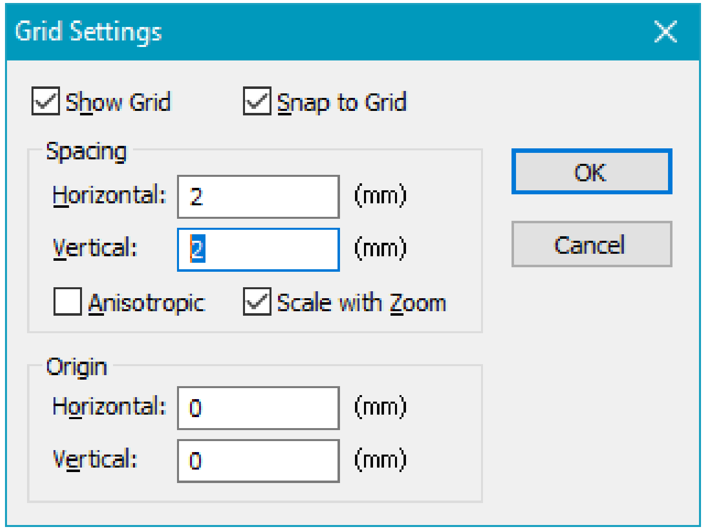


2. In the **Insert** mode the insertion point is aligned to the nodes of grid or to existing shapes.

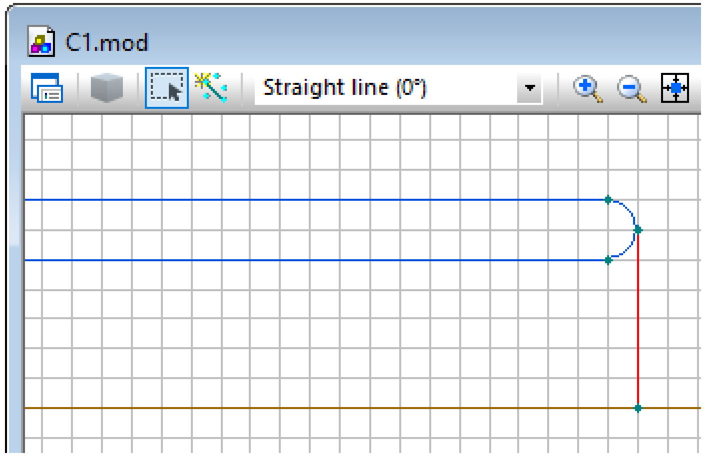


3. You can control the snapping grid, change the grid step, switch snapping on and off. Use the [Grid Settings](#) command from the [View](#) menu or [context](#) menu

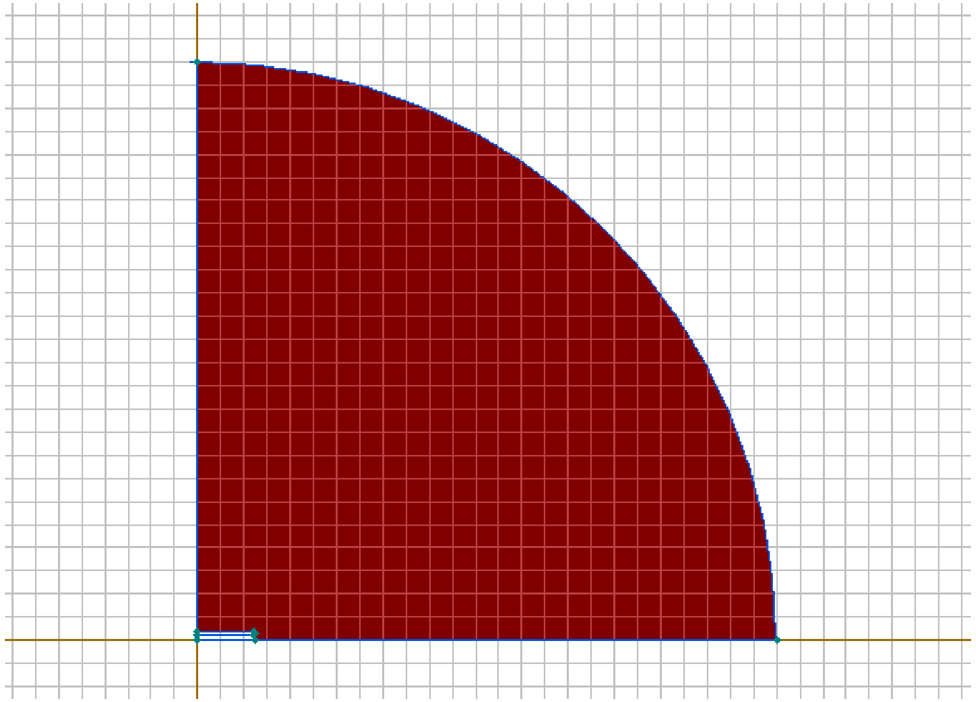




Draw the plane capacitor



1. Create a boundary between air and dielectric: switch to Insert mode, set the arc angle to zero and drag a straight line (shown in red)



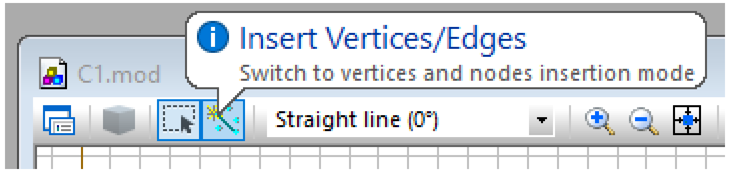
2. Create a quarter-circular artificial outer boundary:
   - Think what radius is enough
   - Create a rectangle
   - Round the corner with an 90-deg arc

3. Remove the unnecessary vertical segment: select and press Del

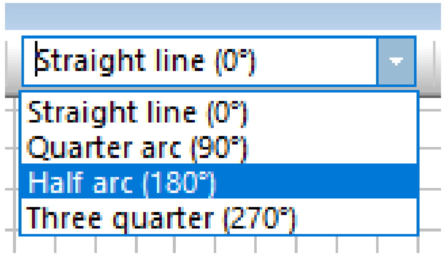
Draw the plane capacitor

To round the conductor's corner:

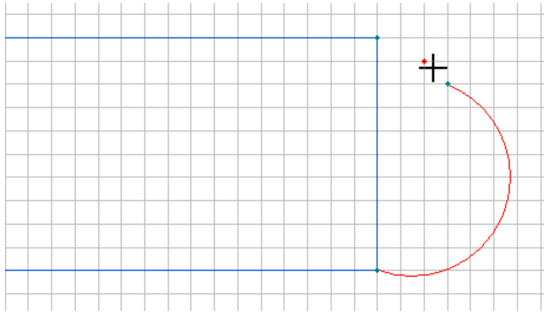
1. Switch to Insert mode



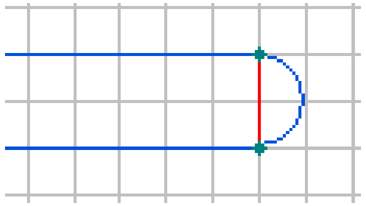
Set the central angle of an arc to 180 degrees:



2. Drag (with left mouse button pressed) from the starting point to the ending point

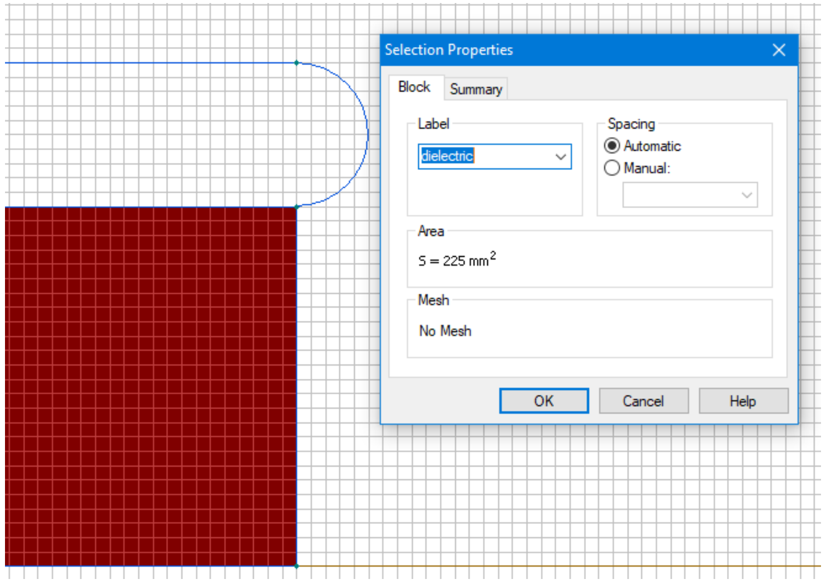


3. Remove the unnecessary vertical segment: select and press Del

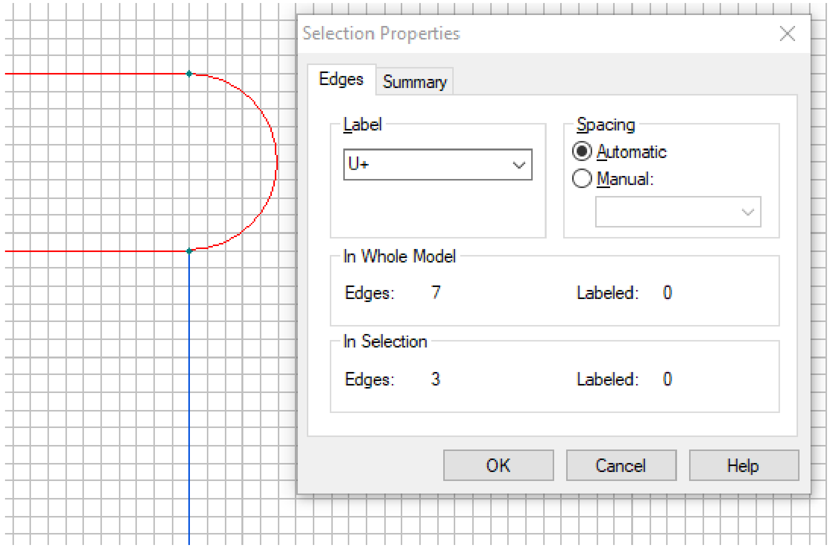


Now it's time to label geometry shapes

1. To label a region (block), select it by a simple click, and go to the Properties window, *either from context menu or press Alt+Enter*

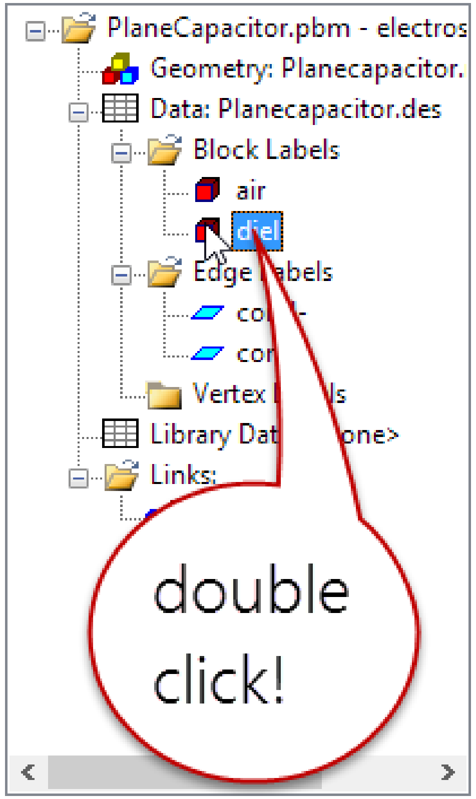


2. To label and edge, select it and bring the Properties window:

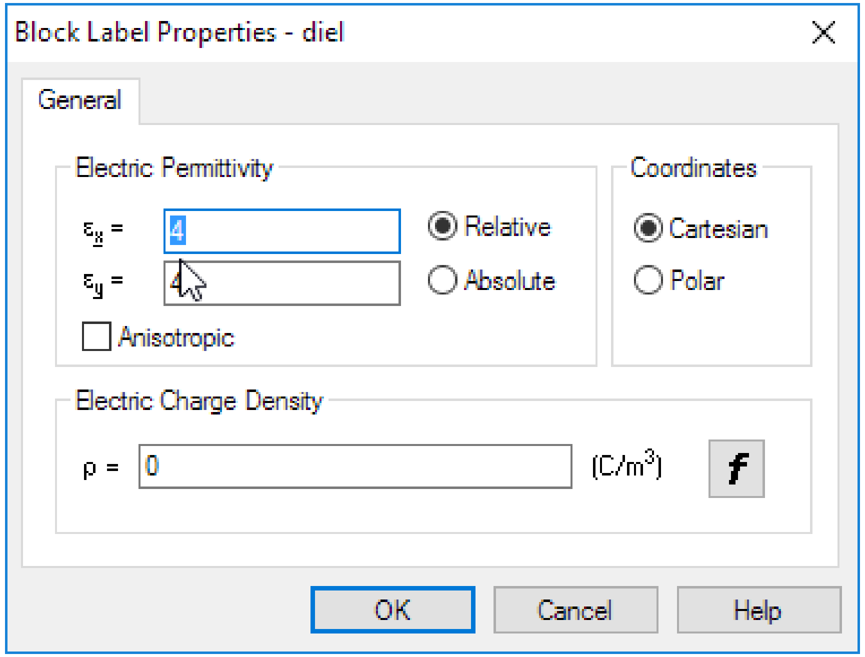


Now set up the physical data: materials and BC

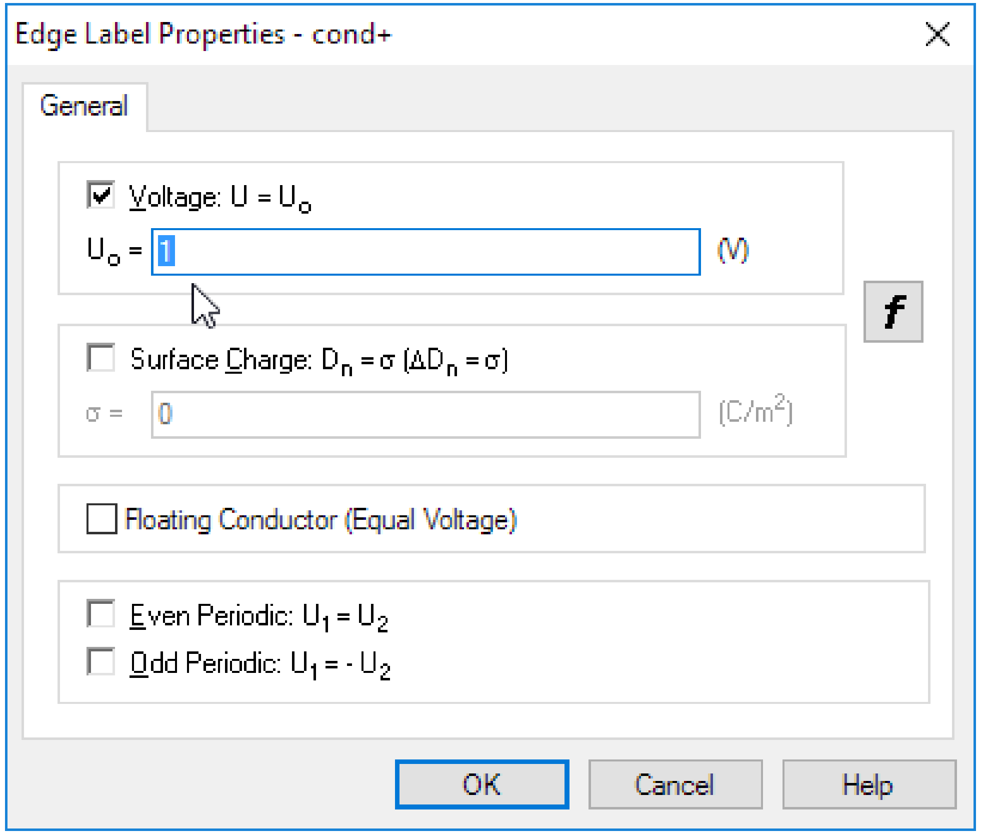
1. Activate label properties



2. Set material property for block labels

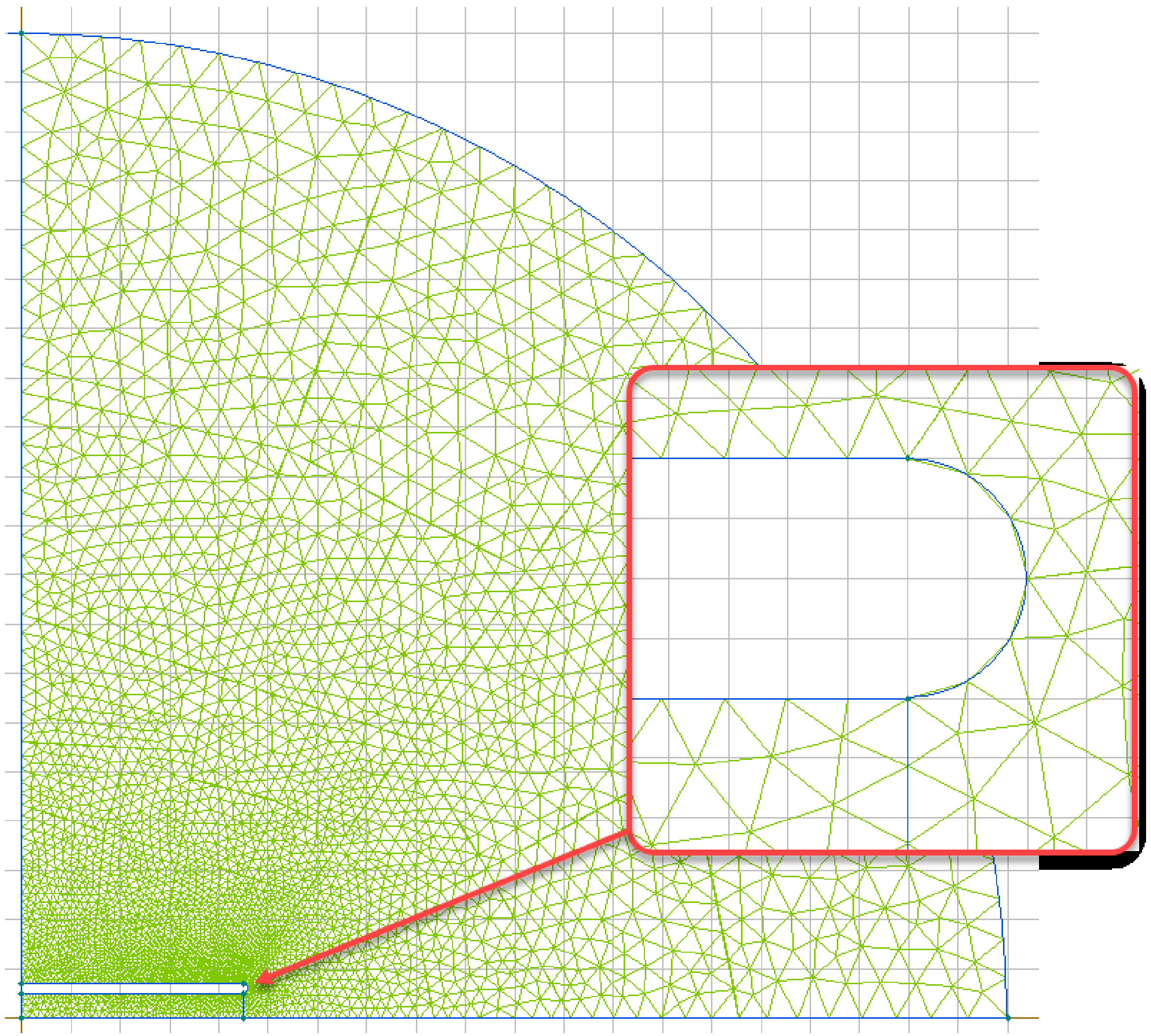


3. Set Dirichlet or Neumann boundary condition



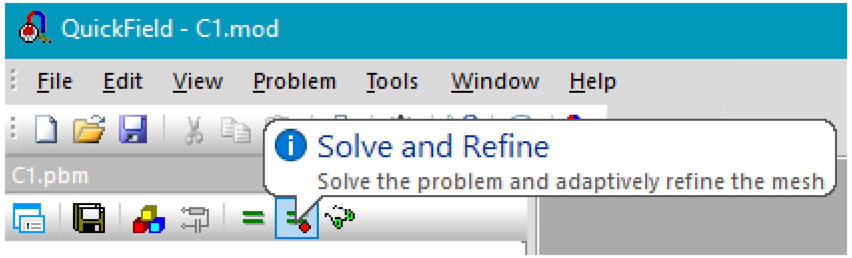
Generate the finite element mesh (triangulate)

The default mesh: Is it mesh density enough or not?

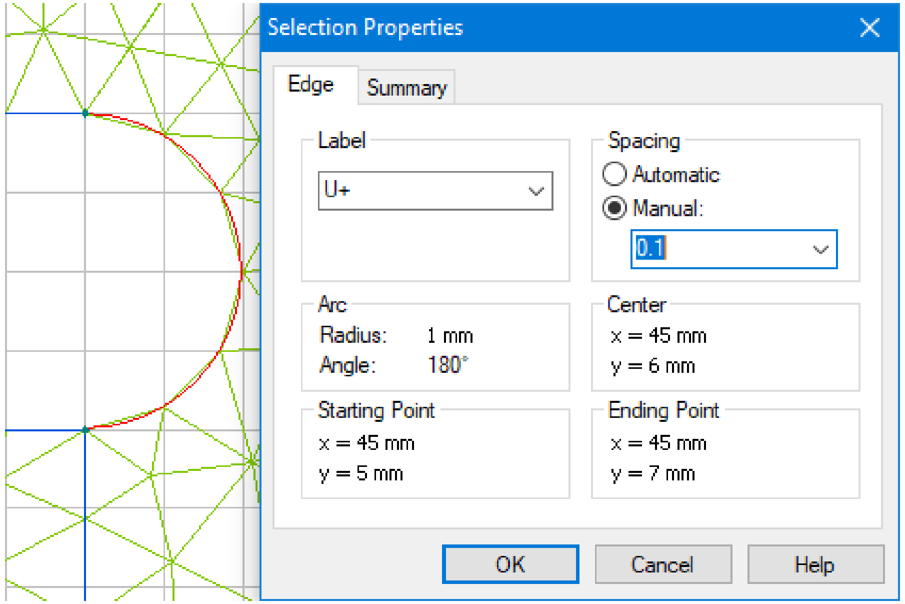


Mesh control options:

1. Automatic mesh adaption (refinement)



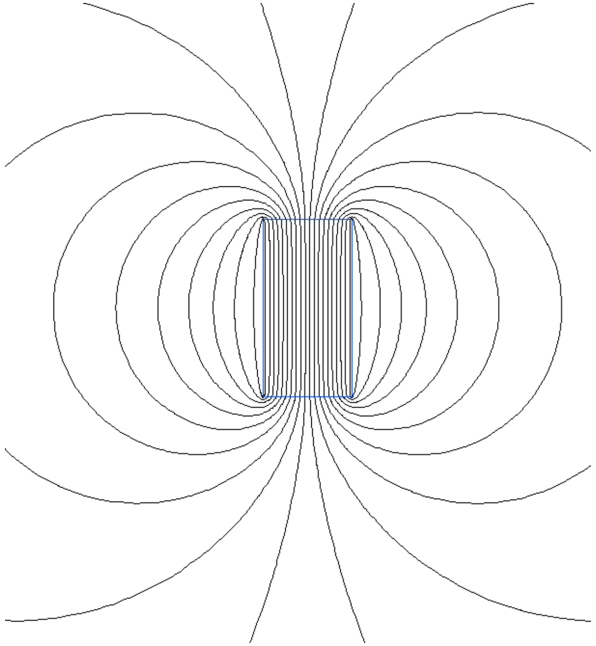
2. Setting the mesh spacing manually



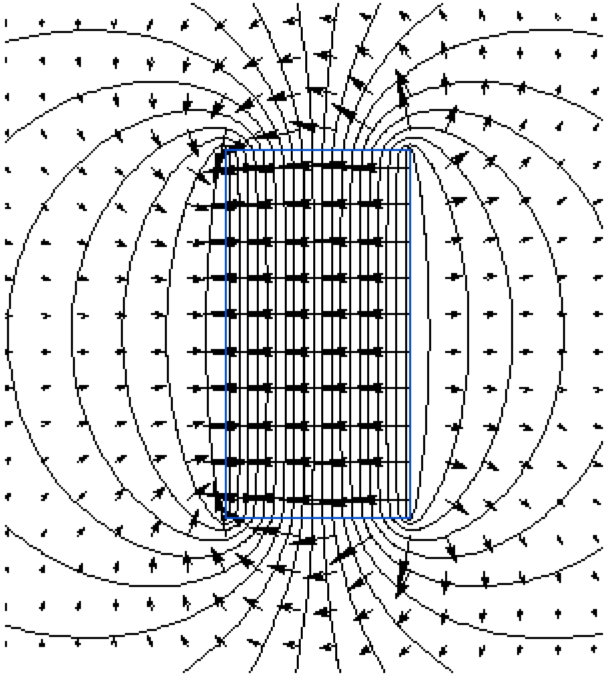
Working with the Field picture

The calculation results may be presented as:

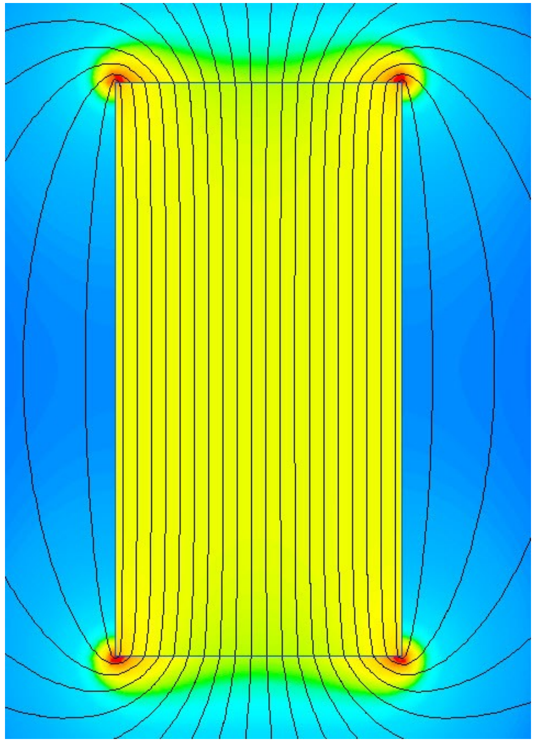
1. Field Lines



2. Vectors

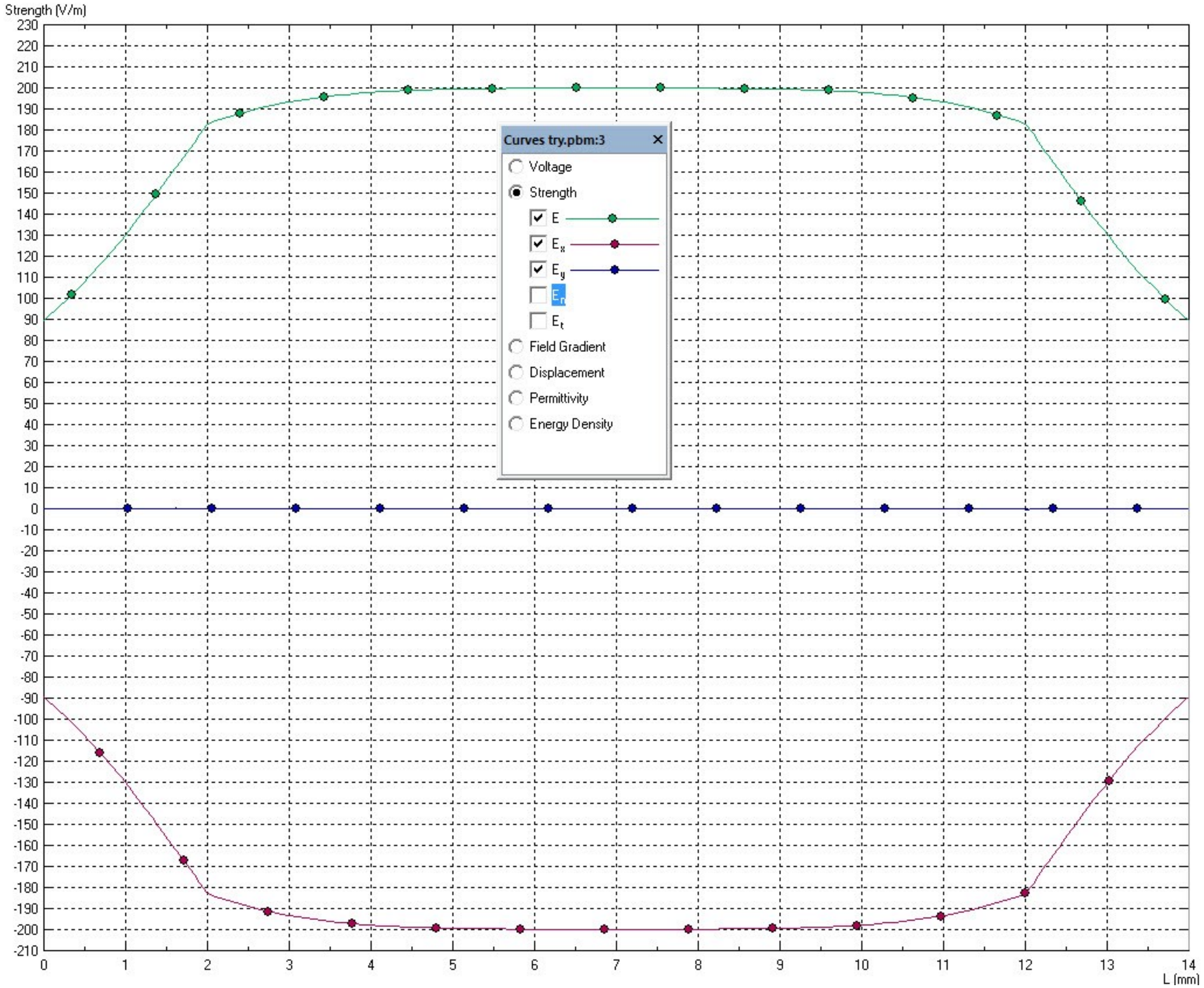


3. Color map



Field postprocessing

4. XY-Plot

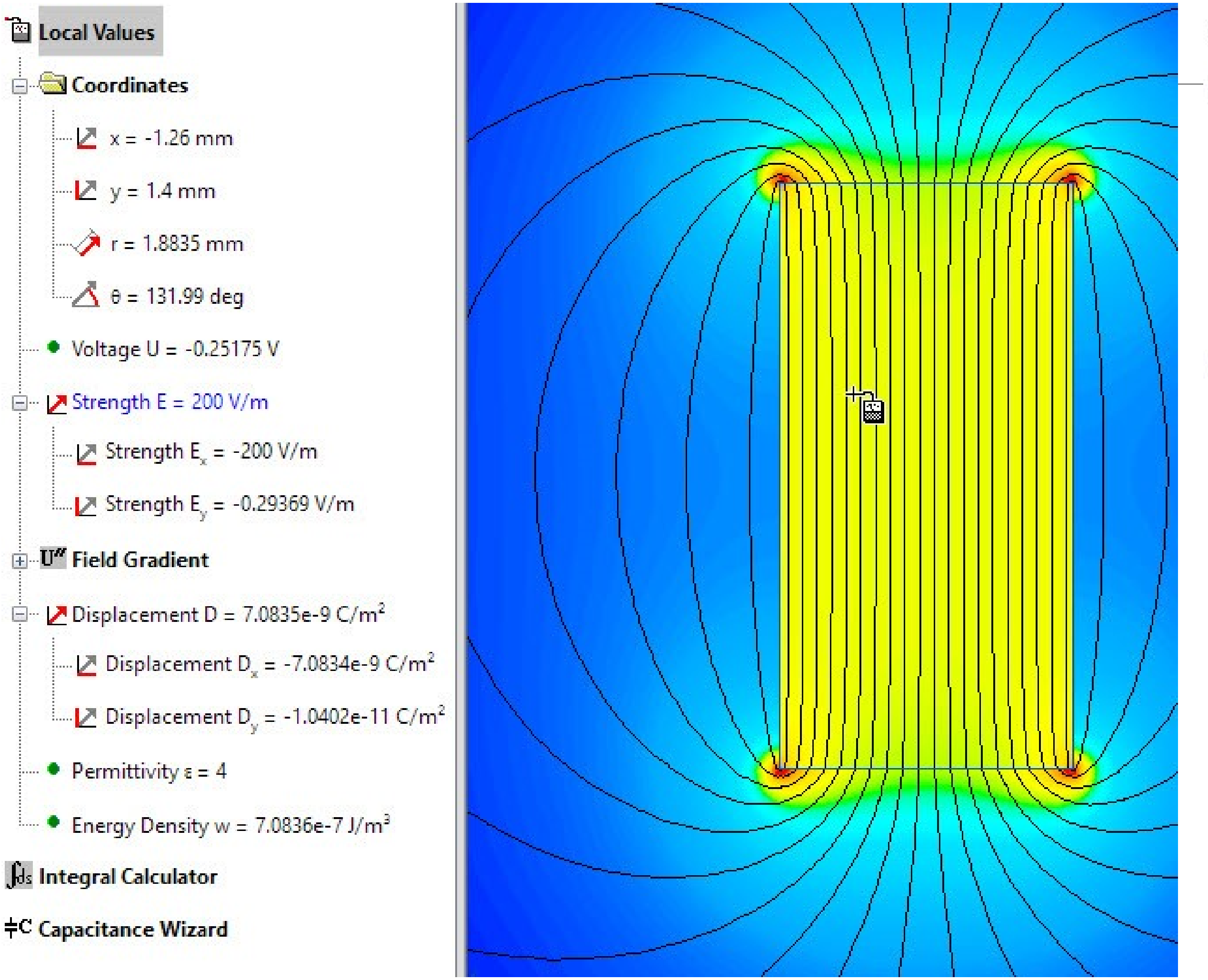


5. Table

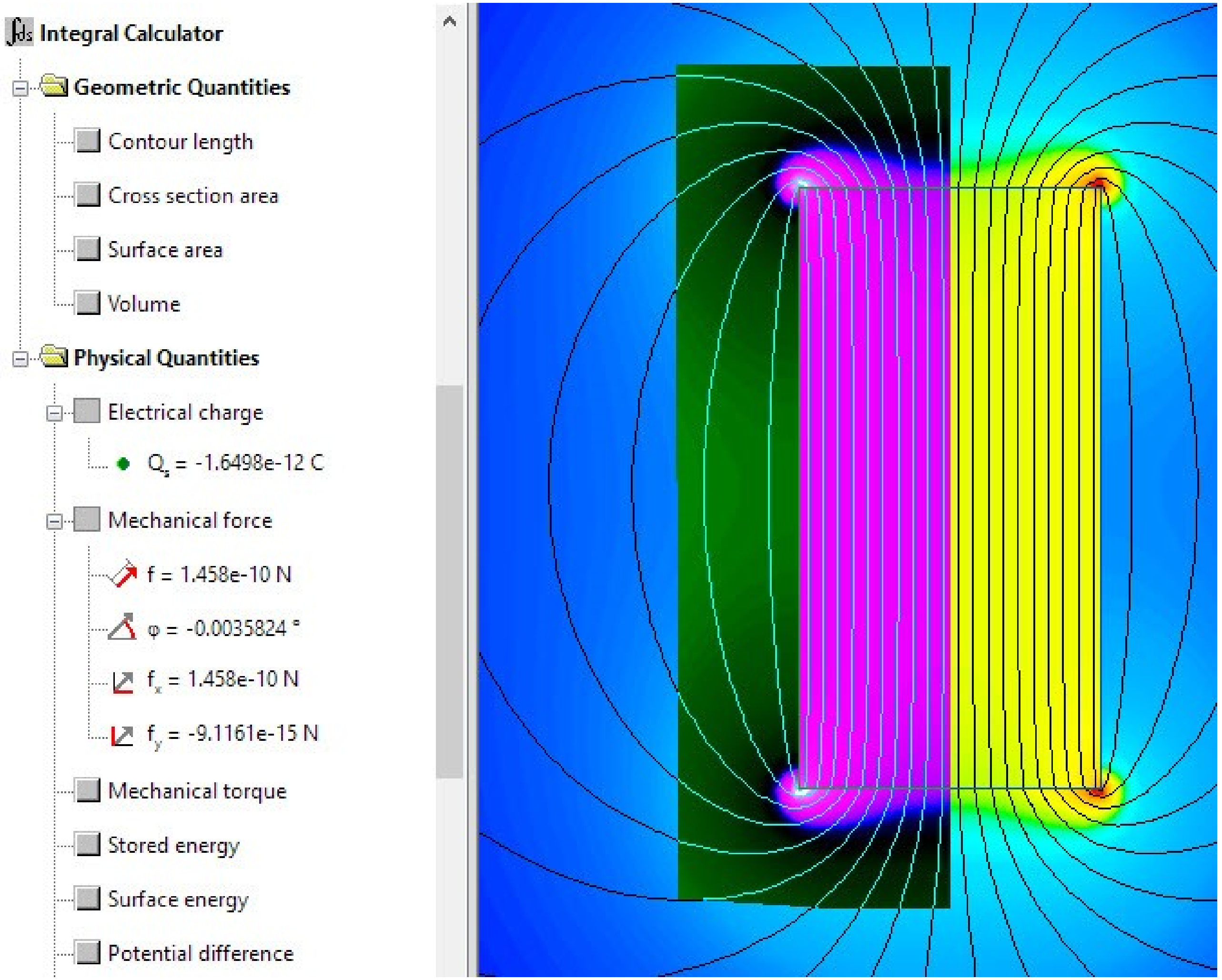
L (mm)	x (mm)	y (mm)	N_x	N_y	U (V)	E (V/m)	E_x (V/m)	E_y (V/m)
0.00000	0.00000	-7.00000	1.00000	-0.00000	2.15068e-4	89.5768	-89.5768	0.0567527
0.700000	0.00000	-6.30000	1.00000	-0.00000	2.23998e-4	116.558	-116.558	-0.134715
1.40000	0.00000	-5.60000	1.00000	-0.00000	-2.86082e-6	150.659	-150.659	0.00779105
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

Please don't forget take into account the symmetry factor

Using a simplest formula

$$C = \varepsilon_0 \varepsilon \frac{S}{d}$$

By Charge and Voltage

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

By Energy and Voltage

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

Theory

ε_0	8.85E-12	F/m
ε	4	
d	10	mm
w	100	mm
L	80	mm
S	0.008	m^2
C	2.83E-11	F
	28.333	pF

By Charge and Voltage

Qs	2.96E-09	C
ΔU	100	V
C	2.9642E-11	F
	29.642	pF

By Energy and Voltage

W	1.48E-07	J
C	2.9644E-11	F
	29.644	pF

Please send your report together with all relevant QuickField files

Report content:

1. Brief task description and given data
2. Sketch of the geometry model with no mesh
3. Dependency of maximal field E_{max} on the number of mesh nodes (about 5 points).
   If you also investigate E_{max} dependency on the radius of the artificial outer boundary, it will be a plus.
4. Capacitance calculations:
   - by a simple formula (theory)
   - using charge
   - using energy
5. Maximal field intensity E_{max} and the field in the middle E_c
6. Relevant screenshots at your choice
7. Be prepared to explain how and why you've set the boundary conditions