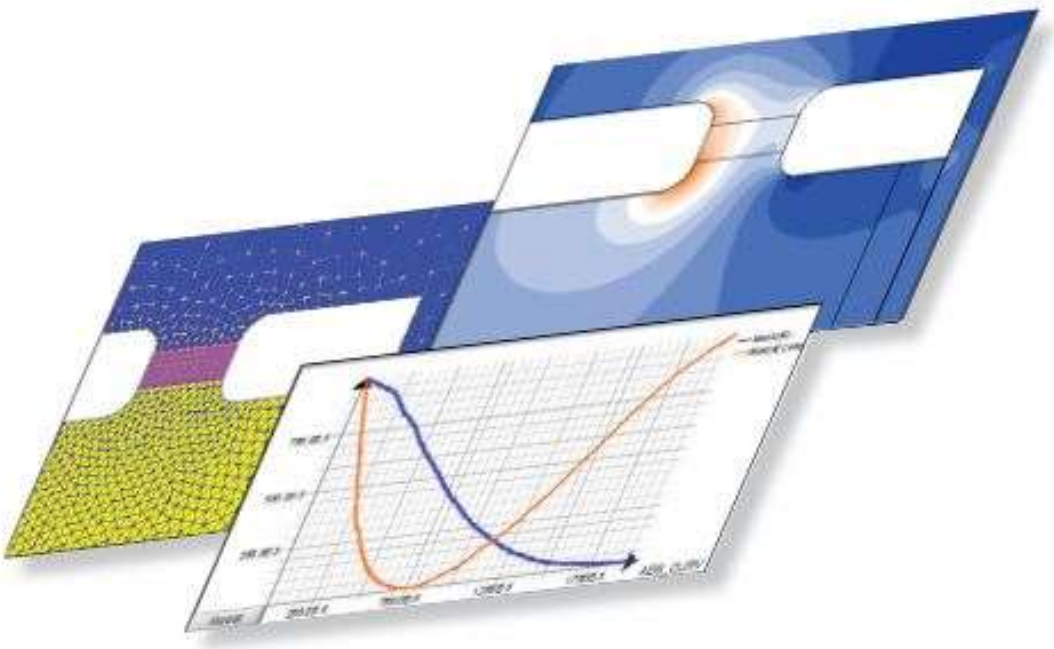
CAE package for electromagnetic and thermal analysis using finite elements

Altair® Flux®

Electrostatic application tutorial

2D technical example



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Foreword

*(Please read before starting this document)

Description of the example

The goal of this technical example is to demonstrate the ability and advantage of Flux for the simulation of cylindrical cell computation problems. This example contains the general steps and all the data needed to describe the different simulations.

To begin

This example is designed for the user who is already familiar with the basic functions of Flux software.
For beginner users, please report to the "Flux Starting Guide" opened automatically by the supervisor. (If not opened, please open it by clicking on the button "?" on the top right of the supervisor). The interface contains videos, which helps the beginners while using Flux for the first time.

Support files included...

To view the completed stages of the example project, the user will find the .py files, including the geometry, mesh, physics and post-processing descriptions. The .py files corresponding to the different study cases in this example are available in the folder:
.\DocExamples\Examples2D\Tutorial_Technical\ElectrostaticApplication\
Supplied files are command files written in Pyflux language. The user can launch them in order to automatically produce the Flux projects for each case.
(*.py files are launched by accessing **Project/Command file from the Flux drop down menu.)*

Supplied files		Contents	Flux file obtained after launching the .py file
CASE1	buildGeomesh.py	Geometry and mesh	…\geomeshbuilt
	buildphys.py	physics	…\physbuilt
	solving.py	Solving process	…\solved
	postprocessing.py	Post processing	…\postprocessed
CASE2	TESTCASE_INI.FLU	Initial Flux project	
	buildphys.py	Physics	…\physbuilt
	solving.py	Solving process	…\solved
	postprocessing.py	Post processing	…\postprocessed
CASE3	TESTCASE_INI.FLU	Initial Flux project	
	buildPhys.py	physics	…\physbuilt
	solving.py	Solving process	…\solved
	postprocessing.py	Post processing	…\postprocessed

Note : some directories may contain a main.py enabling the launch of the other command files

Table of Contents

1. General information

Introduction

This chapter contains the presentation of the **studied device** and the **Flux software**.

Contents

This chapter contains the following topics:

1.1. Overview

Introduction

This section presents the studied device (a cylindrical cell for the measurement of resistivity and permittivity of liquids) and the strategy of the device description in Flux.

Contents

This section contains the following topics:

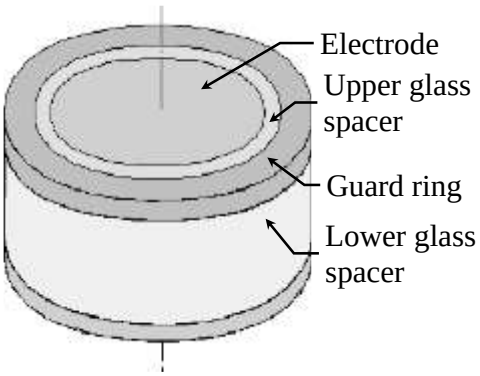
1.1.1. Description of the studied device

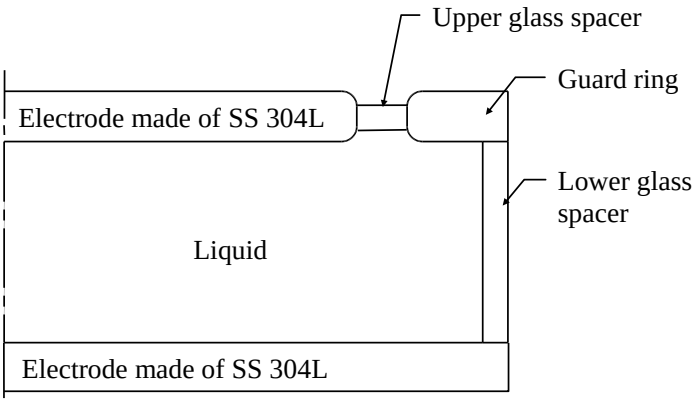
Studied device

The device to be analyzed is a cylindrical cell for the measurement of resistivity and permittivity of liquids.

The studied device consists of:
- two circular upper and lower electrodes
- a guard ring
- two glass spacers
  - one is situated between the upper electrode and the guard ring
  - another is situated between the guard ring and the lower electrode

The physical model and the axial section of the studied device are presented in the figures below.





Operating principle

The analyzed cell is used to measure the resistivity and permittivity of liquids. The testing liquid is placed between two plate electrodes to form a capacitor. The measured capacitance is then used to calculate permittivity. When simply measuring the dielectric material between two electrodes, stray capacitance or edge capacitance is formed on the edges of the electrodes and consequently the measured capacitance is larger than the capacitance of the dielectric material. A solution to the measurement error caused by edge capacitance is to use the guard electrode. The guard electrode absorbs the electric field at the edge and the capacitance that is measured between the electrodes is only composed of the current that flows through the dielectric material.

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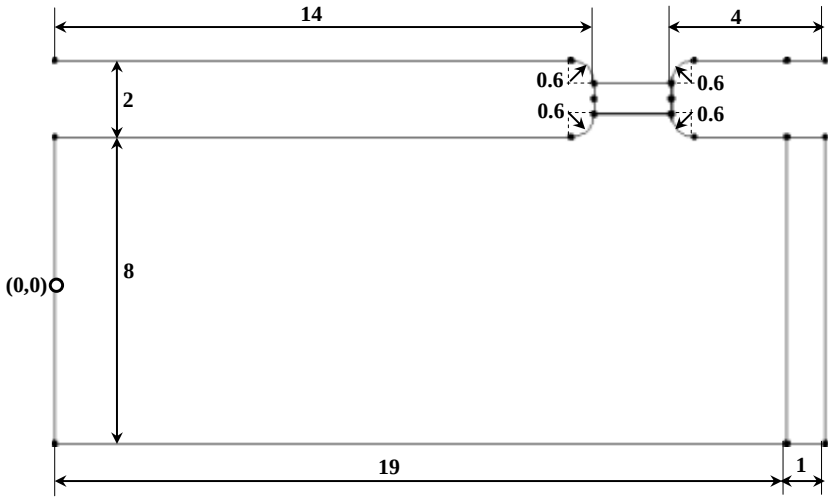
Geometry

The device has an axial symmetry around its main axis.

The dimensions (in millimeters) of the device are presented in the figure below.



Materials

The measurement cell is composed of the following materials:

- the upper and lower electrodes are made of SS 304L, an austenitic Chromium-Nickel stainless steel
- the upper and lower spacers are made of glass, an insulator characterized by the constant relative permittivity

The testing liquids are:

- pure water
- mineral oil, a material with a high dielectric constant

Sources

The electric field is due to the dc voltage applied to electrodes as follows:

- V = -250 V on the lower electrode
- V = 250 V on the upper electrode

1.1.2. Studied cases

Studied cases

Three cases are carried out in a Electro Static application:

- case 1: static study, a testing liquid is pure water
- case 2: multi-parametric computation
- case 3: static study, a testing liquid is mineral oil

Case 1

The first case is a static study.

This study is a very easy problem of electrostatics of axisymmetric type. The testing liquid is pure water.

Case 2

The second case is a multi-parametric computation.

In this study two parameters – physical and geometric – are used.
The physical parameter is the relative permittivity of the testing liquid (pure water) varying between 10 and 120. The geometric parameter is the curvature radius of the rounded corners of the electrodes varying between 0.6 mm and 0.8 mm. The last parameter determines the height of the upper glass spacer. The height of the upper spacer decreases when the value of the curvature radius increases.

Case 3

The third case is a static study.

This study differs from case 1 only by the nature of the testing material.
The testing liquid is mineral oil.

1.2. Strategy to build the Flux project

Introduction

This section presents outlines of the geometry building process, mesh generating process and physical properties description process of the measurement cell.

Contents

This section contains the following topics:

Preliminary

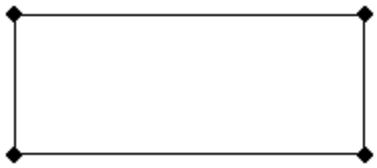
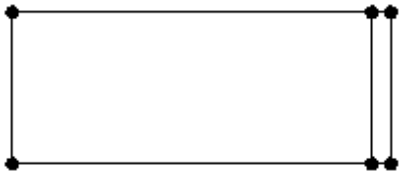
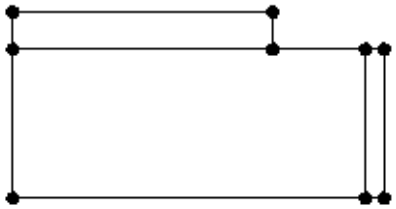
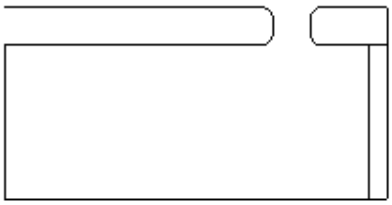
Before starting the project construction, we must define the application with which the calculation will be made: the **2D Electro Static application**.

1.2.1. Main stages for geometry description

Outline

The device is modeled in the axisymmetric study domain, i.e. the device is described in a XY-plane cross-section and has symmetry with respect to the Y-axis. The lower electrode is modeled by physical line region, it is not necessary to build its geometry.

An outline of the **geometry building process** of the measurement cell is presented in the table below.

Stage	Description	
1	Creation of geometric parameters to simplify the geometry construction	• RADIUS (curvature radius of the corners of the upper electrode and guard ring): 0.6 mm • RINF_EXT (outer radius of the infinite box): 40 mm • RINF_INT (inner radius of the infinite box): 30 mm
2	Creation of the liquid part	
3	Creation of the lower glass spacer	
4	Creation of the electrode	
5	Creation of the guard ring	
6	Modification of the geometry of the electrode and guard ring, Creation of some fillets	

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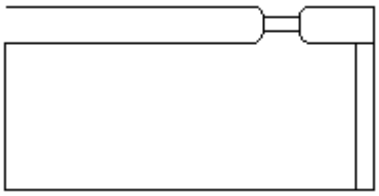
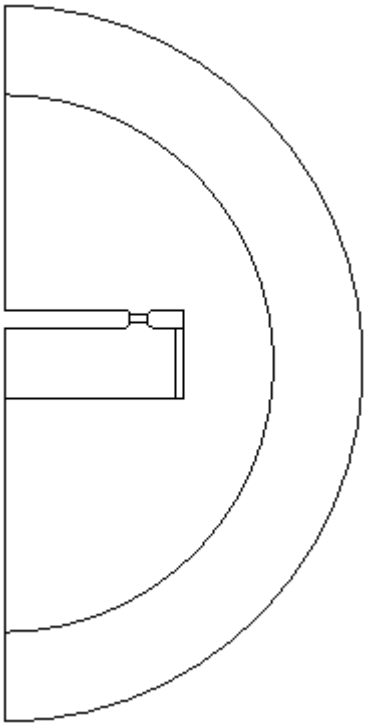
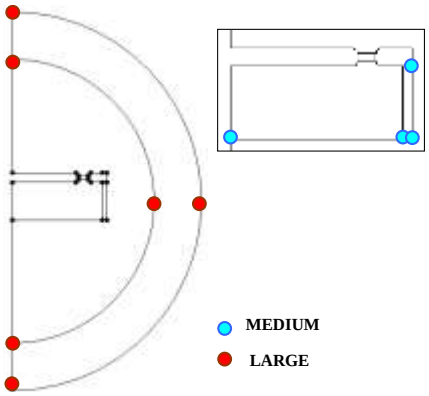
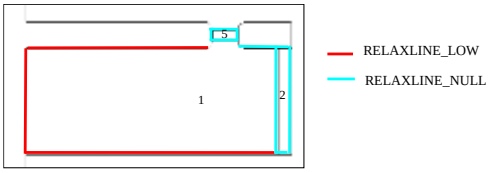
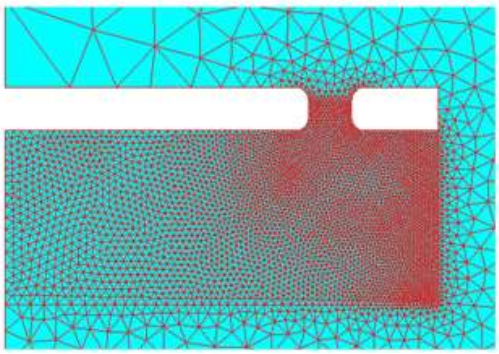
7	Creation of the upper glass spacer	
8	Creation of the infinite box and closing the domain.	

1.2.2. Main stages for mesh generation

Outline

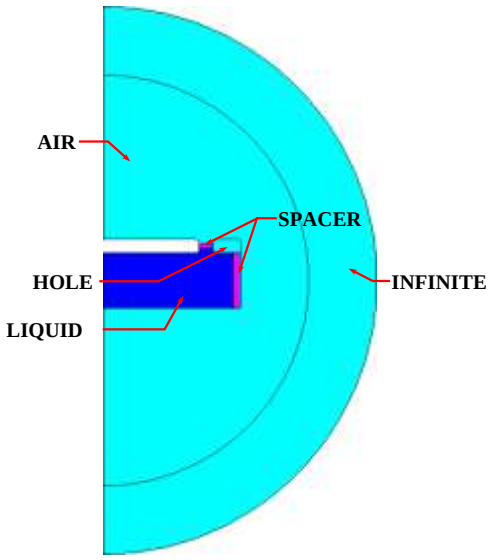
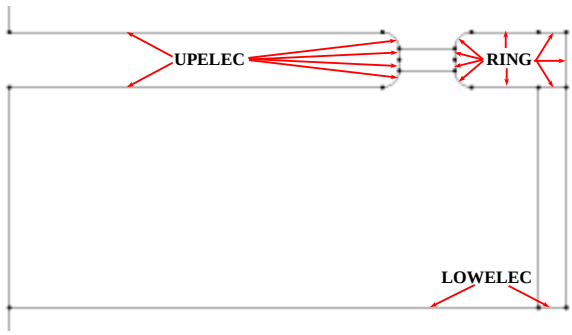
An outline of the **mesh generating process** of the measurement cell is presented in the table below.

Stage	Description	
1	Meshing the device and analyze of the mesh	Mesh with the default settings of AIDED MESH. It is possible to improve the mesh quality
2	Modify aided mesh information	Aided mesh information are modified to improve the global mesh
3	Assign local meshpoint	
4	Assign local relaxation on lines (see figure) and faces 1, 2 and 5	
5	Meshing: • meshing lines • meshing faces	

1.2.3. Main stages for physical description

Outline

An outline of the **physical description process** of the measurement cell is presented in the table below.

Stage	Description	
1	Creation of 2 materials	• WATER – isotropic material with a linear dielectric characteristic • GLASS – isotropic material with a linear dielectric characteristic
2	Creation and assignment of face regions	
3	Creation and assignment of line regions	

2. Construction of the Flux project

Introduction

This chapter contains the **geometry description, mesh generation** and **physical description** of the **measurement cell** presented in a manner less detailed then the chapters relating to the studied cases. The user must have good understanding of all functionalities of the Flux preprocessor.

Project name

The Flux project is **GEO_MESH_PHYS.FLU**.

Contents

This chapter contains the following topics:

Preliminary

First, the physical application is defined. The required physical application is the Electro Static 2D application.
The characteristics of the application are presented in the table below.
Remark: Before, close Sketcher context if it is automatically opened.

☞ **Project → CloseSketcher2DContext**

Electro Static 2D application	
Definition	
2D domain type	**Reference for potential (infinity, symmetry…)**
Axisymmetric	Floating potential

☞ **Application → Define → Electric → Electro Static 2D**

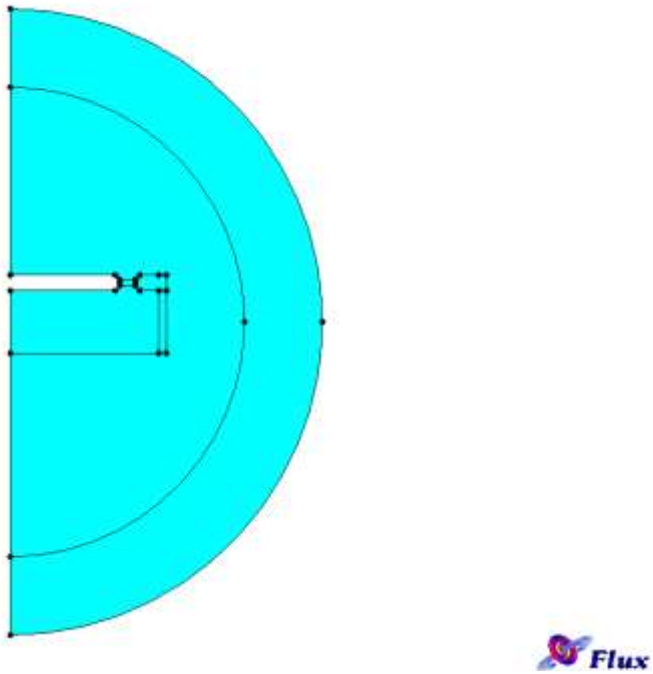
2.1. Geometry description process

Geometry description	Mesh generation	Physic description	Solving process	Result post-processing

Introduction

This section presents the general steps of the geometry construction and the data required to describe the measurement cell geometry.

The cell object is presented in the figure below.

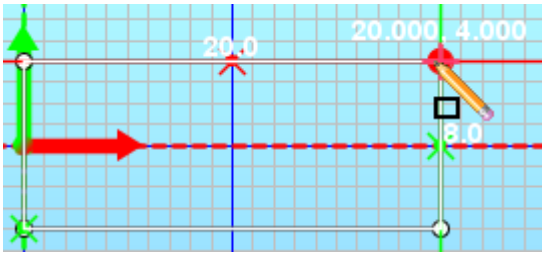
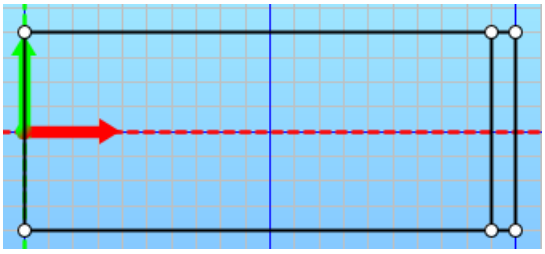
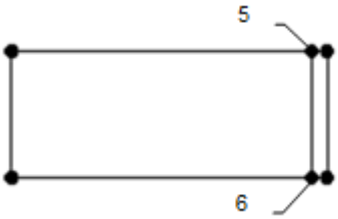


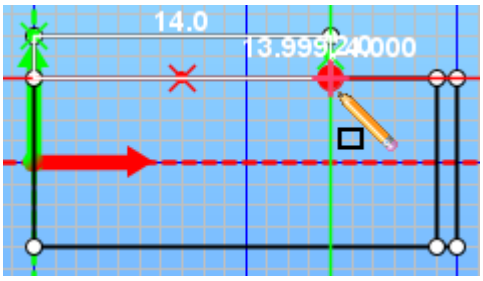
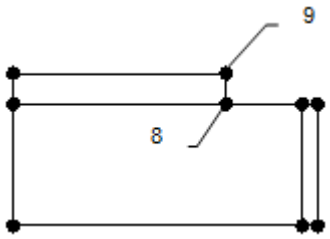
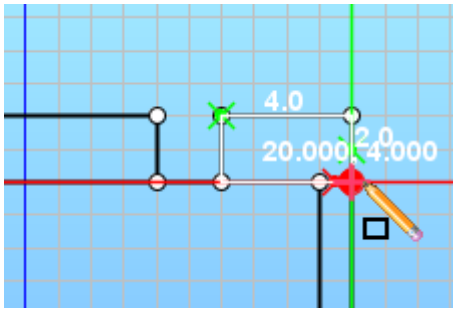
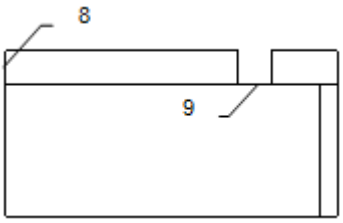
Goal

The geometry is created in the Sketcher using rectangle, line creation and geometric parameters.

Continued on next page

Action The steps of the construction of the cell are presented in the following table.

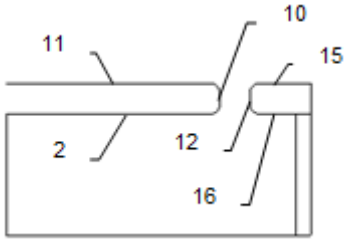
Step	Action	Illustration
0	Open sketcher context	
	☞ **Geometry → Sketcher 2D context**	
1	Creation of geometric parameters	• RADIUS (curvature radius of the corners of the upper electrode and guard ring): 0.6 mm • RINF_EXT (outer radius of the infinite box): 40 mm • RINF_INT (inner radius of the infinite box): 30 mm
	☞ **Construction → Geometric parameter → New**	
2	Creation of a rectangle by a diagonal between a first point (0 ; -4) and a second point (20 ; 4) dimensions of 20 x 8.	
	☞ **Construction → Rectangle → Rectangle diagonal**	
3	Creation of a second rectangle inside the first one in order to create the lower glass spacer. (first point : 19 ; 4, second point : 20; -4)	
	☞ **Construction → Rectangle → Rectangle diagonal**	
4	Verify the coordinates of the selected points Flux point / X / Y 5 / 19 / 4 6 / 19 / -4	
	☞ **Select points, right click and choose Edit array**	

5	Creation of a rectangle in order to create the electrode (first point : 0 ; 6, second point : 14 ; 4)	
	☞ **Construction → Rectangle → Rectangle diagonal**	
6	Verify the coordinates of the selected points Flux point | X | Y 8 | 14 | 4 9 | 14 | 6	
	☞ **Select points, right click and choose Edit array**	
7	Creation of a rectangle in order to model the guard ring (first point : 16 ; 6 and second point : 20 ; 4)	
	☞ **Construction → Rectangle → Rectangle diagonal**	
8	Deletion of lines 8 and 9	
	☞ **Select lines, right click and choose Delete**	

9

Creation of four fillets in order to model four curved lines for the electrode and the guard line

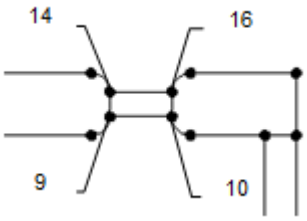
Curved line	line	line	radius
13	11	10	radius
17	10	2	radius
18	15	12	radius
19	12	16	radius



☞ **Tools → Fillet**

10

Creation of two lines to model the upper glass spacer.

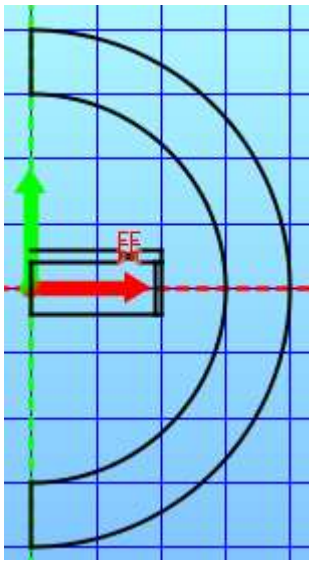


☞ **Construction → Line → Polyline**

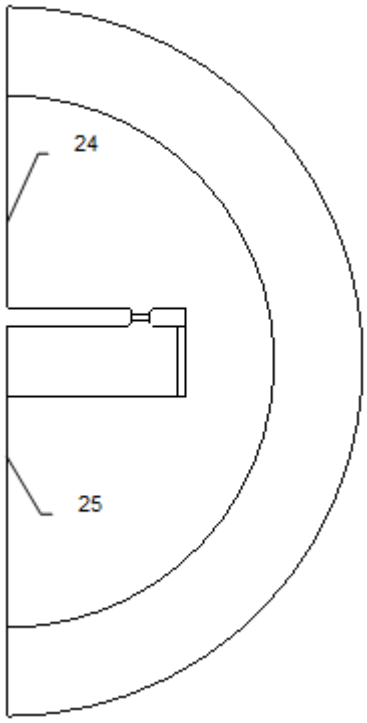
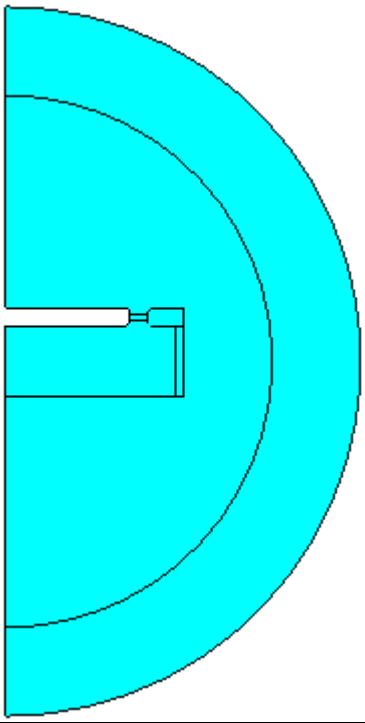
11

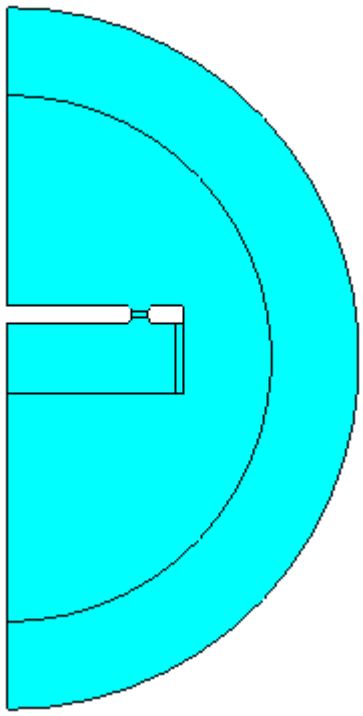
Creation of the infinite box of the disc type

Name	Internal radius	External radius
InfinitBox	RINF_INT	RINF_EXT

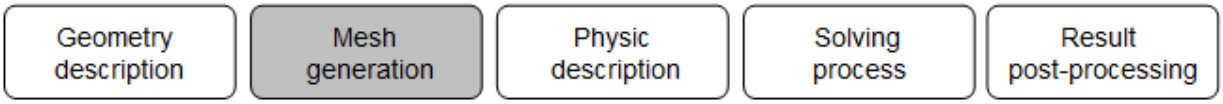


☞ **Select Domain → Infinite box → New**

12	Creation of two lines in order to close the domain	
	☞ **Construction → Line → Polyline**	
13	Closing of the sketcher context. The project opens in the geometry context of Flux and faces are automatically created.	
	☞ **Select Project → CloseSketcher2DContext**	

14	Deletion of face 4.		
	☞	**Select the face, right click and choose Delete**	

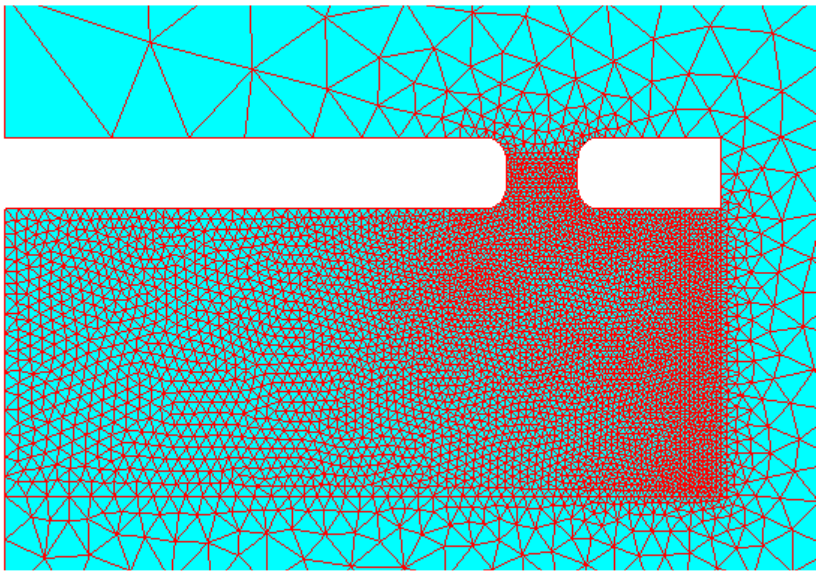
2.2. Mesh generation process



Introduction

This section presents the general steps of mesh generation for the computation domain and the data required to describe the measurement cell mesh.

The meshed measurement cell is presented in the figure below.



Contents

This section contains the following topics:

2.2.1. Mesh the device

Goal

Mesh generation process is an essential step of the Finite Element method. At this stage, the computation domain is divided in small elements.
Each node of the mesh constitute a support where the **state variable** approximation (such as scalar or vector potentials, temperature, etc.) and the **derived fields** (such as magnetic field and induction, magnetic flux density, electric field, thermal flux density, etc.) are computed.
Aided mesh is activated by default in Flux. Such tool permits to obtain a first basic mesh with global settings.

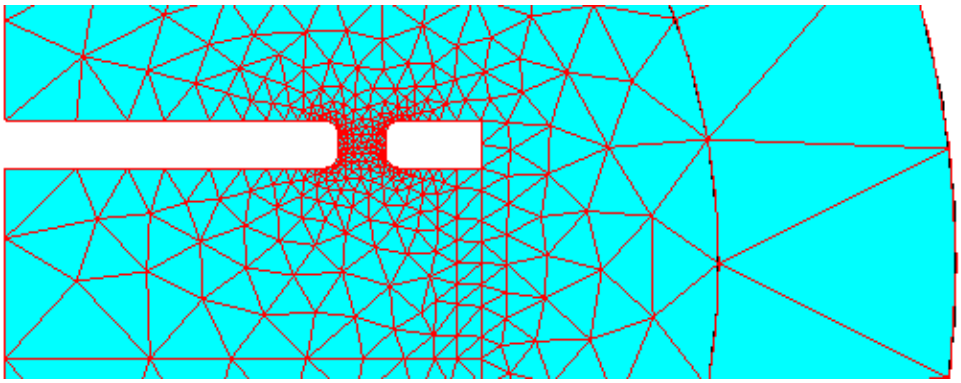
Action

Mesh the device.

☞ **Mesh → Mesh domain** 

Result

The result appears as below.



Comments

To optimize the accuracy of the results, it is advised to have a mesh:
- with well proportioned mesh elements (close to equilateral triangle)
- with an Infinite box of at least 2 elements large
- taking into account the physics (the mesh must be denser in the areas with important field variation)

For instance, the solution to improve the mesh here is:
- to assign local mesh point
- to create and assign local relaxations on lines and faces
- to modify the aided deviation

2.2.2. Modify the aided deviation

Goal

The aided deviation is modified in order to refine the mesh closed by the curved lines of the upper electrode and the guard ring.

Data

The modified characteristic of the aided mesh is presented in the table below.

Deviation		
Assign	**Type**	**Value**
Assign – **Included** Infinite Box	Relative	**0.75**

☞ **Mesh → Aided Mesh → Edit** 

Action

Mesh domain.

☞ **Mesh → Mesh domain** 

2.2.3. Modify the mesh point and assign it to points

Goal

Mesh points enable the user to add some local mesh information in order to control the mesh in specific areas. In this case:

- LARGE meshpoint permits to have an Infinite box with 3 elements large
- MEDIUM meshpoint permits to obtain a denser mesh in the device part

Data

The modified characteristics of the mesh points are presented in the table below.

Mesh point				
Name	**Comment**	**Unit**	**Value**	**Color**
LARGE	Large mesh size	mm	**(RINF_EXT-RINF_INT)/2.5**	Red
MEDIUM	Medium mesh size	mm	**1.2**	Turquoise

☞ **Mesh → Mesh point → Edit array**

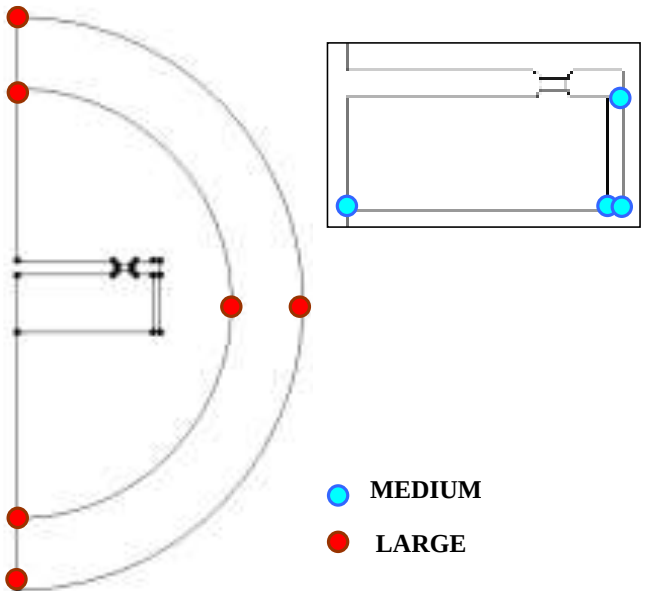
Action

Assign mesh point to points.

☞ **Mesh → Assign mesh information → Assign mesh point / line / generator → Assign mesh point to points**

Outline

The assignment of the mesh points to points is presented in the figure below.

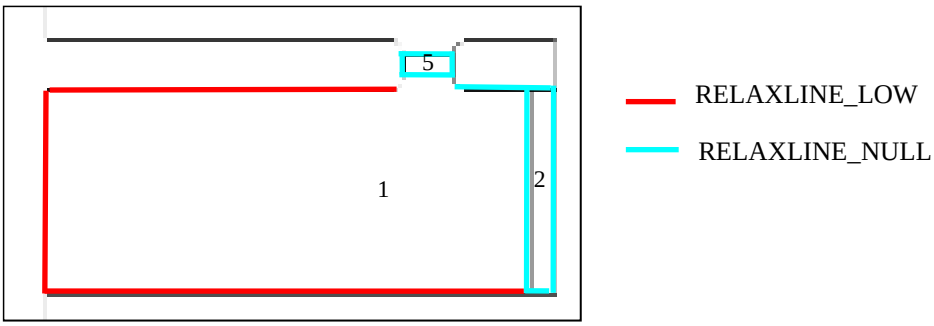


2.2.4. Create and assign relaxation on faces and lines

Goal

Relaxation on faces and lines can be usefull to control the harmonious progression of the mesh density from the smallest to the biggest mesh size element.
In our case, it is interesting to limit the relaxation effect on the device by imposing:

- a null relaxation on the lines surrounding the spacers
- a low relaxation on somes lines surrounding face 1
- a null relaxation on faces 1, 2, 5. Elements located in the center of the liquid region (close to symmetry line) will be a little bigger.



Data (1)

The characteristics of the relaxation on lines are presented in the table below.

Relaxation on lines			
Name	**Comment**	**Value**	**Color**
RELAXLINE_LOW	Low relaxation on lines	r = 0.25	Red
RELAXLINE_NULL	Null relaxation on lines	r = 0.00	Turquoise

☞ **Mesh → Relaxation → Relaxation line → New** 

Action (1)

Assign relaxation to lines.

☞ **Mesh → Assign mesh information → Assign relaxation / shadow → Assign relaxation to lines** 

Continued on next page

Data (2) The characteristics of the relaxation on face are presented in the table below.

Relaxation on faces			
Name	**Comment**	**Value**	**Color**
RELAXFACE_NULL	Null relaxation on faces	r = 0.00	Turquoise

☞ **Mesh → Relaxation → Relaxation face → New** 

Action (2) Assign relaxation to face.

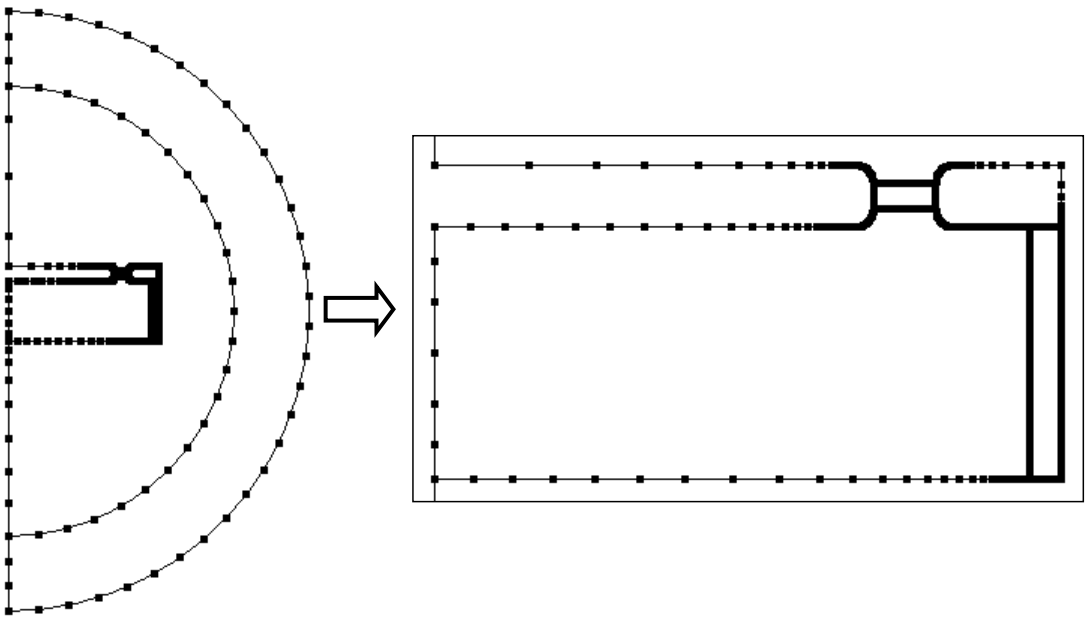
☞ **Mesh → Assign mesh information → Assign relaxation / shadow → Assign relaxation to faces** 

2.2.5. Mesh lines and faces

Action (1) Mesh lines.

☞ **Mesh → Mesh → Mesh lines**

Result (1) After the lines have been meshed the next figure is displayed in the graphic zone.



Action (2) Mesh faces.

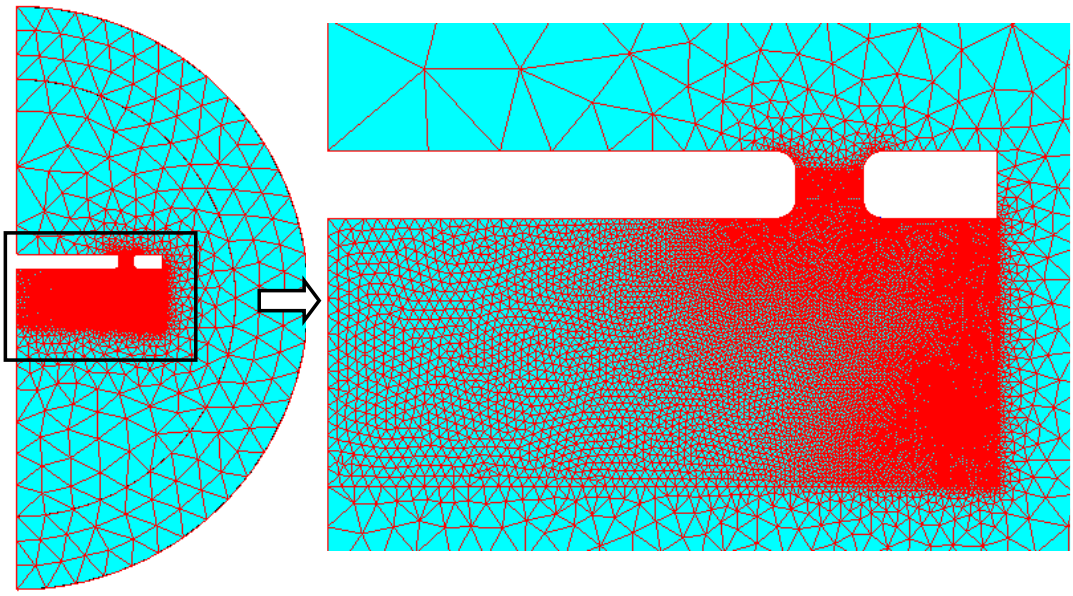
☞ **Mesh → Mesh → Mesh faces**

Note: another solution is to select the command Mesh domain.

Continued on next page

Result (2)

The mesh of the study domain and the detail of the mesh in the device zone are presented in the figure below.



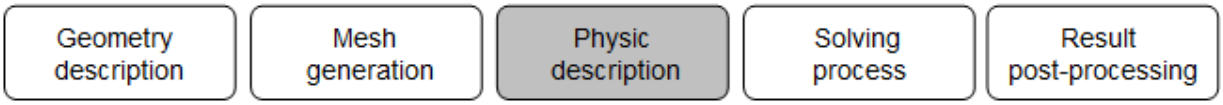
The following comments will be displayed in the History zone.

```
Meshing of 5 faces

Automatic mesh of 25 lines
18:22:35     207 sec. Internal meshing of the lines

Automatic meshing of 5  faces
Boundary meshing of the faces achieved in 1 iteration(s)
Internal meshing of the 5 faces
Faces internal meshing achieved
Boundary meshing of the faces achieved in 1 iteration(s)
Internal meshing of the 5 faces
Faces internal meshing achieved
Boundary meshing of the faces achieved in 1 iteration(s)
Internal meshing of the 5 faces
Faces internal meshing achieved
End of topological mesh regularization
18:22:44     215 sec.   21340 1st order surfacic elements created

18:22:44     215 sec. Generating 2nd order elements is running
  Total number of nodes --> 42934
18:22:44     216 sec. End generating 2nd order elements

Surface elements :
   Number of elements not evaluated     : 0  %
   Number of excellent quality elements : 99.93  %
   Number of good quality elements      : 0.06  %
   Number of average quality elements   : 0  %
   Number of poor quality elements      : 0  %
   meshFaces executed
```

Comments

The mesh takes into account geometry constraints. We also assume that the electric field with highest intensity and strongest variation will be located in the area between the two electrodes. The mesh must be denser in this area.

2.3. Physical description process



Introduction

This section presents the definition of the physical properties – materials and regions of the model.

Contents

This section contains the following topics:

2.3.1. Create materials

Goal

The creation of “material” entities enables the user to assign physical material properties to face regions. The two materials are linear isotropic characterized by the relative permittivity:

- the first material is water defined for the cell contents
- the second material is glass defined for the spacer

Data

The characteristics of the materials are presented in the table below.

D(E) dielectric property**: linear isotropic**		
Name	**Comment**	**Relative permittivity**
WATER	Pure water at 20 degrees	80
GLASS	Classical glass	7

Action

Create materials.

☞ **Physics → Material → New**

2.3.2. Create face regions

Introduction

Four face regions are necessary for the physical description of the measurement cell.
Four following face regions will be created:

- the LIQUID region corresponding with the contents of the cell
- the SPACER region for the upper and lower glass spacer
- the AIR region corresponding with the air surrounding the device
- The INFINITE region, already created during the infinite box creation, will be edited to activate its physical properties.

Goal

Physical region are necessary to carry out the physical description of the model. They enable the user to group some entities (here faces grouped in face regions) that have the same physical properties. It is also possible to assign material and or conducting properties for instance.

Data

The characteristics of the face regions are presented in the table below.

Face region				
Name	**Comment**	**Type**	**Material/ conductor**	**Color**
LIQUID	Contents of the cell	Dielectric region with charge source	WATER	Yellow
SPACER	Upper and lower glass spacer	Dielectric region with charge source	GLASS	Magenta
AIR	Air surrounding the device	Air or vacuum region	-	Cyan
*INFINITE**	*Infinite region*	*Air or vacuum region*	-	*Green*

Action

Create face regions.

☞ **Physics → Face region → New** 

*The region already created and assigned during the creation of the infinite box.

2.3.3. Assign face regions to faces

Introduction

The INFINITE region has been already assigned during the creation of the infinite box. The three face regions (LIQUID, SPACER, and AIR) are assigned to faces.

Goal

The assignment operation enables the user to “link” the physical properties he has just created with the geometrics entities.

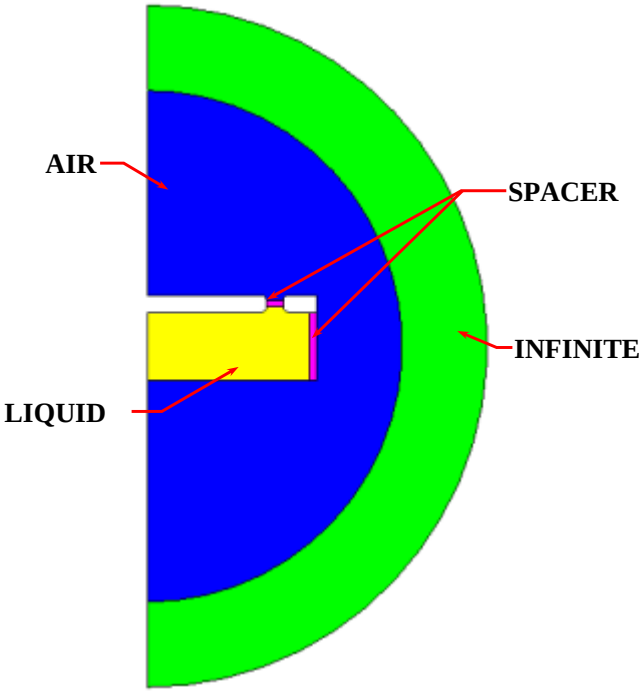
Action

Assign face regions to faces.

☞ **Physics → Face region → Assign regions to faces (completion mode)**

Outline

The region assignment is presented in the figure below.



2.3.4. Create line regions

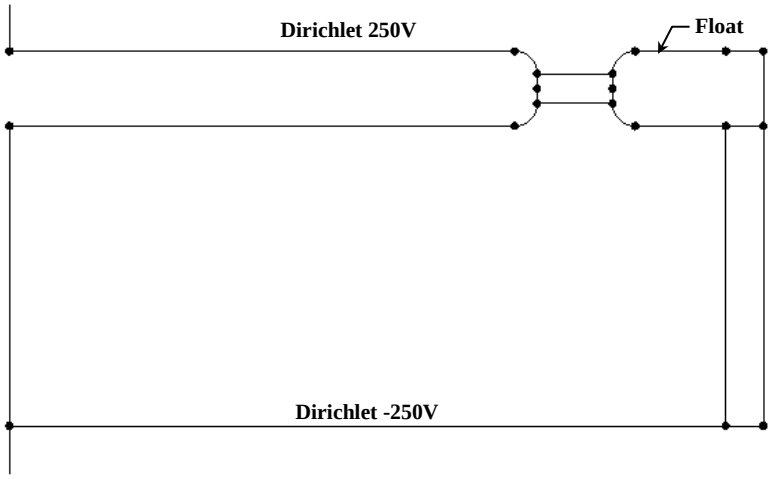
Introduction

Three line regions are created to define the boundary conditions (LOWELEC, UPELEC, and RING).

Boundary conditions

The boundary conditions of the problem are the following:

- **Dirichlet** conditions on the electrodes, in order to set the values of the electric potential:
  - V = -250 V on the lower electrode (LOWELEC line region)
  - V = 250 V on the upper electrode (UPELEC line region)
- **Float** condition on the outline of the guard ring (RING line region)



Data

The characteristics of the line regions are presented in the table below.

Line region					
Name	**Comment**	**Type**		**Expression**	**Color**
LOWELEC	Line region modeling the lower electrode	Boundary condition: imposed electric potential	Formula with I/O parameters	-250	Magenta
UPELEC	Line region delimiting the upper electrode	Boundary condition: imposed electric potential	Formula with I/O parameters	250	Red
RING	Line region delimiting the guard ring	Perfect conductor with floating potential	-	-	Yellow

☞ **Physics → Line region → New**

2.3.5. Assign line regions to lines

Introduction

The line regions (LOWELEC, UPELEC and RING) are assigned to lines.

Action

Assign line regions to lines.

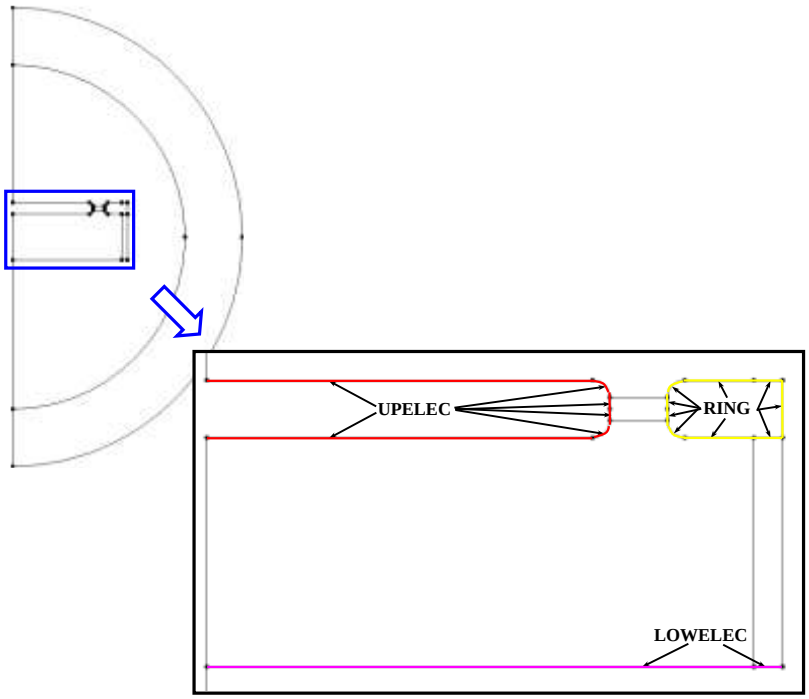
☞ **Physics → Line region → Assign regions to lines**

Outline

The line regions are assigned as follows:

- the line region LOWELEC is assigned to the two lines represented the lower electrode
- the line region UPELEC is assigned to the six lines of the upper electrode
- the line region RING is assigned to the nine lines of the guard ring

The region assignment is presented in the figure below.



3. Case 1: static study

Case 1

The first case is a static study.

This study is a very easy problem of electrostatics of axisymmetric type. The testing liquid is pure water.

Starting Flux project

The Flux project is **GEO_MESH_PHYS.FLU**.

New project

The new Flux project is saved under the name CASE1.FLU

Contents

This chapter contains the following topics:

3.1. Case 1: solving process

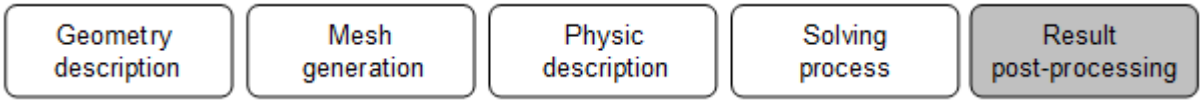
Geometry description	Mesh generation	Physic description	Solving process	Result post-processing

Goal The case 1 is solved using the default scenario with reference values.

Action Solve CASE1.

☞ **Solving → Solve**

3.2. Case 1: results post-processing



Introduction

This section explains how to analyze the principal results of case 1.

Contents

This section contains the following topics:

3.2.1. Display default graphic post processing

Goal

The display of graphic post processing enables the user to check if the problem is correctly formulated and emphasizes both the electric field concentration areas and the direction of the field. It also enables the user to check the mesh quality. This is the first, indispensable control of the accuracy of the results.

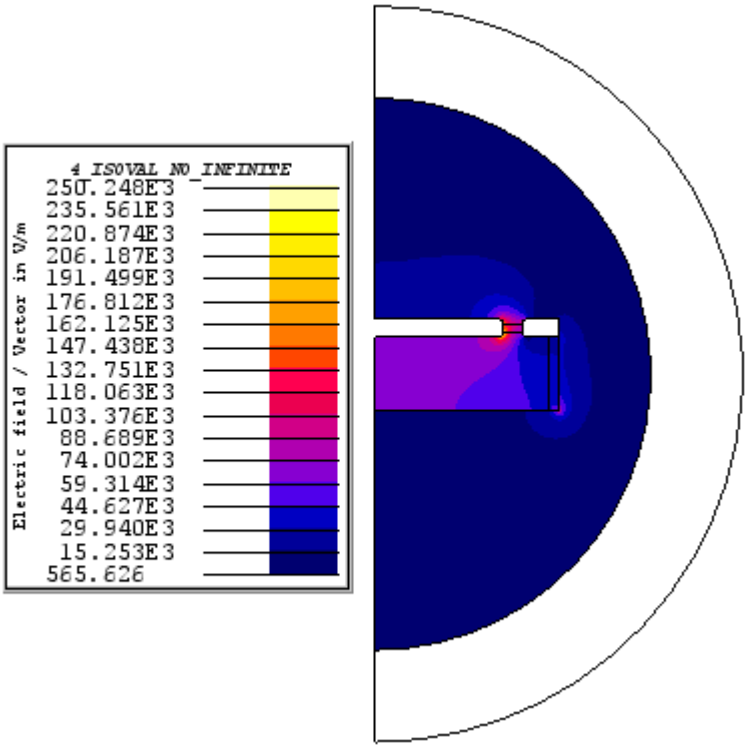
Action (1)

Display isovalues (4_ISOVAL_NO_INFINITE)

☞ **Graphic → Isovalues → Display isovalues**

Result (1)

The isovalues of the electric field are displayed below.



Action (2)

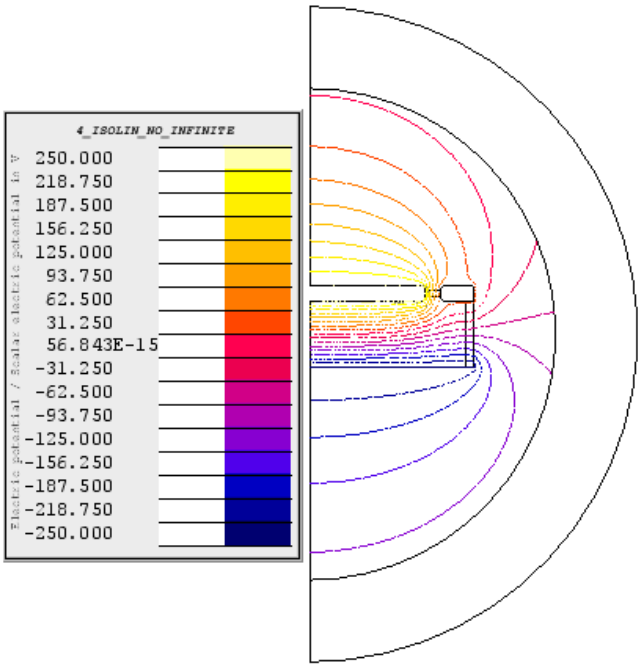
Display isolines (4_ISOLIN_NO_INFINITE)

☞ **Graphic → Isolines → Display isolines**

Continued on next page

Result (2)

The isolines of the scalar electric potential are displayed below.



3.2.2. Display arrows of the electric field on a region boundaries

Goal

The boundary vectors are used to visualize the value and the orientation of the electric field on the outline of a region.

Data

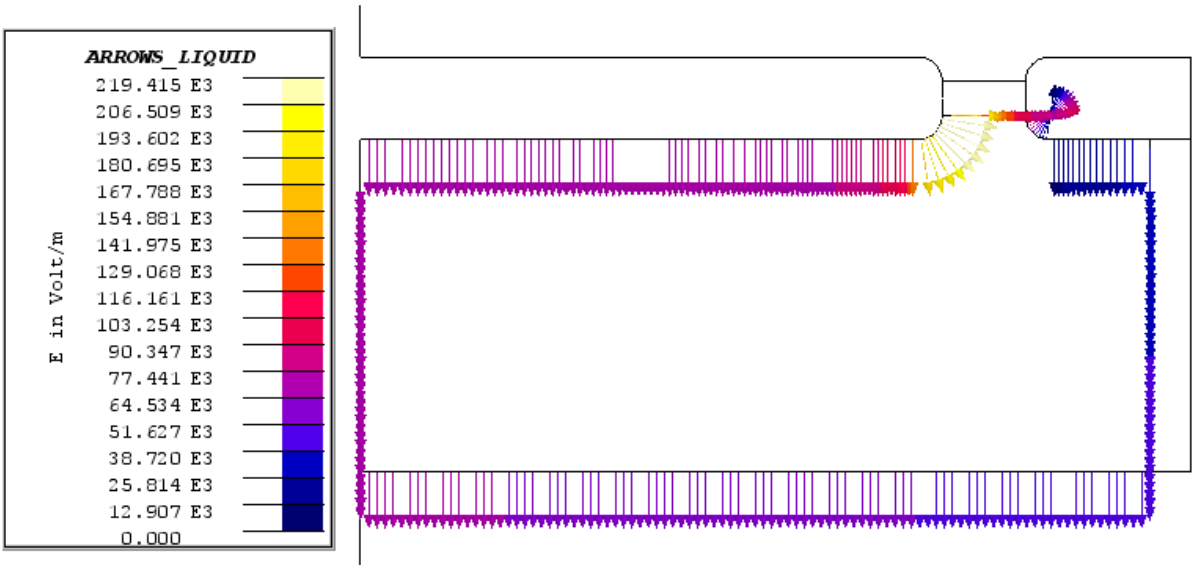
The characteristics of the arrows are presented below.

Arrows on boundary				
Name	**Comment**	**Spatial group**	**Quantity**	**Formula**
ARROWS_LIQUID	-	S_LIQUID	Electric field / Vector [V/m]	E

☞ **Graphic → Arrows boundary → New** 

Result

The boundary vectors on the LIQUID region are displayed as presented in the figure below.



3.2.3. Compute the electric potential on a point

Goal

We will compute the local quantity:
- of the electric potential
- at the point with coordinates X = 13 mm and Y = 0 mm

Data

The characteristics of the computation are presented below.

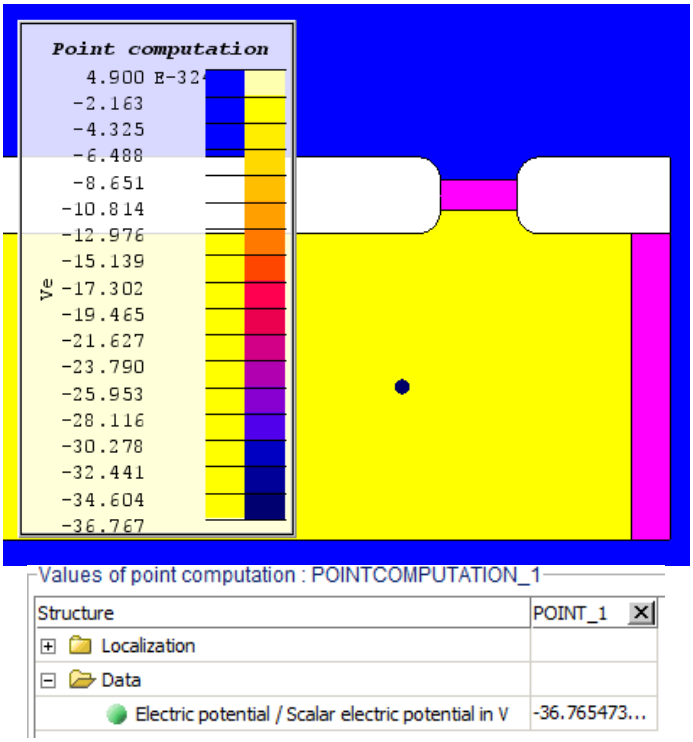
Quantities computation on **points**			
Name	**Comment**	**Quantity**	**Formula**
POTENTIAL	Point in the LIQUID region	Electric potential / Scalar electric potential [V]	Ve

Point defined by its **coordinates**				
Coordinates		**localization**	**Coord. system**	**Region**
first	**second**			
13	0	no constraint	XY1	LIQUID

☞ **Computation → On point → New session Quantities computation on points**

Results

The results are presented in the figures below.



3.2.4. Compute the energy on LIQUID region

Goal

We will compute the local quantity:
- of the energy
- on LIQUID region

Data

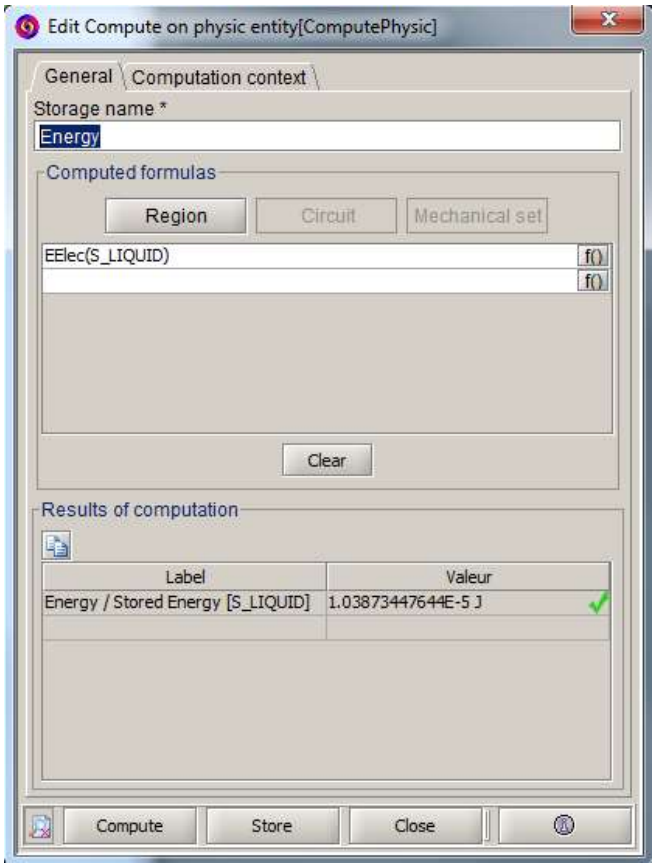
The characteristics of the computation are presented below.

Computation on physical entity		
Name	**Region**	
	Group	**Quantity**
Energy	S_LIQUID	Energy / Stored Energy

☞ **Computation → On physical entity → Compute**

Result

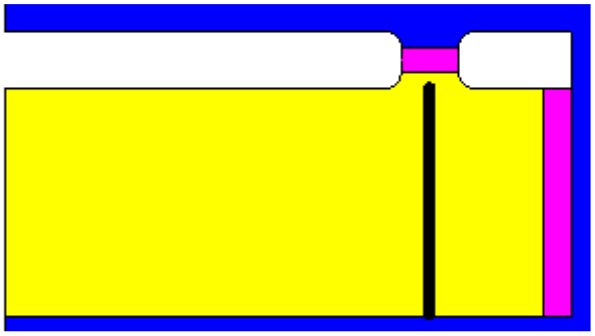
The result is presented in the figure below.



3.2.5. Plot a 2D curve of the electric field variation along a path

Goal

A 2D curve of the electric field along a path crossing the liquid region is computed and displayed.



Data (1)

The characteristics of the path are presented in the table below.

Path defined by **2 points**			
Name	**Comment**	**Definition**	**Discretization by intervals**
LIQUID_PATH	Path in the LIQUID region	by coordinates	50

Path defined by coordinates					
Path points					
Starting point			**Ending point**		
Coord. system	**Coordinates**		**Coord. system**	**Coordinates**	
	First	**Second**		**First**	**Second**
XY1	15	4	XY1	15	-3.9

☞ **Support → Path → New → Add**

Data (2)

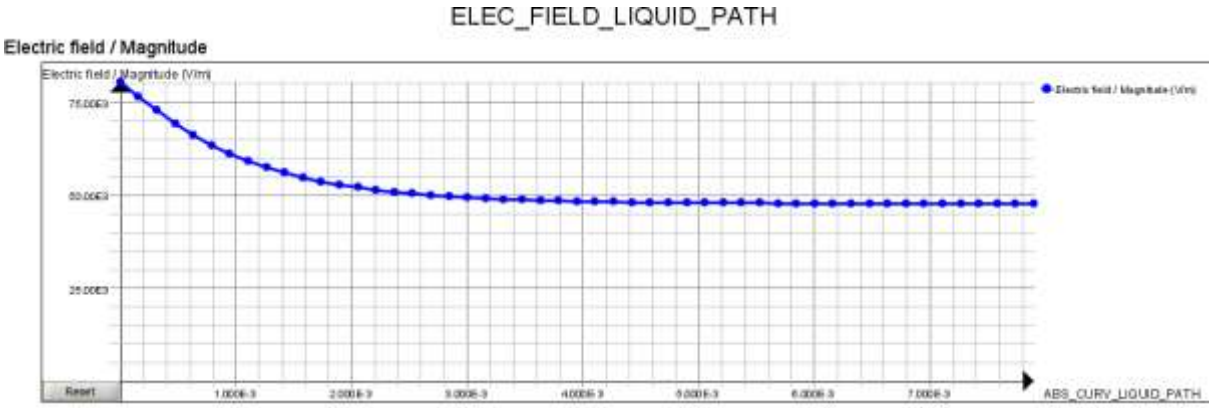
The characteristics of the curve are presented in the table below.

2D curve (XYZ path)			
Name	**Path**	**Quantity**	**Formula**
ELEC_FIELD_LIQUID_PATH	LIQUID_PATH	Electric field / Magnitude [V/m]	ModV(E)

☞ **Curve → 2D curve (Path) → New 2D curve (Path)**

Continued on next page

Result The curve is displayed as presented in the figure below.



3.2.6. Plot a 2D curve of normal and tangential components of the electric field along a path

Goal

We will plot the normal and tangential components of the electric field along the path already defined.

Data

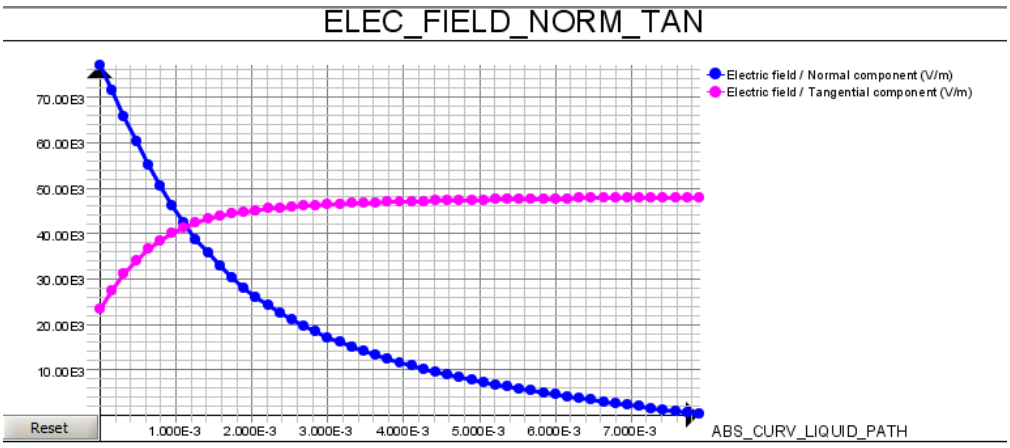
The characteristics of the curve are presented in the table below.

2D curve (XYZ path)		
Name	**Path**	**Quantity**
ELEC_FIELD_NORM_TAN	LIQUID_ PATH	Electric field / Normal component
		Electric field / Tangential component

☞ **Curve → 2D curve (Path) → New 2D curve (Path)**

Result

The curves are displayed as presented in the figure below.

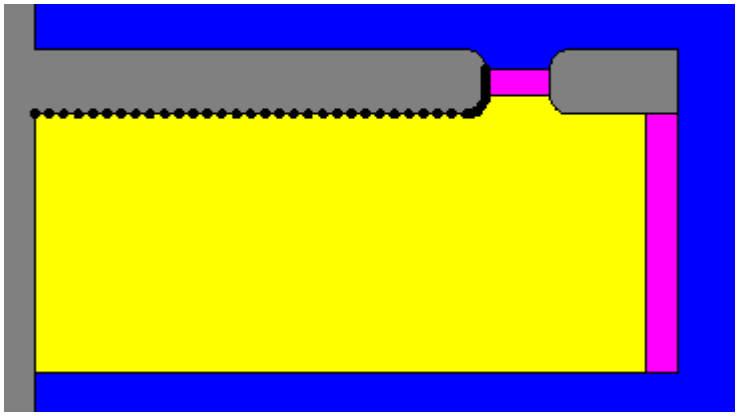


Note: display graph in absolute mode

3.2.7. Plot a 2D curve of the electric field along a path

Goal

A 2D curve of the relative permittivity along a path on the lines of the electrode is computed and displayed.



Data (1)

The characteristics of the path are presented in the table below.

Compound path			
Name	**Type: Line**	**Region**	**Discretization by intervals**
ELECT_PATH	Line 3	LIQUID	30
	Line 5	LIQUID	5
	Line 4	SPACER	5
	Line 16	SPACER	5

☞ **Support → Path → New**

Data (2)

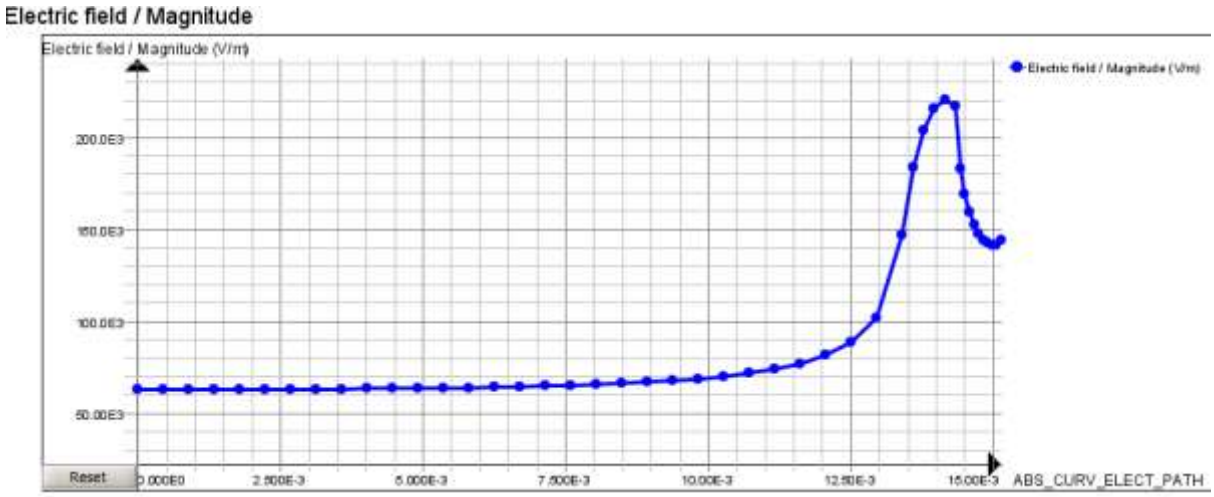
The characteristics of the curve are presented in the table below.

2D curve (XYZ path)			
Name	**Path**	**Quantity**	**Formula**
ELEC_FIELD_UPELEC_PATH	ELECT_PATH	Electric field / Magnitude	ModV(E)

☞ **Curve → 2D curve (Path) → New 2D curve (Path)**

Continued on next page

Result The curve is displayed as presented in the figure below.



4. Case 2: multi-parametric computation

Case 2

The second case is a multi-parametric computation.

In this study two parameters – physical and geometric – are used.
The physical parameter is the relative permittivity of the testing liquid (pure water) varying between 10 and 120. The geometric parameter is the curvature radius of the rounded corners of the electrodes varying between 0.6 mm and 0.8 mm. The last parameter determines the height of the upper glass spacer. The height of the upper spacer decreases when the value of the curvature radius increases.

Starting Flux project

The Flux project is **GEO_MESH_PHYS.FLU**.

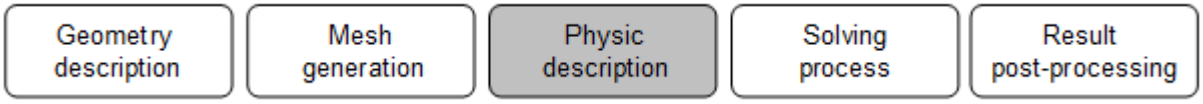
New project

The new Flux project is saved under the name CASE2.FLU

Contents

This chapter contains the following topics:

4.1. Case 2: physical description



Introduction

This section explains how to modify the initial physical description

Contents

This section contains the following topics:

4.1.1. Create an I/O parameter

Goal

A physical In/Out parameter is created. This parameter enables the variation of the relative permittivity of WATER material.

Data

The characteristics of the I/O parameter defined by a scenario are described in the table below.

I/O parameters controlled via a scenario	
Name	**Reference value**
EPSR_WATER	80

☞ **Parameter/Quality → I/O Parameter → New** 

4.1.2. Modify a material

Goal

The WATER material is modified in order to enter the changes produced by the I/O parameter creation.

Data

The characteristics of the material modification are described in the table below.

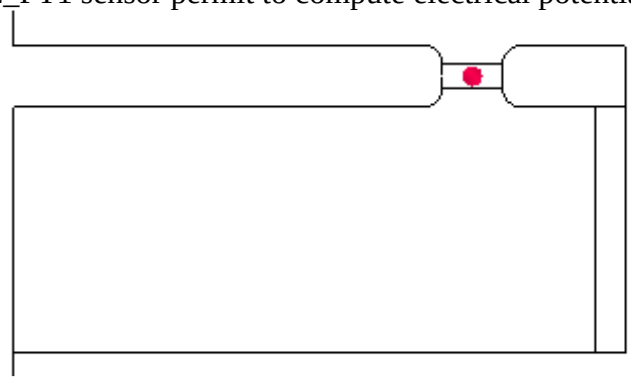
D(E) dielectric property**: linear isotropic**		
Name	**Comment**	**Relative permittivity**
WATER	Pure water at 20 degrees	EPSR_WATER

4.1.3. Create sensors

Goal

Three sensors are created on the same point. This point is located at the center of the spacer between the two electrodes

- MODE_PT1 sensor permits to compute vector component of the electric field on the point
- VOLTAGE_PT1 sensor permit to compute electrical potential on the point



Data

The characteristics of the sensors are described below.

Sensor: Point (a spatial quantity on a point)				
Name	**Formula**	**Support: point**		
		Coord. system	**Coordinates**	
			1st	**2nd**
MODE_POINT1	ModV(E)	XY1	15	5
VOLTAGE_POINT1	Ve		15	5

☞ **Parameter/Quality → Sensor → New** 

4.2. Case 2: solving process

Geometry description	Mesh generation	Physic description	Solving process	Result post-processing

Introduction

This section explains how to prepare and solve case 2.

Data

The characteristics of the solving scenario are presented in the table below.

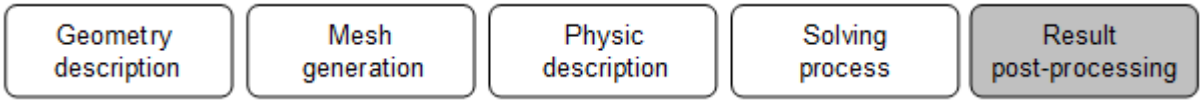
Solving scenario		
Name	**Comment**	**Type**
SCENARIO1	study using geometrical and physical parameter	multi-values

Solving scenario					
Parameter control					
Controlled parameter	**Type**	**Interval**			
		Lower limit	**Higher limit**	**Method**	**Step value**
EPSR_WATER	Multi-values	10	120	Step value	10
RADIUS	Multi-values	0.6	0.7	Step number (lin)	5
	Multi-values	0.7	0.8	List of steps	0.7
					0.73
					0.77
					0.8

☞ **Solving → Solving scenario → New**

☞ **Solving → Solve**

4.3. Case 2: results post-processing



Introduction

This section explains how to analyze the principal results of case 2.

Contents

This section contains the following topics:

4.3.1. Display default graphic post processing at a selected parametric step

Goal

The default isovalues of the electric field are displayed in order to give information on its intensity and control the quality of the mesh.

Data (1)

The characteristics* of the computation step are presented in the table below.

Scenario and computation step		
Scenario	**Computation step**	
	Parameter name	**Value**
SCENARIO_1	RADIUS	0.8
	EPSR_WATER	80

* These characteristics are located in the dialog box below the data tree.

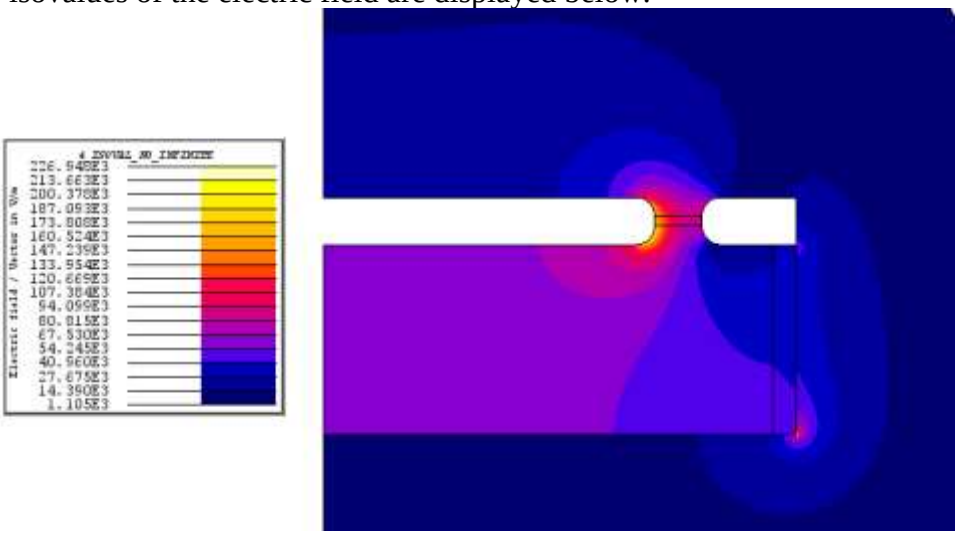
Action

Display isovalues

☞ **Graphic → Isovalues → Display isovalues**

Result

The isovalues of the electric field are displayed below.



4.3.2. Create animation of isovalues of the electric field on face regions versus I/O parameter

Goal

The animation of isovalues of the electric field for different values of the radius parameter is created.

Data

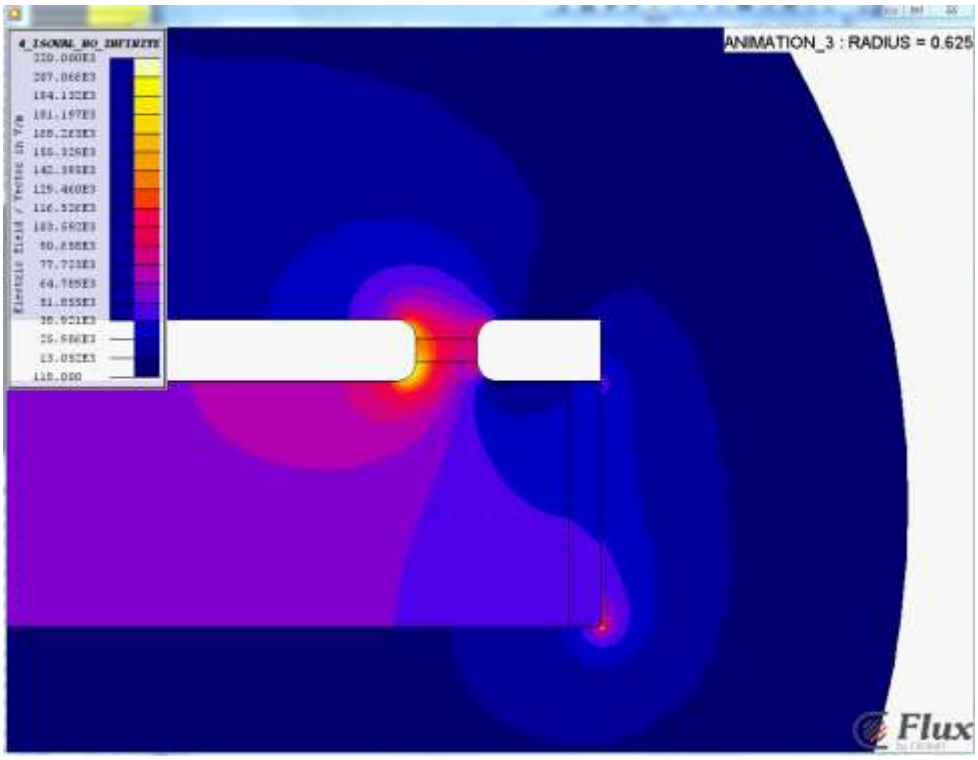
The characteristics of the animation are presented in the table below.

Animation							
Name	General (All Steps)					Display	
	Pilot: RADIUS				Build options	Isovalues	
	Parameters	Current value	min	max			
ANIMATION_1	EPSR_WATER	80			Build video	4_ISOVAL_NO_INFINITE	
	RADIUS		0.6	0.8		min	118
						max	220e3

☞ Graphic →Animation → New

Result

The animation video is created in the project repertory in a .AVI file.



4.3.3. Plot a 3D curve of the electric field at a point versus I/O parameters

Goal

The values of the electric field as function of the relative permittivity and the curvature of the electrode's radius is computed and displayed in a 3D curve (I/O parameter).

Data

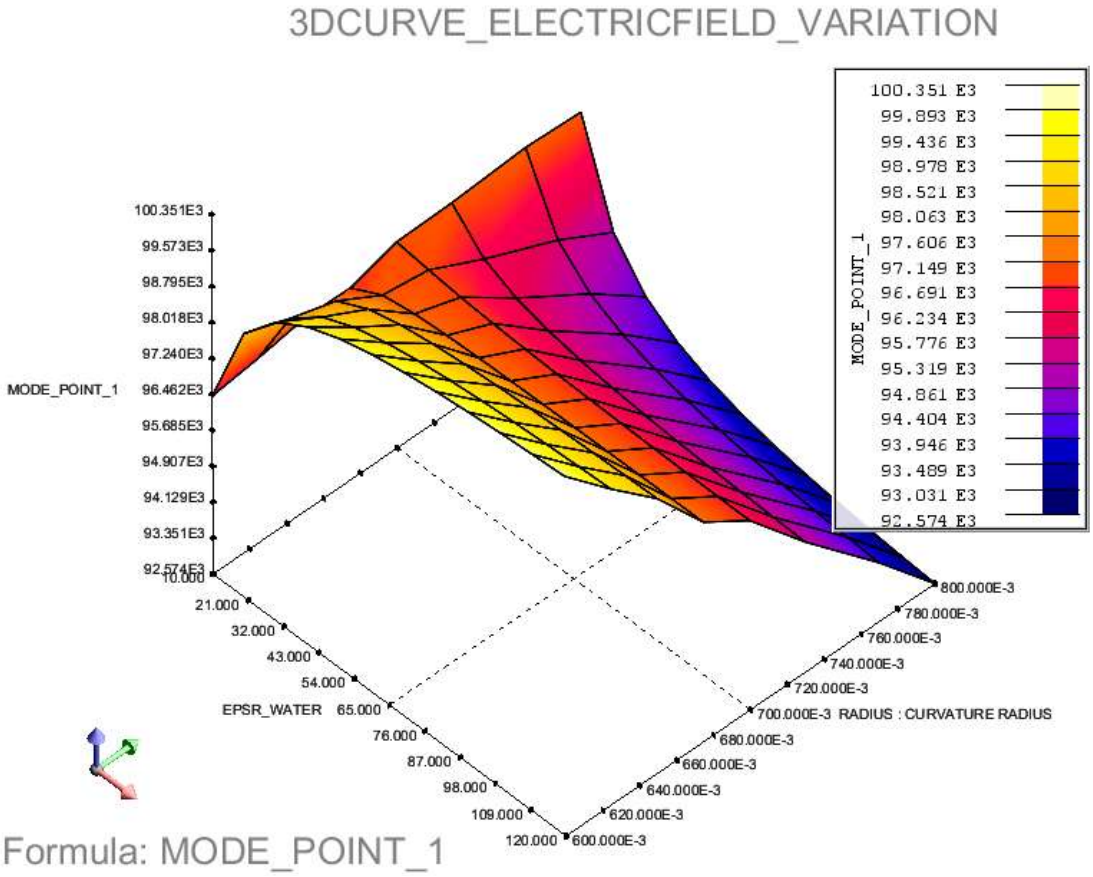
The characteristics of the 3D curve are presented in the table below.

3D curve (2 I/O parameters)				
Name	Parameter			Formula f()
	Name	Limit min.	Limit max.	Sensor
3DCURVE_ELECTRIC FIELD_VARIATION	EPSR_WATER	10	120	MODE_POINT1
	RADIUS	0.6	0.8	

☞ **Curve → 3D Curve (2 I/O parameter) → New 3D Curve (2 I/O parameter)**

Result

The following diagram shows the electric field variation as function of the permittivity of the liquid and the radius of the electrode.



4.3.4. Plot a 3D curve of the potential at a point versus I/O parameters

Goal

The values of the electric potential as function of the relative permittivity and the radius of curvature of the electrode is computed and displayed in a 3D curve (I/O parameter).

Data

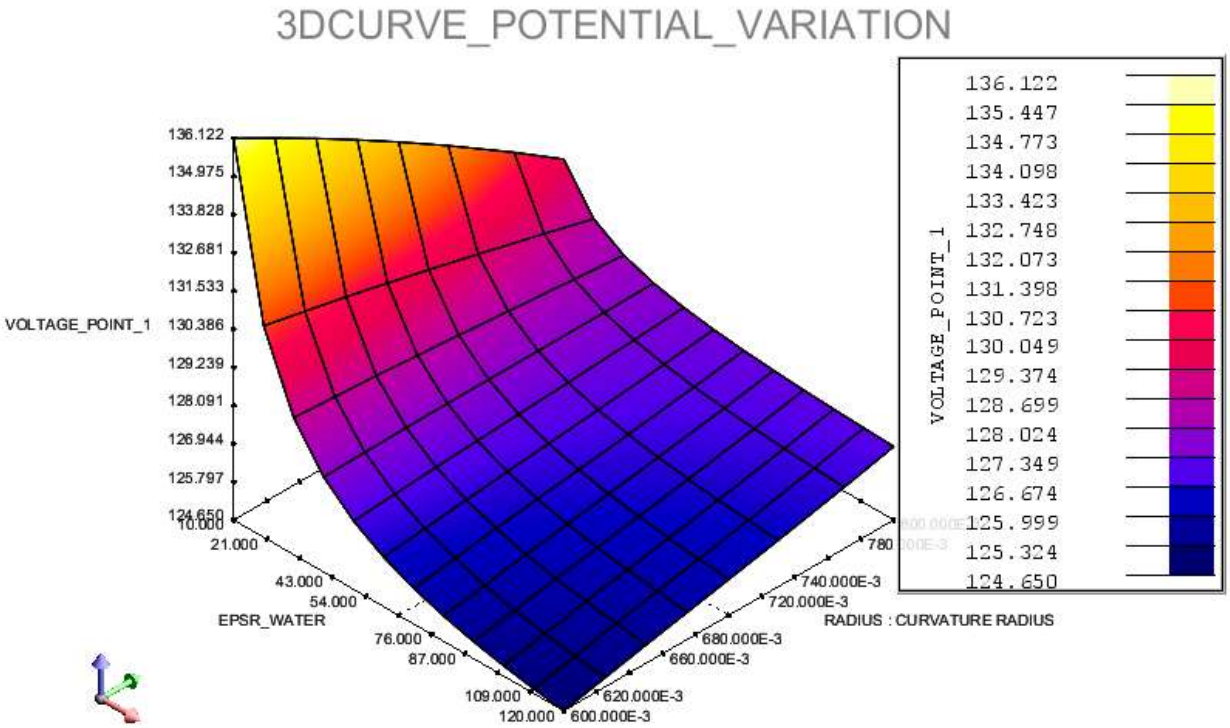
The characteristics of the 3D curve are presented in the table below.

3D curve (2 I/O parameters)				
Name	Parameter			Formula
	Name	Limit min.	Limit max.	Sensor
3DCURVE_POTENTIAL_VARIATION	EPSR_WATER	10	120	VOLTAGE_PT1
	RADIUS	0.6	0.8	

☞ **Curve → 3D Curve (2 I/O parameter) → New 3D Curve (2 I/O parameter)**

Result

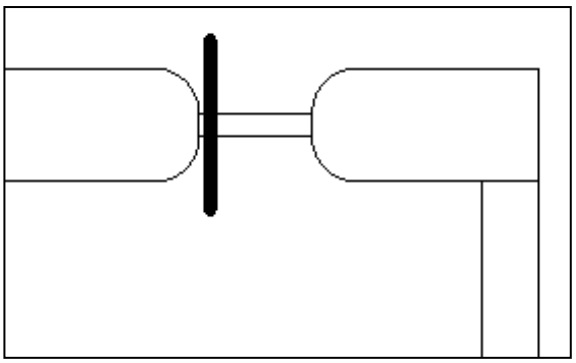
The following diagram shows the voltage variation as function of the permittivity of the liquid and the radius of the electrode.



4.3.5. Plot a 3D curve of electric field along a path versus I/O parameter

Goal

A path is created in order to plot a 3D curve of the electric field variation along a path as function of the curvature radius.



Data (1)

The characteristics of the path are presented in the table below.

Path defined by **2 points**			
Name	**Comment**	**Definition**	**Discretization**
PATH_1	Crossing glass spacer	by coordinates	100

Path defined by coordinates					
Path points					
Starting point			**Ending point**		
Coord. system	**Coordinates**		**Coord. system**	**Coordinates**	
	First	**Second**		**First**	**Second**
XY1	14.2	3.5	XY1	14.2	6.5

☞ **Support → Path → New**

Data (2)

The characteristics of the 3D curve are presented in the table below.

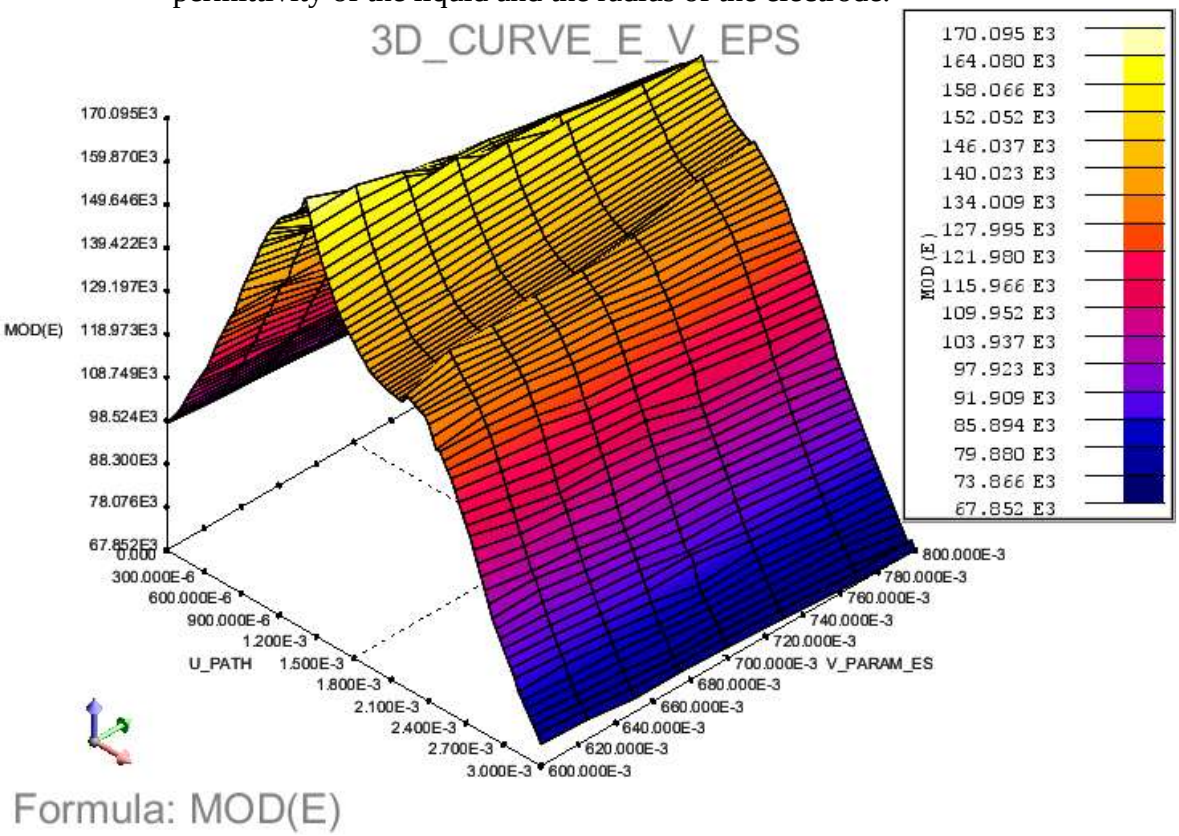
3D curve (Path + I/O parameter)						
Name	**Path**	**Parameter**				**Quantity**
		Name	**Current value**	**Limit min.**	**Limit max.**	
3D_CURVE_E_V_EPS	Path_1	EPSR_WATER	80			Electric field / Magnitude
		RADIUS		0.6	0.8	

☞ **Curve → 3D Curve (Path + I/O parameter) → New 3D Curve (Path + I/O parameter)**

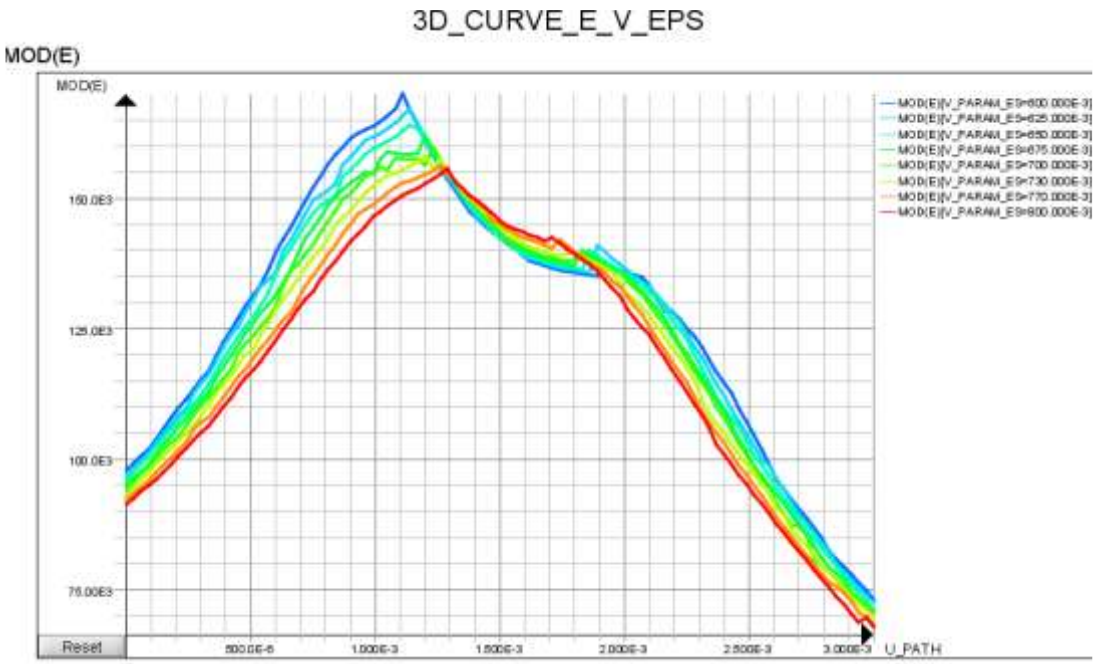
Continued on next page

Result

The following diagram shows the electric field variation as function of the permittivity of the liquid and the radius of the electrode.



The results can also be displayed in a 2D representation



4.3.6. Plot a 2D curve of the energy versus I/O parameter

Goal

The values of the energy stored in the SPACER region are computed as function of the permittivity.

Data

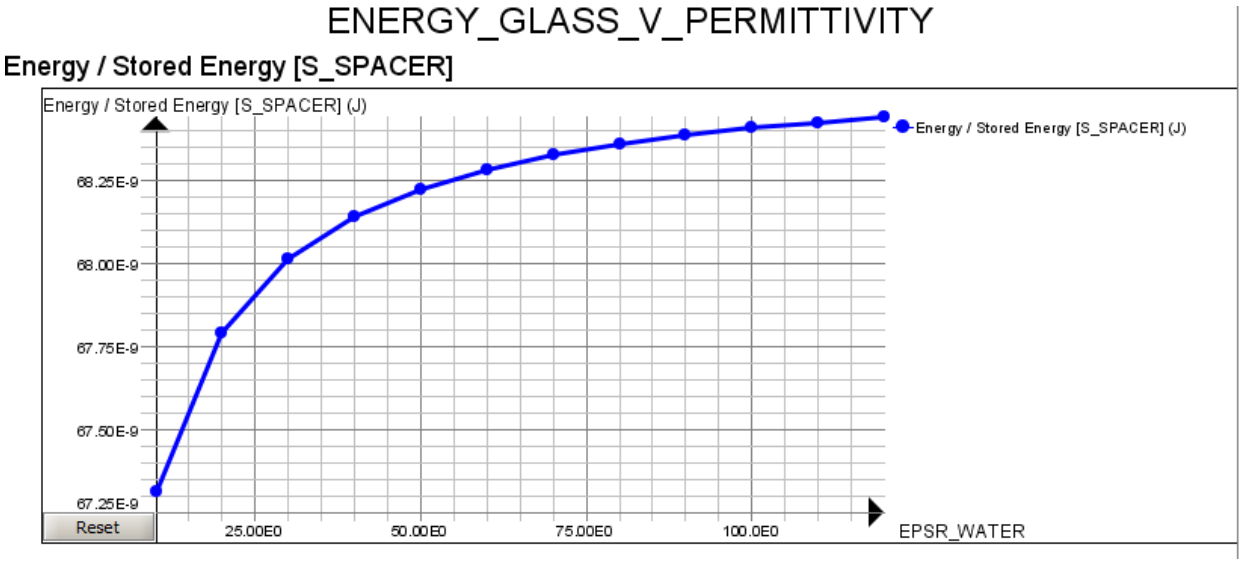
The characteristics of the 2D curve are presented in the table below.

2D curve (I/O parameter)						
Name	Parameter				Region	
	Name	Current value	Limit min.	Limit max.	Spatial group	Quantity
ENERGY_GLASS_V_PERMITTIVITY	EPSR_WATER		10	120	S_SPACER	Energy / Energy stored
	RADIUS	0.8				

☞ **Curve → 2D Curve (I/O parameter) → New 2D Curve (I/O parameter)**

Result

The curve is displayed as presented in the figure below.
Remark: choose a minimum stored energy displayed value of 67.25e-9J.



5. Case 3: static study, material with the low relative permittivity

Case 3

The third case is a static study.

This study differs from case 1 only by the nature of the testing material.
The testing liquid is mineral oil.

Project name

The Flux project is **GEO_MESH_PHYS.FLU**.

Starting Flux project

The new Flux project is saved under the name CASE3.FLU

Contents

This chapter contains the following topics:

5.1. Case 3: modifying physical properties

Introduction This section explains how to prepare case 3.

Project name The Flux project is **CASE3.FLU**.

Contents This section contains the following topics:

5.1.1. Create a material

Goal

A new material is defined for the cell contents; the material is linear isotropic characterized by the relative permittivity.

Data

The characteristics of the materials are presented in the tables below.

D(E) dielectric property**: linear isotropic**		
Name	**Comment**	**Relative permittivity**
OIL	Mineral oil	2.5

☞ **Physics → Material → New**

5.1.2. Modify the LIQUID face region

Goal

The new OIL material is assigned to the LIQUID face region.

Data

The characteristics of the materials are presented in the tables below.

Face region			
Name	**Type**	**Matérial**	**Color**
LIQUID	Dielectric region with charge source	OIL	Yellow

5.2. Case 3: solving process

Introduction The case 3 is solved using the default scenario with reference values.

Action Solve case 3.

☞	**Solving → Solve**	

5.3. Case 3: results post-processing

Introduction

This section explains how to analyze the principal results of case 3.

Contents

This section contains the following topics:

5.3.1. Display isolines of the electric potential on face regions

Goal

Isolines of the electric field are created in order to give information on its intensity and control the quality of the mesh.

Data

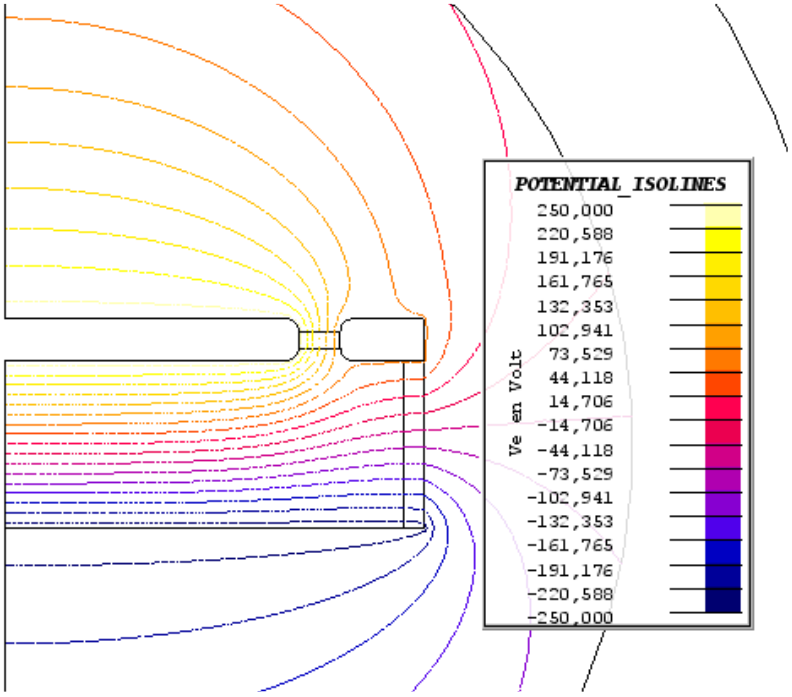
The characteristics of the isolines are presented below.

Isolines on face regions		
Spatial Group	**Quantity**	**Formula**
S_LIQUID	Electric potential / Scalar electric potential [V]	Ve
S_AIR		

☞ **Graphic → Isolines → New**

Result

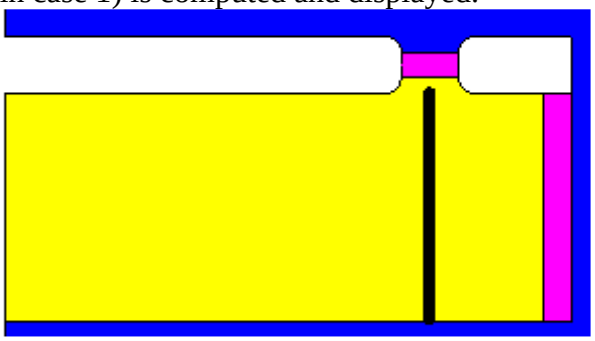
The isolines of the electric potential in the LIQUID and AIR regions are displayed below.



5.3.2. Plot a 2D curve of the electric field along a path

Goal

A 2D curve of the electric field along a path crossing the liquid region (already created in case 1) is computed and displayed.



Data (1)

The characteristics of the path are presented in the table below.

Path defined by **2 points**			
Name	**Comment**	**Definition**	**Discretization by intervals**
LIQUID_PATH	Path in the LIQUID region	by coordinates	50

Path defined by coordinates					
Path points					
Starting point			**Ending point**		
Coord. system	**Coordinates**		**Coord. system**	**Coordinates**	
	First	**Second**		**First**	**Second**
XY1	15	4	XY1	15	-3.9

☞ **Support → Path → New**

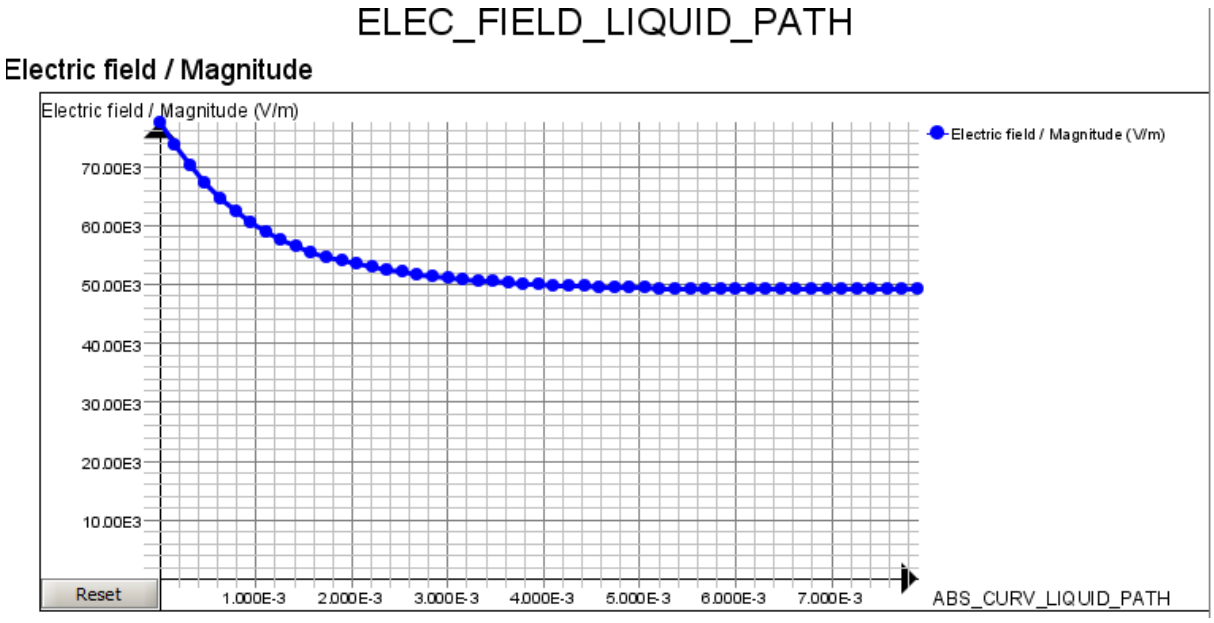
Data (2)

The characteristics of the curve are presented in the table below.

2D curve (XYZ path)			
Name	**Path**	**Quantity**	**Formula**
ELEC_FIELD_LIQUID_PATH	LIQUID_PATH	Electric field / Magnitude [V/m]	ModV(E)

☞ **Curve → 2D curve (Path) → New 2D curve (Path)**

Result The curve is displayed as presented in the figure below.



5.3.3. Import and superimpose 2D curve

Goal

The ELEC_FIELD_LIQUID_PATH curve in case 1 is exported from the case 1 directory. Then this curve is imported in case 3 directory to compare it with the ELEC_FIELD_LIQUID_PATH curve from case 3..

Data (1)

The characteristics of the txt export from case 1 are presented in the table below.

TXT export (case 1)	
Name	**Text file**
ELEC_FIELD_LIQUID_PATH	ELEC_FIELD_LIQUID_PATH_case1.txt

☞ **Curve → 2D curve (Path) → TXT export**

Action

Import case 1 curve in case 3

☞ **Curve → 2D curve (Path) → Import a 2D curve – Flux file (txt)**

Data (2)

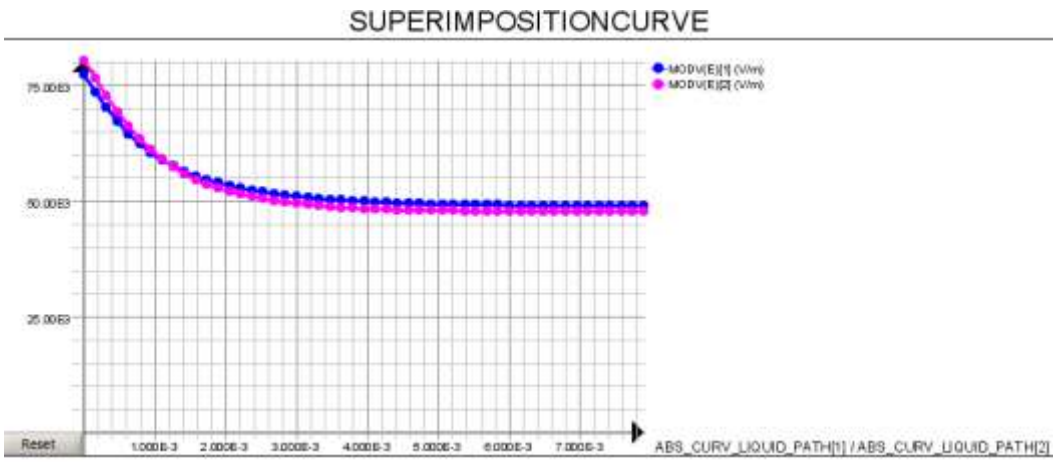
The characteristics of the curves superimposition in case 3 are presented in the table below.

Superimpose 2D curves (case 3)		
Name	**Interpolation**	**Curves**
SuperimpositionCurve	Linear	ELEC_FIELD_LIQUID_PATH
		ELEC_FIELD_LIQUID_PATH _IMPORT_1

☞ **Curve → 2D curve (Path) → Superimpose 2D curves (path)**

Result

The superimposed curves are displayed as presented in the figure below.
Remark: Choose the “Absolute” display mode



Display the graph in absolute mode

5.3.4. Compute the energy on LIQUID region

Goal

We will compute the local quantity of the energy in the LIQUID region.

Data

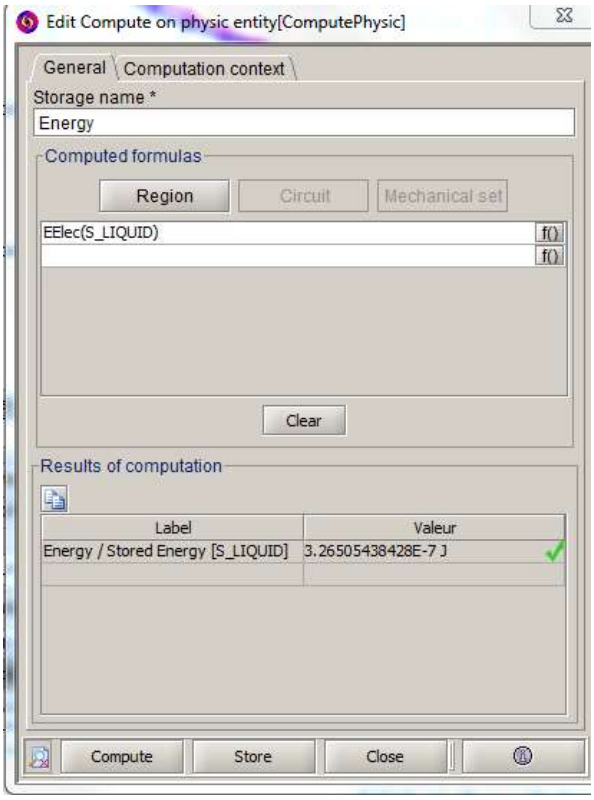
The characteristics of the computation are presented below.

Computation on physical entity		
Name	**Region**	
	Group	**Quantity**
Energy	S_LIQUID	Energy / Stored Energy

☞ **Computation → On physical entity → Compute**

Result

The result is presented in the figure below.



Note: The energy stored in the LIQUID region is lower than the value corresponding to case 1 (roughly $1.04e^{-5}$ J). Actually, compared to water the relative permittivity of the oil is lower.