

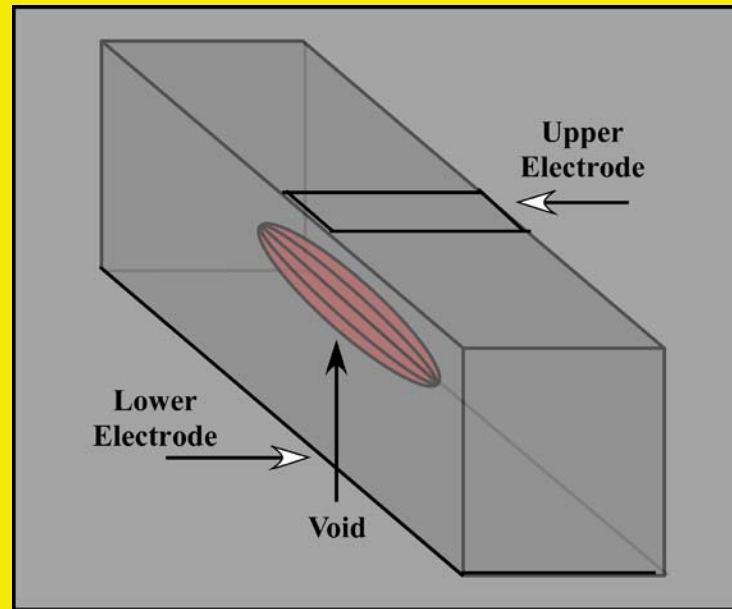
Expanding Your Materials Horizons

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Pryor Knowledge Systems, Inc.



Electrical Impedance Tomography (EIT)

EIT is a Non-Invasive Methodology developed for the Measurement of Differential Impedance and Void Detection.



This technology (EIT) was independently developed through research in several different disciplines.

Reference information can now be found under several different acronyms in the literature.

Examples of these independently developed methodologies are:

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3. **Civil Engineering** (electrical resistance tomography)
4. **Industrial Processes** (possibly other acronyms)

The problem of diverse reference sources with different acronyms (names) in different disciplines is commonly found in many of the disciplines that employ mathematical modeling and simulation.

In this presentation, EIT is chosen as the demonstrative modeling methodology area.

Consider the following diverse reference sources typically employed for the acquisition of materials properties data.

Materials Properties Data Sources

1. **The Literature** (manual search procedure, manual data entry)

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6. **Proprietary COMSOL Materials Library** (direct data selection)
7. **Proprietary PKS-MPD Materials Properties Database** (direct data search, COMSOL library file creation and entry)

EIT Model Parameter Space

1. Potential Frequency Range 1 Hz - 10^{10} Hz

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2. Mammalian Species: Human, Bovine (Cow), Ovine (Sheep), etc.

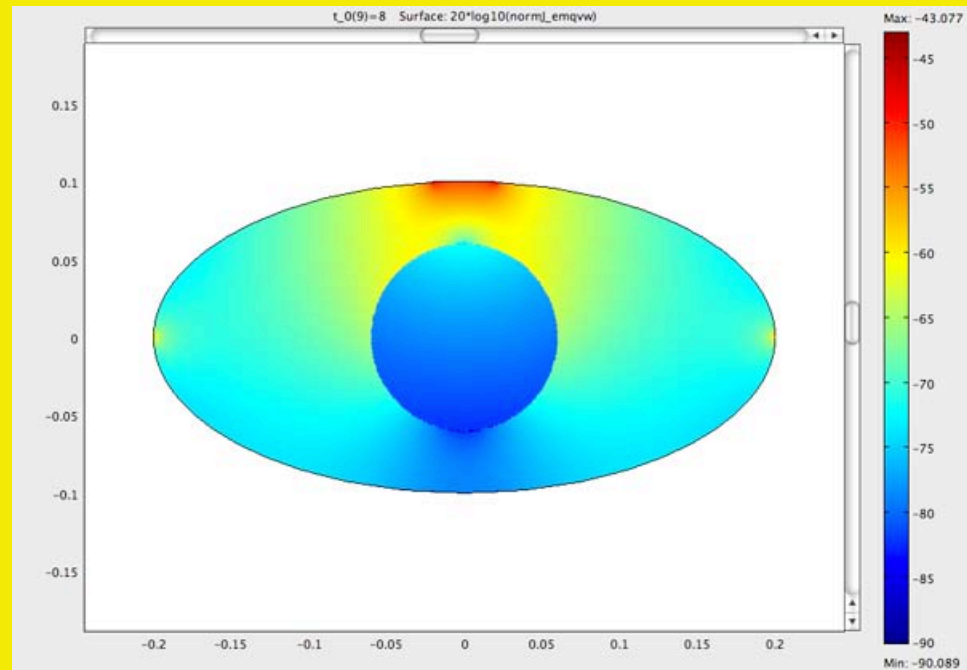
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2. Mammalian Species: Human, Bovine (Cow), Ovine (Sheep), etc.
3. Types of Tissue: Muscle, Lung, Heart, etc.
4. Materials and Tissue Properties: Conductivity, Density, Permeability, Permittivity, Resistivity, etc.

COMSOL Multiphysics First Principles EIT Ovine Lung Function Model



This EIT Model Parameter Space

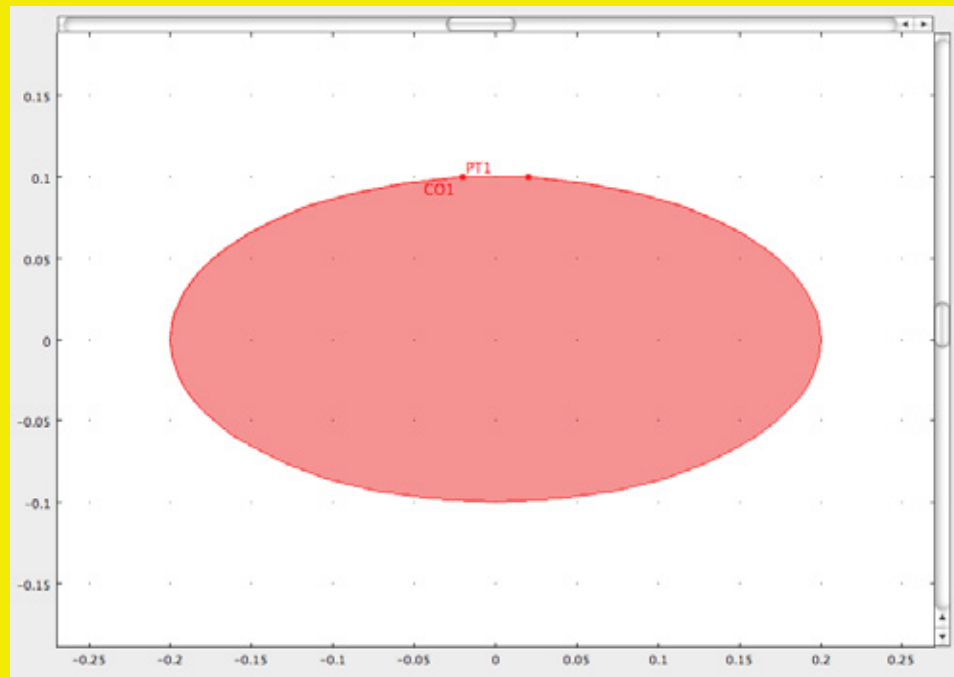
1. Frequency 1×10^4 Hz.
2. Mammalian Species: Ovine (Sheep).
3. Types of Tissue: Muscle, Lung.
4. Inorganic Materials: Air.
5. Materials and Tissue Properties: Conductivity, Permittivity
6. Temperature of Property Value Measurement

This EIT Model Subdomain Space

1. In this EIT Model, Subdomain Regions (muscle, lung, air) are not defined geometrically.
2. In this EIT Model, Subdomain Regions (muscle, lung, air) are defined logically through the use of a set of Scalar Equations.
3. Defining the Subdomain Parameters logically reduces the model's geometrical complexity and eliminates the need to use ALE (moving mesh) techniques.

EIT Ovine Lung Function Model

Single Geometric Subdomain



EIT Ovine Lung Function Model Single Geometric Subdomain

Materials Properties Data Retrieval

Consider the following reference source (PKS-MPD) employed for the acquisition of this model's materials properties data.

This source generates and exports a file for the selected materials properties matched to the COMSOL Version (e.g. 3.5a) that can imported directly into the COMSOL Model's Material Library through the Add Library function.

EIT Ovine Lung Function Model

Tissue Relative Permittivity Retrieval

The screenshot shows the PKS-MPD software interface. At the top, there is a toolbar with icons for Exit, View Selected Properties, Generate Properties Report, Export to File, View Export Log, Clear All Selections, and Instructions. The ASM International logo is also present. Below the toolbar, there are tabs for Property, Material Type, Composition, and Other Characteristics. The 'Property' tab is active, showing a dropdown menu with 'Relative permittivity (epsilon_r)' selected. A checkbox 'Specify selection criteria for this property' is checked. The 'Value Range Selection' section includes input fields for Min. (1.1000e+4), Max. (3.1000e+4), T0 (3.5000e+1), and Freq (9.5000e+3), along with a unit of measure dropdown set to 'degC'. A 'UOM' button and a 'NONE' field are also visible. On the right, there are radio buttons for 'AND', 'OR', and 'NOT', and an 'Add to Search' button. Below this, the 'Selection Criteria' section shows a table with 5 materials selected. The table has columns for No., Field, Op, Criteria, Count, and Remove. The first row shows 'Type' with criteria 'Tissue' and a count of 74. The second row shows 'Other' with criteria 'Name @muscle@' and a count of 2. The third row shows 'Other' with criteria 'Name @lung@' and a count of 3. At the bottom, there is a 'Select Model Software' button and a dropdown menu showing 'COMSOL Multiphysics 3.5a'.

PKS-MPD

Exit View Selected Properties Generate Properties Report Export to File View Export Log Clear All Selections Instructions

Property Material Type Composition Other Characteristics

Select a property from the list:
Relative permittivity (epsilon_r)

Specify selection criteria for this property

Value Range Selection:

Min. Max. Select a unit of measure:
Value: 1.1000e+4 3.1000e+4 UOM NONE
T0: 3.5000e+1 4.0000e+1 degC
Freq: 9.5000e+3 10.5e3 Hz

AND
 OR
 NOT

Add to Search

Selection Criteria: **Materials Selected :** 5










No.	Field	Op	Criteria	Count	Remove
1	Type		Tissue	74	<input type="checkbox"/>
3	Other	AND	Name @muscle@	2	<input type="checkbox"/>
4	Other	OR	Name @lung@	3	<input type="checkbox"/>

Select Model Software COMSOL Multiphysics 3.5a

EIT Ovine Lung Function Model

Tissue Electrical Conductivity Retrieval

PKS-MPD

  Exit  View Selected Properties  Generate Properties Report  Export to File  View Export Log  Clear All Selections  Instructions 

Property | Material Type | Composition | Other Characteristics

Select a property from the list:
Electrical Conductivity (sigma)

Specify selection criteria for this property

Value Range Selection:

Min.	Max.	Select a unit of measure:	
Value: 6.0000e-2	4.0000e-2	UOM	S/m
T0: 3.5000e+1	4.0000e+1	degC	
Freq: 9.5000e+3	1.0500e+4	Hz	

AND
 OR
 NOT

Add to Search

Selection Criteria: Materials Selected : 5

No.	Field	Op	Criteria	Count	Remove
1	Type		Tissue	74	<input type="checkbox"/>
3	Other	AND	Name @muscle@	2	<input type="checkbox"/>
4	Other	OR	Name @lung@	3	<input type="checkbox"/>

Select Model Software: COMSOL Multiphysics 3.5a

EIT Ovine Lung Function Model

Air Relative Permittivity Retrieval

PKS-MPD

Exit View Selected Properties Generate Properties Report Export to File View Export Log Clear All Selections Instructions

Property Material Type Composition Other Characteristics

Select a property from the list:

Specify selection criteria for this property

AND
 OR
 NOT

Add to Search

Selection Criteria: Materials Selected : 1

No.	Field	Op	Criteria	Count	Remove
1	Type		Gas	29	<input type="checkbox"/>
2	Other	AND	Name @air@	33	<input type="checkbox"/>
3	Property	AND	Relative permittivity (epsilon _r)	452	<input type="checkbox"/>

Select Model Software COMSOL Multiphysics 3.5a

EIT Ovine Lung Function Model, Constants Values Table

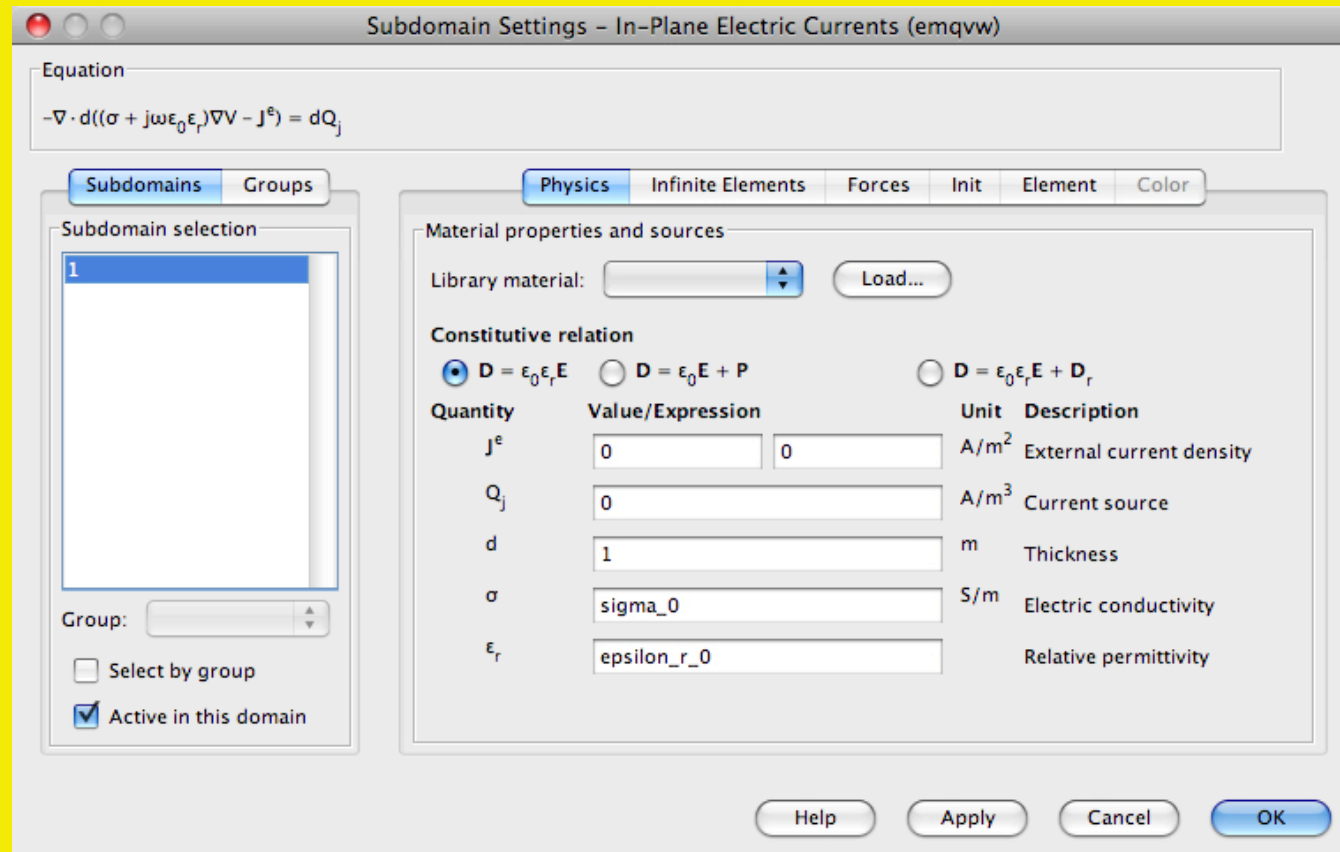
Selected Materials Properties, Variables and Values

Variable	Value	Parameter
sig_m	0.3621[S/m]	Muscle conductivity
eps_r_m	3.043e4	Muscle relative permittivity
x_0	0.0[m]	x position of cavity center
y_0	0.0[m]	y position of cavity center
r_0	0.05[m]	Cavity radius
t_0	0.0[s]	Time init
sig_L	0.06366[S/m]	Lung inflated conductivity
eps_r_L	1.634e4	Lung inflated relative permittivity
freq_01	1.0e4[Hz]	Frequency
sig_air	1e-15 [S/m]	Conductivity of air
eps_r_air	1	Relative permittivity of air

EIT Ovine Lung Function Model Scalar Equations Table

Equation	Value	Parameter
sigma_0	$(\text{sig_m} * (((x-x_0)^2 + (y-y_0)^2) > r_{00}^2)) +$ $(\text{sig_L} * (r_{00}^2 \geq ((x-x_0)^2 + (y-y_0)^2) \geq r_{02}^2)) +$ $(\text{sig_air} * (((x-x_0)^2 + (y-y_0)^2) < r_{02}^2))$	Model conductivity
epsilon_r_0	$1 + (\text{eps_r_m} - 1) * (((x-x_0)^2 + (y-y_0)^2) > r_{00}^2) +$ $(\text{eps_r_L} - 1) * (r_{00}^2 \geq ((x-x_0)^2 + (y-y_0)^2) \geq r_{02}^2) +$ $(\text{eps_r_air} * (((x-x_0)^2 + (y-y_0)^2) < r_{02}^2))$	Model permittivity
r_00	$r_0 * (1.4 - \cos((t_0[1/s] * \pi) / 8)) / 2$	Lung Outer Wall Radius
r_02	$r_{00} - 0.01$	Lung Inner Wall Radius

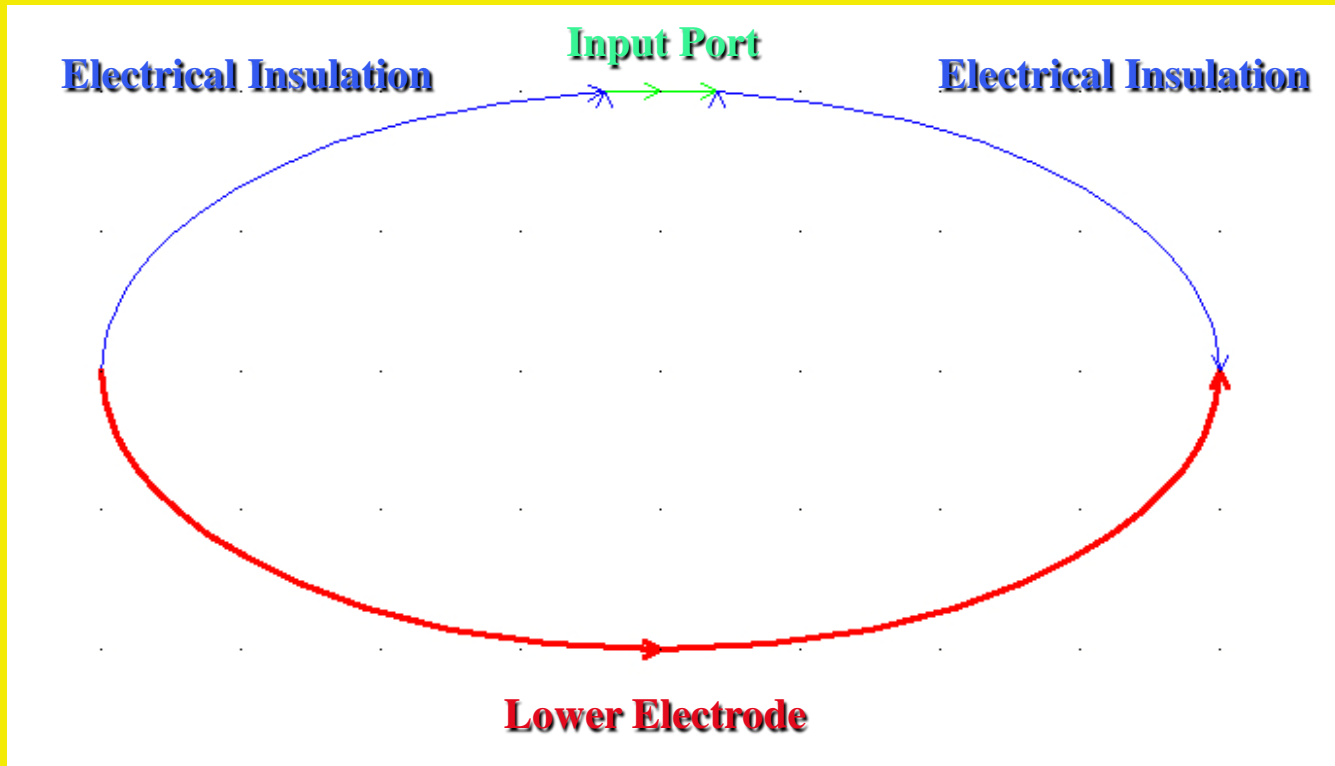
This EIT Model Subdomain Settings



This EIT Model Boundary Settings

Boundary	Setting
1,4,5,8 (blue)	Electrical Insulation
2,3 (green)	Port
6,7 (red)	Ground
Port Tab	Setting
Port Number	1
Input property	Fixed current density
Use port as input	Check Checkbox
Input current	1e-4 [A]

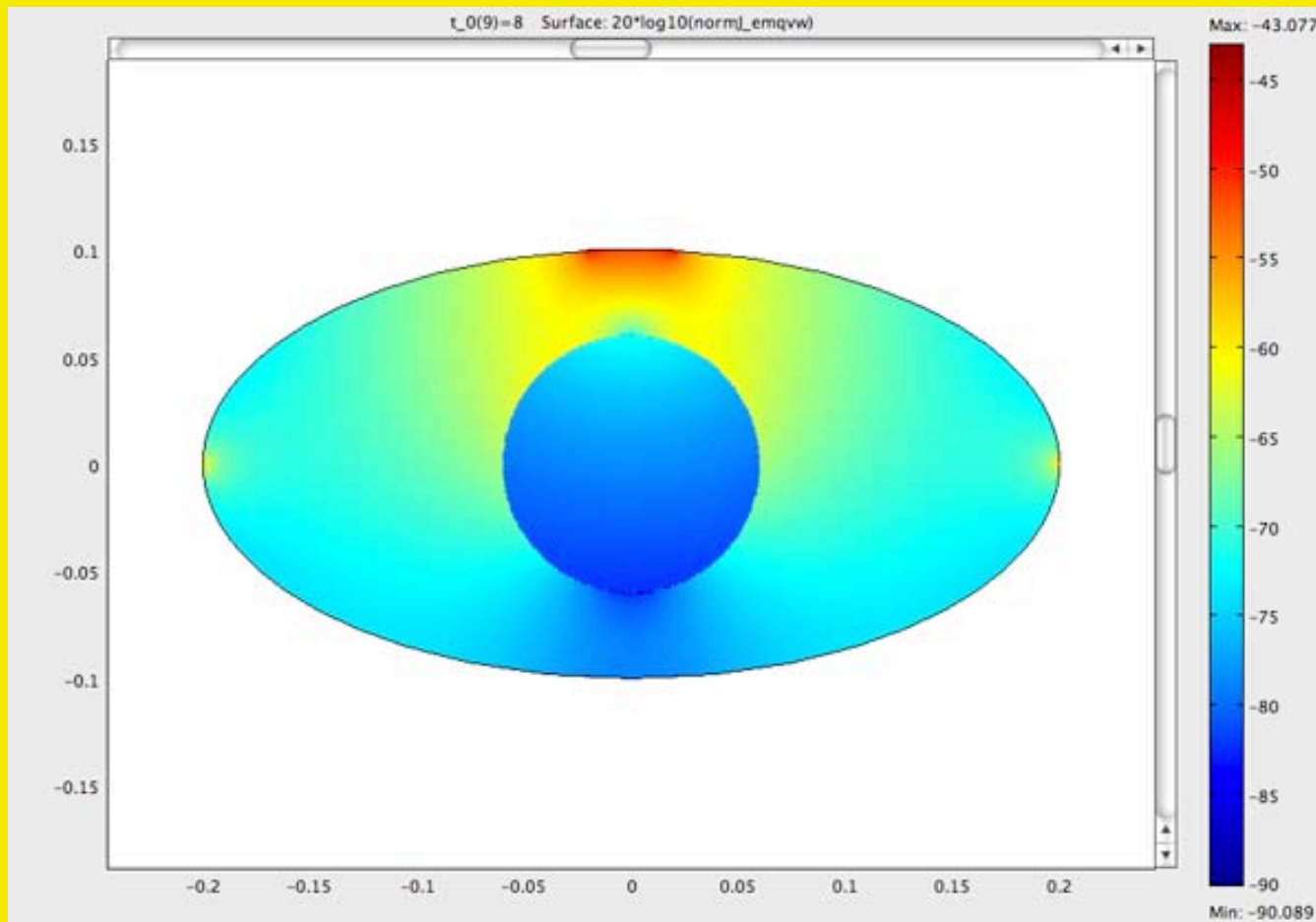
This EIT Model Boundary Settings, Graphic



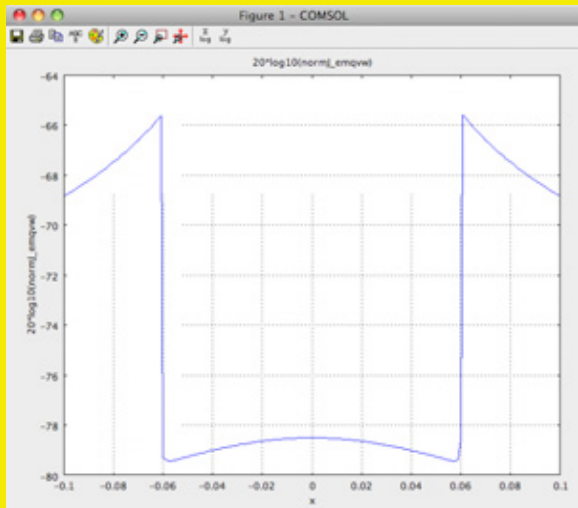
This EIT Model Meshing and Solution

- 1. Model meshed with a size limit of 0.001, using a Triangle (advancing front) mesh.**
- 2. Model solved with Parametric Solver on t_0 , range(0,32/32,32).**

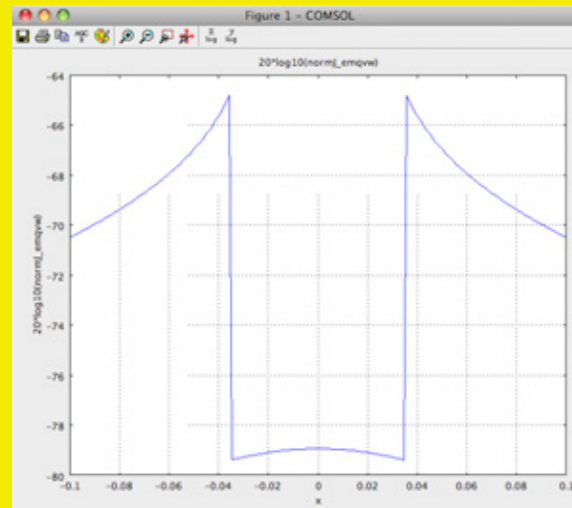
This EIT Model Solution Graphic Single Solution, Maximum Inflation



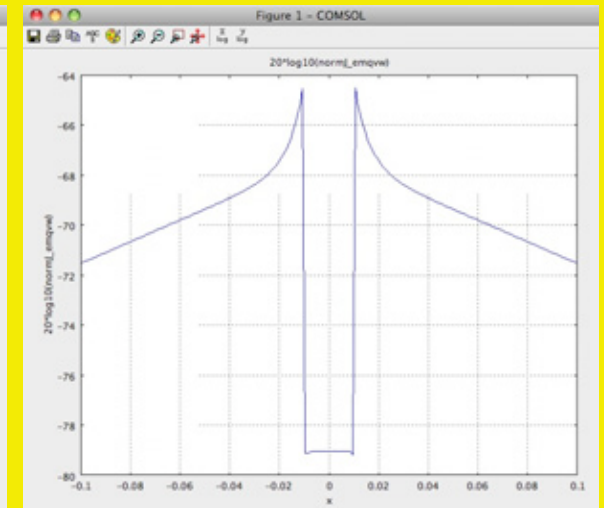
This EIT Model Solution Graphic Cross-Section Plots



Maximum-Inflation



Half-Inflation



Minimum-Inflation

This EIT Model Solution Movie

QuickTime™ and a
decompressor
are needed to see this picture.

Thank You!