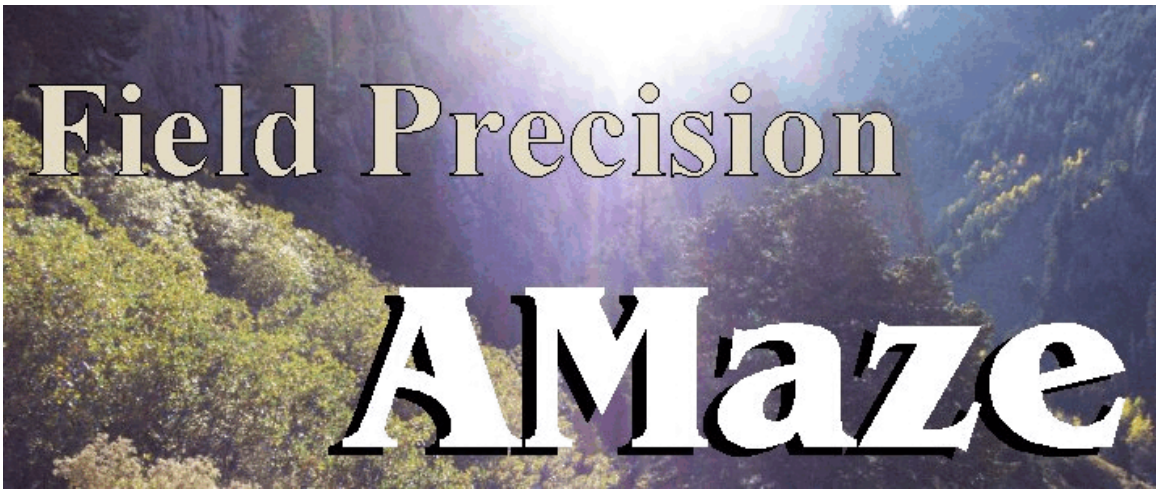

HiPhi

Three-dimensional Electrostatics

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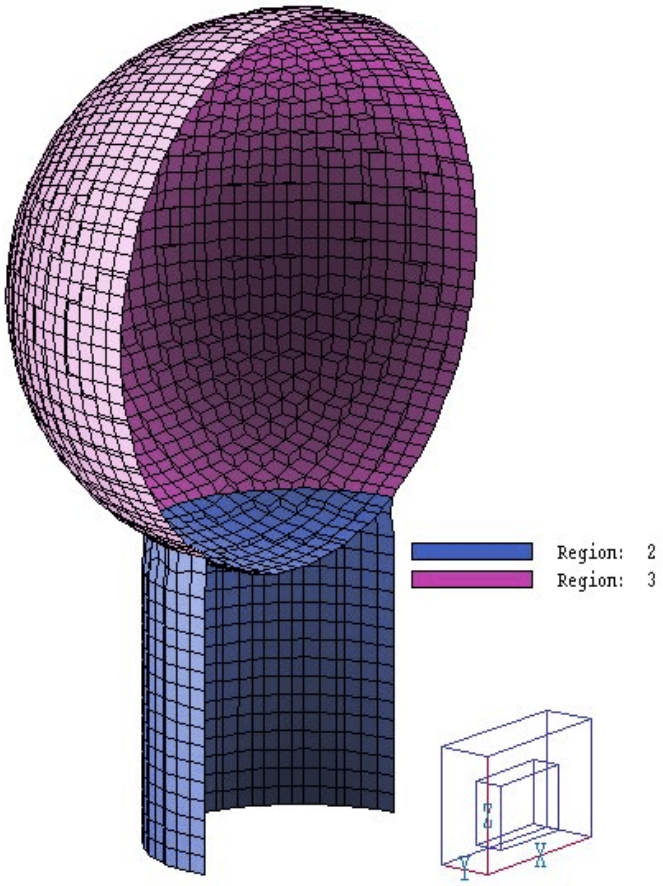

Figure 1.1. Geometry defined by the **MetaMesh** script `WALKTHRU.MIN`

1.2. Test run

A quick way to understand the solution procedure is to step through an example. The calculation we shall consider describes a spherical high-voltage electrode on a nylon support at an offset position inside a rectangular grounded chamber. The calculation utilizes a symmetry boundary to minimize the run time. Figure 1.1 shows the geometry of the electrode and support. The **MetaMesh** script file is listed in Table 1.1.

Table 1.1. MetaMesh script file for WALKTHRU.MIN

```
* File WALKTHRU.MIN
GLOBAL
  XMesh
    0.00   9.00  N 90
  End
  YMesh
    0.00   3.00  N 30
  End
  ZMesh
    0.00   6.00  N 60
  End
  RegName 1 Solution volume
  RegName 2 Dielectric support
  RegName 3 Spherical electrode
  RegName 4 Grounded boundary
END

PART 1
* Solution region
  Type Box
  Region 1
  Fab  18.0  6.00  12.00
END

PART 2
* Dielectric support
  Type Cylinder
  Region 2
  Fab 0.80 4.00
  Shift 4.00 0.00 0.00
  Surface Region 1
END

PART 3
* Spherical electrode
  Type Sphere
  Region 3
  Fab 1.5
  Shift 4.00  0.00  3.00
  Surface Region 1
  Surface Part 2
END

PART 4
* Boundary, upper Y
  Type BoundYUp
  Region 4
END

PART 5
* Boundary, upper X
  Type BoundXUp
  Region 4
END

PART 6
* Boundary, lower X
  Type BoundXDn
  Region 4
END

PART 7
* Boundary, upper Z
  Type BoundZUp
  Region 4
END

PART 8
* Boundary, lower Z
  Type BoundZDn
  Region 4
END

ENDFILE
```

To prepare move the example files `WALKTHRU.MIN`, `WALKTHRU.HIN` and `WALKTHRU.SCR` to the working directory (*i.e.*, `\AMAZE\BUFFER`). Run `AMAZE.EXE` (the **AMaze** program launcher) and click on *Set data directory*. Move to `\AMAZE\BUFFER` and click *OK*. Then launch **MetaMesh**. Pick *Load MIN file* from the *File* menu. If **AMaze** is set up correctly, the program transfers to `\AMAZE\BUFFER` and the file `WALKTHRU.HIN` appears in the dialog. Open the file.

Next, pick *Process mesh.* The program lists information on the conversion process on the screen and in the file WALKTHRU.MLS. Click the right mouse button to continue. Finally, pick *Save mesh* from the *File* menu. At this point, you can use the plot functions of **MetaMesh** to examine the geometry of the mesh or proceed to the electrostatic solution.

Run **HiPhi** from **AMaze**. After the program starts, pick *Run* from the main menu or use the run tool. In the dialog, pick the file WALKTHRU.EIN. Table 1.2 shows the contents of the file. **HiPhi** calculates the element matrices and coupling coefficient necessary for the finite-element solution and then proceeds with the relaxation process. The program creates the binary output file WALKTHRU.HOU and the ASCII listing file WALKTHRU.HLS. The run takes about 60 seconds on a 1.7 GHz Pentium 4 computer. You can use the *Edit listing file* command to inspect WALKTHRU.ELS.

Table 2.1 HiPhi script WALKTHRU.HIN

```
* File WALKTHRU.HIN
ResTarget = 1.0E-7
MaxCycle = 1000
DUnit = 100.0
NCheck = 25
* Solution volume
Epsi(1) = 1.0
* Dielectric support
Epsi(2) = 3.5
* Spherical electrode
Potential(3) = 25000.0
* Boundary
Potential(4) = 0.0
ENDFILE
```

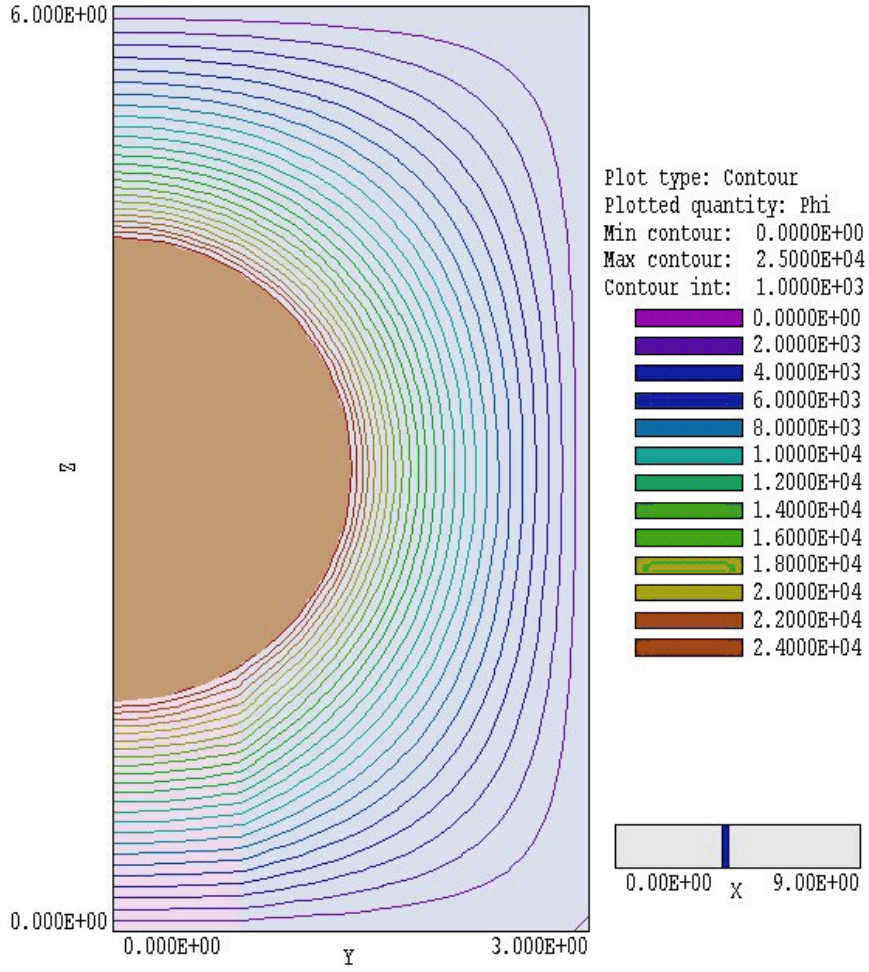

Figure 1.2. Slice plot normal to the *x* axis at position *x* = 4.05

Following a successful solution, start the program **PhiView.** Pick *Load solution file* from the *File* menu or click on the tool. Pick the file WALKTHRU.HOU in the dialog. **PhiView** can generate a wide variety of 2D and 3D plots. Chapters 10, 11 and 12 give detailed information. Here, we will look at two examples. To create the 2D equipotential plot of Fig. 1.2, go to the *Slice plot* menu. On the *Change view* popup menu, pick the command *Set slice plane properties*. Click the *X Axis* button, move the slider to *x* = 4.05, and then click OK. You should see the equipotential plot of Fig. 1.2. Note the slope discontinuity of equipotential lines at the edge of the dielectric.

PhiView also has 3D plot capabilities. Return to the main menu and click on *Surface plots*. On the *Plot control* popup menu click on *Surface plot style*. The default plot shows the variation of electric field in a plane

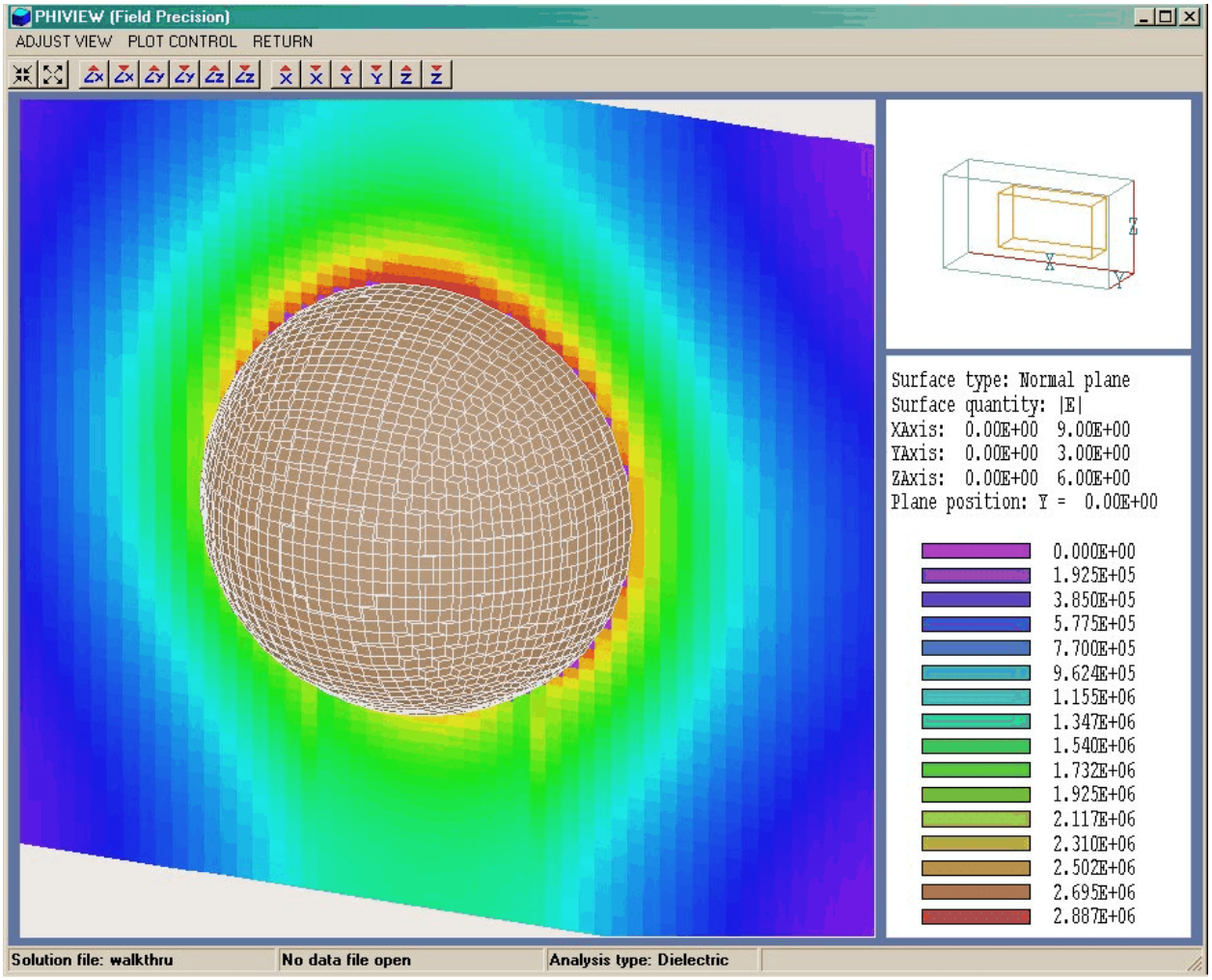

Figure 1.3. Working environment of **PhiView** showing a surface plot of |**E**| in a normal plane.

normal to *z*. Click the button for the *y* axis, move the slider to $y = 0.0$ and click *OK*. Next, we shall add the spherical electrode to the plot for reference. On the *Plot control* menu click on *Displayed regions*. Activate Region 3 and click *OK*. To get a better view, we need to rotate the plot. On the *Adjust view* menu click on *Set surface view*. Set the view angles to approximately $\theta_x = -80.0°$, $\theta_y = 0.0°$ and $\theta_z = -150.0°$. With some tuneup using the zoom and displacement tools, you should see the plot of Fig. 1.3. The figure shows the variation of |E| over the symmetry. The dielectric support is at the bottom.

You can experiment with commands to move through the solution space or to change the style of the plot. You can also check the *Hardcopy* or *Plot file* functions in the *Export plot* popup menu. Remember to set the correct

printer in Windows before using the *Default printer* command..

Plots are pleasing, but the ultimate aim of the program is to generate numbers. Return to the main menu and click on *Run script* in the *File* menu. In the dialog, pick the file `WALKTHRU.SCR`. There is a delay while **PhiView** performs a extensive analysis. To begin, we shall inspect the instructions in the data script. In the *File* menu click on *Edit script* and choose `WALKTHRU.SCR`. The internal program editor loads and shows the following content:

```
INPUT WalkThru.HOU
OUTPUT WallThru
FULLANALYSIS
REGION 3
ENDFILE
```

The first statement ensure that the proper solution file is loaded and second statement opens a data file to write the results. The command *FullAnalysis* instructs the program to take volume integrals over all regions of the solution volume, while the command *Region 3* initiates volume and surface integrals over the electrode region. To inspect the new file `WALKTHRU.DAT` click on the command *Edit data file* in the *File* menu. Choose the file and click *OK*.

Table 1.3 summarizes results listed in the file. HiPhi has computed the volume of regions by taking Gaussian integrals over individual hexahedron elements. The computed volume of the spherical electrode (Region 3) is 7.0657×10^{-6} m^3, close to the theoretical value of the half-sphere of radius 1.5 cm: 7.0686×10^{-6} m^3. The computed total electrostatic field energy is 4.8640×10^{-4} J at an applied potential of 2.5×10^4 V. Using the expression $E = CV^2/2$, we find that the capacitance of the half-assembly is 1.5565 pF. Next consider the surface integral values determined in response to the command *Region 3*. The calculated surface area is 1.4271×10^{-3} m^2 while the theoretical prediction is 1.4137×10^{-3} m^2. We can also double-check the capacitance calculation using the surface charge value determined by integrating the normal electric field over the surface of the electrode. The calculated result is 3.9776×10^{-8} coulombs. The formula $C = Q/V$ gives the capacitance as 1.5910 pF, within 2% of the volume integral result.

Table 1.3. Information in the file WALKTHRU.DAT

```
---------- Global analysis of the solution volume ----------

        Fixed potential regions
  NReg  Potential     Volume
           (V)         (m3)
  ============================
    3  2.50000E+04  7.06573E-06
    4  0.00000E+00  0.00000E+00

          Dielectric  regions
  NReg   Epsilon        Rho        |E|(min)     |E|(max)     Energy
       (relative)     (c/m3)       (V/m)        (V/m)         (J)
=====================================================================
   1   1.00000E+00  0.00000E+00  1.22847E+01  3.75397E+06  4.23005E-04
   2   3.50000E+00  0.00000E+00  1.72222E+05  2.94126E+06  6.33973E-05

  Global field energy:   4.86402E-04 J
  Global volume:   1.61998E-04

---------- Analysis of Region Number   3 ----------

  Fixed potential:   2.50000E+04
  Volume integral quantities
  Volume:   7.06573E-06 (m3)
  Surface integral quantities
    Surface area:   1.42706E-03 (m2)
    Induced change:   3.97756E-08 (coulombs)
```