Companion software for "Volker Ziemann, *Hands-on Accelerator physics using MATLAB, CRCPress, 2019*" (https://www.crcpress.com/9781138589940)

TEM-mode in a coaxial waveguide (Section 6.2)

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Important: this example requires the PDE toolbox!

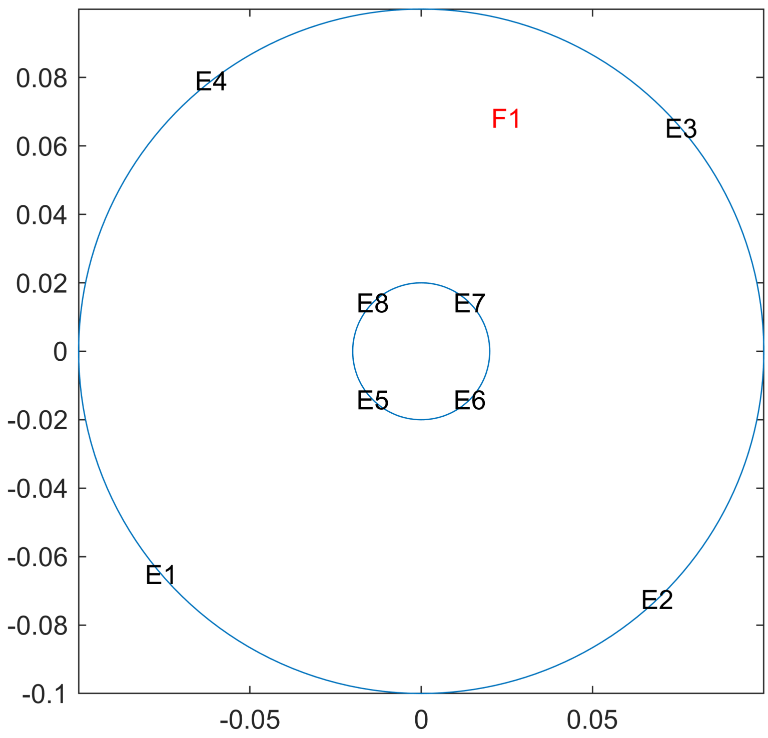
The central conductor present in coaxial waveguides causes the fields to be purely transverse; both longitudinal compenents E_z and $H_z$vanish in the region between the conductors, which forces the transverse fields to obey Equation 6.6 and 6.7. This in turn implies that the fields can be expressed as derivatives $E_x = -\partial\Phi/\partial x$ and $E_y = -\partial\Phi/\partial y$ of a potential Φ, which obeys Laplace's equation $\triangle\Phi = 0$ with constant potentials specified on the metallic boundaries.

In order to solve this problem, we define the domain in which to solve $\triangle\Phi = 0$ as the difference between two concentric circles labeled `outer` and `inner`, create the `model` and add the geometry g to it. The only difference to previous examples is that we here define the region of interest as the difference between two regions.

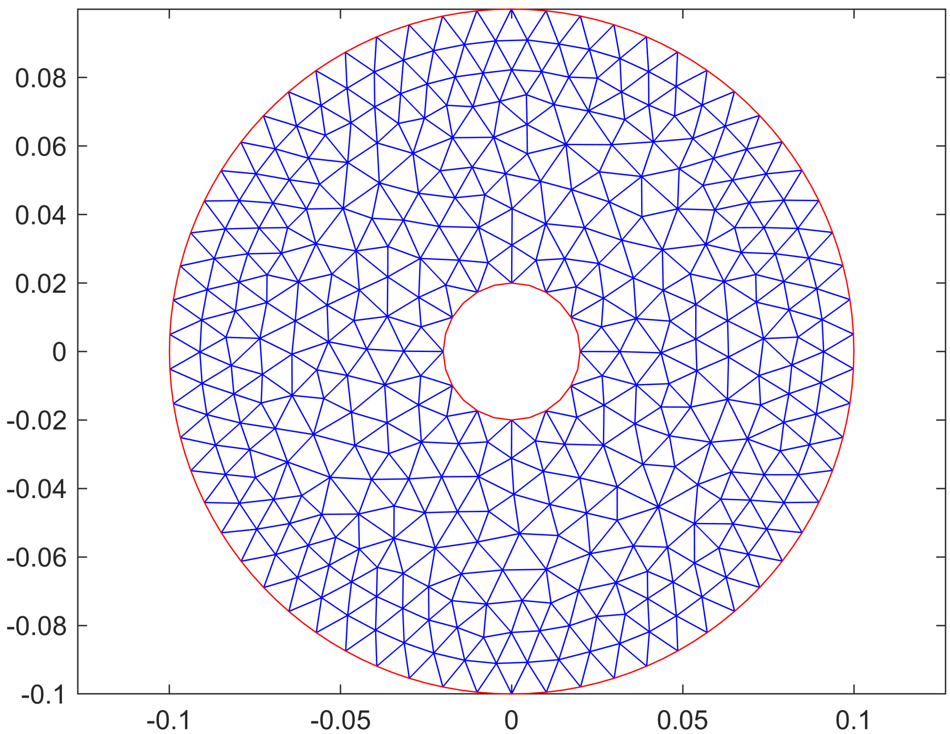
```
clear all; close all;
outer=[1;0;0;0.1]; inner=[1;0;0;0.02];
gd=[outer,inner];
ns=char('outer','inner')';
sf='outer-inner';     % difference
g=decsg(gd,sf,ns);
model=createpde(1);
geometryFromEdges(model,g);
```

After inspecting the `EdgeLabels` and the `SubDomainLabels` we use the first to define the potentials u = Φ on the inner and outer conductors to be 0 and 1, respectively. The Laplace operator in cartesian coordinates is given by the the second derivatives, which we take into account by specifying `c=1` in `specifyCoefficients()`. At this point we can generate the mesh and display it.

```
pdegplot(model,'EdgeLabels','on','SubDomainLabels','on'); axis equal
```




```
applyBoundaryCondition(model,'Edge',[1:4],'u',0); % outer
applyBoundaryCondition(model,'Edge',[5:8],'u',1); % inner
specifyCoefficients(model,'m',0,'d',0,'c',1,'a',0,'f',0,'Face',1);
generateMesh(model,'Hmax',0.01);
figure; pdemesh(model); axis equal;
```

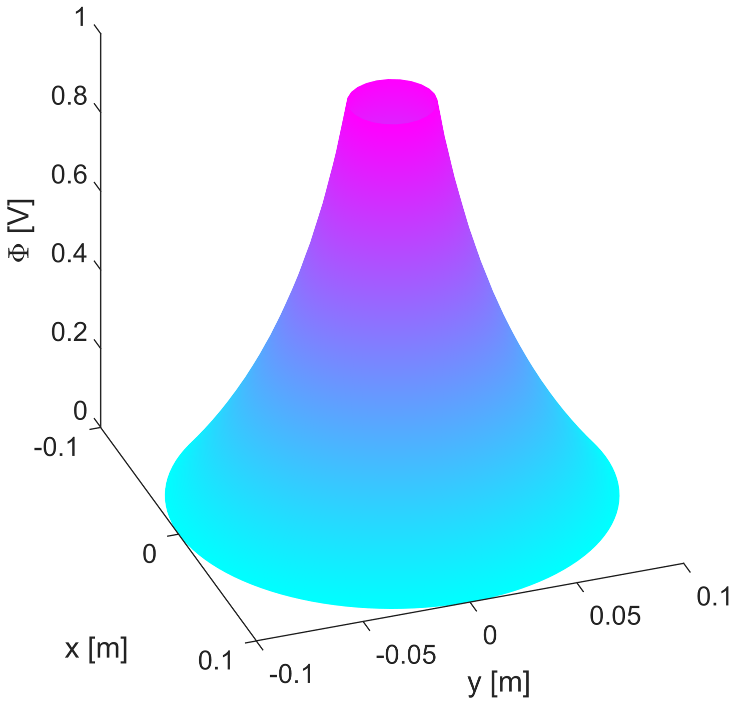


Having defined the `model`, we now call `solvepde()` to obtain the potential u, which is available as member NodalSolution in the structure `result`, which is retturned from `solvepde()`. Likewise, the gradients are available and helps us to define the fields `Ex` and `Ey`. From Equation 6.7 we find the magnetic field components `Hx` and `Hy`.

```
result=solvepde(model);
Phi=result.NodalSolution;
Ex=-result.XGradients;
Ey=-result.YGradients;
Hx=-Ey; Hy=Ex;                  % eq. 6.7
```

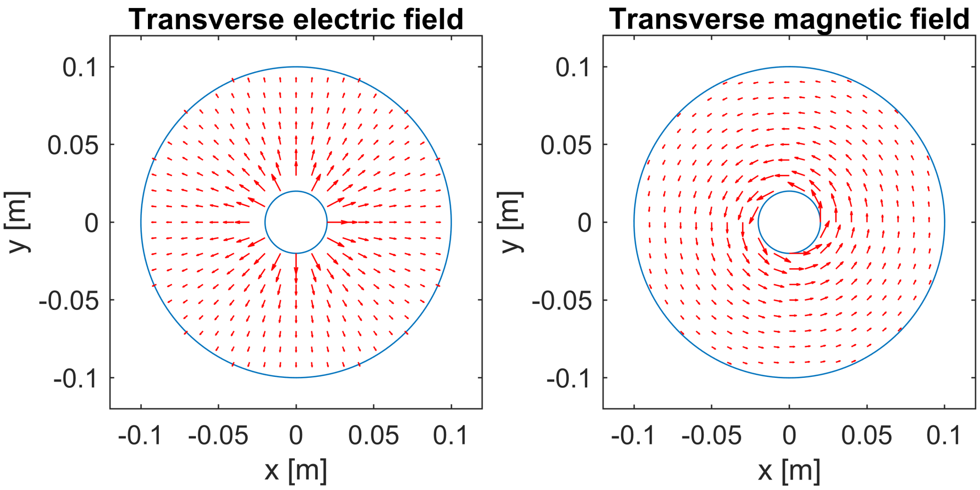
The function `meshToPet()` returns information about the points p, the edges e, and triangles `t`, which we need to display Φ in the first plot. Subsequent calls to pdeplot() then shows the

```
[p,e,t]=meshToPet(model.Mesh);
figure; pdesurf(p,t,Phi); axis square; view([70,30]);
xlabel('x [m]'); ylabel('y [m]'); zlabel('\Phi [V]');
```



Subsequent calls to `pdeplot()` with the option `flowdata` then produce plots where arrow indicate the direction and magnitude of the electric and magnetic fields.

```
figure
subplot(1,2,1);
pdegplot(model); hold on; pdeplot(model,'flowdata',[Ex,Ey]);
xlim([-0.12,0.12]); ylim([-0.12,0.12]); axis square;
xlabel('x [m]'); ylabel('y [m]'); title('Transverse electric field');
subplot(1,2,2);
pdegplot(model); hold on; pdeplot(model,'flowdata',[Hx,Hy]);
xlim([-0.12,0.12]); ylim([-0.12,0.12]); axis square;
xlabel('x [m]'); ylabel('y [m]'); title('Transverse magnetic field');
```


Transverse electric field
Transverse magnetic field
0.1
0.05
0
-0.05
-0.1
y [m]
-0.1
-0.05
0
0.05
0.1
x [m]