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

C-magnet, the upper half with shims (Section 4.3.2)

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Important: this example requires the PDE toolbox!

Here we use the model of the upper half of the C-magnet and small pieces of iron to the ends of the pole gap, so-called *shims*, in order to increase the extent of the region where the filed is constant. Therefore we just copy the description of the geometry from `CmagnetUpperHalf.mlx`

```
clear all; close all
Cmag=[2; 8; ...    %..Yoke
    0;0;0.3;0.3;1;1;-0.6;-0.6; ...
    0;0.3;0.3;0.05;0.05;0.8;0.8;0];
C1=[2;4;0;0;0.3;0.3;  0.1;0.3;0.3;0.1;zeros(8,1)];
C2=[2;4;1;1;1.3;1.3;  0.1;0.3;0.3;0.1;zeros(8,1)];
World=[2;4; -1;1.6;1.6;-1;0;0;1;1;zeros(8,1)];
```

and add the two small pieces of iron `S1` and `S2` to the left and rright end of the pole gap. We parametrize its size by the width `dx` and height `dy` of the shims.

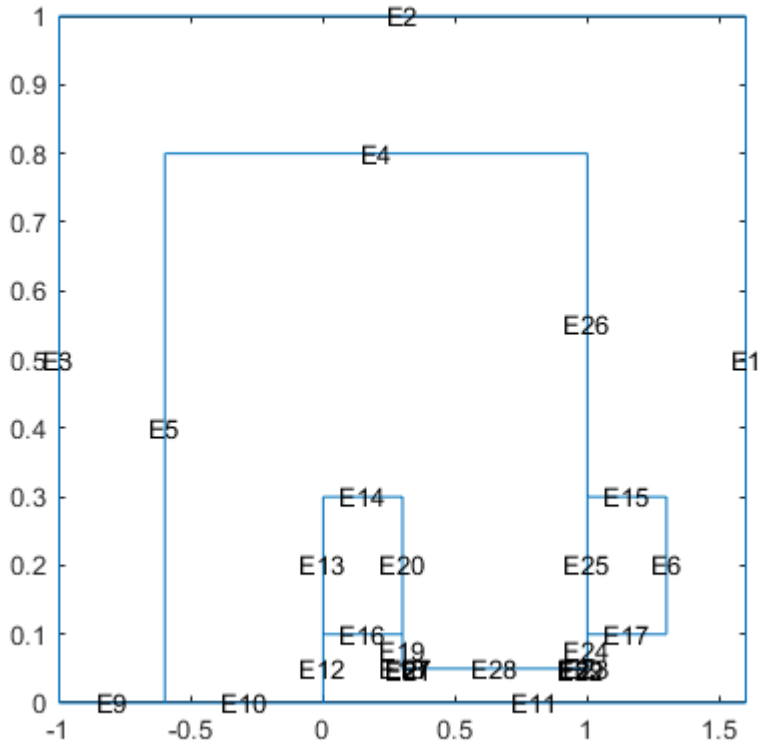
```
dx=0.050; dy=0.002; % shim width and height 50 mm x 2 mm
S1=[2;4;0.3;0.3+dx;0.3+dx;0.3;0.05-dy;0.05-dy;0.05;0.05;zeros(8,1)];     % left shim
S2=[2;4;0.95;0.95+dx;0.95+dx;0.95;0.05-dy;0.05-dy;0.05;0.05;zeros(8,1)]; % right shim
```

Now we are ready to define the geometry follwing the recipe used in the previous examples. Do not forget to add the shims!

```
gd=[World,Cmag,C1,C2,S1,S2];  % assemble geometry
ns=char('World','Cmag','C1','C2','S1','S2')';  % names of the regions
sf='World+Cmag+C1+C2+S1+S2';
g=decsg(gd,sf,ns);
```

After creating the model, we display the EdgeLabels, which allows us to specify the boundary conditions. This is equivalent to that section from `CmagnetUpperHalf.mlx`. Note that the there are many edges near the end of the pole gap. Those are the shims. Zoom in and inspect them.

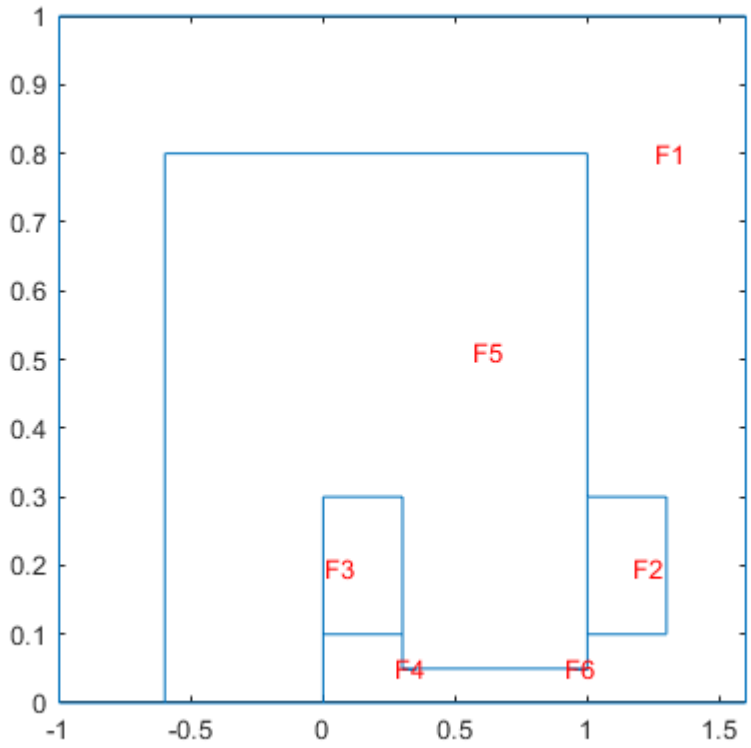
```
model=createpde(1);
geometryFromEdges(model,g);
pdegplot(model,'EdgeLabels','on');axis square
```




```
applyBoundaryCondition(model,'Edge',[1:3],'u',0);
applyBoundaryCondition(model,'Edge',[9:11],'q',0,'g',0);
```

The next step is to inspect the SubDomainLabels and specify the material properties in the different regions. Again, note that the shims; they are named F4 and F6 now and we specify their coefficient c = $1/\mu_r$ to be that of iron.

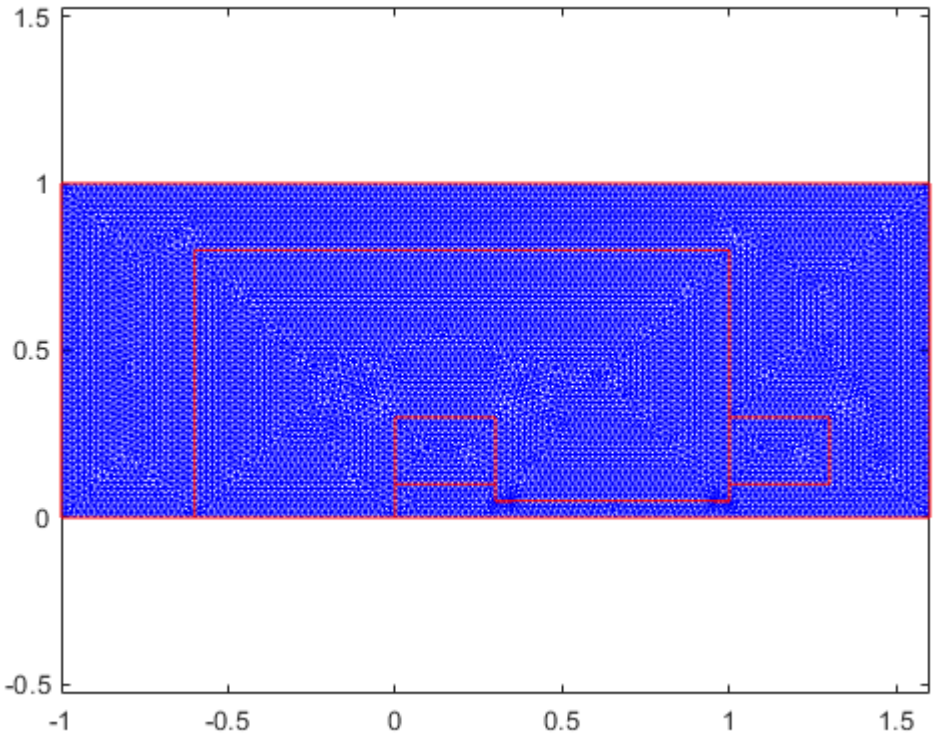
```
pdegplot(model,'SubDomainLabels','on');
axis square;
```



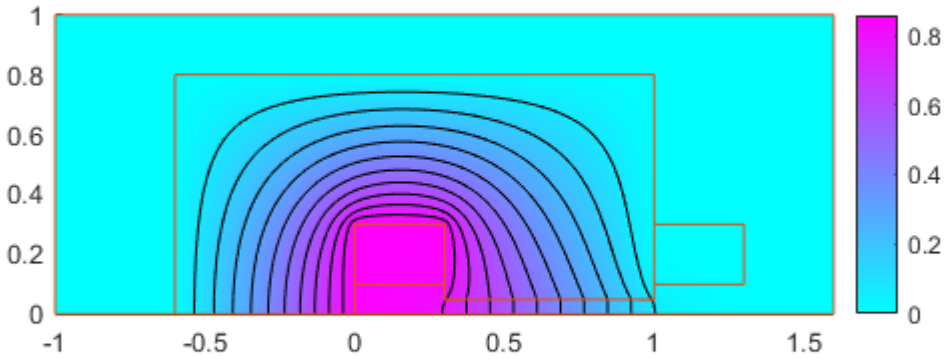

```
specifyCoefficients(model,'m',0,'d',0,'c',1,'a',0,'f',0,'Face',1);
specifyCoefficients(model,'m',0,'d',0,'c',1,'a',0,'f',-0.8378,'Face',2);
specifyCoefficients(model,'m',0,'d',0,'c',1,'a',0,'f',0.8378,'Face',3);
specifyCoefficients(model,'m',0,'d',0,'c',1/5000,'a',0,'f',0,'Face',4:6);
```

Now we generate the mesh with a smaller mesh size Hmax and furthermore note that the mesh becomes even smaller near the shims. Just zoom into the plot. Now we plot the potential, which is available as `result.NodalSolution` and superimpose the geometry.

```
generateMesh(model,'Hmax',0.02); figure; pdemesh(model);
```

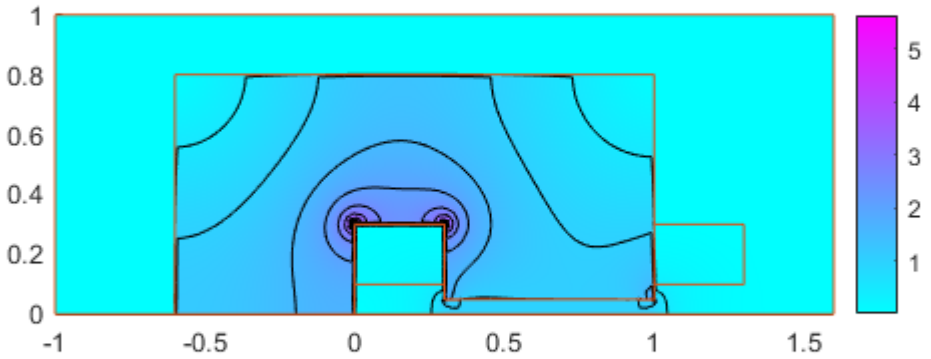



```
result=solvepde(model);
figure;
pdeplot(model,'xydata',result.NodalSolution,'contour','on');
hold on; pdegplot(model)
```



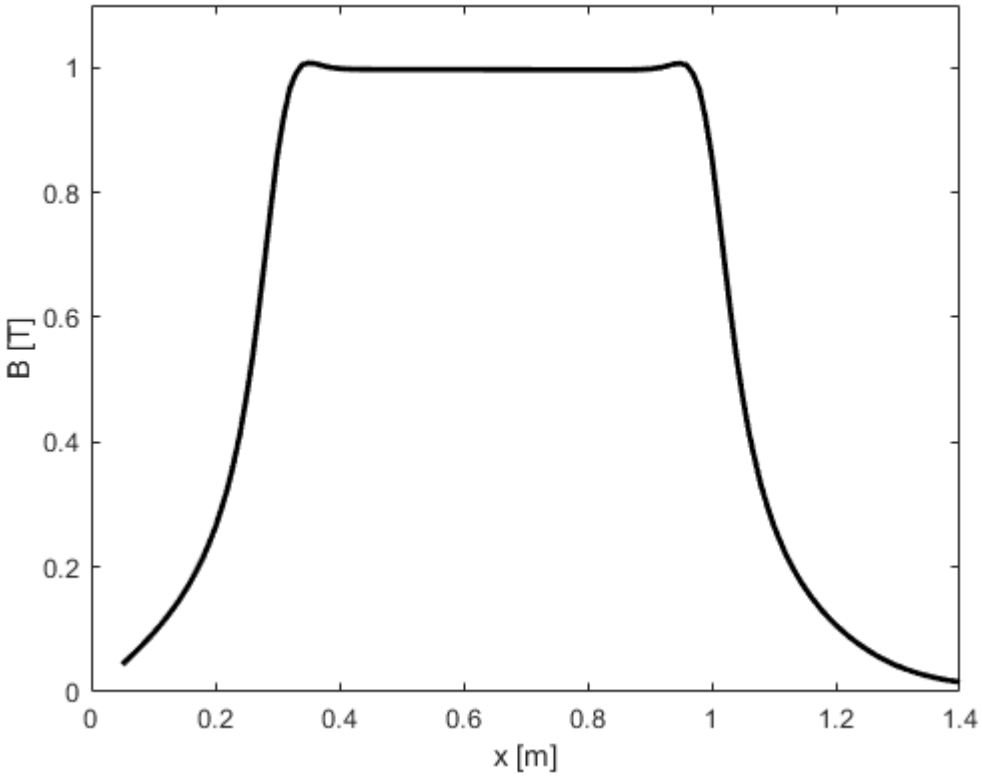
The post-processing steps are the same as in `CmagnetUpperHalf.mlx`. We just calculate the magnitude of the magnetic field `Bn` and plot it with contour lines and the geometry superimposed.

```
Bn=hypot(result.XGradients,result.YGradients);
figure; pdeplot(model,'xydata',Bn,'contour','on');
hold on; pdegplot(model);
```



Also the field in the gap is plotted. Here we observe that the 2mm shims actually bend the field at the edges a bit upwards. Thus, they are to high and we have to reduce the size to maybe 1mm, which is easily accomplished by just changing dy where the shims are defined.

```
x=0.05:0.01:1.4; y=zeros(1,length(x));    % define line
[By,Bx]=evaluateGradient(result,x,y);  Bx=-Bx;
B=hypot(Bx,By);
figure; plot(x,B,'k','LineWidth',2)
xlabel('x [m]'); ylabel('B [T]'); ylim([0,1.1]);
```




```
dlmwrite('Cmag_shim_2mm.dat',[x',B],'delimiter','\t');
```

Here we also write the magnetic field along the line into a file, such that we can later use it and compare configurations with shims of different sizes.