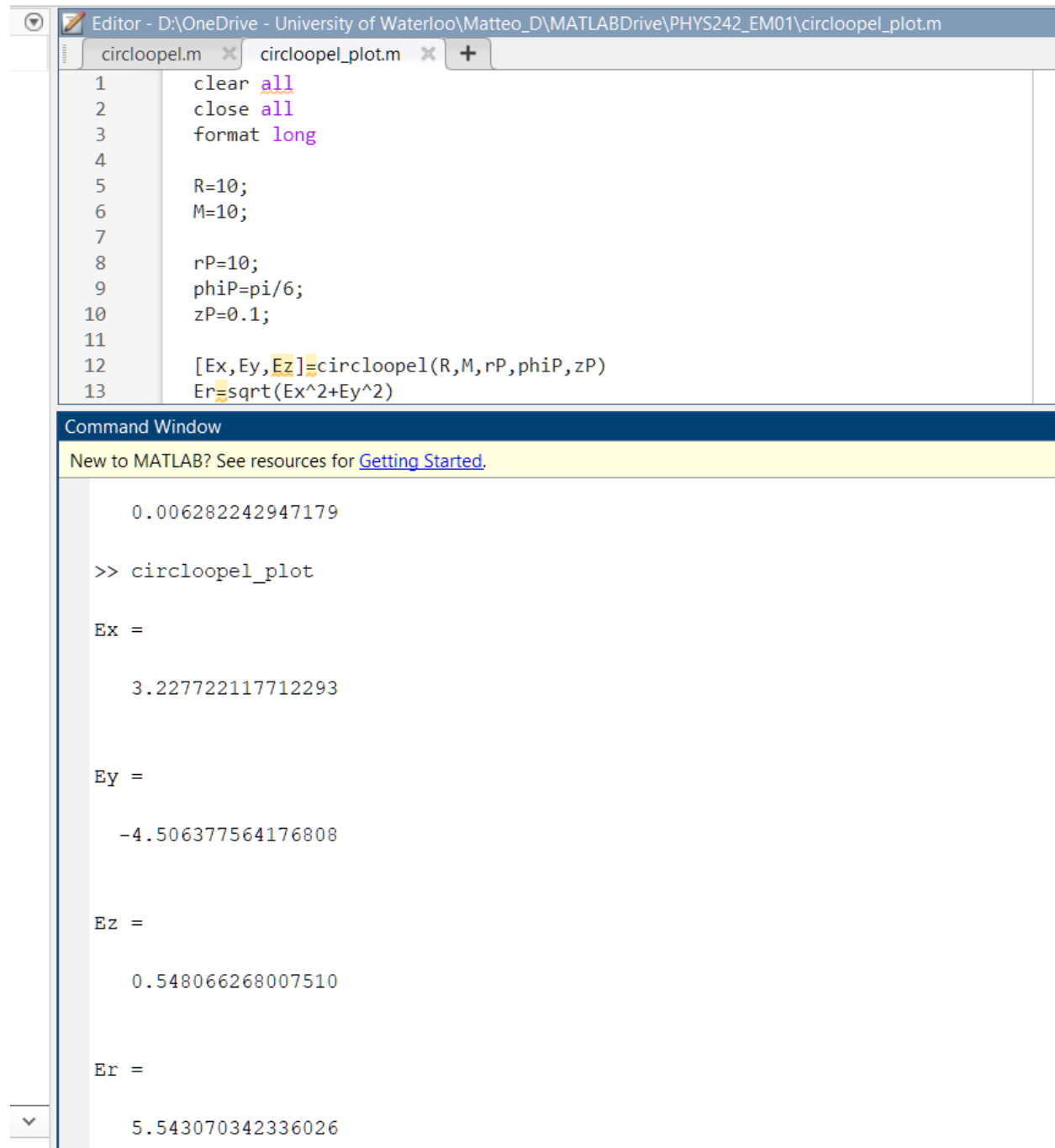


Convergence

P₁ close to ring:



The image shows a MATLAB Editor window with two tabs: `circloopel.m` and `circloopel_plot.m`. The `circloopel.m` tab is active, displaying the following code:

```
1 clear all
2 close all
3 format long
4
5 R=10;
6 M=10;
7
8 rP=10;
9 phiP=pi/6;
10 zP=0.1;
11
12 [Ex,Ey,Ez]=circloopel(R,M,rP,phiP,zP)
13 Er=sqrt(Ex^2+Ey^2)
```

Below the editor is the Command Window, which displays the output of the `circloopel` function:

```
New to MATLAB? See resources for Getting Started.

0.006282242947179

>> circloopel_plot

Ex =

3.227722117712293

Ey =

-4.506377564176808

Ez =

0.548066268007510

Er =

5.543070342336026
```

Editor - D:\OneDrive - University of Waterloo\Matteo_D\MATLABDrive\PHYS242_EM01\circloopel_plot.m

circloopel.m x circloopel_plot.m x +

```
1 clear all
2 close all
3 format long
4
5 R=10;
6 M=100;
7
8 rP=10;
9 phiP=pi/6;
10 zP=0.1;
11
12 [Ex,Ey,Ez]=circloopel(R,M,rP,phiP,zP)
13 Er=sqrt(Ex^2+Ey^2)
```

Command Window

New to MATLAB? See resources for [Getting Started](#).

```
0.006282242947179

>> circloopel_plot

Ex =

-3.322267220677585

Ey =

6.935259995671693

Ez =

6.033320001230522

Er =

7.689947379088682
```

Editor - D:\OneDrive - University of Waterloo\Matteo_D\MATLABDrive\PHYS242_EM01\circlloopel_plot.m

circloopel.m x circlloopel_plot.m x +

```
1 clear all
2 close all
3 format long
4
5 R=10;
6 M=1000;
7
8 rP=10;
9 phiP=pi/6;
10 zP=0.1;
11
12 [Ex,Ey,Ez]=circlloopel(R,M,rP,phiP,zP)
13 Er=sqrt(Ex^2+Ey^2)
```

Command Window

New to MATLAB? See resources for [Getting Started](#).

```
0.006282242947179

>> circlloopel_plot

Ex =

0.489228233498501

Ey =

0.289567866343497

Ez =

19.997566035457115

Er =

0.568501375258486
```

Editor - D:\OneDrive - University of Waterloo\Matteo_D\MATLABDrive\PHYS242_EM01\circloopel_plot.m

circloopel.m x circloopel_plot.m x +

```
1 clear all
2 close all
3 format long
4
5 R=10;
6 M=10000;
7
8 rP=10;
9 phiP=pi/6;
10 zP=0.1;
11
12 [Ex,Ey,Ez]=circloopel(R,M,rP,phiP,zP)
13 Er=sqrt(Ex^2+Ey^2)
```

Command Window

New to MATLAB? See resources for [Getting Started](#).

```
0.006282242947179

>> circloopel_plot

Ex =

0.492293127491485

Ey =

0.284225569674862

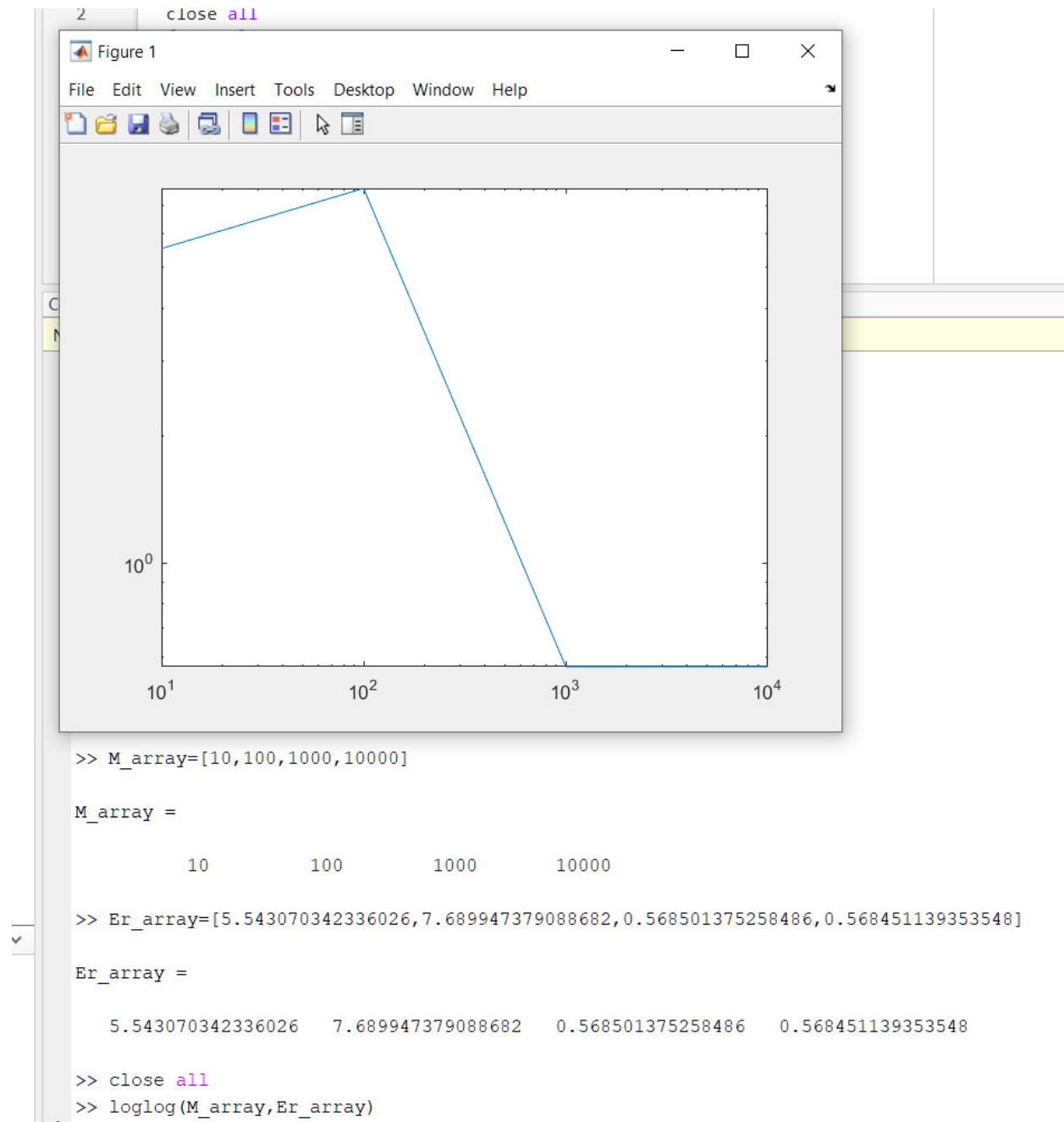
Ez =

20.001296115891442

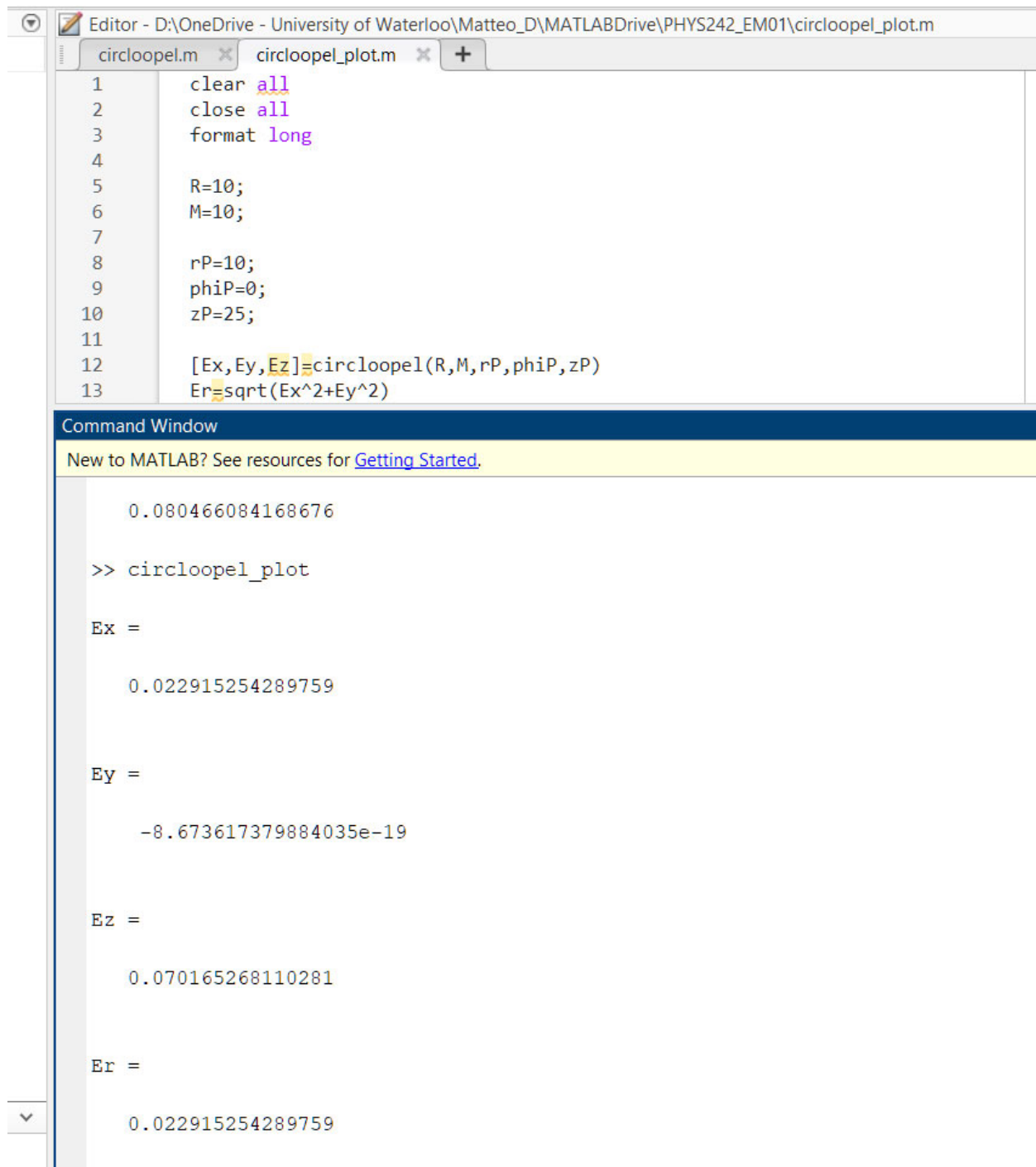
Er =

0.568451139353548
```

convergence plot P₁:



P₂ far way:



The image shows a MATLAB Editor window with two tabs: 'circloopel.m' and 'circloopel_plot.m'. The 'circloopel.m' tab is active, displaying the following code:

```
1 clear all
2 close all
3 format long
4
5 R=10;
6 M=10;
7
8 rP=10;
9 phiP=0;
10 zP=25;
11
12 [Ex,Ey,Ez]=circloopel(R,M,rP,phiP,zP)
13 Er=sqrt(Ex^2+Ey^2)
```

Below the editor is the Command Window, which contains the following text:

```
New to MATLAB? See resources for Getting Started.
```

```
0.080466084168676

>> circloopel_plot

Ex =

0.022915254289759

Ey =

-8.673617379884035e-19

Ez =

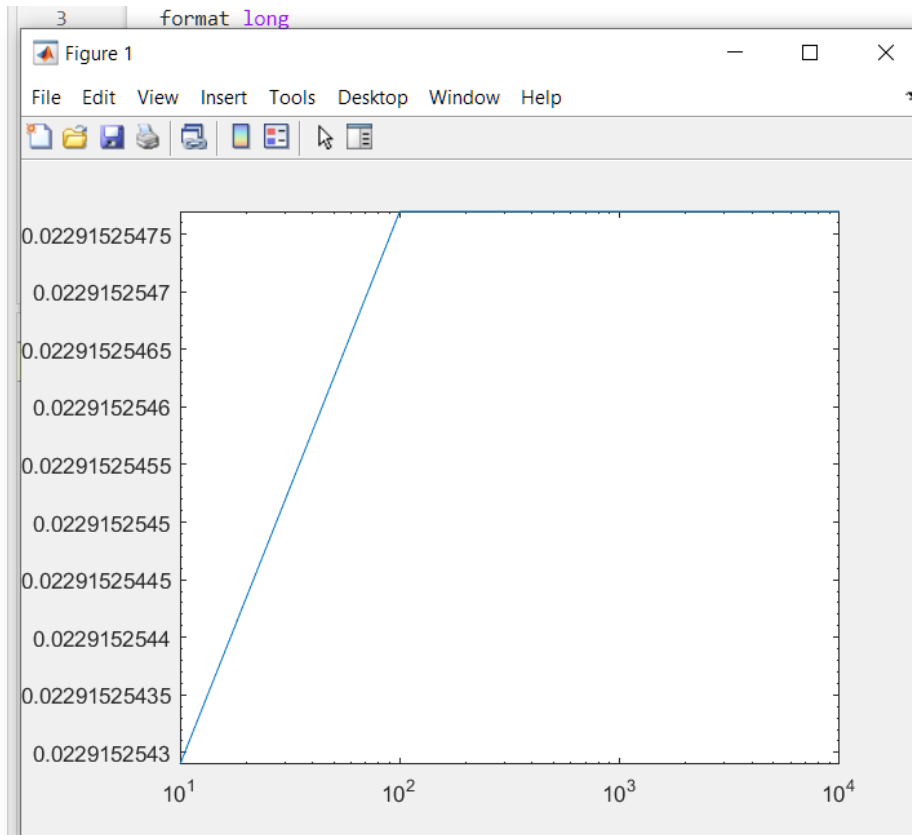
0.070165268110281

Er =

0.022915254289759
```

and similarly for M=100, 1000, 10000

convergence plot P₂:



```
>> close all
>> M_array=[10,100,1000,10000]

M_array =

    10    100   1000  10000

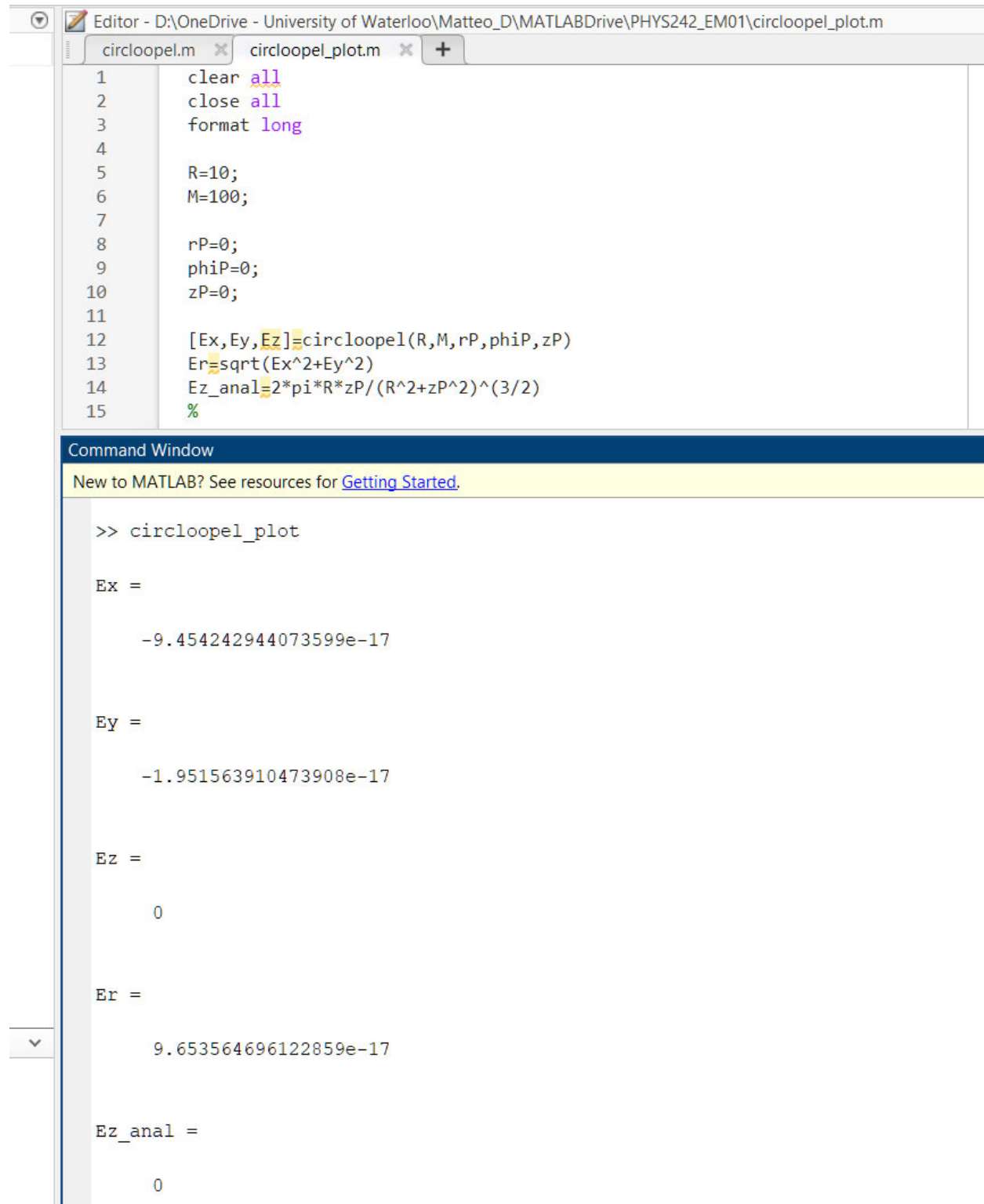
>> Er_array=[0.022915254289759,0.022915254769731,0.022915254769731,0.022915254769731]

Er_array =

    0.022915254289759    0.022915254769731    0.022915254769731    0.022915254769731

>> loglog(M_array,Er_array)
```

Comparison with analytical result on z axis:



The image shows a MATLAB environment with two windows. The top window is the Editor, showing a script named `circloopel.m` with 15 lines of code. The bottom window is the Command Window, showing the execution of the `circloopel_plot` function and the resulting values for `Ex`, `Ey`, `Ez`, `Er`, and `Ez_anal`.

```
1 clear all
2 close all
3 format long
4
5 R=10;
6 M=100;
7
8 rP=0;
9 phiP=0;
10 zP=0;
11
12 [Ex,Ey,Ez]=circloopel(R,M,rP,phiP,zP)
13 Er=sqrt(Ex^2+Ey^2)
14 Ez_anal=2*pi*R*zP/(R^2+zP^2)^(3/2)
15 %
```

Command Window

New to MATLAB? See resources for [Getting Started](#).

```
>> circloopel_plot

Ex =

    -9.454242944073599e-17

Ey =

   -1.951563910473908e-17

Ez =

         0

Er =

    9.653564696122859e-17

Ez_anal =

         0
```


Editor - D:\OneDrive - University of Waterloo\Matteo_D\MATLABDrive\PHYS242_EM01\circloopel_plot.m

circloopel.m x circloopel_plot.m x +

```
1 clear all
2 close all
3 format long
4
5 R=10;
6 M=100;
7
8 rP=0;
9 phiP=0;
10 zP=25;
11
12 [Ex,Ey,Ez]=circloopel(R,M,rP,phiP,zP)
13 Er=sqrt(Ex^2+Ey^2)
14 Ez_anal=2*pi*R*zP/(R^2+zP^2)^(3/2)
15 %
```

Command Window

New to MATLAB? See resources for [Getting Started](#).

```
>> circloopel_plot

Ex =

    -5.095750210681871e-18

Ey =

    -3.950561665994057e-18

Ez =

    0.080466084168676

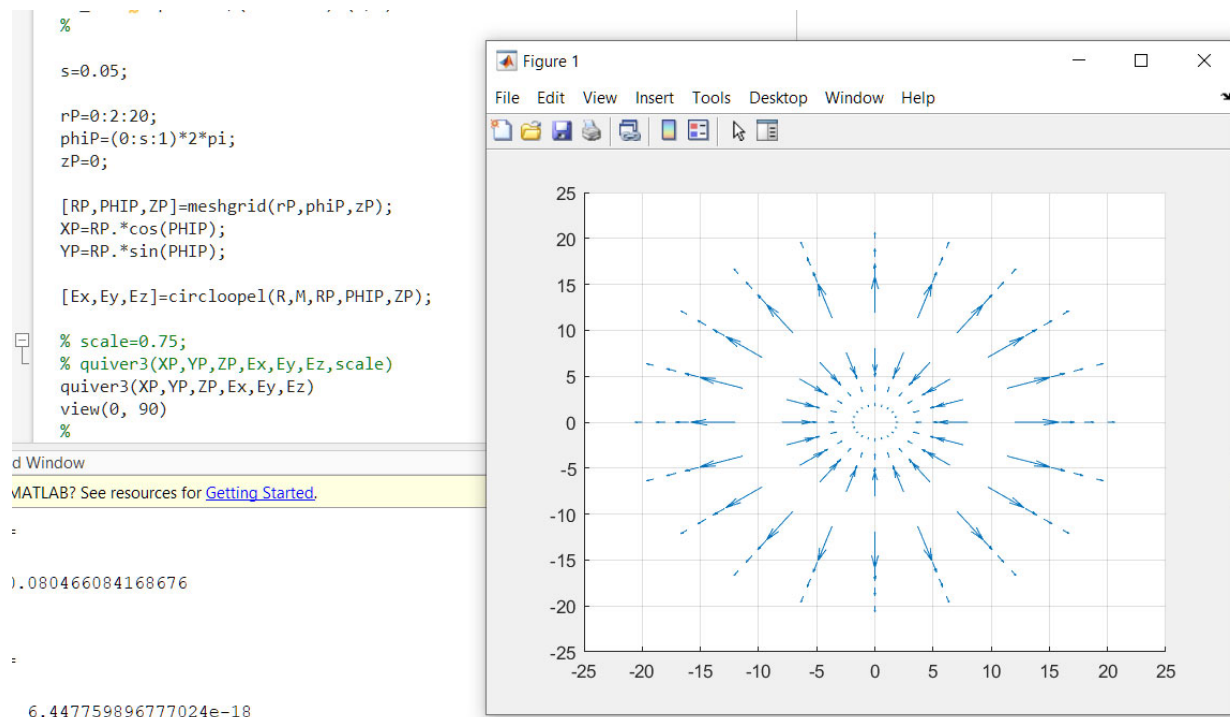
Er =

    6.447759896777024e-18

Ez_anal =

    0.080466084168676
```

Plots



ring “visible” where arrows are missing
arrows point away from ring
arrows are symmetric with respect to z axis

```

s=0.05;

rP=0:2:20;
phiP=(0:s:1)*2*pi;
zP=25;

[RP,PHIP,ZP]=meshgrid(rP,phiP,zP);
XP=RP.*cos(PHIP);
YP=RP.*sin(PHIP);

[Ex,Ey,Ez]=circloopel(R,M,RP,PHIP,ZP);

% scale=0.75;
% quiver3(XP,YP,ZP,Ex,Ey,Ez,scale)
quiver3(XP,YP,ZP,Ex,Ey,Ez)
view(0, 90)
%

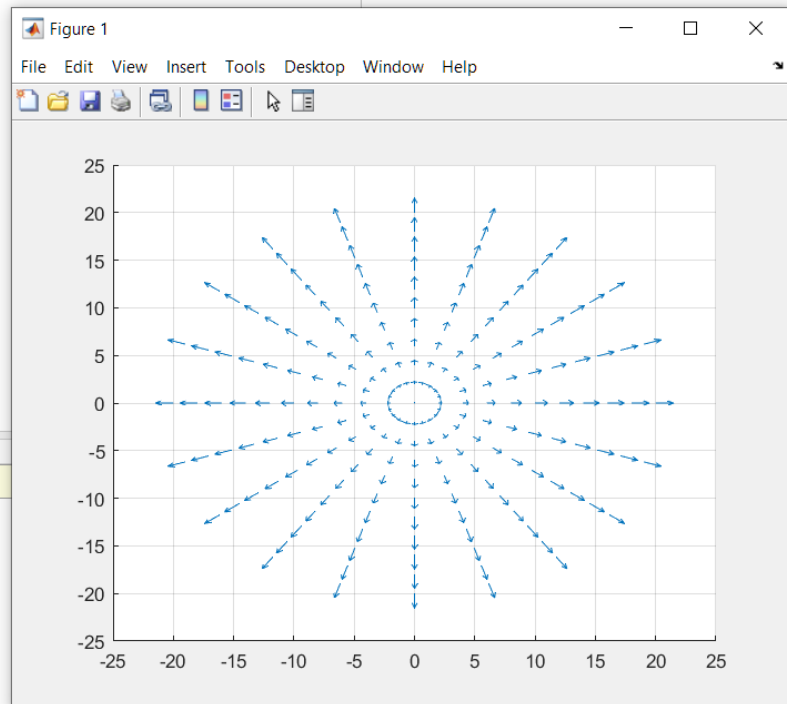
```

indow

LAB? See resources for [Getting Started](#).

30466084168676

.447759896777024e-18



CODE:

```
function [Ex,Ey,Ez]=circloope1(R,M,rP,phiP,zP)
% ,phiQ_vec
% Ke=\lambda/(4*pi*epsilon0)=1;

% R=10;

% M=100;
Delta_phi=2*pi/M;
Delta_ell=R*Delta_phi;

% rP=0;
% phiP=0;
% zP=0.1;

m=0;
phiQ=0;
DeltaEx=0;
Ex=0;
DeltaEy=0;
Ey=0;
DeltaEz=0;
Ez=0;

for m=1:M

    phiQ=-Delta_phi+m*Delta_phi;
    % phiQ_vec(m)=phiQ;

    DeltaEx=Delta_ell*(rP.*cos(phiP)-R*cos(phiQ))./(rP.^2+R^2-2*R*rP.*cos(phiQ-
phiP)+zP.^2).^(3/2);
    Ex=Ex+DeltaEx;

    DeltaEy=Delta_ell*(rP.*sin(phiP)-R*sin(phiQ))./(rP.^2+R^2-2*R*rP.*cos(phiQ-
phiP)+zP.^2).^(3/2);
    Ey=Ey+DeltaEy;

    DeltaEz=Delta_ell*zP./(rP.^2+R^2-2*R*rP.*cos(phiQ-phiP)+zP.^2).^(3/2);
    Ez=Ez+DeltaEz;

end

end
% DDD
```

```
clear all
close all
format long

R=10;
M=100;
```

```

rP=0;
phiP=0;
zP=25;

[Ex,Ey,Ez]=circloopel(R,M,rP,phiP,zP)
Er=sqrt(Ex^2+Ey^2)
Ez_anal=2*pi*R*zP/(R^2+zP^2)^(3/2)
%

s=0.05;
rP=0:2:20;
phiP=(0:s:1)*2*pi;
zP=25;

[RP,PHIP,ZP]=meshgrid(rP,phiP,zP);
XP=RP.*cos(PHIP);
YP=RP.*sin(PHIP);

[Ex,Ey,Ez]=circloopel(R,M,RP,PHIP,ZP);

% scale=0.75;
% quiver3(XP,YP,ZP,Ex,Ey,Ez,scale)
quiver3(XP,YP,ZP,Ex,Ey,Ez)
view(0,90)
%
% DDD

```

OLD CODE:

```
clear all
close all
format long

R=10;
M=10; % 20

rP=15;
phiP=pi/6;
zP=20;

[Ex,Ey,Ez]=circloopel(R,M,rP,phiP,zP)
Er=sqrt(Ex^2+Ey^2)
Ez_anal=2*pi*R*zP/(R^2+zP^2)^(3/2)
%

% rP=0;
% phiP=pi;
% zP=20; % 9; 20; 0

s=0.05; % 0.01

% rP=(0:s:1)*20; % 15
rP=0:2:20;
% phiP=[0:2*pi/s:2*pi];
phiP=(0:s:1)*2*pi;
zP=0; % 1; 25

% [XP,YP,ZP]=meshgrid(rP.*cos(phiP),rP.*sin(phiP),zP);
[RP,PHIP,ZP]=meshgrid(rP,phiP,zP);
XP=RP.*cos(PHIP);
YP=RP.*sin(PHIP);

% [Bx,By,Bz] = circloopmag(R,M,rP,phiP,zP);
[Ex,Ey,Ez]=circloopel(R,M,RP,PHIP,ZP);
% [BX,BY,BZ]=meshgrid(Bx,By,Bz);
% Br=sqrt(Bx.^2+By.^2);
% Bphi=zeros(1,length(Br));

% scale=0.75;
% quiver3(XP,YP,ZP,Ex,Ey,Ez,scale)
% quiver3(XP,YP,ZP,Bx',By',Bz')
quiver3(XP,YP,ZP,Ex,Ey,Ez)
% view(0, 90)
%
```