Theory of Electromagnetic Fields, Experiment 2

Author: Ying Yiwen
Number: 12210159

Abstract—There are two ways to compute the electric field and express them by potential distribution, equipotential line distribution, and electric field line distribution, which is integral method and infinitive method. The result of infinitive method also varies with the number of segments. The experiment focus on the difference of above methods to find out whether the integral computation can be simplified by infinitive method. It comes out that, with enough number of segments in infinitive method (about 40), the error is small enough to be ignored. When the distance of testing point and the line charge is far larger than the length of it, the integral computation can be replaced by infinitive method.

I. Experiment Principle

The electric field strength E produced by a point charge in a vacuum is:

$$\mathrm{E} = k\frac{Q}{R^2}\mathrm{a}_R \tag{1}$$

where the coefficient $k = 9 \times 10^9 F/m$, is the electrostatic force measure, Q is the charge of the point charge, and R is the distance of this point charge to the field point.

If we take infinity as the point of zero potential, the potential generated by a point charge in a vacuum is:

$$V = k\frac{Q}{R} \tag{2}$$

The electric field strength can also be expressed as a negative gradient of the potential:

$$\mathrm{E} = -\nabla V \tag{3}$$

The potential generated by N point charges in a vacuum is:

$$\mathrm{V} = \sum_{i=1}^{N} k\frac{Q_i}{R_i} \tag{4}$$

Similarly, the electric field strength generated by N point charges in vacuum can be found from equation (3).

For line charge, we can use integral to calculate the electric potential of it, the principle is as follows:

$$\begin{aligned}
\mathrm{V} &= k\int_{-1}^{1}\frac{\rho dx}{\mathrm{R}} \\
&= k\int_{-1}^{1}\frac{\rho dx}{\sqrt{(x-X_0)^2+Y_0^2}} \\
&= \mathrm{k}\rho dx \ln\left|(x-X_0)+\sqrt{(x-X_0)^2+Y_0^2}\right|\Bigg|_{-1}^{1} \\
&= k\rho ln\left(\frac{1-X_0+\sqrt{(1-X_0)^2+Y_0^2}}{-1-X_0+\sqrt{(-1-X_0)^2+Y_0^2}}\right)
\end{aligned}$$

When the source of the electric field is a continuous distribution of charge, the problem can be solved by the method of differential element method or integral. The specific operation steps of the micro-element method:

1) Uniformly divide the line charge into a number of small segments of charge;
2) Take each small segment of charge as a point charge to deal with, use the formula (2) to solve for the potential generated in space;
3) Use formula (4) to get the entire line charge generated by the potential;
4) Use formula (3) to solve for the entire line charge generated by the electric field intensity.

There is a certain error between the result obtained by the calculus method and the real value, which depends on the number of segments in step 1 above, and in general, the more segments, the smaller the error. In some cases, it is also possible to use calculus to solve for the true electric field distribution. This makes it possible to study the relationship between the error caused by the calculus method and the number of segments.

II. Key Code Implementation

A. Compute the Electric Field by Integral Method

```
%select region
k=9e9;%electric constant
p=1e-9;%charge density
xm=2;%set x region
```

```
ym=2;%set y region
x=linspace(-xm,xm,100);% divide x axis
y=linspace(-ym,ym,100);% divide y axis
[X,Y]=meshgrid(x,y);%form coordinate
r1=1-X+sqrt((1-X).^2+Y.^2);%calculate r1
r2=-1-X+sqrt((-1-X).^2+Y.^2);%calculate r2
V=k.*p.*log(r1./r2);%calculate potential
```

B. Compute the Electric Field by Infinitive Method

```
%select region
k=9e9;%electric constant
p=1e-9;%charge density
xm=2;%set x region
ym=2;%set y region
x=linspace(-xm,xm,100);% divide x axis
y=linspace(-ym,ym,100);% divide y axis
[X,Y]=meshgrid(x,y);%form coordinate
V=0;
for i = 1:20
r=sqrt((X-0.1*i+1.05).^2+Y.^2);% compute r of every dx
V=V+k*p/10./r;%compute V
end
```

C. Obeserve the Electric Field

```
%draw volt graph
figure;%create figure
mesh(X,Y,V);%draw potential figure
grid on;%set grid on
hold on;%several graphs
%label and title
title(sprintf('Potential Graph of Line Charge in Vaccum\n(By Integral Method)'),'Ying Yiwen,12210159','FontSize',14);%title
xlabel('X-axis(unit:m)','FontSize',10);%xlabel
ylabel('Y-axis(unit:m)','FontSize',10);%ylabel
zlabel('V(unit:v)','FontSize',10);%zlabel
%save figure
saveas(gcf,'figure1-1.jpg');
```

D. Obeserve the Equipotential Line

```
%Select value of equipotential
Vmin=0;%minimum equipotential
Vmax=100;%maximum equipotential
Veq=linspace(Vmin,Vmax,101);%divide equipotential line
%draw equipotential graph
figure;%create figure
contour(X,Y,V,Veq);%draw equipotential figure
grid on;%set grid on
hold on;%several graphs
%label and title
plot([-1,1], [0,0], 'r', 'LineWidth', 3);%draw the line charge
title(sprintf('Equipotential Graph of Line Charge in Vaccum\n(By Integral Method)'),'Ying Yiwen,12210159','FontSize',14);%title
xlabel('X-axis(unit:m)','FontSize',10);%xlabel
ylabel('Y-axis(unit:m)','FontSize',10);%ylabel
%save figure
saveas(gcf,'figure1-2.jpg');
```

E. Compute the Electric Field Line

```
%compute electric field line
[Ex,Ey]=gradient(-V);%compute electric field intensity
del_theta=10;%set division
theta=(0:del_theta:360).*pi/180;%divide angle
xs1=-1.2:0.1:1.2;%compute x value of location 1
xs2=-1.2:0.1:1.2;%compute x value of location 2
ys1=0.05*ones(length(xs1),1);%compute y value of location 1
ys2=-0.05*ones(length(xs1),1);%compute y value of location 2
```

F. Observe the Electric Field Line

```
%Plot the distribution of electric field lines in the field
figure;%create figure
hold on;%several graphs
%label and title
a=streamline(X,Y,Ex,Ey,xs1,ys1);%Electric field line1
```

```
set(a,'linewidth',1.5,'color',[0.5,0,0.6]);%set line type
b=streamline(X,Y,Ex,Ey,xs2,ys2);%Electirc field line2
set(b,'linewidth',1.5,'color',[0.5,0,0.6]);%set line type
contour(X,Y,V,Veq);%draw equipotential figure
plot([-1,1], [0,0], 'r', 'LineWidth', 3);%draw the line charge
grid on;%set grid on
title(sprintf('Electirc Field Line of Line Charge in Vaccum\n(By Integral Method)'),'Ying Yiwen,12210159','FontSize',14);%title
xlabel('X-axis(unit:m)','FontSize',10);%xlabel
ylabel('Y-axis(unit:m)','FontSize',10);%ylabel
%save figure
saveas(gcf,'figure1-3.jpg');%save current figure
```

G. RMS calculation

```
%draw the difference of various divisons
%integral method
r1=1-X+sqrt((1-X).^2+Y.^2);%calculate r1
r2=-1-X+sqrt((-1-X).^2+Y.^2);%calculate r2
V=k.*p.*log(r1./r2);%calculate potential
differ=[];%an array to save the difference
%infinitive method, 50 parts
for i = 5:5:100
temp=0;
for j = 1:i
r=sqrt((X-(2/i)*j+1+(1/i)).^2+Y.^2);%compute r of every dx
temp=temp+2*k*p/i./r;%compute V
end
difference=sum(sum((V-temp).^2))/10000;%compute the total of difference
differ=[differ difference];
end
x=5:5:100;%x-axis
figure;%create new figure
plot(x, differ, '-o');%plot the line chart
grid on;%set grid on
%label and title
title(sprintf('Potential Difference Graph of Line Charge in Vaccum\n(Integral Method & Infinitive Method)'),'Ying Yiwen,12210159','FontSize',14);%title
xlabel('Number of Segements','FontSize',10);%xlabel
ylabel('RMS','FontSize',10);%ylabel
%save figure
saveas(gcf,'figure5-4.jpg');%save current figure
```

Above are the main code of the experiment. Little changes are applied to get differenr results in different background as follows. The complete code is shown in the appendix.

III. The Electric Field Computed by Integral Method

As there is no use of approximation, the Integral method can give the exact amount of electric potential at everywhere in the region we determined. The result of that can also be used as reference to compare the result of the infinitive method.

To show the electric field easily, we choose region as x:[-2,2], y:[-2,2], precision as 0.04 to draw the graph. It should be clarified that, outside that region, there is also electric field, which is just not shown for our observation.

By further computation, we can get the potential graph, equipotential graph, and electric field line graph, as follows:

Fig.1.Potential Graph of Line Charge in Vaccum
Fig.2.Equipotential Graph of Line Charge in Vaccum
Fig.3.Electirc Field Line of Line Charge in Vaccum

Those three figures shows the electric field of line charge computed by integral method in different ways.

The red line at the center represents the line charge. Around the line charge, the electric potential is the highest in the region, and the equipotential line is also the most dense. Electric field lines, represented by purple lines, radiate outward from the line charge.

IV. The Electric Field Computed by Infinitive Method

An integral can be mathematically approximated as the sum of the results of countless calculations of tiny segments. Therefore, for integrals that are difficult to calculate in many cases, we choose from time to time to use the method of infinitive instead. Within acceptable

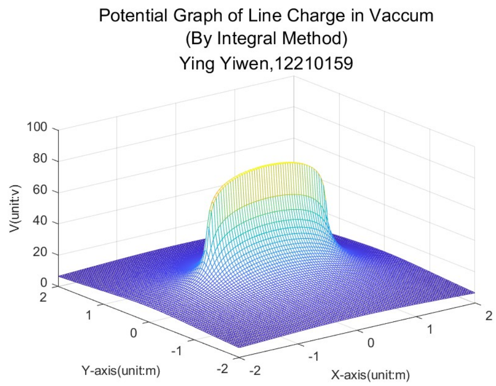

Fig. 1. Potential Graph of Line Charge in Vaccum

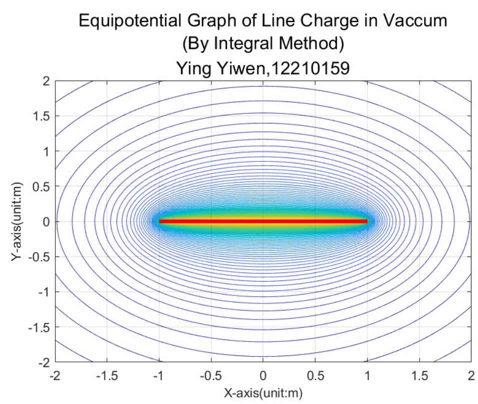

Fig. 2. Equipotential Graph of Line Charge in Vaccum

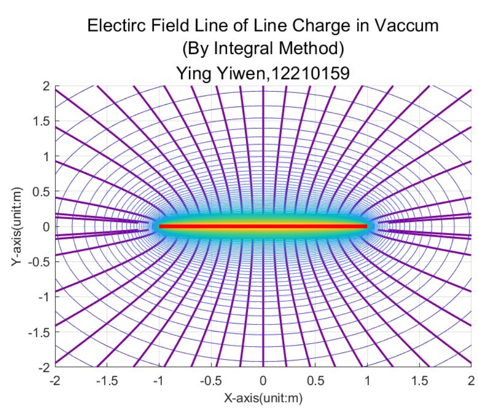

Fig. 3. Electirc Field Line of Line Charge in Vaccum

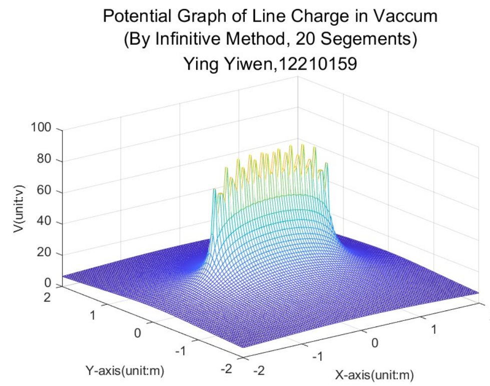

Fig. 4. Potential Graph of Line Charge in Vaccum

limits, the object of the calculation is approximated in order to simplify the calculation.

In this experiment, we are going to explore what kind of approximation can be made in the calculation of the electric field distribution, using the infinitive method instead of the integral calculation. The experiment is carried out to observe the calculation results by means of potential diagrams, equipotential curves, and electric field lines, and to compare them with the exact results obtained in the previous section.

A. Divide the Line Charge into 20 Segments

After divide the line charge into 20 segments, as each part of the line charge is small, we can see them as 20 point charges. For point charges, it's easy to compute the electric field led by them.

By further computation, we can get the potential graph, equipotential graph, and electric field line graph, as follows:

Fig.4.Potential Graph of Line Charge in Vaccum
Fig.5.Equipotential Graph of Line Charge in Vaccum
Fig.6.Electirc Field Line of Line Charge in Vaccum

From figure4, we can easily find that, there are many spines, especially near the line charge. That may be due to the division is not precise enough. However, the general tendency of potential graph is similar to that of the reference (integral method).

As a result, we can try the computation based on different number of segments in dividing the line charge.

B. Divide the Line Charge into 50 Segments

We divide the line charge into 50 segments, which can be seen as 50 point charges. In the same way, we can work

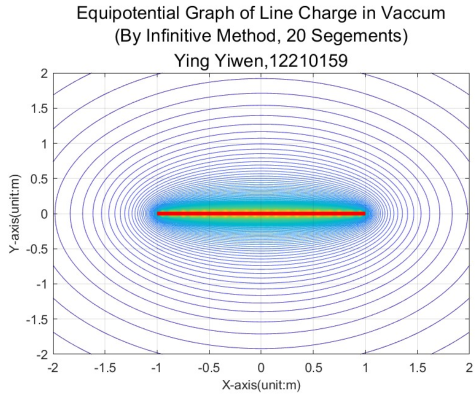

Fig. 5. Equipotential Graph of Line Charge in Vaccum

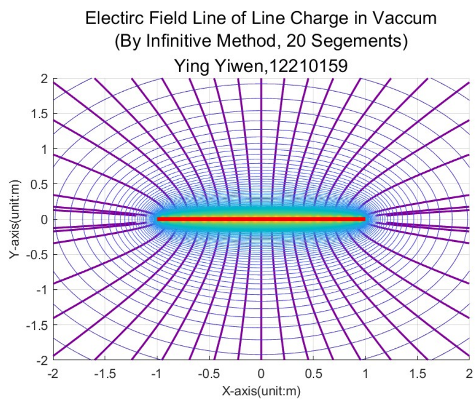

Fig. 6. Electirc Field Line of Line Charge in Vaccum

out the electric field and observe them in the potential graph, equipotential graph, and electric field line graph, as follows:

Fig.7.Potential Graph of Line Charge in Vaccum
Fig.8.Equipotential Graph of Line Charge in Vaccum
Fig.9.Electirc Field Line of Line Charge in Vaccum

Comparing figure.1 and figure.7, we can come out that the electric field computed by infinitive method is similar with that by integral method this time. For equipotential graph and elcetric field line graph, the shape of them are also simalr to the results from the integral method.

In practice, we need to note what level of precision is appropriate. In other words, we should explore the variation of the results with the number of segments and its marginal effect. In this way, we can rationally choose the most economical method in practical engineering applications without compromising the accuracy of our results.

Therefore, we should continue to investigate whether

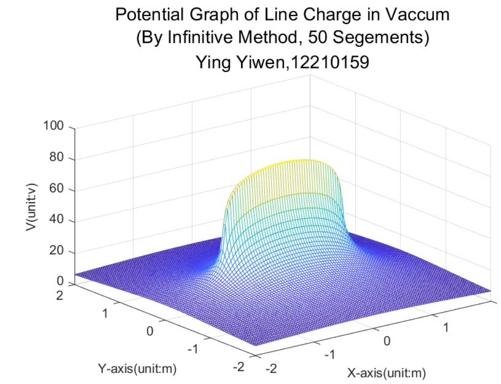

Fig. 7. Potential Graph of Line Charge in Vaccum

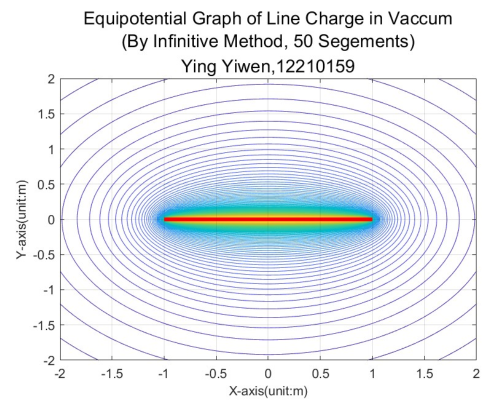

Fig. 8. Equipotential Graph of Line Charge in Vaccum

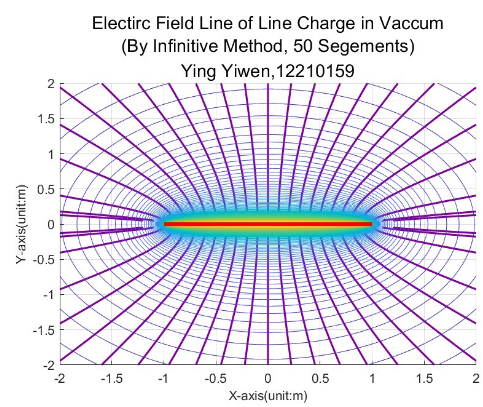

Fig. 9. Electirc Field Line of Line Charge in Vaccum

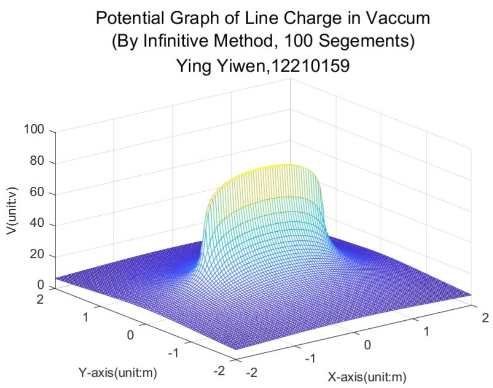

Fig. 10. Potential Graph of Line Charge in Vaccum

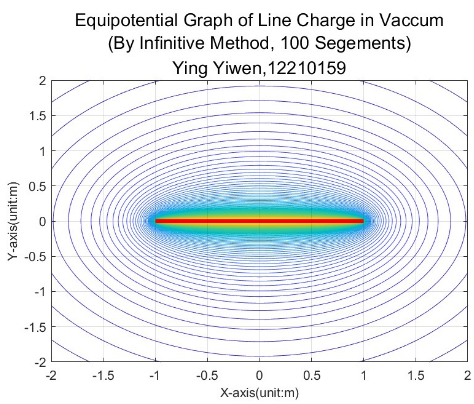

Fig. 11. Equipotential Graph of Line Charge in Vaccum

there are very good results as the number of segments continues to increase.

C. Divide the Line Charge into 100 Segments

This time, each part is rather small. From theory, the result should be rather better. Similarly, we divide the line charge into 100 segments. Then, we can work out the electric field and observe them in the potential graph, equipotential graph, and electric field line graph, as follows:

Fig.10.Potential Graph of Line Charge in Vaccum

Fig.11.Equipotential Graph of Line Charge in Vaccum

Fig.12.Electirc Field Line of Line Charge in Vaccum

From the graph, we really get results very similar to the reference. However, we're sad to find that, the results have little difference compared to that in the division of 50 segments.

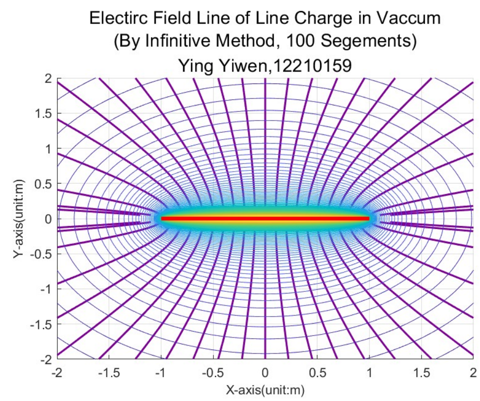

Fig. 12. Electirc Field Line of Line Charge in Vaccum

It can be suggested that, when the number of segments is extremely high, there may be little difference in the precision of the outcome. After a typical number of segments, the cost of time and space still increases when the number of sements increaes, while the result is almost the same.

Thus, it's important for us to find that typical number, so that we can get the number we should use in practice. Comparing the result from different number of segments, maybe we can deduce that conclusion.

V. The Threshold Value for the division

First, for 20 segments, 50 segments, and 100 segments, which are discussed above by the graphs, we give a new standard to measure aganist the precision. It's easy to show the graph of the difference of electric potential by set the z-axis as $V_{integral} - V_{infinitive}$.

We can see the difference in electric potential by the potential graph as follows:

Fig.13.Potential Difference Graph of Line Charge in Vaccum, 20 Segments

Fig.14.Potential Difference Graph of Line Charge in Vaccum, 50 Segments

Fig.15.Potential Difference Graph of Line Charge in Vaccum, 100 Segments

Taking a look at the three pictures, we can see that the results of the integral method and the infinitive method produce a large difference at the neighbouring line charge. On the one hand, this may be due to the fact that the potential gradient at that location is larger and the absolute value is also larger, so the absolute difference value will also be larger. On the other hand, the infinitive method treats the tiny line charge as a point charge, whereas close to the line charge, the scale difference between the distance from the line charge and the length of the line charge is not large, so it is not

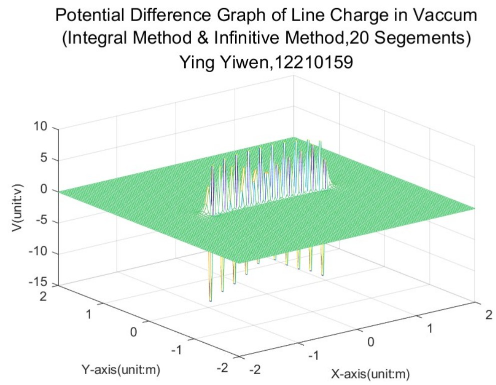

Fig. 13. Potential Difference Graph of Line Charge in Vaccum, 20 Segments

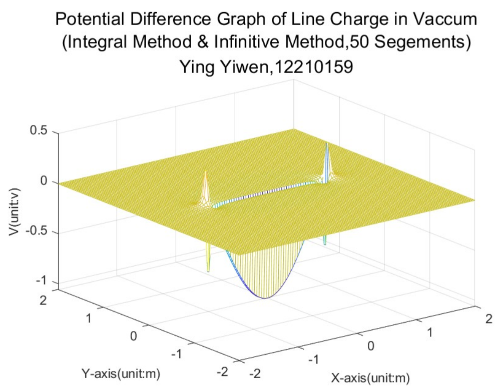

Fig. 14. Potential Difference Graph of Line Charge in Vaccum, 50 Segments

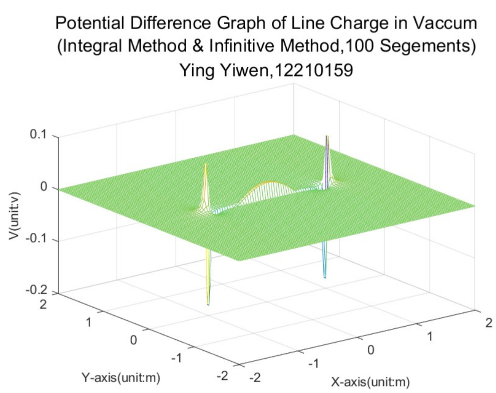

Fig. 15. Potential Difference Graph of Line Charge in Vaccum, 100 Segments

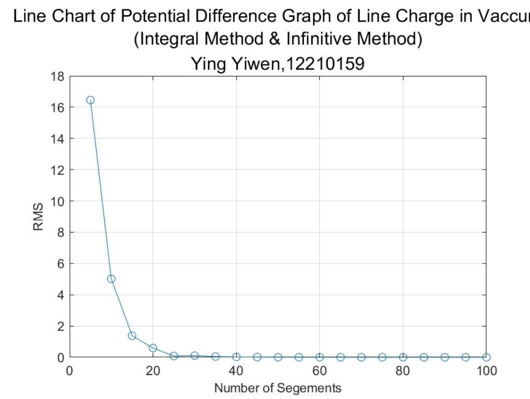

Fig. 16. Line Chart of Potential Difference Graph of Line Charge in Vaccum

possible to make such an approximation, and therefore a larger value of the absolute difference will be produced.

In addition, at both ends of the line charge, the difference between both methods is the largest of all points.

It is also noticeable that there is essentially no difference between the results of the integral and micrometric methods at other points in the selected region.

Comparing these three graphs, we can see that the difference between the two methods decreases significantly as the number of segmentation segments grows.

In judging the results, instead of graph, root-mean-square is also counted to judge the precision of the result. The RMS can give only one value for each case, which makes it easier to compare the effect of different numbers of segments on the accuracy of the results.

To find the threshold value for the division, we should try enough examples to select a best one.

Comparing the RMS results, we can plot the line chart:

Fig.16.Line Chart of Potential Difference Graph of Line Charge in Vaccum.

It can be found that, the threshold value may be between 20 and 60. We can zoom in and look at the difference to find the most appropriate value, which is plot in the line chart:

Fig.17.Line Chart of Potential Difference Graph of Line Charge in Vaccum.

Through this figure, we deduce that the threshold may be about 40.

VI. Conclusion

Observing the potential field graph, equipotential graph, and electric field line graph, the infinitive method

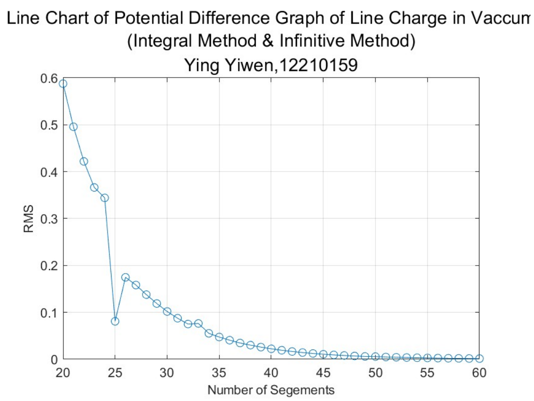

Fig. 17. Line Chart of Potential Difference Graph of Line Charge in Vaccum

can generally estimate the potential field of the line charge instead of integral method, and it's true that the infinitive method is easier to compute in most cases.

The error is little enough to be ignored when the division is about 40 segments or more, or the testing point is far away from the line charge (the distance between the testing point and the line charge is much bigger than the length of the line charge).

Experience:

Try myself to complete the code with different methods.

Use line chart of root-mean-square to find the threshold.

Try the format of science paper writing.

VII. Appendix: Matlab Code

A. Calculate the potential distribution, equipotential line distribution, and electric field line distribution of a line charge at each point in a two-dimensional plane using calculus methods

```
clc,clear,close all;
%by integral
%select region
k=9e9;%electric constant
p=1e-9;%charge density
xm=2;%set x region
ym=2;%set y region
x=linspace(-xm,xm,100);% divide x axis
y=linspace(-ym,ym,100);% divide y axis
[X,Y]=meshgrid(x,y);%form coordinate
r1=1-X+sqrt((1-X).^2+Y.^2);%calculate r1
r2=-1-X+sqrt((-1-X).^2+Y.^2);%calculate r2
V=k.*p.*log(r1./r2);%calculate potential
%draw volt graph
figure;%create figure
mesh(X,Y,V);%draw potential figure
grid on;%set grid on
hold on;%several graphs
%label and title
title(sprintf('Potential Graph of Line Charge in Vaccum\n(By Integral Method)'),'Ying Yiwen,12210159','FontSize',14);%title
xlabel('X-axis(unit:m)','FontSize',10);%xlabel
ylabel('Y-axis(unit:m)','FontSize',10);%ylabel
zlabel('V(unit:v)','FontSize',10);%zlabel
%save figure
saveas(gcf,'figure1-1.jpg');
%Select value of equipotential
Vmin=0;%minimum equipotential
Vmax=100;%maximum equipotential
Veq=linspace(Vmin,Vmax,101);%divide equipotential line
%draw equipotential graph
figure;%create figure
contour(X,Y,V,Veq);%draw equipotential figure
grid on;%set grid on
hold on;%several graphs
%label and title
plot([-1,1], [0,0], 'r', 'LineWidth', 3);%draw the line charge
title(sprintf('Equipotential Graph of Line Charge in Vaccum\n(By Integral Method)'),'Ying Yiwen,12210159','FontSize',14);%title
xlabel('X-axis(unit:m)','FontSize',10);%xlabel
ylabel('Y-axis(unit:m)','FontSize',10);%ylabel
%save figure
saveas(gcf,'figure1-2.jpg');
%compute electric field line
[Ex,Ey]=gradient(-V);%compute electric field intensity
del_theta=10;%set division
theta=(0:del_theta:360).*pi/180;%divide angle
xs1=-1.2:0.1:1.2;%compute x value of location 1
```

```
xs2=-1.2:0.1:1.2;%compute x value of location 2
ys1=0.05*ones(length(xs1),1);%compute y value of location 1
ys2=-0.05*ones(length(xs1),1);%compute y value of location 2
%Plot the distribution of electric field lines in the field
figure;%create figure
hold on;%several graphs
%label and title
a=streamline(X,Y,Ex,Ey,xs1,ys1);%Electric field line1
set(a,'linewidth',1.5,'color',[0.5,0,0.6]);%set line type
b=streamline(X,Y,Ex,Ey,xs2,ys2);%Electirc field line2
set(b,'linewidth',1.5,'color',[0.5,0,0.6]);%set line type
contour(X,Y,V,Veq);%draw equipotential figure
plot([-1,1], [0,0], 'r', 'LineWidth', 3);%draw the line charge
grid on;%set grid on
title(sprintf('Electirc Field Line of Line Charge in Vaccum\n(By Integral Method)'),'Ying Yiwen,12210159','FontSize',14);%title
xlabel('X-axis(unit:m)','FontSize',10);%xlabel
ylabel('Y-axis(unit:m)','FontSize',10);%ylabel
%save figure
saveas(gcf,'figure1-3.jpg');%save current figure
```

B. Calculate the potential distribution, equipotential line distribution, and electric field line distribution of a line charge at each point in a two-dimensional plane using the microelement method

1)Divide into 20 segments

```
clc,clear,close all;
%by infinitive method,20 parts
%select region
k=9e9;%electric constant
p=1e-9;%charge density
xm=2;%set x region
ym=2;%set y region
x=linspace(-xm,xm,100);% divide x axis
y=linspace(-ym,ym,100);% divide y axis
[X,Y]=meshgrid(x,y);%form coordinate
V=0;
for i = 1:20
r=sqrt((X-0.1*i+1.05).^2+Y.^2);%compute r of every dx
V=V+k*p/10./r;%compute V
end
%draw volt graph
figure;%create figure
mesh(X,Y,V);%draw potential figure
grid on;%set grid on
hold on;%several graphs
%label and title
title(sprintf('Potential Graph of Line Charge in Vaccum\n(By Infinitive Method, 20 Segements)'),'Ying Yiwen,12210159','FontSize',14);%title
xlabel('X-axis(unit:m)','FontSize',10);%xlabel
ylabel('Y-axis(unit:m)','FontSize',10);%ylabel
zlabel('V(unit:v)','FontSize',10);%zlabel
%save figure
saveas(gcf,'figure2-1.jpg');%save current figure
%Select value of equipotential
Vmin=0;%minimum equipotential
Vmax=100;%maximum equipotential
Veq=linspace(Vmin,Vmax,101);%divide equipotential line
%draw equipotential graph
figure;%create figure
contour(X,Y,V,Veq);%draw equipotential figure
grid on;%set grid on
hold on;%several graphs
%label and title
plot([-1,1], [0,0], 'r', 'LineWidth', 3);%draw the line charge
title(sprintf('Equipotential Graph of Line Charge in Vaccum\n(By Infinitive Method, 20 Segements)'),'Ying Yiwen,12210159','FontSize',14);%title
xlabel('X-axis(unit:m)','FontSize',10);%xlabel
ylabel('Y-axis(unit:m)','FontSize',10);%ylabel
%save figure
saveas(gcf,'figure2-2.jpg');%save current figure
%compute electric field line
```

```
[Ex,Ey]=gradient(-V);%compute electric field intensity
del_theta=10;%set division
theta=(0:del_theta:360).*pi/180;% divide angle
xs1=-1.2:0.1:1.2;%compute x value of location 1
xs2=-1.2:0.1:1.2;%compute x value of location 2
ys1=0.05*ones(length(xs1),1);%compute y value of location 1
ys2=-0.05*ones(length(xs1),1);% compute y value of location 2
%Plot the distribution of electric field lines in the field
figure;%create figure
hold on;%several graphs
%label and title
a=streamline(X,Y,Ex,Ey,xs1,ys1);% Electric field line1
set(a,'linewidth',1.5,'color',[0.5,0,0.6]);%set line type
b=streamline(X,Y,Ex,Ey,xs2,ys2);% Electirc field line2
set(b,'linewidth',1.5,'color',[0.5,0,0.6]);%set line type
contour(X,Y,V,Veq);%draw equipotential figure
plot([-1,1], [0,0], 'r', 'LineWidth', 3);%draw the line charge
grid on;%set grid on
title(sprintf('Electirc Field Line of Line Charge in Vaccum\n(By Infinitive Method, 20 Segements)'),'Ying Yiwen,12210159','FontSize',14);%title
xlabel('X-axis(unit:m)','FontSize',10);%xlabel
ylabel('Y-axis(unit:m)','FontSize',10);%ylabel
%save figure
saveas(gcf,'figure2-3.jpg');%save current figure
```

2)Divide into 50 segments

```
clc,clear,close all;
%by infinitive method,50 parts
%select region
k=9e9;%electric constant
p=1e-9;%charge density
xm=2;%set x region
ym=2;%set y region
x=linspace(-xm,xm,100);% divide x axis
y=linspace(-ym,ym,100);% divide y axis
[X,Y]=meshgrid(x,y);%form coordinate
V=0;
for i = 1:50
r=sqrt((X-0.04*i+1.02).^2+Y.^2);% compute r of every dx
V=V+k*p/25./r;%compute V
end
%draw volt graph
figure;%create figure
mesh(X,Y,V);%draw potential figure
grid on;%set grid on
hold on;%several graphs
%label and title
title(sprintf('Potential Graph of Line Charge in Vaccum\n(By Infinitive Method, 50 Segements)'),'Ying Yiwen,12210159','FontSize',14);%title
xlabel('X-axis(unit:m)','FontSize',10);%xlabel
ylabel('Y-axis(unit:m)','FontSize',10);%ylabel
zlabel('V(unit:v)','FontSize',10);% zlabel
%save figure
saveas(gcf,'figure3-1.jpg');%save current figure
%Select value of equipotential
Vmin=0;%minimum equipotential
Vmax=100;%maximum equipotential
Veq=linspace(Vmin,Vmax,101);%divide equipotential line
%draw equipotential graph
figure;%create figure
contour(X,Y,V,Veq);%draw equipotential figure
grid on;%set grid on
hold on;%several graphs
%label and title
plot([-1,1], [0,0], 'r', 'LineWidth', 3);%draw the line charge
title(sprintf('Equipotential Graph of Line Charge in Vaccum\n(By Infinitive Method, 50 Segements)'),'Ying Yiwen,12210159','FontSize',14);%title
xlabel('X-axis(unit:m)','FontSize',10);%xlabel
ylabel('Y-axis(unit:m)','FontSize',10);%ylabel
%save figure
saveas(gcf,'figure3-2.jpg');%save
```

```
current figure
%compute electric field line
[Ex,Ey]=gradient(-V);%compute electric field intensity
del_theta=10;%set division
theta=(0:del_theta:360).*pi/180;%divide angle
xs1=-1.2:0.1:1.2;%compute x value of location 1
xs2=-1.2:0.1:1.2;%compute x value of location 2
ys1=0.05*ones(length(xs1),1);%compute y value of location 1
ys2=-0.05*ones(length(xs1),1);%compute y value of location 2
%Plot the distribution of electric field lines in the field
figure;%create figure
hold on;%several graphs
%label and title
a=streamline(X,Y,Ex,Ey,xs1,ys1);%Electric field line1
set(a,'linewidth',1.5,'color',[0.5,0,0.6]);%set line type
b=streamline(X,Y,Ex,Ey,xs2,ys2);%Electirc field line2
set(b,'linewidth',1.5,'color',[0.5,0,0.6]);%set line type
contour(X,Y,V,Veq);%draw equipotential figure
plot([-1,1], [0,0], 'r', 'LineWidth', 3);%draw the line charge
grid on;%set grid on
title(sprintf('Electirc Field Line of Line Charge in Vaccum\n(By Infinitive Method, 50 Segements)'),'Ying Yiwen,12210159','FontSize',14);%title
xlabel('X-axis(unit:m)','FontSize',10);%xlabel
ylabel('Y-axis(unit:m)','FontSize',10);%ylabel
%save figure
saveas(gcf,'figure3-3.jpg');%save current figure
```

3)Divide into 100 segments

```
clc,clear,close all;
%by infinitive method,100 parts
%select region
k=9e9;%electric constant
p=1e-9;%charge density
xm=2;%set x region
ym=2;%set y region
x=linspace(-xm,xm,100);% divide x axis
y=linspace(-ym,ym,100);% divide y axis
[X,Y]=meshgrid(x,y);%form coordinate
V=0;
for i = 1:100
r=sqrt((X-0.02*i+1.01).^2+Y.^2);%compute r of every dx
V=V+k*p/50./r;%compute V
end
%draw volt graph
figure;%create figure
mesh(X,Y,V);%draw potential figure
grid on;%set grid on
hold on;%several graphs
%label and title
title(sprintf('Potential Graph of Line Charge in Vaccum\n(By Infinitive Method, 100 Segements)'),'Ying Yiwen,12210159','FontSize',14);%title
xlabel('X-axis(unit:m)','FontSize',10);%xlabel
ylabel('Y-axis(unit:m)','FontSize',10);%ylabel
zlabel('V(unit:v)','FontSize',10);%zlabel
%save figure
saveas(gcf,'figure4-1.jpg');%save current figure
%Select value of equipotential
Vmin=0;%minimum equipotential
Vmax=100;%maximum equipotential
Veq=linspace(Vmin,Vmax,101);%divide equipotential line
%draw equipotential graph
figure;%create figure
contour(X,Y,V,Veq);%draw equipotential figure
grid on;%set grid on
hold on;%several graphs
%label and title
plot([-1,1], [0,0], 'r', 'LineWidth', 3);%draw the line charge
title(sprintf('Equipotential Graph of Line Charge in Vaccum\n(By Infinitive Method, 100 Segements)'),'Ying Yiwen,12210159','FontSize',14);%title
xlabel('X-axis(unit:m)','FontSize',10);%xlabel
ylabel('Y-axis(unit:m)','FontSize',10);%ylabel
```

```
%save figure
saveas(gcf,'figure4-2.jpg');%save current figure
%compute electric field line
[Ex,Ey]=gradient(-V);%compute electric field intensity
del_theta=10;%set division
theta=(0:del_theta:360).*pi/180;% divide angle
xs1=-1.2:0.1:1.2;%compute x value of location 1
xs2=-1.2:0.1:1.2;%compute x value of location 2
ys1=0.05*ones(length(xs1),1);%compute y value of location 1
ys2=-0.05*ones(length(xs1),1);% compute y value of location 2
%Plot the distribution of electric field lines in the field
figure;%create figure
hold on;%several graphs
%label and title
a=streamline(X,Y,Ex,Ey,xs1,ys1);% Electric field line1
set(a,'linewidth',1.5,'color',[0.5,0,0.6]);%set line type
b=streamline(X,Y,Ex,Ey,xs2,ys2);% Electirc field line2
set(b,'linewidth',1.5,'color',[0.5,0,0.6]);%set line type
contour(X,Y,V,Veq);%draw equipotential figure
plot([-1,1], [0,0], 'r', 'LineWidth', 3);%draw the line charge
grid on;%set grid on
title(sprintf('Electirc Field Line of Line Charge in Vaccum\n(By Infinitive Method, 100 Segements)'),'Ying Yiwen,12210159','FontSize',14);%title
xlabel('X-axis(unit:m)','FontSize',10);%xlabel
ylabel('Y-axis(unit:m)','FontSize',10);%ylabel
%save figure
saveas(gcf,'figure4-3.jpg');%save current figure
```

C. Calculate the difference between the calculus and microelement

1)Linearly calculate the difference

```
clc,clear,close all;
%difference between integral method and infinitive method with 20 parts
%select region
k=9e9;%electric constant
p=1e-9;%charge density
xm=2;%set x region
ym=2;%set y region
x=linspace(-xm,xm,100);% divide x axis
y=linspace(-ym,ym,100);% divide y axis
[X,Y]=meshgrid(x,y);%form coordinate
%infinitive method, 20 parts
V1=0;
for i = 1:20
r=sqrt((X-0.1*i+1.05).^2+Y.^2);% compute r of every dx
V1=V1+k*p/10./r;%compute V
end
%integral method
r1=1-X+sqrt((1-X).^2+Y.^2);%calculate r1
r2=-1-X+sqrt((-1-X).^2+Y.^2);% calculate r2
V2=k.*p.*log(r1./r2);%calculate potential
V=V2-V1;%calculate the difference
%draw volt graph
figure;%create figure
mesh(X,Y,V);%draw potential figure
grid on;%set grid on
%label and title
title(sprintf('Potential Difference Graph of Line Charge in Vaccum\n(Integral Method & Infinitive Method,20 Segements)'),'Ying Yiwen,12210159','FontSize',14);%title
xlabel('X-axis(unit:m)','FontSize',10);%xlabel
ylabel('Y-axis(unit:m)','FontSize',10);%ylabel
zlabel('V(unit:v)','FontSize',10);% zlabel
%save figure
saveas(gcf,'figure5-1.jpg');%save current figure
%infinitive method, 50 parts
V1=0;
for i = 1:50
r=sqrt((X-0.04*i+1.02).^2+Y.^2);% compute r of every dx
V1=V1+k*p/25./r;%compute V
end
```

```
V=V2-V1;%calculate the difference
%draw volt graph
figure;%create figure
mesh(X,Y,V);%draw potential figure
grid on;%set grid on
%label and title
title(sprintf('Potential Difference Graph of Line Charge in Vaccum\n(Integral Method & Infinitive Method,50 Segements)'),'Ying Yiwen,12210159','FontSize',14);%title
xlabel('X-axis(unit:m)','FontSize',10);%xlabel
ylabel('Y-axis(unit:m)','FontSize',10);%ylabel
zlabel('V(unit:v)','FontSize',10);%zlabel
%save figure
saveas(gcf,'figure5-2.jpg');%save current figure
%infinitive method, 100 parts
V1=0;
for i = 1:100
r=sqrt((X-0.02*i+1.01).^2+Y.^2);%compute r of every dx
V1=V1+k*p/50./r;%compute V
end
V=V2-V1;%calculate the difference
%draw volt graph
figure;%create figure
mesh(X,Y,V);%draw potential figure
grid on;%set grid on
%label and title
title(sprintf('Potential Difference Graph of Line Charge in Vaccum\n(Integral Method & Infinitive Method,100 Segements)'),'Ying Yiwen,12210159','FontSize',14);%title
xlabel('X-axis(unit:m)','FontSize',10);%xlabel
ylabel('Y-axis(unit:m)','FontSize',10);%ylabel
zlabel('V(unit:v)','FontSize',10);%zlabel
%save figure
saveas(gcf,'figure5-3.jpg');%save current figure
```

2)Calculate the RMS

```
clc,clear,close all;
%draw the difference of various divisons
%select region
k=9e9;%electric constant
p=1e-9;%charge density
xm=2;%set x region
ym=2;%set y region
x=linspace(-xm,xm,100);% divide x axis
y=linspace(-ym,ym,100);% divide y axis
[X,Y]=meshgrid(x,y);%form coordinate
%integral method
r1=1-X+sqrt((1-X).^2+Y.^2);%calculate r1
r2=-1-X+sqrt((-1-X).^2+Y.^2);%calculate r2
V=k.*p.*log(r1./r2);%calculate potential
differ=[];%an array to save the difference
%infinitive method
for i = 5:5:100
temp=0;
for j = 1:i
r=sqrt((X-(2/i)*j+1+(1/i)).^2+Y.^2);%compute r of every dx
temp=temp+2*k*p/i./r;%compute V
end
difference=sum(sum((V-temp).^2))/10000;%compute the total of difference
differ=[differ difference];
end
x=5:5:100;%x-axis
figure;%create new figure
plot(x, differ, '-o');%plot the line chart
grid on;%set grid on
%label and title
title(sprintf('Line Chart of Potential Difference Graph of Line Charge in Vaccum\n(Integral Method & Infinitive Method)'),'Ying Yiwen,12210159','FontSize',14);%title
xlabel('Number of Segements','FontSize',10);%xlabel
ylabel('RMS','FontSize',10);%ylabel
%save figure
saveas(gcf,'figure5-4.jpg');%save current figure
```

```
clc,clear,close all;
%draw the difference of various divisons
%select region
```

```
k=9e9;%electric constant
p=1e-9;%charge density
xm=2;%set x region
ym=2;%set y region
x=linspace(-xm,xm,100);% divide x axis
y=linspace(-ym,ym,100);% divide y axis
[X,Y]=meshgrid(x,y);%form coordinate
%integral method
r1=1-X+sqrt((1-X).^2+Y.^2);%calculate r1
r2=-1-X+sqrt((-1-X).^2+Y.^2);%calculate r2
V=k.*p.*log(r1./r2);%calculate potential
differ=[];%an array to save the difference
%infinitive method
for i = 20:1:60
temp=0;
for j = 1:i
r=sqrt((X-(2/i)*j+1+(1/i)).^2+Y.^2);%compute r of every dx
temp=temp+2*k*p/i./r;%compute V
end
difference=sum(sum((V-temp).^2))/10000;%compute the total of difference
differ=[differ difference];
end
x=20:1:60;%x-axis
figure;%create new figure
plot(x, differ, '-o');%plot the line chart
grid on;%set grid on
%label and title
title(sprintf('Line Chart of Potential Difference Graph of Line Charge in Vaccum\n(Integral Method & Infinitive Method)'),'Ying Yiwen,12210159','FontSize',14);%title
xlabel('Number of Segements','FontSize',10);%xlabel
ylabel('RMS','FontSize',10);%ylabel
%save figure
saveas(gcf,'figure5-5.jpg');%save current figure
```