Theory of Electromagnetic Fields, Experiment 1

Author: Ying Yiwen
Number: 12210159

Content

1 Experiment Principle

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

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

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, i.e:

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

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

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

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

2 Case 1: Electric Field Distribution of Two Equal Amounts of Point Charges of the Same Sex

Point charge $Q_1 = 1 \times 10^{-9} C$ locates at P_1 [-0.01,0]
Point charge $Q_2 = 1 \times 10^{-9} C$ locates at P_2 [0.01,0]

2.1 Parameter Preparetion

```
clc,clear,close all;
%Electric field distribution of two equal amounts of point
    charges of the Same Sex
%Select the range of field domain.
k=9e9;
Q=1e-9;
Q2=1e-9;
xm=0.05;
ym=0.05;
x=linspace(-xm,xm,50);
y=linspace(-ym,ym,50);
[X,Y]=meshgrid(x,y);
%Compute electric potential at every point.
R1=sqrt((X+0.01).^2+Y.^2);
R2=sqrt((X-0.01).^2+Y.^2);
V=k*Q./R1+k*Q2./R2;
```

2.2 Plot the Distribution of Potential at Each Point in the Field

```
%Plot the distribution of potential at each point in the field
figure;
mesh(X,Y,V);
hold on;
%Chart label
title('真空中两个等量同性点电荷的电场分布','应逸雯12210159','
    FontSize',16);
xlabel('X轴(单位:m)','FontSize',12);
ylabel('Y轴(单位:m)','FontSize',12);
%Save figure
saveas(gcf,'图1-1.jpg');
```

Figure 1 is a simulation of the electric field distribution of two equal amount of point charges of the same sex in vacuum. The larger the Z value, the higher the potential.

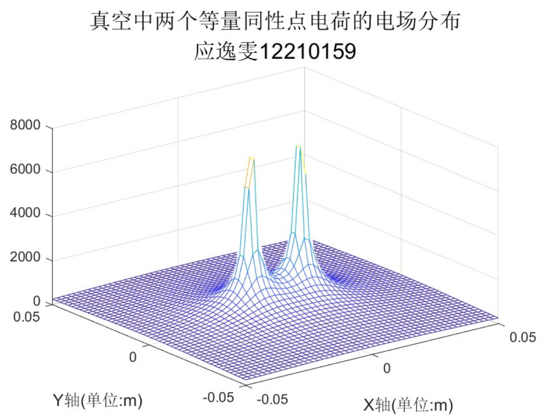

Fig. 1: Electric field distribution of two equal amounts of point charges of the Same Sex in vacuum

2.3 Plot the distribution of equipotential lines in the field

```
%Select the appropriate equipotential value
Vmin=200;
Vmax=5000;
Veq=linspace(Vmin,Vmax,101);
%Plot the distribution of equipotential lines in the field
figure;
contour(X,Y,V,Veq);
grid on;
hold on;
%Draw the charges
plot(-0.01,0,'o','MarkerSize',12);
plot(0.01,0,'o','MarkerSize',12);
%Chart label
title('真空中两个等量同性点电荷电场的等电位线','应逸雯12210159',
    'FontSize',16);
xlabel('X轴(单位:m)','FontSize',12);
ylabel('Y轴(单位:m)','FontSize',12);
%Save figure
saveas(gcf,'图1-2.jpg');
```

Figure 2 shows the equipotential lines of two equal point charge electric fields in a vacuum. The equipotential line is densest near the two charges.

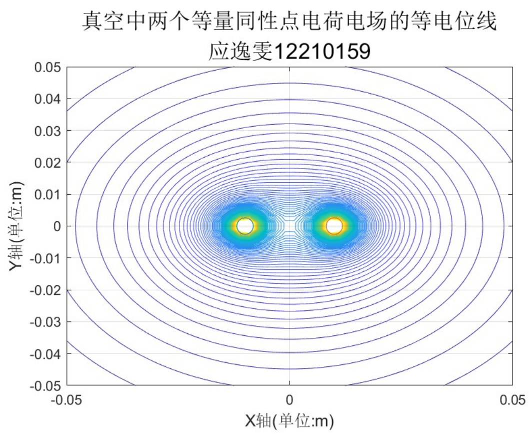

Fig. 2: The equipotential line of two equal point charge electric fields in a vacuum

2.4 Plot the Distribution of Equipotential and Electric Field Lines (Represented by Smooth Continuous Curves) in the Field

```
%Calculated field line
[Ex,Ey]=gradient(-V);
del_theta=10;
theta=(0:del_theta:360).*pi/180;
xs1=-0.01+0.001*cos(theta);
xs2=0.01+0.001*cos(theta);
ys1=0.001*sin(theta);
%Plot the distribution of equipotential and electric field lines
    (represented by smooth continuous curves) in the field
figure;
streamline(X,Y,Ex,Ey,xs1,ys1);
streamline(X,Y,Ex,Ey,xs2,ys1);
grid on;
hold on;
contour(X,Y,V,Veq);
%Draw the charges
plot(-0.01,0,'o','MarkerSize',12);
plot(0.01,0,'o','MarkerSize',12);
%Chart label
title(sprintf('真空中两个等量同性点电荷电场的等电位线和电力线\n
    (用光滑连续曲线表示)'),'应逸雯12210159','FontSize',16);
xlabel('X轴(单位:m)','FontSize',12);
ylabel('Y轴(单位:m)','FontSize',12);
%Save figure
```

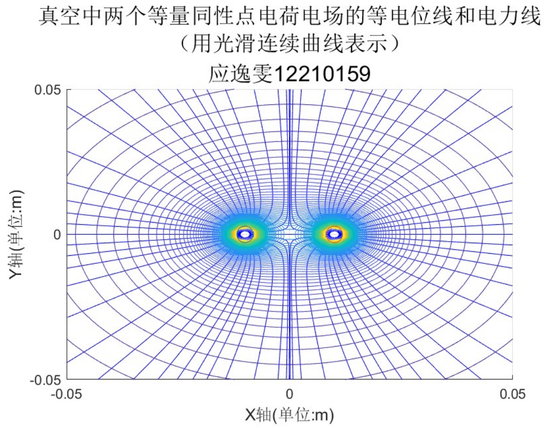

Fig. 3: Equipotential and power lines of field of two equal point charge of the same sex in a vacuum

```
saveas(gcf,'图1-3.jpg');
```

Figure 3 shows the equipotential and power lines of field of two equal point charge of the same sex in a vacuum (represented by smooth continuous curves). The power line radiates from the two charges.

2.5 Plot the Distribution of Equipotential and Electric Field Lines (Represented by Normalized Arrows) in the Field

```
%Calculated electric field strength
E=sqrt(Ex.^2+Ey.^2);
Ex=Ex./E;
Ey=Ey./E;
%Plot the distribution of equipotential and electric field lines
    (represented by normalized arrows) in the field
figure;
quiver(X,Y,Ex,Ey);
hold on;
contour(X,Y,V,Veq);
%Draw the charges
plot(-0.01,0,'o','MarkerSize',12);
plot(0.01,0,'o','MarkerSize',12);
%Chart label
title(sprintf('真空中两个等量同性点电荷电场的等电位线和电力线\n
    （用归一化箭头表示）'),'应逸雯12210159','FontSize',16);
xlabel('X轴(单位:m)','FontSize',12);
ylabel('Y轴(单位:m)','FontSize',12);
```

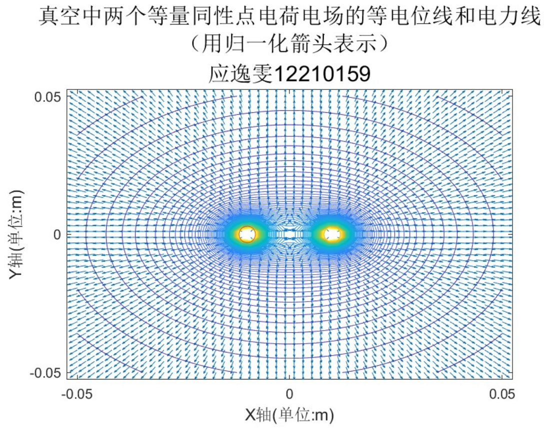

Fig. 4: Equipotential and power lines of electric fields of two equal point charge of the same sex in a vacuum (represented by normalized arrows)

```
%Save figure
saveas(gcf,'图1-4.jpg');
```

Figure 4 shows the equipotential and power lines of electric fields of two equal point charge of the same sex in a vacuum (represented by normalized arrows). The normalized arrow shows the direction of the electric field on the basis of the smooth curve.

3 Case 2: The Electric Field Distribution of Two Equally Opposite Point Charges

Point Charge $Q_1 = 5 \times 10^{-9}C$ locates at P_1 [-2,0]

Point Charge $Q_2 = -5 \times 10^{-9}C$ locates at P_2 [2,0]

3.1 Parameter Preperation

```
clc,clear,close all;
%Electric field distribution of two equally opposite point
    charges
%Select the field range
k=9e9;
Q=5e-9;
Q2=-5e-9;
xm=10;
ym=10;
x=linspace(-xm,xm,50);
y=linspace(-ym,ym,50);
[X,Y]=meshgrid(x,y);
%Calculate the potential at each point
R1=sqrt((X+2).^2+Y.^2);
R2=sqrt((X-2).^2+Y.^2);
V=k*Q./R1+k*Q2./R2;
```

3.2 Plot the Distribution of Potential at Each Point in the Field

```
%Plot the distribution of potential at each point in the field
figure;
mesh(X,Y,V);
hold on;
%Chart label
title('真空中两个等量异性点电荷的电场分布','应逸雯12210159','
    FontSize',16);
xlabel('X轴(单位:m)','FontSize',12);
ylabel('Y轴(单位:m)','FontSize',12);
%Save figure
saveas(gcf,'图2-1.jpg');
```

Figure 5 is a simulation of the electric field distribution of two equally opposite point charges in a vacuum. The larger the Z value, the higher the potential.

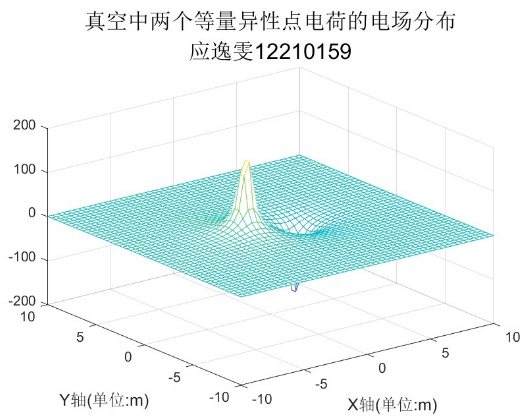

Fig. 5: Electric field distribution of two equally opposite point charges in a vacuum

3.3 Plot the Distribution of Equipotential Lines in the Field

```
%Select the appropriate equipotential value
Vmin=-50;
Vmax=50;
Veq=linspace(Vmin,Vmax,101);
%Plot the distribution of equipotential lines
figure;
contour(X,Y,V,Veq);
grid on;
hold on;
%Draw the charges
plot(-2,0,'o','MarkerSize',12);
plot(2,0,'o','MarkerSize',12);
%Chart label
title('真空中两个等量异性点电荷电场的等电位线','应逸雯12210159',
    'FontSize',16);
xlabel('X轴(单位:m)','FontSize',12);
ylabel('Y轴(单位:m)','FontSize',12);
%Save figure
saveas(gcf,'图2-2.jpg');
```

Figure 6 shows the equipotential lines of two identically charged point electric fields in a vacuum. The equipotential lines are symmetric about the y axis. It's densest near the two charges.

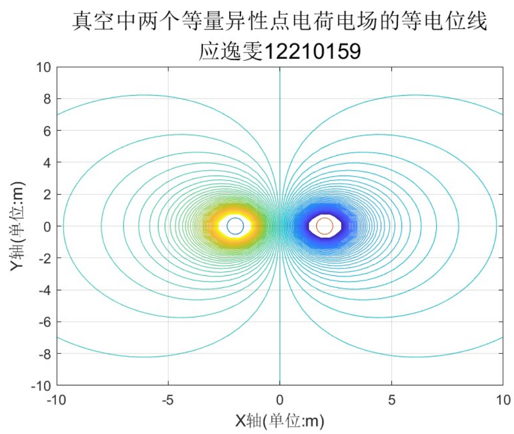

Fig. 6: An equipotential line of two equally opposite point charge electric fields in a vacuum

3.4 Plot the Distribution of Equipotential and Electric Field Lines (Represented by Smooth Continuous Curves) in the Field

```
%Calculated field line
[Ex,Ey]=gradient(-V);
del_theta=5;
theta=(0:del_theta:360).*pi/180;
xs1=-2+0.0005*cos(theta);
xs2=2+0.0005*cos(theta);
ys1=0.0005*sin(theta);
%Plot the distribution of equipotential and electric field lines
    (represented by smooth continuous curves) in the field
figure;
streamline(X,Y,Ex,Ey,xs1,ys1);
streamline(X,Y,-Ex,-Ey,xs2,ys1);
grid on;
hold on;
contour(X,Y,V,Veq);
%Draw the charges
plot(-2,0,'o','MarkerSize',12);
plot(2,0,'o','MarkerSize',12);
%Chart label
title(sprintf('真空中两个等量异性点电荷电场的等电位线和电力线\n
    (用光滑连续曲线表示)'),'应逸雯12210159','FontSize',16);
xlabel('X轴(单位:m)','FontSize',12);
ylabel('Y轴(单位:m)','FontSize',12);
%Save figure
```

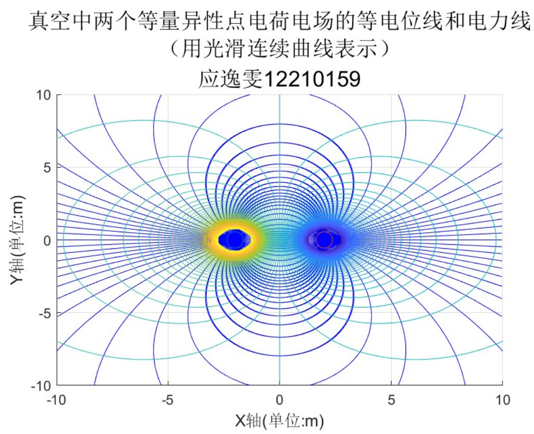

Fig. 7: Equipotential and power lines of two equally opposite point charge electric fields in a vacuum

```
saveas(gcf, '图2-3.jpg');
```

Figure 7 shows the equipotential lines and power lines of two equally opposite point charge electric fields in a vacuum (represented by smooth continuous curves). The power lines move from positive to negative charge, forming a closed loop.

3.5 Plot the Distribution of Equipotential and Electric Field Lines (Represented by Normalized Arrows) in the Field

```
%Calculated electric field strength
E=sqrt(Ex.^2+Ey.^2);
Ex=Ex./E;
Ey=Ey./E;
%Plot the distribution of equipotential and electric field lines
    (represented by normalized arrows) in the field
figure;
quiver(X,Y,Ex,Ey);
hold on;
contour(X,Y,V,Veq);
%Draw the charges
plot(-2,0,'o','MarkerSize',12);
plot(2,0,'o','MarkerSize',12);
%Chart label
title(sprintf('真空中两个等量异性点电荷电场的等电位线和电力线\n
    （用归一化箭头表示）'),'应逸雯12210159','FontSize',16);
xlabel('X轴(单位:m)','FontSize',12);
ylabel('Y轴(单位:m)','FontSize',12);
```

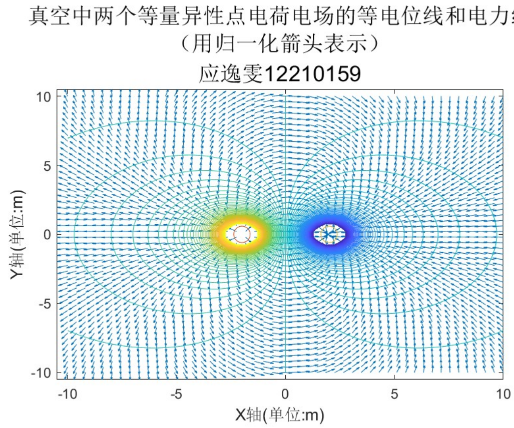

Fig. 8: Equipotential lines and power lines of two identically charged point electric fields in a vacuum (represented by normalized arrows)

```
%Save figure
saveas(gcf,'图2-4.jpg');
```

Figure 8 shows the equipotential lines and the power lines of two identically charged point electric fields in a vacuum (represented by normalized arrows). The normalized arrow shows the direction of the electric field on the basis of the smooth curve.

4 Case 3: The Electric Field Distribution of Three Equal Points of the Same Sex at the Vertex of an Equilateral Triangle

Point charge $Q_1 = 8 \times 10^{-9}C$ locates at P_1 $[-\sqrt{3}, -1]$
Point charge $Q_2 = 8 \times 10^{-9}C$ locates at P_2 $[\sqrt{3}, -1]$
Point charge $Q_3 = 8 \times 10^{-9}C$ locates at P_3 [0,2]

4.1 Parameter Preparation

```
clc,clear,close all;
%The electric field distribution of three equal points of the
    same sex at the vertex of an equilateral triangle
%Select the field range
k=9e9;
Q=8e-9;
xm=5;
ym=5;
x=linspace(-xm,xm,100);
y=linspace(-ym,ym,100);
[X,Y]=meshgrid(x,y);
%Calculate the potential at each point
R1=sqrt((X+sqrt(3)).^2+(Y+1).^2);
R2=sqrt((X-sqrt(3)).^2+(Y+1).^2);
R3=sqrt(X.^2+(Y-2).^2);
V=k*Q./R1+k*Q./R2+k*Q./R3;
```

4.2 Plot the Distribution of Potential at Each Point in the Field

```
%Plot the distribution of potential at each point in the field
figure;
mesh(X,Y,V);
hold on;
%Chart label
title('真空中三个等量同性点电荷的电场分布','应逸雯12210159','
    FontSize',16);
xlabel('X轴(单位:m)','FontSize',12);
ylabel('Y轴(单位:m)','FontSize',12);
%Save figure
```

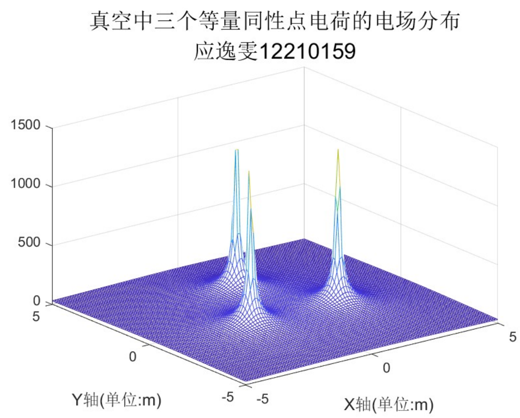

Fig. 9: Electric field distribution of three equal point charges in a vacuum

```
saveas(gcf, '图3-1.jpg');
```

Figure 9 is a simulation of the electric field distribution of three equal point charges in a vacuum. You can see that the electric field distribution around the three charges is symmetrical.

4.3 Plot the distribution of equipotential lines in the field

```
%Select the appropriate equipotential value
Vmin=10;
Vmax=100;
Veq=linspace(Vmin,Vmax,101);
%Plot the distribution of equipotential lines
figure;
contour(X,Y,V,Veq);
grid on;
hold on;
%Draw the charges
plot(-sqrt(3),-1,'o','MarkerSize',12);
plot(sqrt(3),-1,'o','MarkerSize',12);
plot(0,2,'o','MarkerSize',12);
%Chart label
title('真空中三个等量同性点电荷电场的等电位线','应逸雯12210159',
    'FontSize',16);
xlabel('X轴(单位:m)','FontSize',12);
ylabel('Y轴(单位:m)','FontSize',12);
%Save figure
saveas(gcf, '图3-2.jpg');
```

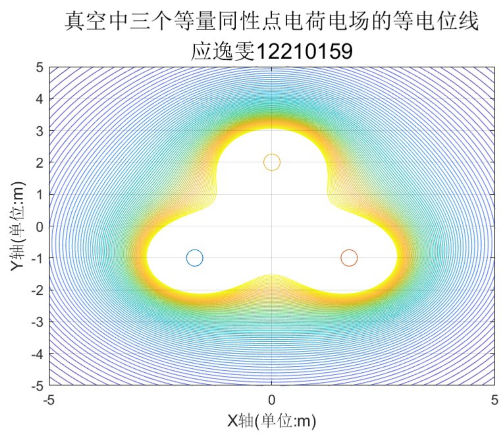

Fig. 10: Equipotential lines of three equal point charge electric fields in a vacuum

Figure 10 shows the equipotential lines of three equal point charge electric fields in a vacuum. The equipotential lines spread out evenly around the three charges.

4.4 Plot the Distribution of Equipotential and Electric Field Lines (Represented by Smooth Continuous Curves) in the Field

```
%Calculated field line
[Ex,Ey]=gradient(-V);
del_theta=5;
theta=(0:del_theta:360).*pi/180;
xs1=-sqrt(3)+0.5*cos(theta);
xs2=sqrt(3)+0.5*cos(theta);
xs3=0.5*cos(theta);
ys1=-1+0.5*sin(theta);
ys2=-1+0.5*sin(theta);
ys3=2+0.5*sin(theta);
%Plot the distribution of equipotential and electric field lines
    (represented by smooth continuous curves) in the field
figure;
streamline(X,Y,Ex,Ey,xs1,ys1);
streamline(X,Y,Ex,Ey,xs2,ys2);
streamline(X,Y,Ex,Ey,xs3,ys3);
grid on;
hold on;
contour(X,Y,V,Veq);
%Draw the charges
plot(-sqrt(3),-1,'o','MarkerSize',12);
```

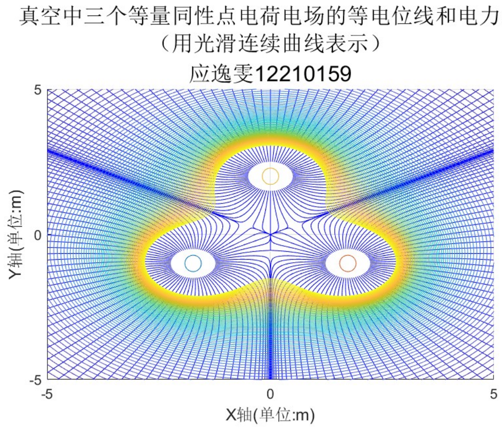

Fig. 11: Equipotential and power lines of three equal point charge electric fields in vacuum

```
plot(sqrt(3),-1,'o','MarkerSize',12);
plot(0,2,'o','MarkerSize',12);
%Chart label
title(sprintf('真空中三个等量同性点电荷电场的等电位线和电力线\n
    （用光滑连续曲线表示）'),'应逸雯12210159','FontSize',16);
xlabel('X轴(单位:m)','FontSize',12);
ylabel('Y轴(单位:m)','FontSize',12);
%Save figure
saveas(gcf,'图3-3.jpg');
```

Figure 11 shows the equipotential and power lines of three equal point charge electric fields in a vacuum (represented by smooth continuous curves). The power lines within each sector are symmetrical and extend outward.

4.5 Plot the Distribution of Equipotential and Electric Field Lines (Represented by Normalized Arrows) in the Field

```
%Calculated electric field strength
E=sqrt(Ex.^2+Ey.^2);
Ex=Ex./E;
Ey=Ey./E;
%Plot the distribution of equipotential and electric field lines
    (represented by normalized arrows) in the field
figure;
quiver(X,Y,Ex,Ey);
hold on;
contour(X,Y,V,Veq);
```

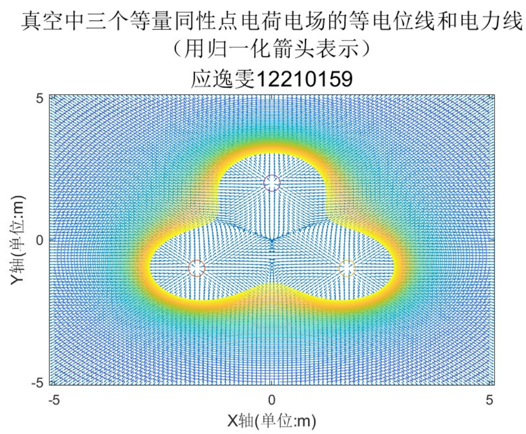

Fig. 12: Equipotential and power lines of three equal point charge electric fields in a vacuum (represented by normalized arrows)

```
%Draw the charges
plot(-sqrt(3),-1,'o','MarkerSize',12);
plot(sqrt(3),-1,'o','MarkerSize',12);
plot(0,2,'o','MarkerSize',12);
%Chart label
title(sprintf('真空中三个等量同性点电荷电场的等电位线和电力线\n
    （用归一化箭头表示）'),'应逸雯12210159','FontSize',16);
xlabel('X轴(单位:m)','FontSize',12);
ylabel('Y轴(单位:m)','FontSize',12);
%Save figure
saveas(gcf,'图3-4.jpg');
```

Figure 12 shows the equipotential and power lines of three equal point charge electric fields in a vacuum (represented by normalized arrows). The normalized arrow shows the direction of the electric field on the basis of the smooth curve.

5 Experimental Experience

Learned the use of the following functions:

mesh(X,Y,V) ——Draw a three-dimensional grid diagram

contour(X,Y,V,Veq) ——Draw a contour map

streamline(X,Y,Ex,Ey,xs,ys) ——Flow plotting

quiver(X,Y,Ex,Ey) ——Draw a vector field diagram

The electric field distribution image, equipotential line image and power line image drawn can directly express the electric field in this case, and promote the understanding of the electric field of two equal point charges of the same sex, two equal point charges of the same sex, and three equal point charges of the same sex located at the vertex of an equilateral triangle.

In drawing the graphs, I found that the parameters and limits I choose greatly affects the effectiveness of the mapping. After trying several parameters, the graph I show in this report is which I suppose can clearly show the results.