Engineering electromagnetic theory lab1

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Case 1: Electric field distribution of two identical point charges

1.Calculation and plot of the potential distribution of each point in the field

(1) Matlab code:

```
k = 9e9;
Q1 = 1e-9;
Q2 = 1e-9;
xm = 0.05;
ym = 0.05;
x = linspace(-xm,xm,45);
y = linspace(-ym,ym,45);
[X,Y] = meshgrid(x,y);
R1 = sqrt((X+0.01).^2+Y.^2);
R2 = sqrt((X-0.01).^2+Y.^2);
V1 = k*Q1./R1;
V2 = k*Q2./R2;
V = V1+V2;
mesh(X,Y,V)
hold on;
title('The plot of electric potential distribution of a point charge in the
vacuum(LanJingqi12313517)', 'fontsize',12);
xlabel('X axis(unit:m)','FontSize',12);
ylabel('Yaxis(unit:m)','FontSize',12);
hold off;
```

(2) Experiment result(Figure 1)

2.Plot the distribution of potential lines and streamlines

(1) Matlab code:

```
Vmin = 200;
Vmax = 8000;
Veq = linspace(Vmin,Vmax,20);
contour(X,Y,V,Veq);
grid on;
hold on;
plot(0,0,'o', 'MarkerSize',12)
title('Isopotential Line of single Point charge Electric Field in vacuum
(LanJingqi12313517)', 'fontsize', 8);
xlabel('X axis(unit: m)', 'fontsize', 12);
ylabel('Y axis(unit: m)', 'fontsize', 12);
hold off;
```

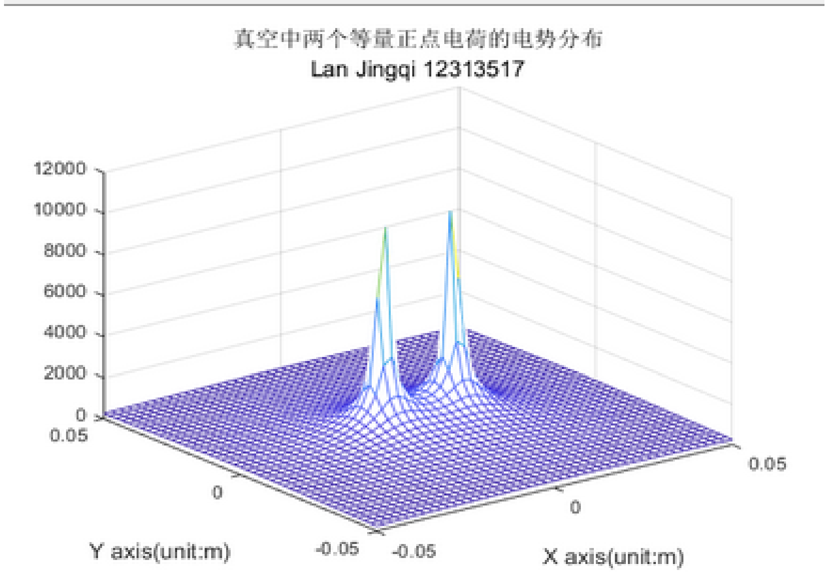

Figure 1: Electric field distribution of two identical point charges

(2) Experiment result

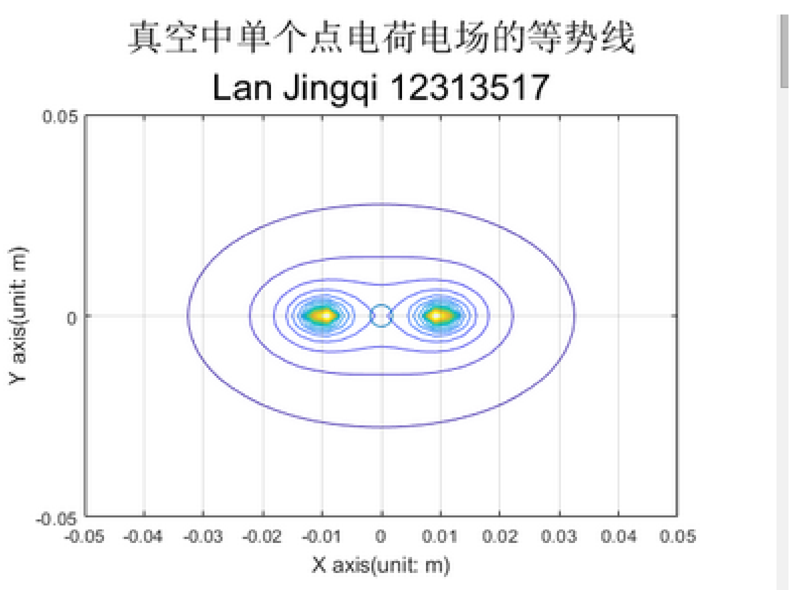

Figure 2: Electric field distribution of two identical point charges

3.Plot the distribution of equipotential lines and streamlines (expressed by smooth continuous curves) in the field

(1) Matlab code:

```
[Ex,Ey]=gradient(-V);
del_theta=5;
theta=(0:del_theta:360).*pi/180;
xs=0.015*cos(theta);
```

```
ys=0.015*sin(theta);
figure;
streamline(X,Y,Ex,Ey,xs,ys)
grid on
hold on
contour(X,Y,V,Veq);
plot(0,0,'o', 'MarkerSize',12)
title('Isopotential Line and Power Line of a single Point charge Electric Field in
vacuum (expressed by smooth continuous Curves)(LanJingqi12313517)' , 'fontsize',6)              % title th
xlabel('X axis(unit: m)', 'fontsize', 12);
ylabel('Y axis (unit: m)', 'fontsize', 12);
hold off;
```

(2) Experiment result

figure:

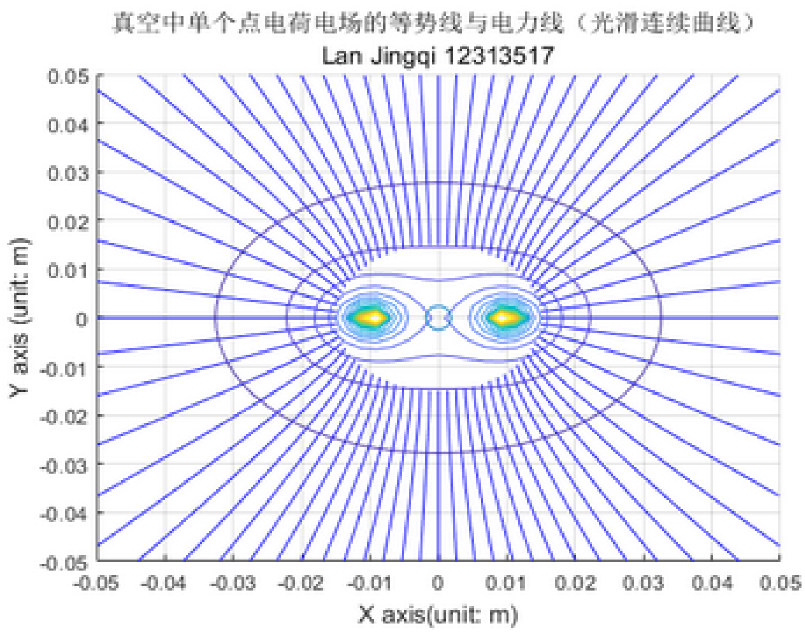

Figure 3: Electric field distribution of two identical point charges

4.Plot the distribution of potential lines and streamlines (expressd bu normalizesd arrows) in the field

(1) Matlab code:

```
E=sqrt(Ex.^2+Ey.^2);
Ex=Ex./E;
Ey=Ey./E;
quiver(X,Y,Ex,Ey);
hold on;
contour(X,Y,V,Veq);
title('Equipotential lines and electric field lines of a single point charge electric
field in vacuum represented by normalized arrowhead(LanJingqi12313517)', 'fontsize', 6);
xlabel('X  axis(unit: m)', 'fontsize', 12);
ylabel('Y  axis(unit: m)', 'fontsize', 12);
hold off;
```

(2) Experiment result

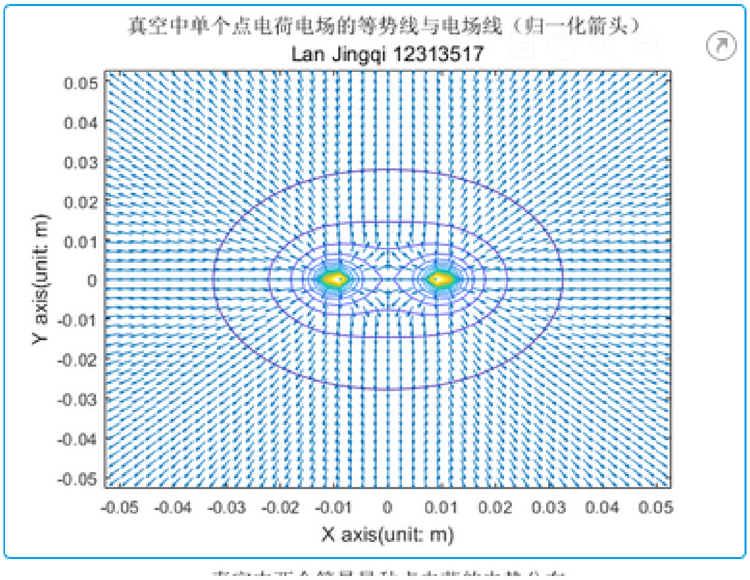

Figure 4: Electric field distribution of two identical point charges

Brief analysis: The simulation demonstrates the electric field and potential distribution of two identical positive point charges. The 3D potential plot shows sharp peaks near each charge, decreasing with distance. Equipotential lines are densely packed around the charges, reflecting a strong field, and bend symmetrically due to repulsion. Field lines radiate outward, confirming the expected repulsive behavior. The results validate the superposition principle, with orthogonal intersections between field lines and equipotential contours, and a neutral midpoint where the net field is zero. The symmetry and theoretical consistency are clearly observed.

Case 2: Electric field distribution of two opposite point charges with the same magnitude

1.Calculation and plot of the potential distribution of each point in the field

(1) Matlab code:

```
k = 9e9;
Q1 = 5e-9;
Q2 = -5e-9;
xm = 3;
ym = 3;
P1 = [-2,0];
P2 = [2,0];
x = linspace(-xm,xm,50);
y = linspace(-ym,ym,50);
[X,Y] = meshgrid(x,y);
R1 = sqrt((X+2).^2+Y.^2);
R2 = sqrt((X-2).^2+Y.^2);
V1 = k*Q1./R1;
V2 = k*Q2./R2;
V = V1+V2;
mesh(X,Y,V)
hold on;
title('The plot of electric potential distribution of a point charge in the
```

```
vacuum(LanJingqi12313517)', 'fontsize',8);
xlabel('X axis(unit:m)','FontSize',12);
ylabel('Yaxis(unit:m)','FontSize',12);
hold off;
```

(2) Experiment result

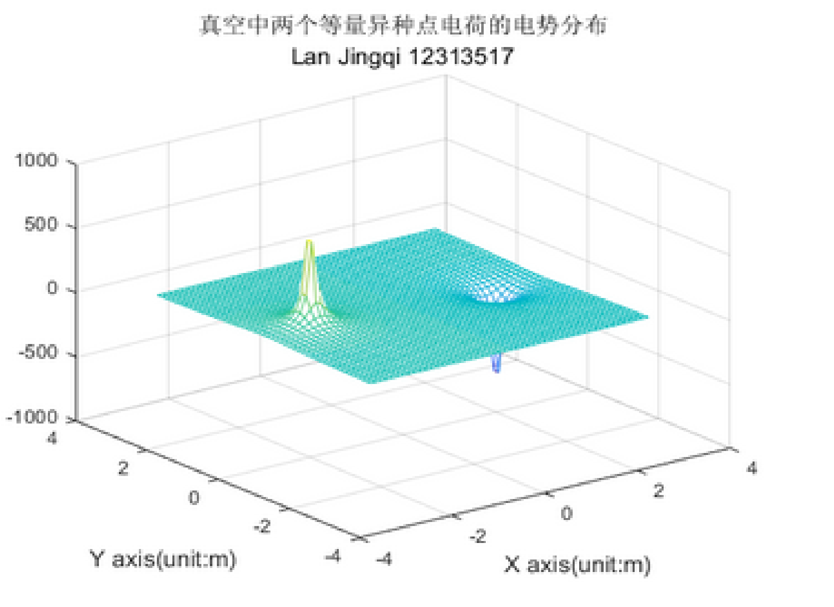

Figure 5: Electric field distribution of two identical point charges

2.Plot the distribution of potential lines and streamlines

(1) Matlab code:

figure:

```
Vmin = -250;
Vmax = 250;
Veq = linspace(Vmin,Vmax,50);
contour(X,Y,V,Veq);
grid on;
hold on;
title('Isopotential Line of single Point charge Electric Field in vacuum(LanJingqi
12313517)', 'fontsize', 8);
xlabel('X axis(unit: m)', 'fontsize', 12);
ylabel('Y axis(unit: m)', 'fontsize', 12);
hold off;
```

(2) Experiment result

See at Figure 6

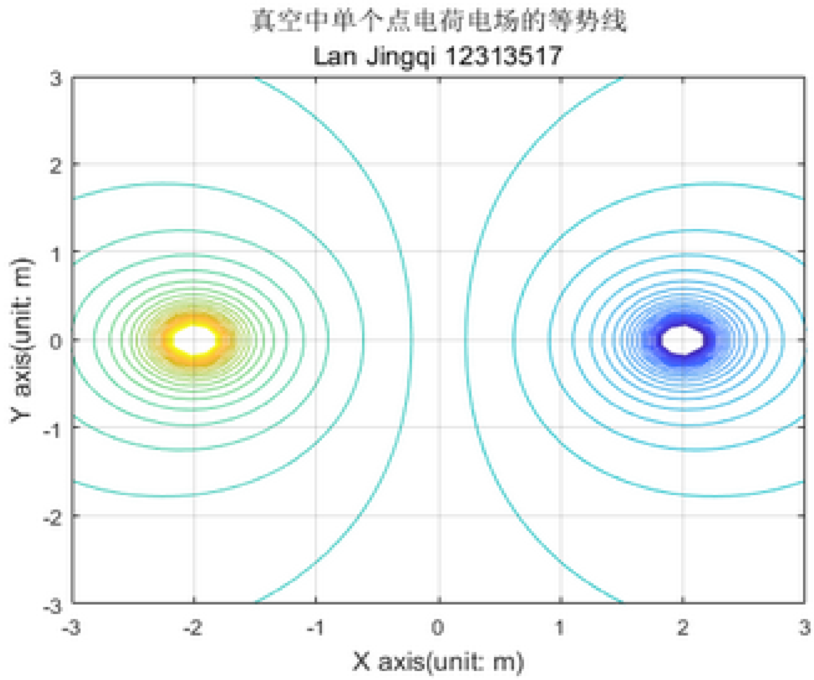

Figure 6: Electric field distribution of two identical point charges

3.Plot the distribution of equipotential lines and streamlines (expressed by smooth continuous curves) in the field

(1) Matlab code:

```
[Ex,Ey]=gradient(-V);
del_theta=10;
theta=(0:del_theta:360).*pi/180;
startx_pos = P1(1) + 0.3*cos(theta);
starty_pos = P1(2) + 0.3*sin(theta);
startx_neg = P2(1) + 0.3*cos(theta);
starty_neg = P2(2) + 0.3*sin(theta);

figure
contour(X,Y,V,Veq);
grid on,hold on;
h = streamline(X, Y, Ex, Ey, [startx_pos startx_neg], [starty_pos starty_neg]);
hold on;
plot(-2,0,'o', 'MarkerSize',10);
hold on;
plot(2,0,'o', 'MarkerSize',10);
hold off;

title('Isopotential Line and Power Line of a single Point charge Electric Field in
vacuum (expressed by smooth continuous Curves)(LanJingqi12313517)', 'fontsize', 6);
xlabel('X axis(unit: m)', 'fontsize', 14);
ylabel('Y axis(unit: m)', 'fontsize', 14);
```

(2) Experiment result(Figure 7)

See at Figure 7

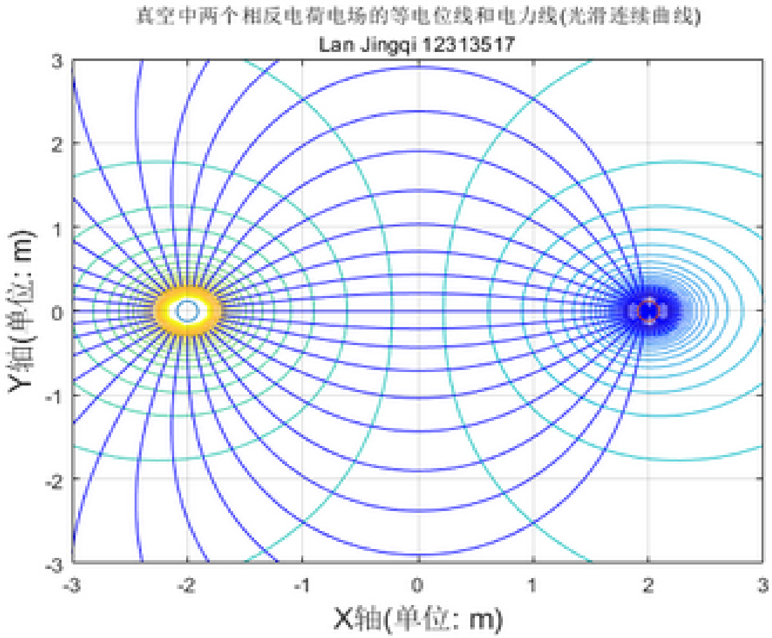

Figure 7: Electric field distribution of two identical point charges

4.Plot the distribution of potential lines and streamlines (expressd bu normalizesd arrows) in the field

(1) Matlab code:

```
E=sqrt(Ex.^2+Ey.^2);
Ex=Ex./E;
Ey=Ey./E;
quiver(X,Y,Ex,Ey);
hold on;
contour(X,Y,V,Veq);
title('Equipotential lines and electric field lines of a single point charge electric
field in vacuum represented by normalized arrowhead(LanJingqi12313517)', 'fontsize', 6);
xlabel('X  axis(unit: m)', 'fontsize', 12);
ylabel('Y  axis(unit: m)', 'fontsize', 12);
hold off;
```

(2) Experiment result

See at Figure 8

Brief analysis: The simulation demonstrates the electric potential and field distribution between two opposite point charges (+5nC and -5nC). The 3D potential plot shows a distinct saddle point at the center, with positive potential radiating from the positive charge and negative potential surrounding the negative charge. Equipotential lines curve symmetrically between the charges, illustrating their attractive interaction. Electric field lines originate from the positive charge and converge at the negative charge, with the strongest field intensity occurring near each charge. The results clearly visualize the characteristic dipole field pattern, confirming the expected behavior of opposite charges in electrostatic theory.

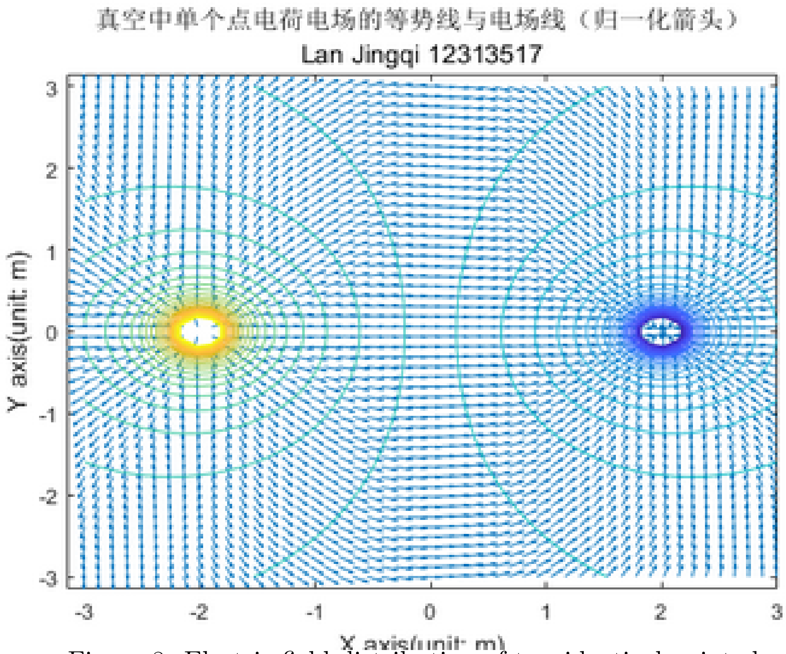

Figure 8: Electric field distribution of two identical point charges

Case 3: Electric Field Distribution of three identical point charges located at the vertices of an equilateral triangle

1.Calculation and plot of the potential distribution of each point in the field

(1) Matlab code:

```
k = 9e9;
Q1 = 8e-9;
Q2 = 8e-9;
Q3 = 8e-9;
xm = 3;
ym = 3;
x = linspace(-xm,xm,50);
y = linspace(-ym,ym,50);
[X,Y] = meshgrid(x,y);
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);
P1 = [-sqrt(3),-1]; P2 = [sqrt(3),-1]; P3 = [0,2]
V1 = k*Q1./R1;
V2 = k*Q2./R2;
V3 = k*Q3./R3;
V = V1+V2+V3;
mesh(X,Y,V)
hold on;
title('The plot of electric potential distribution of a point charge in the
vacuum(LanJingqi12313517)', 'fontsize',8);
xlabel('X axis(unit:m)','FontSize',12);
ylabel('Yaxis(unit:m)','FontSize',12);
hold off;
```

(2) Experiment result

See at Figure 9:

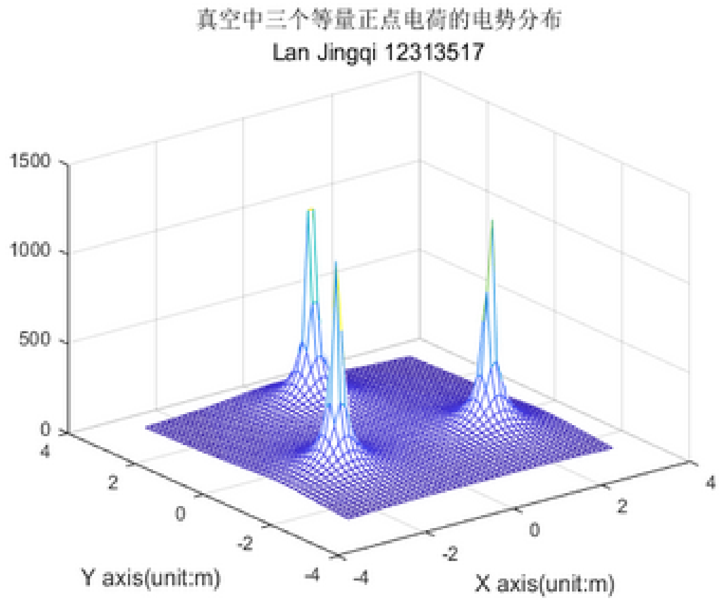

Figure 9: Electric field distribution of two identical point charges

2.Plot the distribution of potential lines and streamlines

(1) Matlab code:

```
Vmin = -1000;
Vmax = 1000;
Veq = linspace(Vmin,Vmax,150);
contour(X,Y,V,Veq);
grid on;
hold on;
title('Isopotential Line of single Point charge Electric Field in vacuum(LanJingqi
12313517)', 'fontsize', 8);
xlabel('X axis(unit: m)', 'fontsize', 12);
ylabel('Y axis(unit: m)', 'fontsize', 12);
hold off;
```

(2) Experiment result

See at Figure 10

3.Plot the distribution of equipotential lines and streamlines (expressed by smooth continuous curves) in the field

(1) Matlab code:

```
[Ex,Ey]=gradient(-V);
del_theta=5;
theta=(0:del_theta:360).*pi/180;
xs = [P1(1)+0.3*cos(0:pi/6:2*pi), P2(1)+0.3*cos(0:pi/6:2*pi), P3(1)+0.3*cos(0:pi/6:2*pi)];
ys = [P1(2)+0.3*sin(0:pi/6:2*pi), P2(2)+0.3*sin(0:pi/6:2*pi), P3(2)+0.3*sin(0:pi/6:2*pi)];
```

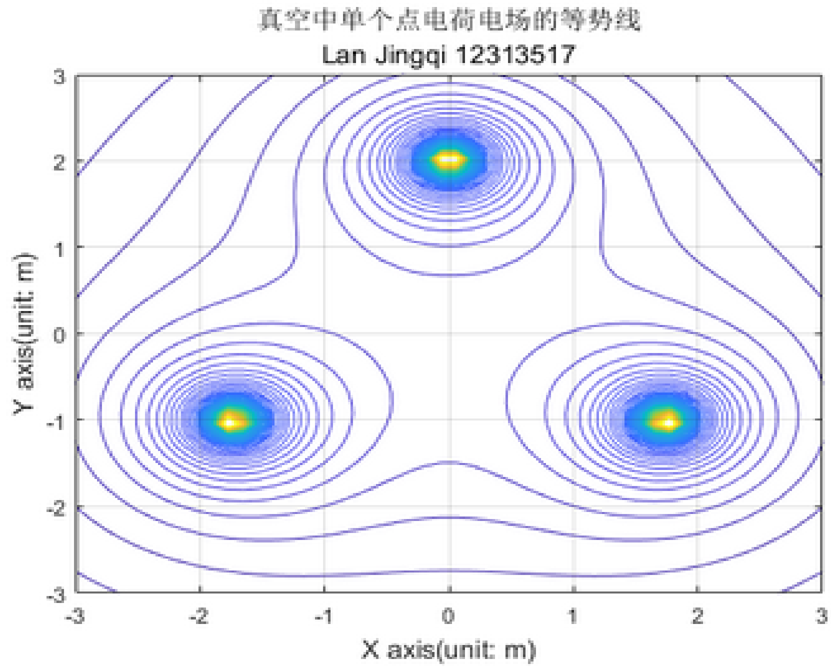

Figure 10: Electric field distribution of two identical point charges

```
figure;
streamline(X,Y,Ex,Ey,xs,ys)
grid on
hold on
contour(X,Y,V,Veq);
title('Isopotential Line and Power Line of a single Point charge Electric Field in
vacuum (expressed by smooth continuous Curves)(LanJingqi12313517)' , 'fontsize',6)            % title th
xlabel('X axis(unit: m)', 'fontsize', 12);
ylabel('Y axis (unit: m)', 'fontsize', 12);
hold off;
```

(2) Experiment result

See at Figure 11

4.Plot the distribution of potential lines and streamlines (expressd bu normalizesd arrows) in the field

(1) Matlab code:

```
E=sqrt(Ex.^2+Ey.^2);
Ex=Ex./E;
Ey=Ey./E;
quiver(X,Y,Ex,Ey);
hold on;
contour(X,Y,V,Veq);
title('Equipotential lines and electric field lines of a single point charge electric
field in vacuum represented by normalized arrowhead(LanJingqi12313517)', 'fontsize', 6);
xlabel('X  axis(unit: m)', 'fontsize', 12);
ylabel('Y  axis(unit: m)', 'fontsize', 12);
hold off;
```

(2) Experiment result

See at Figure 12

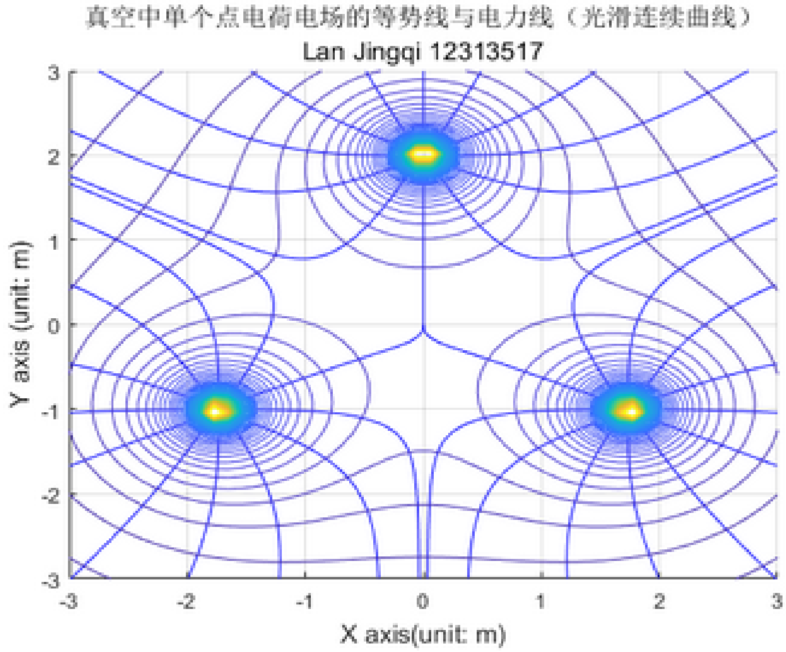

Figure 11: Electric field distribution of two identical point charges

Brief analysis: The simulation visualizes the electric potential and field distribution of three identical +8nC charges arranged in an equilateral triangle configuration. The 3D potential plot shows three distinct peaks corresponding to each charge location, with the potential decreasing radially outward from each source. Equipotential lines exhibit hexagonal symmetry around the central region, reflecting the balanced repulsive forces between the three charges. Electric field lines radiate outward from each charge and curve to avoid one another, demonstrating the mutual repulsion in this symmetric configuration. The central area shows a relatively uniform potential gradient, while the strongest fields occur in the immediate vicinity of each charge. The results clearly illustrate the complex but symmetric interaction pattern expected from three equally spaced identical charges.

Summary and Experience

Through these three electrostatic simulations, I have gained a comprehensive understanding of how point charge configurations create distinct electric potential and field patterns. The experiments demonstrated how identical charges produce repulsive fields with symmetrical potential distributions, while opposite charges form characteristic dipole fields with field lines connecting from positive to negative. The three-charge configuration revealed more complex but still symmetrical patterns, showing how multiple charges interact through superposition. I learned to visualize these phenomena through 3D potential plots, equipotential lines, and field line representations, confirming theoretical predictions about charge interactions. The MATLAB implementations taught me practical skills in numerical computation and field visualization, while the analysis reinforced fundamental electrostatic concepts including Coulomb's law, potential theory, and field superposition. These exercises have strengthened my ability to connect mathematical models with physical phenomena in electromagnetics.

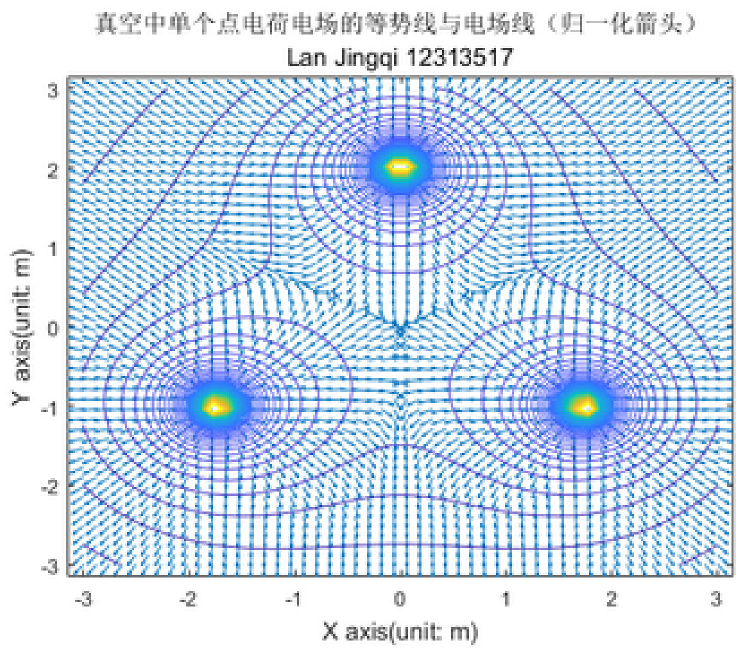

Figure 12: Electric field distribution of two identical point charges