

Engineering Electromagnetics - Experiment 1

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A Case 1: Electric field distribution of two identical point charges

A.1 Define the parameters

A.1.1 Matlab Code

```
1 clear;% clear all variables in memory
2 clc;% Clear the contents of the command window
3 %% define
4 k=9e9; % set electrostatic constant
5 Q=1e-9;% Set charge Q
6 xm=0.1;% Set the range of the field in x direction
7 ym=0.1;% Set the range of the field in y direction
8
9 x=linspace(-xm,xm,100);% evenly divide the x axis into 100 segments
10 y=linspace(-ym,ym,100);% evenly divide the y axis into 100 segments
11 [X,Y]=meshgrid(x,y); % To form the coordinates of each point in the field.
12 x1=-0.01; %define the location of the charges
13 x2=0.01;
14 y1=0;
15 y2=0;
16 R1=sqrt((X-x1).^2+Y.^2); % calculate the distance between each point and the source charge (the origin).
17 R2=sqrt((X-x2).^2+Y.^2);
18 V1=k*Q./R1; %calculate the electric potential
19 V2=k*Q./R2;
```

A.2 Electric Potential Distribution

A.2.1 Matlab Code

```
1 %% part1
2 sumV = V1+V2; % plot the distribution of electric potential
3 figure1 = figure;%define figure
4 surf(X,Y,sumV);
5 shading interp; %disable the grid
6 colormap default; %set the colour map
7 hold on;
8 title('the plot of electric potential distribution of two identical point charges in the vacuum';'樊青远 11812418'}, 'f
9 pbaspect([1 1 1]);
10 xlabel('X axis(unit: m)','fontsize',12);% label the x axis
11 ylabel('Y axis(unit: m)','fontsize',12);% label the y axis
12 zlabel('Electric Potential (unit: V/m)','fontsize',12); %label the z axis
13 colorbar;
14 saveas(figure1,'../fig/A1.jpg');
```

A.2.2 Figure

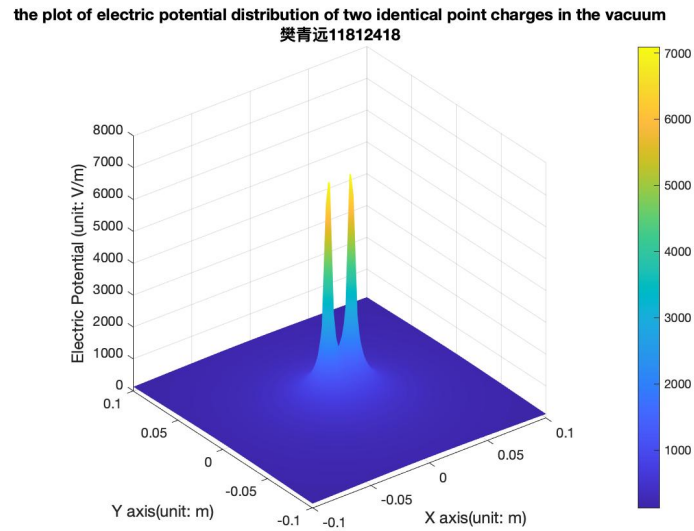


Figure 1: The plot of electric potential distribution of opposite point charges in the vacuum

A.3 Isopotential Line

A.3.1 Matlab Code

```
1  %% part2
2
3  Tmax=max(max(sumV)); %find the maximum potential value
4  Tmin=min(min(sumV)); %find the maximum potential value
5  Vmin=200; % set the minimum potential value for a family of equipotential lines
6  Vmax=2000; % set the maximum potential value for a family of equipotential lines
7  Veq=linspace(Vmin,Vmax,50); % set the potential for 10 equipotential lines
8  figure1 = figure;%define figure
9  contour(X,Y,sumV,Veq); % plot 10 equipotential lines
10 grid on; % form a grid % hold the plot
11 hold on;
12 plot(0,0,'o', 'MarkerSize',12) % plot a charge at the origin
13 title({'Isopotential Line of two identical point charges Electric Field in vacuum (Unit: V)';'樊青远 11812418'}, 'fontsi
14 pbaspect([1 1 1]);
15 xlabel('X axis(unit: m)','fontsize',12);% label the x axis
16 ylabel('Y axis(unit: m)','fontsize',12);% label the y axis
17 colorbar;
18 hold off;
19 saveas(figure1,'../fig/A2.jpg');
```

A.3.2 Figure

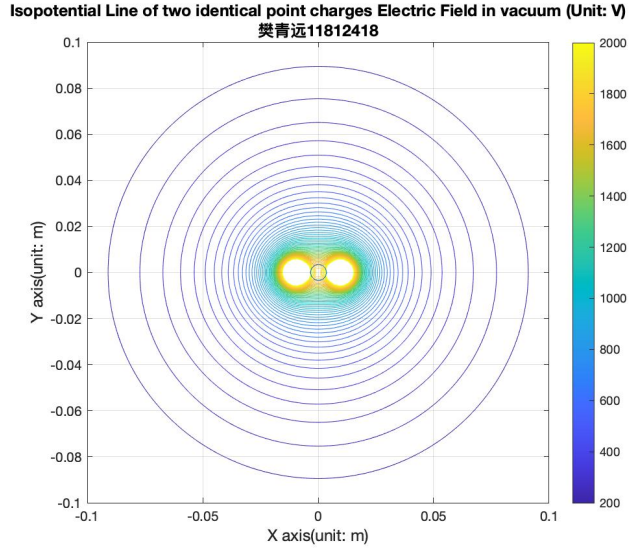


Figure 2: Isopotential Line of opposite point charges charges Electric Field in vacuum

A.4 Isopotential Line and Power Line by Smooth Continuous Curves

A.4.1 Matlab Code

```
1  %% part3
2  [Ex,Ey]=gradient(-sumV); % Calculation of two components of Electric Field intensity at each Point in the Field
3  del_theta=10; % Set the angle difference between adjacent field lines;
4  theta=(0:del_theta:360).*pi/180; % express the angle into radian
5  xs=x1+0.0001*cos(theta); % generate the x coordinate for the start of the field line for q1
6  ys=y1+0.0001*sin(theta); % generate the y coordinate for the start of the field line for q1
7  xs2=x2+0.0001*cos(theta); % generate the x coordinate for the start of the field line for q2
8  ys2=y2+0.0001*sin(theta); % generate the y coordinate for the start of the field line for q2
9  figure1 = figure;%define figure
10 hold on % hold the plot
11 grid on;
12 streamline(X,Y,Ex,Ey,xs,ys) % generate the field lines?
13 streamline(X,Y,Ex,Ey,xs2,ys2) % generate the field lines?
14 contour(X,Y,sumV,Veq); % plot 100 equipotential lines
15 plot(0,0,'o','MarkerSize',12) % plot the point charge at the origin
16 title(' Isopotential Line and Power Line of two identical point charges Electric Field in vacuum';...
17 'Unit: V';'樊青远 11812418'} , 'fontsize',12);
18 pbaspect([1 1 1]);
19 xlabel('X axis(unit: m)','fontsize',12);% label the x axis
20 ylabel('Y axis(unit: m)','fontsize',12);% label the y axis
21 colorbar;
22 xlim([-0.03 0.03]); % set the limit of axis
23 ylim([-0.03 0.03]); % set the limit of axis
24 saveas(figure1,'../fig/A3.jpg');
```

A.4.2 Figure

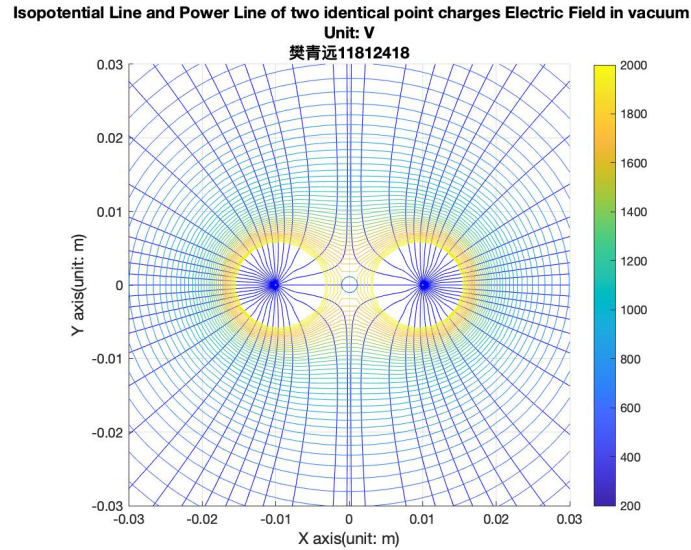


Figure 3: Isopotential Line and Power Line of opposite point charges charges Electric Field in vacuum (expressed by smooth continuous curves)

A.5 Isopotential Line and Power Line by Normalized Arrowhead

A.5.1 Electric potential distribution

```
1  %% part4
2  E=sqrt(Ex.^2+Ey.^2); % calculate the magnitude of electric field magnitude at each point.
3  Ex=Ex./E;
4  Ey=Ey./E; % normalize the magnitude of the electric field
5  figure1 = figure;%define figure
6  quiver(X,Y,Ex,Ey); % using normalized arrowhead to represent electric field
7  hold on;
8  contour(X,Y,sumV,Veq);% plot the equipotential lines
9  title({'Equipotential lines and electric field lines of'; 'two identical point charges electric field in vacuum';...
10       'Unit: V';'樊青远 11812418'}, 'fontsize',12);
11  pbaspect([1 1 1]);
12  xlabel('X axis(unit: m)','fontsize',12);% label the x axis
13  ylabel('Y axis(unit: m)','fontsize',12);% label the y axis
14  colorbar; %enable colour bar
15  xlim([-0.03 0.03]); % set the limit of axis
16  ylim([-0.03 0.03]); % set the limit of axis
17  saveas(figure1,'../fig/A4.jpg');
```

A.5.2 Figure

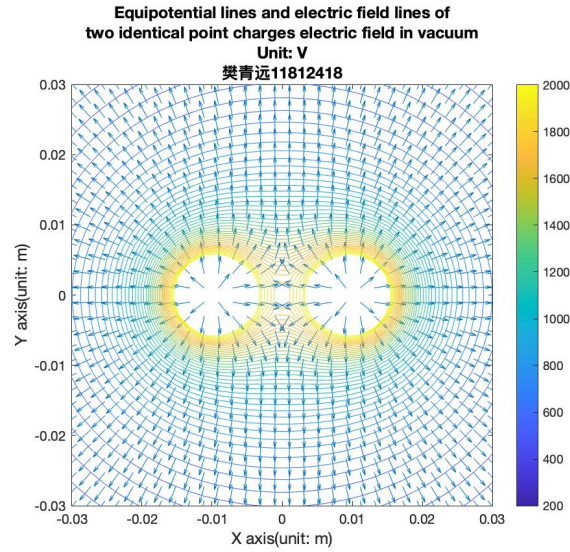


Figure 4: Equipotential lines and electric field lines of a single point charge electric field in vacuum (represented by normalized arrowhead)

A.6 Analytics

The figures above shows the electric field distribution between two identical charges.

Seen from the figure, we could discover that the the closer to the positive charge, the higher the potential and the denser the electric field lines. And the electric field lines are always perpendicular to the electric potential streamline.

At the midpoint of the two charges, the direction of the electric force can be any direction, so we could not draw the direction of the electric field line there.

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

B.1 Define the parameters

B.1.1 Matlab Code

```
1 clear; % clear all variables in memory
2 clc; % Clear the contents of the command window
3 k=9e9; % set electrostatic constant
4 Q=5e-9; % Set charge Q
5 xm=0.1; % Set the range of the field in x direction
6 ym=0.1; % Set the range of the field in y direction
7
8 %% define
9 k=9e9; % set electrostatic constant
10 Q=1e-9;% Set charge Q
11 xm=2;% Set the range of the field in x direction
12 ym=2;% Set the range of the field in y direction
13
14 x= linspace(-xm+1,xm+1,100);% evenly divide the x axis into 100 segments
15 y= linspace(-ym,ym,100);% evenly divide the y axis into 100 segments
16 [X,Y]=meshgrid(x,y); % To form the coordinates of each point in the field.
17 x1=0.01; %define the location of the charges
18 x2=2;
19 y1=0;
20 y2=0;
21 R1=sqrt((X-x1).^2+Y.^2); % calculate the distance between each point and the source charge (the origin).
22 R2=sqrt((X-x2).^2+Y.^2);
23 V1=k*Q./R1; %calculate the electric potential
24 V2=-k*Q./R2;
```

B.2 Electric Potential Distribution

B.2.1 Matlab Code

```
1 %% part1
2 sumV = V1+V2; % plot the distribution of electric potential
3 figure1 = figure;%define figure
4 surf(X,Y,sumV);
5 shading interp; %disable the grid
6 colormap default; %set the colour map
7 hold on;
8 title('the plot of electric potential distribution of two identical point charges in the vacuum';'樊青远 11812418'}, 'f
9 pbaspect([1 1 1]);
10 xlabel('X axis(unit: m)','fontsize',12);% label the x axis
11 ylabel('Y axis(unit: m)','fontsize',12);% label the y axis
12 zlabel('Electric Potential (unit: V/m)','fontsize',12); %label the z axis
13 colorbar;
14 saveas(figure1,'../fig/B1.jpg');
```

B.2.2 Figure

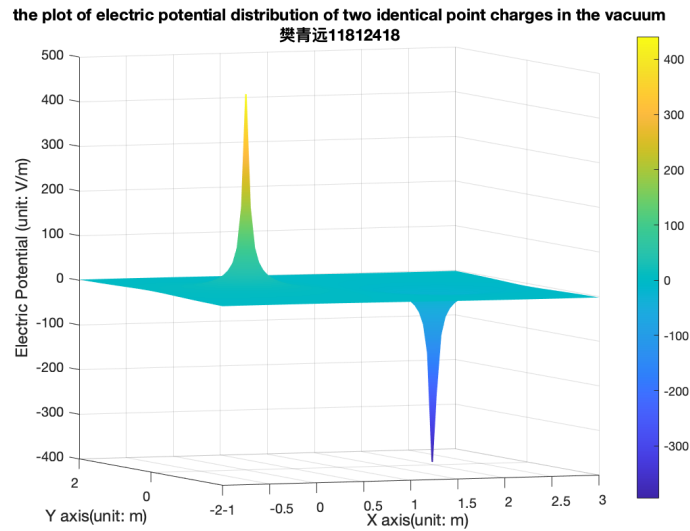


Figure 5: The plot of electric potential distribution of opposite point charges in the vacuum

B.3 Isopotential Line

B.3.1 Matlab Code

```
1  %% part2
2
3  Tmax=max(max(sumV)); %find the maximum potential value
4  Tmin=min(min(sumV)); %find the maximum potential value
5  Vmin=-1000; % set the minimum potential value for a family of equipotential lines
6  Vmax=1000; % set the maximum potential value for a family of equipotential lines
7  Veq=linspace(Vmin,Vmax,501); % set the potential for equipotential lines
8  figure1 = figure;%define figure
9  contour(X,Y,sumV,Veq); % plot 10 equipotential lines
10 grid on; % form a grid % hold the plot
11 hold on;
12 plot(0,0,'o', 'MarkerSize',12) % plot a charge at the origin
13 title({'Isopotential Line of two opposite point charges Electric Field in vacuum (Unit: V)';'樊青远 11812418'}, 'fontsize',12);
14 pbaspect([1 1 1]);
15 xlabel('X axis(unit: m)','fontsize',12);% label the x axis
16 ylabel('Y axis(unit: m)','fontsize',12);% label the y axis
17 colorbar;
18 hold off;
19 saveas(figure1,'../fig/B2.jpg');
```

B.3.2 Figure

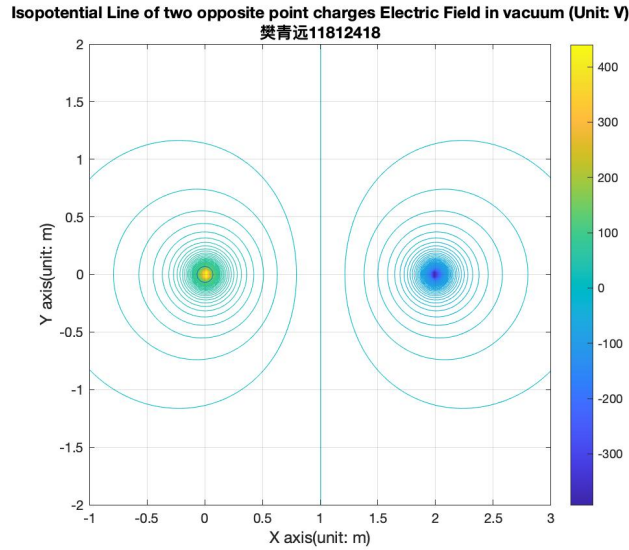


Figure 6: Isopotential Line of opposite point charges charges Electric Field in vacuum

B.4 Isopotential Line and Power Line by Smooth Continuous Curves

B.4.1 Matlab Code

```
1  %% part3
2  [Ex,Ey]=gradient(-sumV); % Calculation of two components of Electric Field intensity at each Point in the Field
3  del_theta=10; % Set the angle difference between adjacent field lines;
4  theta=(0:del_theta:360).*pi/180; % express the angle into radian
5  xs=x1+0.02*cos(theta); % generate the x coordinate for the start of the field line for q1
6  ys=y1+0.02*sin(theta); % generate the y coordinate for the start of the field line for q1
7  xs2=x2+0.02*cos(theta); % generate the x coordinate for the start of the field line for q2
8  ys2=y2+0.02*sin(theta); % generate the y coordinate for the start of the field line for q2
9  figure1 = figure;%define figure
10 hold on % hold the plot
11 streamline(X,Y,Ex,Ey,xs,ys) % generate the field lines?
12 streamline(X,Y,Ex,Ey,xs2,ys2) % generate the field lines?
13 grid on % from the grid
14 contour(X,Y,sumV,Veq); % plot 100 equipotential lines
15 plot(0,0,'o','MarkerSize',12) % plot the point charge at the origin
16 title(' Isopotential Line and Power Line of two opposite point charges Electric Field in vacuum';...
17       'Unit: V';'樊青远 11812418'} , 'fontsize',12);
18 pbaspect([1 1 1]);
19 xlabel('X axis(unit: m)','fontsize',12);% label the x axis
20 ylabel('Y axis(unit: m)','fontsize',12);% label the y axis
21 colorbar;
22 %xlim([-0.03 0.03]); % set the limit of axis
23 %ylim([-0.03 0.03]); % set the limit of axis
24 saveas(figure1,'../fig/B3.jpg');
```

B.4.2 Figure

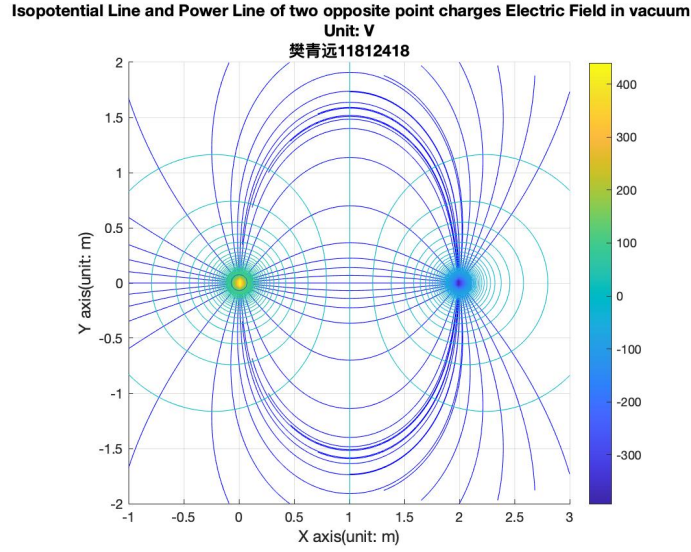


Figure 7: Isopotential Line and Power Line of opposite point charges charges Electric Field in vacuum (expressed by smooth continuous curves)

B.5 Isopotential Line and Power Line by Normalized Arrowhead

B.5.1 Electric potential distribution

```
1  %% optimize the mesh of arrows
2  x_arr=linspace(-xm+1,xm+1,20);% evenly divide the x axis into 100 segments
3  y_arr=linspace(-ym,ym,20);% evenly divide the y axis into 100 segments
4  [X_arr,Y_arr]=meshgrid(x_arr,y_arr); % To form the coordinates of each point in the field.
5  x1_arr=0.01; %define the location of the charges
6  x2_arr=2;
7  R1_arr=sqrt((X_arr-x1_arr).^2+Y_arr.^2); % calculate the distance between each point and the source charge (the origin).
8  R2_arr=sqrt((X_arr-x2).^2+Y_arr.^2);
9  V1_arr=k*Q./R1_arr; %calculate the electric potential
10 V2_arr=-k*Q./R2_arr;
11
12 sumV_arr = V1_arr+V2_arr; % plot the distribution of electric potential
13 [Ex_arr,Ey_arr]=gradient(-sumV_arr);
14
15 %% part4
16 E_arr=sqrt(Ex_arr.^2+Ey_arr.^2); % calculate the magnitude of electric field magnitude at each point.
17 Ex_arr=Ex_arr./E_arr;
18 Ey_arr=Ey_arr./E_arr; % normalize the magnitude of the electric field
19 figure1 = figure;%define figure
20 q1 = quiver(X_arr,Y_arr,Ex_arr,Ey_arr,0); % using normalized arrowhead to represent electric field
21 set(q1,'AutoScale','on', 'AutoScaleFactor', 0.5)
22 hold on;
23 contour(X,Y,sumV,Veq);% plot the equipotential lines
24 title({'Equipotential lines and electric field lines of'; 'two opposite point charges electric field in vacuum';...
25 'Unit: V';'樊青远 11812418'} , 'fontsize',12);
26 pbaspect([1 1 1]);
```

```

27 xlabel('X axis(unit: m)','fontsize',12);% label the x axis
28 ylabel('Y axis(unit: m)','fontsize',12);% label the y axis
29 colorbar; %enable colour bar
30 %xlim([-0.03 0.03]); % set the limit of axis
31 %ylim([-0.03 0.03]); % set the limit of axis
32 saveas(figure1,'../fig/B4.jpg');

```

B.5.2 Figure

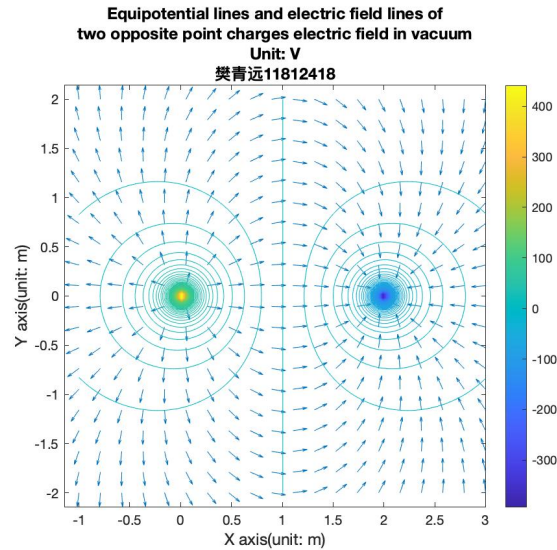


Figure 8: Equipotential lines and electric field lines of a single point charge electric field in vacuum (represented by normalized arrowhead)

B.6 Analytics

The figures above shows the electric field distribution between opposite point charges.

Seen from the figure, we could discover that the the closer to the positive charge, the higher the potential and the denser the electric field lines. Besides, the density of the electric field lines and equipotential line is also higher when it close to the negative point charge. And the electric field lines are always perpendicular to the electric potential streamline.

At the midline of the two charges, the direction of the electric force are perpendicular to the x axis, so the electric force on that line are parallel to the axis.

The electric potential on the midline of the two charges is zero.

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

C.1 Define the parameters

C.1.1 Matlab Code

```
1 clear;% clear all variables in memory
2 clc; % Clear the contents of the command window
3 k=9e9; % set electrostatic constant
4 Q=8e-9; % Set charge Q
5 xm=3; % Set the range of the field in x direction
6 ym=3; % Set the range of the field in y direction
7 %% Define
8 x=linspace(-xm,xm,100); % evenly divide the x axis
9 y=linspace(-ym+0.5,ym+0.5,40); % evenly divide the y axis
10 [X,Y]=meshgrid(x,y); % To form the coordinates of each point in the field.
11 x1=-sqrt(3); %define the coordinate of the charges
12 y1=-1;
13 x2=sqrt(3);
14 y2=-1;
15 x3=0;
16 y3=2;
17 R1=sqrt((X-x1).^2+(Y-y1).^2);% calculate the distance between each point and the source charge (the origin).
18 R2=sqrt((X-x2).^2+(Y-y2).^2);
19 R3=sqrt((X-x3).^2+(Y-y3).^2);
20 V1=k*Q./R1; %define the potential influenced by each charge
21 V2=k*Q./R2;
22 V3=k*Q./R3;
```

C.2 Electric Potential Distribution

C.2.1 Matlab Code

```
1 %% Part 1
2
3 sumV = V1+V2+V3;
4 figure1 = figure;%define figure
5 surf(X,Y,sumV);
6 shading interp; %disable the grid
7 colormap default; %set the colour map
8 hold on;
9 title('the plot of electric potential distribution of two identical point charges in the vacuum';'樊青远 11812418'), 'f
10 pbaspect([1 1 1]);
11 xlabel('X axis(unit: m)','fontsize',12);% label the x axis
12 ylabel('Y axis(unit: m)','fontsize',12);% label the y axis
13 zlabel('Electric Potential (unit: V/m)','fontsize',12); %label the z axis
14 colorbar;
15 saveas(figure1,'../fig/C1.jpg');
```

C.2.2 Figure

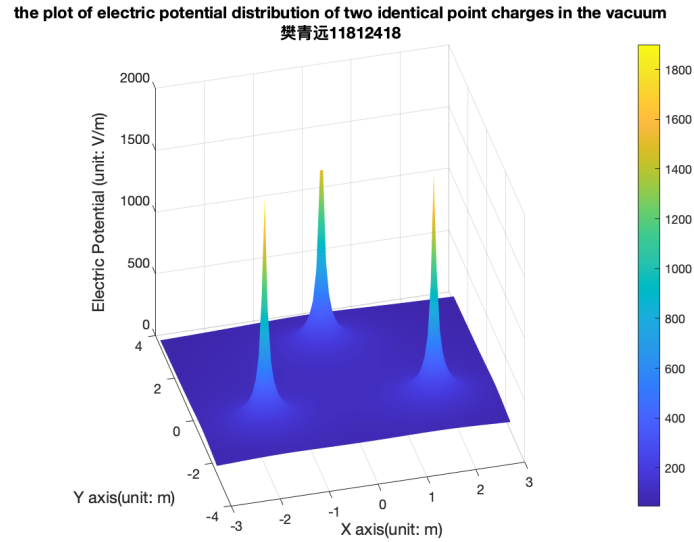


Figure 9: The plot of electric potential distribution of opposite point charges charges in the vacuum

C.3 Isopotential Line

C.3.1 Matlab Code

```
1  %% part2
2
3  Tmax=max(max(sumV)); %find the maximum potential value
4  Tmin=min(min(sumV)); %find the maximum potential value
5  Vmin=-2000; % set the minimum potential value for a family of equipotential lines
6  Vmax=2000; % set the maximum potential value for a family of equipotential lines
7  Veq=linspace(Vmin,Vmax,500); % set the potential for equipotential lines
8  figure1 = figure;%define figure
9  contour(X,Y,sumV,Veq); % plot 10 equipotential lines
10 grid on; % form a grid % hold the plot
11 hold on;
12 plot(0,0,'o', 'MarkerSize',12) % plot a charge at the origin
13 title({'Isopotential Line of two identical point charges Electric Field in vacuum (Unit: V)';'樊青远 11812418'}, 'fontsi
14 pbaspect([1 1 1]);
15 xlabel('X axis(unit: m)','fontsize',12);% label the x axis
16 ylabel('Y axis(unit: m)','fontsize',12);% label the y axis
17 colorbar;
18 hold off;
19 saveas(figure1,'../fig/C2.jpg');
```

C.3.2 Figure

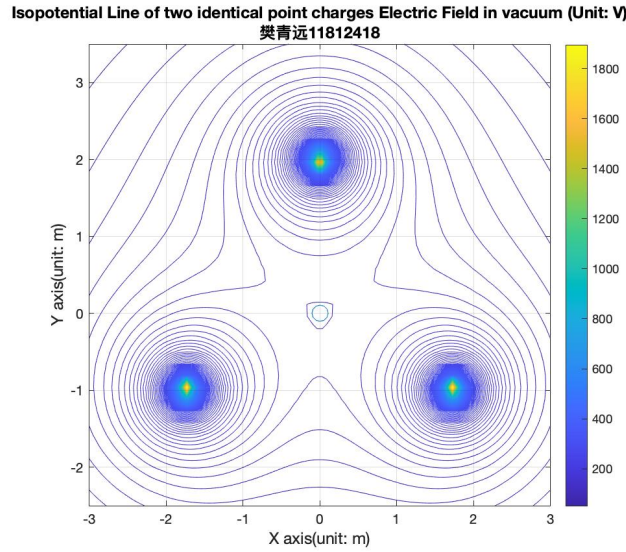


Figure 10: Isopotential Line of opposite point charges charges Electric Field in vacuum

C.4 Isopotential Line and Power Line by Smooth Continuous Curves

C.4.1 Matlab Code

```
1 %% part3
2 [Ex,Ey]=gradient(-sumV); % Calculation of two components of Electric Field intensity at each Point in the Field
3 del_theta=5; % Set the angle difference between adjacent field lines;
4 theta=(0:del_theta:360).*pi/180; % express the angle into radian
5 xs=x1+0.4*cos(theta); % generate the x coordinate for the start of the field line of charge1
6 ys=y1+0.4*sin(theta); % generate the y coordinate for the start of the field line of charge1
7 xs2=x2+0.4*cos(theta); % generate the x coordinate for the start of the field line of charge2
8 ys2=y2+0.4*sin(theta); % generate the y coordinate for the start of the field line of charge2
9 xs3=x3+0.4*cos(theta); % generate the x coordinate for the start of the field line of charge3
10 ys3=y3+0.4*sin(theta); % generate the y coordinate for the start of the field line of charge3
11 figure1 = figure;%define figure
12 hold on
13 streamline(X,Y,Ex,Ey,xs,ys) % generate the field lines?
14 streamline(X,Y,Ex,Ey,xs2,ys2) % generate the field lines?
15 streamline(X,Y,Ex,Ey,xs3,ys3) % generate the field lines?
16 grid on % from the grid
17 % hold the plot
18 contour(X,Y,sumV,Veq); % plot 100 equipotential lines
19 plot(0,0,'o', 'MarkerSize',12) % plot the point charge at the origin
20 title({'Isopotential Line and Power Line of two identical point charges Electric Field in vacuum';...
21 'Unit: V';'樊青远 11812418'}, 'fontsize',12);
22 pbaspect([1 1 1]);
23 xlabel('X axis(unit: m)','fontsize',12);% label the x axis
24 ylabel('Y axis(unit: m)','fontsize',12);% label the y axis
25 colorbar;
```



```

26 %xlim([-0.03 0.03]); % set the limit of axis
27 %ylim([-0.03 0.03]); % set the limit of axis
28 saveas(figure1,'../fig/C3.jpg');

```

C.4.2 Figure

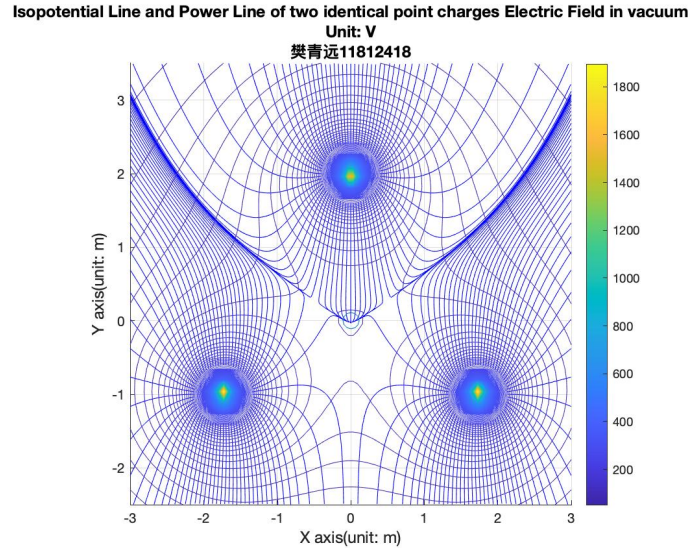


Figure 11: Isopotential Line and Power Line of opposite point charges charges Electric Field in vacuum (expressed by smooth continuous curves)

C.5 Isopotential Line and Power Line by Normalized Arrowhead

C.5.1 Matlab Code

```

1  %% optimize the mesh of arrows
2  x_arr=linspace(-xm,xm,20);% evenly divide the x axis into 100 segments
3  y_arr=linspace(-xm+0.5,xm+0.5,20);% evenly divide the y axis into 100 segments
4  [X_arr,Y_arr]=meshgrid(x_arr,y_arr); % To form the coordinates of each point in the field.
5  x1_arr=0.01; %define the location of the charges
6  x2_arr=2;
7  R1_arr=sqrt((X_arr-x1_arr).^2+Y_arr.^2); % calculate the distance between each point and the source charge (the origin).
8  R2_arr=sqrt((X_arr-x2).^2+Y_arr.^2);
9  V1_arr=k*Q./R1_arr; %calculate the electric potential
10 V2_arr=-k*Q./R2_arr;
11
12 sumV_arr = V1_arr+V2_arr; % plot the distribution of electric potential
13 [Ex_arr,Ey_arr]=gradient(-sumV_arr);
14
15 %% part4
16 E_arr=sqrt(Ex_arr.^2+Ey_arr.^2); % calculate the magnitude of electric field magnitude at each point.
17 Ex_arr=Ex_arr./E_arr;
18 Ey_arr=Ey_arr./E_arr; % normalize the magnitude of the electric field
19 figure1 = figure;%define figure

```

```

20 q1 = quiver(X_arr,Y_arr,Ex_arr,Ey_arr,0); % using normalized arrowhead to represent electric field
21 set(q1,'AutoScale','on','AutoScaleFactor', 0.5)
22 hold on;
23 contour(X,Y,sumV,Veq);% plot the equipotential lines
24 title({'Equipotential lines and electric field lines of'; 'two identical point charges electric field in vacuum';...
25 'Unit: V';'樊青远 11812418'} , 'fontsize',12);
26 pbaspect([1 1 1]);
27 xlabel('X axis(unit: m)','fontsize',12);% label the x axis
28 ylabel('Y axis(unit: m)','fontsize',12);% label the y axis
29 colorbar; %enable colour bar
30 %xlim([-0.03 0.03]); % set the limit of axis
31 %ylim([-0.03 0.03]); % set the limit of axis
32 saveas(fgure1,'../fig/C4.jpg');

```

C.5.2 Figure

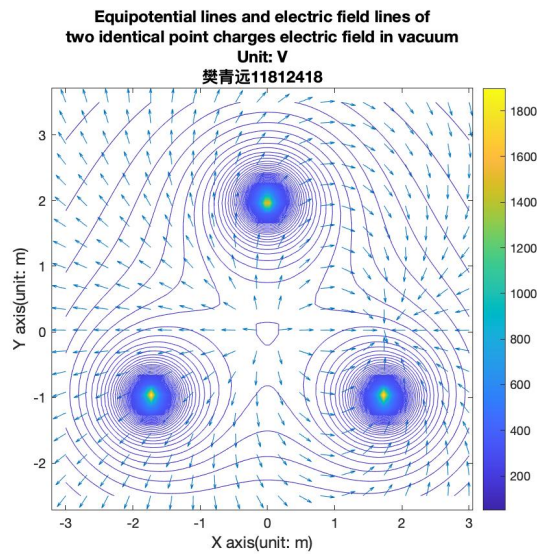


Figure 12: Equipotential lines and electric field lines of a single point charge electric field in vacuum (represented by normalized arrowhead)

C.6 Analytics

The figures above shows the electric field distribution between three point charges. The three charges are arranged in equilateral triangles.

Seen from the figure, we could discover that the the closer to the positive charge, the higher the potential and the denser the electric field lines.

From the figure, we could also find that the electric field is larger on the midline of every two charges, relatively.

D Summary

From this lab, we have learned the fundamental operation and some useful for us to plot a clear figure like the *contour()* for the equipotential lines, *streamline()* for the electric field line, *surf()* to generate the vector space of the electric field and *quiver()* arrow field.

By analyzing the figure we plotted, we could also gain a deeper insight to the electric field distribution of multiple charges in a 2D plane.

Furthermore, we also found that the density of the electric field sample has a significant impact on the results. When the mesh is too spare, the highest point of the electric potential could be ignored. However, the overdensity of the mesh could also lead to unacceptable waiting time to plot the figure. A similar situation occurs in the process of drawing electric field lines, as the overdensity of the electric field lines could make the reader hard to recognize the figure.