Engineering Electromagnetics - Experiment 1

Name: 樊青远 | Student ID: 11812418

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Contents

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

A.1 Define the parameters

A.1.1 Matlab Code

```
clear;% clear all variables in memory
clc;% Clear the contents of the command window
%% define
k=9e9; % set electrostatic constant
Q=1e-9;% Set charge Q
xm=0.1;% Set the range of the field in x direction
ym=0.1;% Set the range of the field in y direction

x=linspace(-xm,xm,100);% evenly divide the x axis into 100 segments
y=linspace(-ym,ym,100);% evenly divide the y axis into 100 segments
[X,Y]=meshgrid(x,y);  % To form the coordinates of each point in the field.
x1=-0.01; %define the location of the charges
x2=0.01;
y1=0;
y2=0;
R1=sqrt((X-x1).^2+Y.^2); % calculate the distance between each point and the source charge (the origin).
R2=sqrt((X-x2).^2+Y.^2);
V1=k*Q./R1; %calculate the electric potential
V2=k*Q./R2;
```

A.2 Electric Potential Distribution

A.2.1 Matlab Code

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

A.2.2 Figure

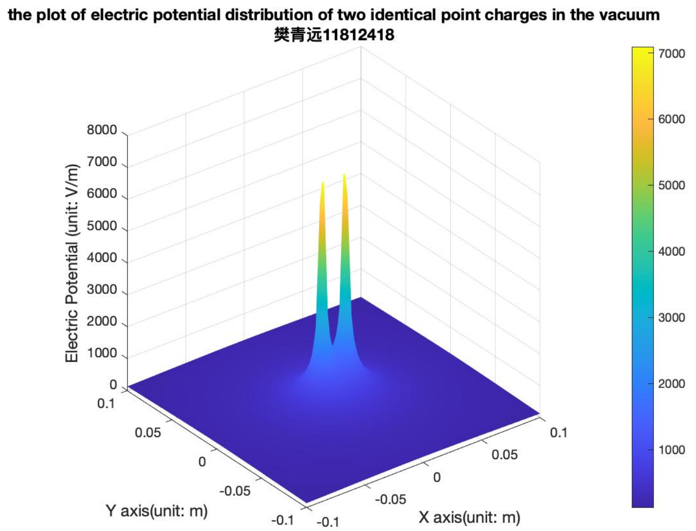

Figure 1: The plot of electric potential distribution of opposite point charges charges in the vacuum

A.3 Isopotential Line

A.3.1 Matlab Code

```
%% part2

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

A.3.2 Figure

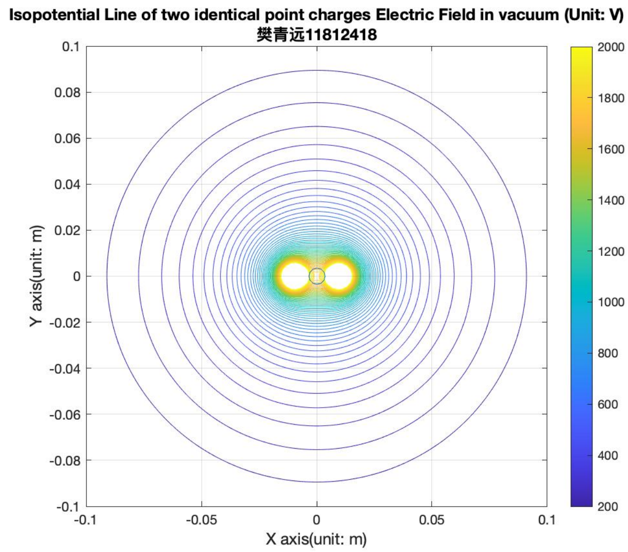

Figure 2: Isopotential Line of opposite point charges charges Electric Field in vacuum

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

A.4.1 Matlab Code

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

A.4.2 Figure

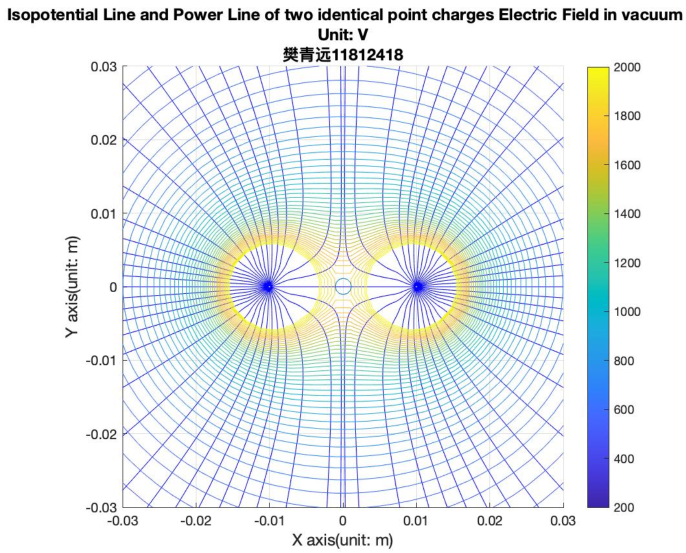

Figure 3: Isopotential Line and Power Line of opposite point charges charges Electric Field in vacuum (expressed by smooth continuous curves)

A.5 Isopotential Line and Power Line by Normalized Arrowhead

A.5.1 Electric potential distribution

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

A.5.2 Figure

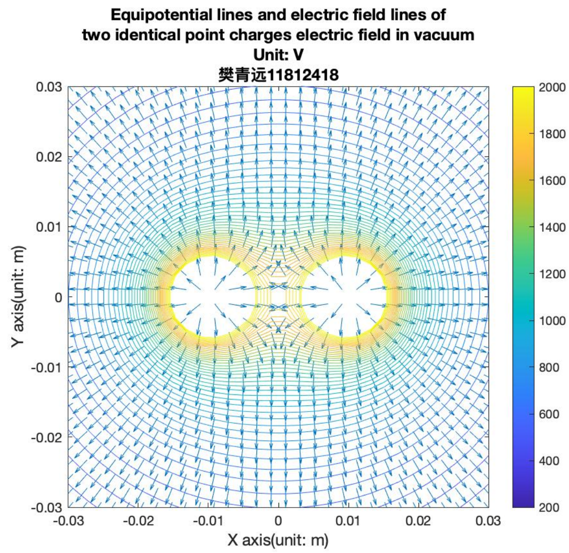

Figure 4: Equipotential lines and electric field lines of a single point charge electric field in vacuum (represented by normalized arrowhead)

A.6 Analytics

The figures above shows the electric fild 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

```
clear; % clear all variables in memory
clc; % Clear the contents of the command window
k=9e9;  % set electrostatic constant
Q=5e-9;  % Set charge Q
xm=0.1; % Set the range of the field in x direction
ym=0.1; % Set the range of the field in y direction

%% define
k=9e9; % set electrostatic constant
Q=1e-9;% Set charge Q
xm=2;% Set the range of the field in x direction
ym=2;% Set the range of the field in y direction

x=linspace(-xm+1,xm+1,100);% evenly divide the x axis into 100 segments
y=linspace(-ym,ym,100);% evenly divide the y axis into 100 segments
[X,Y]=meshgrid(x,y);  % To form the coordinates of each point in the field.
x1=0.01; %define the location of the charges
x2=2;
y1=0;
y2=0;
R1=sqrt((X-x1).^2+Y.^2); % calculate the distance between each point and the source charge (the origin).
R2=sqrt((X-x2).^2+Y.^2);
V1=k*Q./R1; %calculate the electric potential
V2=-k*Q./R2;
```

B.2 Electric Potential Distribution

B.2.1 Matlab Code

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

B.2.2 Figure

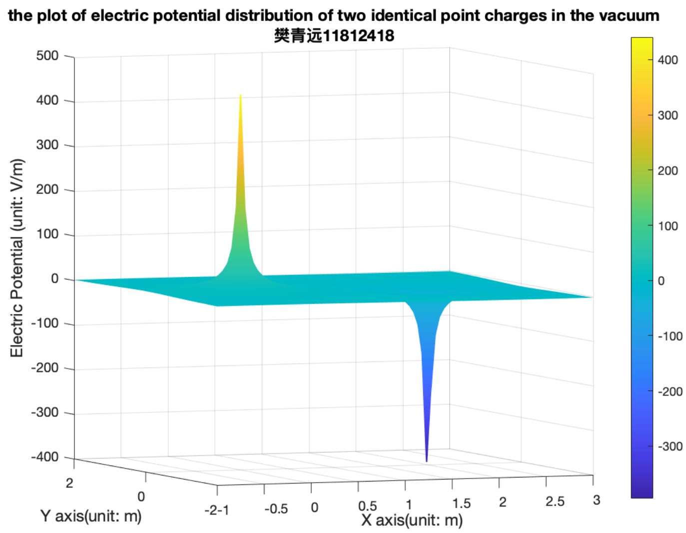

Figure 5: The plot of electric potential distribution of opposite point charges charges in the vacuum

B.3 Isopotential Line

B.3.1 Matlab Code

```
%% part2

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

B.3.2 Figure

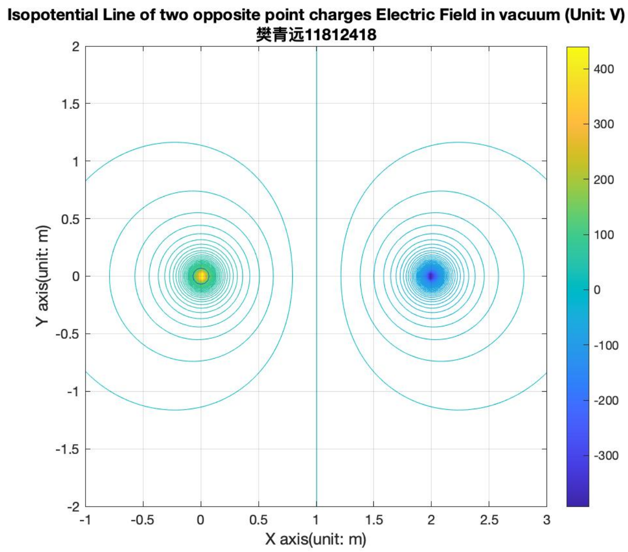

Figure 6: Isopotential Line of opposite point charges charges Electric Field in vacuum

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

B.4.1 Matlab Code

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

B.4.2 Figure

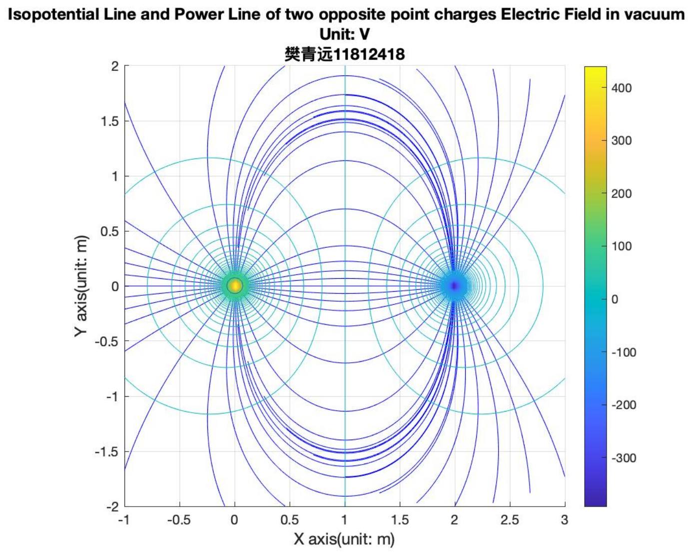

Figure 7: Isopotential Line and Power Line of opposite point charges charges Electric Field in vacuum (expressed by smooth continuous curves)

B.5 Isopotential Line and Power Line by Normalized Arrowhead

B.5.1 Electric potential distribution

```
%% optimize the mesh of arrows
x_arr=linspace(-xm+1,xm+1,20);% evenly divide the x axis into 100 segments
y_arr=linspace(-ym,ym,20);% evenly divide the y axis into 100 segments
[X_arr,Y_arr]=meshgrid(x_arr,y_arr);  % To form the coordinates of each point in the field.
x1_arr=0.01; %define the location of the charges
x2_arr=2;
R1_arr=sqrt((X_arr-x1_arr).^2+Y_arr.^2); % calculate the distance between each point and the source charge (the origin).
R2_arr=sqrt((X_arr-x2).^2+Y_arr.^2);
V1_arr=k*Q./R1_arr; %calculate the electric potential
V2_arr=-k*Q./R2_arr;

sumV_arr = V1_arr+V2_arr; % plot the distribution of electric potential
[Ex_arr,Ey_arr]=gradient(-sumV_arr);

%% part4
E_arr=sqrt(Ex_arr.^2+Ey_arr.^2); % calculate the magnitude of electric field magnitude at each point.
Ex_arr=Ex_arr./E_arr;
Ey_arr=Ey_arr./E_arr;   % normalize the magnitude of the electric field
figure1 = figure;%define figure
q1 = quiver(X_arr,Y_arr,Ex_arr,Ey_arr,0);  % using normalized arrowhead to represent electric field
set(q1,'AutoScale','on', 'AutoScaleFactor', 0.5)
hold on;
contour(X,Y,sumV,Veq);% plot the equipotential lines
title({'Equipotential lines and electric field lines of'; 'two opposite point charges electric field in vacuum';...
    'Unit: V';'樊青远 11812418'} , 'fontsize',12);
pbaspect([1 1 1]);
```

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

B.5.2 Figure

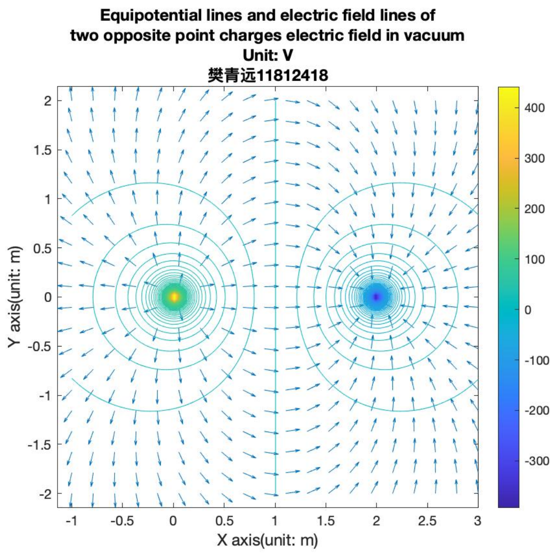

Figure 8: Equipotential lines and electric field lines of a single point charge electric field in vacuum (represented by normalized arrowhead)

B.6 Analytics

The figures above shows the electric fild 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

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

C.2 Electric Potential Distribution

C.2.1 Matlab Code

```
%% Part 1

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

C.2.2 Figure

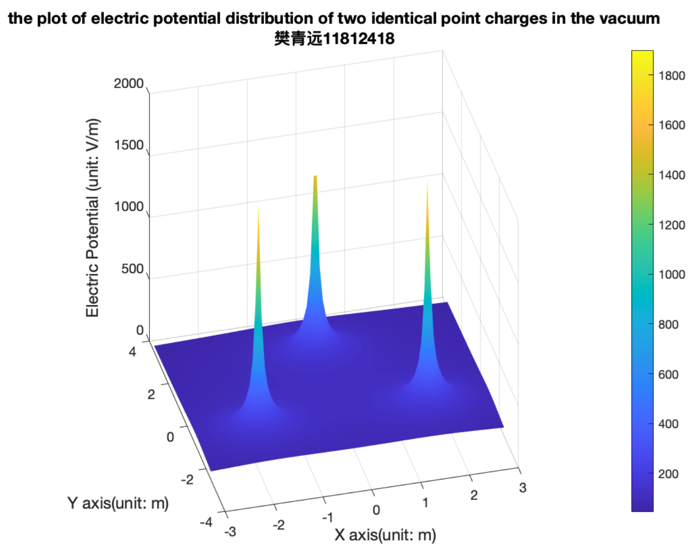

Figure 9: The plot of electric potential distribution of opposite point charges charges in the vacuum

C.3 Isopotential Line

C.3.1 Matlab Code

```
%% part2

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

C.3.2 Figure

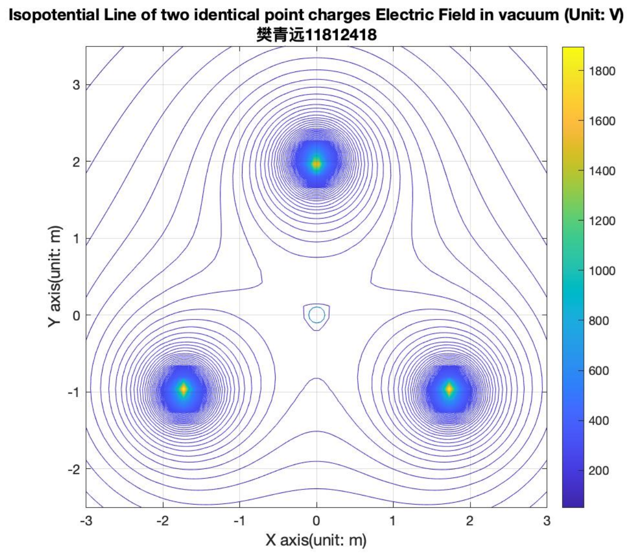

Figure 10: Isopotential Line of opposite point charges charges Electric Field in vacuum

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

C.4.1 Matlab Code

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

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

C.4.2 Figure

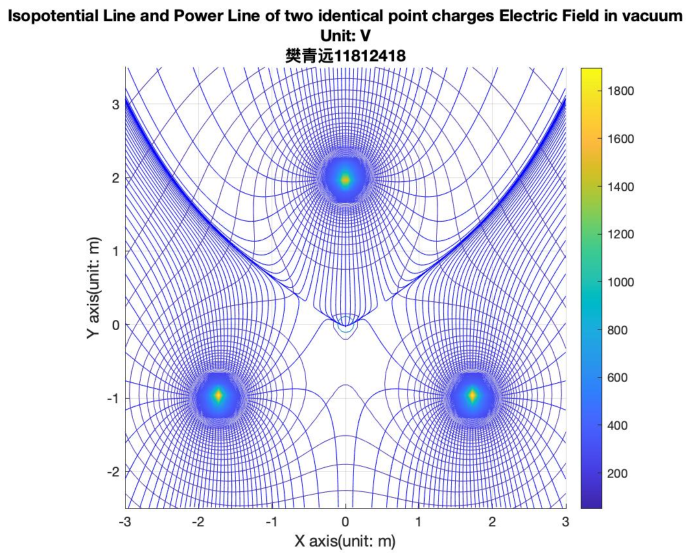

Figure 11: Isopotential Line and Power Line of opposite point charges charges Electric Field in vacuum (expressed by smooth continuous curves)

C.5 Isopotential Line and Power Line by Normalized Arrowhead

C.5.1 Matlab Code

```matlab
    %% optimize the mesh of arrows
    x_arr=linspace(-xm,xm,20);% evenly divide the x axis into 100 segments
    y_arr=linspace(-xm+0.5,xm+0.5,20);% evenly divide the y axis into 100 segments
    [X_arr,Y_arr]=meshgrid(x_arr,y_arr);  % To form the coordinates of each point in the field.
    x1_arr=0.01; %define the location of the charges
    x2_arr=2;
    R1_arr=sqrt((X_arr-x1_arr).^2+Y_arr.^2); % calculate the distance between each point and the source charge (the origin).
    R2_arr=sqrt((X_arr-x2).^2+Y_arr.^2);
    V1_arr=k*Q./R1_arr; %calculate the electric potential
    V2_arr=-k*Q./R2_arr;

    sumV_arr = V1_arr+V2_arr; % plot the distribution of electric potential
    [Ex_arr,Ey_arr]=gradient(-sumV_arr);

    %% part4
    E_arr=sqrt(Ex_arr.^2+Ey_arr.^2); % calculate the magnitude of electric field magnitude at each point.
    Ex_arr=Ex_arr./E_arr;
    Ey_arr=Ey_arr./E_arr;    % normalize the magnitude of the electric field
    figure1 = figure;%define figure
```

```
    q1 = quiver(X_arr,Y_arr,Ex_arr,Ey_arr,0);  % using normalized arrowhead to represent electric field
    set(q1,'AutoScale','on', 'AutoScaleFactor', 0.5)
    hold on;
    contour(X,Y,sumV,Veq);% plot the equipotential lines
    title({'Equipotential lines and electric field lines of'; 'two identical point charges electric field in vacuum';...
        'Unit: V';'樊青远 11812418'} , 'fontsize',12);
    pbaspect([1 1 1]);
    xlabel('X axis(unit: m)','fontsize',12);% label the x axis
    ylabel('Y axis(unit: m)','fontsize',12);% label the y axis
    colorbar; %enable colour bar
    %xlim([-0.03 0.03]); % set the limit of axis
    %ylim([-0.03 0.03]); % set the limit of axis
    saveas(figure1,'../fig/C4.jpg');
```

C.5.2 Figure

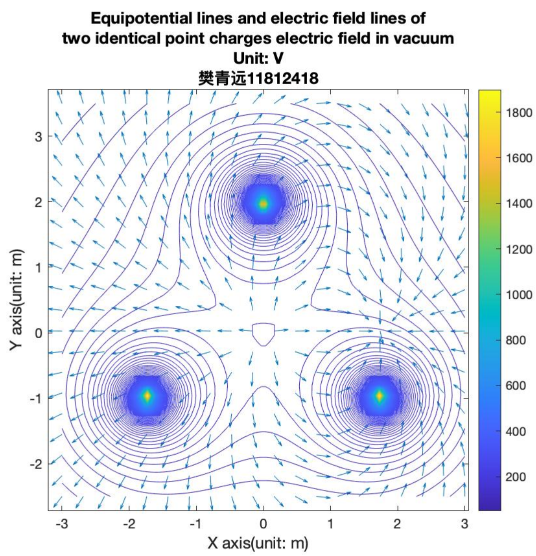

Figure 12: Equipotential lines and electric field lines of a single point charge electric field in vacuum (represented by normalized arrowhead)

C.6 Analytics

The figures above shows the electric fild 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.