UNIVERSITY
OF WOLLONGONG
IN DUBAI

Assignment Cover Sheet

Student Name	Student number
Taha Yaseen Parker	8243578

Subject code and name	ECTE213 – Engineering Electromagnetics
Lab Instructor	Mr. Mahmoud Alkakuri
Title of Assignment	Lab 1
Date and time due	21 January 2025, 23.55
Lab Number	1

Student declaration and acknowledgment

By submitting this assignment online, the submitting student declares on behalf of the team that:

1. All team members have read the subject outline for this subject, and this assessment item meets the requirements of the subject detailed therein.
2. This assessment is entirely our work, except where we have included fully documented references to the work of others. The material in this assessment item has yet to be submitted for assessment.
3. Acknowledgement of source information is by the guidelines or referencing style specified in the subject outline.
4. All team members know the late submission policy and penalty.
5. The submitting student undertakes to communicate all feedback with the other team members.

Lab 1

Exercise 1.1

a. We are given the following two vectors **x**, **y** represented in rectangular coordinates and spherical coordinates, respectively.

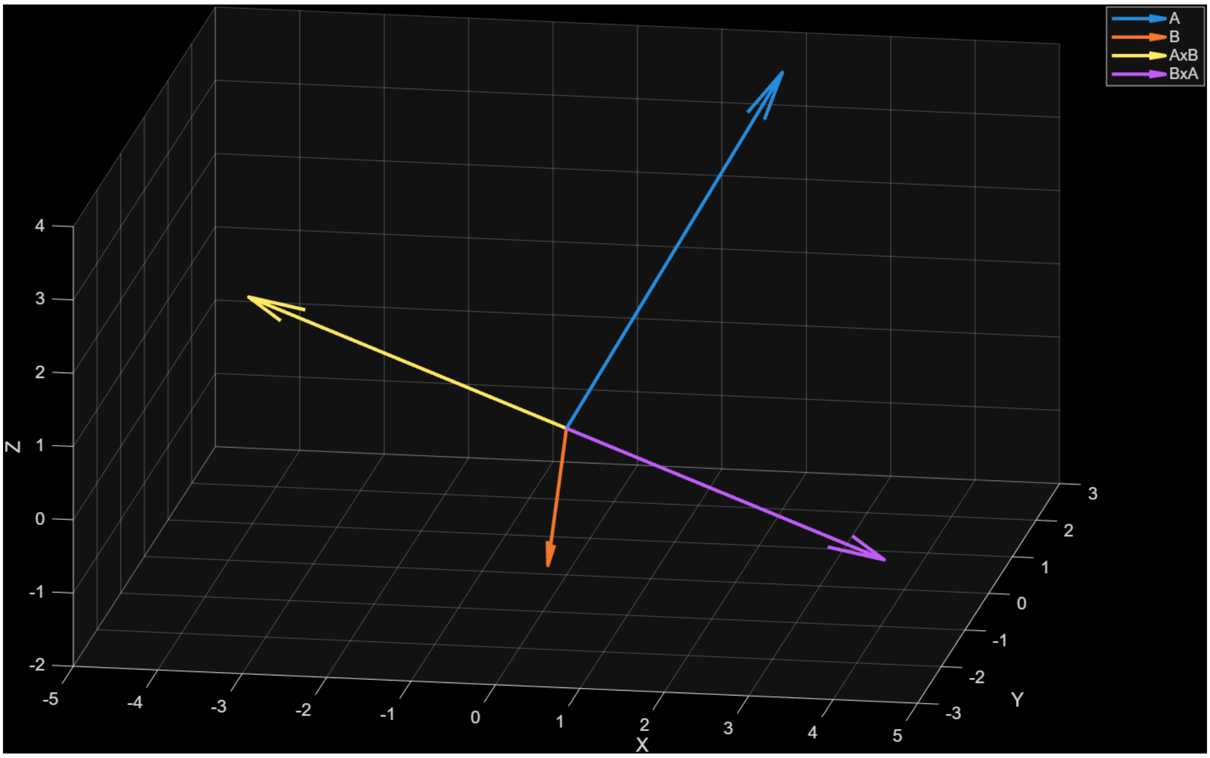
$$x = 2a_x + 3a_y + 4a_z$$

$$y = 2a_r + 3a_\theta + 4a_\Phi \ (r = 2,\ \theta = 3,\ \Phi = 4,\ \text{in radian})$$

Use MATLAB to find their dot product and cross product and represent the results in the rectangular coordinate system.

Hint: You may transform vector into rectangular coordinates first using the relations in Table 1.1, and then conduct the dot product and cross product of **x** and **y** in the rectangular coordinate system.

```
r = 2; theta = 3; phi = 4;
x = [2; 3; 4];
y = [r * sin(theta) * cos(phi); r * sin(theta) * sin(phi); r *
cos(theta)];

dot(x, y)
cross(x, y)

viewcross(x, y)
```



b. There is a two-dimensional (2D) vector field defined by

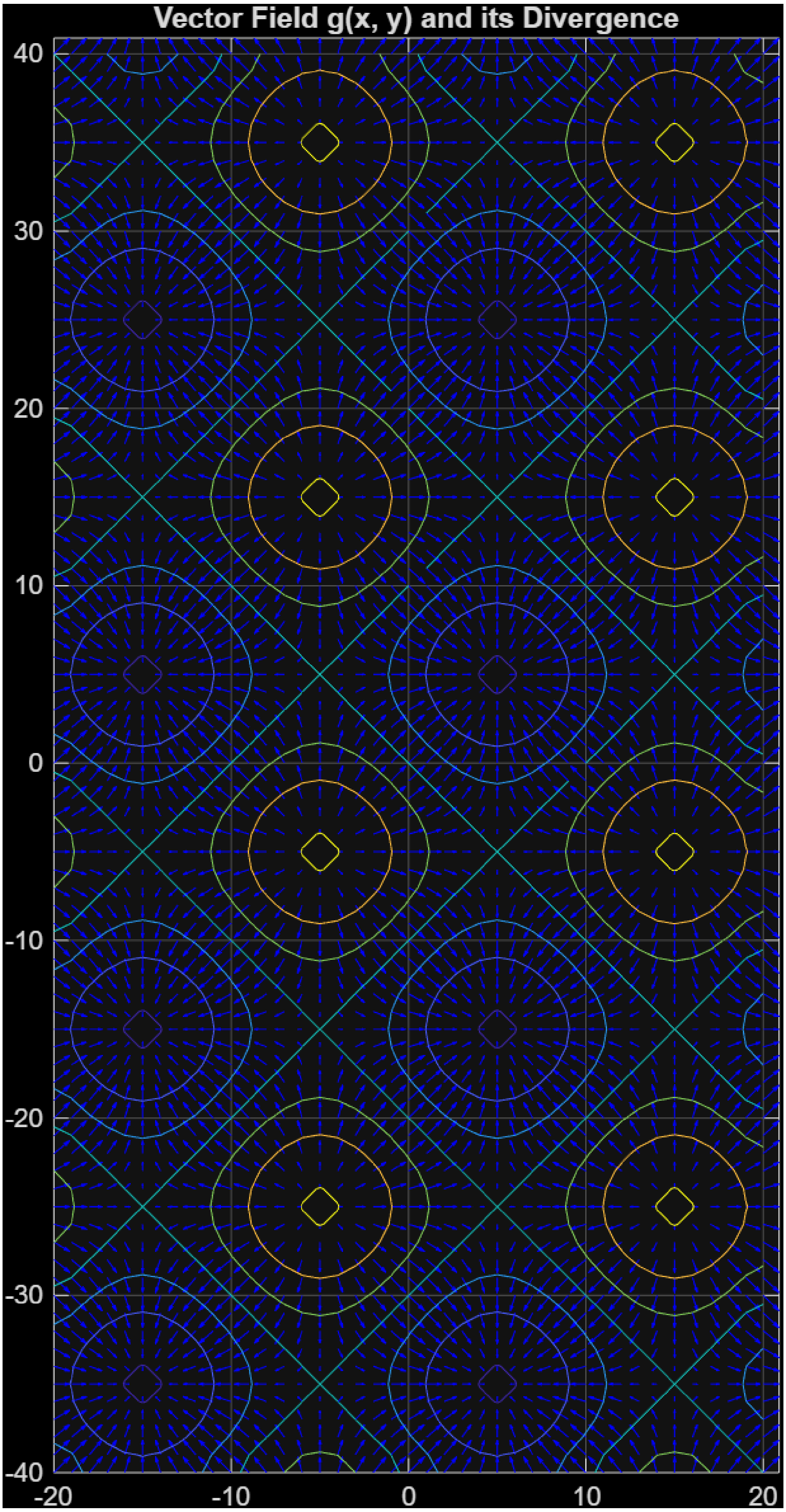
$$g(x,y) = \cos(0.1\,\pi\,x)\,a_x + \cos(0.1\,\pi\,y)\,a_y$$

Write a MATLAB script using the quiver and contour commands to visualize the field and its divergence. Assume the region of interest to be $-20 \le x \le 20$, $-40 \le y \le 40$.

Hint: Mesh the 2D space as

```
gx=-20:1:20; gy=-40:1:40; [x,y]=meshgrid(gx,gy);
```

```
% Define the grid space for the vector field
gx = -20:1:20;  % X-axis range
gy = -40:1:40;  % Y-axis range
[x, y] = meshgrid(gx, gy);  % Create a 2D grid of x and y values

% Define the vector field components
g_x = cos(0.1 * pi * x);  % x-component of the vector field
g_y = cos(0.1 * pi * y);  % y-component of the vector field

% Compute the divergence of the vector field
div_g = divergence(x, y, g_x, g_y);

% Plot the vector field using quiver
figure; % Create a new figure window
quiver(x, y, g_x, g_y, 'b'); % Quiver plot for vector field (blue
arrows)
hold on; % Hold the current plot for overlaying additional plots
contour(x, y, div_g); % Contour plot for divergence
hold off; % Release the current plot

% Formatting the plot
title('Vector Field g(x, y) and its Divergence');
axis equal; % Maintain aspect ratio
grid on; % Add grid for clarity
```


Vector Field g(x, y) and its Divergence
40
30
20
10
0
-10
-20
-30
-40
-20
-10
0
10
20

Exercise 1.2

a. Two point charges with $Q_1 = Q_2 = 1$ C are placed at $(x_0, y_0, z_0) = (-1, 0, 0)$ and $(x_1, y_1, z_1) = (1, 0, 0)$ in free space. Write down an expression for the electric potential function $V(x, y, z)$.
Hint: For a point charge located at (x_0, y_0, z_0) in free space, the electric potential it induces at a point (x, y, z) is given by

$$V(x,y,z) = \frac{Q}{4\pi\epsilon_0}\left(\frac{1}{\sqrt{(x-x_0)^2 + (y-y_0)^2 + (z-z_0)^2}}\right)$$

We can write a similar expression for a point charge at (x_1, y_1, z_1). The electric potential also satisfies the superposition principle.

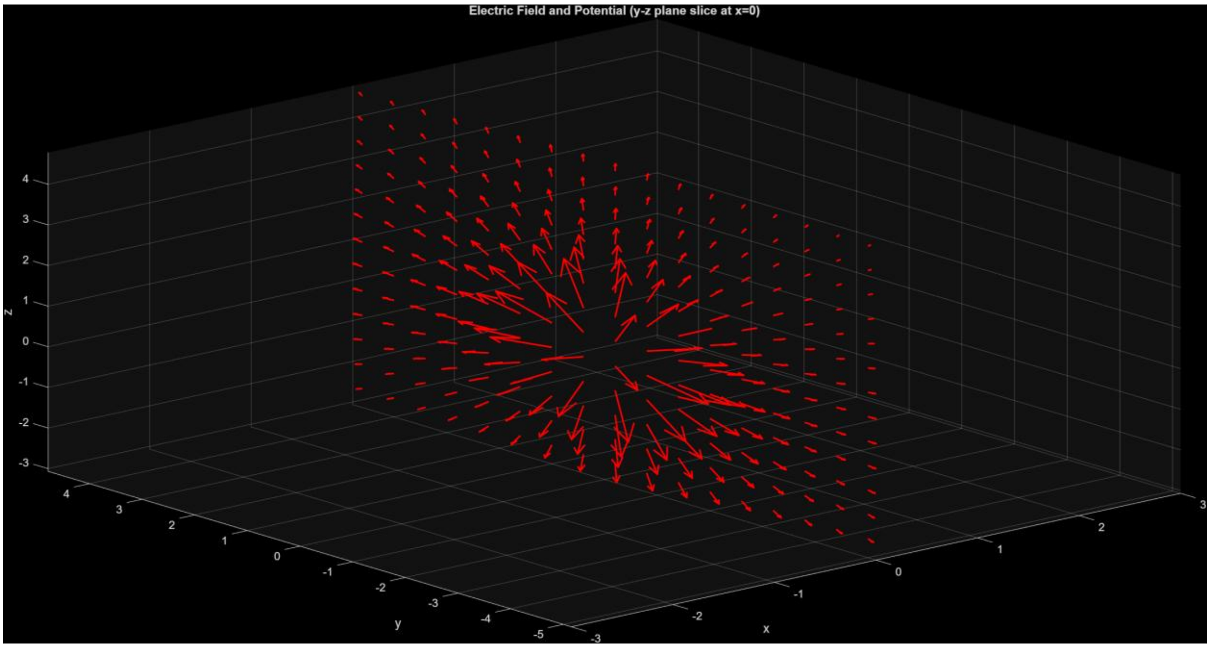
```
x0 = -1; y0 = 0; z0 = 0;     % Position of first charge at (-1,0,0)
x1 = 1;  y1 = 0; z1 = 0;     % Position of second charge at (1,0,0)
epsilon0 = 8.85e-12;         % Permittivity of free space (F/m)
k = Q/(4*pi*epsilon0);       % Calculate Coulomb's constant times charge
(N·m²/C)

r0 = sqrt((x-x0).^2 + (y-y0).^2 + (z-z0).^2);  % Distance from first
charge
r1 = sqrt((x-x1).^2 + (y-y1).^2 + (z-z1).^2);  % Distance from second
charge

V0 = k * (1./r0);            % Potential due to first charge
V1 = k * (1./r1);            % Potential due to second charge
```

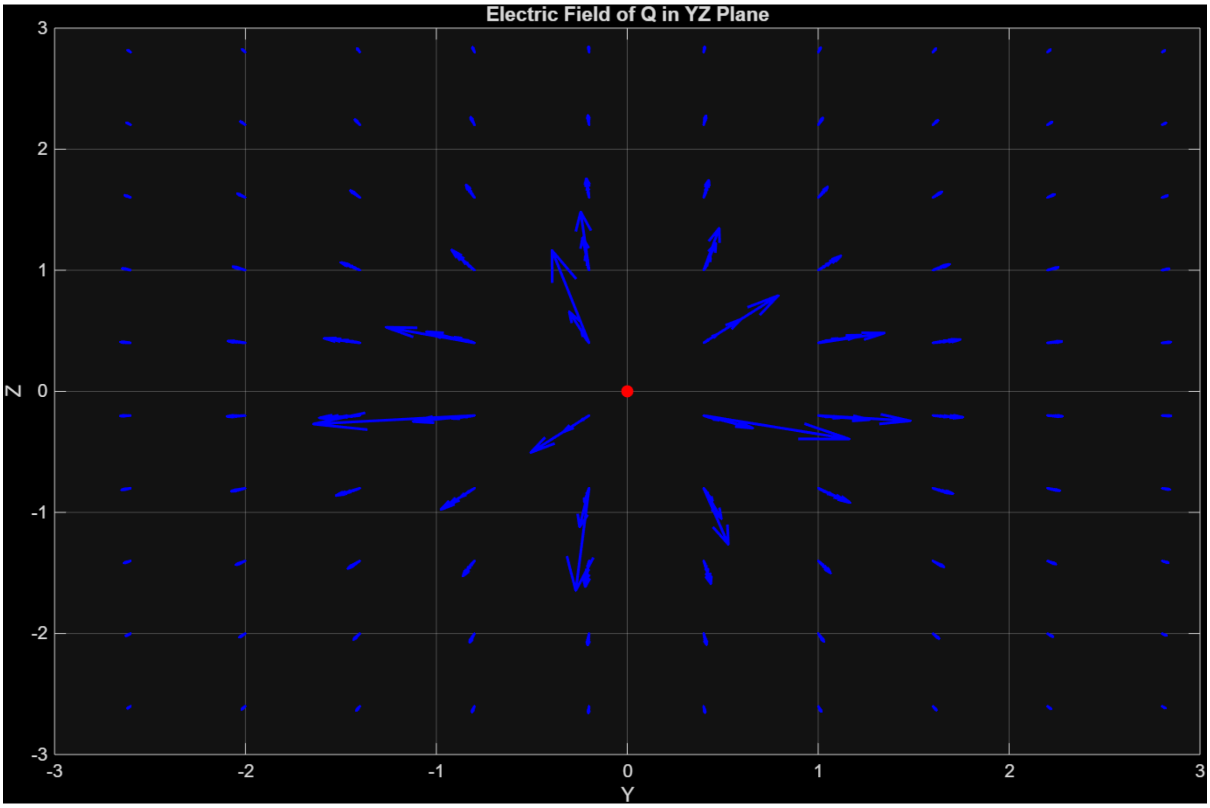
b. Write a MATLAB script to find and visualize the electric field **E** of Task 1.2.a in the 3D space and on the y-z plane (x = 0).
Hint: Mesh the 3D space as

```
gx=-5:0.5:5; gy=-5:0.6:5; gz=-5:0.6:5; [x,y,z]=meshgrid(gx,gy,gz);
```

```
% Define physical constants and charge parameters
Q = 1;                          % Charge magnitude (-1 C)
epsilon0 = 8.85e-12;            % Permittivity of free space (F/m)
k = Q / (4 * pi * epsilon0);    % Coulomb's constant times charge

% Charge positions
x0 = -1;  y0 = 0;  z0 = 0;       % First charge at (-1,0,0)
x1 = 1;   y1 = 0;  z1 = 0;       % Second charge at (1,0,0)

% Create a 3D grid for field calculation
gx = -5:0.5:5;                   % X grid points from -5 to 5 with
step 0.5
```

```
gy = -5:0.6:5;                     % Y grid points from -5 to 5 with
step 0.6
gz = -5:0.6:5;                     % Z grid points from -5 to 5 with
step 0.6
[x, y, z] = meshgrid(gx, gy, gz);     % Create 3D grid matrices

% Compute distances from each charge
r0 = sqrt((x - x0).^2 + (y - y0).^2 + (z - z0).^2);    % Distance from
charge 1
r1 = sqrt((x - x1).^2 + (y - y1).^2 + (z - z1).^2);    % Distance from
charge 2

% Compute electric potential from each charge
V0 = k ./ r0;                     % Potential due to charge 1
V1 = k ./ r1;                     % Potential due to charge 2
V_total = V0 + V1;                % Superposition principle: total
potential

% Compute electric field components using the negative gradient of
V_total
[Ex, Ey, Ez] = gradient(-V_total, 0.5, 0.6, 0.6);
[Ex0, Ey0, Ez0] = gradient(-V0, 0.5, 0.6, 0.6);

% Find the index where x = 0
lengthg = length(gx);
pos_0 = (lengthg + 1) / 2;          % Middle index for x = 0 plane

% === 3D Visualization: Potential Slices and Full Electric Field ===
figure(1)
quiver3(x(:, pos_0, :), y(:, pos_0, :), z(:, pos_0, :), ...
        Ex(:, pos_0, :), Ey(:, pos_0, :), Ez(:, pos_0, :), ...
        1.5, 'r', 'linewidth', 1.5);
xlim([-3,3]); ylim([-3,3]); zlim([-3,3]);
xlabel('x'); ylabel('y'); zlabel('z');
title('Electric Field and Potential (y-z plane slice at x=0)');
grid on;

% === 2D Visualization: Potential Slices and Electric Field ===
figure(2)
quiver(y, z, Ey0, Ez0, 1.5, 'b', 'linewidth', 1.5);
hold on
plot(y0, z0, 'r.', 'MarkerSize', 20);
xlabel('Y');
ylabel('Z');
title('Electric Field of Q in YZ Plane');
grid on;
axis([-3 3 -3 3]);
```

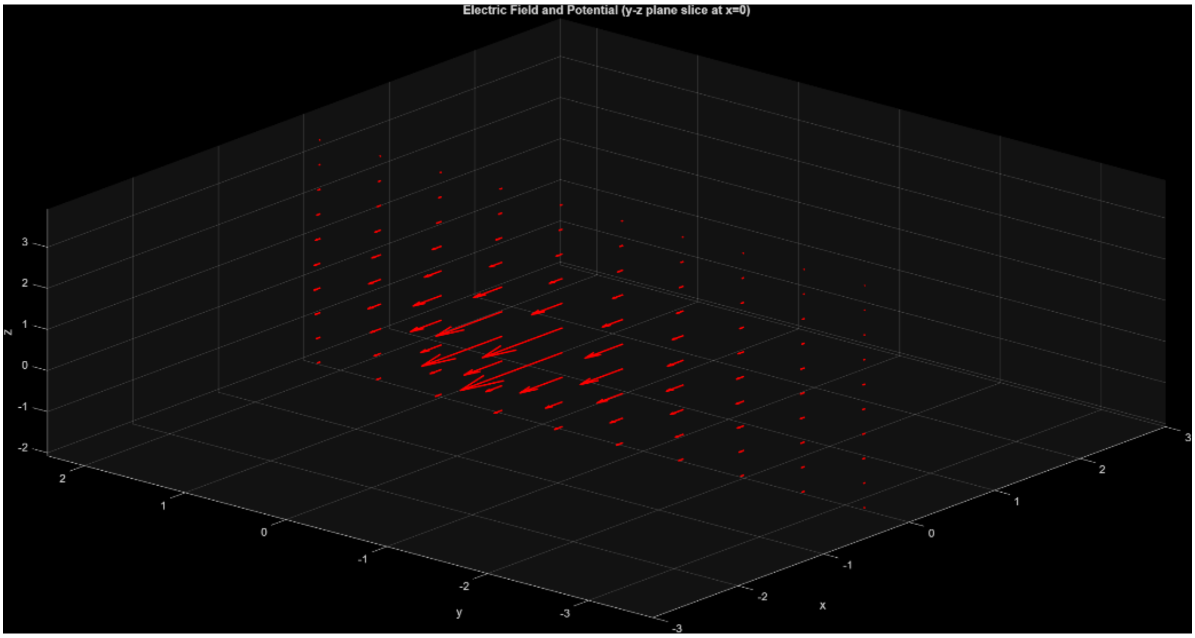

Electric Field and Potential (y-z plane slice at x=0)
z
y
x

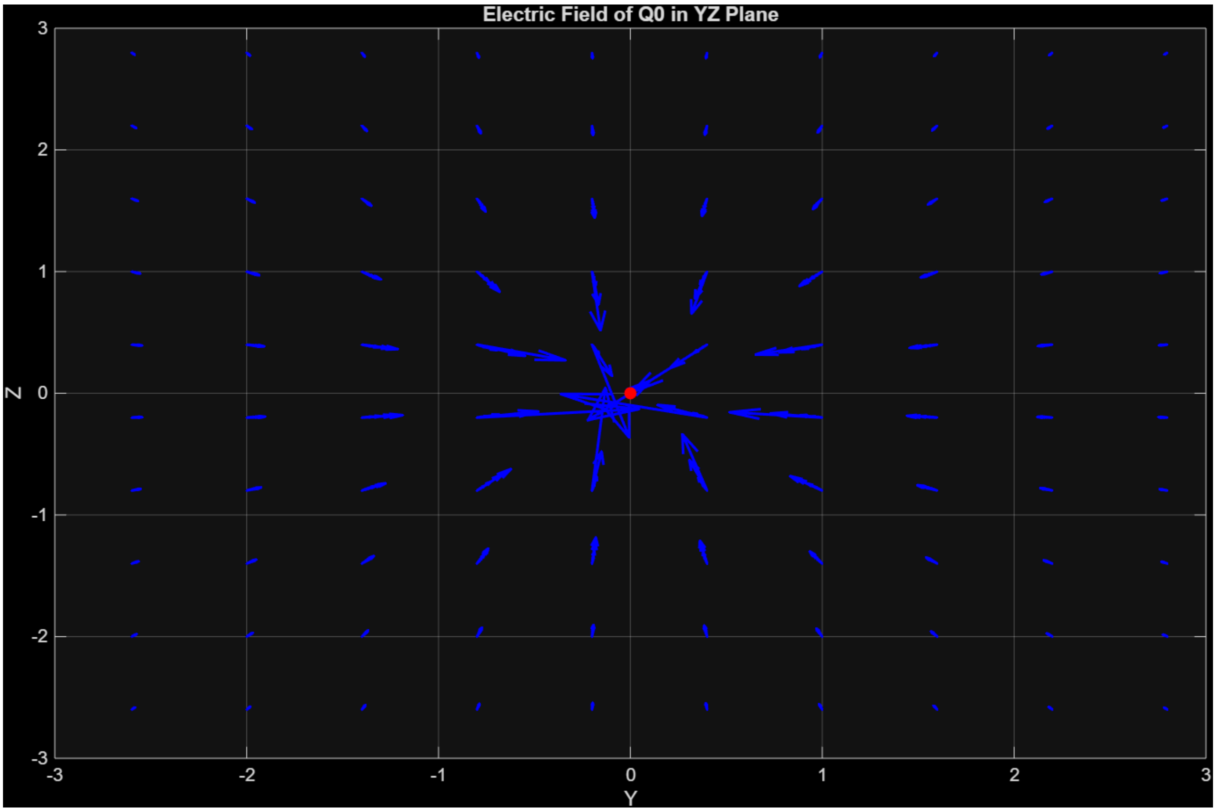

Electric Field of Q in YZ Plane
Z
Y

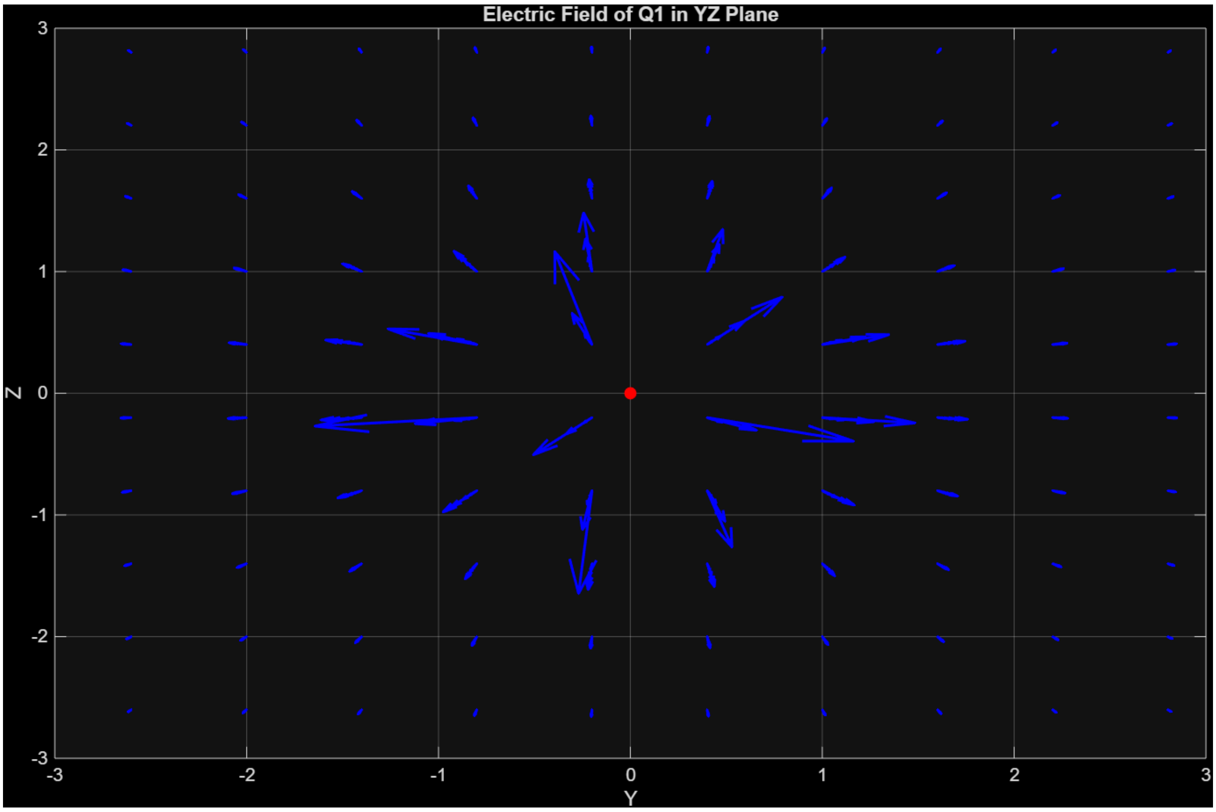
c. Assume that the charge at $(x_0, y_0, z_0) = (-1, 0, 0)$ is changed to $Q_0 = -1$ C. Repeat the task in Task 1.2.b.

```
% Define physical constants and charge parameters
Q0 = -1;                                % Charge magnitude (-1 C)
Q1 = 1;                                 % Charge magnitude (1 C)
epsilon0 = 8.85e-12;                    % Permittivity of free space (F/m)
k0 = Q0 / (4 * pi * epsilon0);          % Coulomb's constant times charge
k1 = Q1 / (4 * pi * epsilon0);          % Coulomb's constant times charge

% Charge positions
x0 = -1;  y0 = 0;  z0 = 0;             % First charge at (-1,0,0)
x1 = 1;   y1 = 0;  z1 = 0;             % Second charge at (1,0,0)

% Create a 3D grid for field calculation
gx = -5:0.5:5;                          % X grid points from -5 to 5 with
step 0.5
gy = -5:0.6:5;                          % Y grid points from -5 to 5 with
step 0.6
gz = -5:0.6:5;                          % Z grid points from -5 to 5 with
step 0.6
[x, y, z] = meshgrid(gx, gy, gz);      % Create 3D grid matrices

% Compute distances from each charge
r0 = sqrt((x - x0).^2 + (y - y0).^2 + (z - z0).^2);    % Distance from
charge 1
r1 = sqrt((x - x1).^2 + (y - y1).^2 + (z - z1).^2);    % Distance from
charge 2

% Compute electric potential from each charge
V0 = k0 ./ r0;                          % Potential due to charge 1
V1 = k1 ./ r1;                          % Potential due to charge 2
V_total = V0 + V1;                      % Superposition principle: total
potential

% Compute electric field components using the negative gradient of
V_total
[Ex, Ey, Ez] = gradient(-V_total, 0.5, 0.6, 0.6);
[Ex0, Ey0, Ez0] = gradient(-V0, 0.5, 0.6, 0.6);
[Ex1, Ey1, Ez1] = gradient(-V1, 0.5, 0.6, 0.6);

% Find the index where x = 0
lengthg = length(gx);
pos_0 = (lengthg + 1) / 2;             % Middle index for x = 0 plane
```

```matlab
% === 3D Visualization: Potential Slices and Full Electric Field ===
figure(1)
quiver3(x(:, pos_0, :), y(:, pos_0, :), z(:, pos_0, :), ...
        Ex(:, pos_0, :), Ey(:, pos_0, :), Ez(:, pos_0, :), ...
        1.5, 'r', 'linewidth', 1.5);
xlim([-3,3]); ylim([-3,3]); zlim([-3,3]);
xlabel('x'); ylabel('y'); zlabel('z');
title('Electric Field and Potential (y-z plane slice at x=0)');
grid on;

% === 2D Visualization: Potential Slices and Electric Field ===
figure(2)
quiver(y, z, Ey0, Ez0, 1.5, 'b', 'linewidth', 1.5);
hold on
plot(y0, z0, 'r.', 'MarkerSize', 20);
xlabel('Y');
ylabel('Z');
title('Electric Field of Q0 in YZ Plane');
grid on;
axis([-3 3 -3 3]);

figure(3)
quiver(y, z, Ey1, Ez1, 1.5, 'b', 'linewidth', 1.5);
hold on
plot(y1, z1, 'r.', 'MarkerSize', 20);
xlabel('Y');
ylabel('Z');
title('Electric Field of Q1 in YZ Plane');
grid on;
axis([-3 3 -3 3]);
```




Electric Field of Q0 in YZ Plane
Z
Y
3
2
1
0
-1
-2
-3
-3
-2
-1
0
1
2
3


Electric Field of Q1 in YZ Plane
Z
Y
3
2
1
0
-1
-2
-3
-3
-2
-1
0
1
2
3

XXXXXXX