Experiment : 4

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Course : B.Sc. Hons. Electronics
Semester : 5th

Experiment : 4

Aim : Representation of the Gradient of a scalar field, Divergence and Curl of Vector Fields.

Apparatus Required : A desktop with Scilab installed in it.

Theory :

- The gradient of a scalar field V is a vector that represents both the magnitude and the direction of the maximum space rate of increase of V.

  For cartesian coordinates,

$$\nabla V = \frac{\partial V}{\partial x} a_x + \frac{\partial V}{\partial y} a_y + \frac{\partial V}{\partial z} a_z$$

  For cylindrical coordinates,

$$\nabla V = \frac{\partial V}{\partial \rho} a_\rho + \frac{1}{\rho}\frac{\partial V}{\partial \varphi} a_\varphi + \frac{\partial V}{\partial z} a_z$$

  For spherical coordinates,

$$\nabla V = \frac{\partial V}{\partial r} a_r + \frac{1}{r}\frac{\partial V}{\partial \theta} a_\theta + \frac{1}{r\, sin\theta}\frac{\partial V}{\partial \varphi} a_\varphi$$

- The divergence of A at a given point P is the outward flux per unit volume as the volume shrinks about P.

  For cartesian coordinates,

$$\nabla . \mathrm{A} = \frac{\partial A_x}{\partial x} + \frac{\partial A_y}{\partial y} + \frac{\partial A_z}{\partial z}$$

  For cylindrical coordinates,

$$\nabla . \mathrm{A} = \frac{1}{\rho}\frac{\partial}{\partial x}(\rho A_\rho) + \frac{1}{\rho}\frac{\partial A_\varphi}{\partial \varphi} + \frac{\partial A_z}{\partial z}$$

  For spherical coordinates,

$$\nabla . A = \frac{1}{r^2}\frac{\partial}{\partial r}(r^2 A_r) + \frac{1}{r\ sin\theta}\frac{\partial}{\partial \theta}(A_\theta sin\theta) + \frac{1}{r\ sin\theta}\frac{\partial A_\varphi}{\partial \varphi}$$

- The curl of A is an axial (or rotational) vector whose magnitude is the maximum circulation of A per unit area as the area lends to zero and whose direction is the normal direction of the area when the area is oriented so as to make the circulation maximum.

For cartesian coordinates,

$$\nabla \times A = \left[\frac{\partial A_z}{\partial y} - \frac{\partial A_y}{\partial z}\right] a_x + \left[\frac{\partial A_x}{\partial z} - \frac{\partial A_z}{\partial x}\right] a_y + \left[\frac{\partial A_y}{\partial x} - \frac{\partial A_x}{\partial y}\right] a_z$$

For cylindrical coordinates,

$$\nabla \times A = \left[\frac{1}{\rho}\frac{\partial A_z}{\partial \varphi} - \frac{\partial A_\varphi}{\partial z}\right] a_\rho + \left[\frac{\partial A_\rho}{\partial z} - \frac{\partial A_z}{\partial \rho}\right] a_\varphi + \frac{1}{\rho}\left[\frac{\partial}{\partial \rho}(\rho A_\varphi) - \frac{\partial A_\rho}{\partial \varphi}\right] a_z$$

For spherical coordinates,

$$\nabla \times A = \frac{1}{r\ sin\theta}\left[\frac{\partial A_\varphi sin\theta}{\partial \theta} - \frac{\partial A_\theta}{\partial \varphi}\right] a_r + \frac{1}{r}\left[\frac{1}{sin\theta}\frac{\partial A_r}{\partial \varphi} - \frac{\partial}{\partial r}(r A_\varphi)\right] a_\theta + \frac{1}{r}\left[\frac{\partial(\rho A_\varphi)}{\partial r} - \frac{\partial A_r}{\partial \theta}\right] a_\varphi$$

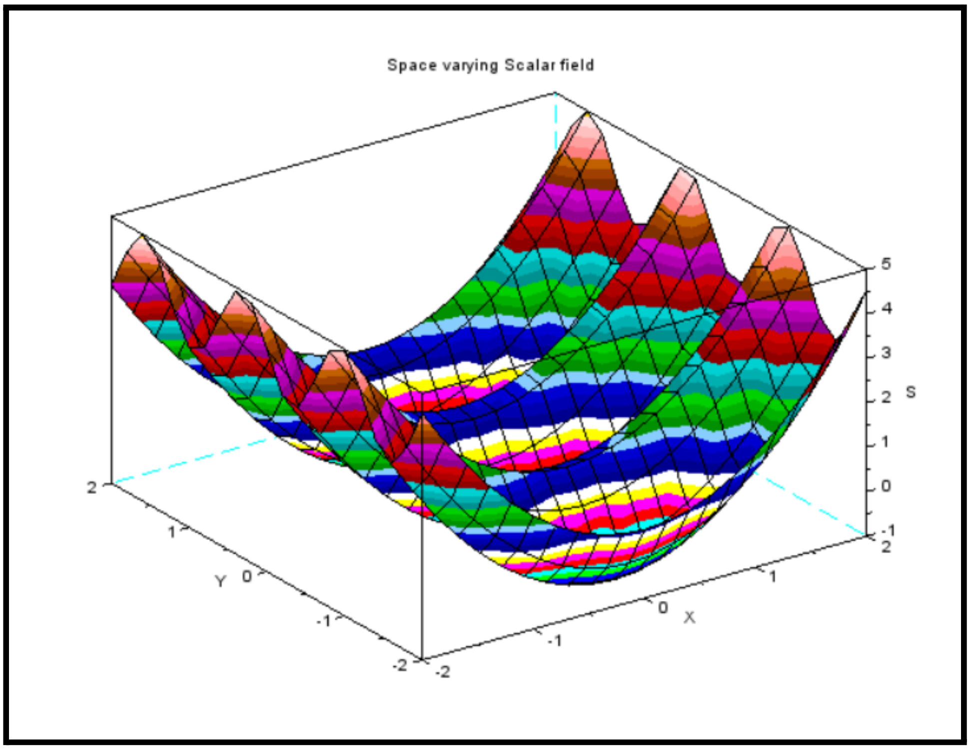
1. Gradient of a scalar field :-

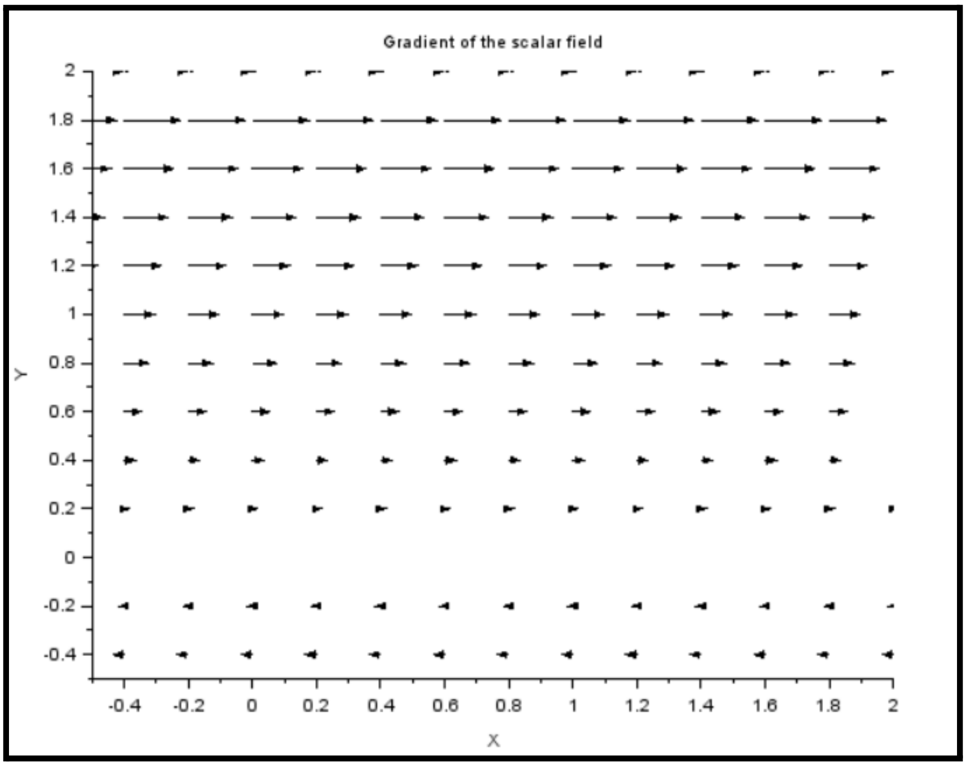
Program 1 :

Expt-4-Gradient-Program-1-Vishal-Anand.sce

```
a = -2:0.2:2;
b = -2:0.2:2;
[x,y] = meshgrid(a,b);
s = x.^2 + sin(5*y);
surf(a,b,s,'facecolor','interp');
xlabel('X');
ylabel('Y');
zlabel('S');
title("Space varying Scalar field");
g1 = 2*x*y*+x;
g2 = x.^2+x;
scf;
champ(a,b,g1,g2,rect = [-0.5,-0.5,2,2]);
xlabel('X')
ylabel('Y');
title("Gradient of the scalar field");
```

Output :


Space varying Scalar field
S
Y
X

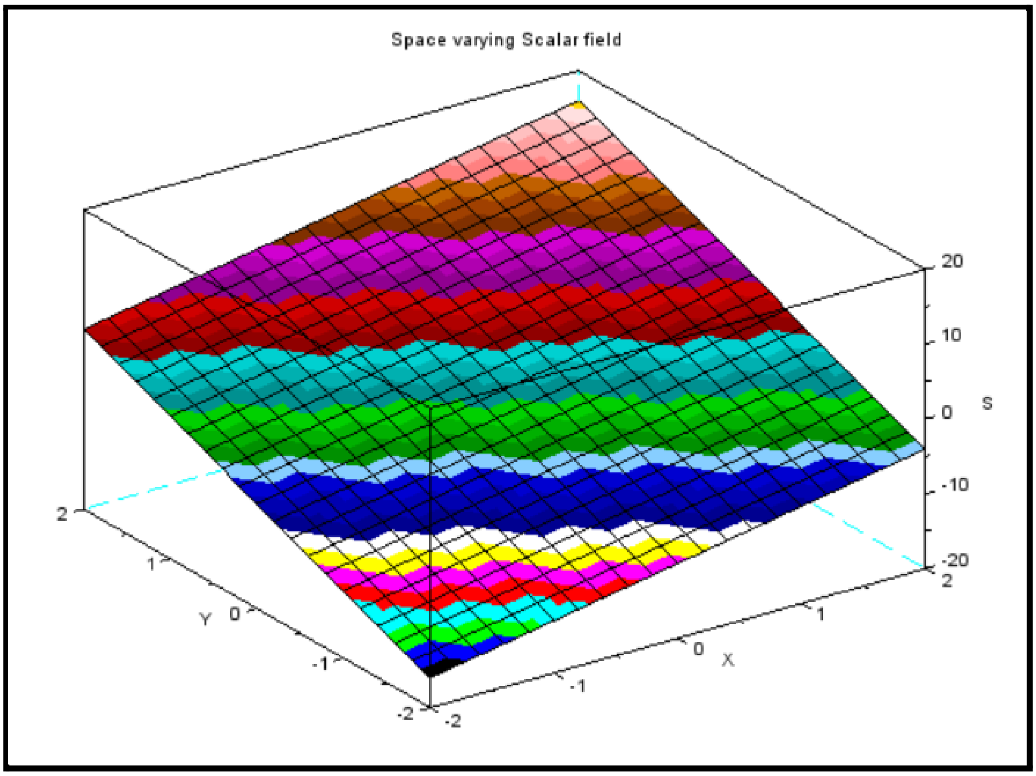

Gradient of the scalar field
Y
X

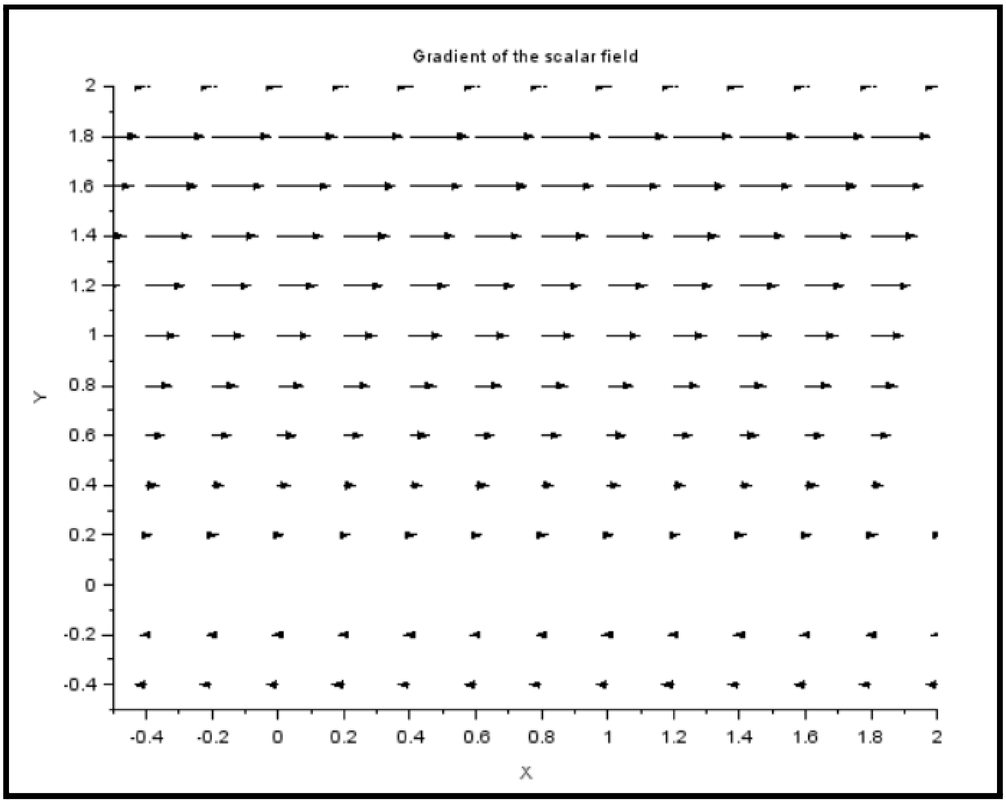
Program 2 :

Expt-4-Gradient-Program-2-Vishal-Anand.sce

```
a = -2:0.2:2;
b = -2:0.2:2;
[x,y] = meshgrid(a,b);
s = 3*x + 5.*y + x.^2*y;
surf(a,b,s,'facecolor','interp');
xlabel('X');
ylabel('Y');
zlabel('S');
title("Space varying Scalar field");
g1 = 2*x*y*+x;
g2 = x.^2+x;
scf;
champ(a,b,g1,g2,rect = [-0.5,-0.5,2,2]);
xlabel('X');
ylabel('Y');
title("Gradient of the scalar field");
```

Output :





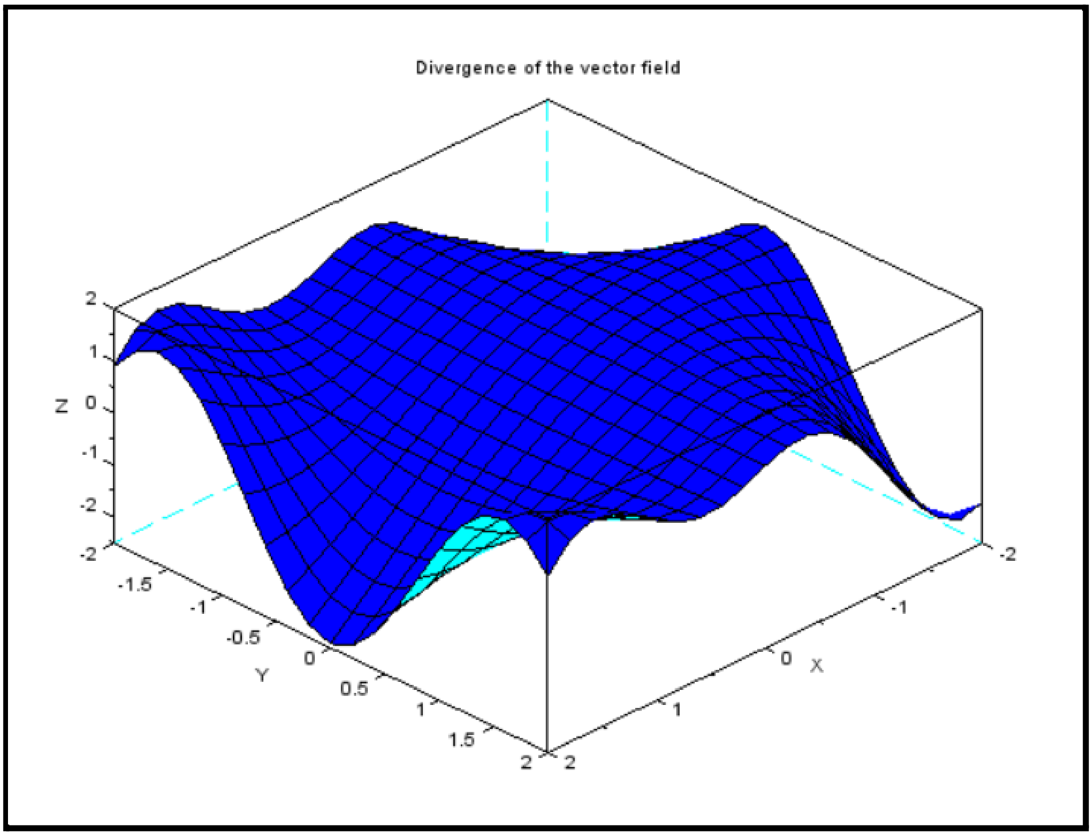
2. Divergence of vector field :-

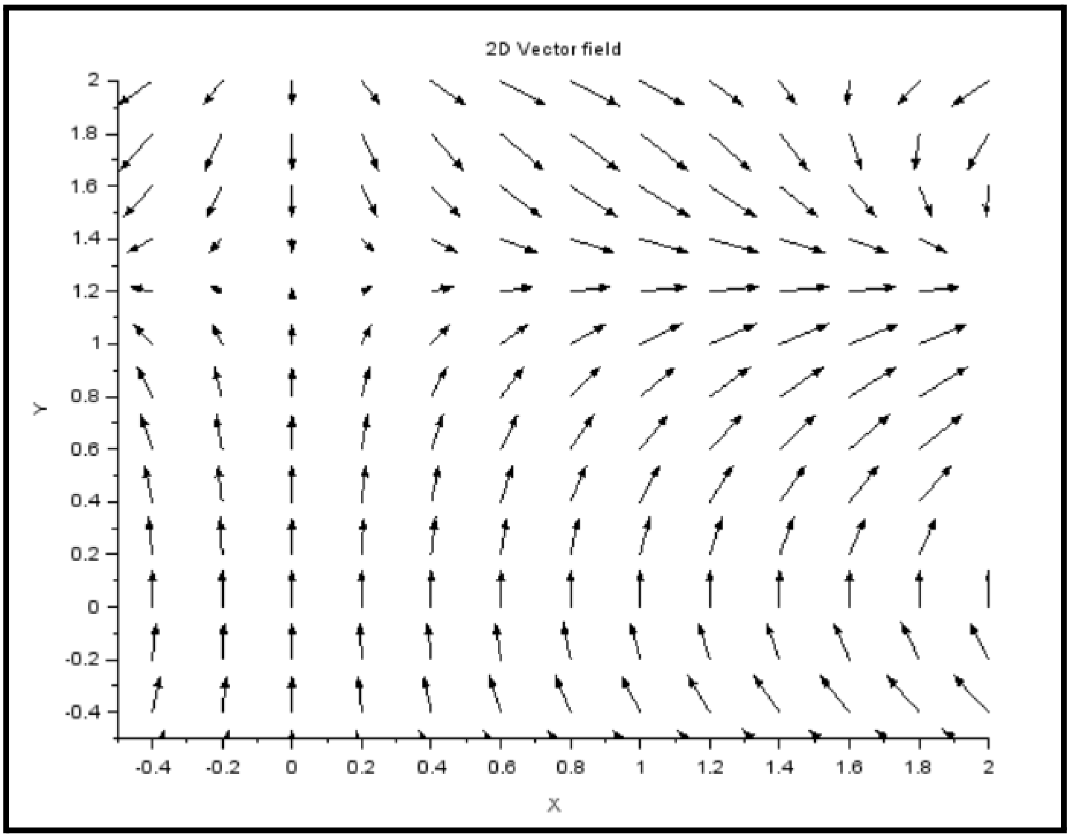
Program 1 :

Expt-4-Divergence-Program-1-Vishal-Anand.sce

```
a = -2:0.2:2;
b = -2:0.2:2;
[x,y] = meshgrid(a,b);
m = size(x);
px = sin(x.*y);
py = cos(x.^2);
scf;
champ(a,b,px,py,rect = [-0.5,-0.5,2,2]);
xlabel('X');
ylabel('Y');
title("2D Vector field");
d1 = (-y.*(cos(x.*y)));
d2 = cos(y);
d = d1 + d2;
scf;
plot3d(a,b,d);
xlabel('X');
ylabel('Y');
title("Divergence of the vector field");
```

Output :



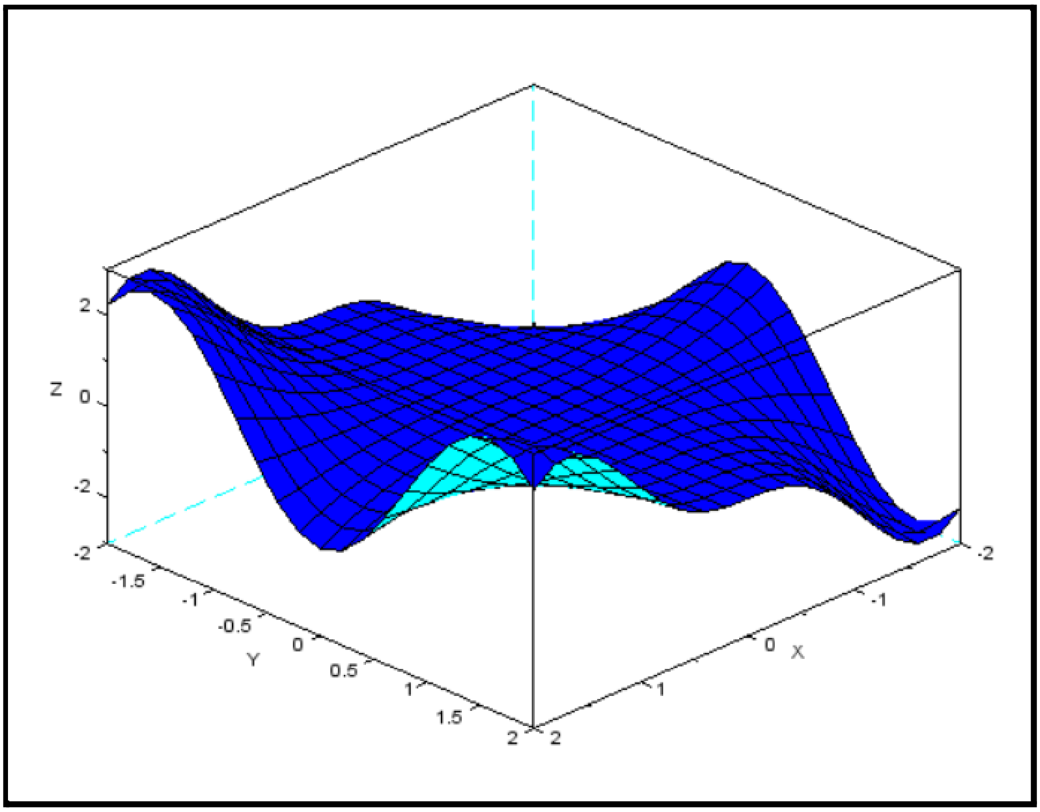


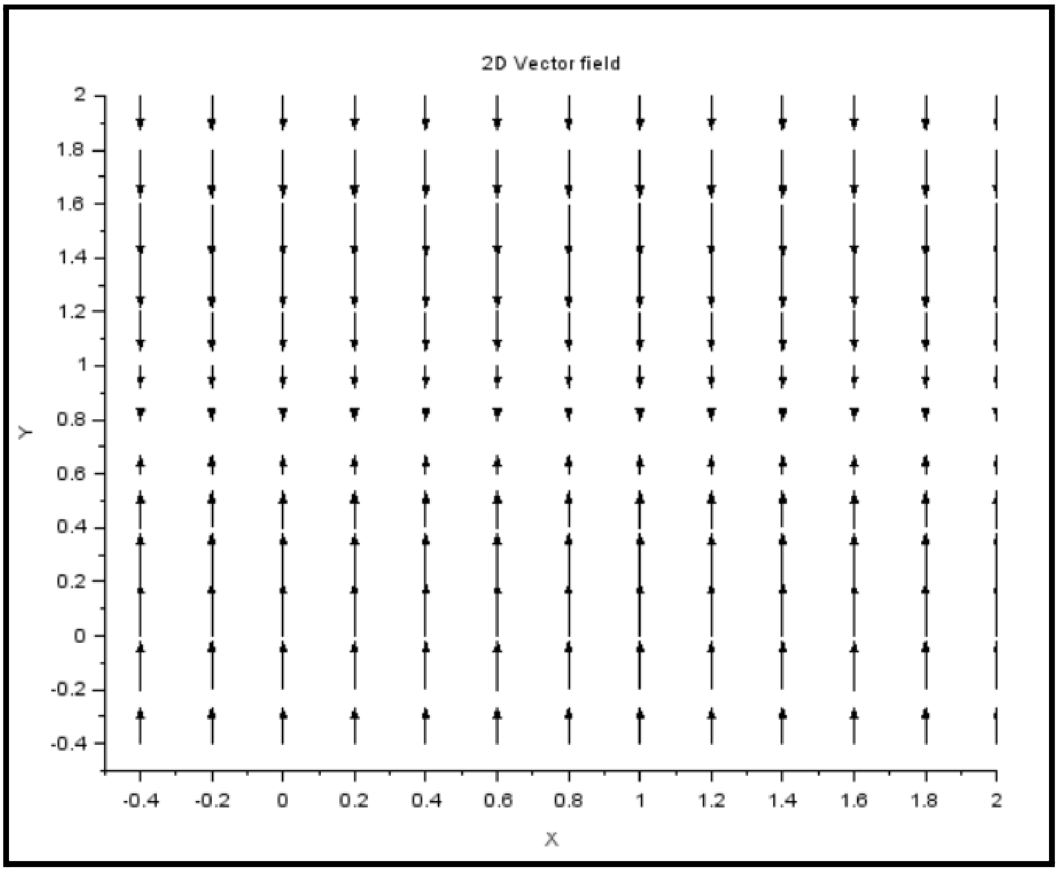
Program 2 :

Expt-4-Divergence-Program-2-Vishal-Anand.sce

```
a = -2:0.2:2;
b = -2:0.2:2;
[x,y] = meshgrid(a,b);
m = size(x);
px = sin(x.^2*y);
py = cos(x.*2);
scf;
champ(a,b,px,py,rect = [-0.5,-0.5,2,2]);
xlabel('X');
ylabel('Y');
title("2D Vector field");
d1 = (-y.*(cos(x.*y)));
d2 = sin(y);
d = d1 + d2;
scf;
plot3d(a,b,d);
xlabel('X');
ylabel('Y');
```

Output :





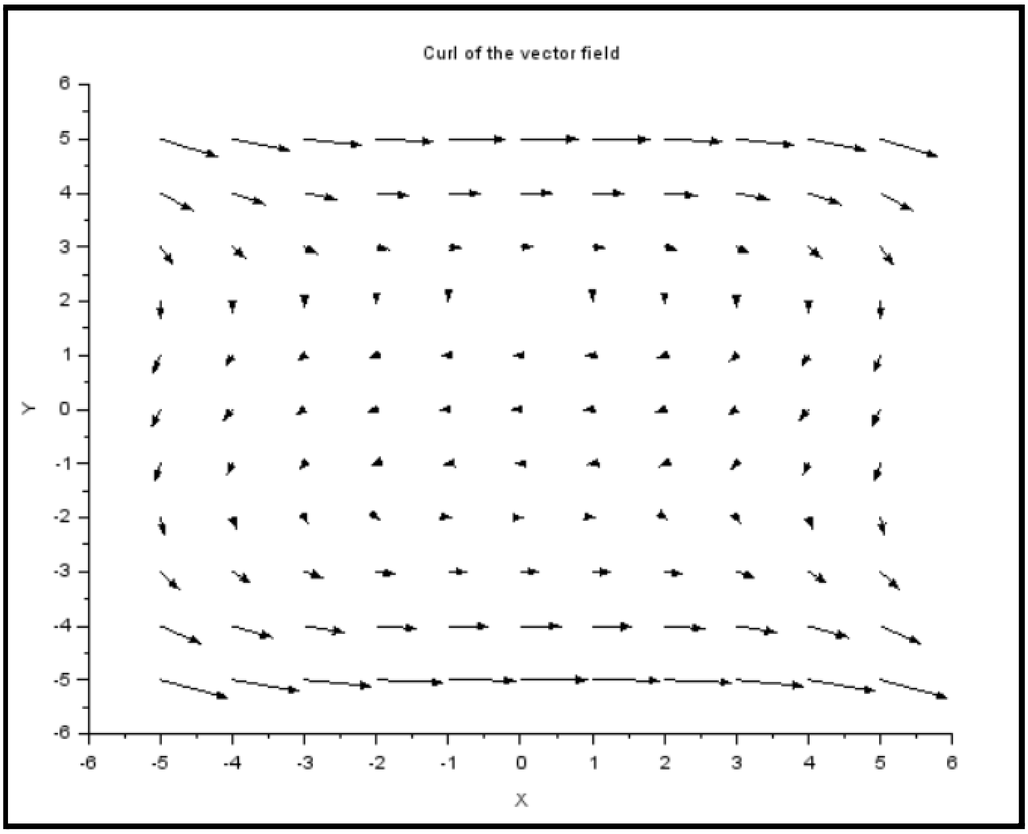
3. Curl of vector field :-

Program 1 :

Expt-4-Curl-Program-1-Vishal-Anand.sce

```
clc;
a = -5:5;
b = -5:5;
c = -5:5;
[x,y,z] = meshgrid(a,b,c);
cx = 3*x.^2 + 2*z - x;
cy = -y.^2;
champ(a,b,cx,cy,rect = [-5,-5,5,5]);
xlabel('X');
ylabel('Y');
title("Curl of the vector field");
```

Output :

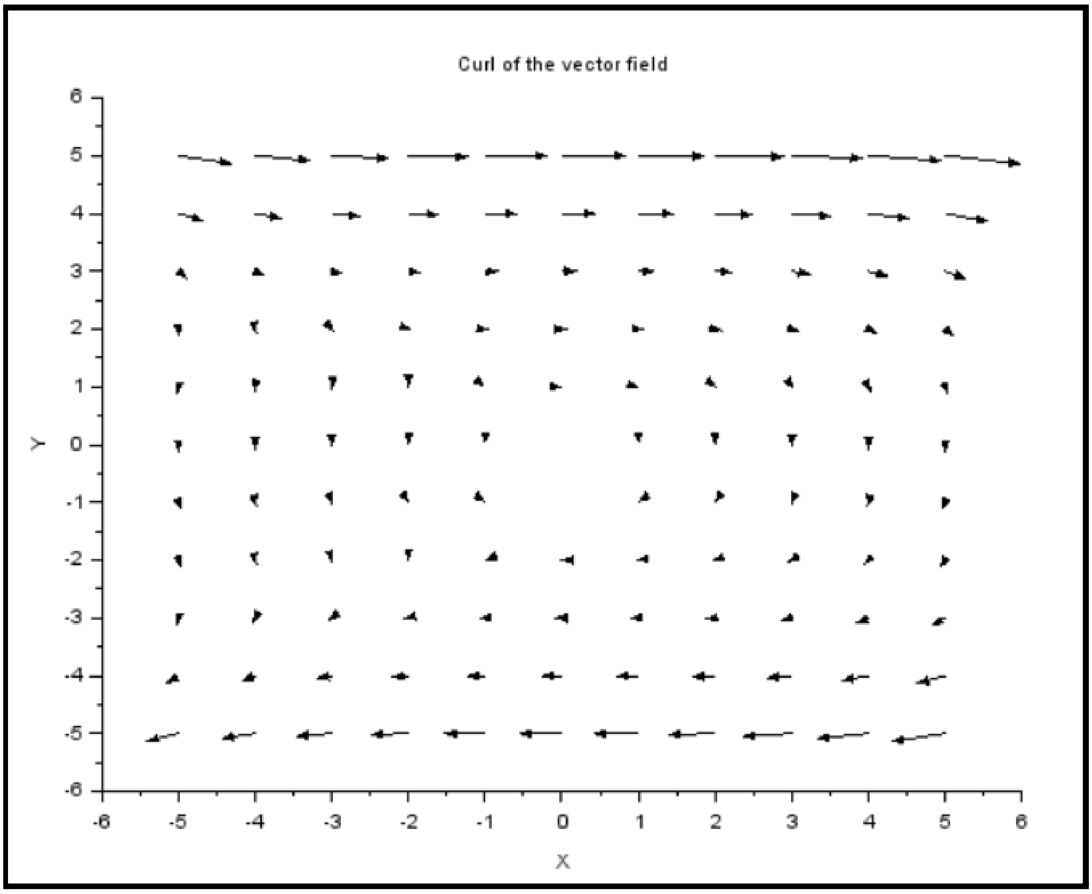


Program 2 :

Expt-4-Curl-Program-2-Vishal-Anand.sce

```
clc;
a = -5:5;
b = -5:5;
c = -5:5;
[x,y,z] = meshgrid(a,b,c);
cx = x.^2 + x.^3 + x.*y;
cy = -y.^2;
champ(a,b,cx,cy,rect = [-5,-5,5,5]);
xlabel('X');
ylabel('Y');
title("Curl of the vector field");
```

Output :



Result : Gradient of a scalar field, Divergence and Curl of Vector Fields are represented and plotted with 2 programs run successfully on Scilab software.