1A:

code:

```
clear;close all;
global B;
global mass;
global E;
B=zeros(1,3);
V=zeros(1,3);
E=zeros(1,3);
B(1,1)=0;
B(1,2)=0;
B(1,3)=5;
mass=1;
E(1,1)=0;
E(1,2)=0;
E(1,3)=0;
timescale=5;
dt=timescale/10000;


tstart=0;
tfinal=1*timescale;

u0=zeros(6,1);
u0(1)=0;  % x
u0(2)=0;   % y
u0(3)=0;  % z
u0(4)=5;   % vx
u0(5)=0; % vy
u0(6)=0;  % vz

[t,u]=ode45(@rhsl4p1a,[tstart:dt:tfinal],u0);

x=u(:,1);
y=u(:,2);
z=u(:,3);

vx=u(:,4);
vy=u(:,5);
vz=u(:,6);

plot3(x,y,z);
```

RHS:

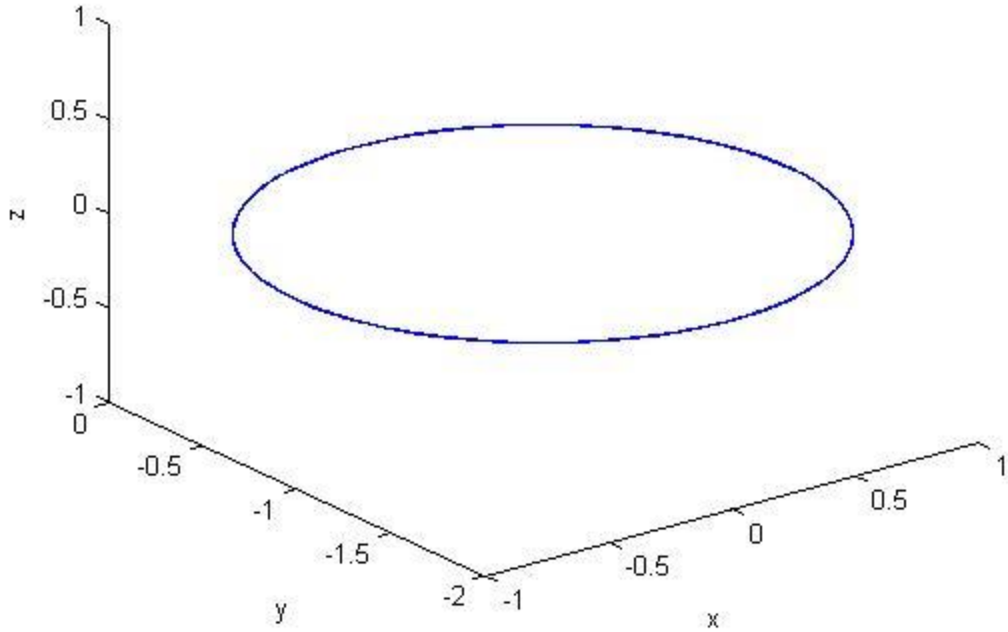
```
function F=rhsl4p1a(t,u)

global B;
global mass;
global E;


F=zeros(6,1);
a=[u(4) u(5) u(6)];
force=cross(a,B);

F(1)=u(4);
F(2)=u(5);
F(3)=u(6);
F(4)=force(1,1)/mass;
F(5)=force(1,2)/mass;
F(6)=force(1,3)/mass;
```

graph:

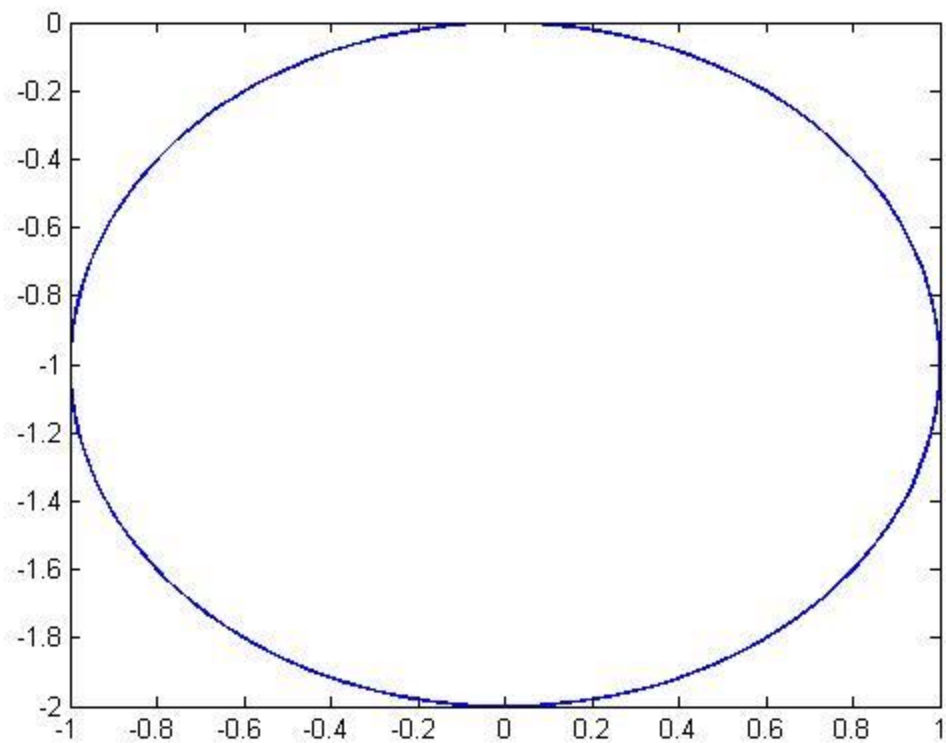
CASE 1:
for velocity perpendicular to B:
V in x direction:
B in Z:

(First 2 graphs in both the cases shows the motion of the particle for time>timeperiod. Next 2 graphs shows the motion of particle for time<timeperiod so that we can see the direction of the motion of particles)

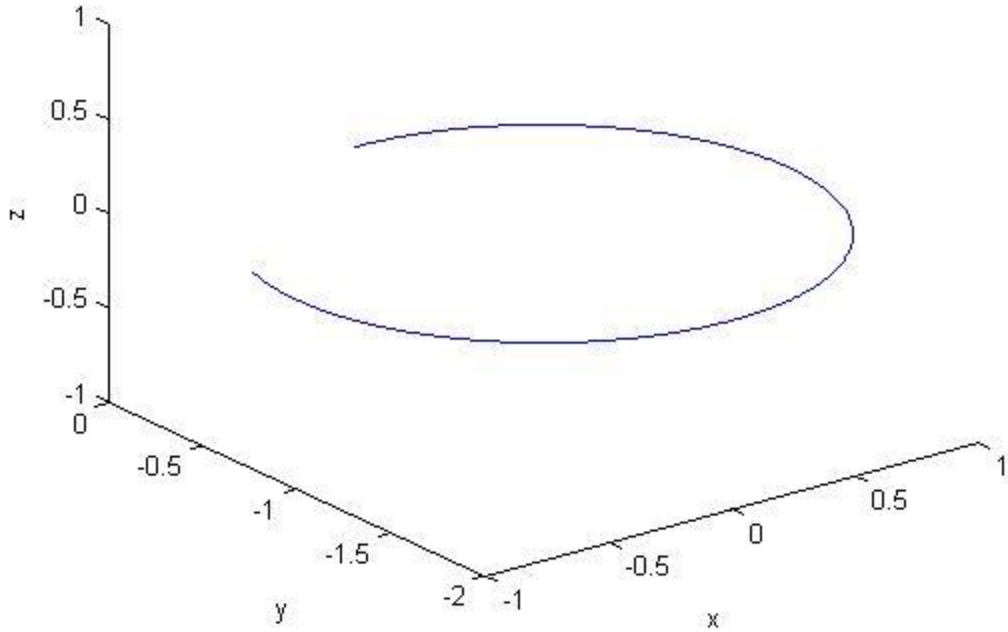
for +ve q



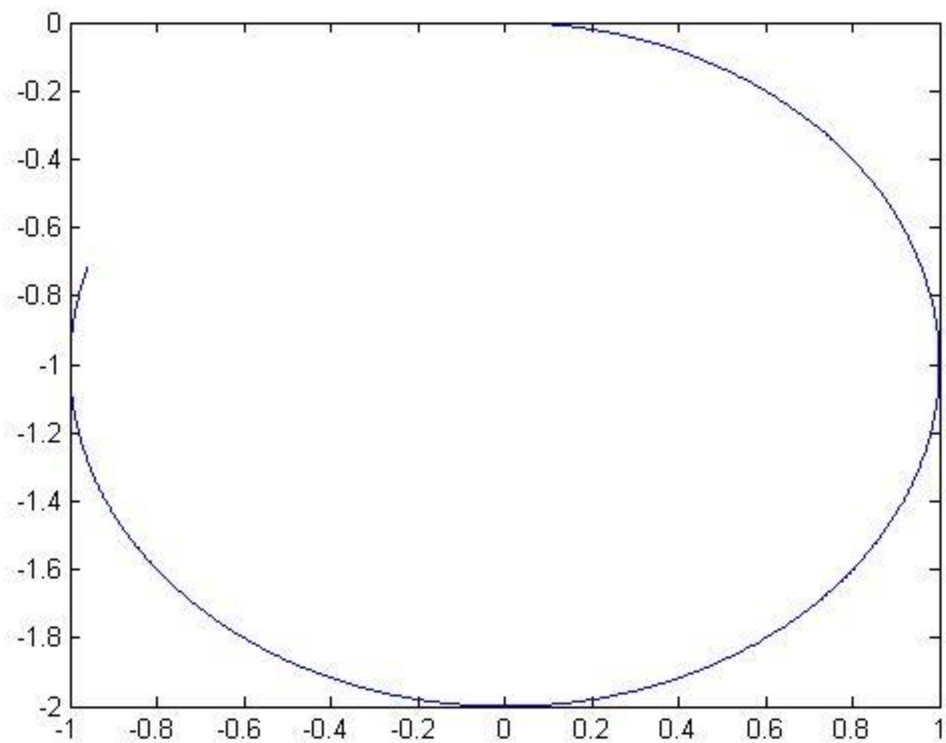
1
0.5
z
0
-0.5
-1
0
-0.5
-1
-1.5
-2
y
-1
-0.5
0
0.5
1
x



0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
-1.6
-1.8
-2
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1

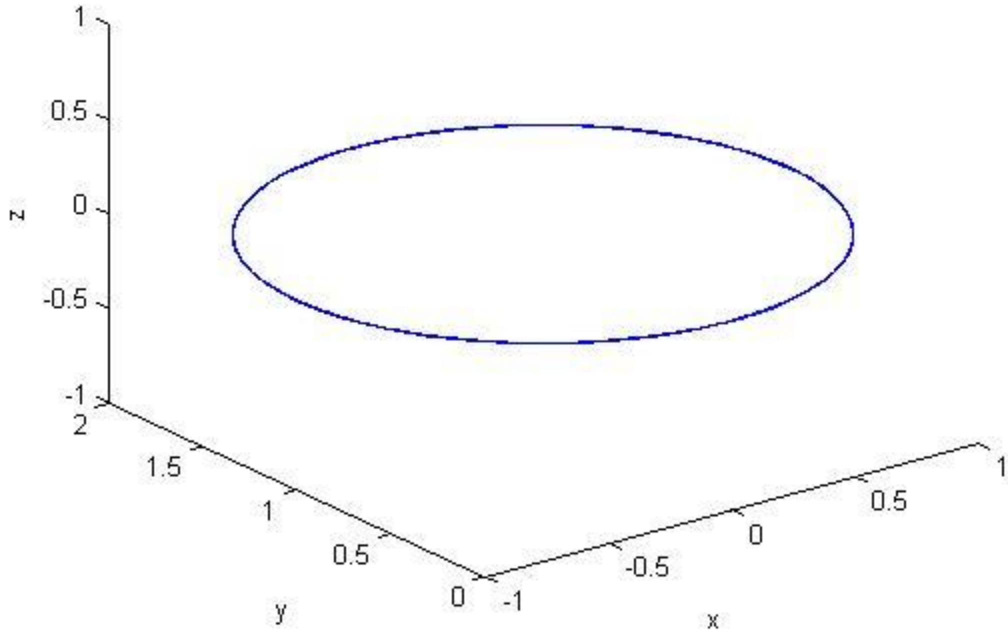


1
0.5
0
-0.5
-1
z
0
-0.5
-1
-1.5
-2
y
-1
-0.5
0
0.5
1
x

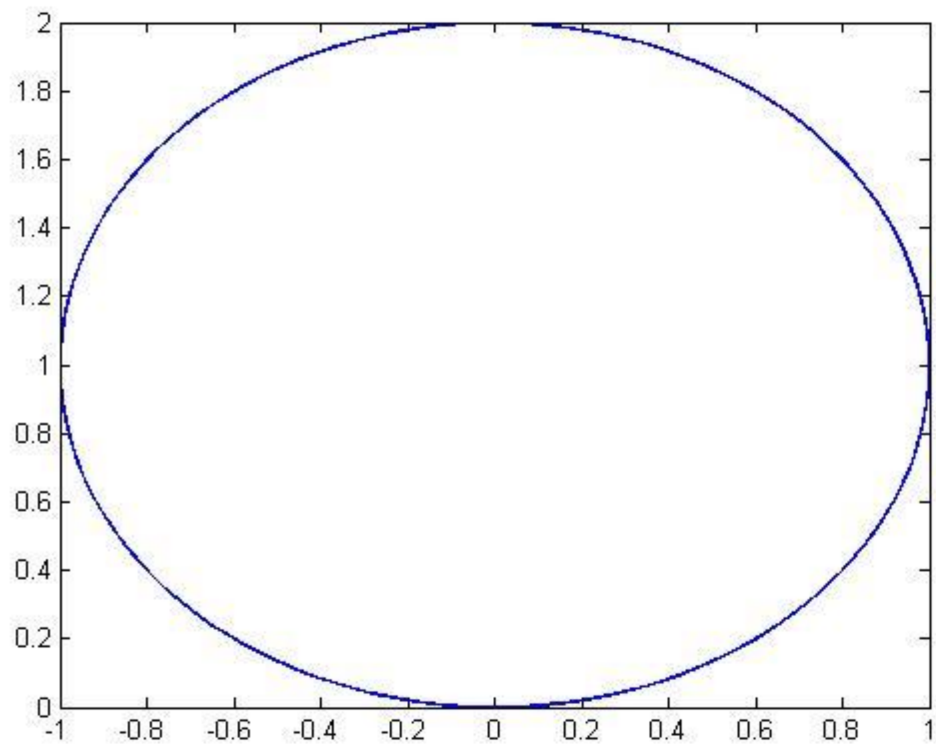


0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
-1.6
-1.8
-2
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1

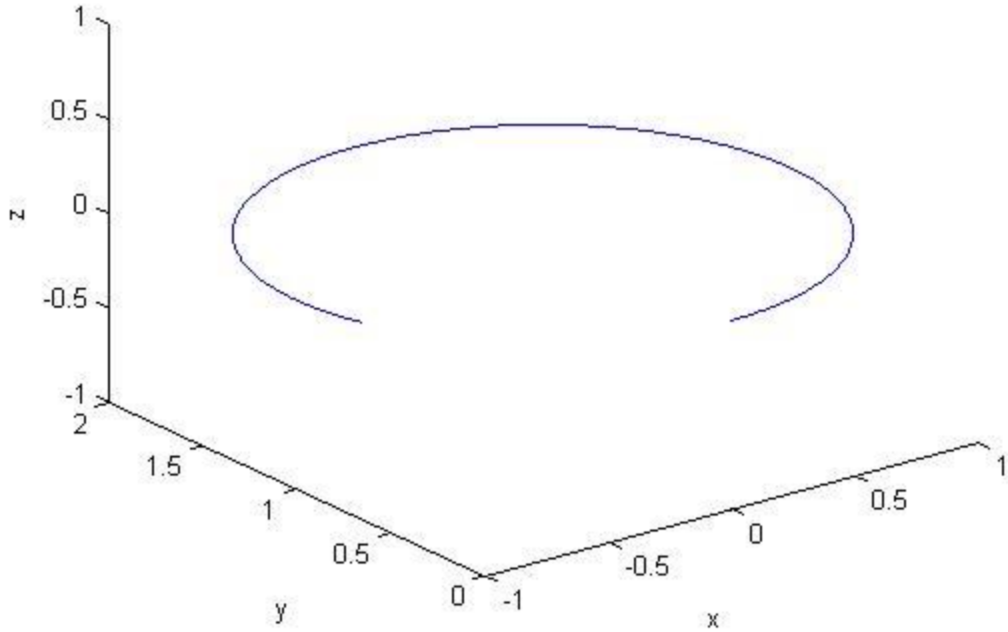
for -ve Q:



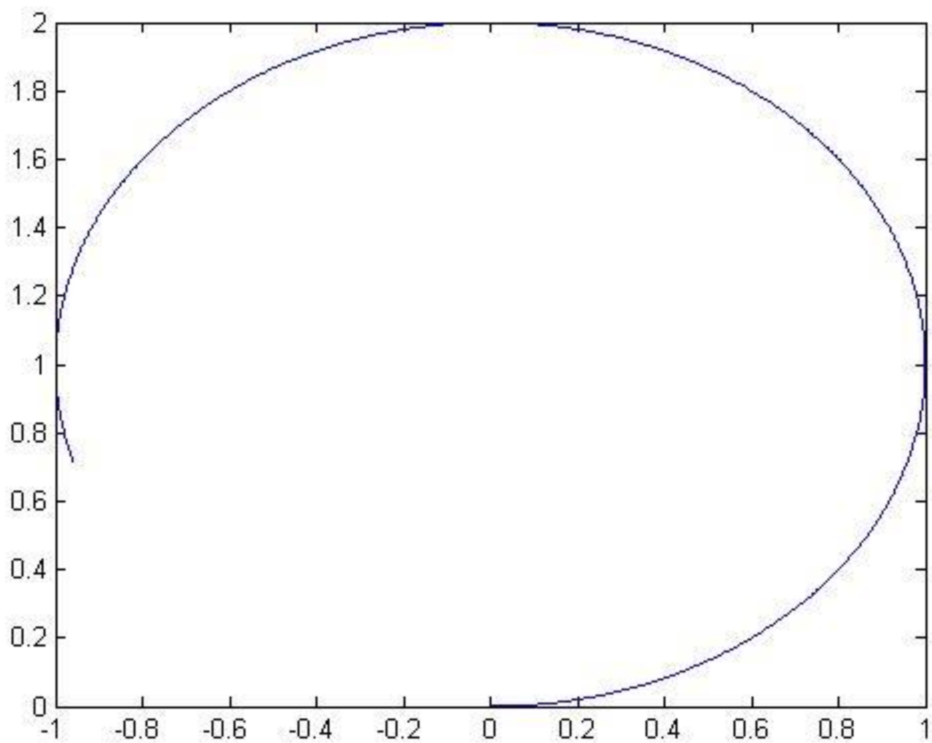
1
0.5
z
0
-0.5
-1
2
1.5
1
0.5
y
0
-1
-0.5
0
0.5
1
x



2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1



1
0.5
0
-0.5
-1
z
2
1.5
1
0.5
0
y
-1
-0.5
0
0.5
1
x



2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1

Here we know that velocity and magnetic field both are perpendicular to each other and as force is cross product of them, particle would have circular motion. Moreover, sign of charge (i.e. +ve or -ve) will tell us the direction of the motion i.e. clockwise or anticlockwise. It would be opposite for +ve and -ve charges.
From the above graphs we can see that our analytical calculation and computational calculation matches.

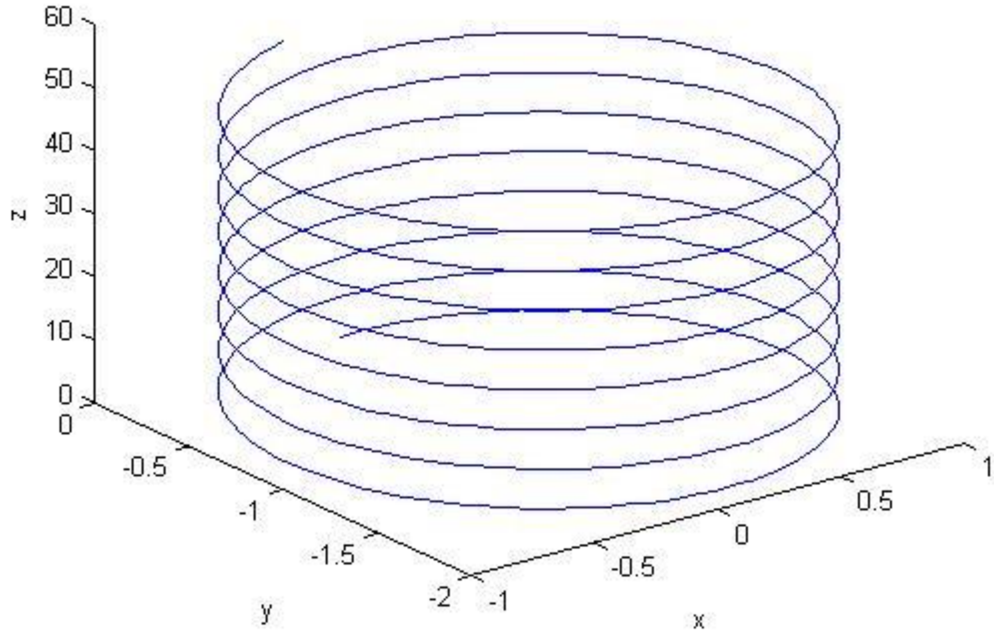
CASE 2:
for velocity in both perpendicular and parallel to B:
V in x and z:
B in Z:

Here velocity in x direction would be responsible for the circular motion of the particle.

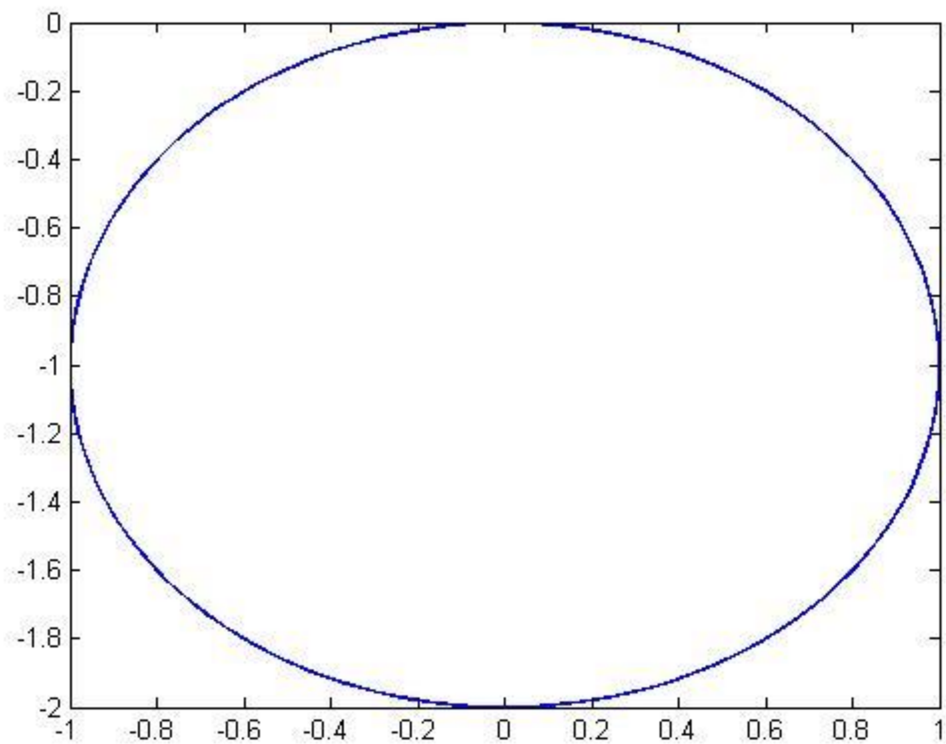
Velocity in z direction would be responsible for the linear motion of the particle.As force is cross product of velocity and magnetic field , B is in z direction so velocity in z direction would not be contributing in that force, hence velocity in z direction remains constant and would be responsible for the linear motion of the particle.

Here circular motion of +ve and -ve charges would be opposite whereas , velocity in z direction remains same so both will move upwards.

for +ve q:

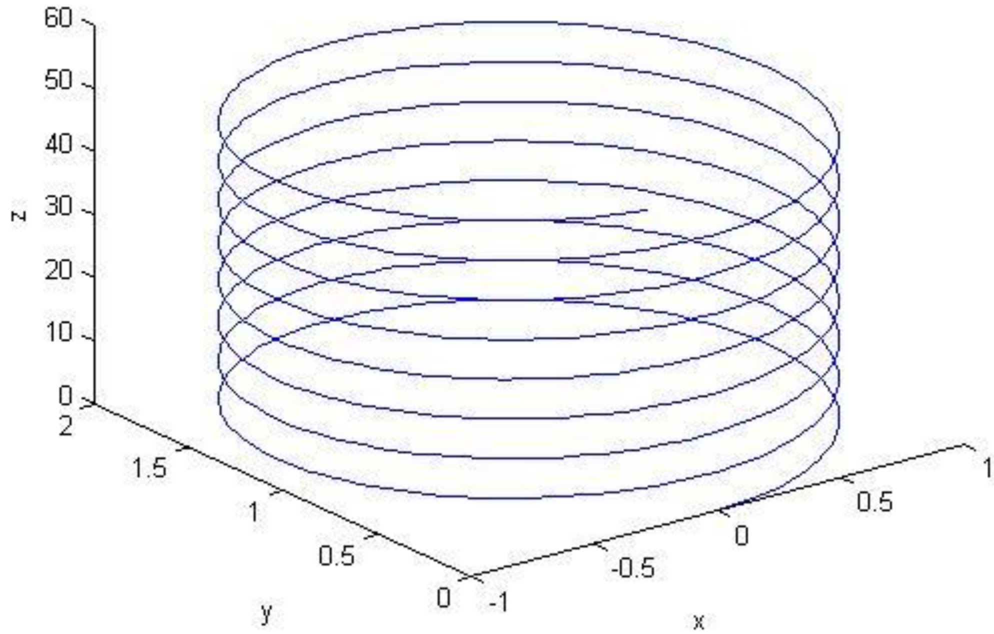


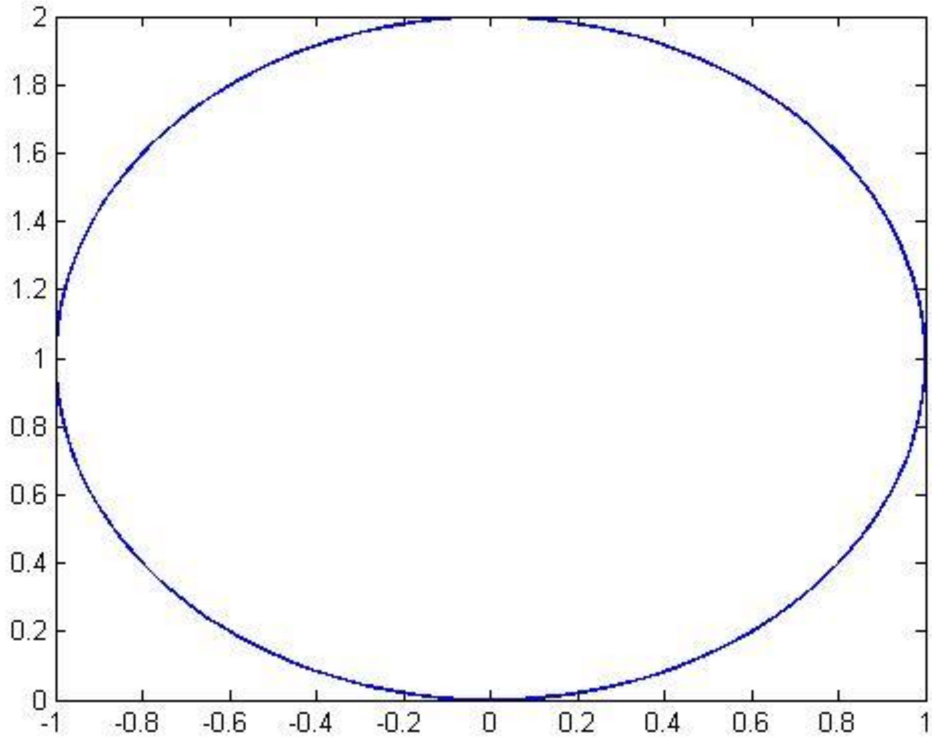
60
50
40
30
20
10
0
z
0
-0.5
-1
-1.5
-2
y
-1
-0.5
0
0.5
1
x



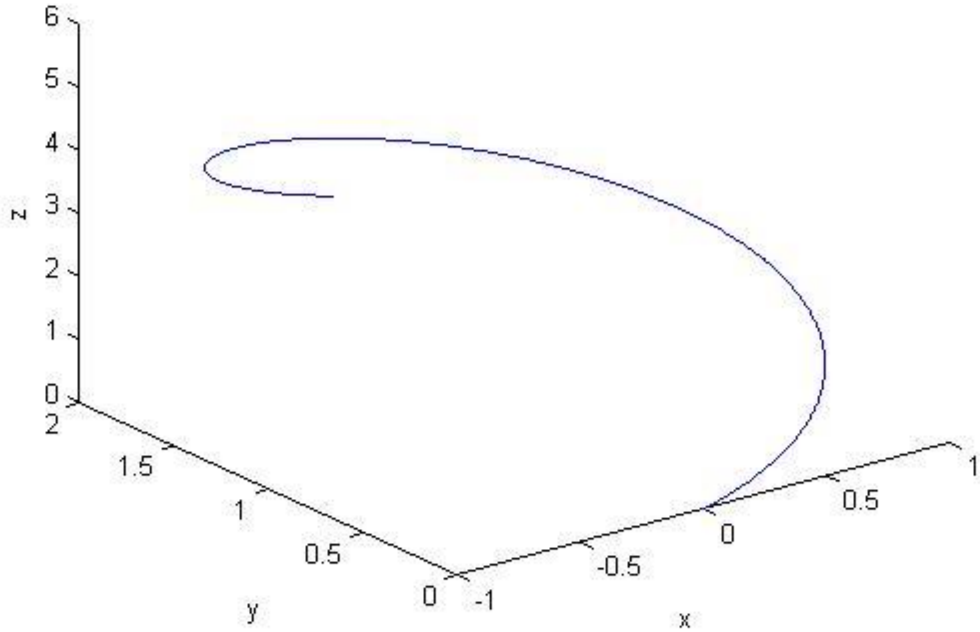
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
-1.6
-1.8
-2
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1

for -ve q:::

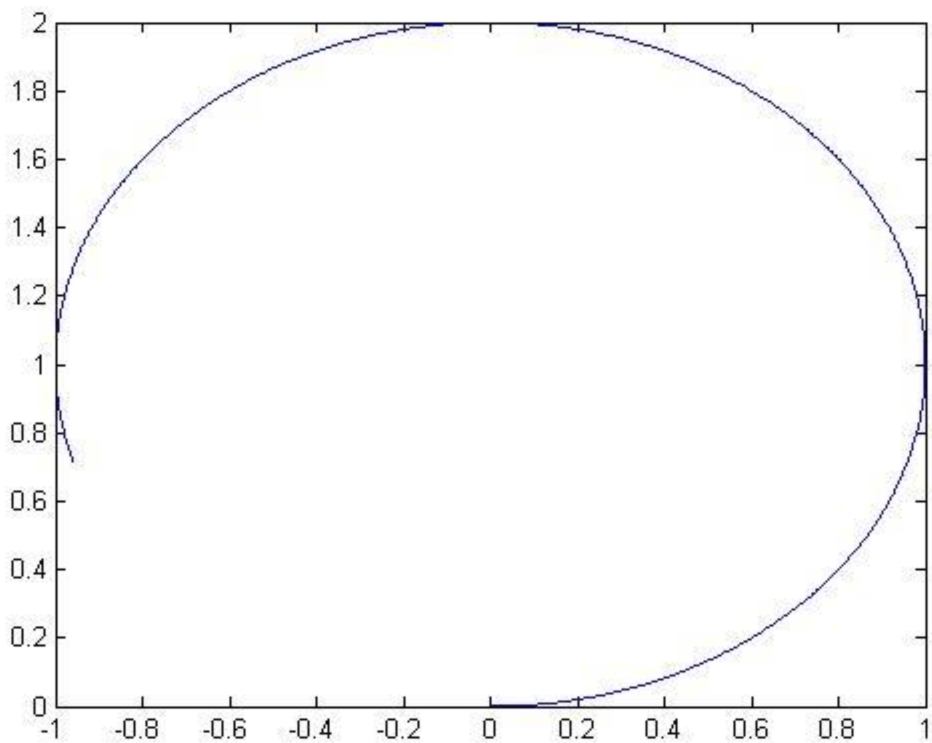




Next graph is the same, we just decreased the time for computation to show its direction.



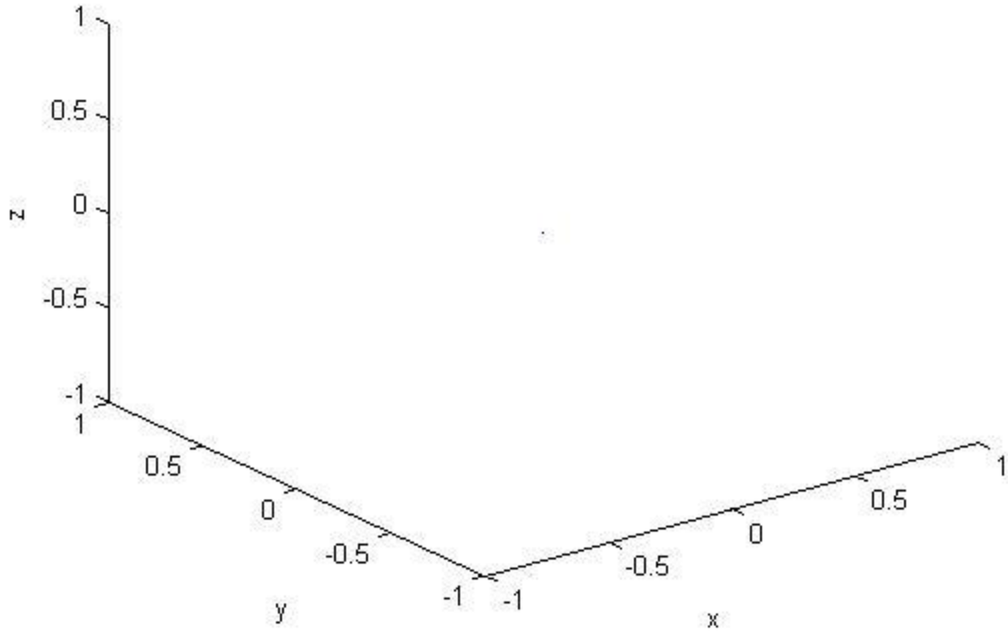
6
5
4
3
2
1
0
z
2
1.5
1
0.5
0
y
-1
-0.5
0
0.5
1
x



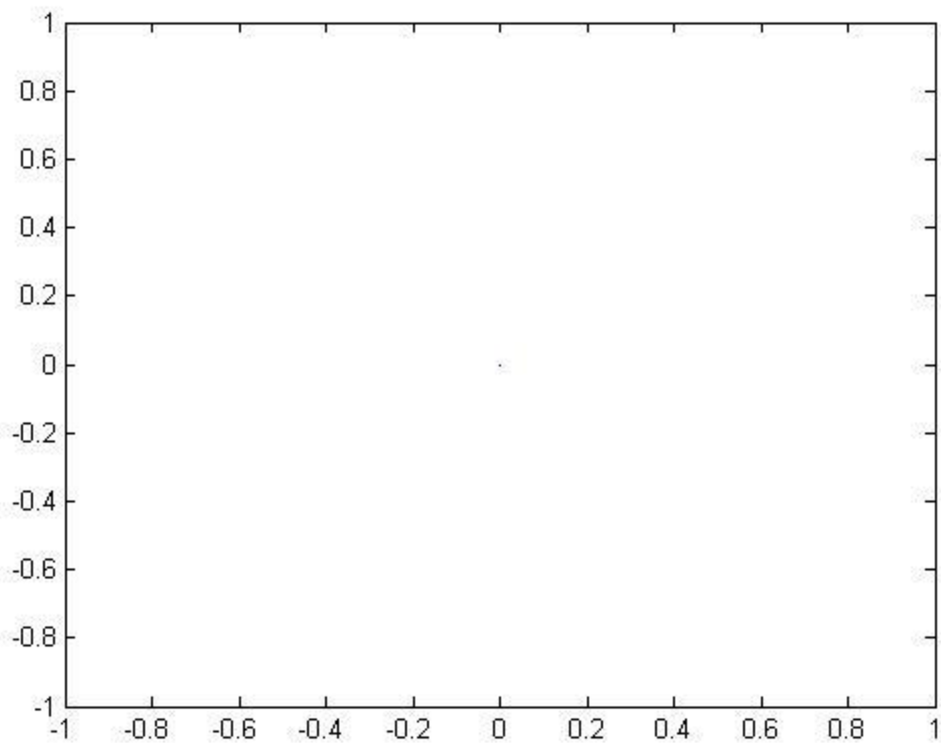
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1

CASE 3:
for V=0;
magnetic field =0:

When both velocity and magnetic field are zero or only velocity is zero , particle will remain on its position (stationary). As force is cross product of velocity and magnetic field , for
ce is zero , hence particle has no acceleration , hence particle would have its initial velocity throughout the time taken ,but initial velocity is zero so particle will remain stationary.



z
y
x
1
0.5
0
-0.5
-1

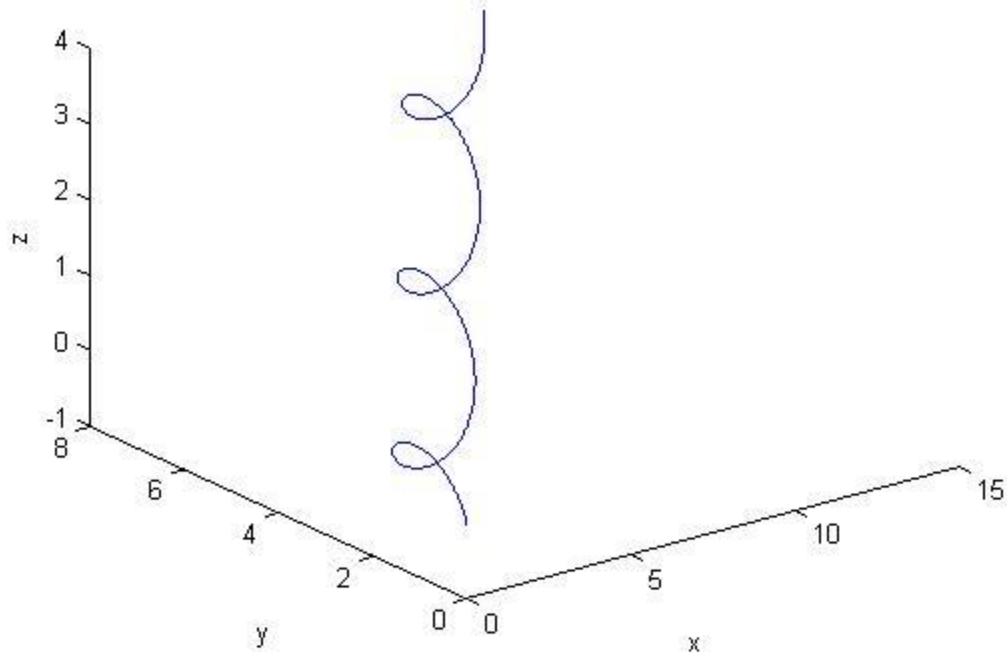


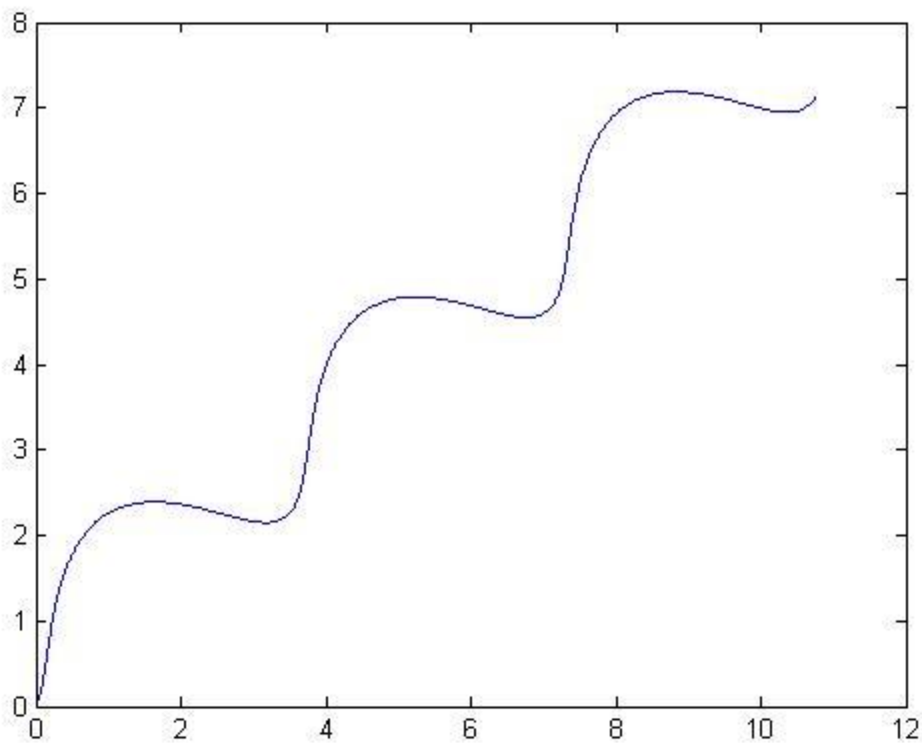
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1

CASE 4:
for vin all dir:
for b in all dir:

v=(1,2,3)
B=(3,2,1)

Here velocity in direction of B will be responsible for linear motion. Velocity not in direction of B would be responsible for circular motion.

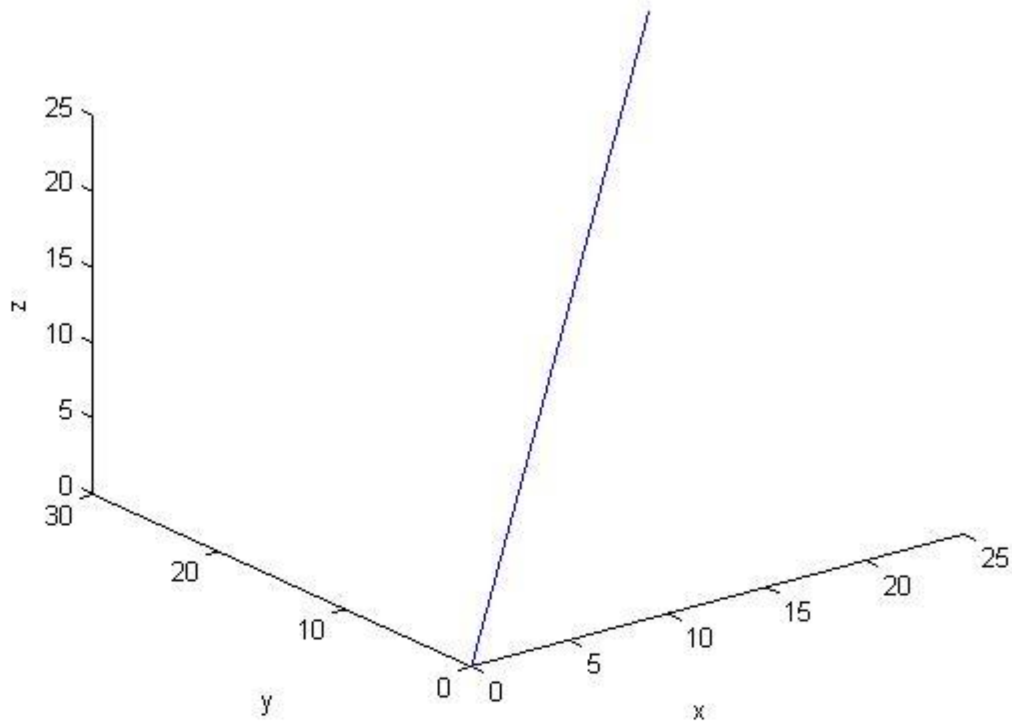




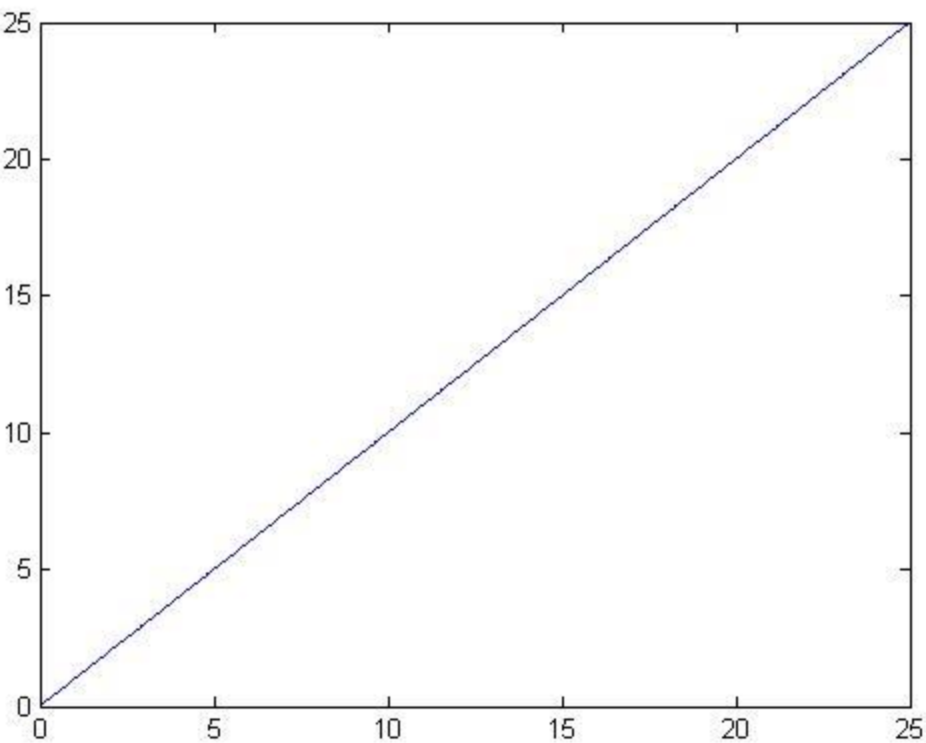
CASE 5:

v(5,5,5)
B(5,5,5)

When velocity and magnetic field both are in same direction or magnetic field is zero , force would be zero, hence acceleration would be zero , hence particle will have same initial velocity throughout the time. Hence the graph would be straight line.



25
20
15
z
10
5
0
30
20
10
y
0
0
5
10
15
20
25
x



25
20
15
10
5
0
0
5
10
15
20
25

If we change initial position , the graph will just shift from origin to those coordinates.

1B

code:

```
clear;close all;
global B;
global mass;
global E;
B=zeros(1,3);
V=zeros(1,3);
E=zeros(1,3);
B(1,1)=0;
B(1,2)=0;
B(1,3)=5;
mass=1;
E(1,1)=0;
E(1,2)=0;
E(1,3)=0;
global q;
q=1;
timescale=10;
dt=timescale/1000;


tstart=0;
tfinal=5*timescale;

u0=zeros(6,1);
u0(1)=0;  % x
u0(2)=0;   % y
u0(3)=0;  % z
u0(4)=5;   % vx
u0(5)=0; % vy
u0(6)=0;  % vz

[t,u]=ode45(@rhsl4p1a,[tstart:dt:tfinal],u0);

x=u(:,1);
y=u(:,2);
z=u(:,3);
```

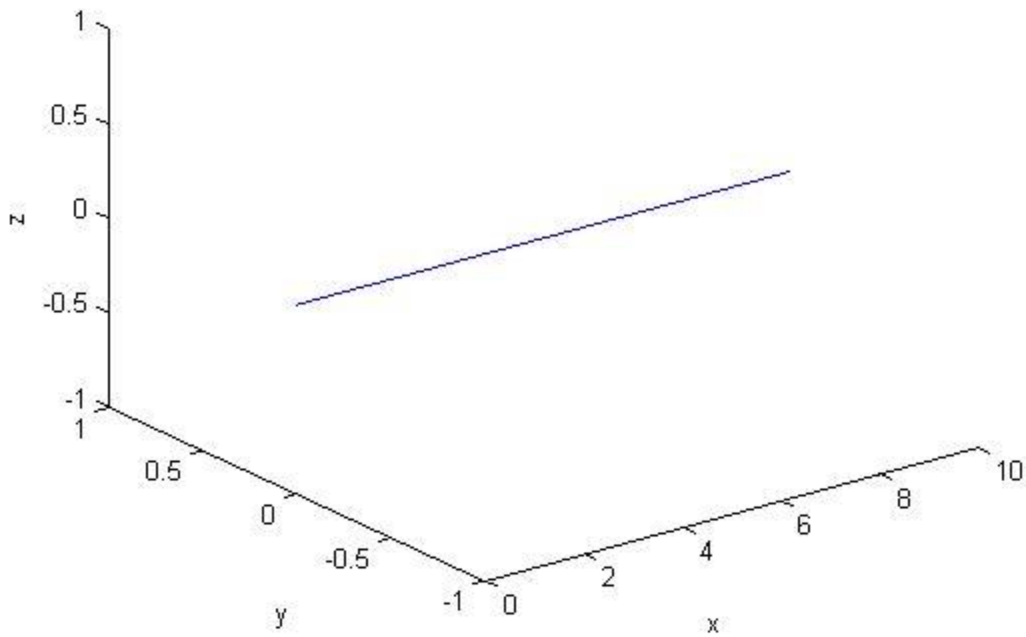
```
vx=u(:,4);
vy=u(:,5);
vz=u(:,6);
a=[x y z];
plot (x,y)
figure
plot3(x,y,z);
xlabel('x');
ylabel('y');
zlabel('z');
```

RHS:

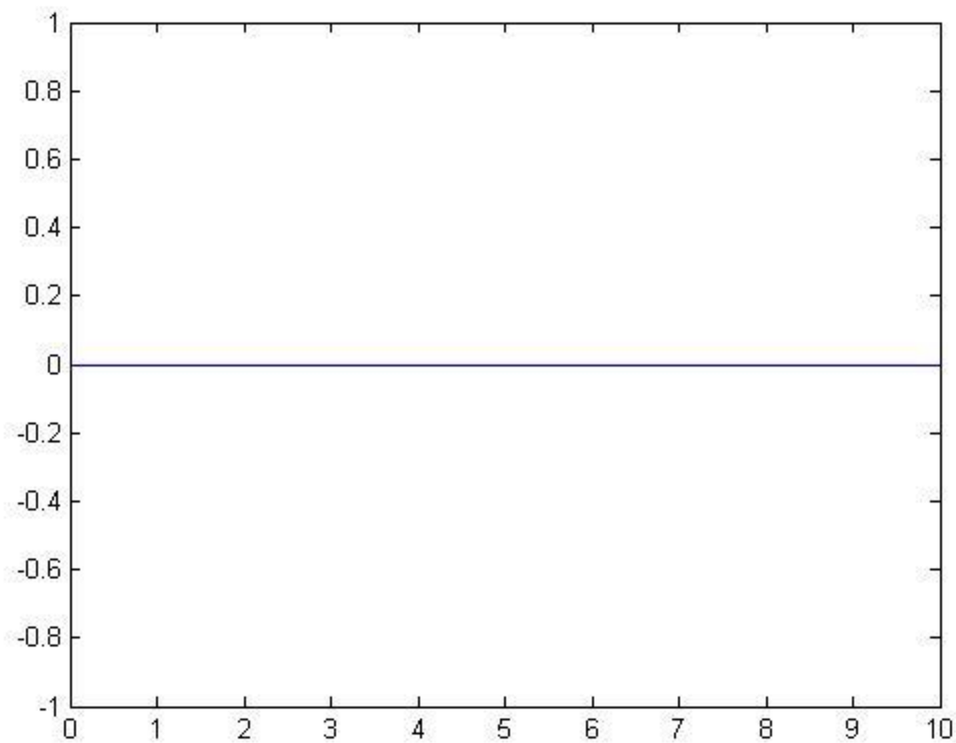
```
function F=rhsl4p1a(t,u)

global B;
global mass;
global E;
global q;

F=zeros(6,1);
a=[u(4) u(5) u(6)];
force=q*E+ q*cross(a,B);
%B(1,3)=B(1,3)+0.01*u(1);
F(1)=u(4);
F(2)=u(5);
F(3)=u(6);
F(4)=force(1,1)/mass;
F(5)=force(1,2)/mass;
F(6)=force(1,3)/mass;
```

CASE 1:
for v0=e0/b0
v=(1,0,0)
E=(0,5,0)
B=(0,0,5)

Here , as v0x= E0y/B0z ;
F = q{E0y - V0x*B0z }
So force will become zero , hence particle will continue its motion with same initial velocity.



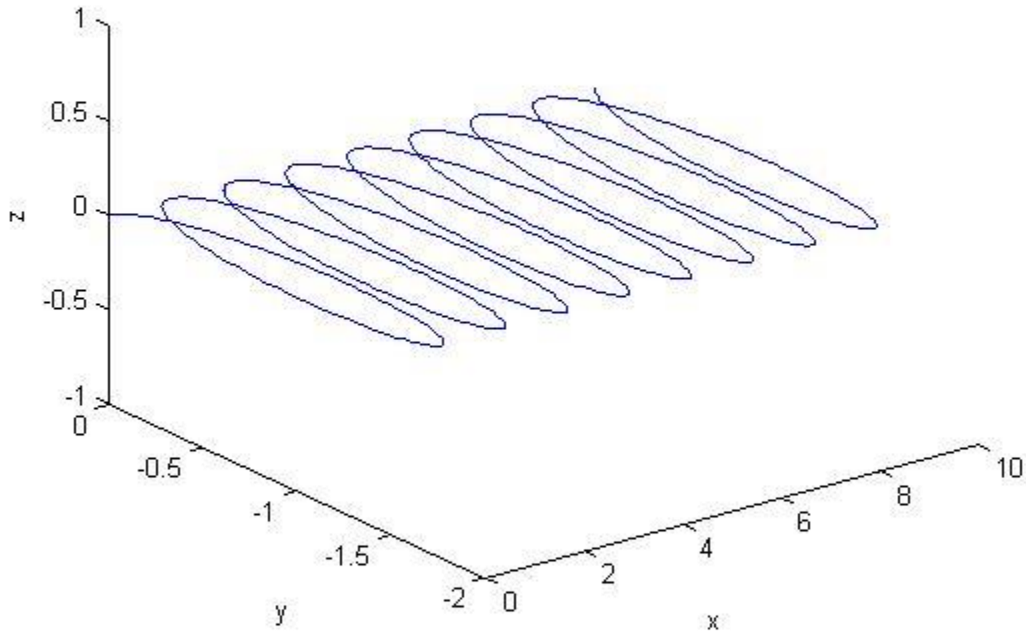
1
0.5
0
-0.5
-1
z
1
0.5
0
-0.5
-1
y
0
2
4
6
8
10
x



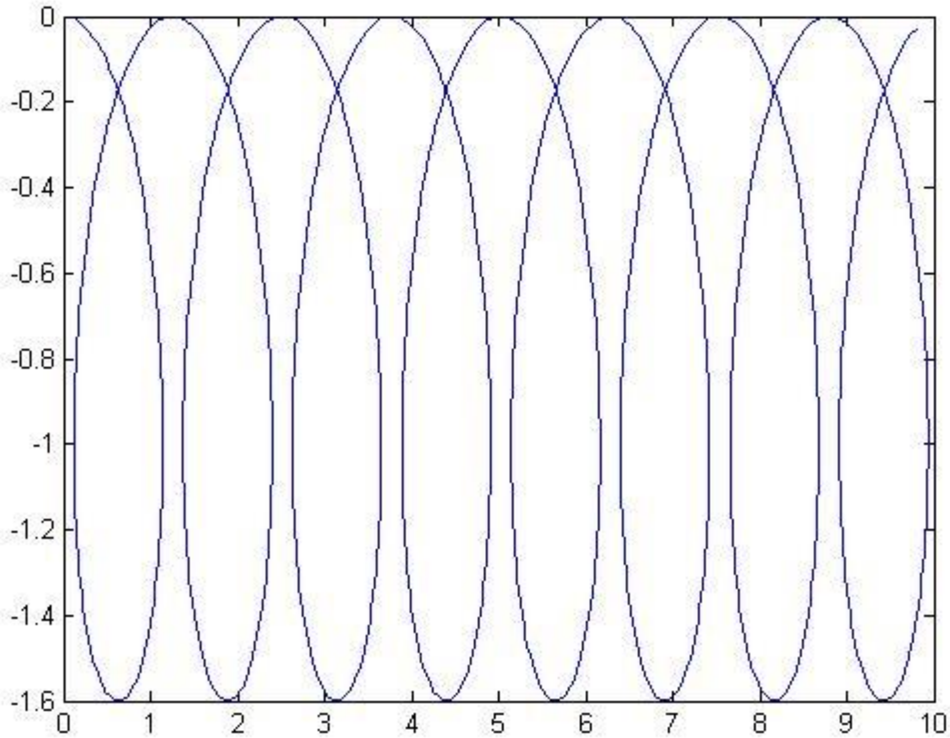
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
0
1
2
3
4
5
6
7
8
9
10

CASE 2:

for +ve q
v=(5,0,0)
E=(0,5,0)
B=(0,0,5)

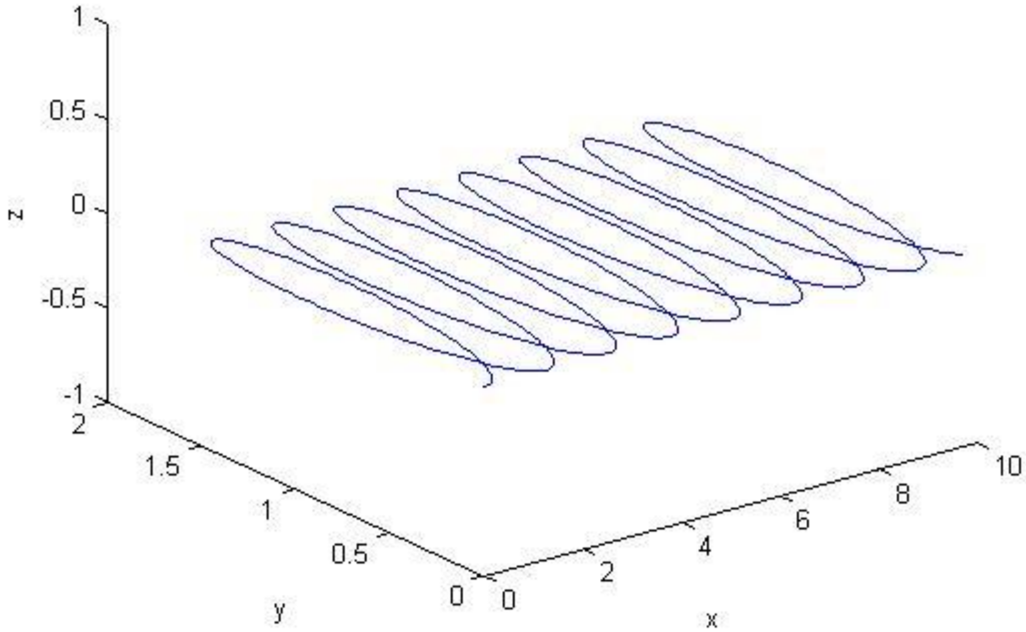


Here , circular motion of the particle is due to magnetic field and drift is due to electric field.

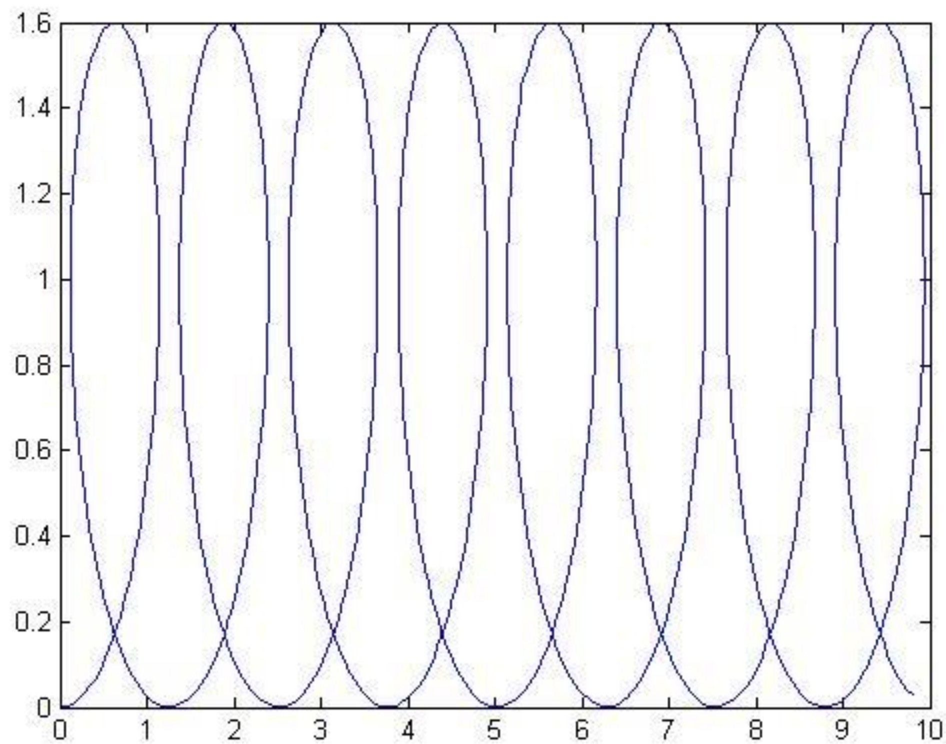


for -ve q

+ve and -ve charge will move in opposite directions i.e. one in clockwise and other in anticlockwise.



1
0.5
0
-0.5
-1
z
2
1.5
1
0.5
0
y
0
2
4
6
8
10
x

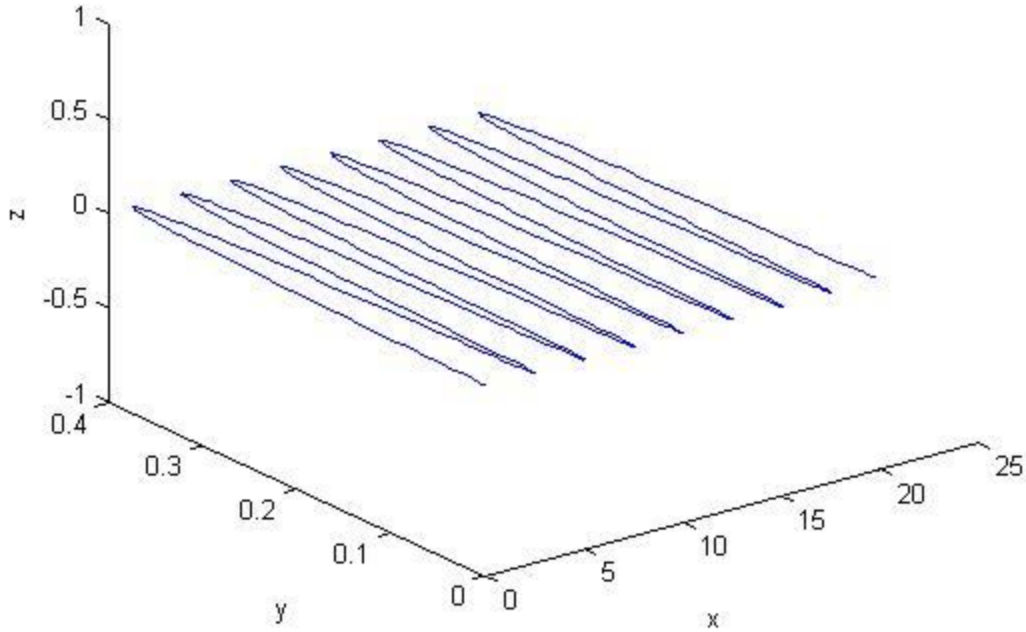


1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
1
2
3
4
5
6
7
8
9
10

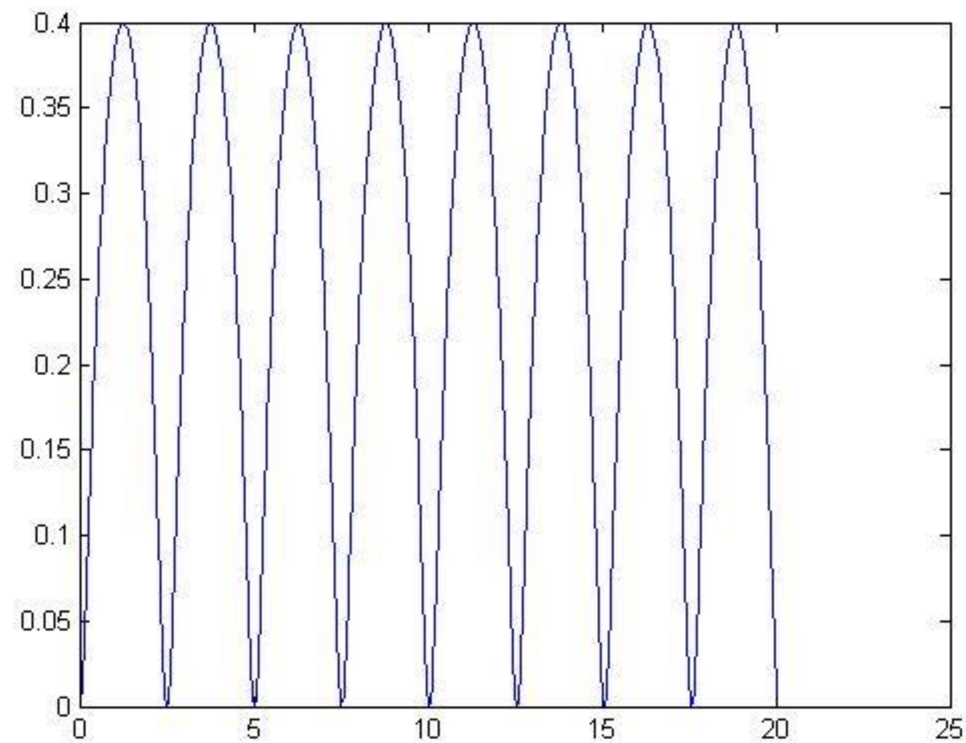
CASE 3:

for electric field big enough not to make the motion circular anymore

When the magnitude of Electric field increases, the overall contribution of it in force increases. Hence if we see the trajectory, it would be less circular(due to B) and more drift(due to E). As we keep on increasing the value of E , we can see lesser and lesser circular motion.



1
0.5
0
-0.5
-1
z
0.4
0.3
0.2
0.1
0
y
0
5
10
15
20
25
x

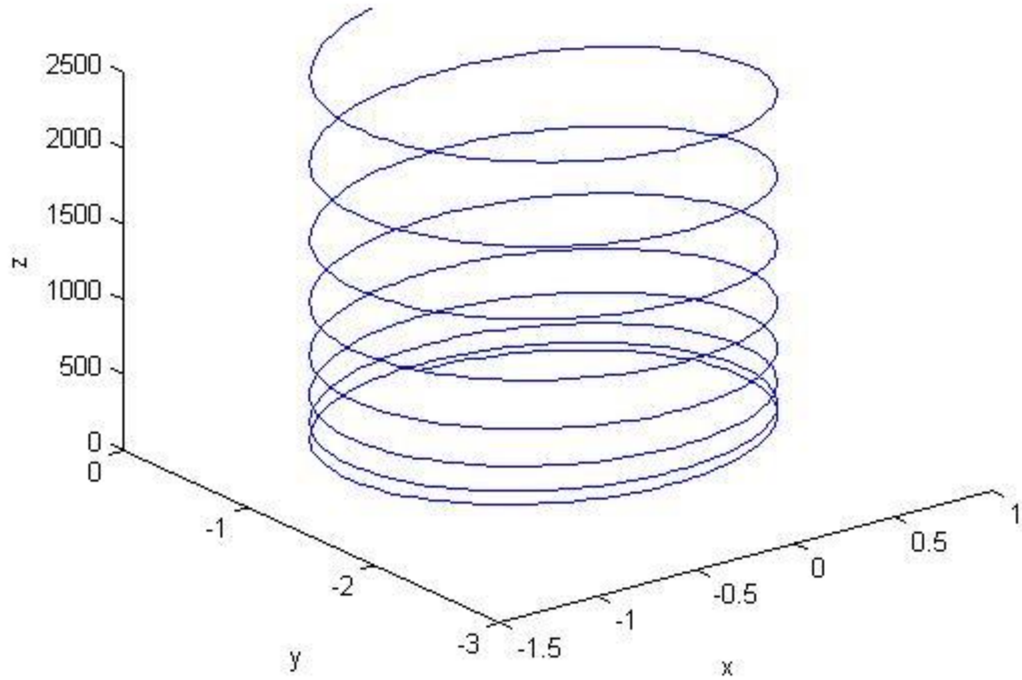


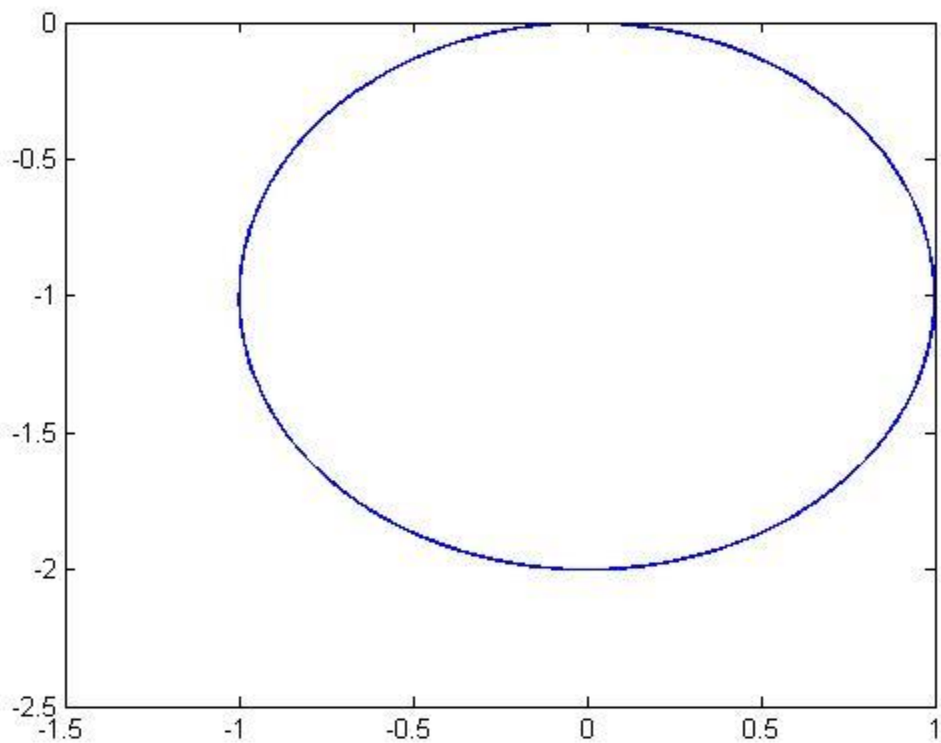
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
5
10
15
20
25

CASE 4:

For V and B to be parallel.

Here, initially B and V are parallel, so B would not be responsible for the initial motion of particle. Only E would be responsible for the initial motion of particle. Now as E acts on it , It changes the velocity of the particle and gradually B starts acting on that particle. Hence both the fields cause further motion. Initially the velocity would be less and it would increase as it moves further


2500
2000
1500
z
1000
500
0
0
-1
-2
-3
y
-1.5
-1
-0.5
0
0.5
1
x


0
-0.5
-1
-1.5
-2
-2.5
-1.5
-1
-0.5
0
0.5
1

1c:

Code:

```
clear;close all;
global B;
global mass;
global E;
B=zeros(1,3);
V=zeros(1,3);
E=zeros(1,3);
B(1,1)=0;
B(1,2)=0;
B(1,3)=5;
mass=1;
E(1,1)=0;
E(1,2)=0;
E(1,3)=0;
global q;
q=1;
timescale=10;
dt=timescale/1000;


tstart=0;
tfinal=5*timescale;

u0=zeros(6,1);
u0(1)=0;  % x
u0(2)=0;   % y
u0(3)=0;  % z
u0(4)=5;   % vx
u0(5)=0; % vy
u0(6)=0;  % vz

[t,u]=ode45(@rhsl4p1a,[tstart:dt:tfinal],u0);

x=u(:,1);
y=u(:,2);
z=u(:,3);

vx=u(:,4);
vy=u(:,5);
vz=u(:,6);
a=[x y z];
plot (x,y)
figure
plot3(x,y,z);
xlabel('x');
ylabel('y');
```

```
zlabel('z');
```

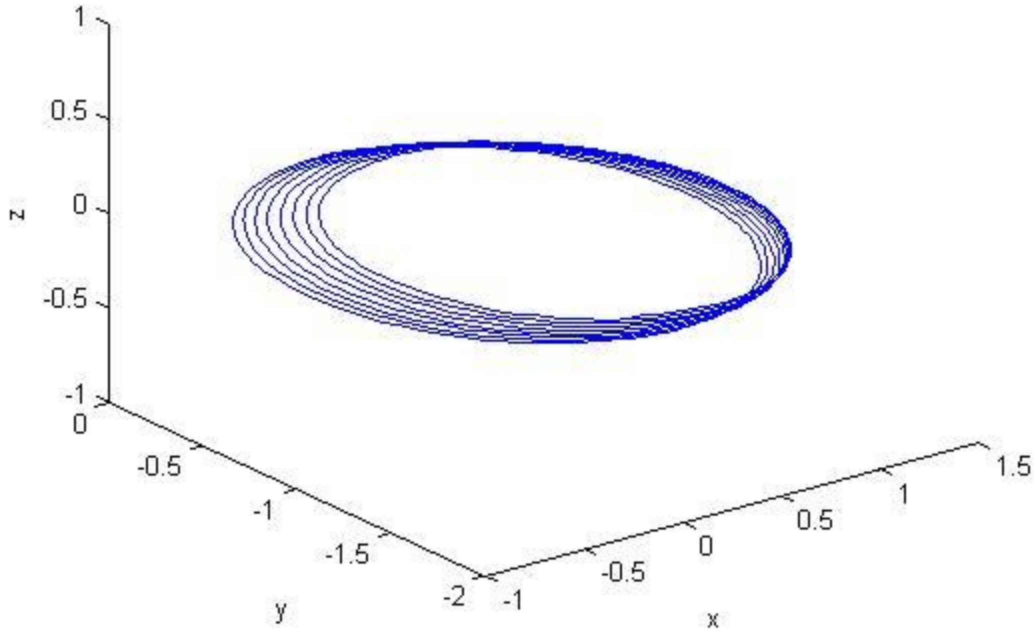
RHS:

```
function F=rhsl4p1a(t,u)

global B;
global mass;
global E;
global q;

F=zeros(6,1);
a=[u(4) u(5) u(6)];
force=q*E+ q*cross(a,B);
B(1,3)=B(1,3)+0.01*u(1);
F(1)=u(4);
F(2)=u(5);
F(3)=u(6);
F(4)=force(1,1)/mass;
F(5)=force(1,2)/mass;
F(6)=force(1,3)/mass;
```

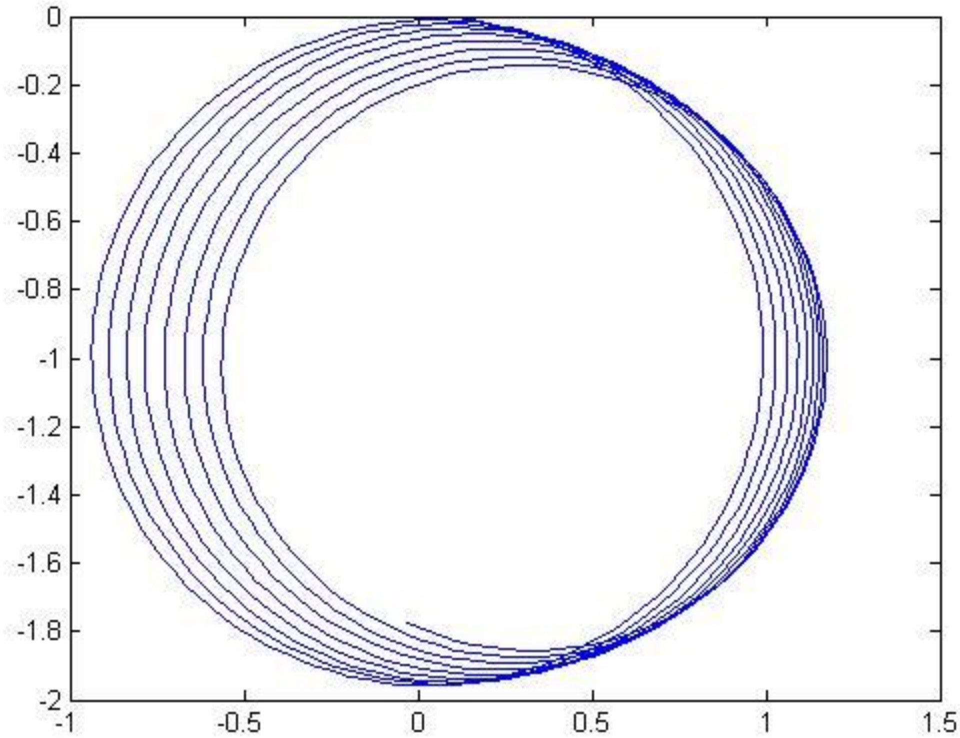
Static and non uniform magnetic field -> changes with position, but remains constant at one position.

CASE 1:

for v=(5,0,0)
B at (0,0,0)=(0,0,5);
and Bz is increasing with the increase in X direction:

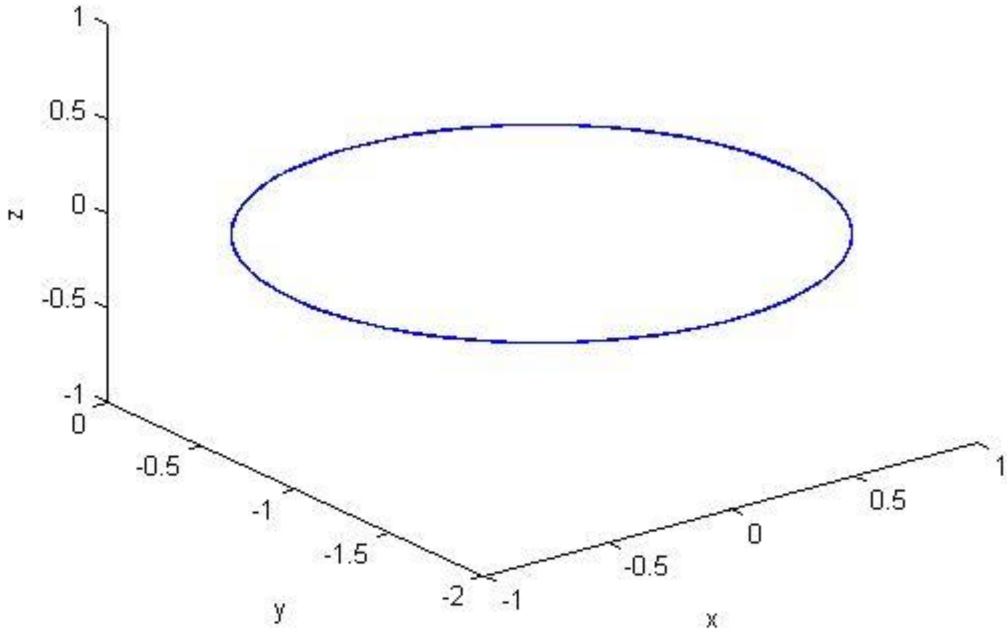


We know that as B increases , force and acceleration increases. But we know the fact that as the value of acceleration increases radius of that circular motion decreases. So, the position where acceleration is more i.e. B is more , radius of the circular motion is less and vice versa. Hence in this case circle shifts in the direction of increasing B.

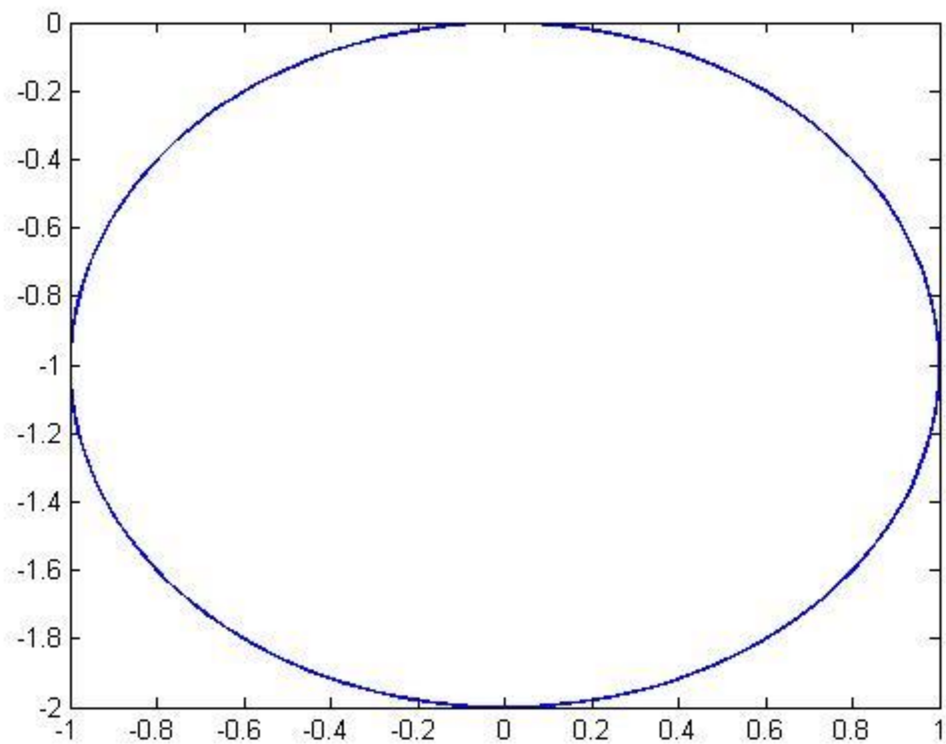


CASE 2:
for v=(5,0,0)
B at (0,0,0)=(0,0,5);
and Bz is increasing with the increase in its (Z) direction:

Here our motion is in XY plane , and B is increasing in Z direction , so it would not affect the trajectory as particle's motion is restricted to XY plane. Trajectory would remain circular.



1
0.5
0
-0.5
-1
z
0
-0.5
-1
-1.5
-2
y
-1
-0.5
0
0.5
1
x



0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
-1.6
-1.8
-2
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1

CASE 3:

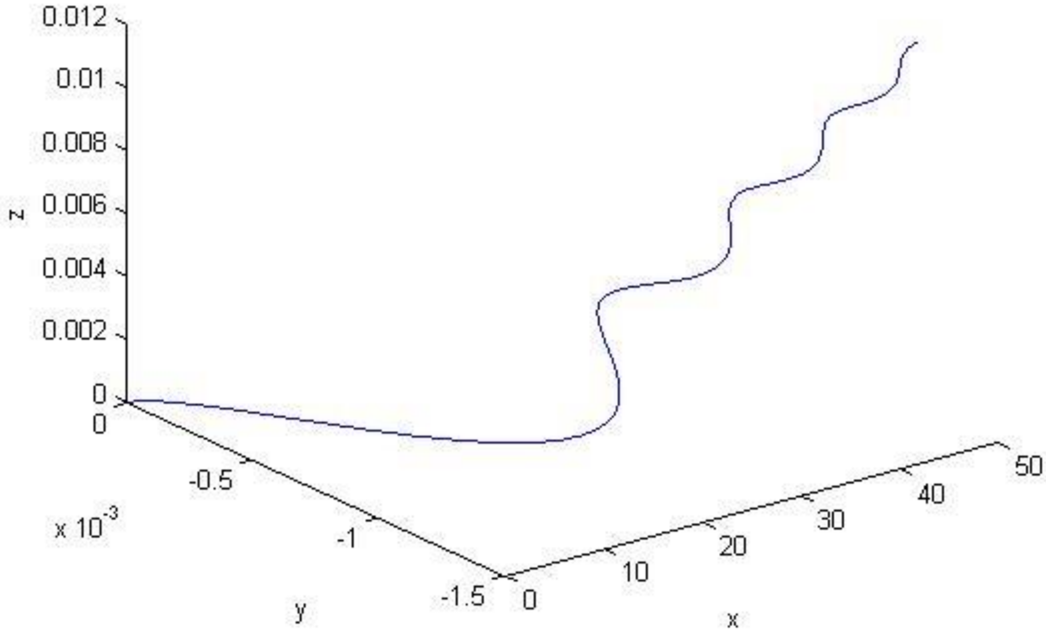
for v=(5,0,0)
B at (0,0,0)=(0,0,5);
and Bz is increasing with the increase in its (Z) direction:and initial position is also (0,0,1)

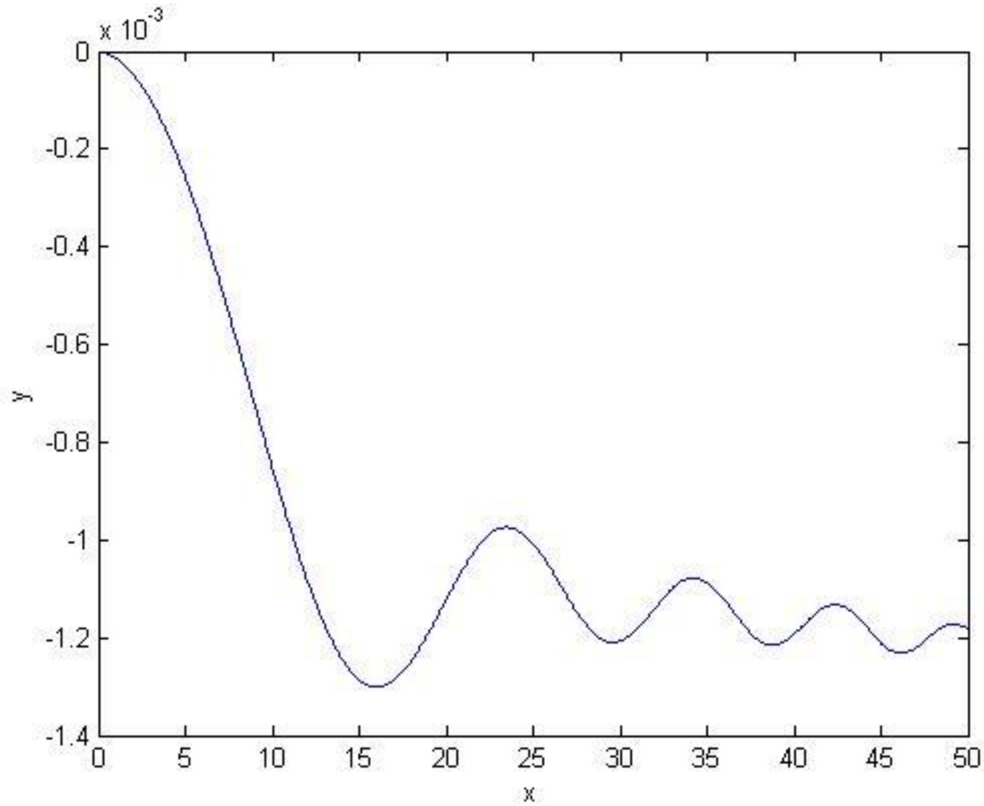
Here graph would remain same as the above graph , except it would shift its z position from (0,0,0) to (0,0,1) because the value of B at point (0,0,1) will remain constant.

CASE 4:

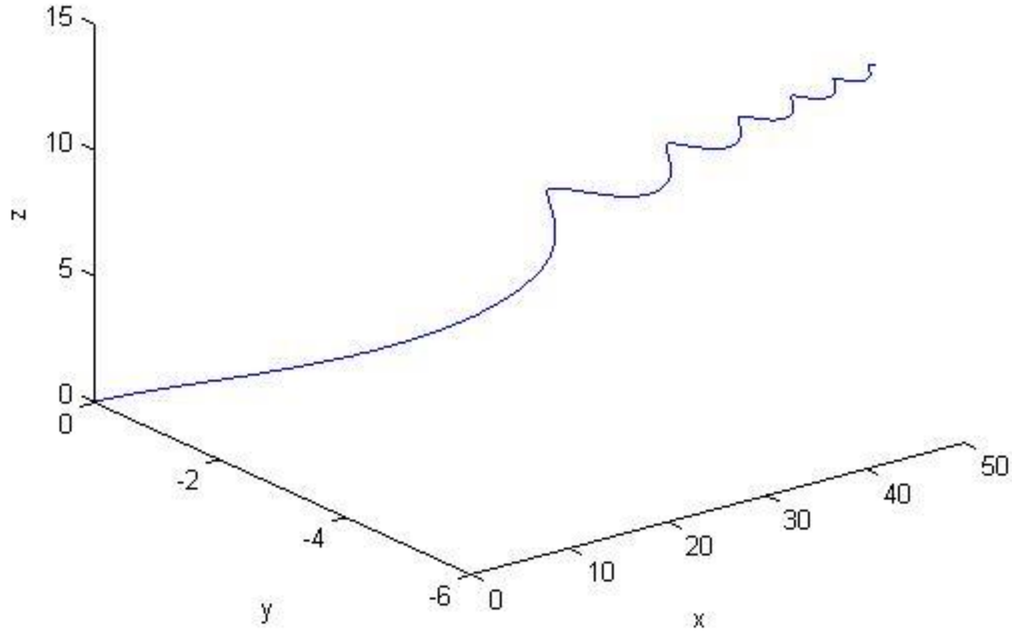
B is zero at center : and increasing with x,y and z:
initial position at (0,0,0)

B is increasing in x direction and velocity also in x direction.

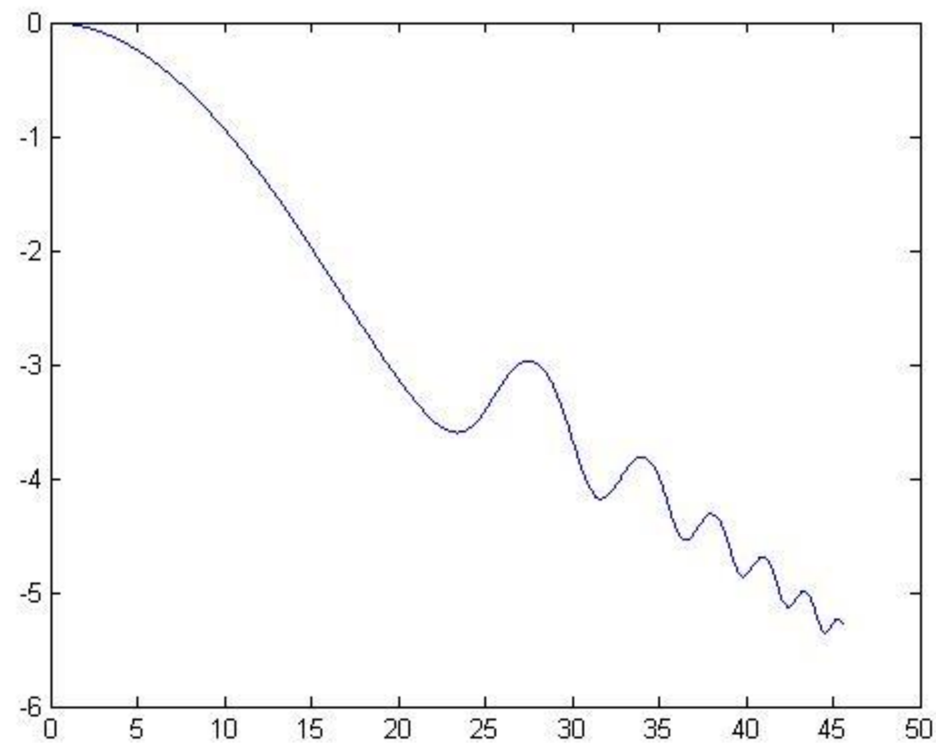

0.012
0.01
0.008
0.006
0.004
0.002
0
z
0
-0.5
-1
-1.5
x 10^-3
y
0
10
20
30
40
50
x


x 10^-3
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
y
0
5
10
15
20
25
30
35
40
45
50
x

CASE 5:
very little magnitude at origin.and then gradually increasing :



15
10
5
0
z
0
-2
-4
-6
y
0
10
20
30
40
50
x



0
-1
-2
-3
-4
-5
-6
0
5
10
15
20
25
30
35
40
45
50

We know that circular motion of particle is due to B , so when the value of B is less, the motion would be less circular(i.e.more radius) , and when value of B increases ,the motion would be more circular (i.e.less radius)
So here the motion gradually becomes more circular when we move forward in direction of increasing velocity.

1D:
Code:
Code:

```
clear;close all;
global B;
global mass;
global E;
B=zeros(1,3);
V=zeros(1,3);
E=zeros(1,3);
B(1,1)=0;
B(1,2)=0;
B(1,3)=5;
mass=1;
E(1,1)=0;
E(1,2)=0;
E(1,3)=0;
global q;
q=1;
timescale=10;
dt=timescale/1000;


tstart=0;
tfinal=5*timescale;

u0=zeros(6,1);
u0(1)=0;  % x
u0(2)=0;   % y
u0(3)=0;  % z
u0(4)=5;   % vx
u0(5)=0; % vy
u0(6)=0;  % vz
```

```
[t,u]=ode45(@rhsl4p1a,[tstart:dt:tfinal],u0);

x=u(:,1);
y=u(:,2);
z=u(:,3);

vx=u(:,4);
vy=u(:,5);
vz=u(:,6);
a=[x y z];
plot (x,y)
figure
plot3(x,y,z);
xlabel('x');
ylabel('y');
zlabel('z');
```

RHS:

```
function F=rhsl4p1a(t,u)

global B;
global mass;
global E;
global q;
global g;
global bint;
g=9.8;
F=zeros(6,1);
a=[u(4) u(5) u(6)];
force=q*E+ q*cross(a,B)+[0  -g*mass 0];
%B(1,3)=bint+.1*u(3);
%B(1,1)=bint+.1*u(1);
%B(1,2)=bint+.1*u(2);
F(1)=u(4);
F(2)=u(5);
F(3)=u(6);
F(4)=force(1,1)/mass;
F(5)=force(1,2)/mass;
F(6)=force(1,3)/mass;
```

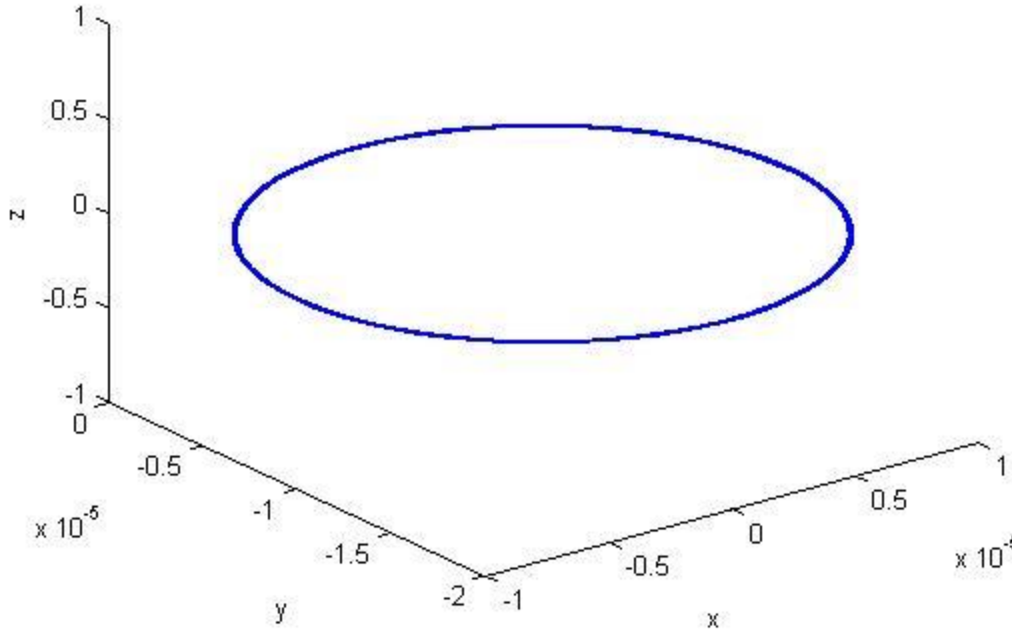
CASE 1:

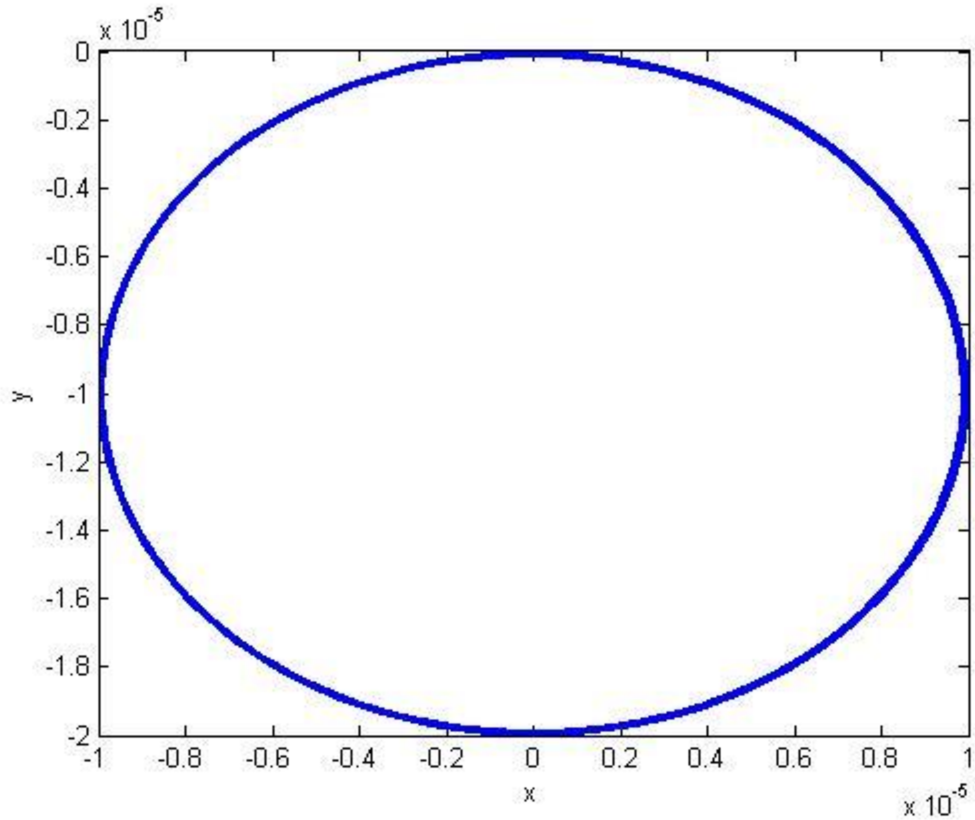
gravity is in Y direction:

B is in Z direction

and initial velocity is in x direction :

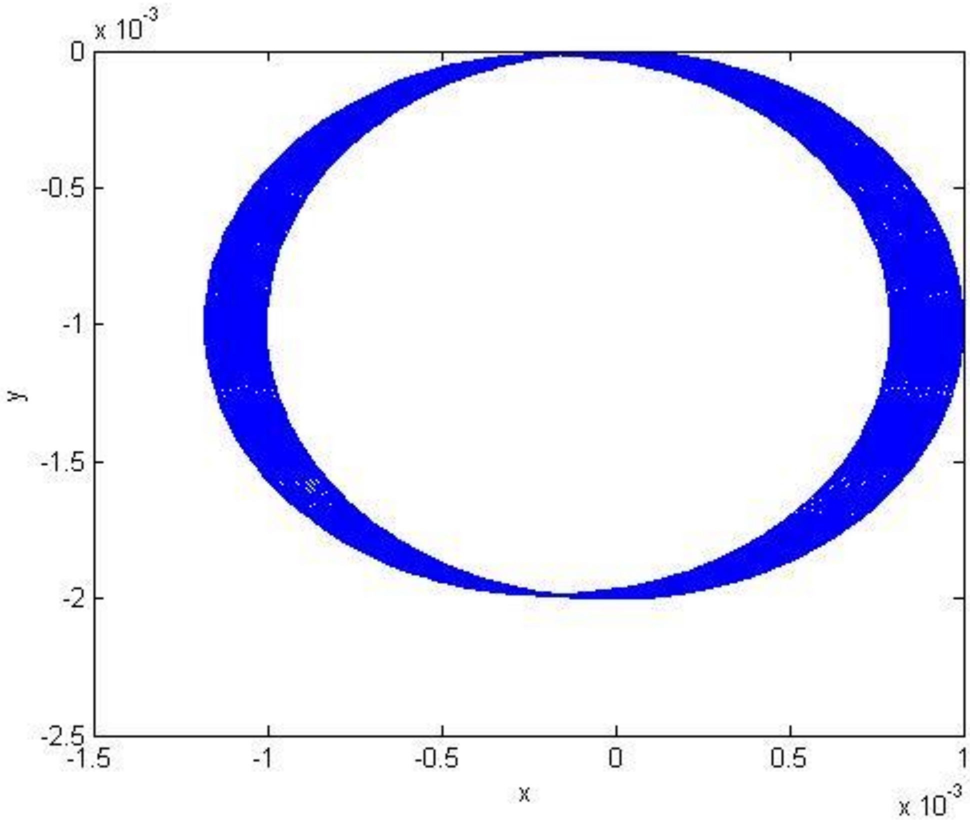
For very small value of mass,value of gravitational force would be negligible in comparison to other forces as they do not depend on mass. So it will be like no gravitation force at all i.e. We can neglect gravitational force.


1
0.5
z
0
-0.5
-1
0
-0.5
x 10-5
-1
-1.5
y
-2
-1
-0.5
0
0.5
1
x 10-5
x


x 10-5
0
-0.2
-0.4
-0.6
-0.8
y
-1
-1.2
-1.4
-1.6
-1.8
-2
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
x
x 10-5

CASE 2:

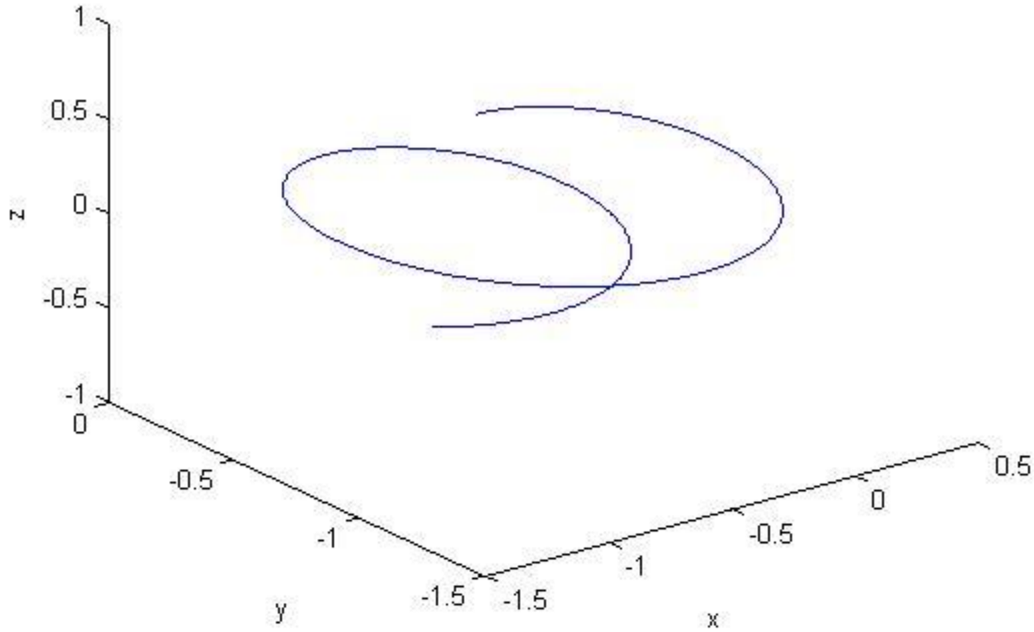
Now for a mass that can significantly increase the value of gravitational force:



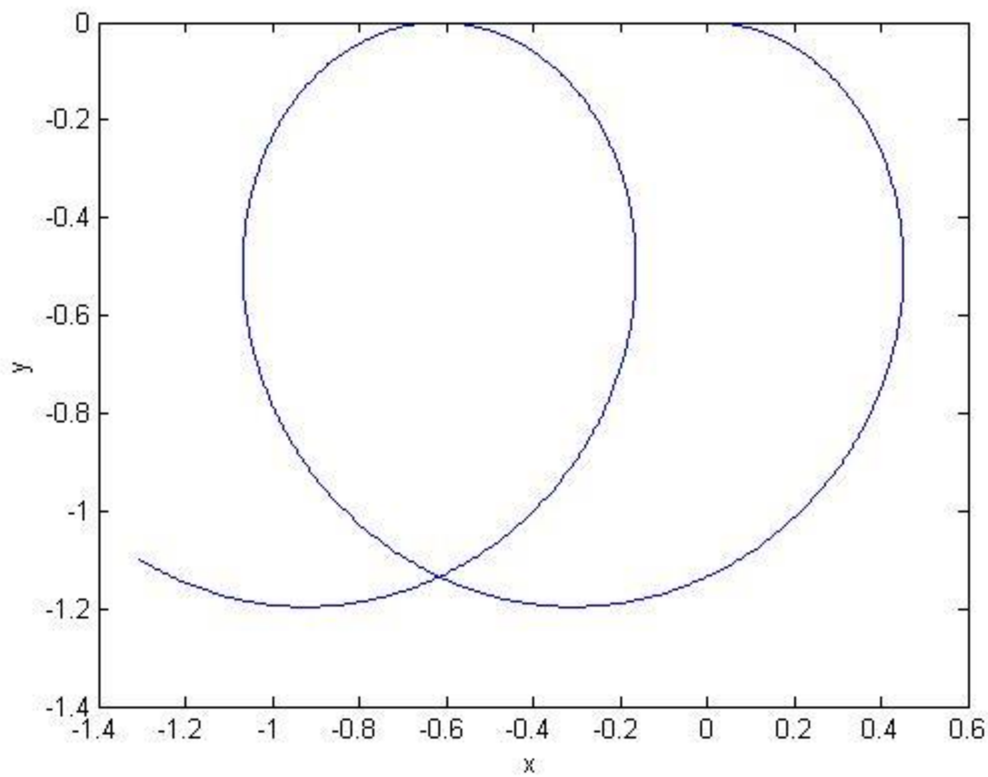
Here we cannot neglect the effect of gravitational field.

CASE 3:

By increasing more the value of mass we get the following graph. It will no more remain negligible and at times it might be the most effective force.



1
0.5
0
-0.5
-1
z
0
-0.5
-1
-1.5
y
-1.5
-1
-0.5
0
0.5
x



0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
y
-1.4
-1.2
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
x

Q:2

Code:

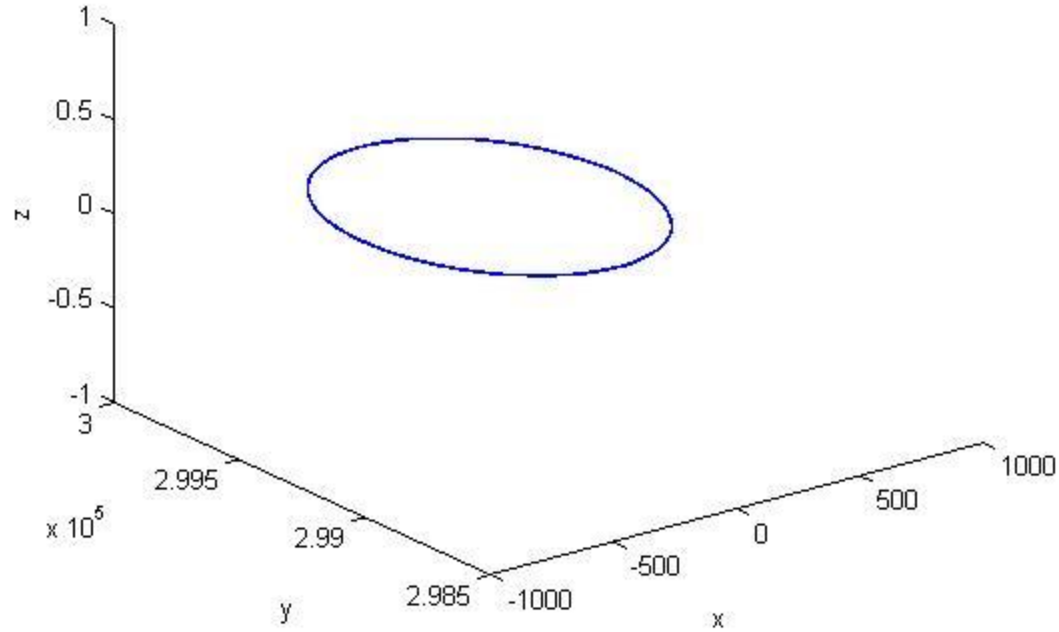
```
clear;close all;
global B;
global mass;
global E;
global bint;
B=zeros(1,3);
V=zeros(1,3);
E=zeros(1,3);
B(1,1)=0;
B(1,2)=0;
B(1,3)=.00005;
bint=.0005;
k=1.3807e-23;
T=300;

mass=9.109e-31;
E(1,1)=0;
E(1,2)=0;
E(1,3)=0;
global q;
q=1.6e-19;
timescale=.00001;
dt=timescale/1000;
tstart=0;
tfinal=timescale;
u0=zeros(6,1);
u0(1)=0;  % x
u0(2)=300000;   % y
u0(3)=0;  % z
u0(4)=(k*T)/mass;   % vx
u0(5)=0; % vy
u0(6)=0;  % vz
[t,u]=ode45(@rhsl4p1a,[tstart:dt:tfinal],u0);
x=u(:,1);
y=u(:,2);
z=u(:,3);
```

```
vx=u(:,4);
vy=u(:,5);
vz=u(:,6);
a=[x y z];
plot (x,y)
xlabel('x');
ylabel('y');
figure
plot3(x,y,z);
xlabel('x');
ylabel('y');
zlabel('z');
```

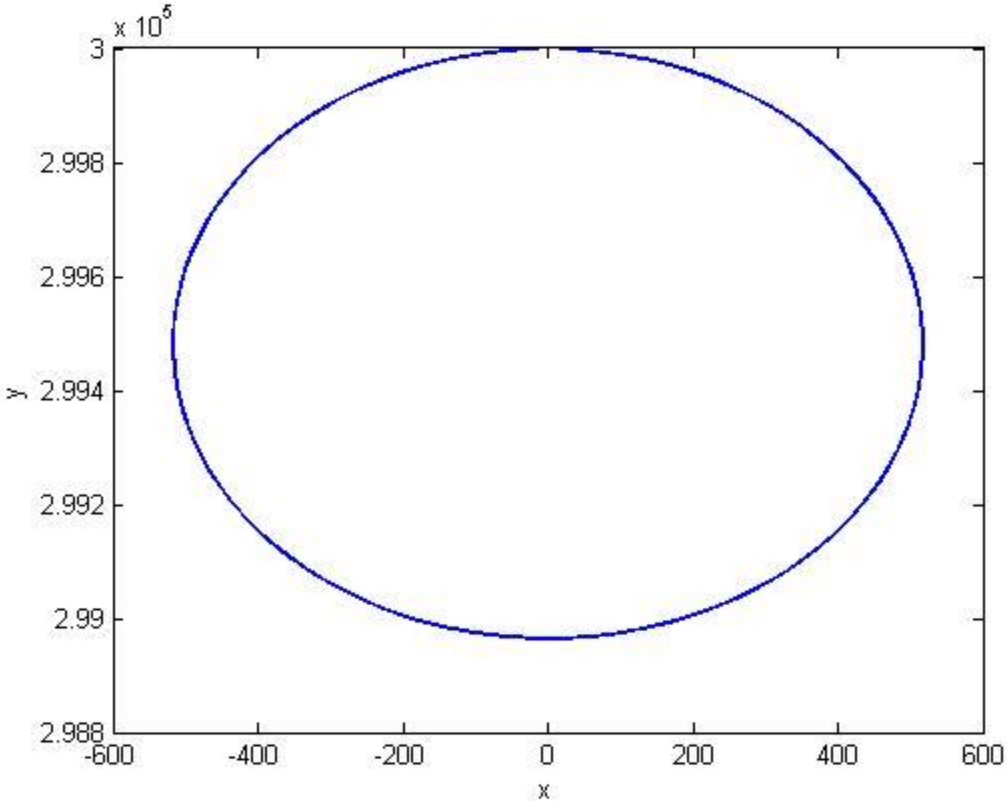
RHS:

```
function F=rhsl4p1a(t,u)

global B;
global mass;
global E;
global q;
global g;
global bint;
g=9.8;
g=g-((g*u(2))/6400000);
F=zeros(6,1);
a=[u(4) u(5) u(6)];
force=q*E+ q*cross(a,B)+[0  -g*mass 0];
%B(1,3)=bint+.1*u(3);
%B(1,1)=bint+.1*u(1);
%B(1,2)=bint+.1*u(2);
F(1)=u(4);
F(2)=u(5);
F(3)=u(6);
F(4)=force(1,1)/mass;
F(5)=force(1,2)/mass;
F(6)=force(1,3)/mass;
```

Graph:



1
0.5
0
-0.5
-1
z
3
2.995
2.99
2.985
x 10^5
y
-1000
-500
0
500
1000
x



x 10^5
3
2.998
2.996
2.994
2.992
2.99
2.988
y
-600
-400
-200
0
200
400
600
x

An electron in a static and uniform magnetic field will move in a circle due to the Lorentz force.
Here 2 forces act on the particle : magnetic and gravitational. But the value of Gravitational field is very less compared to the value of magnetic field , hence we cannot see much effect of gravitational field in its trajectory.

Here the cyclotron radius is 0.0104m and cyclotron frequency is 1398490 Hz i.e. 1.4e6.

Our computation matches with the analytical solution.

Q3:

Here the electron also moves in Y direction by the force of gravity. but mass of the electron is too small so the changes are very small:

The drift velocity is

$$\vec{v}_g = \frac{m}{q}\frac{\vec{g} \times \vec{B}}{B^2}$$

Because of the mass dependence, the gravitational drift for the electrons can normally be ignored.
The dependence on the charge of the particle implies that the drift direction is opposite for ions as for electrons, resulting in a current. In a fluid picture, it is this current crossed with the magnetic field that provides that force counteracting the applied force.

Hence if we calculate our value of gravitational drift velocity it turns out to be 1.16e-6.

And if we calculate it with computation we get the same answer.