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Answer 1:-

The equation of motion for a particle of charge q, under the action of the Lorentz force **F** due to electric (**E**) and magnetic induction (**B**) fields, can be written as

$$m\frac{dv}{dt} = \mathrm{q.(E + (v \times B))}$$

MATLAB Code:-

Main Function

```
clear;
global B;
global E;
global cnst;
display();
B = input('Enter Megnatic Field [Bx By Bz] - ');
E = input('Enter Electric Field Field [Ex Ey Ez] - ');
q=1;
m=1;
cnst = (q/m);
t1=0;
dt=1e-2;
t2=30;
v = input('Enter initial Velocity [Vx Vy Vz] - ');
u0 = [0,0,0,v(1),v(2),v(3)];
[t,u]=ode45(@rhsq1v1,t1:dt:t2,u0);
x = u(:,1);
y = u(:,2);
z = u(:,3);
vx = u(:,4);
vy = u(:,5);
vz = u(:,6);
f1=figure;
plot3(x,y,z);
figure;
plot3(vx,vy,vz);
```

Right Function:-

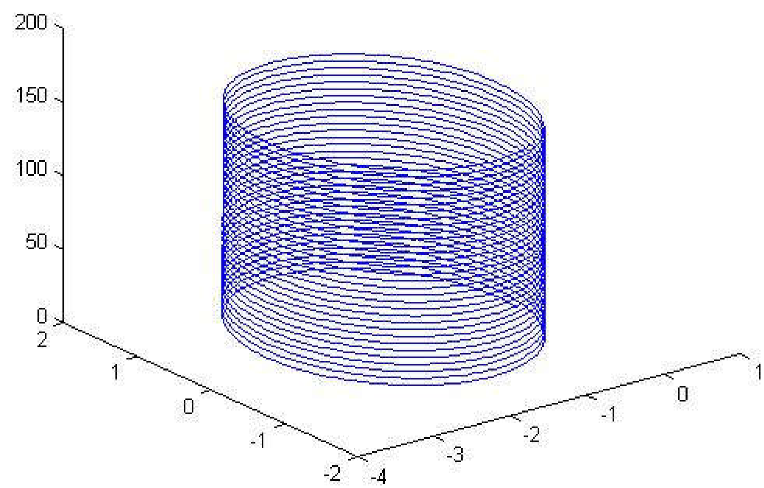
```
function F= rhsq1v1(t,u)
global B;
global E;
global cnst;
F=zeros(length(u),1);
```

```
F(1)=u(4);
F(2)=u(5);
F(3)=u(6);
F(4) = cnst*(E(1) + (u(5)*B(3)-u(6)*B(2)));
F(5) = cnst*(E(2) + (u(6)*B(1)-u(4)*B(3)));
F(6) = cnst*(E(3) + (u(4)*B(2)-u(5)*B(1)));
```

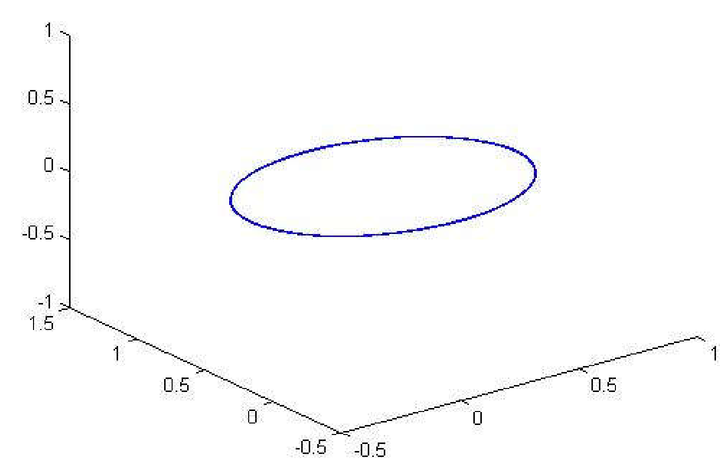
Part 1:-

B (Magnetic Field) – Static & Uniform over the region

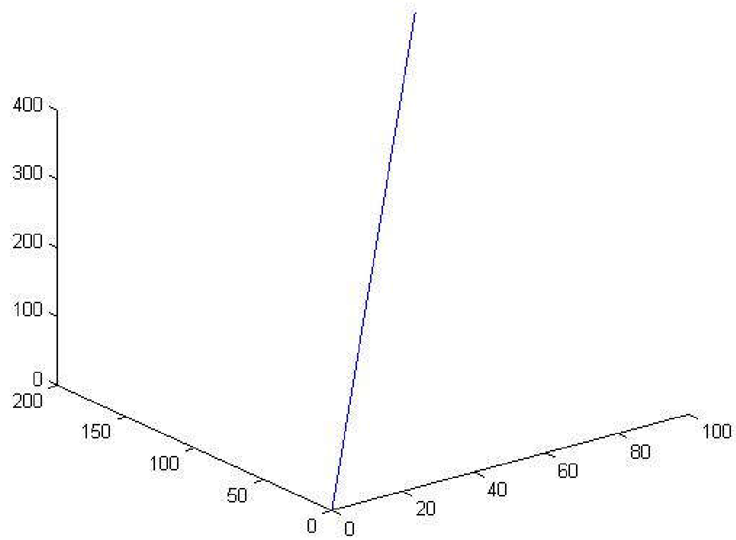
Case 1:-Normal case



Case 2:-If B (Magnetic Field) & V (Velocity) **Perpendicular** to each other (**B⊥V**)



Case 3:- If B (Magnetic Field) & V (Velocity) **Parallel** to each other (**B||V**)

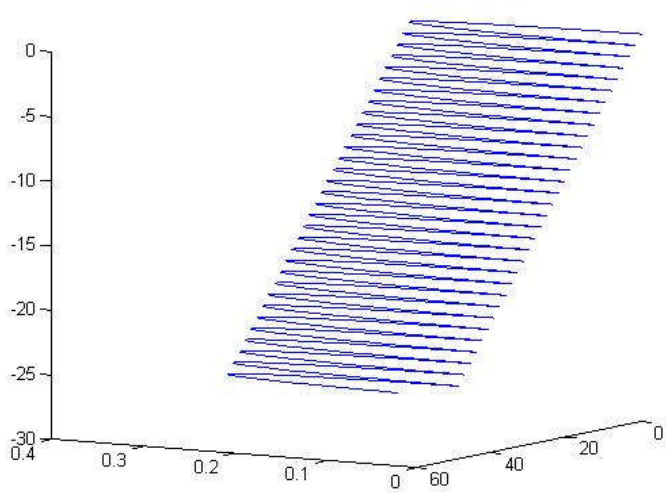


As we can see from all the cases that Uniform & Static Magnetic field will not change the magnitude of the Velocity it only changes the direction of the velocity. Because for the acceleration to change the speed, a component of the acceleration must be in the direction of the velocity. The cross product tells us that the acceleration must be perpendicular to the velocity, and thus can only change the direction of the velocity

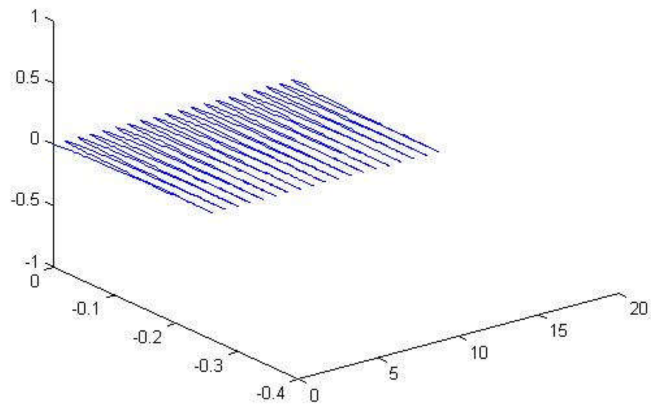
Part 2:-

Static and uniform E (Electric Field) and B (Magnetic Field)

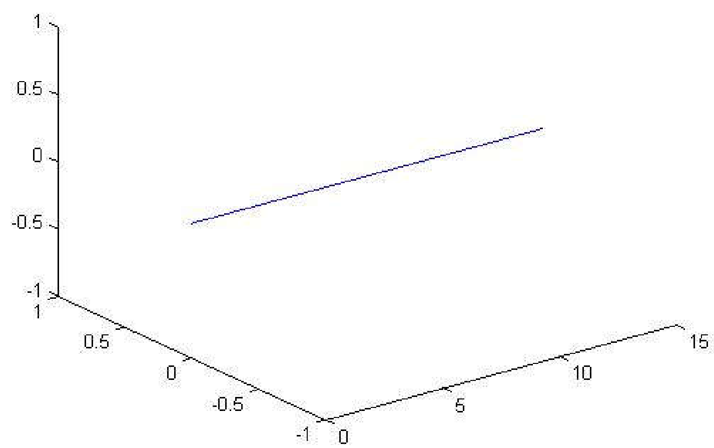
Case 1:- V = $(V_x,0,0)$, B = $(B_x,0,0)$, E = $(0,E_y,0)$



Case 2:- $V = (V_x,0,0)$, $B = (0,0,B_z)$, $E = (0,E_y,0)$



Case 3:- $V = (V_x,0,0)$, $B = (0,0,B_z)$, $E = (0,E_y,0)$ & $V = \frac{E}{B}$



Observation:-

When Magnetic field and Electric field are perpendicular (**B**⊥**E**) to each other then there is No change in magnitude of the velocity. Because constant acceleration depends on the Parallel component of E to B.

Part 3:-

Static and non-uniform B field

MATLAB Code:-

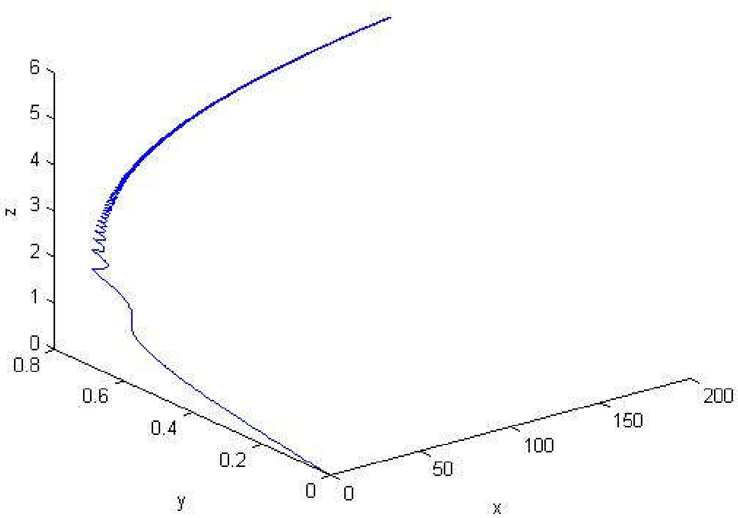
Main Function:-

```
clear;
global cnst;
global B;

B=[0,0,1];
q=1;
m=1;
cnst = q/m;
tstart=0;
dt=1e-2;
tfinal=100;

u0 = [0,0,0,1,1,1];

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

x = u(:,1);
y = u(:,2);
z = u(:,3);
vx = u(:,4);
vy = u(:,5);
vz = u(:,6);

figure;
plot3(x,y,z);
xlabel('x');
ylabel('y');
zlabel('z');
```

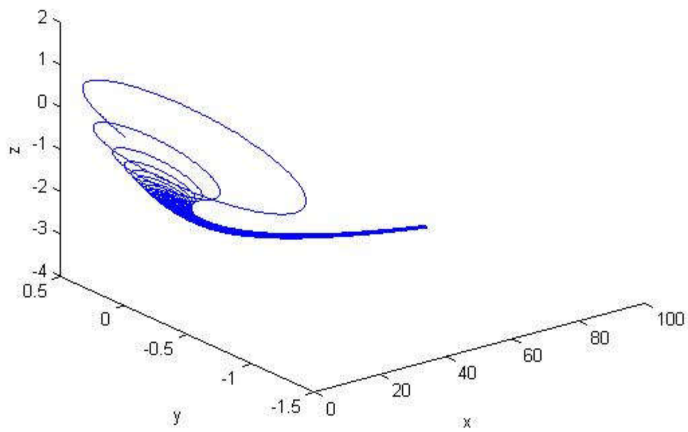
Function Right:-

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

global B;
global cnst;
F=zeros(length(u),1);
F(1)=u(4);
F(2)=u(5);
F(3)=u(6);

B(1) = u(1);

F(4) = (cnst*(u(5)*B(3)-u(6)*B(2)));
F(5) = (cnst*(u(6)*B(1)-u(4)*B(3)));
F(6) = (cnst*(u(4)*B(2)-u(5)*B(1)));
```

Case 1:- B (Magnetic Field) increases as increase in x co-ordinate



Case 2:- B(Magnetic Field) decreases increase in x co-ordinate



Observation:-

As gyro frequency is proportional to square root of magnetic field; gyro frequency increases when magnetic field is increases and decreases as Magnetic field decreases.

Part 4:-

Static and uniform B, and under gravitational force (for different mass)

MATLAB Code:-

Main Function:-

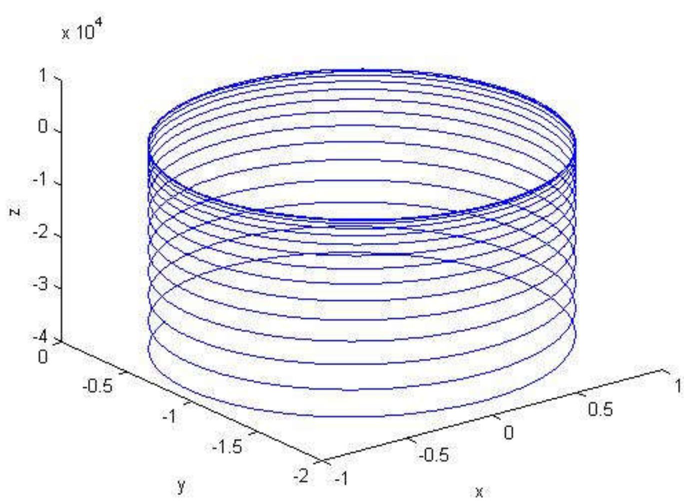
```
clear;
global cnst;
global B;

B=[0,0,1];
q=1;
m=1;
cnst = q/m;
tstart=0;
dt=1e-2;
```

```
tfinal=100;

u0 = [0,0,0,1,0,100];

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

x = u(:,1);
y = u(:,2);
z = u(:,3);
vx = u(:,4);
vy = u(:,5);
vz = u(:,6);

figure;
plot3(x,y,z);
xlabel('x');
ylabel('y');
zlabel('z');
```

Function Right:-

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

global B;
global cnst;
F=zeros(length(u),1);
F(1)=u(4);
F(2)=u(5);
F(3)=u(6);



F(4) = (cnst*(u(5)*B(3)-u(6)*B(2)));
F(5) = (cnst*(u(6)*B(1)-u(4)*B(3)));
F(6) = (-9.8)+(cnst*(u(4)*B(2)-u(5)*B(1)));
```

Output:-



Observation:-

As we can see that the in the z-direction velocity value decreases because there is external force in z-direction which is Gravitation force (Acting in opposite direction of the motion of charged particle).

Answer 2:-

Lorentz Force:- $m\frac{dv}{dt}$ = q.(E + (v×B))

Analytic Solution:-

Lorentz force is towards the centre of the circular trajectory.

Centripetal force to any Circulating Particle is:-

$$F = \frac{mv^2}{r}$$

Assume that the perpendicular component of the velocity to B (Magnetic Field):- V⊥

So we can write above formula as:- $m\frac{dv}{dt}$ = q.(E + V⊥.B)

If E=0,

$\frac{mv\perp^2}{r}$ = q.V⊥.B & we have $\omega = \frac{v}{r}$

V⊥ = $\frac{qB}{m}$.r → $\omega = \frac{qB}{m}$ ________________________________ 1.

r = $\frac{m}{qB}$ V⊥ ____________________________________ 2.

Given, B = 5e-4, V⊥ = $\frac{kT}{m}$

Where k = 1.38e-23 (Boltzmann Constant), T = 1000K, m = 9.104e-31(Mass Of Electron)

So V⊥ = 1.21e5 & B = 5e-4

By putting the given values , ω = 8.8e6 radian/sec & r = 1.37e-2 meter

Computational Solution:-

V×B = $\begin{bmatrix} x & y & z \\ Vx & Vy & Vz \\ 0 & 0 & Bz \end{bmatrix}$ = B_z *(V_y .x – V_x .y)

V∥ = Vz

V⊥ = V_x .x + V_y .y

$$\frac{dV\perp}{dt} = \frac{qBz}{m} * (V_y .x - V_x .y)$$

$$\frac{dVx}{dt} = \omega V_y \quad \& \quad \frac{dVy}{dt} = -\ \omega V_x \quad \& \quad \frac{dVz}{dt} = 0$$

MATLAB Code:-

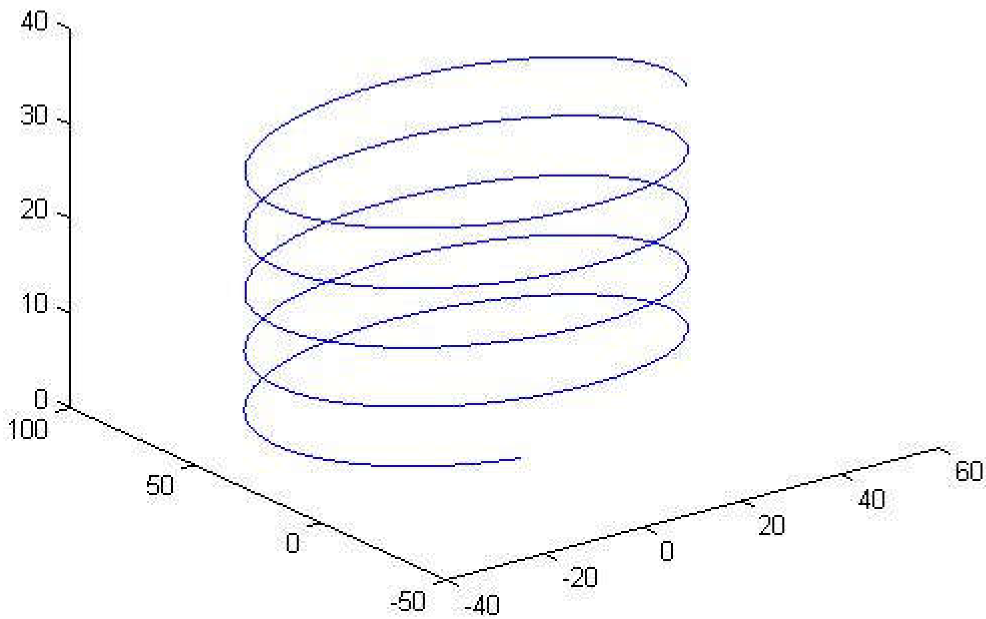
Main Function:-

```
clear;
global B;
global E;
global cnst;
E=[0,0,0];
B=[0,0,5e-5];
q=1.6e-19;
m=9.1e-31;
cnst = ((q*B(3))/m);
t1=0;
dt=1e-1;
t2=30;
u0 = [0,0,0,1.21e5,0,0];
[t,u]=ode45(@new,t1:dt:t2,u0);
x = u(:,1);
y = u(:,2);
z = u(:,3);
f1=figure;
%t = [t1:dt:t2];
plot3(x,y,t);

xlabel('x');
ylabel('y');
zlabel('t');
```

Function new:-

```
function F= new(t,u)
global B;
global E;
global cnst;
F=zeros(length(u),1);
F(1)=u(4);
F(2)=u(5);
F(3)=u(6);
F(4) = cnst*u(5);
F(5) = -cnst*u(4);
F(6) = 0;
```

Output:-



Observation:-

We can see that the Analytic And Computational outputs are same.

Answer 3:-

Gravitational drift velocity

Analytic Solution:-

Formula for Drift Velocity in Magnetic Field & Some External Force is given by,

$$V = \frac{F \times B}{qB^2}$$

Here the force is Gravitational Force

$$F = mg \quad \rightarrow V = \frac{(mg) \times B}{qB^2} \qquad \text{\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_} 3.$$

Here we have assumed that the g (Acceleration due to gravity) remains Constant with Height and also assumed that the Mass of electron remains Constant. So this implies the gravitational Force also remains Constant.

By putting the values we get the value of drift Velocity,

V = 1.11475e-6

Computational Solution:-

$$V \times B = \begin{bmatrix} x & y & z \\ Vx & Vy & Vz \\ 0 & 0 & Bz \end{bmatrix} = B_z * (V_y .x - V_x .y)$$

$$V\| = Vz$$

$$V\perp = V_x .x + V_y .y$$

$$\frac{dV\perp}{dt} = \frac{qBz}{m} * (V_y .x - V_x .y)$$

$$\frac{dVx}{dt} = \omega(V_y + gt) \quad \& \quad \frac{dVy}{dt} = -\omega V_x$$

Here the force in y-direction is due to gravitational force so the acceleration in y-direction is g (Acceleration due to gravity).

$$\frac{dVz}{dt} = 0$$

MATLAB Code:-

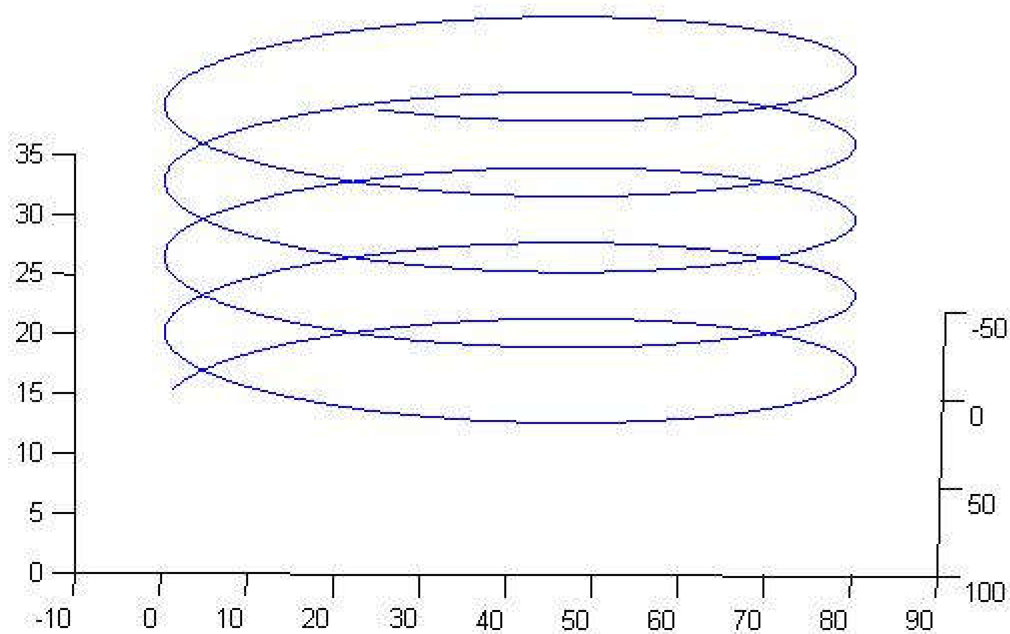
Main Function:-

```
clear;
global B;
global E;
global cnst;
E=[0,0,0];
B=[0,0,5e-5];
q=1.6e-19;
m=9.1e-31;
cnst = ((q*B(3))/m);
t1=0;
global dt;
dt=1e-2;
t2=30;
u0 = [0,0,0,1.21e5,0,0];
[t,u]=ode45(@new,t1:dt:t2,u0);
x = u(:,1);
y = u(:,2);
z = u(:,3);
f1=figure;
%t = [t1:dt:t2];
plot(x,y);

xlabel('x');
ylabel('y');
zlabel('t');
```

Funciton new1:-

```
function F= new1(t,u)
global B;
global E;
global dt;
global cnst;
F=zeros(length(u),1);
F(1)=u(4);
F(2)=u(5);
F(3)=u(6);
F(4) = cnst*(9.8*d + u(5));
F(5) = -cnst*u(4);
F(6) = 0;
```

Output:-



Observation:-

Drift velocity depends on mass and charge so here it remains constant.