Components of the increased velocity ($\vec{v}_{inc}$) of the particles

I. For neutron

1. $\vec{v}_x = v_{inc} \cos\alpha$

$v_{inc} = 1.1923 \times 10^7$ m/s

$\cos\alpha = \cos(53.8) = 0.59$

$\Rightarrow \vec{v}_x = 1.1923 \times 10^7 \times 0.59$ m/s

$= 0.7034 \times 10^7$ m/s

2. $\vec{v}_y = v_{inc} \cos\beta$

$\cos\beta = \cos(36.2) = 0.80$

$\Rightarrow \vec{v}_y = 1.1923 \times 10^7 \times 0.80$ m/s

$= 0.9538 \times 10^7$ m/s

3. $\vec{v}_z = v_{inc} \cos\gamma$

$\cos\gamma = \cos 90^\circ = 0$

$\Rightarrow \vec{v}_z = 1.1923 \times 10^7 \times 0$ m/s

$= 0$ m/s

II. For helion-4

1. $\vec{v}_x = v_{inc} \cos\alpha$

$v_{inc} = 0.3005 \times 10^7$ m/s

$\cos\alpha = \cos(233.8) = -\cos(53.8) = -0.59$

$\Rightarrow \vec{v}_x = 0.3005 \times 10^7 \times (-0.59)$ m/s

$= -0.1772 \times 10^7$ m/s

2. $\vec{v}_y = v_{inc} \cos\beta$

$\cos\beta = \cos(143.8) = -\cos(36.2) = -0.80$

$\Rightarrow \vec{v}_y = 0.3005 \times 10^7 \times (-0.80)$ m/s

$= -0.2404 \times 10^7$ m/s

3. $\vec{v}_z = v_{inc} \cos\gamma$

$\cos\gamma = \cos 90^\circ = 0$

$\Rightarrow \vec{v}_z = 0.3005 \times 10^7 \times 0$ m/s $= 0$ m/s

Components of the final velocity ($\vec{v}_f$) of the particles

I. For neutron

According to	Inhereted velocity ($\vec{v}_{inh}$)	Increased velocity ($\vec{v}_{inc}$)	Final velocity ($\vec{v}_f$) $\vec{v}_f = \vec{v}_{inh} + \vec{v}_{inc}$
x-axis	$\vec{v}_x = -0.956 \times 10^7$ m/s	$\vec{v}_x = 0.7034 \times 10^7$ m/s	$\vec{v}_x = -0.2526 \times 10^7$ m/s
y-axis	$\vec{v}_y = 0.6991 \times 10^7$ m/s	$\vec{v}_y = 0.9538 \times 10^7$ m/s	$\vec{v}_y = 1.6529 \times 10^7$ m/s
z-axis	$\vec{v}_z = 0$ m/s	$\vec{v}_z = 0$ m/s	$\vec{v}_z = 0$ m/s

II. For helion-4

According to	Inhereted velocity ($\vec{v}_{inh}$)	Increased velocity ($\vec{v}_{inc}$)	Final velocity ($\vec{v}_f$) $\vec{v}_f = \vec{v}_{inh} + \vec{v}_{inc}$
x-axis	$\vec{v}_x = -0.956 \times 10^7$ m/s	$\vec{v}_x = -0.1772 \times 10^7$ m/s	$\vec{v}_x = -1.1332 \times 10^7$ m/s
y-axis	$\vec{v}_y = 0.6991 \times 10^7$ m/s	$\vec{v}_y = -0.2404 \times 10^7$ m/s	$\vec{v}_y = 0.4587 \times 10^7$ m/s
z-axis	$\vec{v}_z = 0$ m/s	$\vec{v}_z = 0$ m/s	$\vec{v}_z = 0$ m/s

Final velocity (v_f) of the neutron

$$v_f^2 = v_x^2 + v_y^2 + v_z^2$$

$v_x = 0.2526 \times 10^7$ m/s
$v_y = 1.6529 \times 10^7$ m/s
$v_z = 0$ m/s

$$\Rightarrow v_f^2 = (0.2526 \times 10^7)^2 + (1.6529 \times 10^7)^2 + (0)^2 \ m^2/s^2$$

$$\Rightarrow v_f^2 = (0.06380676 \times 10^{14}) + (2.73207841 \times 10^{14}) + (0) \ m^2/s^2$$

$$\Rightarrow v_f^2 = 2.79588517 \times 10^{14} \ m^2/s^2$$

$$\Rightarrow v_f = 1.6720 \times 10^7 \ m/s$$

Final kinetic energy of the neutron

$$E = \frac{1}{2} m_n v_f^2$$

$v_f^2 = 2.79588517 \times 10^{14}$ m²/s²

$$\Rightarrow E = \frac{1}{2} \times 1.6749 \times 10^{-27} \times 2.79588517 \times 10^{14} \ J$$

$$\Rightarrow E = 2.3414140356 \times 10^{-13} \ J$$

$$\Rightarrow E = 1.4633 \ MeV$$

Angles that make the final velocity ($\vec{v}_f$) of the neutron with axes at point F.

1. With x-axis

$$\cos\alpha = \frac{\vec{v}_x}{v_f}$$

$$\vec{v}_x = -0.2526 \times 10^7 \text{ m/s}$$
$$v_f = 1.6720 \times 10^7 \text{ m/s}$$

$$\Rightarrow \cos\alpha = \frac{-0.2526 \times 10^7}{1.6720 \times 10^7} \frac{\text{m/s}}{\text{m/s}} = -0.1510$$

$$\Rightarrow \alpha \simeq 98.7 \text{ degree} \quad [\because \cos(98.7) = -0.1512]$$

2. With y-axis

$$\cos\beta = \frac{\vec{v}_y}{v_f}$$

$$\vec{v}_y = 1.6529 \times 10^7 \text{ m/s}$$

$$\Rightarrow \cos\beta = \frac{1.6529 \times 10^7}{1.6720 \times 10^7} \frac{\text{m/s}}{\text{m/s}} = 0.9885$$

$$\Rightarrow \beta \simeq 8.7 \text{ degree} \quad [\cos(8.7) = 0.9884]$$

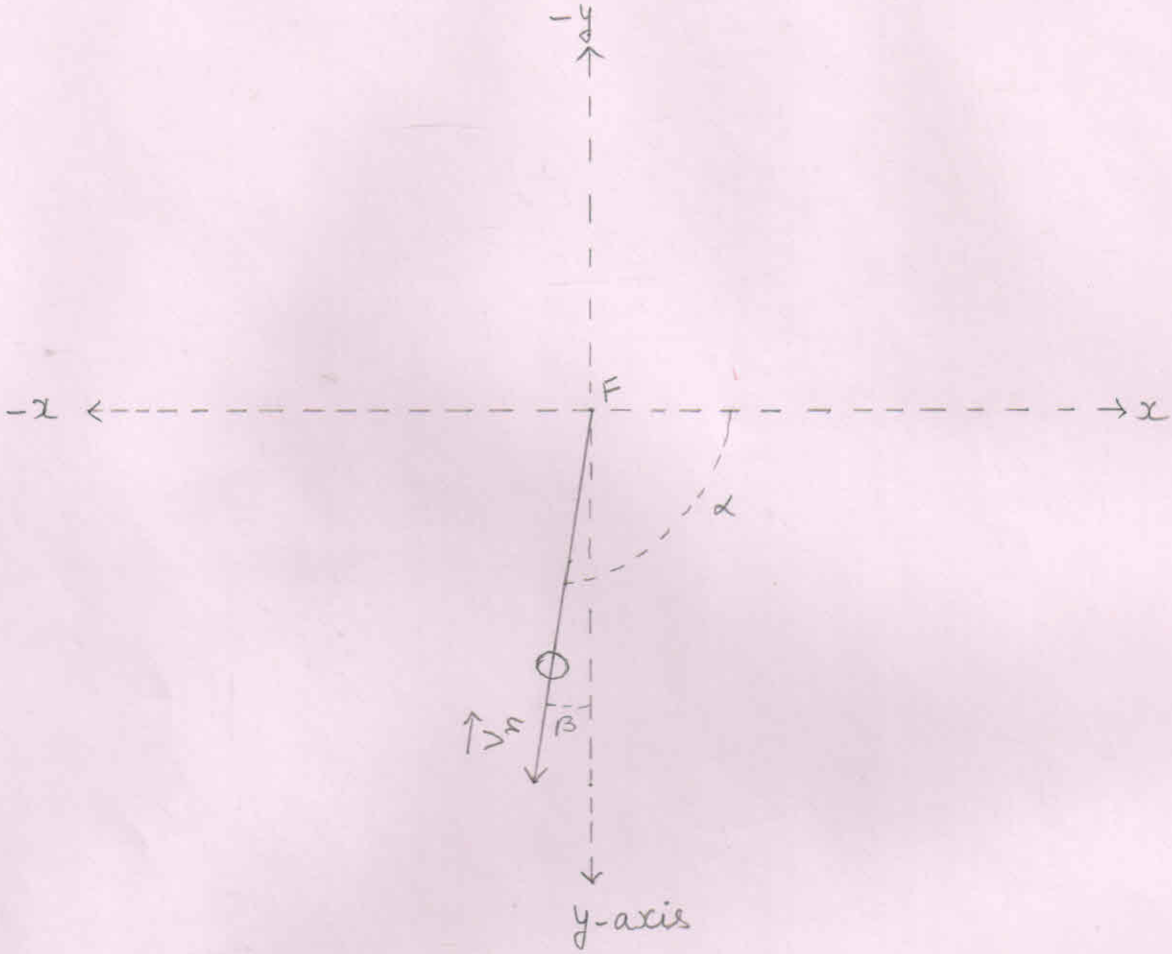
3. With z-axis

$$\cos\gamma = \frac{\vec{v}_z}{v_f}$$

$$\vec{v}_z = 0 \text{ m/s}$$

$$\Rightarrow \cos\gamma = \frac{\vec{v}_z}{v_f} = \frac{0}{v_f} \frac{\text{m/s}}{\text{m/s}} = 0$$

$$\Rightarrow \gamma = 90^\circ$$



$\Rightarrow$ $\vec{V}_n$ = Final velocity of the neutron

$\Rightarrow$ Where,

$\alpha \simeq 98.7$ degree

$\beta \simeq 8.7$ degree

$\gamma = 90^\circ$ degree

Final velocity (v_f) of the helion-4

$$v_f^2 = v_x^2 + v_y^2 + v_z^2$$

$v_x = 1.1332 \times 10^7$ m/s
$v_y = 0.4587 \times 10^7$ m/s
$v_z = 0$ m/s

$$\Rightarrow v_f^2 = (1.1332 \times 10^7)^2 + (0.4587 \times 10^7)^2 + (0)^2 \ m^2/s^2$$

$$\Rightarrow v_f^2 = (1.28414224 \times 10^{14}) + (0.21040569 \times 10^{14}) + (0) \ m^2/s^2$$

$$\Rightarrow v_f^2 = 1.49454793 \times 10^{14} \ m^2/s^2$$

$$\Rightarrow v_f = 1.2225 \times 10^7 \ m/s$$

Final kinetic energy of the helion-4

$$E = \frac{1}{2} m_{He-4} v_f^2$$

$v_f^2 = 1.49454793 \times 10^{14}$ m^2/s^2

$$\Rightarrow E = \frac{1}{2} \times 6.6449 \times 10^{-27} \times 1.49454793 \times 10^{14} \ J$$

$$= 4.9652543877 \times 10^{-13} \ J$$

$$= 3.1032 \ MeV$$

$$\Rightarrow m_{He-4} v_f^2 = 6.64449 \times 10^{-27} \times 1.49454793 \times 10^{14} \ J$$

$$= 9.9305 \times 10^{-13} \ J$$

Acting forces on the helion-4

1. $F_y = q V_x B_z \sin\theta$

$\vec{V}_x = -1.1332 \times 10^7$ m/s

$\vec{B}_z = -1$ Tesla

$q = 2 \times 1.6 \times 10^{-19}$ C

$\sin\theta = \sin 90^\circ = 1$

$\Rightarrow F_y = 2 \times 1.6 \times 10^{-19} \times 1.1332 \times 10^7 \times 1 \times 1$ N
$= 3.6262 \times 10^{-12}$ N

From the right hand palm rule, the direction of force $\vec{F_y}$ is according to $+y$ axis. So,

$$\vec{F_y} = 3.6262 \times 10^{-12} \text{ N}$$

2. $F_z = q V_x B_y \sin\theta$

$\vec{B}_y = 1$ Tesla

$\sin\theta = \sin 90^\circ = 1$

$\Rightarrow F_z = 2 \times 1.6 \times 10^{-19} \times 1.1332 \times 10^7 \times 1 \times 1$ N
$= 3.6262 \times 10^{-12}$ N

From the right hand palm rule, the direction of force $\vec{F_z}$ is according to $+z$ axis. So,

$$\vec{F_z} = 3.6262 \times 10^{-12} \text{ N}$$

3. $F_x = q V_y B_z \sin\theta$

$\vec{V}_y = 0.4587 \times 10^7$ m/s

$\vec{B}_z = -1$ Tesla

$\sin\theta = \sin 90^\circ = 1$

$\Rightarrow F_x = 2 \times 1.6 \times 10^{-19} \times 0.4587 \times 10^7 \times 1 \times 1$ N
$= 1.4678 \times 10^{-12}$ N

From the right hand palm rule, the direction of force $\vec{F_x}$ is according to $+x$ axis. So,

$$\vec{F_x} = 1.4678 \times 10^{-12} \text{ N}$$

4. Resultant force (F_R) :

$$F_R^2 = F_x^2 + F_y^2 + F_z^2$$

$$F_x = 1.4678 \times 10^{-12} \ N$$

$$F = F_y = F_z = 3.6262 \times 10^{-12} \ N$$

$$\Rightarrow F_R^2 = F_x^2 + 2F^2$$

$$\Rightarrow F_R^2 = (1.4678 \times 10^{-12})^2 + 2(3.6262 \times 10^{-12})^2 \ N^2$$

$$\Rightarrow F_R^2 = (2.15443684 \times 10^{-24}) + 2(13.14932644 \times 10^{-24}) \ N^2$$

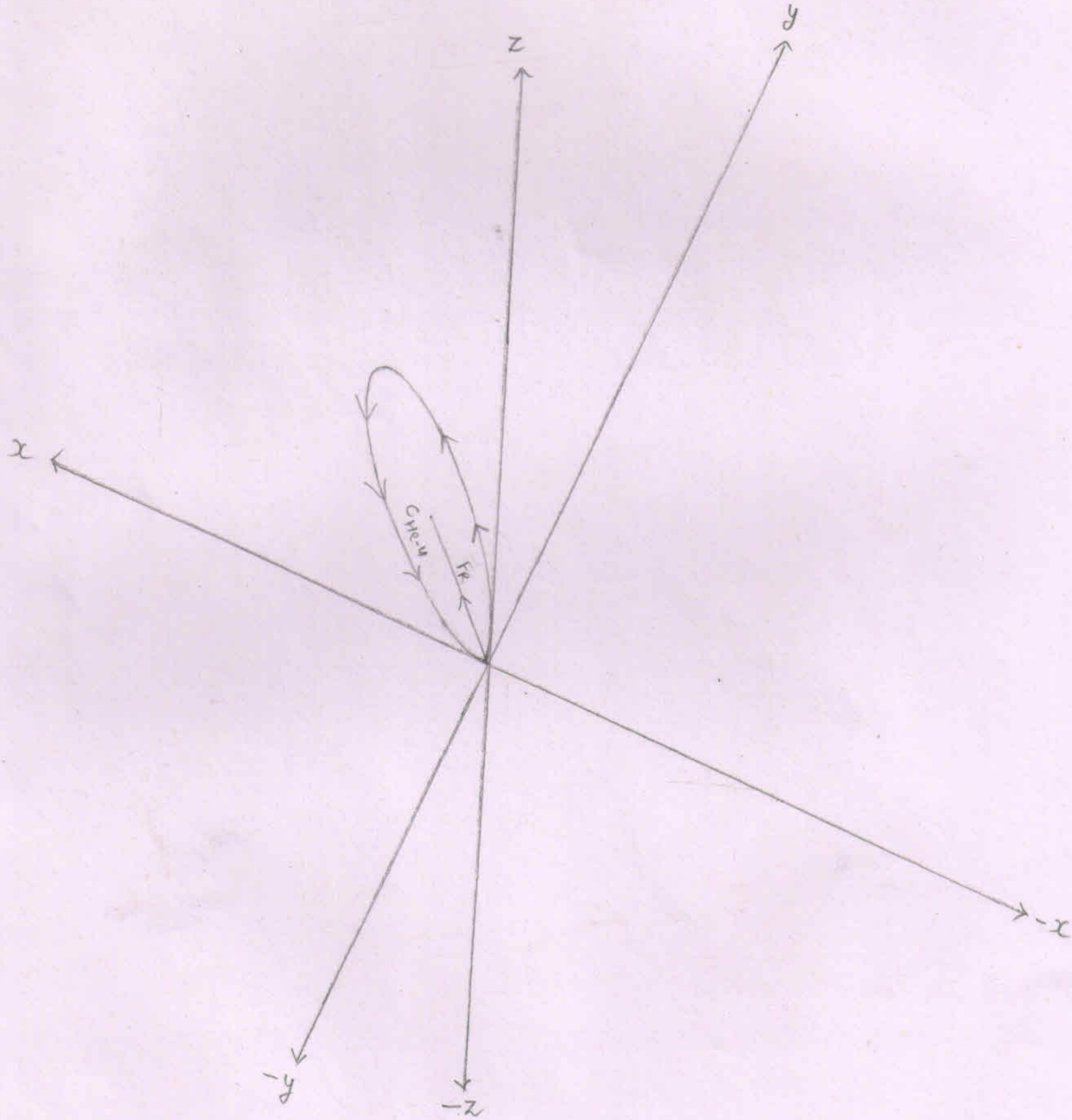
$$\Rightarrow F_R^2 = (2.15443684 \times 10^{-24}) + (26.29865288 \times 10^{-24}) \ N^2$$

$$\Rightarrow F_R^2 = 28.45308972 \times 10^{-24} \ N^2$$

$$\Rightarrow F_R = 5.3341 \times 10^{-12} \ N$$

⇒ The circular orbit to be followed by the helion-4 lies in the I (up) quadrant made up of the positive x axis, positive y axis and positive z axes

⇒ C_{He-4} = center of the circle to be followed by the helion-4



Angles that make the resultant force ($\overrightarrow{F_R}$) [acting on the helium-4 nucleus when the helium-4 nucleus is at point 'F'] with positive x, y and z-axes :-

1. With x-axis

$$\cos\alpha = \frac{F_R \cos\alpha}{F_R} = \frac{\overrightarrow{F_x}}{F_R} = \frac{1.4678 \times 10^{-12}}{5.3341 \times 10^{-12}} \frac{N}{N}$$

$\Rightarrow \cos\alpha = 0.2751$

$\Rightarrow \alpha \simeq 74.05$ $\quad [\because \cos(74.05) = 0.2747]$

2. With y-axis

$$\cos\beta = \frac{F_R \cos\beta}{F_R} = \frac{\overrightarrow{F_y}}{F_R} = \frac{3.6262 \times 10^{-12}}{5.3341 \times 10^{-12}} \frac{N}{N}$$

$\Rightarrow \cos\beta = 0.6798$

$\Rightarrow \beta \simeq 47.2$ degree $\quad [\because \cos(47.2) = 0.6794]$

3. With z-axis

$$\cos\gamma = \frac{F_R \cos\gamma}{F_R} = \frac{\overrightarrow{F_z}}{F_R} = \frac{3.6262 \times 10^{-12}}{5.3341 \times 10^{-12}} \frac{N}{N}$$

$\Rightarrow \cos\gamma = 0.6798$

$\Rightarrow \gamma \simeq 47.2$ degree

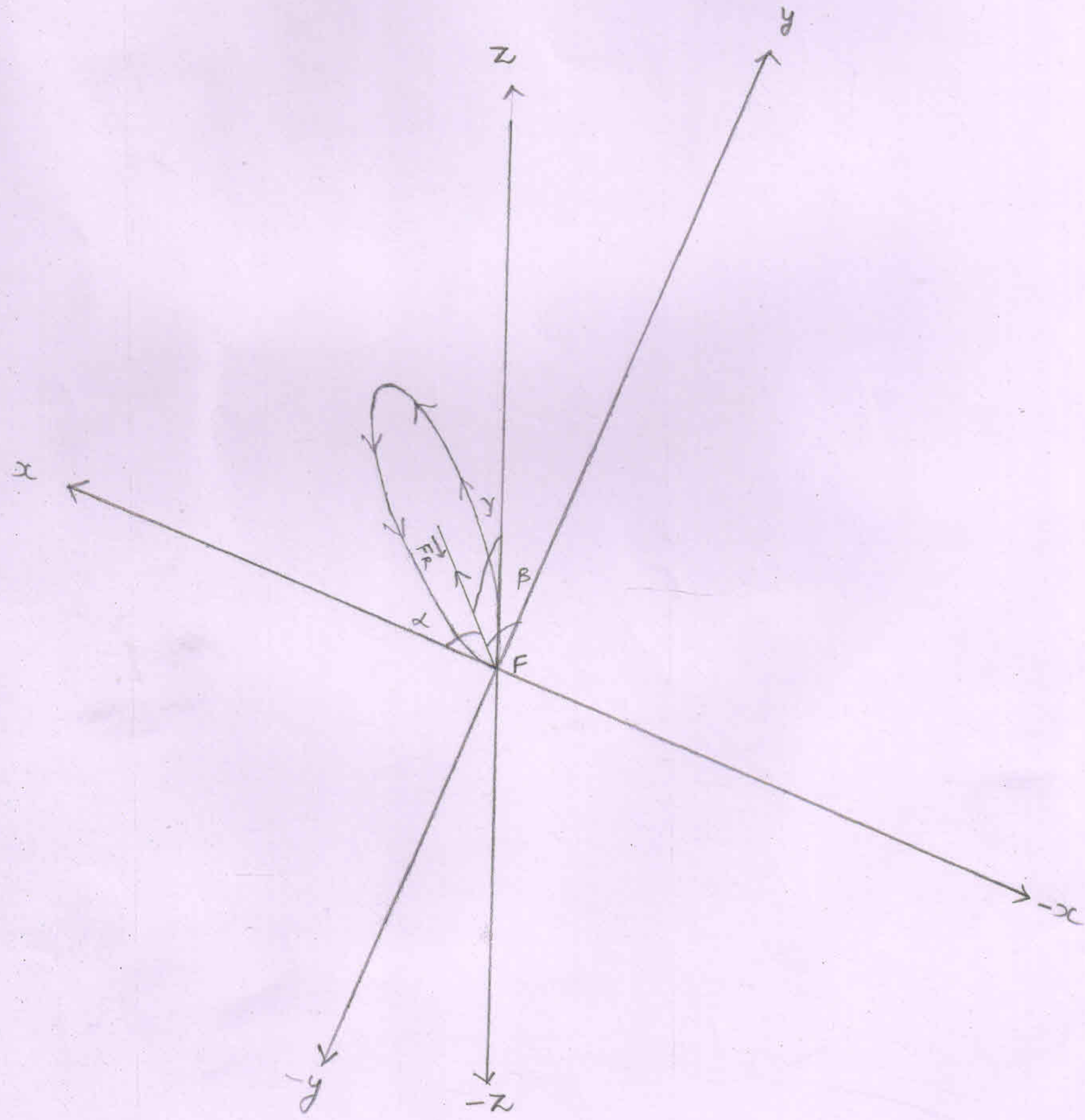
Angles that make the resultant force ($\vec{F_R}$) at point F with positive x, y and z axes.

Where,

$\alpha \simeq 74.05$

$\beta \simeq 47.2$

$\gamma \simeq 47.2$



5. Radius of the circular orbit followed by the helion-4 :-

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

$mv^2 = 9.9305 \times 10^{-13}$ J

$F_R = 5.3341 \times 10^{-12}$ N

$$\Rightarrow r = \frac{9.9305 \times 10^{-13}}{5.3341 \times 10^{-12}} \text{ m}$$

$$\Rightarrow r = 1.86170 \times 10^{-1} \text{ m}$$

$$\Rightarrow r = 18.6170 \times 10^{-2} \text{ m}$$

The cartesian coordinates of the points $P_1(x_1, y_1, z_1)$ and $P_2(x_2, y_2, z_2)$ located on the circumfrence of the circle obtained by the helium-4 nucleus :-

1. $\cos\alpha = \frac{x_2 - x_1}{d}$

$d = 2 \times r$
$= 2 \times 18.6170 \times 10^{-2}\ m$
$= 37.234 \times 10^{-2}\ m$

$\cos\alpha = 0.27$

$\Rightarrow x_2 - x_1 = d \times \cos\alpha$
$\Rightarrow x_2 - x_1 = 37.234 \times 10^{-2} \times 0.27\ m$
$\Rightarrow x_2 - x_1 = 10.0531 \times 10^{-2}\ m$
$\Rightarrow x_2 = 10.0531 \times 10^{-2}\ m$ $[\because x_1 = 0]$

2. $\cos\beta = \frac{y_2 - y_1}{d}$

$\cos\beta = 0.67$

$\Rightarrow y_2 - y_1 = d \times \cos\beta$
$\Rightarrow y_2 - y_1 = 37.234 \times 10^{-2} \times 0.67\ m$
$\Rightarrow y_2 - y_1 = 24.9467 \times 10^{-2}\ m$
$\Rightarrow y_2 = 24.9467 \times 10^{-2}\ m$ $[\because y_1 = 0]$

3. $\cos\gamma = \frac{z_2 - z_1}{d}$

$\cos\gamma = 0.67$

$\Rightarrow z_2 - z_1 = d \times \cos\gamma$
$\Rightarrow z_2 - z_1 = 37.234 \times 10^{-2} \times 0.67\ m$
$\Rightarrow z_2 - z_1 = 24.9467 \times 10^{-2}\ m$
$\Rightarrow z_2 = 24.9467 \times 10^{-2}\ m$ $[\because z_1 = 0]$

The cartesian coordinates of the points $P_1(x_1, y_1, z_1)$ and $P_2(x_2, y_2, z_2)$ located on the circumfrence of the circle obtained by the helion-4.

$\Rightarrow$ The line $\overline{P_1P_2}$ is the diameter of the circle.