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 deuteron

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

$$d = 2 \times r$$
$$= 2 \times 47.9119 \times 10^{-2}\ m$$
$$= 95.8238 \times 10^{-2}\ m$$

$$\cos\alpha = 0.28$$

$\Rightarrow x_2 - x_1 = d \times \cos\alpha$

$\Rightarrow x_2 - x_1 = 95.8238 \times 10^{-2} \times 0.28\ m$

$\Rightarrow x_2 - x_1 = 26.8306 \times 10^{-2}\ m$

$\Rightarrow x_2 = 26.8306 \times 10^{-2}\ m \quad [\because x_1 = 0]$

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

$$\cos\beta = -0.67$$

$\Rightarrow y_2 - y_1 = d \times \cos\beta$

$\Rightarrow y_2 - y_1 = 95.8238 \times 10^{-2} \times (-0.67)\ m$

$\Rightarrow y_2 - y_1 = -64.2019 \times 10^{-2}\ m$

$\Rightarrow y_2 = -64.2019 \times 10^{-2}\ m \quad [\because y_1 = 0]$

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

$$\cos\gamma = -0.67$$

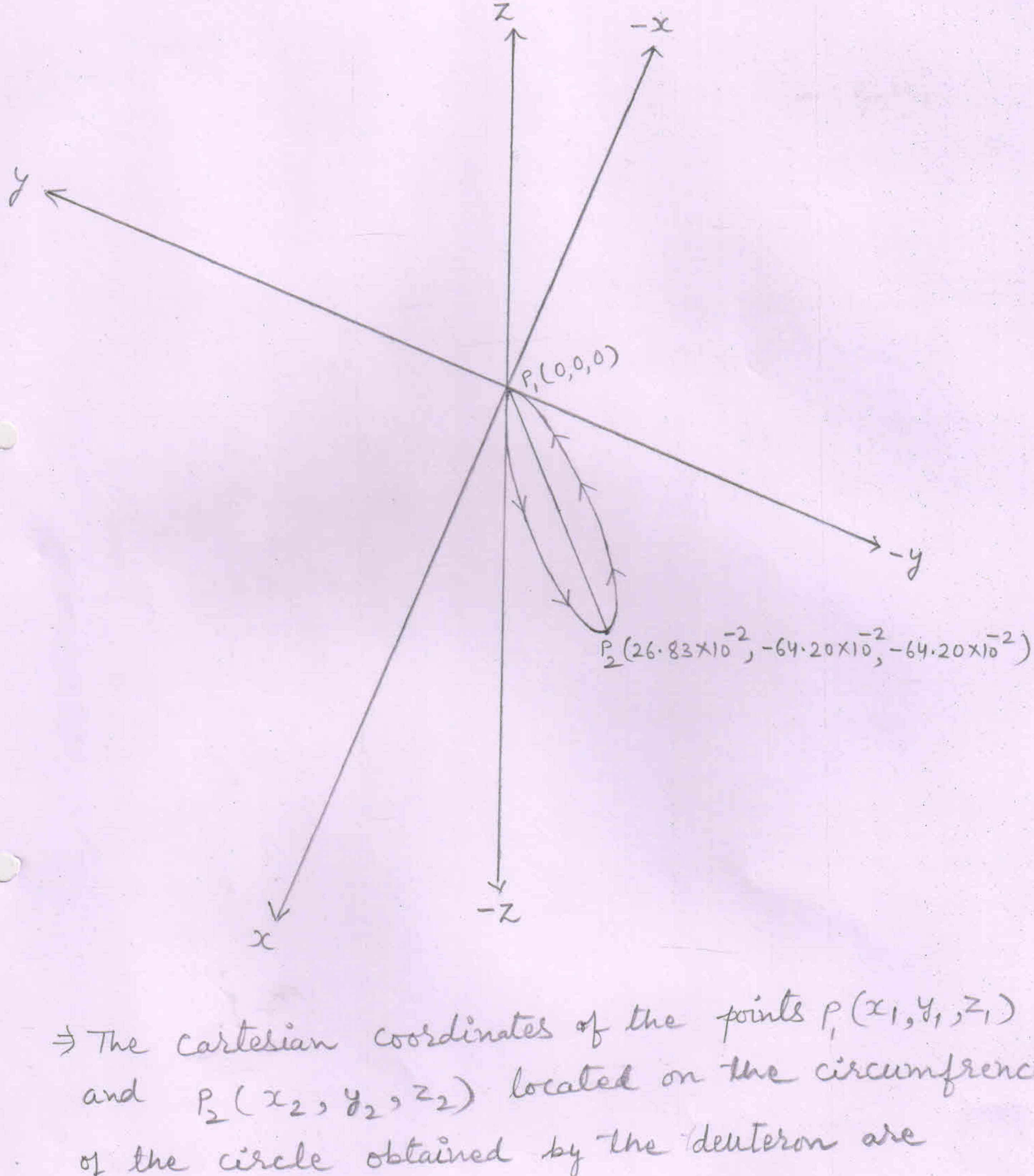
$\Rightarrow z_2 - z_1 = d \times \cos\gamma$

$\Rightarrow z_2 - z_1 = 95.8238 \times 10^{-2} \times (-0.67)\ m$

$\Rightarrow z_2 - z_1 = -64.2019 \times 10^{-2}\ m$

$\Rightarrow z_2 = -64.2019 \times 10^{-2}\ m \quad [\because z_1 = 0]$

The cartesian coordinates of the points $P_1(x_1, y_1, z_1)$ and $P_2(x_2, y_2, z_2)$



⇒ 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 deuteron are as shown above.

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

Final velocity (v_f) of the helion-4

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

$v_x = 1.6183 \times 10^7$ m/s
$v_y = 0.6122 \times 10^7$ m/s
$v_z = 0$ m/s

$$\Rightarrow v_f^2 = (1.6183 \times 10^7)^2 + (0.6122 \times 10^7)^2 + (0)^2 \quad m^2/s^2$$

$$\Rightarrow v_f^2 = (2.61889489 \times 10^{14}) + (0.37478884 \times 10^{14}) + (0) \quad m^2/s^2$$

$$\Rightarrow v_f^2 = 2.99368373 \times 10^{14} \quad m^2/s^2$$

$$\Rightarrow v_f = 1.7302 \times 10^7 \quad m/s$$

Final kinetic energy of the helion-4

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

$v_f^2 = 2.99368373 \times 10^{14}$ m²/s²

$$\Rightarrow E = \frac{1}{2} \times 6.64449 \times 10^{-27} \times 2.99368373 \times 10^{14} \quad J$$

$$= 9.94575080355 \times 10^{-13} \quad J$$
$$= 6.2160 \quad MeV$$

$$\Rightarrow m_{He-4} v_f^2 = 6.64449 \times 10^{-27} \times 2.99368373 \times 10^{14} \quad J$$
$$= 19.8915 \times 10^{-13} \quad J$$

Acting forces on the helion-4

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

$\vec{v}_x = -1.6183 \times 10^7$ m/s

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

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

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

$\Rightarrow F_y = 2 \times 1.6 \times 10^{-19} \times 1.6183 \times 10^7 \times 1 \times 1$ N

$= 5.1785 \times 10^{-12}$ N

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

$$\vec{F_y} = 5.1785 \times 10^{-12} \text{ N}$$

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

$\vec{B_y} = 1$ Tesla

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

$\Rightarrow F_z = 2 \times 1.6 \times 10^{-19} \times 1.6183 \times 10^7 \times 1 \times 1$ N

$= 5.1785 \times 10^{-12}$ N

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

$$\vec{F_z} = 5.1785 \times 10^{-12} \text{ N}$$

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

$\vec{V_y} = 0.6122 \times 10^7$ m/s

$\vec{B_z} = -1$ Tesla

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

$\Rightarrow F_x = 2 \times 1.6 \times 10^{-19} \times 0.6122 \times 10^7 \times 1 \times 1$ N

$= 1.9590 \times 10^{-12}$ N

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

$$\vec{F_x} = 1.9590 \times 10^{-12} \text{ N}$$

4. Resultant force (F_R):

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

$$F_x = 1.9590 \times 10^{-12}\ N$$

$$F = F_y = F_z = 5.1785 \times 10^{-12}\ N$$

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

$$\Rightarrow F_R^2 = (1.9590 \times 10^{-12})^2 + 2(5.1785 \times 10^{-12})^2\ N^2$$

$$\Rightarrow F_R^2 = (3.837681 \times 10^{-24}) + 2(26.81686225 \times 10^{-24})\ N^2$$

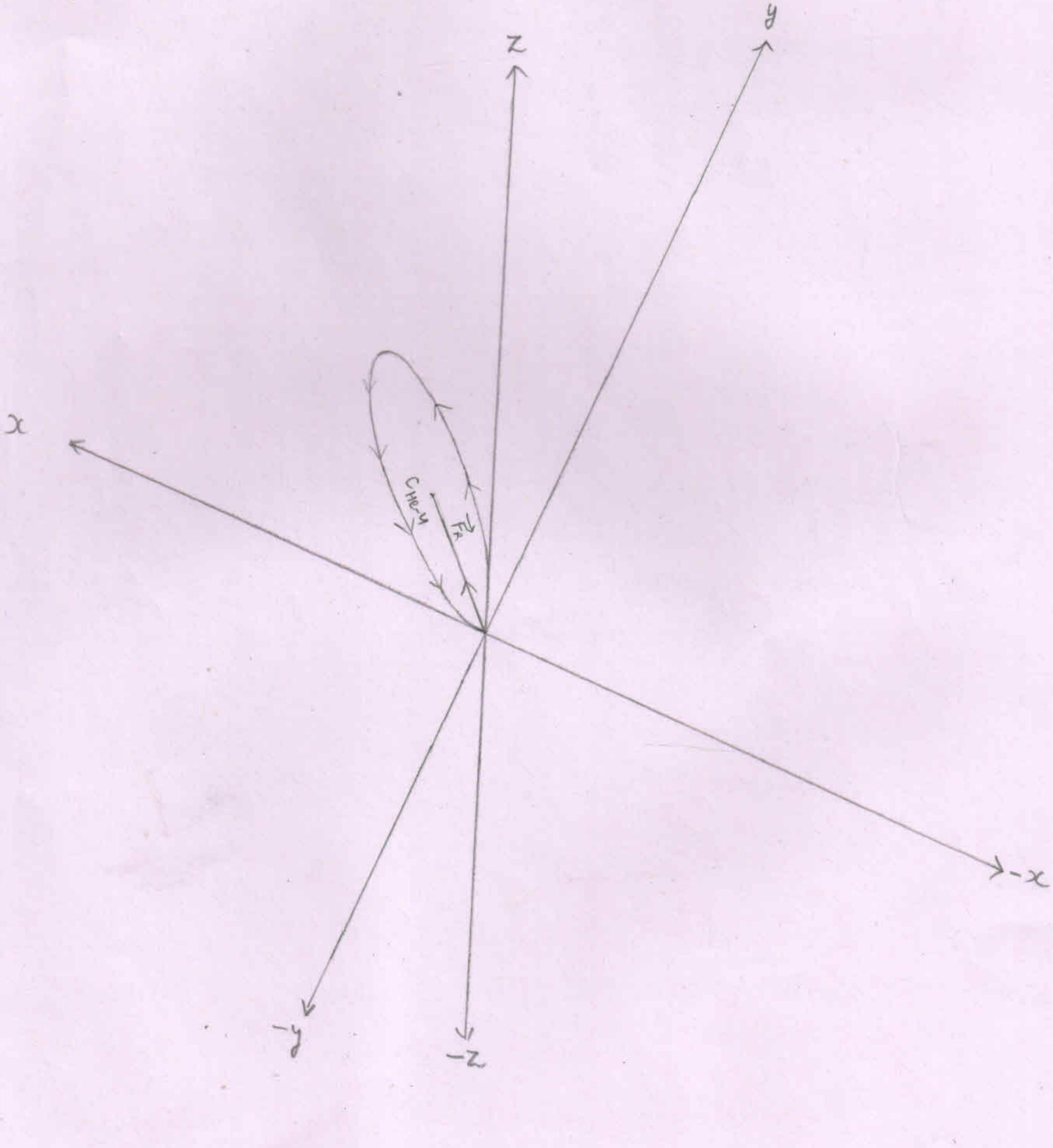
$$\Rightarrow F_R^2 = (3.837681 \times 10^{-24}) + (53.6337245 \times 10^{-24})\ N^2$$

$$\Rightarrow F_R^2 = 57.4714055 \times 10^{-24}\ N^2$$

$$\Rightarrow F_R = 7.5809 \times 10^{-12}\ N$$

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

⇒ c_{He-4} = The centre of the circle to be followed by the helion-4



Angles that make the resultant force ($\vec{F_R}$) [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

$$\cos\alpha = \frac{F_R \cos\alpha}{F_R} = \frac{\vec{F_x}}{F_R} = \frac{1.9590 \times 10^{-12}}{7.5809 \times 10^{-12}} \frac{N}{N}$$

$\Rightarrow \cos\alpha = 0.2584$

$\Rightarrow \alpha \simeq 75.1$ degree $[\because \cos(75.1) = 0.2571]$

2. With y-axis

$$\cos\beta = \frac{F_R \cos\beta}{F_R} = \frac{\vec{F_y}}{F_R} = \frac{5.1785 \times 10^{-12}}{7.5809 \times 10^{-12}} \frac{N}{N}$$

$\Rightarrow \cos\beta = 0.6830$

$\Rightarrow \beta \simeq 47$ degree $[\because \cos(47) = 0.6819]$

3. With z-axis

$$\cos\gamma = \frac{F_R \cos\gamma}{F_R} = \frac{\vec{F_z}}{F_R} = \frac{5.1785 \times 10^{-12}}{7.5809 \times 10^{-12}} \frac{N}{N}$$

$\Rightarrow \cos\gamma = 0.6830$

$\Rightarrow \gamma \simeq 47$ degree

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

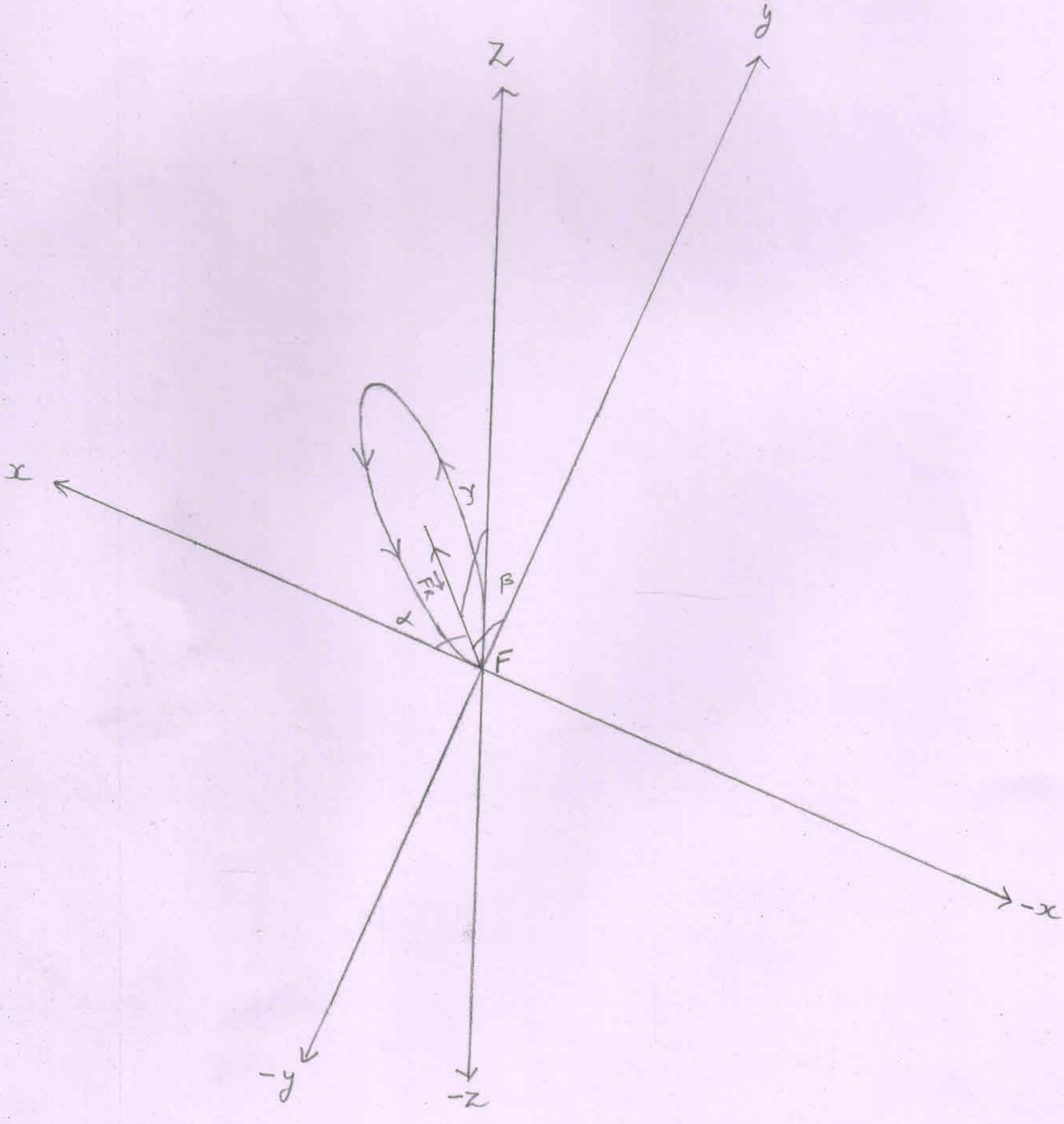
$\Rightarrow$ $\vec{F_R}$ = Resultant force acting on the particle

$\Rightarrow$ where,

$\alpha \simeq 75.1$

$\beta \simeq 47$

$\gamma \simeq 47$



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

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

$mv^2 = 19.8915 \times 10^{-13}$ J

$F_R = 7.5809 \times 10^{-12}$ N

$$\Rightarrow r = \frac{19.8915 \times 10^{-13}}{7.5809 \times 10^{-12}} \text{ m}$$

$\Rightarrow r = 2.62389 \times 10^{-1}$ m

$\Rightarrow r = 26.2389 \times 10^{-2}$ 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. $\cos\alpha = \dfrac{x_2 - x_1}{d}$

$$d = 2 \times r$$
$$= 2 \times 26.2389 \times 10^{-2}\,m$$
$$= 52.4778 \times 10^{-2}\,m$$
$$\cos\alpha = 0.25$$

$\Rightarrow x_2 - x_1 = d \times \cos\alpha$
$\Rightarrow x_2 - x_1 = 52.4778 \times 10^{-2} \times 0.25\,m$
$\Rightarrow x_2 - x_1 = 13.1194 \times 10^{-2}\,m$
$\Rightarrow x_2 = 13.1194 \times 10^{-2}\,m \quad [\because x_1 = 0]$

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

$$\cos\beta = 0.68$$

$\Rightarrow y_2 - y_1 = d \times \cos\beta$
$\Rightarrow y_2 - y_1 = 52.4778 \times 10^{-2} \times 0.68\,m$
$\Rightarrow y_2 - y_1 = 35.6849 \times 10^{-2}\,m$
$\Rightarrow y_2 = 35.6849 \times 10^{-2}\,m \quad [\because y_1 = 0]$

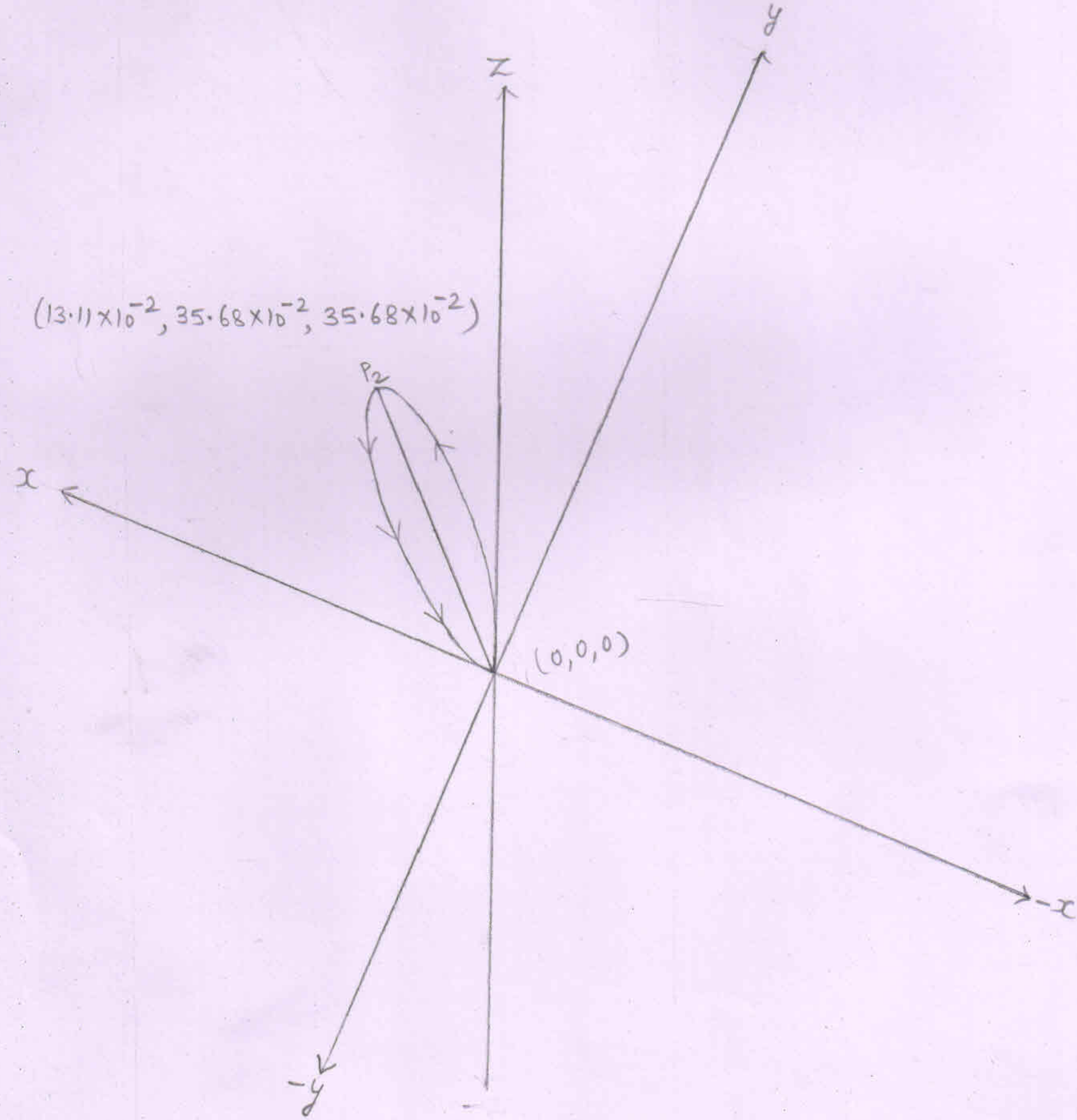
3. $\cos\gamma = \dfrac{z_2 - z_1}{d}$

$$\cos\gamma = 0.68$$

$\Rightarrow z_2 - z_1 = d \times \cos\gamma$
$\Rightarrow z_2 - z_1 = 52.4778 \times 10^{-2} \times 0.68\,m$
$\Rightarrow z_2 - z_1 = 35.6849 \times 10^{-2}\,m$
$\Rightarrow z_2 = 35.6849 \times 10^{-2}\,m \quad [\because z_1 = 0]$

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 circumference of the circle obtained by the helion-4 are as shown below.

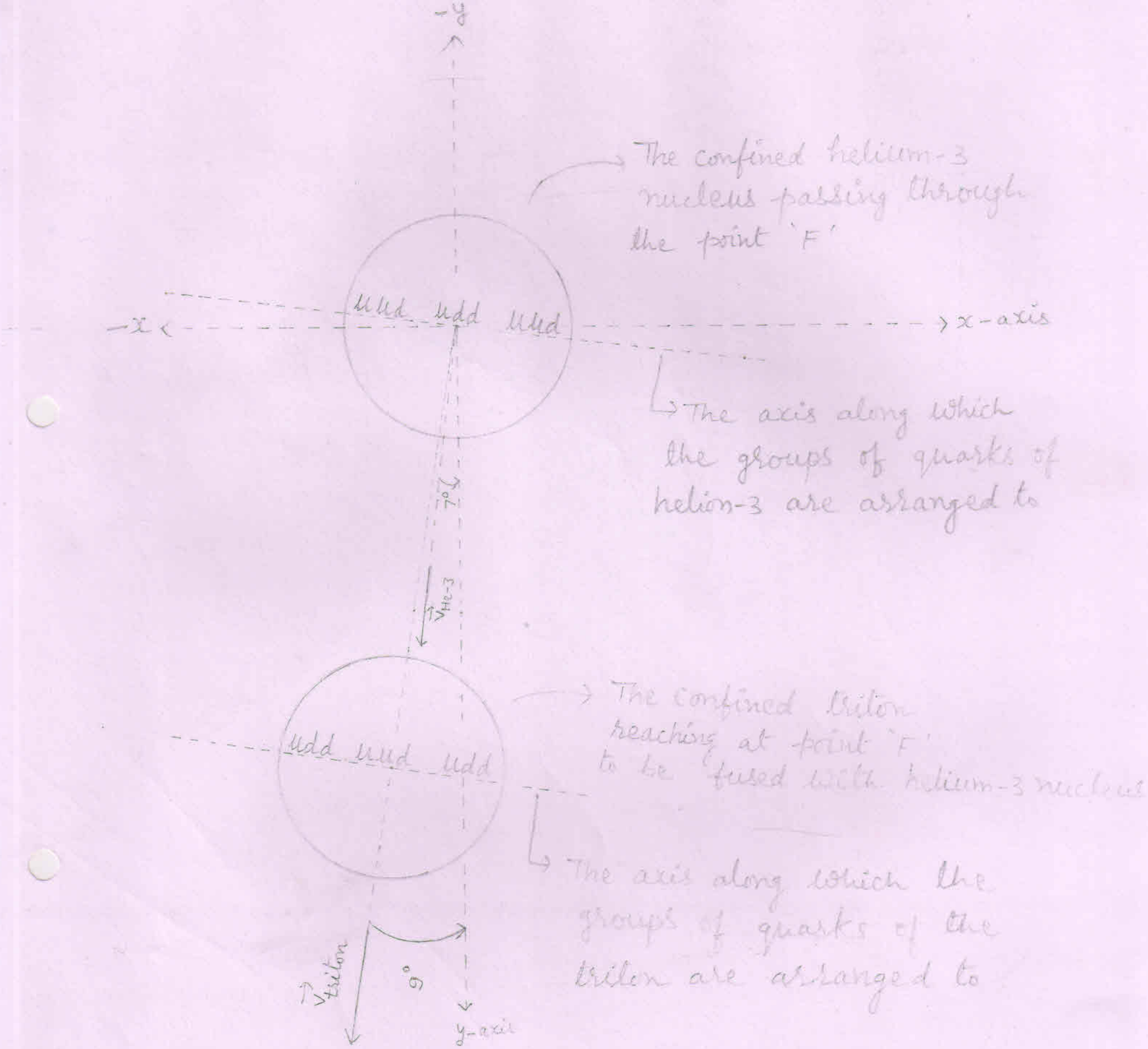
$\Rightarrow$ The line $\overline{P_1 P_2}$ is the diameter of the circle.



For fusion reaction 6(iii) : ${}^{3}_{1}H + {}^{3}_{2}He \rightarrow {}^{5}_{2}He + {}^{1}_{1}H$

1. Interaction of nuclei :-

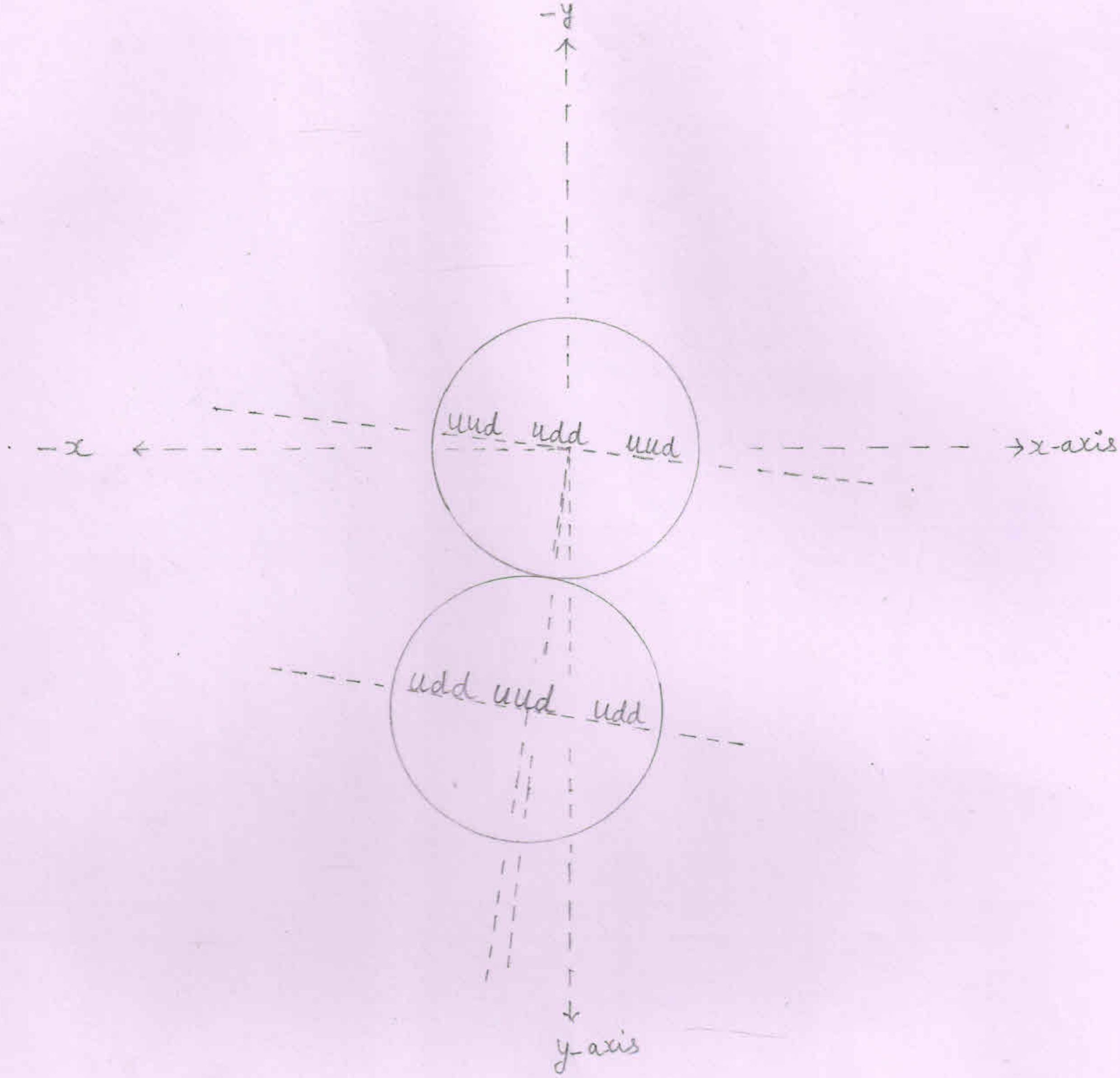
The confined triton reaches at point 'F' and interacts [experiences a repulsive force due to confined helium-3 nucleus passing through the point 'F'] with the confined helium-3 nucleus at point 'F'. The confined triton overcomes the electrostatic repulsive force and – a like two solid spheres join – the confined triton dissimilarly joins with the confined helium-3 nucleus.



1 (1)

Interaction of nuclei

Interaction of nuclei



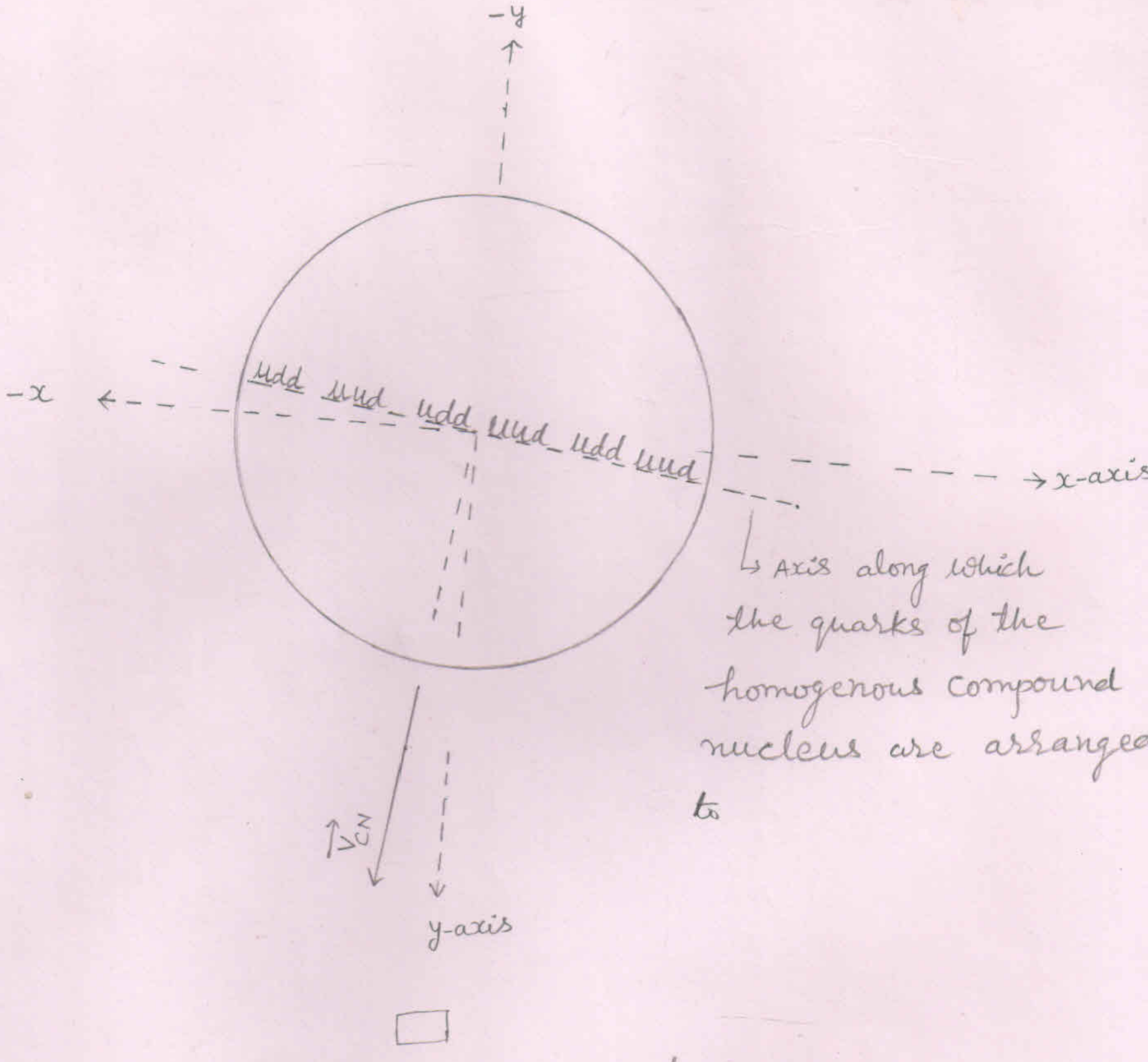
$\square$ 1 (2)

The dissimilarly joined nuclei

2. Formation of the homogenous compound nucleus :-
The constituents (quarks and gluons) of the dissimilarly formed nuclei (the triton and the helion-3) behave like a liquid and form the homogenous compound nucleus having similarly distributed groups of quarks with similarly distributed surrounding gluons.

Thus within the homogenous compound nucleus - each group of quarks is surrounded by gluons in equal proportion. So, within the homogenous compound nucleus there are 6 groups of quarks surrounded by the gluons.

The homogenous compound nucleus



The homogenous compound nucleus

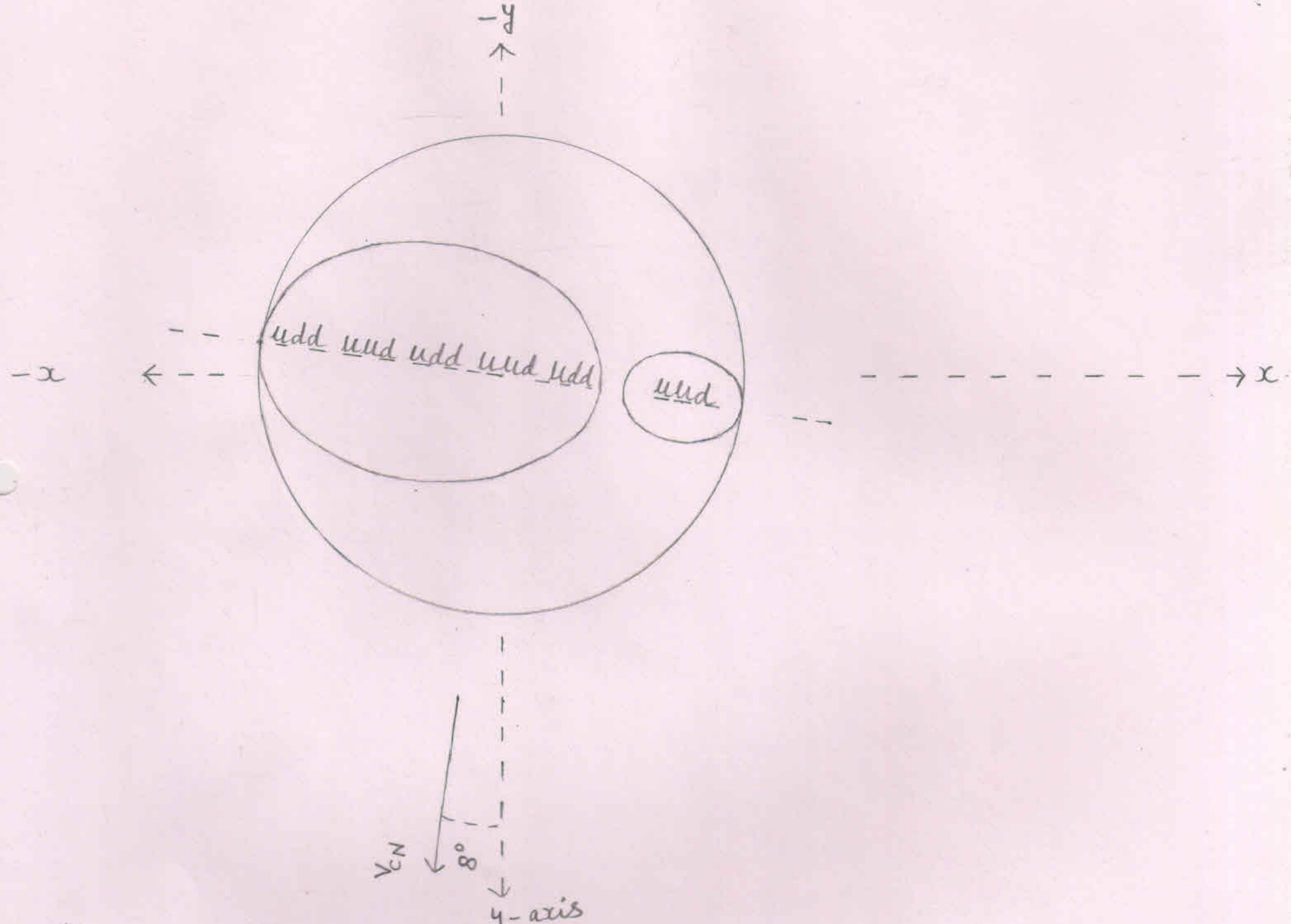
⇒ The axis of quarks is perpendicular to the velocity of the compound nucleus ($\vec{V}_{CN}$).

3. Formation of lobes within into the homogenous compound nucleus or the transformation of the homogenous compound nucleus into the heterogenous compound nucleus :-

The central group of quarks with its surrounding gluons to become a stable and the next higher nucleus (the helion-5) than the reactant one (the helion-3) includes the other four (nearby located) groups of quarks with their surrounding gluons and rearrange to form the 'A' lobe of the heterogenous compound nucleus.

While the remaining group of quarks to become a stable nucleus (the proton) includes its surrounding gluons or mass [out of the available mass (or gluons) that is not included in the formation of the lobe 'A'] and rearrange to form the 'B' lobe of the heterogenous compound nucleus.

Thus, due to formation of two dissimilar lobes within into the homogenous compound nucleus, the homogenous compound nucleus transforms into the heterogenous compound nucleus.



Formation of lobes

⇒ Within into the homogenous compound nucleus, the greater nucleus is the helion-5 and the smaller nucleus is the proton while the remaining space represents the remaining gluons.

⇒ Within into the homogenous compound nucleus, the greater nucleus is the lobe 'A' and the smaller one is the lobe 'B'.

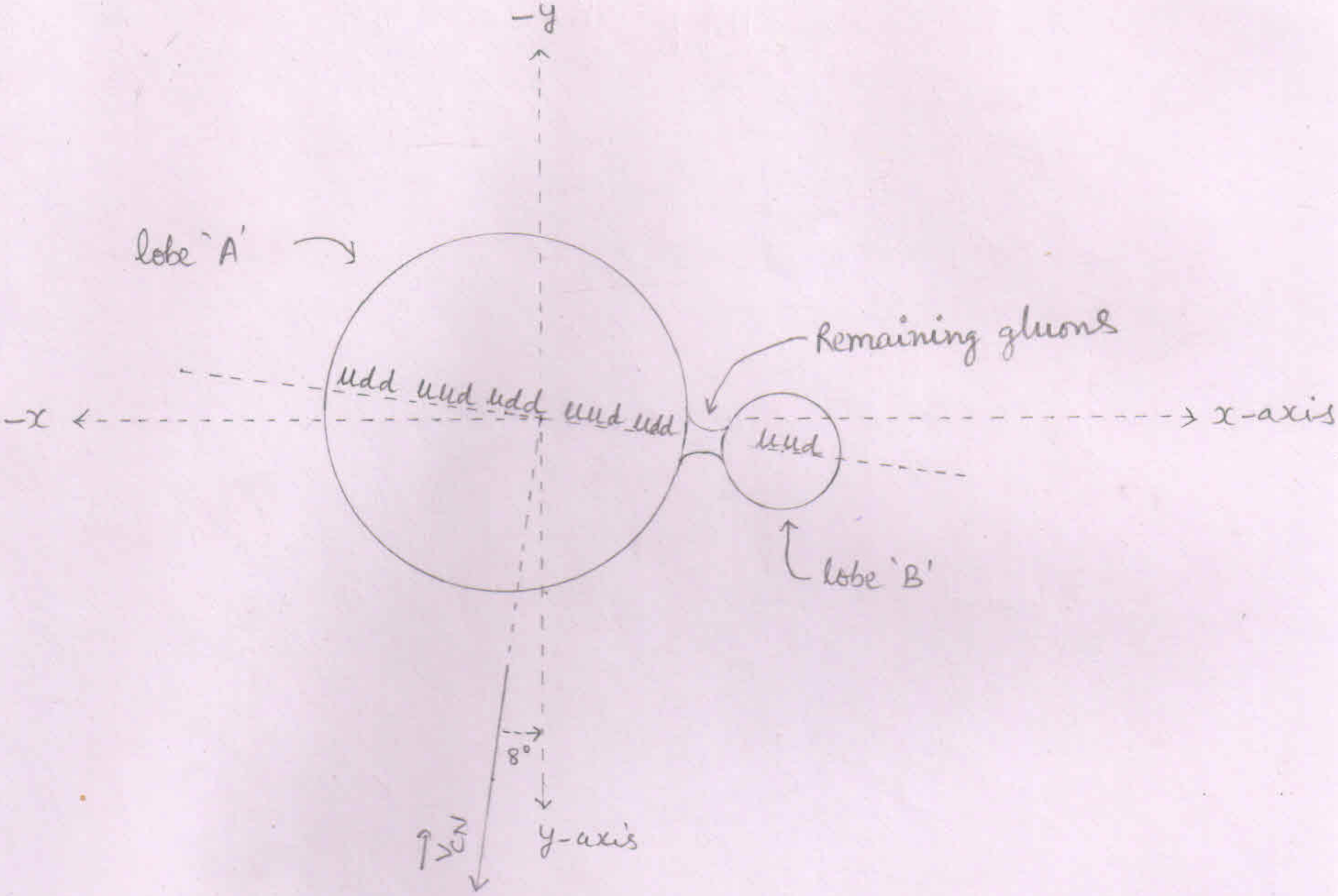
4. Final stage of the heterogenous compound nucleus :-

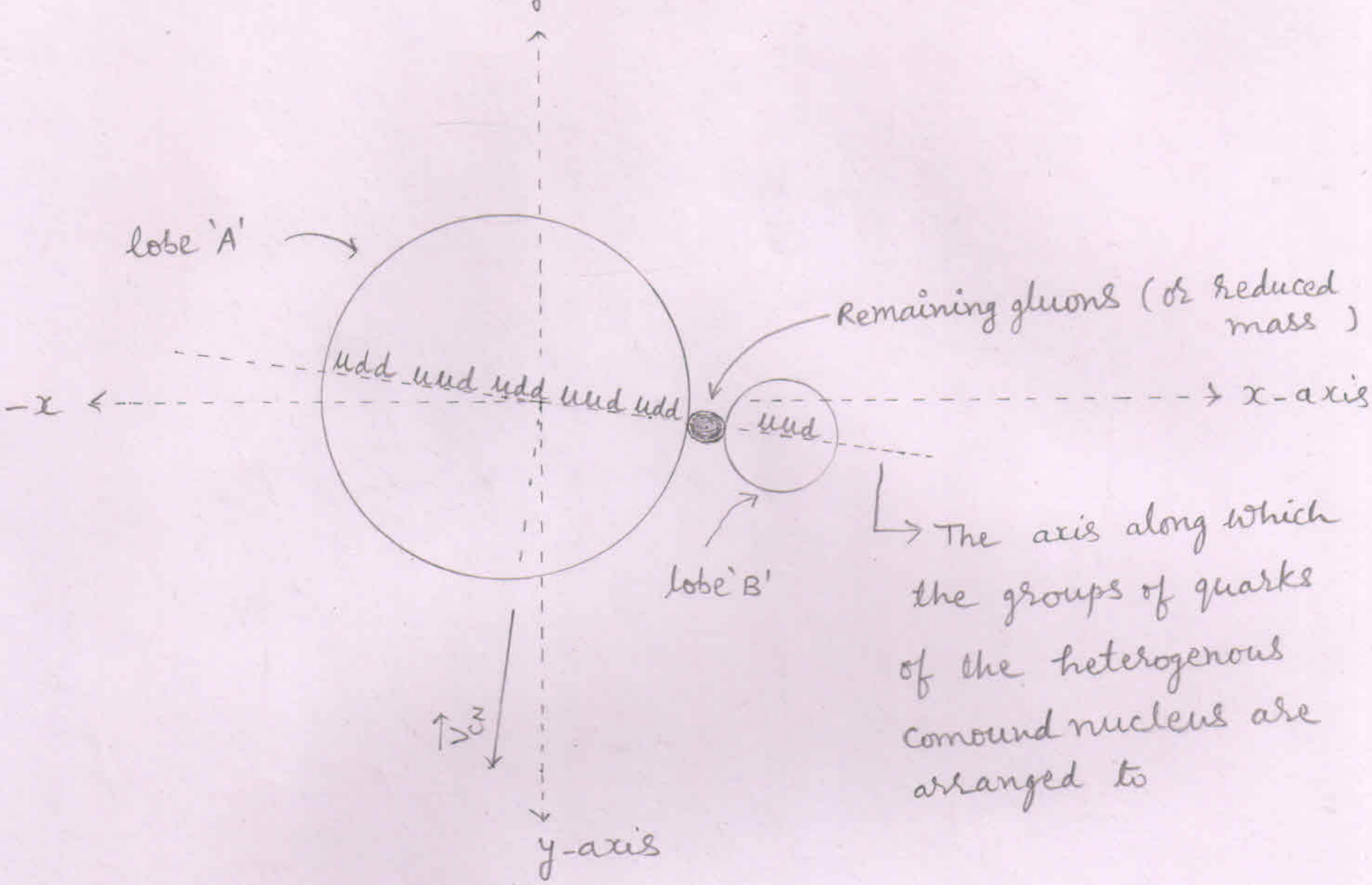
The process of formation of lobes creates voids between the lobes. So, the remaining gluons [or the mass that is not included in the formation of any lobe] rearrange to fill the voids between the lobes and thus the remaining gluons form a node between the two dissimilar lobes of the heterogenous compound nucleus.

Thus, the reduced mass (or the remaining gluons) keeps both the dissimilar lobes – of the heterogenous compound nucleus – joined them together.

So, finally, the heterogenous compound nucleus becomes like an abnormal digit eight or becomes like a dumb-bell.

The heterogenous compound nucleus





Final stage of the heterogenous compound nucleus

The splitting of the heterogenous compound nucleus :-

⇒ The heterogenous compound nucleus, due to its instability, splits according to the lines parallel to the direction of the velocity of the compound nucleus ($\vec{v}_{CN}$) into three particles – the helion-5, the proton and the reduced mass (Δm).

out of them, the two particles (the helion-5 and the proton) are stable while the third one (reduced mass) is unstable.

⇒ According to the law of inertia, each particle that has separated from the compound nucleus has an inhereted velocity ($\vec{v}_{inh}$) equal to the velocity of the compound nucleus ($\vec{v}_{CN}$).

⇒ So, for conservation of momentum

$$M\vec{V}_{CN} = (m_{he-5} + \Delta m + m_p)\,\vec{v}_{CN}$$

Where,

M = mass of the compound nucleus

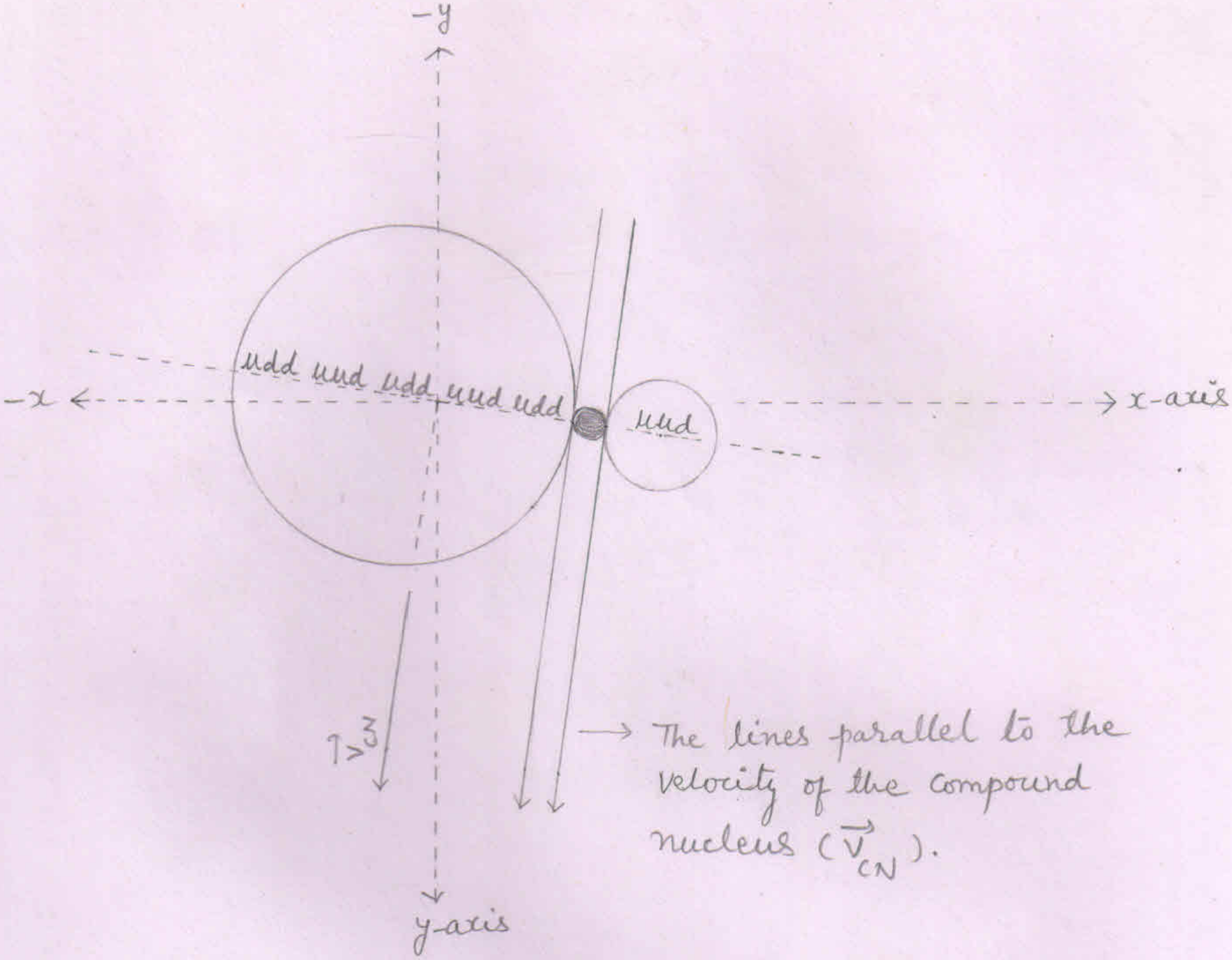
$\vec{V}_{CN}$ = velocity of the compound nucleus

m_{he-5} = mass of the helion-5

Δm = reduced mass

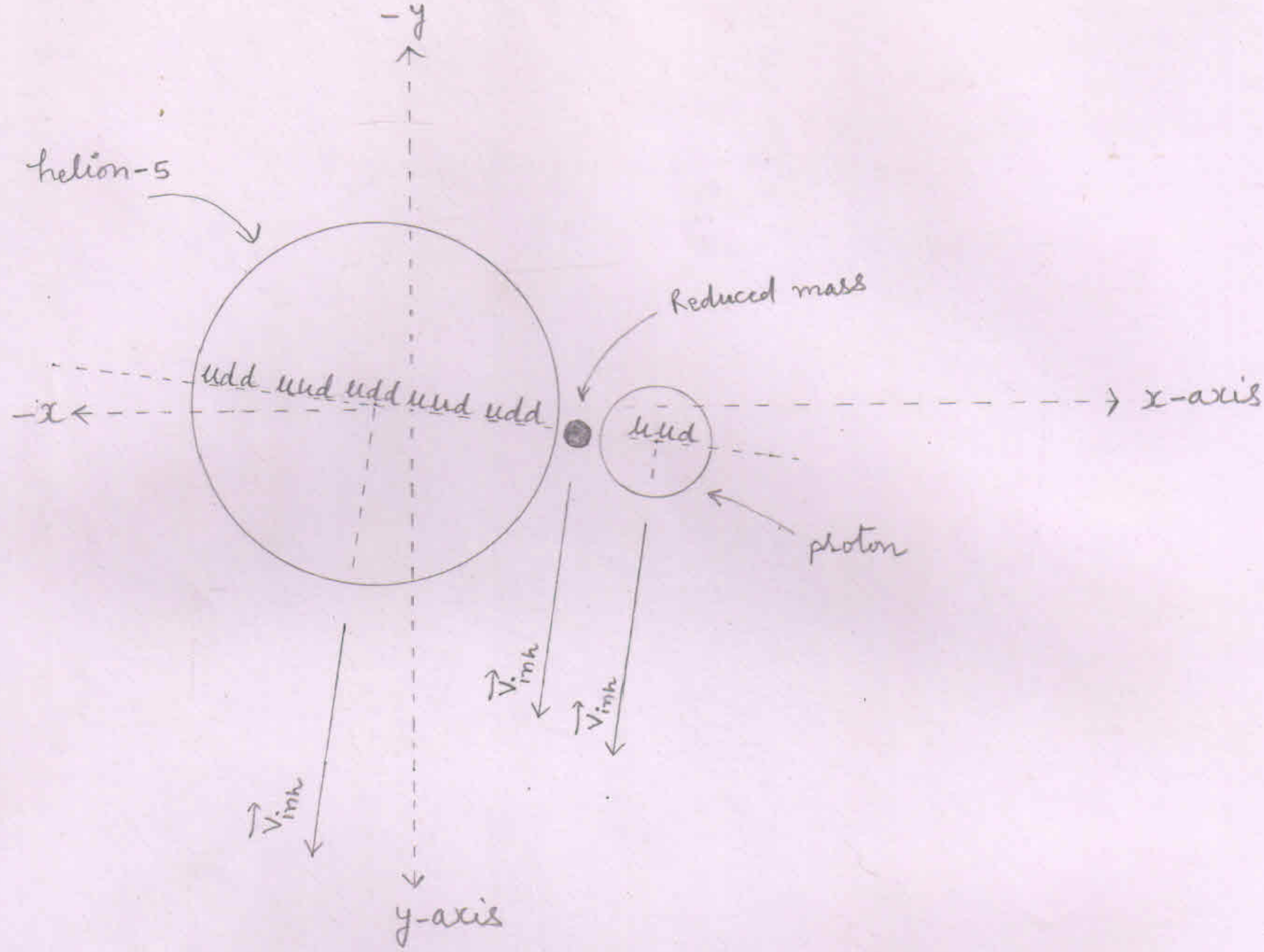
m_p = mass of the proton

The splitting of the heterogenous compound nucleus



The lines parallel to the velocity of the compound nucleus ($\vec{V}_{CN}$).

The splitting of the heterogenous compound nucleus



⇒ The heterogenous compound nucleus splits into three particles – the helion-5, the reduced mass (Δm) and the proton

Inhereted velocity of the particles

⇒ Each particle that has separated from the compound nucleus has an inhereted velocity ($\vec{V}_{inh}$) equal to the velocity of the compound nucleus ($\vec{V}_{CN}$).

I. Inhereted velocity of the helion-5

$$V_{inh} = V_{CN} = 0.8176 \times 10^{7} \text{ m/s}$$

⇒ Components of the inhereted velocity ($\vec{V}_{inh}$) of the helium-5 nucleus :-

1. $\vec{V}_x = V_{inh} \cos\alpha = V_{CN} \cos\alpha = -0.1130 \times 10^{7}$ m/s

2. $\vec{V}_y = V_{inh} \cos\beta = V_{CN} \cos\beta = 0.8098 \times 10^{7}$ m/s

3. $\vec{V}_z = V_{inh} \cos\gamma = V_{CN} \cos\gamma = 0$ m/s

II. Inhereted velocity of the proton

$$V_{inh} = V_{CN} = 0.8176 \times 10^{7} \text{ m/s}$$

⇒ Components of the inhereted velocity ($\vec{V}_{inh}$) of the proton :-

1. $\vec{V}_x = V_{inh} \cos\alpha = V_{CN} \cos\alpha = -0.1130 \times 10^{7}$ m/s

2. $\vec{V}_y = V_{inh} \cos\beta = V_{CN} \cos\beta = 0.8098 \times 10^{7}$ m/s

3. $\vec{V}_z = V_{inh} \cos\gamma = V_{CN} \cos\gamma = 0$ m/s

III. Inhereted velocity (V_{inh}) of the reduced mass (Δm) :-

Propellation of particles

1. Reduced mass

$$\Delta m = [m_t + m_{He-3}] - [m_{He-5} + m_p]$$

$$\Delta m = [3.0155 + 3.0149] - [5.0111 + 1.0072] \text{ amu}$$

$$\Delta m = [6.0304] - [6.0183] \text{ amu}$$

$$\Delta m = 0.0121 \text{ amu}$$

$$\Delta m = 0.021 \quad 0.0121 \times 1.6605 \times 10^{-27} \text{ kg}$$

$$\Delta m = 0.02009205 \times 10^{-27} \text{ kg}$$

2. Inhereted kinetic energy of the reduced mass

$$E_{inh} = \frac{1}{2} \Delta m V_{inh}^2 = \frac{1}{2} \Delta m V_{CN}^2$$

$$V_{CN}^2 = 0.66854504 \times 10^{14} \text{ m}^2/\text{s}^2$$

$$\Rightarrow E_{inh} = \frac{1}{2} \times 0.02009205 \times 10^{-27} \times 0.66854504 \times 10^{14} \text{ J}$$

$$= 0.0067162218 \times 10^{-13} \text{ J}$$

$$= 0.0041 \text{ MeV}$$

3. Released energy (E_R):

$$E_R = \Delta m c^2$$

$$= 0.0121 \times 931 \quad \text{Mev}$$

$$= 11.2651 \quad \text{Mev}$$

4. Total energy (E_T):

$$E_T = E_{inh} + E_R$$

$$= 0.0041 + 11.2651 \quad \text{Mev}$$

$$= 11.2692 \quad \text{Mev}$$

Increased kinetic energy of the proton

$$E_{inc} = \frac{m_{He-5}}{m_{He-5} + m_p} \times E_T$$

$$= \frac{5.0111}{5.0111 + 1.0072} \times 11.2692 \quad \text{Mev}$$

$$= \frac{5.0111}{6.0183} \times 11.2692 \quad \text{Mev}$$

$$= 0.8326437698 3 \times 11.2692 \quad \text{Mev}$$

$$= 9.3832 \quad \text{Mev}$$

Increased kinetic energy of the helion-5

E_{inc} = [E_T − Increased kinetic energy of the proton]

$$= [11.2692 - 9.3832] \quad \text{Mev}$$

$$= 1.8860 \quad \text{Mev}$$

Increased velocity of the proton

$$V_{inc} = \sqrt{\frac{2\, E_{inc}}{m_p}}$$

$$= \left[\frac{2 \times 9.3832 \times 1.6 \times 10^{-13}}{1.6726 \times 10^{-27}}\right]^{\frac{1}{2}} \quad m/s$$

$$= \left[\frac{30.02624}{1.6726} \times 10^{14}\right]^{\frac{1}{2}} \quad m/s$$

$$= \left[17.951835 4657 \times 10^{14}\right]^{\frac{1}{2}} \quad m/s$$

$$= 4.2369 \times 10^{7} \quad m/s$$

Increased velocity of the helion-5

$$V_{inc} = \sqrt{\frac{2\, E_{inc}}{m_{He-5}}}$$

$$= \left[\frac{2 \times 1.886 \times 1.6 \times 10^{-13}}{8.3209 \times 10^{-27}}\right]^{\frac{1}{2}} \quad m/s$$

$$= \left[\frac{6.0352}{8.3209} \times 10^{14}\right]^{\frac{1}{2}} \quad m/s$$

$$= \left[0.72530615678 \times 10^{14}\right]^{\frac{1}{2}} \quad m/s$$

$$= 0.8516 \times 10^{7} \quad m/s$$

Angle of propellation

1. As the reduced mass converts into energy, the total energy (E_T) propell both the particles with equal and opposite momentum according to a ray (line) perpendicular to the direction (line) of the velocity of the compound nucleus ($\vec{V}_{CN}$).

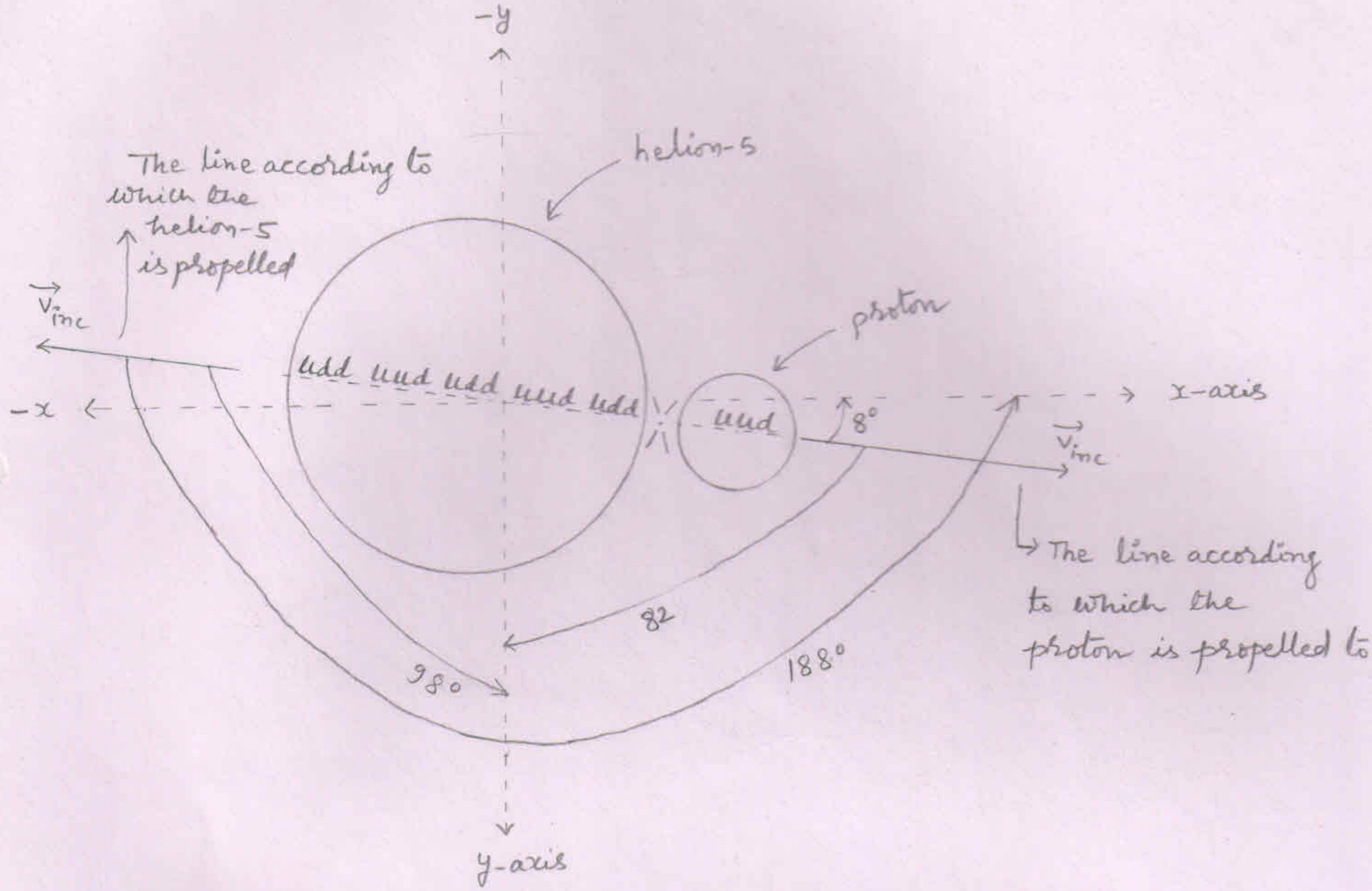
2. We know that when there a fusion process occures, then we find the lighter nucleus in the forward direction [or in the direction of ion beam or in the direction of the velocity of the compound nucleus ($\vec{V}_{CN}$)].

3. At point 'F', as $\vec{V}_{CN}$ makes 98° angle with x-axis, 8° angle with y-axis and 90° angle with z-axis.

4. So, the proton is propelled making 8° angle with x-axis, 82° angle with y-axis and 90° angle with z-axis.

5. While the helion-5 is propelled making 188° angle with x-axis, 98° angle with y-axis and 90° angle with z-axis.

Propellation of the particles



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

I. For proton

1. $\vec{V}_x = V_{inc} \cos\alpha$

$V_{inc} = 4.2369 \times 10^7$ m/s

$\cos\alpha = \cos(8) = 0.99$

$\Rightarrow \vec{V}_x = 4.2369 \times 10^7 \times 0.99$ m/s

$= 4.1945 \times 10^7$ m/s

2. $\vec{V}_y = V_{inc} \cos\beta$

$\cos\beta = \cos(82) = 0.13$

$\Rightarrow \vec{V}_y = 4.2369 \times 10^7 \times 0.13$ m/s

$= 0.5507 \times 10^7$ m/s

3. $\vec{V}_z = V_{inc} \cos\gamma$

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

$\Rightarrow \vec{V}_z = 4.2369 \times 10^7 \times 0$ m/s $= 0$ m/s

II. For helion-5

1. $\vec{V}_x = V_{inc} \cos\alpha$

$V_{inc} = 0.8516 \times 10^7$ m/s

$\cos\alpha = \cos(188) = -\cos(8) = -0.99$

$\Rightarrow \vec{V}_x = 0.8516 \times 10^7 \times (-0.99)$ m/s

$= -0.8430 \times 10^7$ m/s

2. $\vec{V}_y = V_{inc} \cos\beta$

$\cos\beta = \cos(98) = -\cos(82) = -0.13$

$\Rightarrow \vec{V}_y = 0.8516 \times 10^7 \times (-0.13)$ m/s

$= -0.1107 \times 10^7$ m/s

3. $\vec{V}_z = V_{inc} \cos\gamma$

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

$\Rightarrow \vec{V}_z = 0.8516 \times 10^7 \times 0$ m/s $= 0$ m/s

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

I. For proton

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	$\vec{v}_x = -0.1130 \times 10^7$ m/s	$\vec{v}_x = 4.1945 \times 10^7$ m/s	$\vec{v}_x = 4.0815 \times 10^7$ m/s
y-axis	$\vec{v}_y = 0.8098 \times 10^7$ m/s	$\vec{v}_y = 0.5507 \times 10^7$ m/s	$\vec{v}_y = 1.3605 \times 10^7$ 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-5

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	$\vec{v}_x = -0.1130 \times 10^7$ m/s	$\vec{v}_x = -0.8430 \times 10^7$ m/s	$\vec{v}_x = -0.956 \times 10^7$ m/s
y-axis	$\vec{v}_y = 0.8098 \times 10^7$ m/s	$\vec{v}_y = -0.1107 \times 10^7$ m/s	$\vec{v}_y = 0.6991 \times 10^7$ m/s
z-axis	$\vec{v}_z = 0$ m/s	$\vec{v}_z = 0$ m/s	$\vec{v}_z = 0$ m/s

Final velocity of the proton

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

$v_x = 4.0815 \times 10^7$ m/s
$v_y = 1.3605 \times 10^7$ m/s
$v_z = 0$ m/s

$$\Rightarrow v_f^2 = (4.0815 \times 10^7)^2 + (1.3605 \times 10^7)^2 + (0)^2 \ m^2/s^2$$

$$\Rightarrow v_f^2 = (16.65864225 \times 10^{14}) + (1.85096025 \times 10^{14}) + (0) \ m^2/s^2$$

$$\Rightarrow v_f^2 = 18.5096025 \times 10^{14} \ m^2/s^2$$

$$\Rightarrow v_f =$$

Final kinetic energy of the proton

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

$v_f^2 = 18.5096025 \times 10^{14} \ m^2/s^2$

$$\Rightarrow E = \frac{1}{2} \times 1.6726 \times 10^{-27} \times 18.5096025 \times 10^{14} \ J$$

$$= 15.4795805707 \times 10^{-13} \ J$$

$$= 9.6747 \ MeV$$

$$\Rightarrow m_p v_f^2 = 1.6726 \times 10^{-13} \times 18.5096025 \times 10^{14} \ J$$

$$= 30.9591 \times 10^{-13} \ J$$

Acting forces on the proton

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

$\vec{V_x} = 4.0815 \times 10^7$ m/s

$\vec{B_z} = -1$ Tesla

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

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

$\Rightarrow F_y = 1.6 \times 10^{-19} \times 4.0815 \times 10^7 \times 1 \times 1$ N.

$= 6.5304 \times 10^{-12}$ N

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

$$\vec{F_y} = -6.5304 \times 10^{-12} \text{ N}$$

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

$\vec{B_y} = 1$ Tesla

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

$\Rightarrow F_z = 1.6 \times 10^{-19} \times 4.0815 \times 10^7 \times 1 \times 1$ N

$= 6.5304 \times 10^{-12}$ N

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

$$\vec{F_z} = -6.5304 \times 10^{-12} \text{ N}$$

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

$\vec{V_y} = 1.3605 \times 10^7$ m/s

$\vec{B_z} = -1$ Tesla

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

$\Rightarrow F_x = 1.6 \times 10^{-19} \times 1.3605 \times 10^7 \times 1 \times 1$ N

$= 2.1768 \times 10^{-12}$ N

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

4. Resultant force (F_R):

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

$F_x = 2.1768 \times 10^{-12}$ N

$F = F_y = F_z = 6.5304 \times 10^{-12}$ N

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

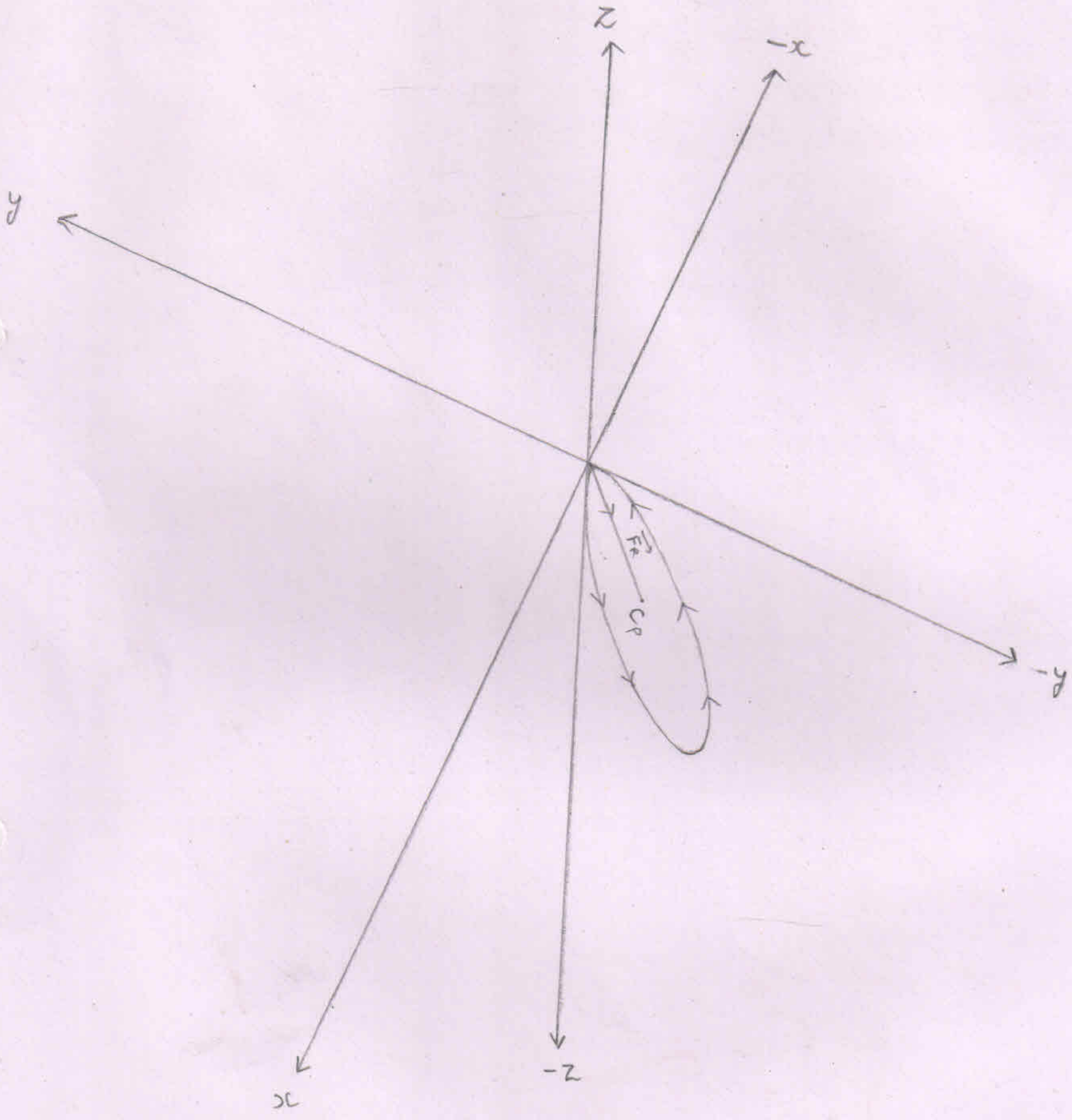
$$\Rightarrow F_R^2 = (2.1768 \times 10^{-12})^2 + 2(6.5304 \times 10^{-12})^2 \ N^2$$

$$\Rightarrow F_R^2 = (4.73845824 \times 10^{-24})^2 + 2(42.64612416 \times 10^{-24}) \ N^2$$

$$\Rightarrow F_R^2 = (4.73845824 \times 10^{-24}) + (85.29224832 \times 10^{-24}) \ N^2$$

$$\Rightarrow F_R^2 = 90.03070656 \times 10^{-24} \ N^2$$

$$\Rightarrow F_R = 9.4884 \times 10^{-12} \ N$$



$\Rightarrow$ The circular orbit to be followed by the proton lies in the IV (down) quadrant made up of positive x axis, negative y axis and the negative z axis.

$\Rightarrow$ c_p = center of the circle to be followed by the proton

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

1. With x-axis

$$\cos\alpha = \frac{F_R \cos\alpha}{F_R} = \frac{\vec{F_x}}{F_R} = \frac{2.1768 \times 10^{-12}}{9.4884 \times 10^{-12}} \frac{N}{N}$$

$\Rightarrow \cos\alpha = 0.2294$

$\Rightarrow \alpha \simeq 76.8$ degree $[\because \cos(76.8) = 0.2283]$

2. With y-axis

$$\cos\beta = \frac{F_R \cos\beta}{F_R} = \frac{\vec{F_y}}{F_R} = \frac{-6.5304 \times 10^{-12}}{9.4884 \times 10^{-12}} \frac{N}{N}$$

$\Rightarrow \cos\beta = -0.6882$

$\Rightarrow \beta \simeq 133.4$ degree $[\because \cos(133.4) = -0.6870]$

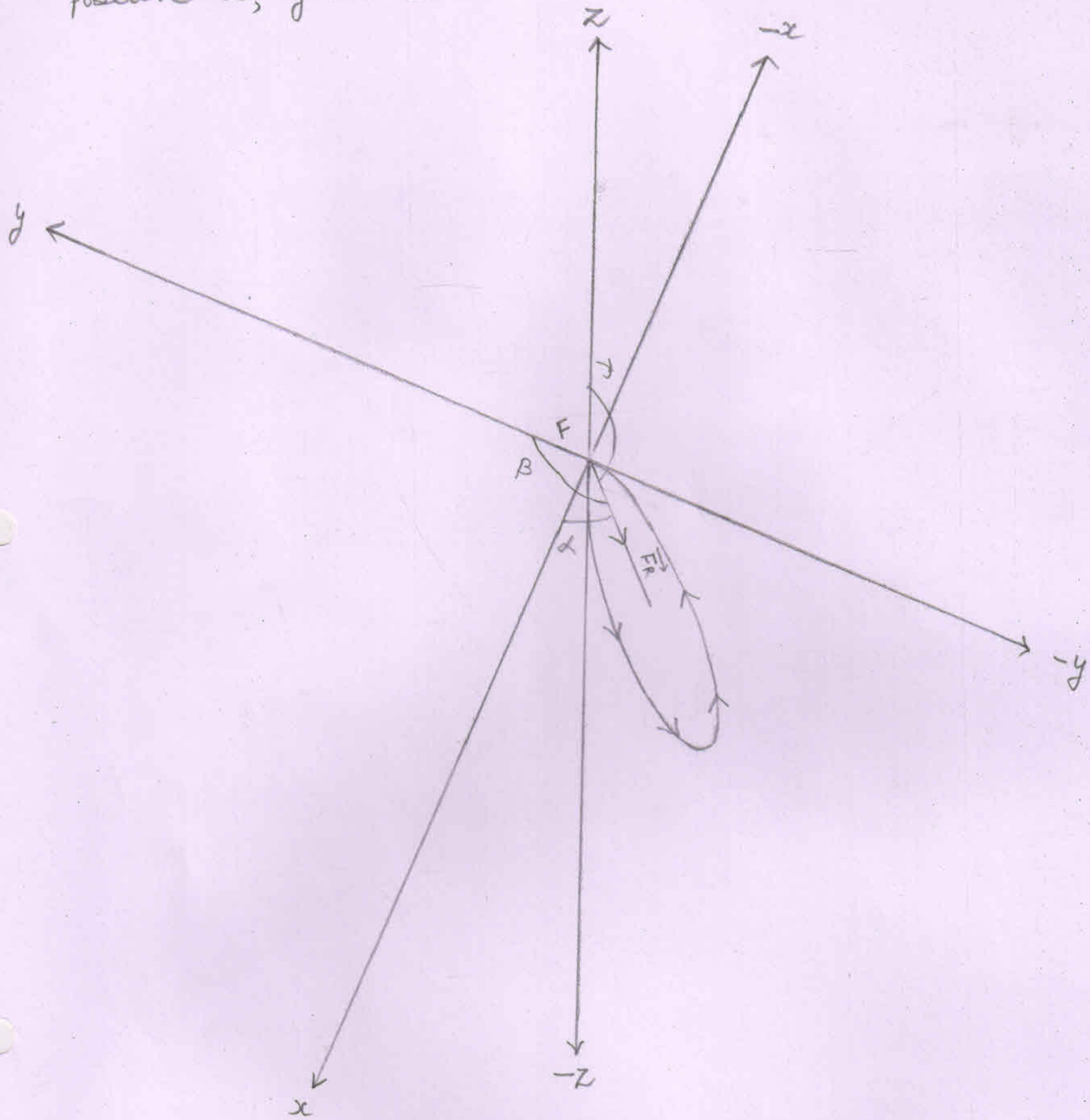
3. With z-axis

$$\cos\gamma = \frac{F_R \cos\gamma}{F_R} = \frac{\vec{F_z}}{F_R} = \frac{-6.5304 \times 10^{-12}}{9.4884 \times 10^{-12}} \frac{N}{N}$$

$\Rightarrow \cos\gamma = -0.6882$

$\Rightarrow \gamma \simeq 133.4$ degree

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



Where,

$\alpha \simeq 76.8$

$\beta \simeq 133.4$

$\gamma \simeq 133.4$

5. Radius of the circular orbit followed by the proton :-

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

$mv^2 = 30.9591 \times 10^{-13}$ J
$F_R = 9.4884 \times 10^{-12}$ N

$$\Rightarrow r = \frac{30.9591 \times 10^{-13}}{9.4884 \times 10^{-12}} \text{ m}$$

$$\Rightarrow r = 3.26283 \times 10^{-1} \text{ m}$$

$$\Rightarrow r = 32.6283 \times 10^{-2} \text{ m}$$

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 proton

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

$$d = 2 \times r$$
$$= 2 \times 32.6283 \times 10^{-2}\ m$$
$$= 65.2566 \times 10^{-2}\ m$$

$$\cos\alpha = 0.22$$

$\Rightarrow x_2 - x_1 = d \times \cos\alpha$

$\Rightarrow x_2 - x_1 = 65.2566 \times 10^{-2} \times 0.22\ m$

$\Rightarrow x_2 - x_1 = 14.3564 \times 10^{-2}\ m$

$\Rightarrow x_2 = 14.3564 \times 10^{-2}\ m$ $[\because x_1 = 0]$

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

$$\cos\beta = -0.68$$

$\Rightarrow y_2 - y_1 = d \times \cos\beta$

$\Rightarrow y_2 - y_1 = 65.2566 \times 10^{-2} \times (-0.68)\ m$

$\Rightarrow y_2 - y_1 = -44.3744 \times 10^{-2}\ m$

$\Rightarrow y_2 = -44.3744 \times 10^{-2}\ m$ $[\because y_1 = 0]$

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

$$\cos\gamma = -0.68$$

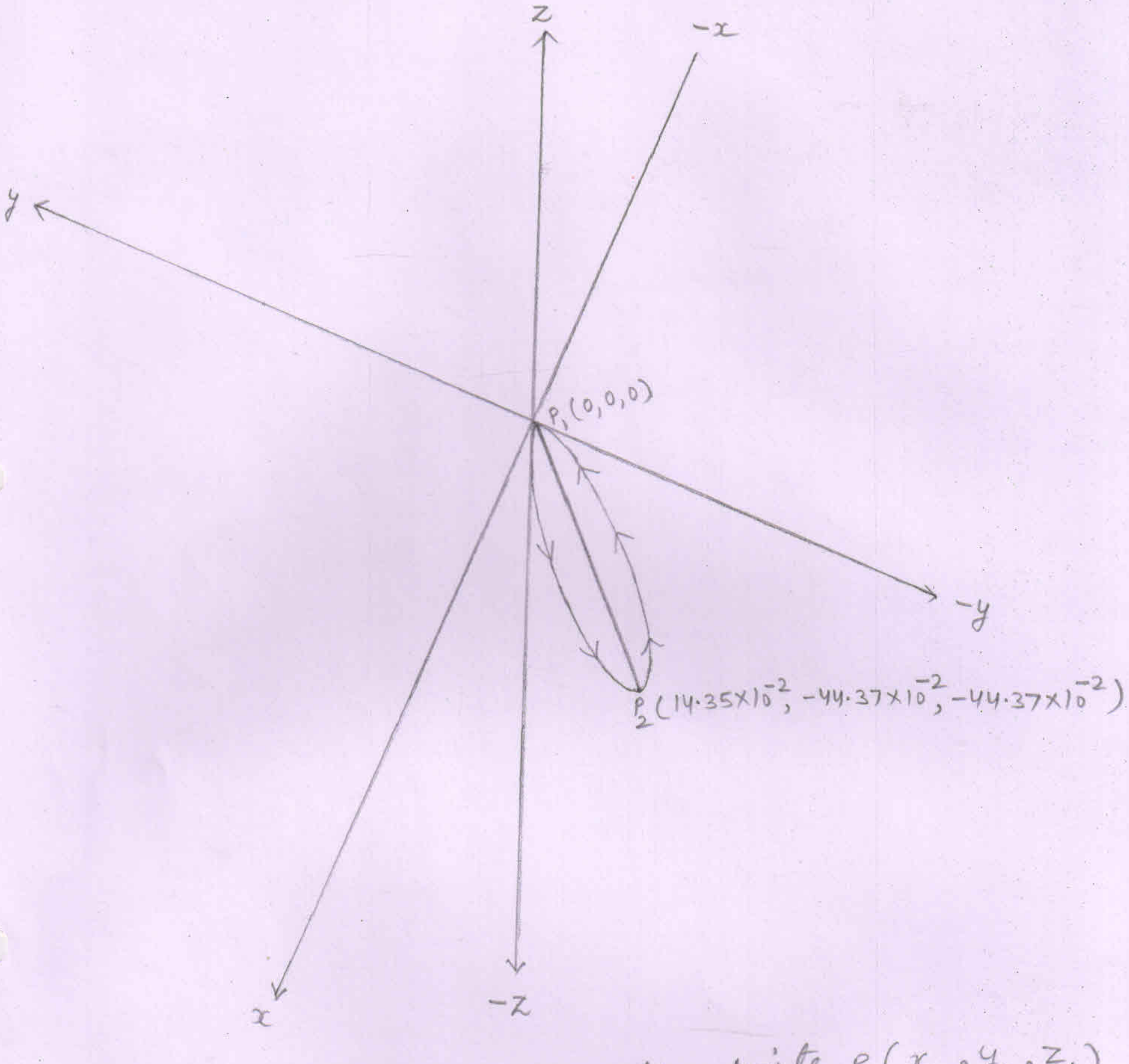
$\Rightarrow z_2 - z_1 = d \times \cos\gamma$

$\Rightarrow z_2 - z_1 = 65.2566 \times 10^{-2} \times (-0.68)\ m$

$\Rightarrow z_2 - z_1 = -44.3744 \times 10^{-2}\ m$

$\Rightarrow z_2 = -44.3744 \times 10^{-2}\ m$ $[\because z_1 = 0]$

The cartesian coordinates of the points $P_1(x_1, y_1, z_1)$ and $P_2(x_2, y_2, z_2)$



⇒ 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 proton are as shown above.

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

Final velocity (v_f) of the helion-5

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

$$v_x = 0.956 \times 10^7 \ m/s$$
$$v_y = 0.6991 \times 10^7 \ m/s$$
$$v_z = 0 \quad m/s$$

$$\Rightarrow v_f^2 = (0.956 \times 10^7)^2 + (0.6991 \times 10^7)^2 + (0)^2 \quad m^2/s^2$$

$$\Rightarrow v_f^2 = (0.913936 \times 10^{14}) + (0.48874081 \times 10^{14}) + (0) \quad m^2/s^2$$

$$\Rightarrow v_f^2 = 1.40267681 \times 10^{14} \quad m^2/s^2$$

$$\Rightarrow v_f = 1.1843 \times 10^7 \quad m/s$$

Angles that make the final velocity ($\vec{V_f}$) of the helion-5 with axes at point F.

1. With x-axis

$$\cos\alpha = \frac{\vec{V_x}}{V_f}$$

$\vec{V_x} = -0.956 \times 10^7$ m/s

$V_f = 1.1843 \times 10^7$ m/s

$$\Rightarrow \cos\alpha = \frac{-0.956\times10^7}{1.1843\times10^7} \frac{m/s}{m/s} = -0.8072$$

$\Rightarrow \alpha \simeq 143.8$ $[\because \cos(143.8) = -\cos(36.2) = -0.8069]$

2. With y-axis

$$\cos\beta = \frac{\vec{V_y}}{V_f}$$

$\vec{V_y} = 0.6991 \times 10^7$ m/s

$$\Rightarrow \cos\beta = \frac{0.6991\times10^7}{1.1843\times10^7} \frac{m/s}{m/s} = 0.5903$$

$\Rightarrow \beta \simeq 53.8$ $[\because \cos(53.8) = 0.5906]$

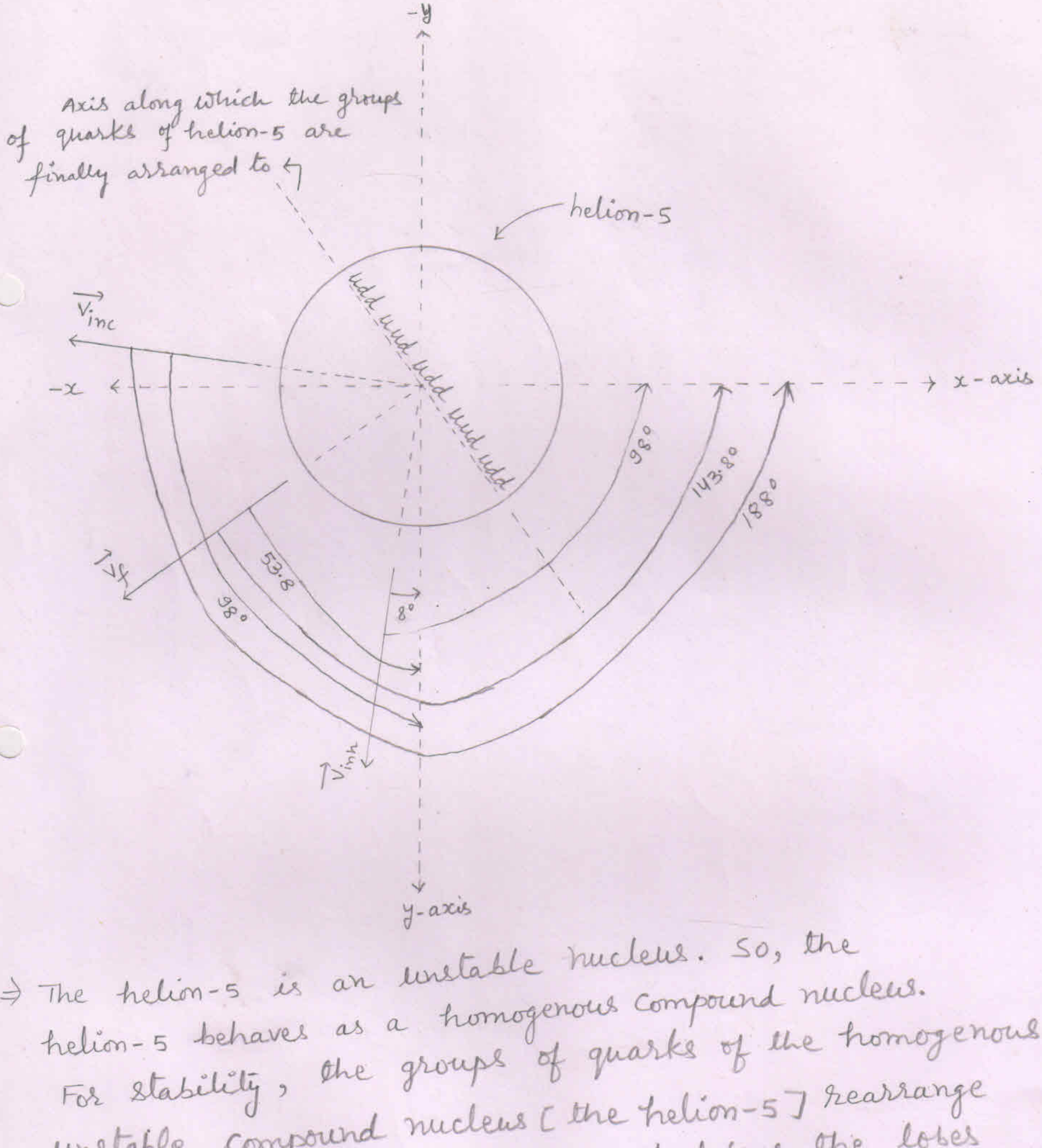
3. With z-axis

$$\cos\gamma = \frac{\vec{V_z}}{V_f}$$

$\vec{V_z} = 0$ m/s

$$\Rightarrow \cos\gamma = \frac{0}{1.1843\times10^7} \frac{m/s}{m/s} = 0$$

$\Rightarrow \gamma = 90^\circ$



⇒ The helion-5 is an unstable nucleus. So, the helion-5 behaves as a homogenous compound nucleus. For stability, the groups of quarks of the homogenous unstable compound nucleus [the helion-5] rearrange with the surrounding gluons and forms the lobes 'A' and 'B'.

Thus the unstable homogenous compound nucleus [the helion-5] turns into the heterogenous compound nucleus.

For the reaction

$$^{5}_{2}He \longrightarrow ^{4}_{2}He + \Delta m + ^{1}_{0}n$$

⇒ The helion-5 is an unstable nucleus. So, the helion-5 behave as a homogenous compound nucleus. So, for stability the helion-5 again undergo to the process of formation of lobes within into it and then undergo to the splitting.

The groups of quarks of the homogenous unstable compound nucleus [the helion-5] rearrange with their surrounding gluons and form the lobes 'A' and 'B'.

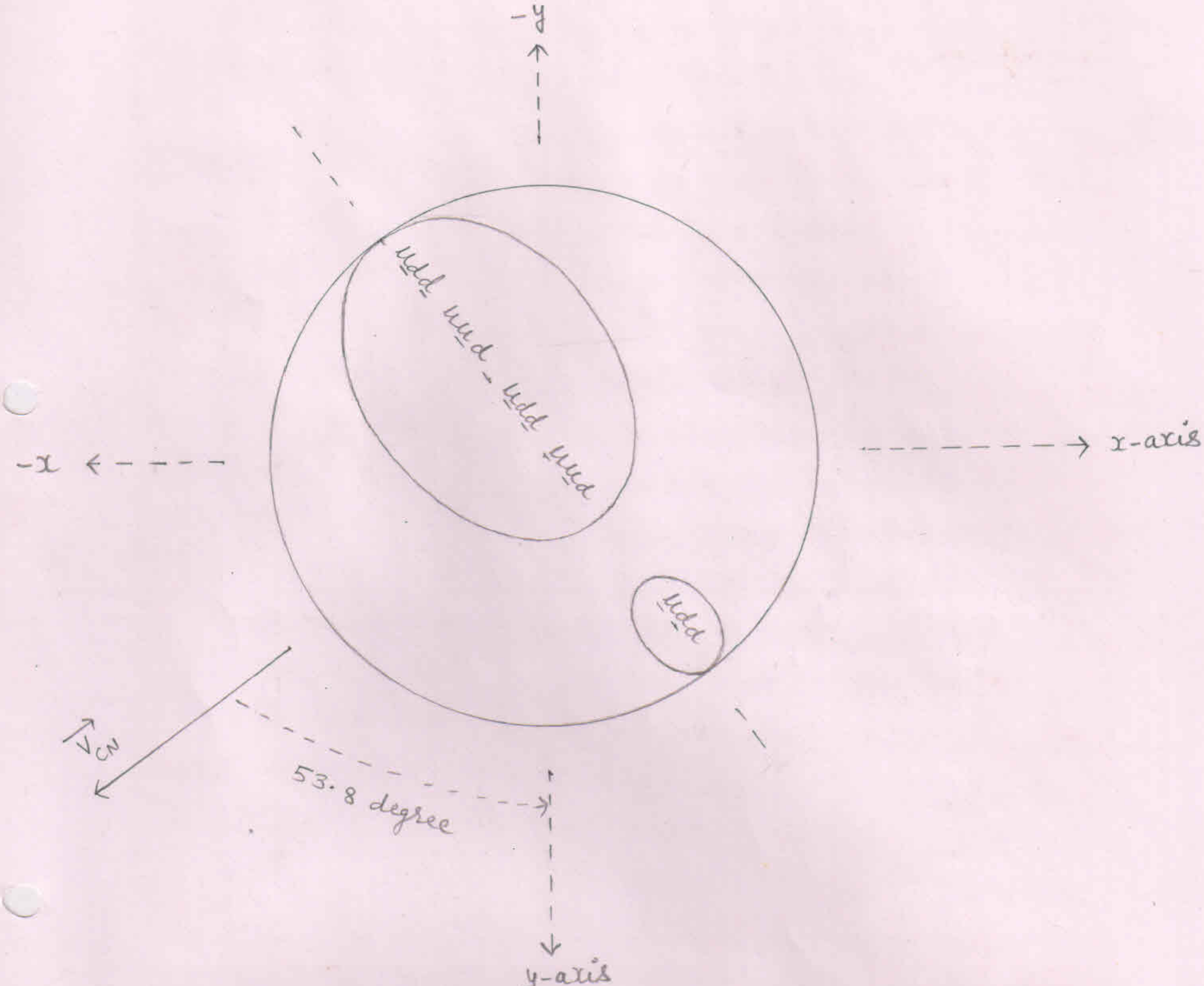
Thus the homogenous compound nucleus [the helion-5] turns into the heterogenous compound nucleus.

Formation of lobes within into the homogenous compound nucleus or the transformation of the homogenous compound nucleus into the heterogenous compound nucleus :-

The central group of quarks with its surrounding gluons to become a stable and the just lower nucleus (the helion-4) than the homogenous one (the helion-5) includes the other three (nearby located) groups of quarks with their surrounding gluons and rearrange to form the 'A' lobe of the heterogenous compound nucleus.

While the remaining group of quarks to become a stable nucleus (the neutron) includes its surrounding gluons or mass [out of the available mass (or gluons) that is not included in the formation of the lobe 'A'] and rearrange to form the 'B' lobe of the heterogenous compound nucleus.

Thus, due to formation of two dissimilar lobes within into the homogenous compound nucleus, the homogenous compound nucleus transforms into the heterogenous compound nucleus.



Formation of lobes

⇒ Within into the homogenous compound nucleus, the greater nucleus is the helium-4 nucleus and the smaller nucleus is the neutron while the remaining space represents the remaining gluons.

⇒ Within into the homogenous compound nucleus, the greater nucleus is the lobe 'A' while the smaller nucleus is the lobe 'B'.

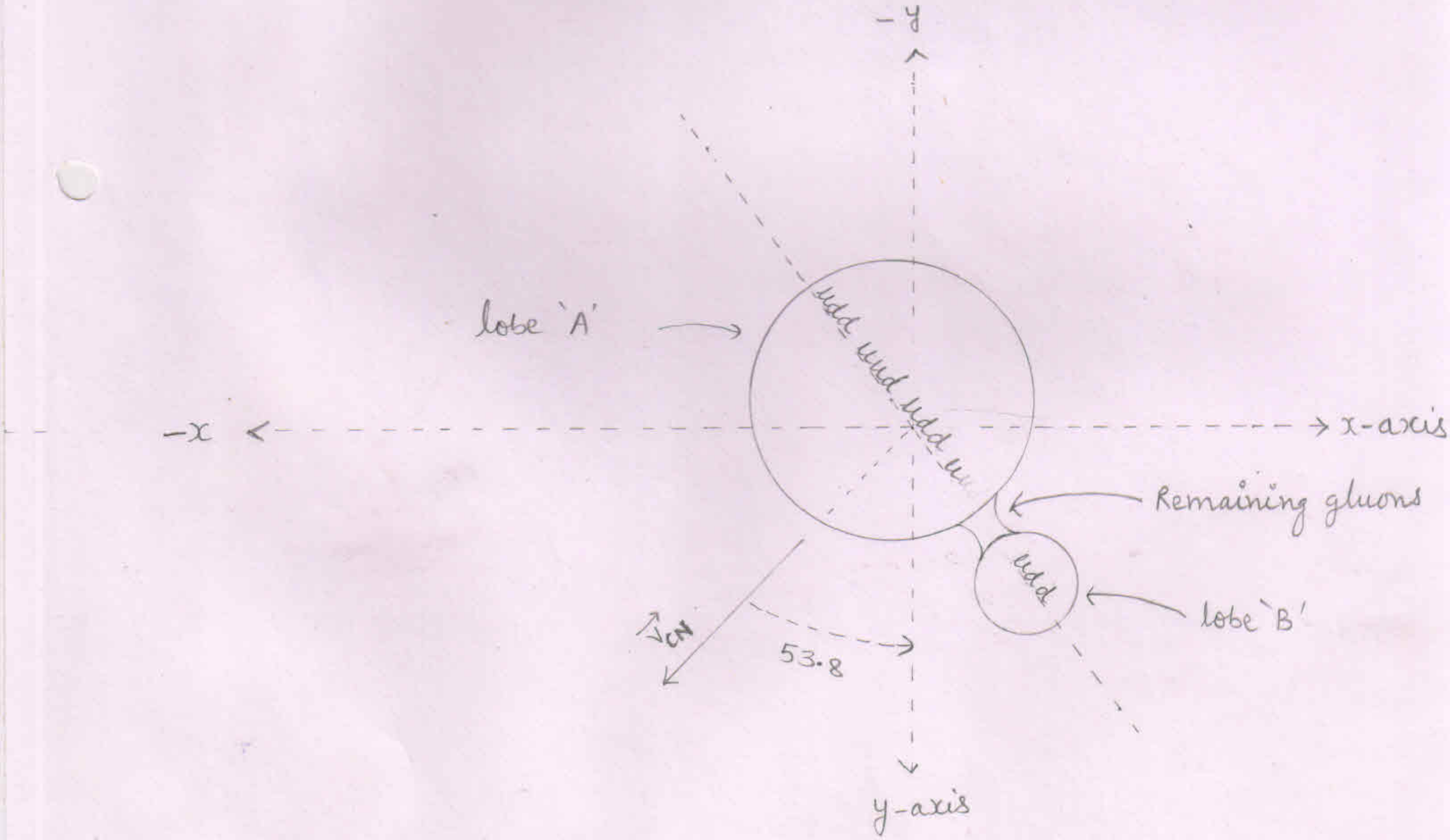
4. Final stage of the heterogenous compound nucleus :-

The process of formation of lobes creates voids between the lobes. so, the remaining gluons [or the mass that is not involved in the formation of any lobe] rearrange to fill the void(s) between the lobes and thus the remaining gluons form a node between the two dissimilar lobes of the heterogenous compound nucleus.

Thus, the reduced mass (or the remaining gluons) keeps both the dissimilar lobes – of the heterogenous compound nucleus – joined them together.

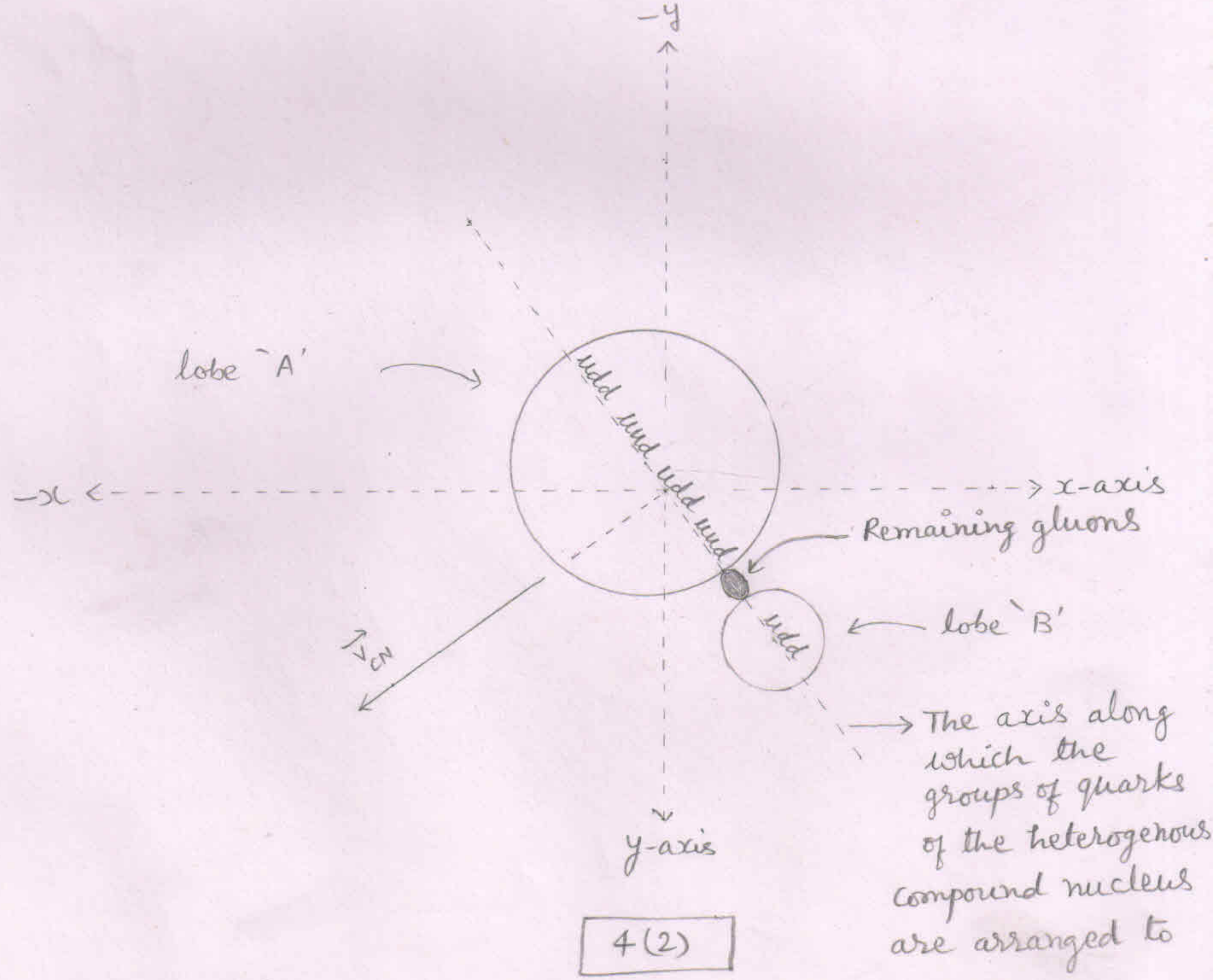
So, finally, the heterogenous compound nucleus becomes like an abnormal digit eight or becomes like a dum

Final Stage of the heterogenous compound nucleus



4 (1)

Final stage of the heterogenous compound nucleus



The splitting of the heterogenous compound nucleus :-

⇒ The heterogenous compound nucleus, due to its instability, splits according to the lines parallel to the direction of the velocity of the compound nucleus ($\vec{V}_{CN}$) into three particles - the helion-4, the neutron and the reduced mass (Δm).

Out of them, the two particles (the helion-4 and the neutron) are stable while the third one (the reduced mass) is unstable.

⇒ According to the law of inertia, each particle that has separated from the compound nucleus has an inhereted velocity ($\vec{V}_{inh}$) equal to the velocity of the compound nucleus ($\vec{V}_{CN}$).

⇒ So, for conservation of momentum

$$M\vec{V}_{CN} = (m_{he-4} + \Delta m + m_n)\,\vec{V}_{CN}$$

Where,

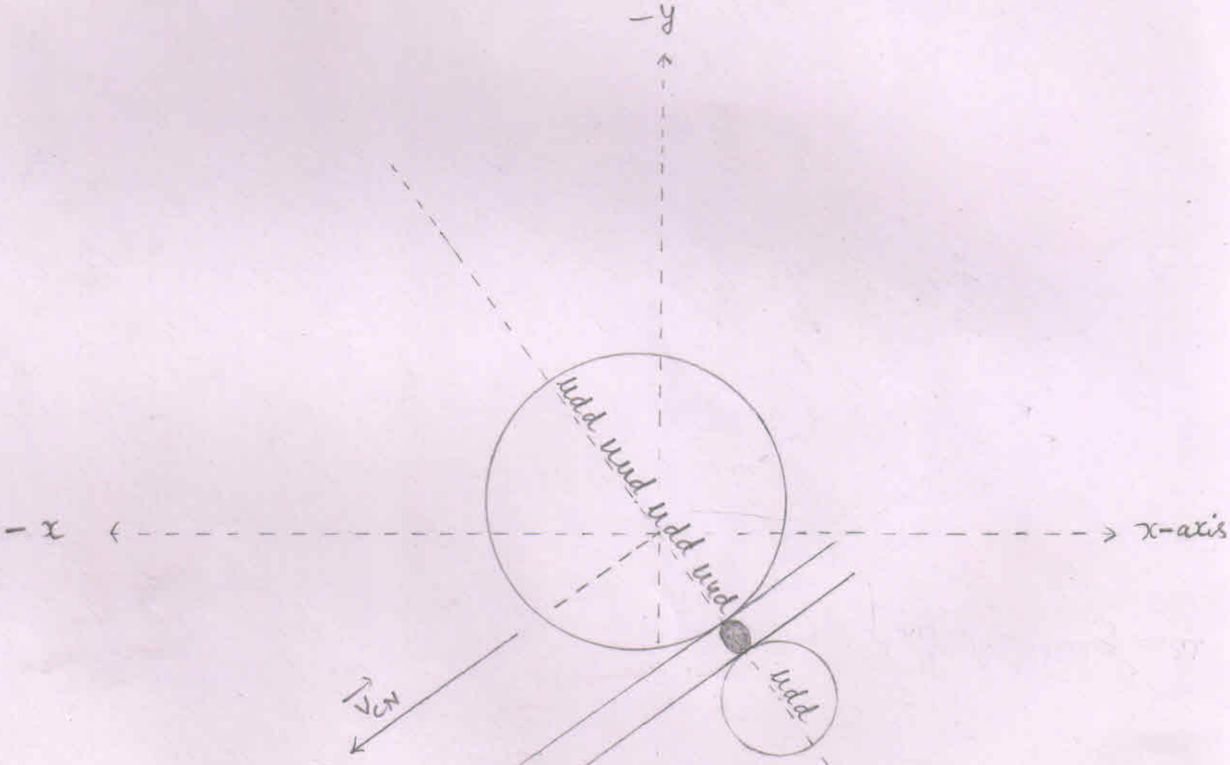
⇒ M = mass of the compound nucleus that is equal to the mass of the helion-5.

⇒ $\vec{V}_{CN}$ = velocity of the compound nucleus that is the final velocity ($\vec{V}_f$) of the helion-5.

⇒ m_{he-4} = mass of helion-4

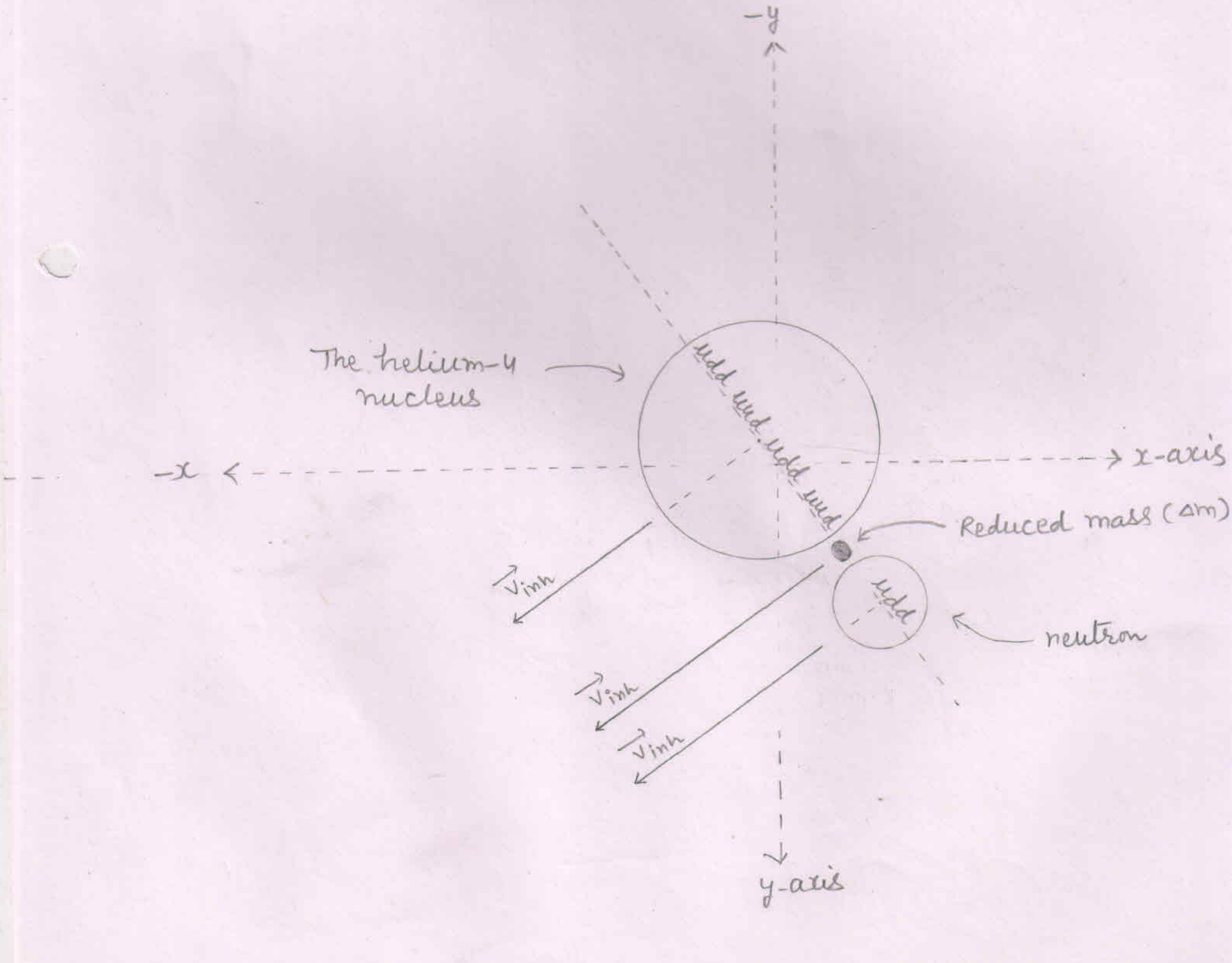
⇒ Δm = reduced mass

The splitting of the heterogenous compound nucleus



The lines parallel to the velocity of the compound nucleus ($\vec{V}_{CN}$).

The splitting of the heterogenous compound nucleus :- The unstable heterogenous compound nucleus [the helion-5] splits into three particles - the helium-4 nucleus, the reduced mass (Δm) and the neutron



Inhereted velocity of the particles

⇒ Each particle that has separated from the compound nucleus has an inhereted velocity ($\vec{V}_{inh}$) equal to the velocity of the compound nucleus ($\vec{V}_{CN}$).

I. Inhereted velocity of the helium-4 nucleus :-

$$V_{inh} = V_{CN} = 1.1843 \times 10^{7} \text{ m/s}$$

⇒ components of the inhereted velocity ($\vec{V}_{inh}$) of helion-4

1. $\vec{V}_x = V_{inh} \cos\alpha = V_{CN} \cos\alpha = -0.956 \times 10^{7}$ m/s

2. $\vec{V}_y = V_{inh} \cos\beta = V_{CN} \cos\beta = 0.6991 \times 10^{7}$ m/s

3. $\vec{V}_z = V_{inh} \cos\gamma = V_{CN} \cos\gamma = 0$ m/s

II. Inhereted velocity of the neutron

$$V_{inh} = V_{CN} = 1.1843 \times 10^{7} \text{ m/s}$$

⇒ components of the inhereted velocity ($\vec{V}_{inh}$) of neutron

1. $\vec{V}_x = V_{inh} \cos\alpha = V_{CN} \cos\alpha = -0.956 \times 10^{7}$ m/s

2. $\vec{V}_y = V_{inh} \cos\beta = V_{CN} \cos\beta = 0.6991 \times 10^{7}$ m/s

3. $\vec{V}_z = V_{inh} \cos\gamma = V_{CN} \cos\gamma = 0$ m/s

III. Inhereted velocity of the reduced mass (Δm):

$$V_{inh} = V_{CN} = 1.1843 \times 10^{7} \text{ m/s}$$

⇔ As the helion-5 is an unstable homogenous compound nucleus. so, the inhereted velocity of the each particle (the helion-4, the neutron and the reduced mass) is equal to the final velocity ($\vec{V}_f$) of the helion-5.

propellation of the particles

1. Reduced mass

$$\Delta m = [m_{He-5}] - [m_{He-4} + m_n]$$

$$\Delta m = [5.0111] - [4.0015 + 1.0086] \text{ amu}$$

$$\Delta m = [5.0111] - [5.0101] \text{ amu}$$

$$\Delta m = 0.001 \text{ amu}$$

$$\Delta m = 0.001 \times 1.6605 \times 10^{-27} \text{ Kg}$$
$$= 0.0016605 \times 10^{-27} \text{ Kg}$$

2. Inhereted kinetic energy of the reduced mass :

$$E_{inh} = \frac{1}{2} \Delta m V_{CN}^2 = \frac{1}{2} \Delta m V_{inh}^2$$

$$V_{inh}^2 = V_{CN}^2 = 1.38022025 \times 10^{14} m^2/s^2$$

$$\Rightarrow E_{inh} = \frac{1}{2} \Delta m v_{inh}^2 = \frac{1}{2} \times 0.0016605 \times 10^{-27} \times 1.38022025 \times 10^{14} \text{ J}$$

$$= 0.00114592786 \times 10^{-13} \text{ J}$$
$$= 0.0007 \text{ Mev}$$

3. Released energy (E_R) :

$$E_R = \Delta mc^2$$
$$= 0.001 \times 931 \text{ Mev}$$
$$= 0.931 \text{ Mev}$$

4. Total energy (E_T) :

$$E_T = E_{inh} + E_R$$
$$= 0.0007 + 0.931 \text{ Mev}$$
$$= 0.9317 \text{ Mev}$$

Increased kinetic energy of the neutron

$$E_{inc} = \frac{m_{He-4}}{m_{He-4} + m_n} \times E_T$$

$$= \frac{4.0015}{4.0015 + 1.0086} \times 0.9317 \quad Mev$$

$$= \frac{4.0015}{5.0101} \times 0.9317 \quad Mev$$

$$= 0.79868665296 \times 0.9317 \quad Mev$$

$$= 0.7441 \quad Mev$$

Increased kinetic energy of the helion-4

$$E_{inc} = [E_T - \text{Increased kinetic energy of neutron}]$$

$$= [0.9317 - 0.7441] \quad Mev$$

$$= 0.1876 \quad Mev$$

Increased velocity of the neutron

$$v_{inc} = \sqrt{\frac{2 E_{inc}}{m_n}}$$

$$= \left[\frac{2 \times 0.7441 \times 1.6 \times 10^{-13}}{1.6749 \times 10^{-27}}\right]^{\frac{1}{2}} \text{ m/s}$$

$$= \left[\frac{2.38112}{1.6749} \times 10^{14}\right]^{\frac{1}{2}} \text{ m/s}$$

$$= \left[1.4216490536 7 \times 10^{14}\right]^{\frac{1}{2}} \text{ m/s}$$

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

Increased velocity of the helion-4

$$v_{inc} = \sqrt{\frac{2 E_{inc}}{m_{He-4}}}$$

$$= \left[\frac{2 \times 0.1876 \times 1.6 \times 10^{-13}}{6.64449 \times 10^{-27}}\right]^{\frac{1}{2}} \text{ m/s}$$

$$= \left[\frac{0.60032}{6.64449} \times 10^{14}\right]^{\frac{1}{2}} \text{ m/s}$$

$$= \left[0.0903485444 3 \times 10^{14}\right]^{\frac{1}{2}} \text{ m/s}$$

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

Angle of propellation

1. As the reduced mass converts into energy, the total energy (E_T) propell both the particles with equal and opposite momentum according to a ray (line) perpendicular to the direction (line) of the velocity of the compound nucleus ($\vec{V}_{CN}$).

2. We know that when there a fusion-process occures, then we find the lighter nucleus in the forward direction [or in the direction of ion beam or in the direction of the velocity of the compound nucleus ($\vec{V}_{CN}$).]

3. At point 'F', as $\vec{V}_{CN}$ makes 143.8 degree angle with x-axis, 53.8 degree angle with y-axis and 90° angle with z-axis.

4. So, the neutron is propelled making 53.8 degree angle with x-axis, 36.2 degree angle with y-axis and 90° angle with z-axis.

5. While the helium-4 nucleus is propelled making 233.8 degree angle with x-axis, 143.8 degree angle with y-axis and 90° angle with z-axis.

Propellation of the particles