$$\underset{\sim}{B}(t) = \sum_{i=0}^{n} \binom{n}{i} (1-t)^{n-i}\, t^i\, \underset{\sim}{P_i}$$

where $0 < t < 1$

start point $P_0 = [2000\text{mm}, 0\text{mm}]$

control point $P_1 = [2000\text{mm}, 10{,}000\text{mm}]$

control point $P_2 = [13\,165.2\text{mm}, 10\,080.3\text{mm}]$

end point $P_3 = [9\,750\text{mm}, 9\,723.7\text{mm}]$

$n = 4$

$$\underset{\sim}{B}(t) = \sum_{i=0}^{4} \binom{4}{i} (1-t)^{4-i}\, t^i\, \underset{\sim}{P_i}$$

$$[x(t), y(t)] = \binom{4}{0}(1-t)^{4-0} t^0 \underset{\sim}{P_0} + \binom{4}{1}(1-t)^{4-1} t^1 \underset{\sim}{P_1} + \binom{4}{2}(1-t)^{4-2} t^2 \underset{\sim}{P_2} + \binom{4}{3}(1-t)^{4-3} t^3 \underset{\sim}{P_3} + \binom{4}{4}(1-t)^0 t^4 \underset{\sim}{P_4}$$

$$= \binom{4}{0}(1-t)^4 \underset{\sim}{P_0} + 4(1-t)^3 t \underset{\sim}{P_1} + 6(1-t)^2 t^2 \underset{\sim}{P_2} + 4(1-t) t^3 \underset{\sim}{P_3} + (1-t)^0 t^4 \underset{\sim}{P_4}$$

$$= (1-t)^4 \underset{\sim}{P_0} + 4(1-t)^3 t \underset{\sim}{P_1} + 6(1-t)^2 t^2 \underset{\sim}{P_2} + 4(1-t) t^3 \underset{\sim}{P_3} + \cancel{t^4 \underset{\sim}{P_4}}$$

$$= (1-t)^4 \underset{\sim}{P_0} + 4(1-t)^3 t \underset{\sim}{P_1} + 6(1-t)^2 t^2 \underset{\sim}{P_2} + 4(1-t) t^3 \underset{\sim}{P_3} + t^4 \underset{\sim}{P_4}$$

There are only 4 points, ~~this~~ is 5

$[x(t), y(t)] =$

$n = 3$

$$\underset{\sim}{B}(t) = \sum_{i=0}^{3} \Big(4$$

$$\text{blue}(t) = (1-t)^3 \times 0\text{mm} + 3(1-t)^2 t \times 10\,000\text{mm} + 3(1-t)t^2 \times 10\,080.3\text{mm} + t^3 \times 9723.7\text{mm}$$

$$= (1-t)^3 \times 0\text{mm} + 3t^2(1-t) \times 10\,080.3\text{mm} + 9\,723.7\text{mm} \times t^3$$

$$= 3t(1-t)^2 \times 10\,000\text{mm}$$

$n=3$

$$\underset{\sim}{B}(t)=\sum_{i=0}^{3}\binom{3}{i}(1-t)^{3-i}\,t^{i}\,\underset{\sim}{P}_i$$

$$\underset{\sim}{B}(t)=\binom{3}{0}(1-t)^3\underset{\sim}{P}_0+\binom{3}{1}(1-t)^2t\,\underset{\sim}{P}_1+\binom{3}{2}(1-t)\,t^2\,\underset{\sim}{P}_2+\binom{3}{3}(1-t)^0t^3\underset{\sim}{P}_3$$

$$\underset{\sim}{B}(t)=(1-t)^3\underset{\sim}{P}_0+3(1-t)^2t\,\underset{\sim}{P}_1+3(1-t)\,t^2\,\underset{\sim}{P}_2+(1-t)^0t^3\underset{\sim}{P}_3$$

$$\underset{\sim}{B}(t)=(1-t)^3\underset{\sim}{P}_0+3(1-t)^2t\,\underset{\sim}{P}_1+3(1-t)\,t^2\,\underset{\sim}{P}_2+t^3\underset{\sim}{P}_3$$

$[\quad t\ ,\ \text{blue}(t)]=(1-t)^3[\qquad]+3(1-t)^2t[\qquad]+3(1-t)t^2[$

$+3(1-t)t^2\times \qquad +t^3\times$

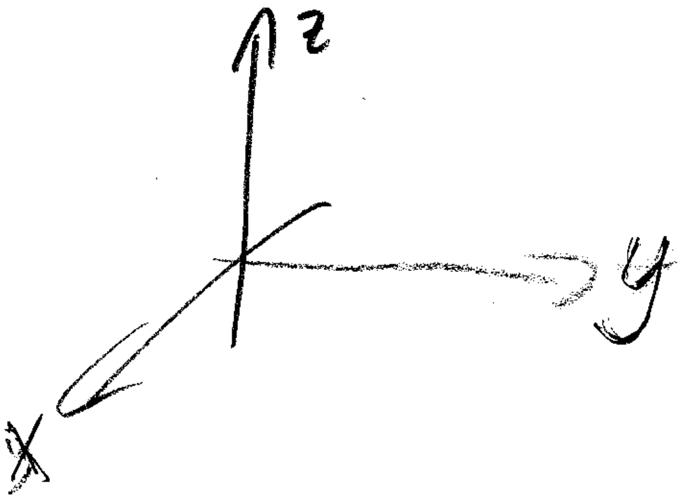
$t\ =(1-t)^3[\qquad]+3(1-t)^2t\times$

$t\ = 2000\,\text{mm}\times(1-t)^3+6000\,\text{mm}\times(1-t)^2t+39\,495.6\,\text{mm}\times(1-t)t^2+97\,500\,\text{mm}\times t^3$

$t=1$

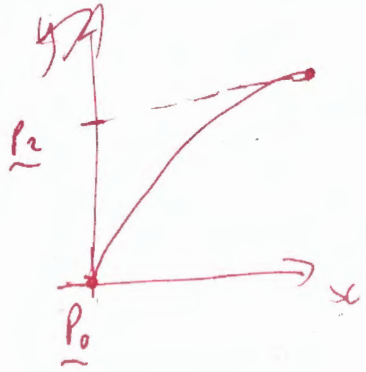
$t=100$

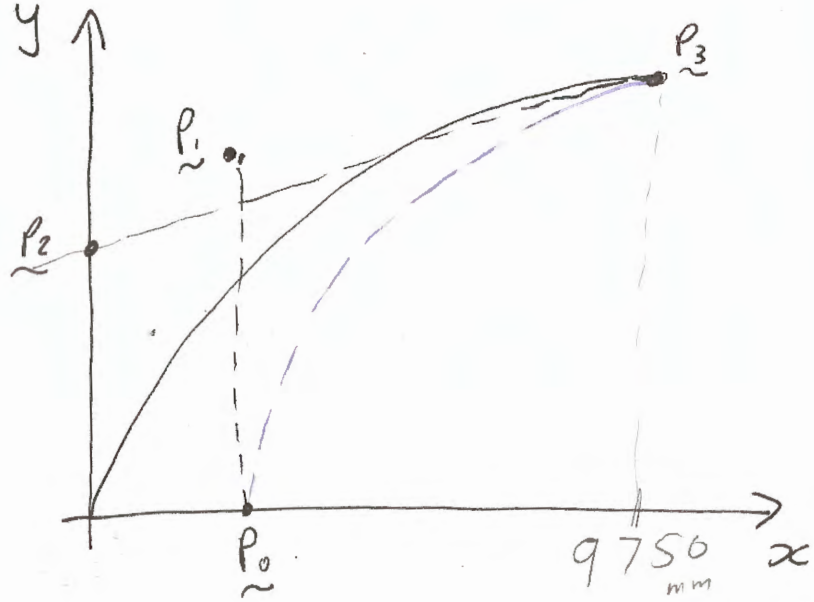
Data Point	t	t	blue(t)
1	97500 0	2000	0
2	24 2019 0.05	2091.49	1426.8
3	22 ~~257~~ 0.1	2396.96	2712.0
4	0.15	2962.9	3862.4
5	0.2	3835.9	4885.5
6	0.25	5062.3	5788.2
7	0.3	6688.7	6577.7
8	0.35	8761.65	7261.0
9	0.4	11327.58	7845.4
10	0.45	14433.0	8337.9
11	0.5	18124.45	8745.5
12	0.55	22448.4	9075.5
13	0.6	27451.4	9335.0
14	0.65	33179.84	9530.0



Data Point	t	(t)	blue (t)
15	0.7	39 680.4	9 670.6
	0.75	46 999.4	9 761.1
	0.8	55 183.4	9 809.4
	0.85	64 279.0	9 822.7
	0.9	74 332.64	9 808.1
	0.95	85 390.8	9 772.7
21	1	97 500	9 723.7

This is not working because it does not fit the geometry of the Bezier Curve – Try this





Green Blue

start point $\tilde{P}_0 = [2000mm, 0mm]$

control point $\tilde{P}_1 = [2000mm, 10,000mm]$

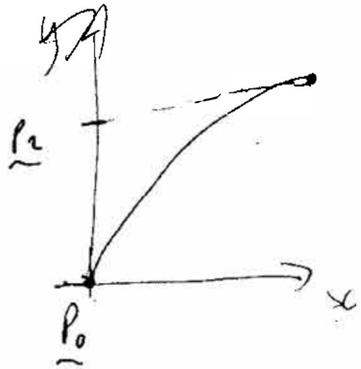
control point $\tilde{P}_2 = [0mm, 8793mm]$

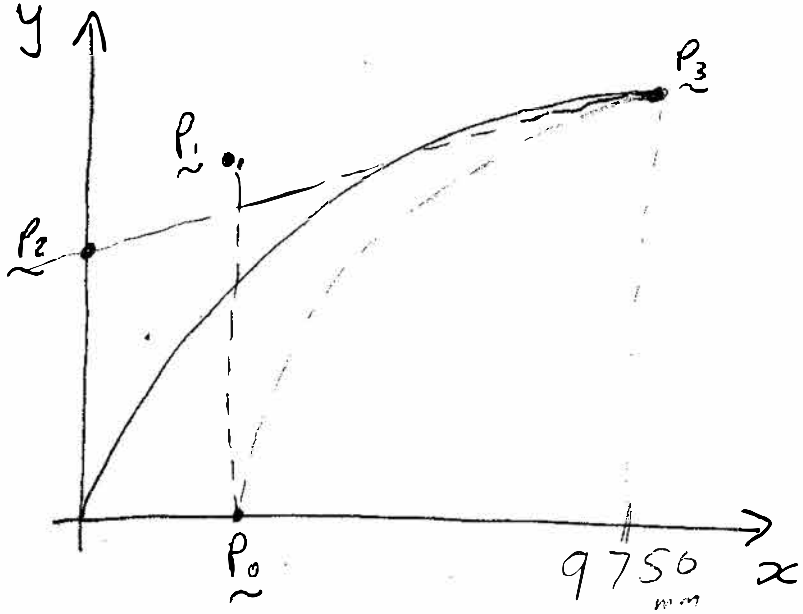
end point $\tilde{P}_3 = [9750mm, 9723.7mm]$

↳ from photograph.

Data Point	t	(t)	b... (t)
15	0.7	39 680.4	9 670.6
	0.75	46 999.4	9 761.1
	0.8	55 183.4	9 809.4
	0.85	64 279.0	9 822.7
	0.9	74 332.64	9 808.1
	0.95	85 390.8	9 772.7
21	1	97 500	9 723.7

This is not working because it does not fit the geometry of the Bezier Curve - Try this





Green Blue

start point $\underset{\sim}{P_0} = [2000mm, 0mm]$

control point $\underset{\sim}{P_1} = [2000mm, 10,000mm]$

control point $\underset{\sim}{P_2} = [0mm, 8\,793mm]$

end point $\underset{\sim}{P_3} = [9\,750mm, 9\,723.7mm]$

from photograph.

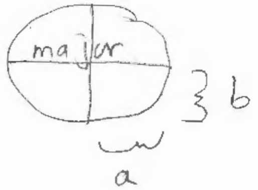
Q. Find the height of the control point $\underset{\sim}{P}_2$

(1) eqn of ellipse [illegible]
(2) differentiate find gradient @ 7750mm
(3) use eqn of straight line ~~and~~ $y = mx + c$ and m = grad point $\underset{\sim}{P}_3$

A. The cross section is elliptical up to $\underset{\sim}{P}_3$, this is an assumption

eqn of an ellipse $\dfrac{x^2}{a^2} + \dfrac{y^2}{b^2} = 1$

Needs Translating



don't derive it again, use the tilted eqn for the ellipse

$$a = \frac{21500\text{mm}}{2} = 10\,750\text{mm}$$ from photograph of toriod

$$b = 9770\text{ mm}$$

$$\frac{x^2}{10\,750\text{mm}^2} + \frac{y^2}{9\,770\text{mm}^2} = 1$$

$$\frac{y^2}{9\,770\text{mm}^2} = 1 - \frac{x^2}{10\,750\text{mm}^2}$$

$$y^2 = 9770\text{m}^2\left(1 - \frac{x^2}{10\,750\text{mm}^2}\right)$$

$$y = 9770\text{mm}\left(1 - \frac{x^2}{10\,750\text{mm}^2}\right)^{\frac{1}{2}}$$ positive result only

$$\frac{dy}{dx} = 9770\text{mm} \times \frac{1}{\cancel{2}}\left(1 - \frac{x^2}{(10\,750\text{mm})^2}\right)^{-\frac{1}{2}} \times -\frac{\cancel{2}x}{(10\,750\text{mm})^2}$$

$$\frac{dy}{dx} = -\frac{9\,770\text{mm}\,x}{(10\,750\text{mm})^2}\left(1 - \frac{x^2}{(10\,750\text{mm})^2}\right)^{-\frac{1}{2}}$$

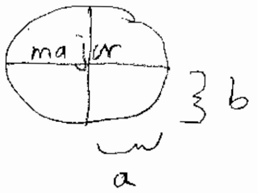
Q. Find the height of the control point P_3

(1) eqn of [illegible]
(2) differentiate find gradient @ 9 750mm
(3) use eqn of straight line ~~and~~ $y = mx + c$ and m = grad point P_3

A. The cross section is elliptical up to P_3, this is an assumption

eqn of an ellipse $\dfrac{x^2}{a^2} + \dfrac{y^2}{b^2} = 1$

Need Translating



don't derive it again, use the eqn for the tilted ellipse

$$a = \frac{21\,500\text{mm}}{2} = 10\,750\text{mm}$$ from photograph of toriod

$$b = 9\,770\text{ mm}$$

$$\frac{x^2}{10\,750\text{mm}^2} + \frac{y^2}{9\,770\text{mm}^2} = 1$$

$$\frac{y^2}{9\,770\text{mm}^2} = 1 - \frac{x^2}{10\,750\text{mm}^2}$$

$$y^2 = 9770\text{m}^2\left(1 - \frac{x^2}{10\,750\text{mm}^2}\right)$$

$$\therefore\ y = 9770\text{mm}\left(1 - \frac{x^2}{10\,750\text{mm}^2}\right)^{\frac{1}{2}}$$ positive result only

$$\frac{dy}{dx} = 9\,770\text{mm} \times \frac{1}{2}\left(1 - \frac{x^2}{(10\,750\text{mm})^2}\right)^{-\frac{1}{2}} \times -\frac{2x}{(10\,750\text{mm})^2}$$

$$\frac{dy}{dx} = -\frac{9\,770\text{mm}\,x}{(10\,750\text{mm})^2}\left(1 - \frac{x^2}{(10\,750\text{mm})^2}\right)^{-\frac{1}{2}}$$

Data Point t | [illegible] (t) | blue (t)

$$\frac{dy}{dx} = \frac{-9770\text{mm}}{(10\ 750\text{mm})^2} x \left(1 - \frac{x^2}{(10\ 750\text{mm})^2}\right)^{-\frac{1}{2}}$$

$$\left.\frac{dy}{dx}\right|_{x=9750\text{mm}} = -\frac{9770\text{mm} \times 9750\text{mm}}{(10\ 750\text{mm})^2} \times \left(1 - \left(\frac{9750\text{mm}}{10\ 750\text{mm}}\right)^2\right)^{-\frac{1}{2}}$$

$$\left.\frac{dy}{dx}\right|_{x=9750\text{mm}} = -\frac{95\ 257\ 500\text{ mm}}{(10\ 750\text{mm})^2} \times \left(1 - \left(\frac{39}{43}\right)^2\right)^{-\frac{1}{2}}$$

$$\left.\frac{dy}{dx}\right|_{x=9750\text{mm}} = -\frac{95\ 257\ 500\text{mm}}{115\ 562\ 500\text{mm}} \times \left(1 - \left(\frac{39}{43}\right)^2\right)^{-\frac{1}{2}}$$

$$= -\frac{190\ 515\text{mm}}{231\ 125\text{mm}} \times \left(1 - \left(\frac{39}{43}\right)^2\right)^{-\frac{1}{2}}$$

$$= -\frac{38\ 103\cancel{\text{mm}}}{46\ 225\cancel{\text{mm}}} \times \left(1 - \left(\frac{39}{43}\right)^2\right)^{-\frac{1}{2}}$$

$$= -\frac{38\ 103}{(215)^2} \times \left(1 - \left(\frac{39}{43}\right)^2\right)^{-\frac{1}{2}}$$

Data Point t (t) (t)

$$\frac{dy}{dx} = \frac{-9770\text{mm}}{(10\,750\text{mm})^2}\, x \left(1 - \frac{x^2}{(10\,750\text{mm})^2}\right)^{-\frac{1}{2}}$$

$$\left.\frac{dy}{dx}\right|_{x=9750\text{mm}} = -\frac{9770\text{mm} \times 9750\text{mm}}{(10\,750\text{mm})^2} \times \left(1 - \left(\frac{9750\text{mm}}{10\,750\text{mm}}\right)^2\right)^{-\frac{1}{2}}$$

$$\left.\frac{dy}{dx}\right|_{x=9750\text{mm}} = -\frac{95\,257\,500\text{ mm}}{(10\,750\text{mm})^2} \times \left(1 - \left(\frac{39}{43}\right)^2\right)^{-\frac{1}{2}}$$

$$\left.\frac{dy}{dx}\right|_{x=9750\text{mm}} = -\frac{95\,257\,500\text{mm}}{115\,562\,500\text{mm}} \times \left(1 - \left(\frac{39}{43}\right)^2\right)^{-\frac{1}{2}}$$

$$= -\frac{190\,515\text{mm}}{231\,125\text{mm}} \times \left(1 - \left(\frac{39}{43}\right)^2\right)^{-\frac{1}{2}}$$

$$= -\frac{38\,103\cancel{\text{mm}}}{46\,225\cancel{\text{mm}}} \times \left(1 - \left(\frac{39}{43}\right)^2\right)^{-\frac{1}{2}}$$

$$= -\frac{38\,103}{(215)^2} \times \left(1 - \left(\frac{39}{43}\right)^2\right)^{-\frac{1}{2}}$$

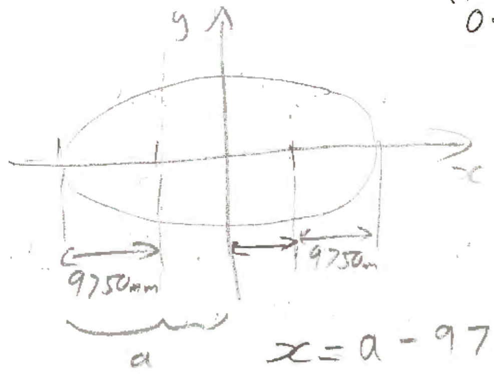
$$\left.\frac{dy}{dx}\right|_{x=9750mm} = \frac{-\frac{38\,103}{(215)^2}}{\pm\sqrt{1-\left(\frac{39}{43}\right)^2}}$$

$$= \pm 1.95710346$$

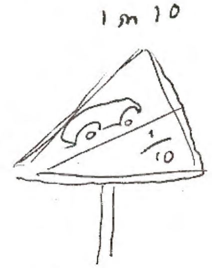
This gradient is way too steep when drawn on Google SketchUp

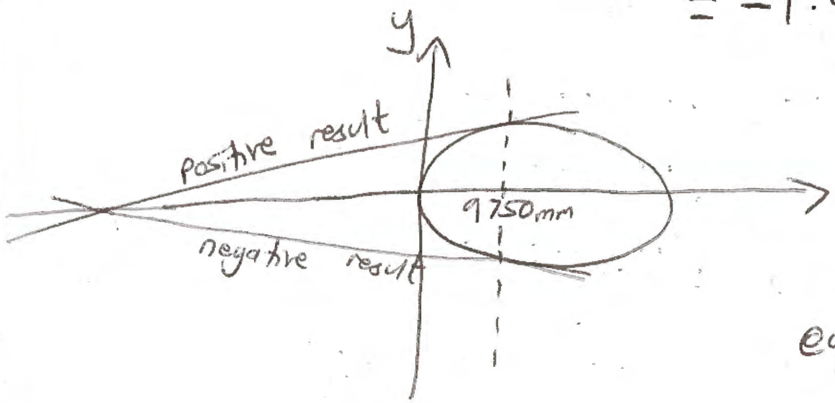
$$\frac{\Delta y}{\Delta x} = \frac{8\,618mm}{90\,289.5mm} = \frac{8\,618mm}{90\,289.5mm}$$

$$= 0.09545$$



$x = a - 9750mm$





The Bezier curve is being drawn above the equtorial plane, so take the positive result.

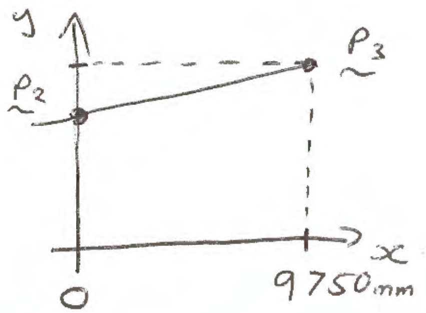
$y = 1.95710x + c$

use $P_3 = [9750mm, 9723.7mm]$ to find c

$9723.7mm = 1.95710 \times 9750mm + c$

$$c = \frac{9723.7mm}{1.95710 \times 9750mm}$$

$c = 0.50958mm$



$y = mx + c$

Find the height of P_3

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$$

$$\frac{(9750mm)^2}{(10\,750mm)^2} + \frac{y^2}{(9770mm)^2} = 1$$

$$\left(\frac{39}{43}\right)^2 + \frac{y^2}{(9770mm)^2} = 1$$

$$y = \frac{8\,618}{90\,289.5} \times 9750mm + c$$

$$9723.7mm = \frac{8618}{90\,289.5} \times 9750mm + c$$

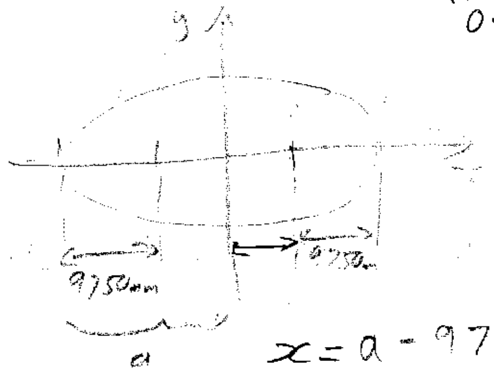
$$c = 9723.7mm - \frac{8\,618}{90\,289.5} \times 9750mm = 8793.076838$$

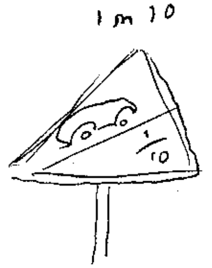
$$\left.\frac{dy}{dx}\right|_{x=9750mm} = \frac{-\dfrac{38\,103}{(215)^2}}{\pm\sqrt{1-\left(\dfrac{39}{43}\right)^2}}$$

$$= \pm 1.95710346$$

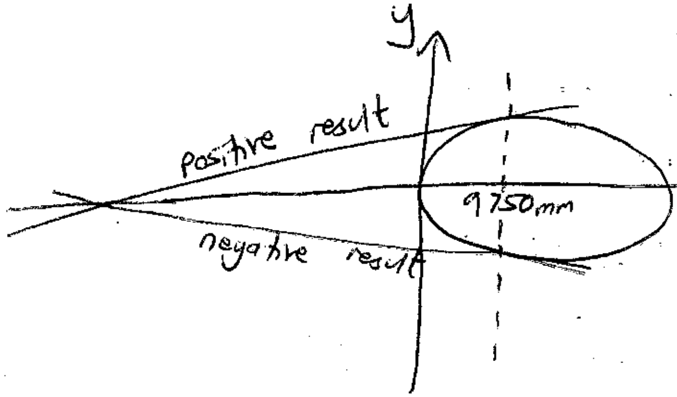
This gradient is way too steep when drawn on Google SketchUp

$$\frac{\Delta y}{\Delta x} = \frac{8\,618mm}{90289.5mm} = \frac{8\,618mm}{90\,289.5\,mm} = 0.09545$$





$x = a - 9750mm$



The Bezier curve is being drawn above the equatorial plane, so take the positive result.

$y = mx + c$

Find the height of P_3

$$\cancel{\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1}$$

$$\frac{(9750mm)^2}{(10\,750mm)^2} + \frac{y^2}{(9770mm)^2} = 1$$

$$\left(\frac{39}{43}\right)^2 + \frac{y^2}{(9770mm)^2} = 1$$

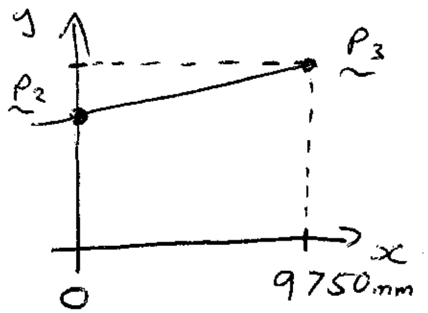
~~$y = 1.95710x + c$~~

~~use $P_3 = [9750\,mm, 9723.7mm]$ to find c~~

~~$9723.7mm = 1.95710 \times 9750mm + c$~~

~~$c = \dfrac{9723.7mm}{1.95710 \times 9750mm}$~~

~~$c = 0.50958\,mm$~~



$$y = \frac{8\,618}{90\,289.5} \times 9750mm + c$$

$$9723.7mm = \frac{8618}{90\,289.5} \times 9750mm + c$$

$$c = 9723.7\,mm - \frac{8\,618}{90\,289.5} \times 9750mm = 8793.076838$$

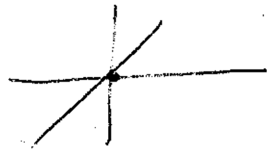
$$\left(\frac{39}{43}\right)^2 + \frac{y^2}{(9\,770\text{mm})^2} = 1$$

$$\frac{y^2}{(9\,770\text{mm})^2} = 1 - \left(\frac{39}{43}\right)^2$$

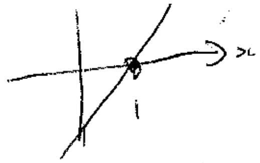
$$y^2 = (9\,770\text{mm})^2\left[1 - \left(\frac{39}{43}\right)^2\right]$$

$$y^2 = 16\,932\,694\text{ mm}^2$$

$$y = 4114.935479\text{mm}$$



$y = x$



$y = x - 1$

Find the height of $\underset{\sim}{P_3}$

$$\frac{x^2}{(a - 9750\text{mm})^2} + \frac{y^2}{b^2} = 1$$

$$\frac{(9750\text{mm})^2}{(10\,750\text{mm} - 9750\text{mm})^2} + \frac{y^2}{(9\,770\text{mm})^2} = 1$$

$$\frac{1\,521}{16} + \frac{y^2}{(9\,770\text{mm})^2} = 1$$

$$\frac{y^2}{(9\,770\text{mm})^2} = 1 - \frac{1521}{16}$$

$$y^2 = (9770mm)^2 \left[1 - \frac{1521}{16}\right]$$

a just x not a

$$y = 9770mm \sqrt{1 - \frac{1521}{16}}$$

$$y = 9770mm \sqrt{1 - 95.0625}$$

Equation of translated ellipse on the meridian it is plannar

$$\frac{(a - 9750mm)^2}{a^2} + \frac{y^2}{b^2} = 1$$

x

$$\frac{10750mm - 9750mm}{10750mm^2} + \frac{y^2}{(9770mm)^2} = 1$$

$$\left(\frac{1000mm}{10750mm}\right)^2 + \frac{y^2}{(9770mm)^2} = 1$$

$$\frac{y^2}{(9770mm)^2} = 1 - \left(\frac{4}{43}\right)^2$$

$$y^2 = 9770mm^2 \left(1 - \left(\frac{4}{43}\right)^2\right)$$

$$y = 9770mm \times \sqrt{1 - \left(\frac{4}{43}\right)^2}$$

$$\boxed{y = 9304.491414}$$

TRANSLATED BY THE WRONG AMOUNT IN THE WRONG DIRECTION.

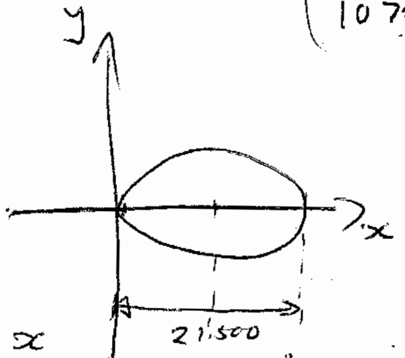
Use the co-ordinate of the end point you have already calculated (tilted ellipse calc)

Just read from Google

~~972.3~~

9723.7mm 9723.7mm

text only file → email whatever



$$\frac{\left(x - \frac{21500}{2}\right)^2}{\frac{21500}{2}} + \frac{y^2}{H^2} = 1$$

$$B(t) = \binom{3}{0}(1-t)^3 \underset{\sim}{P_0} + \binom{3}{1}(1-t)^2 t \underset{\sim}{P_1} + \binom{3}{2}(1-t) t^3 \underset{\sim}{P_2} + \binom{3}{3}\cancel{(1-t)^0} t^3 \underset{\sim}{P_3}$$

$$= (1-t)^3 \underset{\sim}{P_0} + 3(1-t)^2 t \underset{\sim}{P_1} + 3(1-t) t^2 \underset{\sim}{P_2} + t^3 \underset{\sim}{P_3}$$

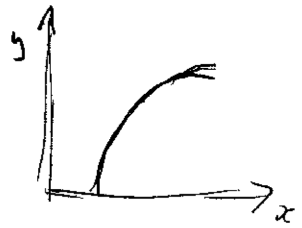
$$\text{green}(t) = 2000\text{mm}(1-t)^3 + 2000\text{mm} \times 3(1-t)^2 t + 0 + t^3\, 9750\text{mm}$$

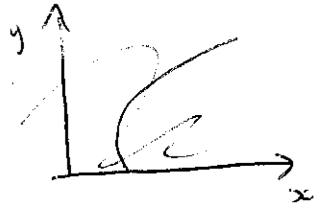
$$= 2000\text{mm}(1-t)^3 + 6000\text{mm}(1-t)^2 t + 9750\text{mm}\, t^3$$

$$\text{blue}(t) = 0 + 10{,}000\text{mm} \times 3 \times (1-t)^2 t + 8793\text{mm} \times 3 \times (1-t) t^2 + 9723.7\text{mm}\, t^3$$

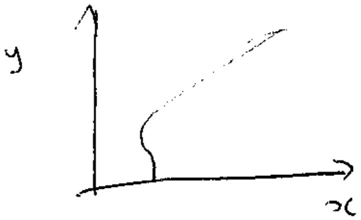
$$= 30{,}000\text{mm}\, t(1-t)^2 + 26\,379\text{mm}\, t^2(1-t) + 9723.7\text{mm}\, t^3$$

data point	t	green(t)/mm	blue(t)/mm
1	0	2000	0
	0.05	1986.7	1417.6
	0.1	1951.7	2677.1
	0.15	1911.4	3788.6
	0.20	1870.0	4761.9
	0.25	1839.4	5607.2
	0.30	1831.3	6334.4
	0.35	1854.5	6953.6
	0.40	1920	7474.7
	0.45	2038.0	7907.8
	0.50	2218.8	8262.8



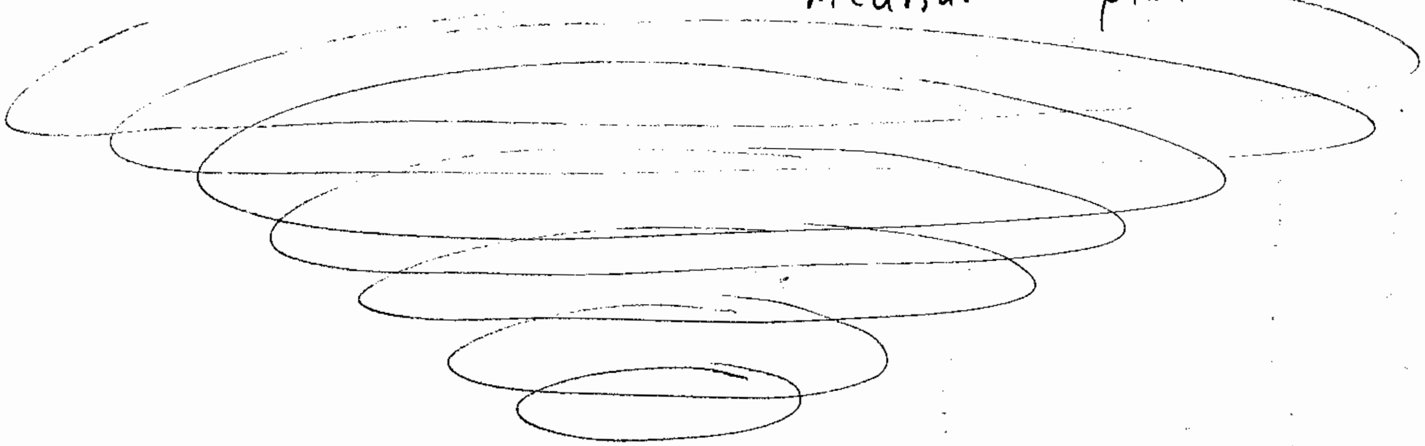


looks like this



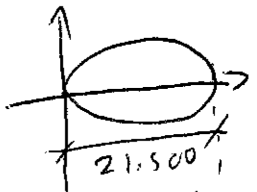
	0.55	2472.7	8549.9
	0.60	2810	8778.9
	0.65	~~32~~ 3241.1	8959.9
	0.70	3776.3	9102.9
	0.75	4425.8	9218.0
	0.80	5200	9315.0
	0.85	6109.2	9404.1
	0.90	7163.8	9495.3
20	0.95	8373.9	9598.5
21	1	9750	9723.7

This table of results will plot on the median plane green & blue axis to give a visually smothe Bezier curve. When this is done, concentric circles are to be drawn from the r=2000mm ring on the equator. Then take verticals from the spiral on the median plane and then join the dots with straight lines.



Eqn of an ellipse $$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$$

translated



$$\frac{\left[x - \left(\frac{21500}{2}\right)\right]^2}{\left(\frac{21500}{2}\right)^2} + \frac{y^2}{H^2} = 1$$

$$\frac{y^2}{H^2} = 1 - \frac{\left[x - \left(\frac{21500}{2}\right)\right]^2}{\left(\frac{21500}{2}\right)^2}$$

$$y^2 = H^2\left(1 - \frac{\left[x - \left(\frac{21500}{2}\right)\right]^2}{\left(\frac{21500}{2}\right)^2}\right)$$

$$y = H\sqrt{1 - \frac{\left(x - \frac{21500mm}{2}\right)^2}{\left(\frac{21500mm}{2}\right)^2}}$$

$$y = 9770mm\sqrt{1 - \frac{\left(x - \frac{21500mm}{2}\right)^2}{\left(\frac{21500mm}{2}\right)^2}}$$

$$y = \pm 9770mm\sqrt{1 - \frac{(x - 10750mm)^2}{(10750mm)^2}}$$

$$y = \pm 9770mm\sqrt{1 - \left[\frac{x}{(10750mm)^2} - 1\right]^2}$$

INVOLUTE OF A CIRCLE

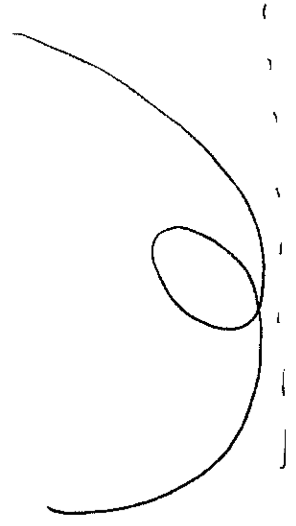
FOLIUM OF DESCARTES

Parametric eqns

$$x = \frac{3at}{1+t^3} \qquad y = \frac{3at^2}{1+t^3}$$

Area of loop $= \frac{3a^2}{2}$

Equation of asymptote: $x + y + a = 0$



$$\frac{21500}{2} = \begin{array}{r} 250 \\ +\ 500 \\ +\ 10{,}000 \\ \hline 10{,}750 \end{array}$$

Height of end point $\underset{\sim}{P}_3$

from photo ratio 9 750mm

$$y = 9770mm \sqrt{1 - \frac{(9750mm - 10750mm)^2}{(10\,750mm)^2}}$$

$$\cancel{y = 9770mm \sqrt{1 - \frac{1000\,000\ mm^2}{10\,750\ mm}}}$$

$$\cancel{y = 9770mm \sqrt{1 - \frac{4000}{43}mm}}$$

$$y = 9770mm \sqrt{1 - \frac{1\,000\,000\ \cancel{mm^2}}{115\,562\,500\ \cancel{mm^2}}}$$

$$y = \pm 9770mm \sqrt{1 - \frac{16}{1849}}$$

$$y = 9727.636657\,mm$$

(take +ve result)

very close to the measurment taken from the ~~3D~~ 3D-model differentiate $y = \pm 9770mm \sqrt{1 - \frac{(x - 10\,750mm)^2}{(10\,750mm)^2}}$ wrt x using the product rule

$\frac{d}{dx}\left(\frac{\cancel{20}}{20}\right) = \frac{1}{20}$

$$\frac{dy}{dx} = \frac{dy}{dx} = \pm 9700mm \frac{d}{dx}\left[1 - \left(\frac{x - 10750mm}{10\,750mm}\right)^2\right]^{1/2}$$

$\frac{d}{dx} 2 = 0$

$$= \pm 9770mm \times \frac{1}{2}\left[1 - \left(\frac{x - 10\,750mm}{10\,750mm}\right)^2\right]^{-1/2} \cdot \left[2\left(\frac{x - 10\,750mm}{10\,750mm}\right) \times \frac{1}{10\,750mm}\right]$$

$u = \frac{x - 10750}{10750}$

$$= \pm 9770mm \times \cancel{\frac{2}{2}}\left[1 - \left(\frac{x - 10750mm}{10\,750mm}\right)^2\right]^{-\frac{1}{2}}\left(\frac{x - 10750mm}{10750mm}\right)\frac{1}{10\,750mm}$$

$10750u = x - 10750$

$u = \frac{1}{10750}x - \frac{10750}{10750}$

$$\frac{dy}{dx} = \pm 9700mm \times \left(1 - \left(\frac{x - 10750mm}{10\,750mm}\right)^2\right]^{-\frac{1}{2}}\left(\frac{x - 10750mm}{(10750mm)^2}\right)$$

$u = \frac{1}{10750}x - 1$

$\frac{du}{dx} = \frac{1}{10750}$

$$= \pm 9700 \times \left[1 - \left(\frac{x - 10\,750mm}{10\,750mm}\right)^2\right]^{-\frac{1}{2}}\left(\frac{x - 10750}{10750^2}\right)$$

$$= \pm 9700\left[1 - \left(\frac{x - 10750mm}{10750mm}\right)^2\right]^{-\frac{1}{2}}\left[\frac{x - 10750mm}{10\,750^2 mm}\right]$$

$\frac{1}{2x^{1/2}} = \frac{1}{2}x^{-\frac{1}{2}}$ ✓

Solve this at $x = 9750mm$, the ratio measurement taken from the photo.

$$\left.\frac{dy}{dx}\right|_{x=9750mm} = \pm 9700\cancel{mm} \times \left[1 - \left(\frac{9750mm - 10750mm}{10750mm}\right)^2\right]^{-\frac{1}{2}} \left[\frac{9750mm - 10750mm}{(10750mm)^2}\right]$$

$$= \pm 9700\cancel{mm} \times \left[1 - \left(-\frac{4}{43}\right)^2\right]^{-\frac{1}{2}} \left[-\frac{2}{231125}\right]$$

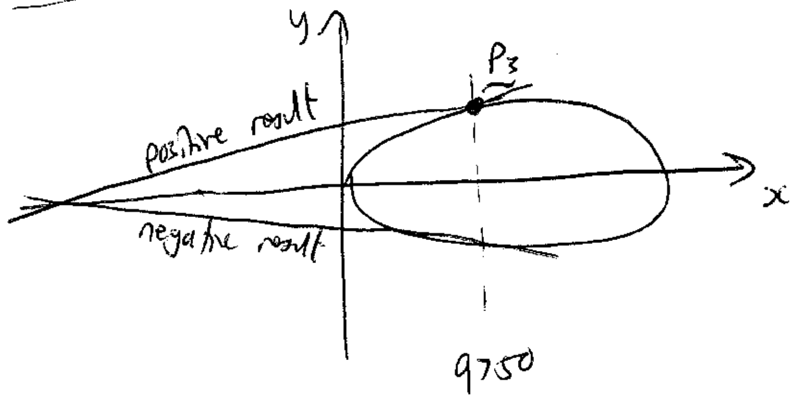
$$= \pm 9700\cancel{mm} \times \frac{1833}{1849} \times \left(-\frac{2}{231125}\right)$$

$$= \mp \frac{9700\cancel{mm} \times 1833 \times 2}{1849 \times 231125}$$

$$= \mp \frac{35560200\cancel{mm}}{427350125}.$$

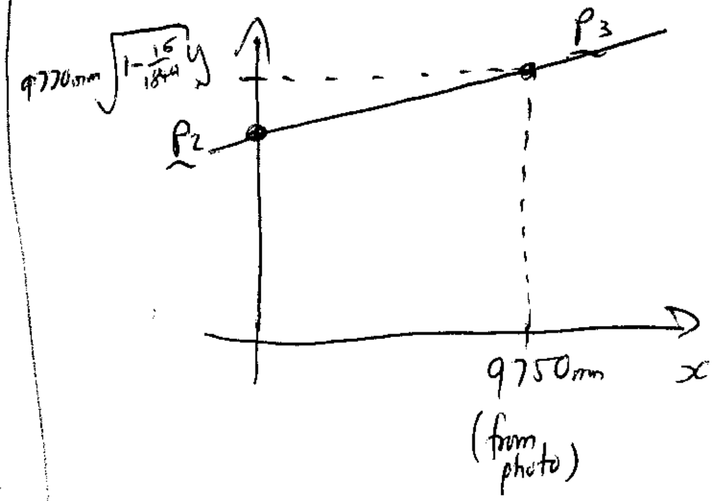
$$= \mp 0.0832109268\cancel{7mm}$$

close to 0.09543 measured from the 3D model



Take the result of gradient and use the co-ordinates of P_3 ~~with~~ with $y = mx + c$ eqn of straight line to find the co-ordinates of P_2 i.e. when ~~y=0~~ $x = 0$.

$$y = \frac{35\ 560\ 200}{427\ 350\ 125}x + C$$



$$C = y - \frac{35\ 560\ 200}{427\ 350\ 125}x$$

at $P_3 = \left[9750\text{mm},\ 9770\text{mm}\sqrt{1-\frac{16}{1849}}\right]$

$$C = 9770\text{mm}\sqrt{1-\frac{16}{1849}} - \frac{35\ 560\ 200}{427\ 350\ 125} \times 9750\text{mm}$$

$$C = 8916.33012 \text{ mm}$$

$$\therefore \quad P_2 = \left[0,\ 8916.33012 \text{ mm}\right]$$

very close to the value measured on the 3D model

$$C = 9770\text{mm} \times \left(\sqrt{1-\frac{16}{1849}} - \frac{35\ 560\ 200}{427\ 350\ 125}\right)$$

Use the Bezier curve function where $n=3$ to ~~plot~~ derive the parametric eqn for green(t) & blue(t)

Green Blue

start point $\underset{\sim}{P_0} = [2000mm, \quad 0mm]$

$\underset{\sim}{P_1} = [2000mm, \quad 10{,}000mm]$ TRY REDUCING THIS VALUE.

$\underset{\sim}{P_2} = [0mm, \quad \cancel{8916.33012mm}]$ $9770mm \times \left(\sqrt{1-\frac{16}{1849}} - \frac{35\,560\,200}{427\,350\,125}\right)]$

$\underset{\sim}{P_3} = [9\,750mm, \quad 9770mm\sqrt{1-\frac{16}{1849}}]$

from photo

$0 < t < 1$

$$\underset{\sim}{B}(t) = \sum_{i=0}^{3} \binom{3}{i} (1-t)^{3-i}\, t^i\, \underset{\sim}{P_i}$$

$$\underset{\sim}{B}(t) = (1-t)^3 \underset{\sim}{P_0} + 3(1-t)^2 t\, \underset{\sim}{P_1} + 3(1-t)t^2 \underset{\sim}{P_2} + t^3 \underset{\sim}{P_3}$$

$x(t)$
$y(t)$
$z(t)$

$$\text{green}(t) = (1-t)^3 \cdot 2\,000mm + 3(1-t)^2 t \cdot 2000mm + 3(1-t)t^2 \cdot 0mm + t^3 \cdot 9750mm$$

$$= 2\,000mm\,(1-t)^3 + 6\,000mm\; t(1-t)^2 + 9750mm\; t^3$$

$$\text{blue}(t) = (1-t)^3 \cdot 0mm + 3(1-t)^2 t\; 10\,000mm + 3(1-t)t^2 \cdot 9770mm \cdot \left(\sqrt{1-\frac{16}{1849}} - \frac{35\,560\,200}{427\,350\,125}\right) + t^3 \cdot$$

$$\text{blue}(t) = 30\,000mm\; t(1-t)^2 + 29\,310mm\left(\sqrt{1-\frac{16}{1849}} - \frac{35\,560\,200}{427\,350\,125}\right)t^2(1-t) + 9\,770mm\sqrt{1-\frac{16}{1849}}\; t^3$$

Plot the table numerical values to 2 d.p. - or 4 or whe

data point	t	green(t) /mm	blue(t) /mm
	0	2000	
1	0.05	1986.71875	
2	0.1	1953.75	
3		1911.40625	
4		1870	
5		1839.84375	
6		1831.25	
7		1854.53125	
8		1920	
		2037.96875	
		2218.75	
		2472.65625	
		2810	
		3241.09375	
		3776.25	
		4425.78125	
		5200	
		6109.21875	
19	0.90	7163.75	
20	0.95	8373.90625	

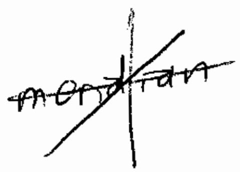
blue(t)/mm requires too much memory for the CASIO fx-85ES

retype eqn in MATHCAD or MATHLAB form.

21	1.0	9750	

3D Bezier Curve, now we have point start pat 4 end point and 3-gradient $y = mx + c \Longrightarrow z = mx + ny + c$? where the 3-gradient can be find from n 4 ~~m~~. How would we find the 3-gradient from the eqn of the tilted ellipse? Do we have a 3-space eqn for the tilted ellipse? What is $\binom{3}{i}$? or $3C_i$?

do we read this gradient from the Photo?



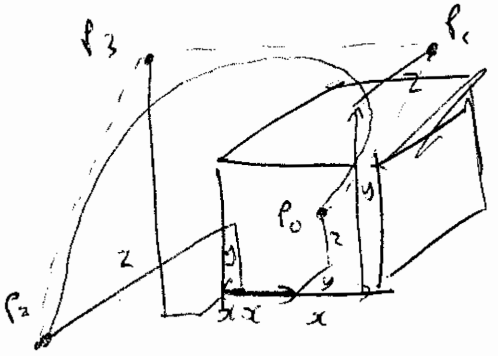
→ This ~~is great~~ the Bezier Curve eqn is $B(t) = \sum_{i=0}^{3} \binom{3}{i} (1-t)^{3-i} t^i \underline{P_i}$

i.e. $[x_B\ y_B\ z_B] = \sum_{i=0}^{3} \binom{3}{i} (1-t)^{3-i} t^i [x_p\ y_p\ z_p]$

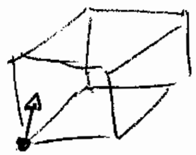
So it is $\underset{\sim}{3D}$! → Make something up.

↳ anything

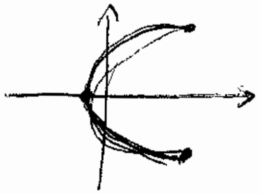
$P_0\ P_1\ P_2\ P_3$



have not plotted



9x13_1000, 100 0
-100, 100 1
-1000 - 100 2

So the Bezier curve looks like this  . Try using start and finish points of  with the correct gradient and see what the ~~y~~ x intercept is

start point $\underset{\sim}{P_0} = \left[9750\,\text{mm},\ 9700\,\text{mm}\sqrt{1 - \frac{16}{1849}} \right]$

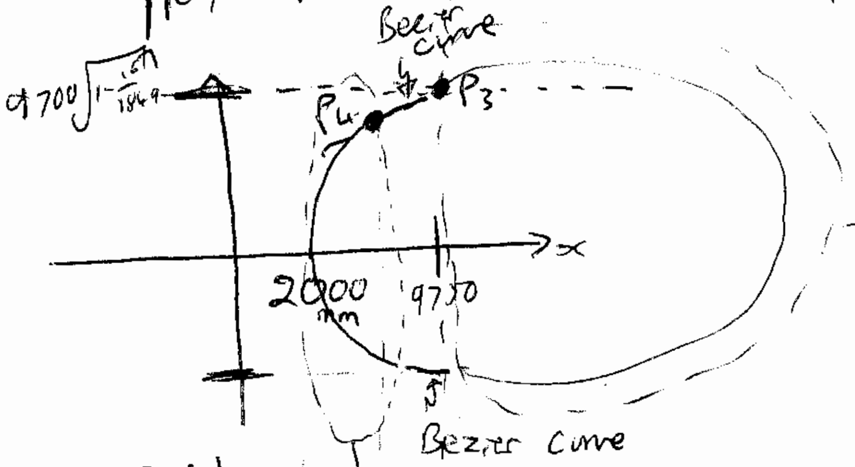
$\underset{\sim}{P_1} = \left[0\,\text{mm},\ 9770 \times \sqrt{1 - \frac{16}{1849}} - \frac{35\,600\,200}{427\,350\,125} \right]$

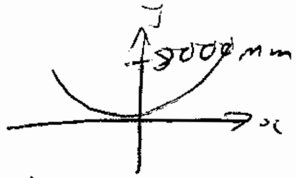
$\underset{\sim}{P_2} = \left[0\,\text{mm},\ -9770\,\text{mm} \times \sqrt{1 - \frac{16}{1849}} - \frac{35\,600\,200}{427\,350\,125} \right]$

end point $\underset{\sim}{P_3} = \left[9750\,\text{mm},\ -9700\,\text{mm}\sqrt{1 - \frac{16}{1849}} \right]$

This is a chance, and wont pass the axis at [2000 mm, 0 mm) - will have to use more than one Bezier curve.

TRY REDUCING THE 10,000





$y = x^2$

$y = ax^2 + bx + c$

By x co-ordinate.

$0 < y \leq 8000\,\text{mm}$

$a =$

$b =$

$c = -2000\,\text{mm}$

condition

· higher order equation

2000 mm

9750 mm

$Z(r)$

new ~~set of~~ variables.

$P_4 = [8000\,mm, 9700\sqrt{1-\frac{16}{(...)}}]$ something less than

8000 mm

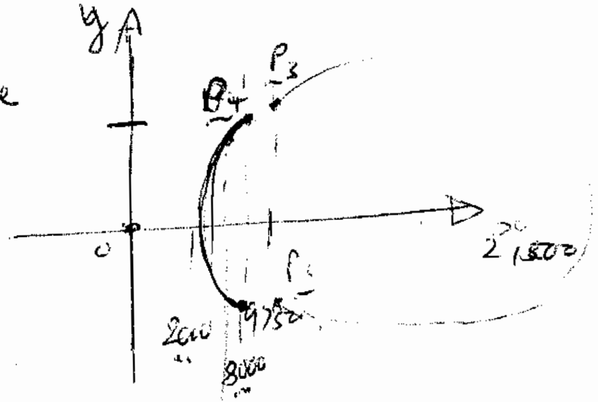
$9770 \times \sqrt{1-\frac{16}{(849}}\ mm = 9657.94018\ mm$

Ellipse, Bezier & Parametric curves which form half the cross section of the toroid

if elliptical

$y = \pm 9770\,mm\sqrt{1-\left(\frac{8000\,mm}{(10750\,mm)^2} - 1\right)^2}$

$y = 114.9578346\ mm$



$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$

$0 < x < 21500$

$\frac{x^2}{21500^2} + \frac{y^2}{9770^2} = 1$

$\frac{x^2}{10750^2} + \frac{y^2}{9770^2} = 1$

$\frac{y^2}{9700^2} = 1 - \frac{x^2}{21500^2}$

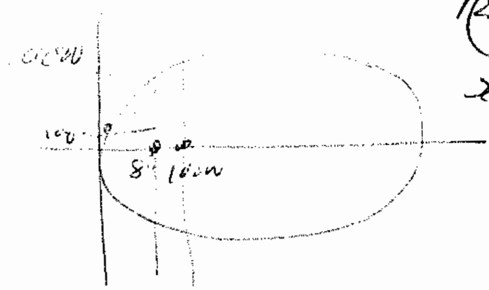
$\frac{y^2}{9770^2} = 1 - \frac{x^2}{10750^2}$

let $a = 0.001$

$z = ay^2 + by + c$

$y^2 = 9700^2\left(1 - \frac{x^2}{21500^2}\right)$

$y^2 = 9770^2\left(1 - \frac{x^2}{10750^2}\right)$



$y = 9700\sqrt{1-\frac{x^2}{21500^2}}$

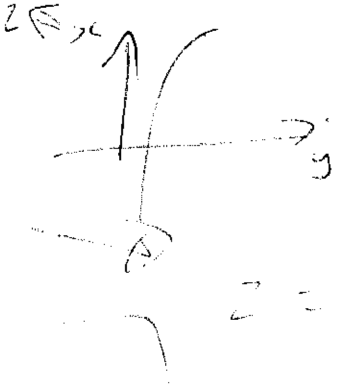
$x = y^2 + 2000$

$y = 9770\,m\sqrt{1-\frac{x^2}{10750^2}}$

$y = 9770\,m\sqrt{1-\left(\frac{x}{10750}\right)^2}$

$(x-10750)^2$

Bad	Better
Bezier Curve →	Parametric Space Curve. - what is the correct term for equations of higher orders?
Pin Cu Sphere →	Dodecahedron Sphere
Pin Cu Torroid →	Wire mesh ~~torroid~~ with spiraling, dark helical vortex



$y = a x^2 + b x + c$

$r = a z^2 + b z + c$

rearrange for $z(r)$

impossible!

$$z = \frac{-b \pm \sqrt{b^2 - 8000a}}{2a}$$

$r = a z^2 + b z + c$

conditions @

$r = 8000$ nm

$z = 9500$ nm

$r = 8000$

$c = 2000$

find a & b

? OMG! Just solving a quadratic.

decide on bonding

$8000 = a\,9500^2 + b\,9500 + 2000$

$0 = a\,9500^2 + b\,9500 - 6000$ ⇒ $6000 = 9500^2 a + 9500 b$

$$z = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$\frac{-b \pm \sqrt{b^2 - 8000a}}{2a}$$

no better!

$$19000a = -b \pm \sqrt{b^2 - 8000a}$$

$$19000a + b = \pm\sqrt{b^2 - 8000a}$$

$$(19000a + b)^2 = b^2 - 8000a$$

AHHHHHHHH!

$$6000 = 9500^2 a + 9500 b$$

$$6 = 90250a + 9.5b$$

$$b = \frac{6 - 90250a}{9.5}$$

a	b	Z
1	-9499	-70
2	-18999	
3	-28499	
4	-37499	
5		
6		
7		
8		
9		
10	-94999.	

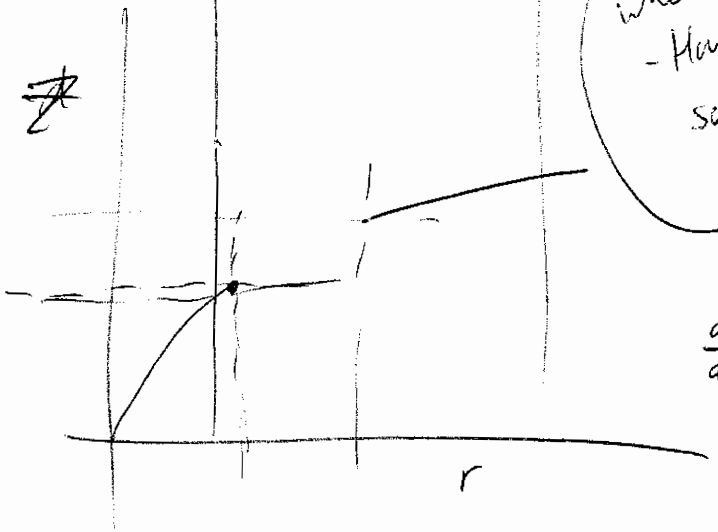
$\frac{ds}{dx}$

$$Z = \frac{-b \pm \sqrt{b^2 - 4a\,2000}}{2 \times a}$$

$$Z = \frac{-b \pm \sqrt{b^2 - 8000a}}{2a}$$

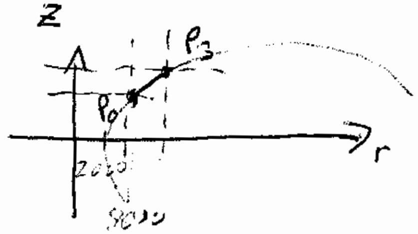
what - How to solve?

Visually solve



$\frac{dz_p}{dr}\Big|_{r=}$

$\frac{dz[\text{ellipse}]}{dr}\Big|_{r=}$ =



plot (x, t, y]

Bezier are Parametric

Parametric are not ? But they want be.

tilted ellipses can be 2D plot $z(r, \phi)$ or ~~z(r, ...)~~

How would we get better to not $z(r, \theta)$

bulge at rim ?

Plotting torios in 3D using MATLAB

Bezier curves are Parametric

Search the MATLAB help for 3D space curves.

Write the script for the ellipse then tilt it.

plot(x, y, 'r', x, z, 'b--')

~~I guess~~ This means red

~~I guess~~ This means a blue dotted line.

Both Excel and Matlab is good. will need another day. What MATLAB would be good for is repeativly drawing the parametric and changeing the values of a & b this is scary because a & b are both any real numbers from $-\infty$ to $+\infty$ so any possiblity of getting close would be to try them all which would take ∞ amount of time. But you don't know if you don't try ? so start from 1 for both and see what happens.

We have the ellipse - good.

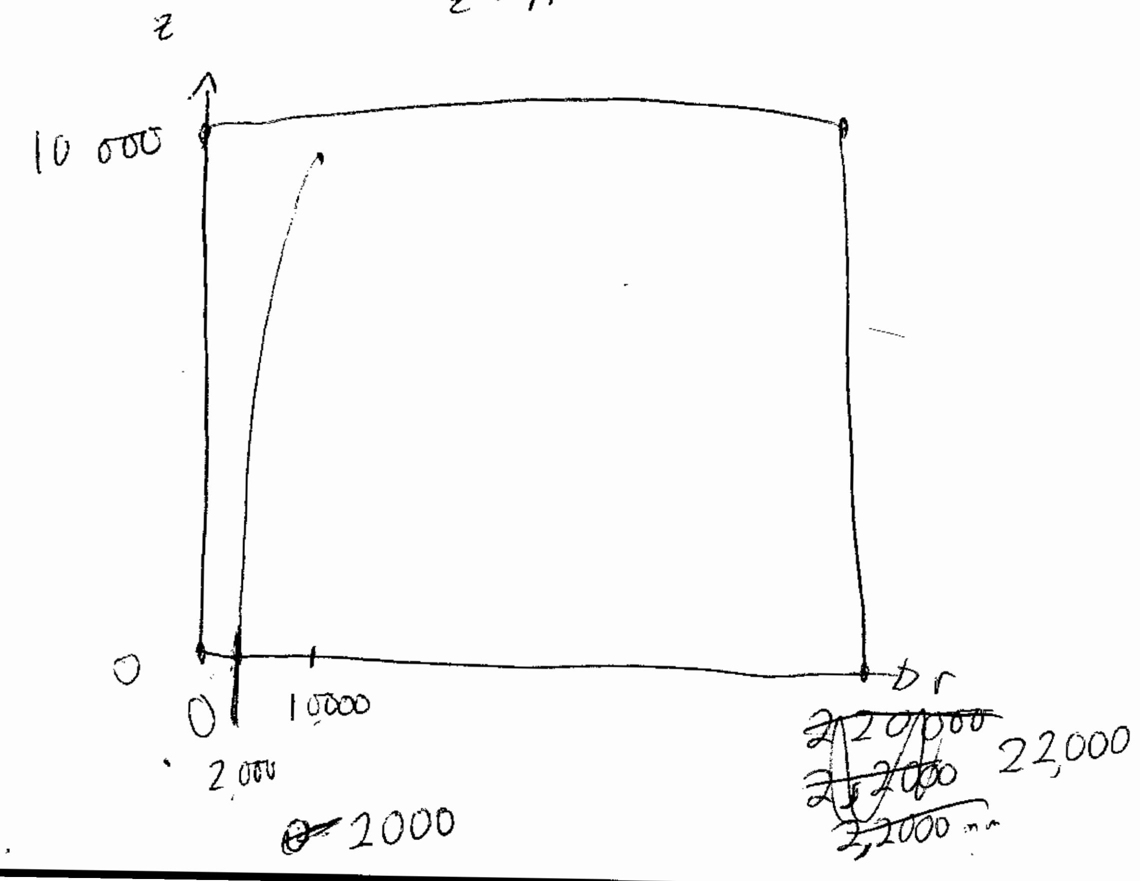
Need to draw a vertcl. for $r = 8000$ mm

MATLAB but no "holes" to ...

- the Bezier Curve eqn is too much for MATLAB to take, so as with Excel, enter the equation term by term, just reading out the table of results first, plotting, add a term, read out ect untill the whole equation works.
- Find the syntax for plotting multiple graphes on one axis, this is aquard for this e.g. because I like to keep the axis of the model. z - vertically up from the equatorial plane and r. radially outwards.
- How can I move all the scripts together?
- If I can produce the data ~~plot~~ what I have plotted on Excel I will be happy. - I.e do not use the semi colon, term by term and
-

axis	0.8×10^4	2.2×10^4	0	10 000
	8,000	22000.	0	10 000
	0	21 500	0	100

$$z = Ar^2 + Br + C$$



USE

- MATLAB
- TEXT ONLY DOCS
- PDFs & JPEGS
-

$a = 0.00005$

$b = 0.1$

$c = 2000$

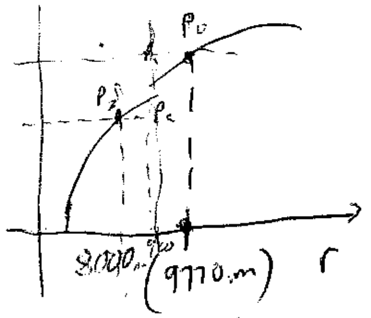
```
z = [0:1:7000];
r = a*z.^2 + b*z + 2000;
```

	P_0	1	2	3	4
r	2000	2000	0		
z	2000	2000	9770m		

Did you specify the height or the r value for the end of the parametric eqn?

find eqns of straight line P_0 to P_1, P_2 to P_3 → find co-ordinates → Sub into Bezier curve

Join the Bezier curve to the para & the ellipse



all you need is to derive the point on paper

we can take this from the previous example.

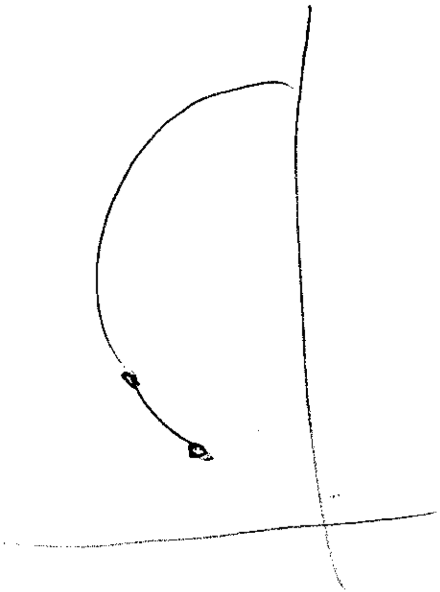
↳ But need to understand how where the parametric curve ends & find the points.

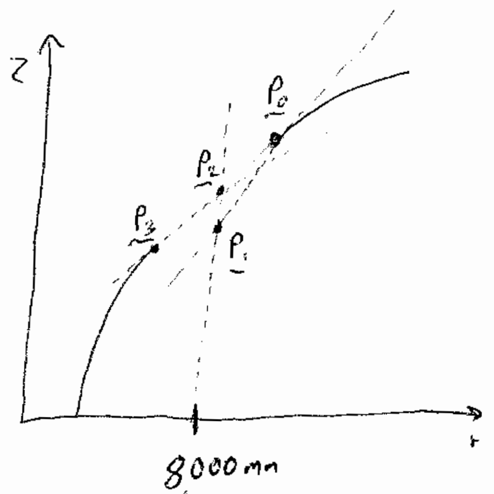
Have you put any constraints on r

If this is correct then just plug it into the equation.

Find these co-ordinates. The $\frac{dz}{dr}\Big|$..

is solve of 9,000mm





$\underset{\sim}{P_0} = \left[9750\text{mm}, \; 9770\text{mm} \sqrt{1 - \frac{16}{1849}} \right]$

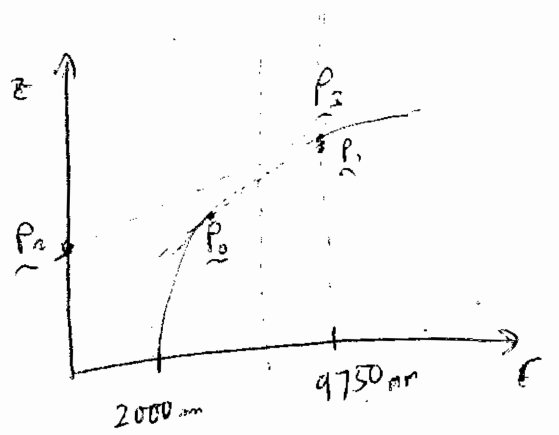
$\underset{\sim}{P_1} = \left[8000\text{mm} , \qquad \right]$

$\underset{\sim}{P_2} = \left[8000\text{mm} , \qquad \right]$

$\underset{\sim}{P_3} = \left[\qquad \right]$

?

use results from before



$\underset{\sim}{P_0} = \left[\qquad , \qquad \right]$

$\underset{\sim}{P_1} = \left[9750\text{mm} , \qquad \right]$

$\underset{\sim}{P_2} = \left[0, \; 9770\text{mm} \times \sqrt{1 - \frac{16}{1849}} - \frac{35\,600\text{mm}}{427\,350\,125} \right]$

$\underset{\sim}{P_3} = \left[9750\text{mm}, \; 9770\text{mm} \times \sqrt{1 - \frac{16}{1849}} \right]$

Parmetric Curve

$r = a z^2 + b z + c$

$\frac{dr}{dz} = 2az + b$

$\left.\frac{dr}{dz}\right|_{2000\text{mm}} = 2az + b$

$= 4\,000\text{mm} \times z + b$

Tangent

need tales of a & b.

$y = mx + c$

$z = (4000\text{mm}\, z + b) r + c$

find y intercept

$r = 0$

$z = c$ dem

Would it not be better to read co-ordinates from the photo of how the shape curves then do a curve fit?

Yea but can still type up what you have done.

cylindrical polar - coordinates

$r(z, \phi) =$

MATLAB

ezplot(d)

s = solve(eq)   eq = x^2
(Matlab assumes it is equal to zero)

double(s(1)) gives a numerical result.

syms t   defines a symbolic variable, t the dependent variable

simplify (cos(x)^2 + 2 + sin(x)^2)

s = taylor(sin(x))

limit (x + 5, 3)

ezplot

title

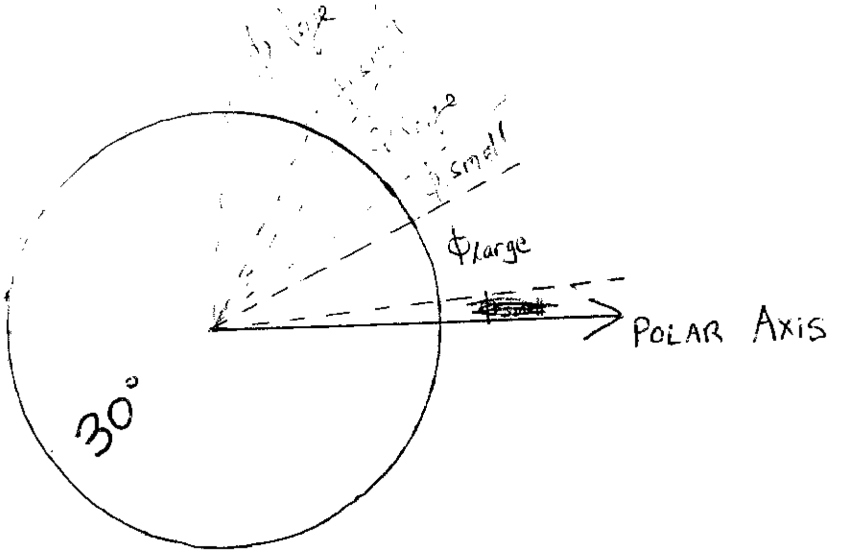
set

get

$\Theta = 63.9543206$ degrees

CO-ORDINATES OF END OF ELLIPSES

12 pairs of points
= 24 points



$2\phi_{small} + \phi_{large} = 30°$

MATLAB

ezplot(d)

s = solve(eq)   eq = x^2
(Matlab assumes it is equal to zero)

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ezplot

title

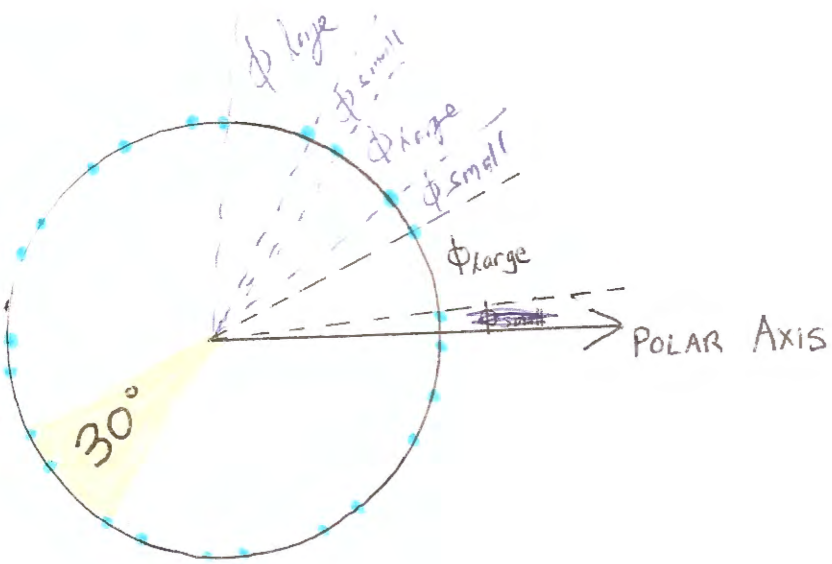
set

get

$\Theta = 63.9545\,6206$ degrees

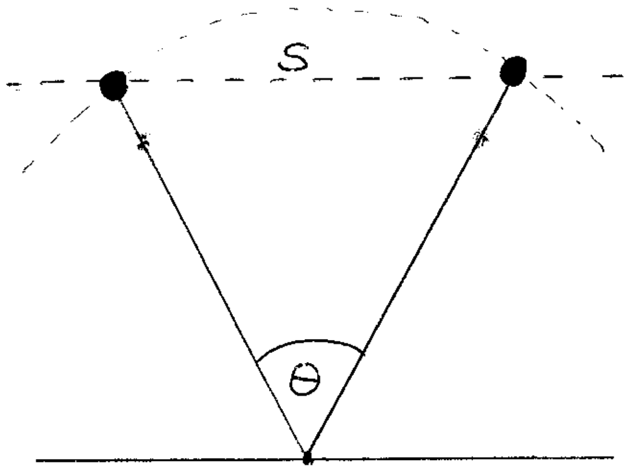
CO-ORDINATES OF END OF ELLIPSES

12 pairs of points
= 24 points



$2\phi_{small} + \phi_{large} = 30°$

DERRIVE AN EQUATION FOR ϕ small

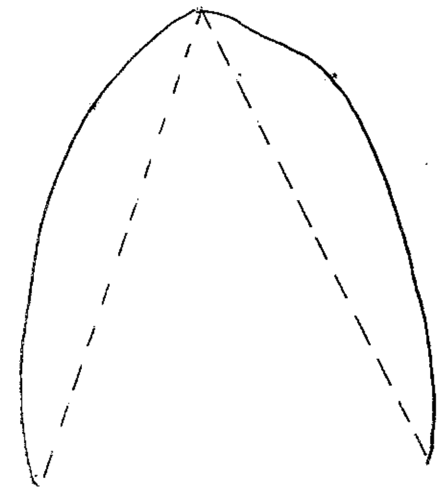


S = seperation

* point where tilted ellipse ends.

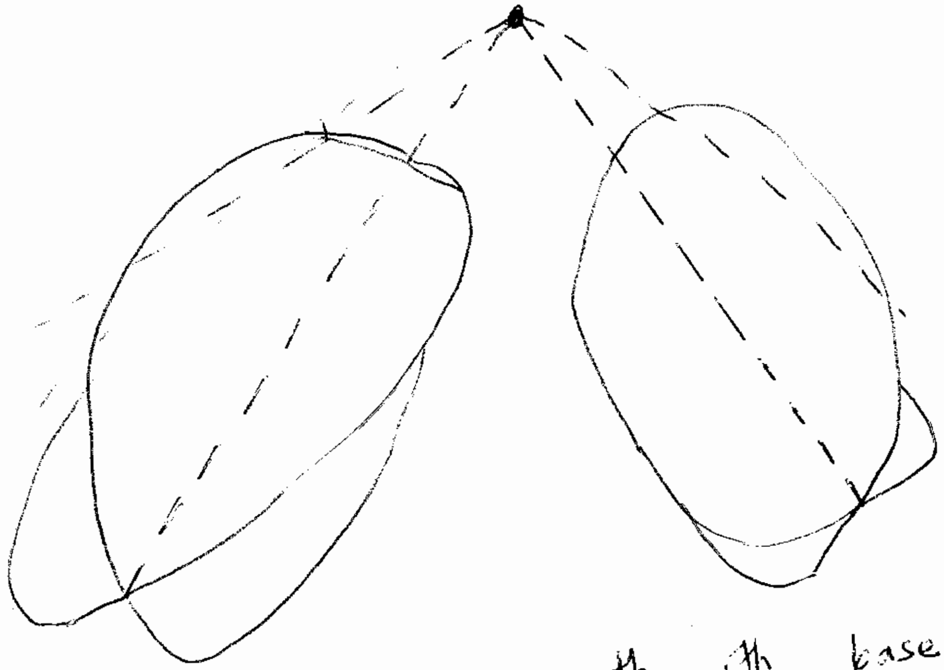
• Height of tilted ell

SIDE VIEW OF TILTED ELLIPSE

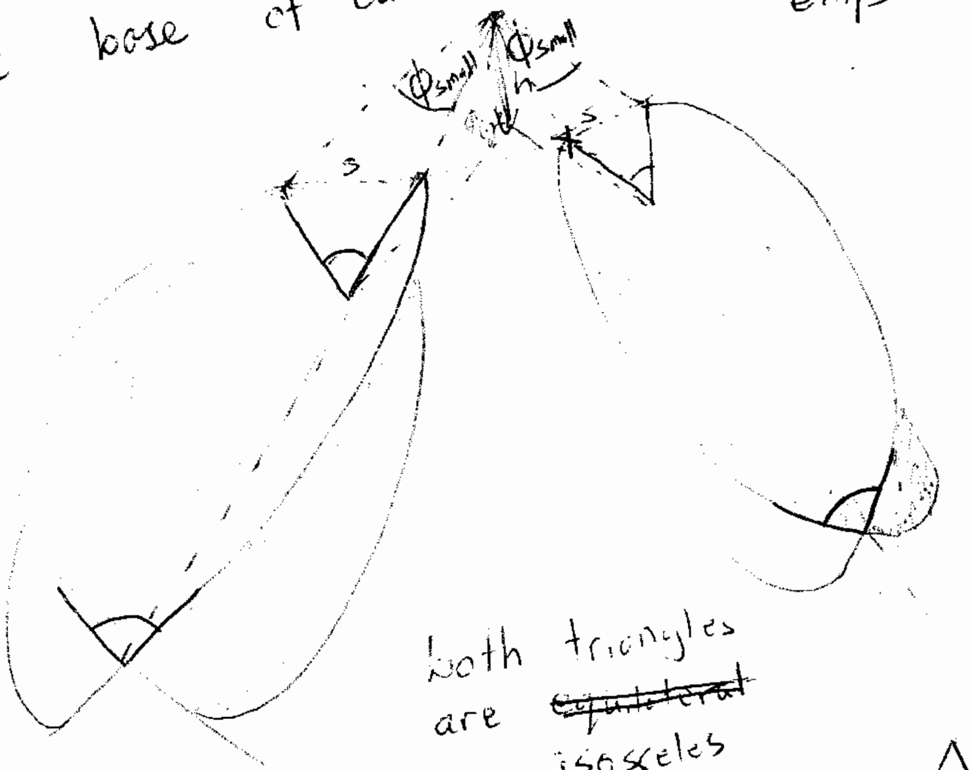


$\phi = \phi(r)$

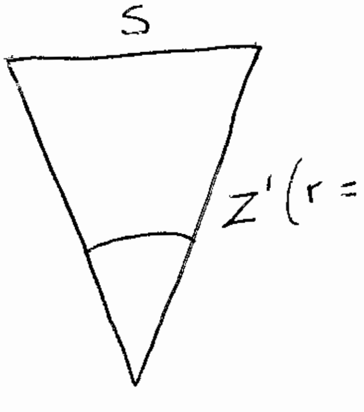
PLAN VIEW OF TILTED ELLIPSE

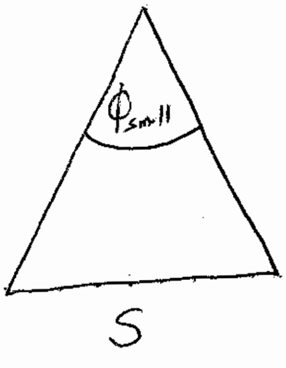


2 triangles, both with base of length. S
the base of each triangle joins the ends of both ellipses.



both triangles are ~~equilateral~~ isosceles





toroid

a surface of revolution generated by revolving any 2D shape in 3D space about an axis coplanar with the 2D shape.

torus

a special case of the toroid where the 2D shape is a circle.

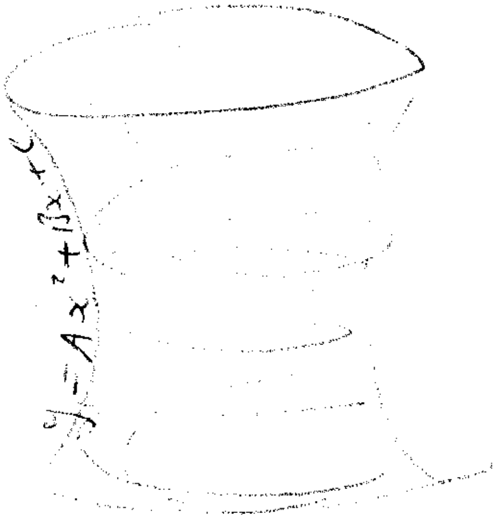
$$\left[\left(\frac{n-1}{2}\right)-\left(\left(INT\left(MOD\left(\frac{(n-1)}{2}\right)\right)\right]\times 30degs + \phi_{small} + 2*$$

R.O -> ... 1

data ... be

sequal
automated.

Send ~~6~~ 6-7



Import photo into MATLAB

Scale photo

Draw graph over top. - Draw parametric graph over top.

imread(filename), but you must give it a variable

A = imread('toroid.jpg');

Display the image

image(A) $\qquad y = Ax^2 + Bx + C$

How does that combine with the parametric eqn of ~~a~~ ~~a~~ double toroid

$x(t) = [R + (R-2r)\times \sin(12t)]\cos t$

$y(t) = [R + (R-2r)\times \sin(12t)]\sin t$

$z(t) = 6 * \cos(ct)$

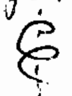
$x = r\cos t$

$y = r\sin t$

$z = ct$

How much does the pitch change by?

Q. How do we change it from

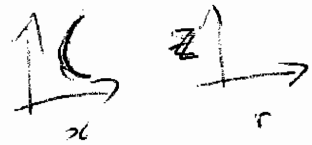


to

?

A. Just ~~chan~~ shorten or lengthen the range of t. → but this will change the height $c \neq C$

the waist is $r \to r(t) \to r(z)$



$r = Az^2 + Bz + C$

let $z = ct$

$r = Ac^2t^2 + Bct + C$

$x(t)$
$y(t)$
$z(t)$

$x = (Ac^2t^2 + Bct + C) * \cos t$

$y = (Ac^2t^2 + Bct + C) * \sin t$

$z = ct$

Try this → does it make the heli bulge?

cylindrical co-ordinates (r, θ, h)

$r(t) = 1$
$\theta(t) = t$
$h(t) = t$

$\Longrightarrow$ $r = Ah^2 + Bh + C$
$\theta(t) = t$
$h(t) = t$

from the wiki page

Copy the data from the parametric equation by not using ;

Can you plot ~~&~~ raw data? If so plot as a scatter graph. This will look like the ~~glass~~ paper weight with patterns in.

---

pitch $= 2\pi c$

$h = \#$ of revs $* 2\pi c$ = ~~range of~~ t = ~~range of~~ t

~~# of revs~~ = $\frac{t}{2\pi}$

$t = 2\pi$ $\cos 2\pi = 1$ $\sin 2\pi = 0$

$x = r$
$y = 0$
$z = 2\pi c$

$h = 2\pi c * \#$ of revs

$\frac{\text{range of } t}{\# \text{ of revs}}$ = ~~[illegible]~~ range of t over one revolution

$\frac{t_{max} - t_{min}}{\# \text{ of revs}} = 2\pi$

$x = r\cos t$
$y = r\sin t$
$z = ct$

$$\frac{\text{range of } t}{\#\text{ of revs}} = \text{range of } t \text{ over one rev}$$

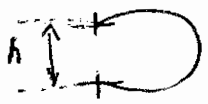
$$\frac{t_{max} - t_{min}}{\#\text{ of revs}} = 2\pi$$

$h = \#\text{ of revs} \times 2\pi c$

what do we set c and $t_{max} - t_{min}$ to to change # of revs?

$$\#\text{ of revs} = \frac{h}{2\pi c} \qquad \#\text{ of revs} = \frac{t_{max} - t_{min}}{2\pi}$$

we need to set h & # of revs



$$h = \text{height} = 9770\,\text{mm} * \sqrt{1 - \frac{16}{1849}} * 2$$

$$\#\text{ of revs} = 2\pi + \phi_{small} + 8 * \frac{2\pi}{12}$$

$$\#\text{ of revs} = 2\pi + \phi_{small} + \underset{\text{missed out}}{\#\text{ of ellipses}} * \frac{2\pi}{12}$$

$$\#\text{ of revs} = 2\pi + \phi_{small} + 8 \times \frac{2\pi}{12}$$

$$\#\text{ of revs} = \cancel{3\pi = 0}\ 2\pi + \phi_{small} + 8 * \frac{\pi}{6}$$

$$= 2\pi + \phi_{small} + 4 * \frac{\pi}{3}$$

$$= 2\pi + \frac{4}{3}\pi + \phi_{small}$$

$$= \frac{6\pi}{3} + \frac{4}{3}\pi + \phi_{small}$$

$$= \frac{10}{3}\pi + \phi_{small}$$

$$\boxed{\#\text{ of revs} = \phi_{small} + \frac{10}{3}\pi}$$

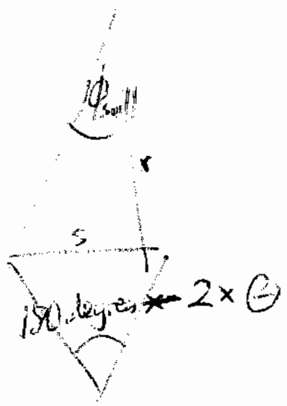
maybe leave it in this form

$$\#\text{ of revs} = \phi_{small} + 2\pi\left(1 + \underset{\text{left out}}{\#\text{ of ellips}}\ \frac{1}{12}\right)$$

$$\boxed{\#\text{ of revs} = \phi_{small} + 2\pi\left(1 + \frac{E}{12}\right)}$$

$$\phi_{small} + 2\theta\left(1+\frac{E}{12}\right) = 9770\,mm * \sqrt{1-\frac{16}{1849}} * 2 * \frac{1}{2\pi}$$

Finding ϕ_{small} and ϕ_{large}



$180^\circ = \phi_{small} + 2\theta$

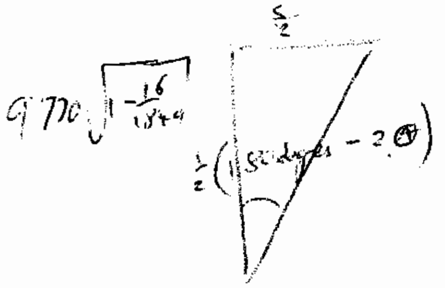
$\phi = \frac{180^\circ - \phi_{small}}{2}$

$$\frac{\sin A}{A} = \frac{\sin B}{B}$$

$$\frac{\sin \phi_{small}}{s} = \frac{\sin(180^\circ - \phi_{small})}{2 * r}$$

See next page for tidyer calculations ⇒

$z'(r = 9750\,mm)$



$$\tan\left[\frac{1}{2}(180^\circ - 2\theta)\right] = \frac{\frac{s}{2}}{9770\sqrt{1-\frac{16}{1849}}}$$

$$2 \times 9770\sqrt{1-\frac{16}{1849}}\tan\frac{1}{2}(180^\circ - 2\theta) = s$$

$$\sin \phi_{small} = \frac{\frac{s}{2}}{9750\,mm}$$

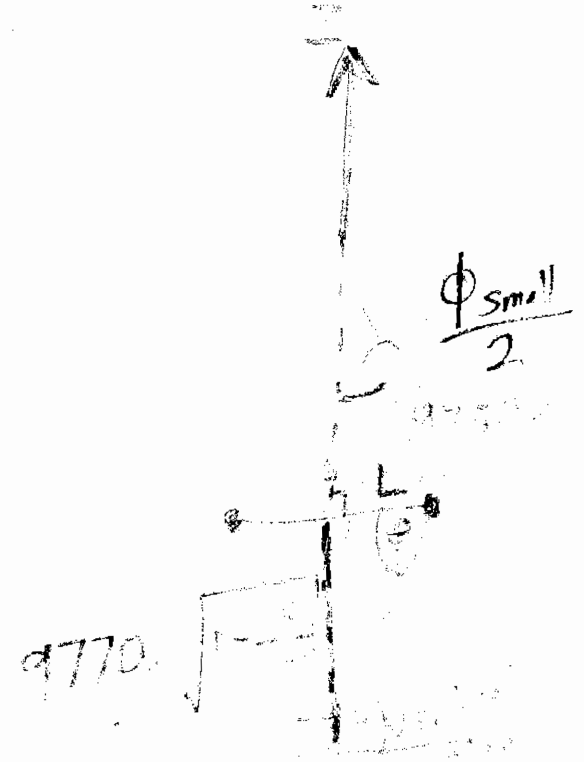
$$2 \times 9750\,mm \sin\phi_{small} = s$$

$$\cancel{2} \times 9770\sqrt{1-\frac{16}{1849}}\tan\frac{1}{2}(180-2\theta) = \cancel{2} \times 9750\,mm \sin\phi_{small}$$

$$\frac{9770}{9750}\sqrt{1-\frac{16}{1849}}\tan\left(\frac{180-2\theta}{2}\right) = \sin\phi_{small}$$

$$\phi_{small} = \arcsin\left(\frac{9770}{9750}\sqrt{1-\frac{16}{1849}}\tan\left(\frac{180-2\theta}{2}\right)\right)$$

$\phi_{small} =$



$\tan\theta =$

from Google Sketchup model

$\phi_{large} \simeq 27.6^\circ$

$\sin\left(\frac{\phi_{small}}{2}\right) = \frac{L}{9750mm}$

$L = 9750mm \times \sin\frac{\phi_{small}}{2}$

equate for L

9770mm

975

The

$= 58.57^\circ$

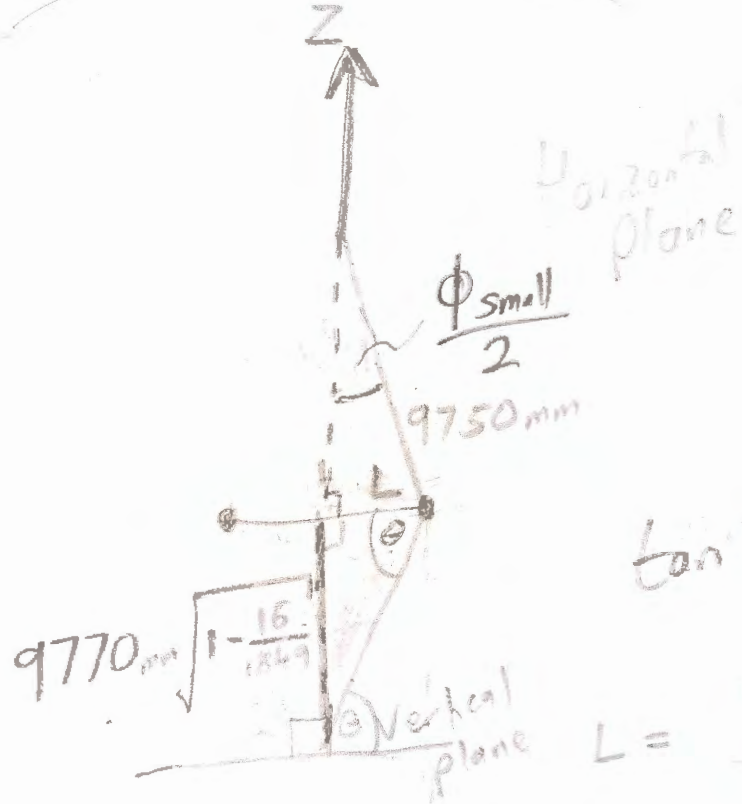
which is too big. By eye

$\phi_{small} \simeq 5^\circ$

$= \frac{977\cancel{0}}{975\cancel{0}} \frac{\sqrt{1-\frac{16}{\ldots}}}{\tan\theta}$

$\phi_{small} = 2\arcsin\left(\frac{977}{975} \times \frac{\sqrt{1+\frac{16}{\ldots}}}{\tan\theta}\right)$

$\theta = 63.45456206^\circ$



$$\tan\theta = \frac{9770_{mm}\sqrt{1-\frac{16}{1849}}}{L}$$

$$L = \frac{9770_{mm}\sqrt{1-\frac{16}{1849}}}{\tan\theta}$$

from Google Sketchup model

$\phi_{large} \simeq 27.6°$

$$\sin\left(\frac{\phi_{small}}{2}\right) = \frac{L}{9750_{mm}}$$

$$L = 9750_{mm} \times \sin\left(\frac{\phi_{small}}{2}\right)$$

equate for L

$$9750_{mm} \times \sin\left(\frac{\phi_{small}}{2}\right) = \frac{9770_{mm}\sqrt{1-\frac{16}{1849}}}{\tan\theta}$$

rearange for ϕ_{small}

$$\sin\left(\frac{\phi_{small}}{2}\right) = \frac{977\cancel{0}}{975\cancel{0}}\,\frac{\sqrt{1-\frac{16}{1849}}}{\tan\theta}$$

$$\phi_{small} = 2\arcsin\left(\frac{977\sqrt{1-\frac{16}{1849}}}{975 \times \tan\theta}\right)$$

$$\theta = 63.9545620 6°$$

This calculates as $\phi_{small} = 58.37°$ which is too big. By eye $\phi_{small} \simeq 5°$ and $\phi_{small} < 30°$

Θ is correct, the calculations have been checked and it looks correct when looking at the photograph. Just need Θ in radians for MATLAB.

$$a = r\sin\left(\frac{\pi}{12}\right)$$

$$\tan\Theta = \frac{H_j}{a}$$

$$\tan\Theta = \frac{8{,}500\,mm}{r\sin\left(\frac{\pi}{12}\right)}$$

$$\Theta = \arctan\frac{8{,}500\,mm}{r\cdot\sin\left(\frac{\pi}{12}\right)}$$

r in this case is the radial distance to the first join above the equator. (not the end of the ellipse)
⇒ Can we use the other triangle formed by the top of the ellipse and the origin?
Yes but we won't.

$$r = \frac{21{,}500\,mm}{2}\left(1 + \sqrt{1 - \left(\frac{8.5}{9.77}\right)^2}\right)$$

$$r = 10750\,mm\left(1 + \sqrt{1 - \left(\frac{8.5}{9.77}\right)^2}\right)$$

This was calculated using MATLAB very quickly :)

Check that the height is correct

not height of join
IS height of end of tilted ellipse

it is just z(9.75)

$$z(r) = H\sqrt{1 - \left(\frac{r-R}{R}\right)^2}$$

$$z(r=9.75) = 9.77\sqrt{1 - \left(\frac{9.75-10.75}{10.75}\right)^2}$$

$$z(r=9.75) = 9.727636657$$

or 9,728 mm Yes! :)

as before :($H = 9.77$ $R = 10.75$

$\phi_{small} << 30°$

$\phi_{large} < 30°$

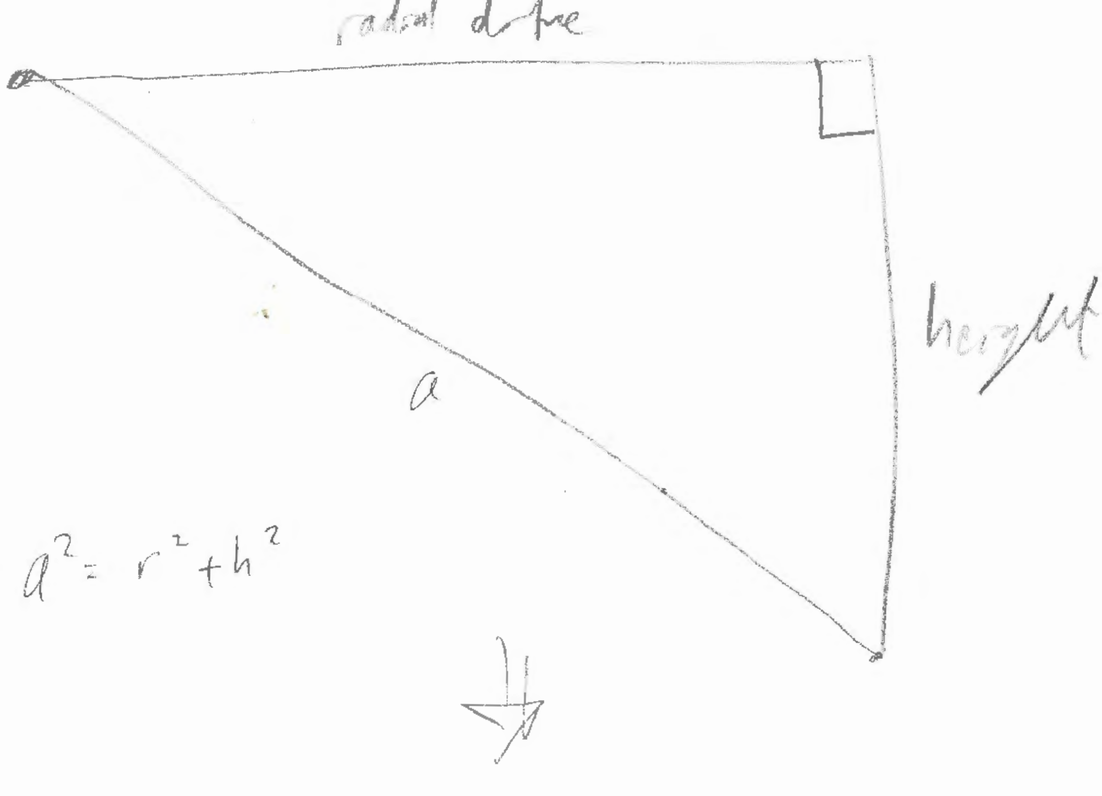
height of ringlet angles are wrong

$2\phi_{small} + \phi_{large} = 30°$

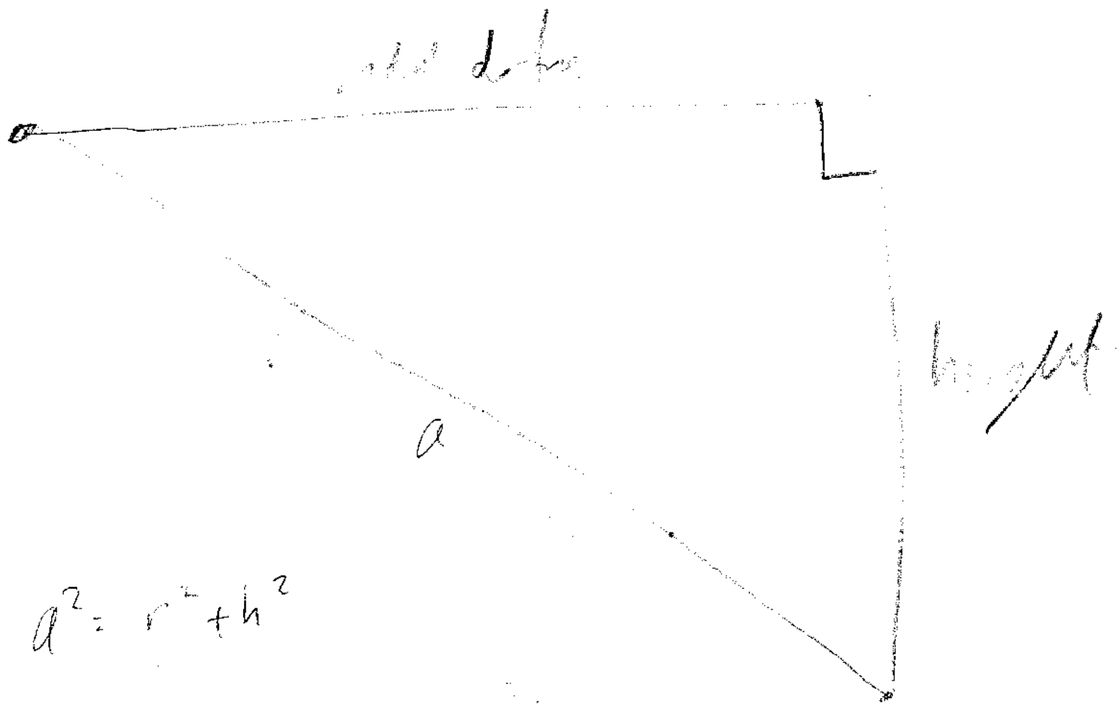
$$\begin{array}{r} 27.6° \\ + \; 2.4° \\ \hline 30.0 \checkmark \end{array}$$

xx :)

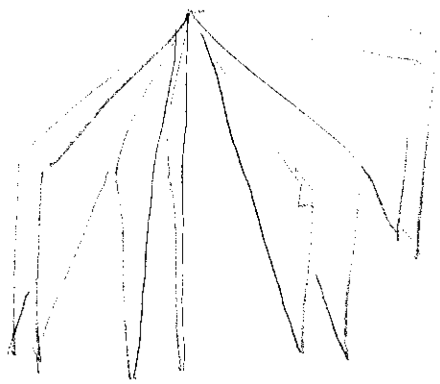
$\boxed{\text{From Sketchup Model } \phi_{small} \approx 2.4°}$



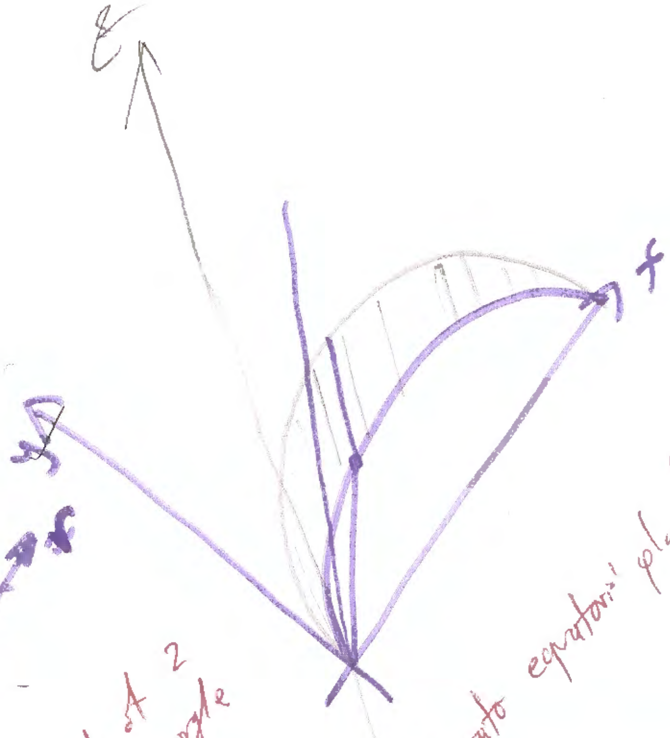
$a^2 = r^2 + h^2$

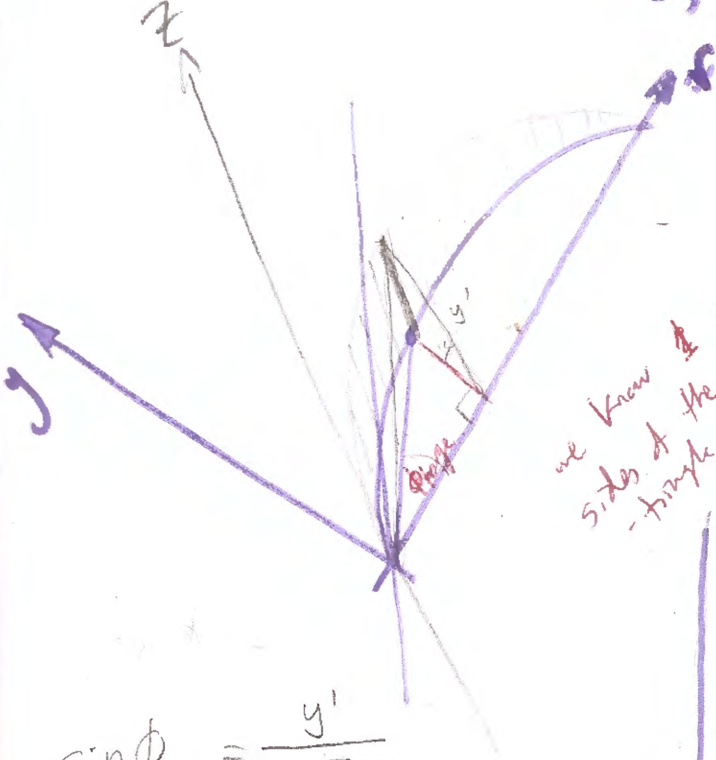


$a^2 = r^2 + h^2$



$43 \times 97) = \frac{42011}{53150}$ $\qquad \frac{42011}{53150}$



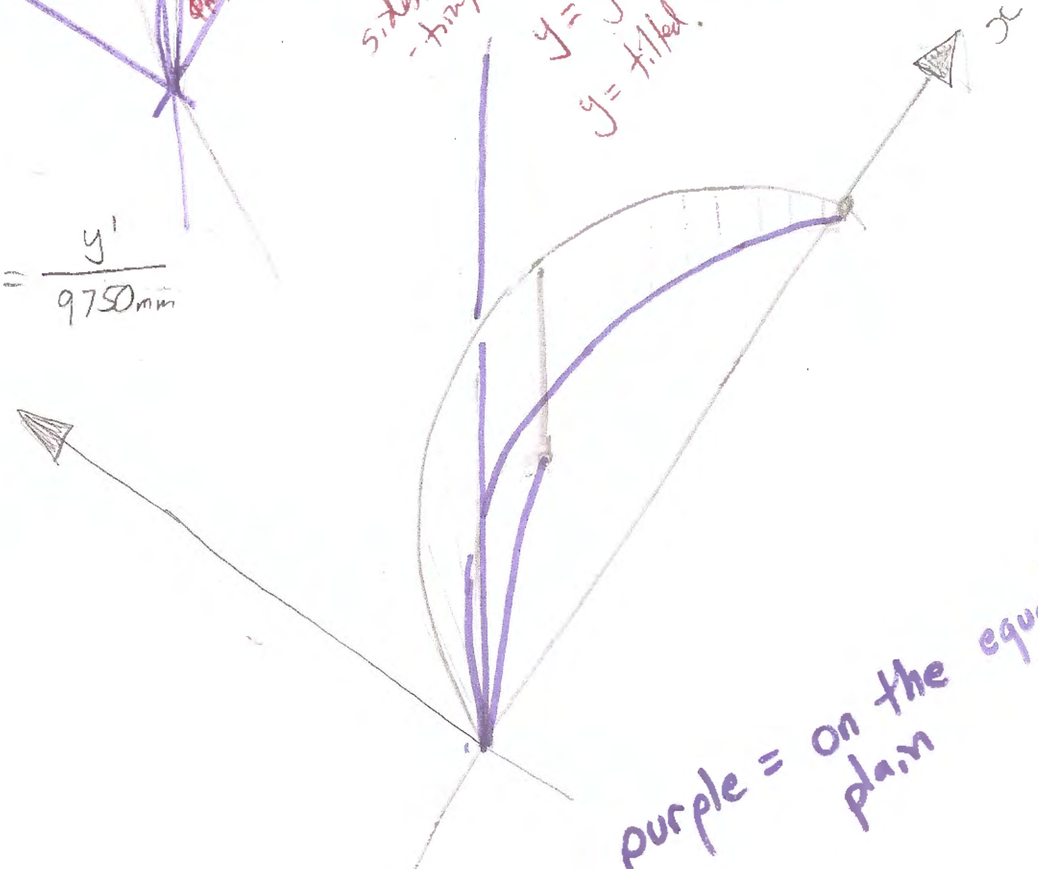


we know of 2 sides of the right-angle triangle

$y = f(x)$

$y =$ tilted ellipse projected onto equatorial plane (x)

$$\sin \phi_{large} = \frac{y'}{9750mm}$$



purple = on the equatorial plain

$$z' = \frac{H}{\sin\theta}\sqrt{1-\left(\frac{r-R}{R}\right)^2}$$

$$\cos\theta = \frac{y}{z'}$$

$$z'\cos\theta = y'$$

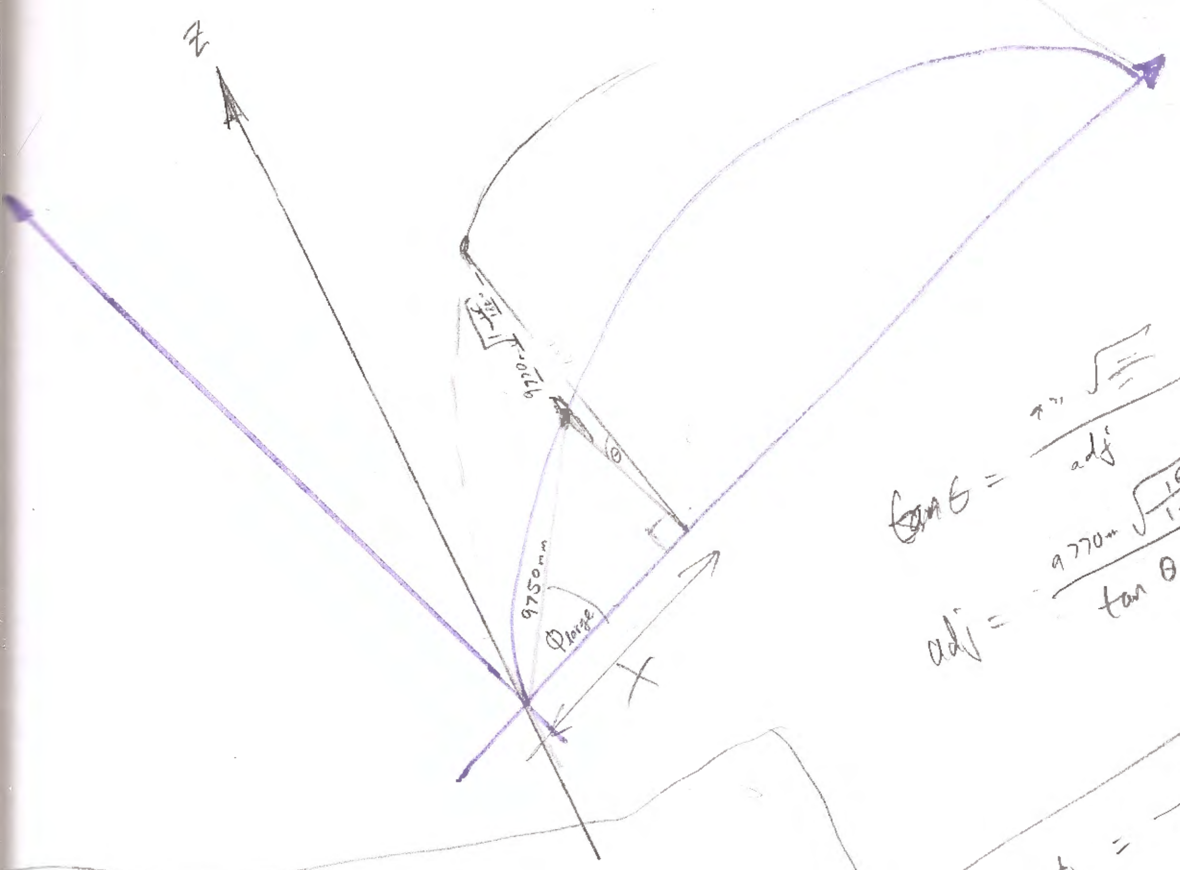
$$\frac{H}{\sin\theta}\sqrt{1-\left(\frac{r-R}{R}\right)^2}\cos\theta = y'$$

$$\cos\phi_{lage} = \frac{X}{9750mm}$$

Equate for r

$$y'\left(r = 9750mm\cos\phi_{large}\right) = H\frac{\cos\theta}{\sin\theta}\sqrt{1-\left(\frac{r-R}{R}\right)^2}$$

$$= H\times\frac{\cos\theta}{\sin\theta}\sqrt{1-\left(\frac{9750mm\cos\phi_{large}-R}{R}\right)^2}$$



$$\tan\theta = \frac{9770\sqrt{\;}}{adj}$$

$$adj = \frac{9770mm\sqrt{\frac{16}{1\ldots}}}{\tan\theta}$$

AIM: find ϕ_{large}

1st find z'

$$\sin\theta = \frac{9770\sqrt{1-\frac{\ldots}{\ldots}}}{y'}$$

$$z' = \frac{9770\sqrt{1-\frac{\ldots}{\ldots}}}{\sin\theta}$$

find X

$$\cos\phi_{lrg} = \frac{X}{9750mm}$$

but $z' = \frac{H}{\sin\theta}\sqrt{1-\left(\frac{X-R}{R}\right)^2}$

$$\frac{9770\sqrt{1-\frac{\ldots}{\ldots}}}{\cancel{\sin\theta}} = \frac{H}{\cancel{\sin\theta}}\sqrt{1-\left(\frac{X-R}{R}\right)^2}$$

rearrange for X

$$9770mm \times \sqrt{1-\frac{16}{1849}} = H \times \sqrt{1-\left(\frac{X-R}{R}\right)^2}$$

$$\left(\frac{9770mm}{H}\sqrt{1-\frac{16}{1849}}\right)^2 = 1-\left(\frac{X-R}{R}\right)^2$$

$$\left(\frac{9770mm}{H}\right)^2\left(1-\frac{16}{1849}\right) = 1-\left(\frac{X-R}{R}\right)^2$$

$$\left(\frac{X-R}{R}\right)^2 = 1-\left(\frac{9770mm}{H}\right)^2\left(1-\frac{16}{1849}\right)$$

$$\frac{X-R}{R} = \sqrt{1-\left(\frac{9770mm}{H}\right)^2\left(1-\frac{16}{1849}\right)}$$

$$\sin\phi_{lg} = \frac{adj}{9750}$$

$$9750mm \sin\phi_{lg} = adj = \frac{9770m\sqrt{\frac{16}{\ldots}}}{\tan\theta}$$

$$9750mm \sin\phi_{large} = \frac{9770mm \times \sqrt{1-\frac{16}{1849}}}{\tan\theta}$$

$$9750mm \sin\phi_{large} \ldots \frac{\sqrt{1-\frac{16}{1849}}}{\tan\theta}$$

$$\sin\phi_1 = \frac{977}{975}\,\frac{\sqrt{1-\frac{16}{1849}}}{\tan\theta}$$

$$\phi_1 = \mathrm{asin}\; \frac{977}{975}\,\frac{\sqrt{1-\frac{16}{1849}}}{\tan\theta}$$

QUICK NUMERICAL CHECK

$\theta = 63.9545\,6206°$

29.18254542°

CLOSE, BUT NOT 27.6°

???

$$\frac{X - R'}{R} = \sqrt{1 - \left(\frac{9770\,mm}{H}\right)^2 \left(1 - \frac{16}{1849}\right)}$$

$$X - R = R\sqrt{1 - \left(\frac{9770\,mm}{H}\right)^2 \left(1 - \frac{16}{1849}\right)}$$

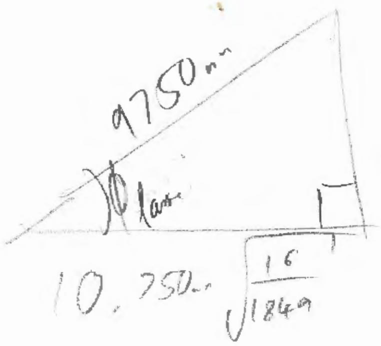
$$X = R\sqrt{1 - \left(\frac{9770\,mm}{\cancel{9770\,mm}}\right)^2 \left(1 - \frac{16}{1849}\right)}$$

$$X = R\sqrt{1 - \left(1 - \frac{16}{1849}\right)}$$

$$X = R\sqrt{\cancel{1} - \cancel{1} + \frac{16}{1849}}$$

$$X = R\sqrt{\frac{16}{1849}}$$

$$X = 10.75\sqrt{\frac{16}{1849}} \quad \text{or} \quad 10750\,mm\sqrt{\frac{16}{1849}}$$



$$\cos \phi_{lzy} = \frac{10\,750\,mm\sqrt{\frac{16}{1849}}}{9750\,mm}$$

$$\phi_{lze} = a\cos \frac{43\sqrt{\frac{16}{1849}}}{39}$$

$$= a\cos\left(\frac{4}{39}\right)$$

$$= 84.11^\circ$$

$\boxed{\text{NO!}}$

$$\Theta = \arctan \frac{8 \cdot 5}{r \cdot \sin(\pi/12)}$$

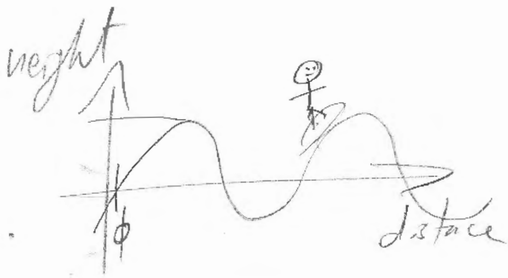
$$\phi_{lage} = \arcsin \frac{977}{975} \times \frac{\sqrt{1 - \frac{16}{1849}}}{\tan\theta}$$

$$\phi_{large} = \arcsin \left[\frac{977}{975} \times \frac{\sqrt{1 - \frac{16}{1849}}}{\left(\frac{8 \cdot 5}{r \sin \pi/12}\right)} \right]$$

$$= \arcsin \left[\frac{977}{975} \times \frac{\sqrt{1 - \frac{16}{1849}}}{\quad} \right]$$

$$= \left[\frac{n-1}{2} - \text{interger} \left| \frac{(n-1), 2}{2} \right| \right] \times 30^\circ + \phi_{small} + 2 \times \text{remainder}\left(\frac{n-1}{2}\right) \times \phi_{large}$$

try MOD$(n-1, 2)$



$\frac{1}{fr}$

freq dist

dist

$\omega t + \phi$ time

$\omega = 2\pi f$

$y = \sin(mx + c)$

dist height $= \sin(2\pi * \text{freq} * \text{dist} + \text{phase shift})$

height of wave $= \sin(2\pi \times \text{freq} \times \text{distance} + \text{phase shift})$

OBJECTIVE 3

$2\pi + \phi_{small} + 8\frac{\pi}{6}$ = angle in radians through which the space curve rotates from the end of one ellipse at the top of the toroid to an end of another ellipse at the bottom of the toroid.

$x = r\cos t$

$y = r\sin t$

$z = ct$

$t = \frac{z}{c}$

$x(z) = r\cos\left(\frac{z}{c}\right)$

$y(z) = r\cos\left(\frac{z}{c}\right)$

$x(z) = r\cos\left(\frac{z}{c} + \text{displacement}\right)$

helices

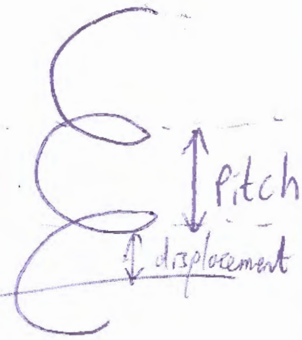
pitch

$$x(z) = r\cos\left(\frac{z}{c} + \overset{\text{phase constant}}{\cancel{\text{displacement}}}\right)$$

pitch $= 2\pi c$

$$x(z) = r\cos\left(\frac{2\pi}{\text{pitch}}z + \overset{\text{phase constant}}{\cancel{\text{displacement}}}\right)$$

$c = \frac{\text{pitch}}{2\pi}$



$$x(z) = r\cos\left(\frac{z}{c} + \text{displacement}\right)$$

But you cant have a cos of a distance ?

Sub in $$c = \frac{2 \times 9770\text{mm} \times \sqrt{1 - \frac{16}{1849}}}{2\pi + \phi_{small} + \frac{8\pi}{6}}$$

$$x(z) = r\cos\left(\frac{2\pi + \phi_{small} + \frac{8\pi}{6}}{2 \times 9770\text{mm} \times \sqrt{1 - \frac{16}{1849}}}\,z + \overset{\text{phase constant}}{\cancel{\text{displacement}}}\right)$$

Phase constant

$\cancel{\frac{\text{displacement}}{\text{wave length}} = \frac{\text{phase constant}}{2\pi}}$

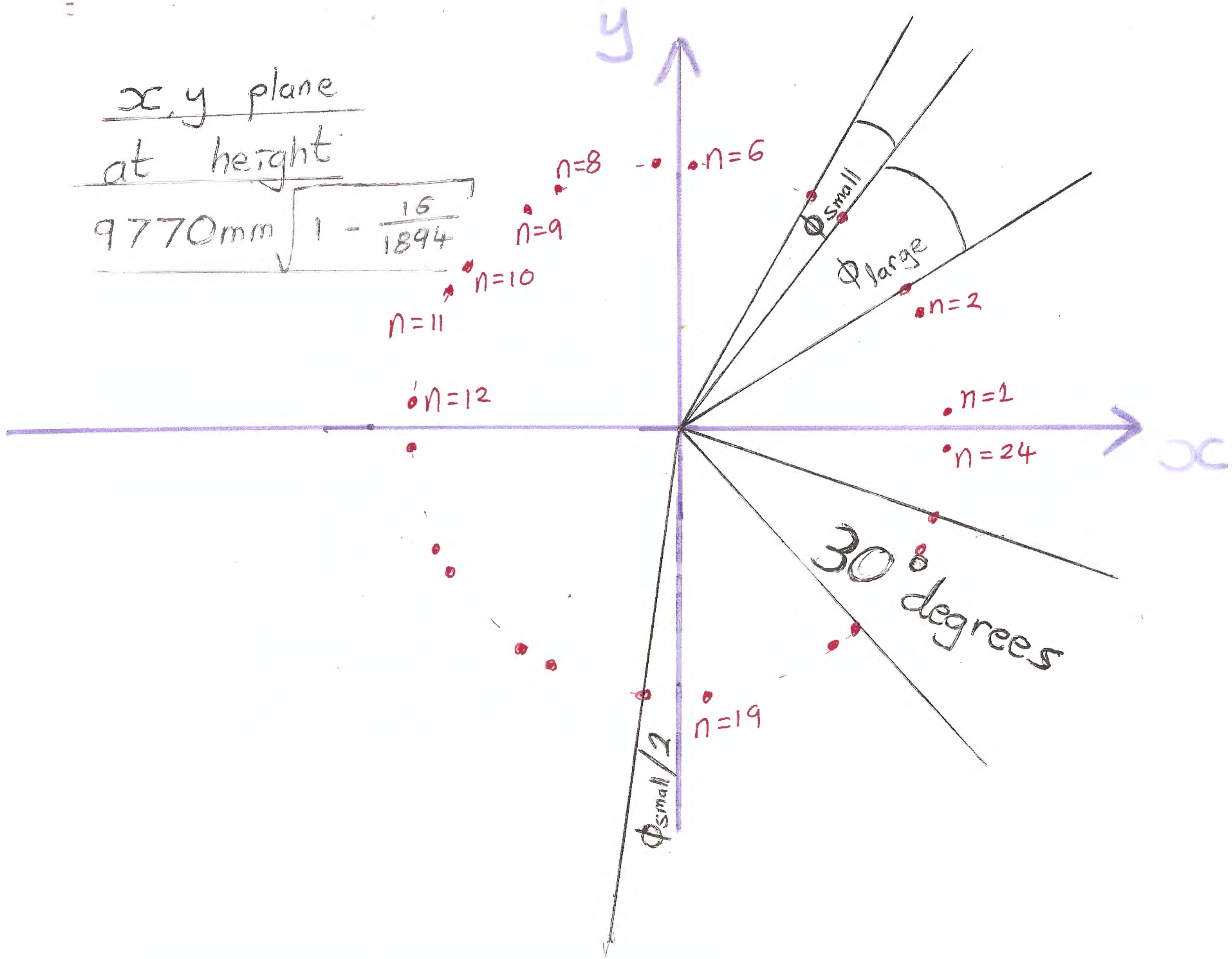
$\frac{\text{displacement}}{\text{pitch}} = \frac{\text{phase constant}}{2\pi}$

phase constant $= \frac{2\pi \text{ displacement}}{\text{pitch}}$

x, y plane

at height

$9770\,\text{mm}\sqrt{1-\frac{16}{1894}}$



~~displac~~

phase constant =

$$x(z) = r\cos\left(\frac{2\pi + \phi_{small} + \frac{8\pi}{6}}{2 \times 9770_{mm} \times \sqrt{1 - \frac{16}{1849}}} + \frac{2\pi \times \text{displacement}}{\text{pitch}}\right)$$

$\text{pitch} = 2\pi c$

$$x(t) = r\cos(t)$$

$$z = ct \Rightarrow t = \frac{z}{c}$$

$$x(z) = r\cos\left(\frac{z}{c}\right)$$

~~$t(t$~~ ~~add~~ more the graph

$$x(z) = r\cos\left(\frac{z}{c} \cancel{+} \text{phase constant}\right)$$

$$x(z) = r\cos\left(\frac{z}{c} \cancel{+} \frac{2\pi}{\text{pitch}} \times \text{displacement}\right) \qquad \text{pitch} = 2\pi c$$

$$x(z) = r\cos\left(\frac{z}{c} \cancel{+} \frac{\cancel{2\pi}}{\cancel{2\pi} c} \times \text{displacement}\right)$$

$$x(z) = r\cos\left[\frac{1}{c}\left(z \cancel{+} \text{displacement}\right)\right]$$

$$x(z) = r\cos\left[\frac{2\pi + \phi_{small} + \frac{8\pi}{6}}{2 \times 9770_{mm} \times \sqrt{1 - \frac{16}{1849}}}\left(z \cancel{+} \text{displacement}\right)\right]$$

But can't plot this $\rightarrow$ need parameter form.

$$x(t) = r\cos\left(t - \frac{\text{displacement}}{c}\right)$$

$$x(t) = r\cos\left(t - \frac{2\pi + \phi_{small} + \frac{8\pi}{6}}{2\times 9770_{nm}\times\sqrt{1-\frac{16}{1849}}} \cdot \text{displacement}\right)$$

units work ☺

But we are not given displacement, we are given angle.

How does the angle thro' which the helix is rotated relate to the phase constant? Are they the same? Yes.

$$\rightarrow x(z) = r\cos\left[\frac{z}{c} - \frac{\text{phase const}}{c}\right]$$
$$x(z) = r\cos\frac{1}{c}\left[z - \text{phase const}\right]$$

~~$x(z) = r\cos\frac{1}{c}$~~

$$x(z) = r\cos\left[\frac{z}{c} - \text{phase constant}\right]$$

$$x(z) = r\cos\left[z\left(\frac{2\pi+\phi_{small}+\frac{8\pi}{6}}{2\times 9770_{nm}\times\sqrt{1-\frac{15}{1849}}}\right) - \text{phase constant}\right]$$

I don't want $x(z)$ I want $x(t)$ but there is no way of getting c in to the eqn without making this substitution.

→ Do not have to! Leave c in $z=ct$ & just use phase constant → Edit all 3 equations together.

$$x(t) = r\cos(t)$$
$$y(t) = r\sin(t)$$
$$z(t) = ct$$

$$x(t) = r\cos(t + \text{phase constant})$$
$$y(t) = r\sin(t + \text{phase constant})$$
$$z(t) = \frac{2\times 9770_{nm}\times\sqrt{1-\frac{16}{1849}}}{2\pi + \phi_{small} + \frac{8\pi}{6}}\, t$$

But no place constant is an angle of t not z ??? so how do we calculate it???

$z = ct$

phase constant in z space = parameter phase constant $\times$ c

do you times it by c or not???

Judging by wave eqn - wave # is outside the brackets so I bet $x(z) = r\cos\frac{1}{c}[z - \text{phase const}_{in\ z}]$

$$r \cos\left(\frac{1}{c}\left[z - \text{phase const in } z\right]\right)$$

$$r \cos \frac{z}{c} - \frac{\text{phase const in } z}{c}$$

$$x(t) = r \cos\left[t - \frac{\text{phase const in } z}{c}\right]$$

$$y(t) = r \sin\left[t - \frac{\text{phase const in } z}{c}\right]$$

$$z(t) = ct$$

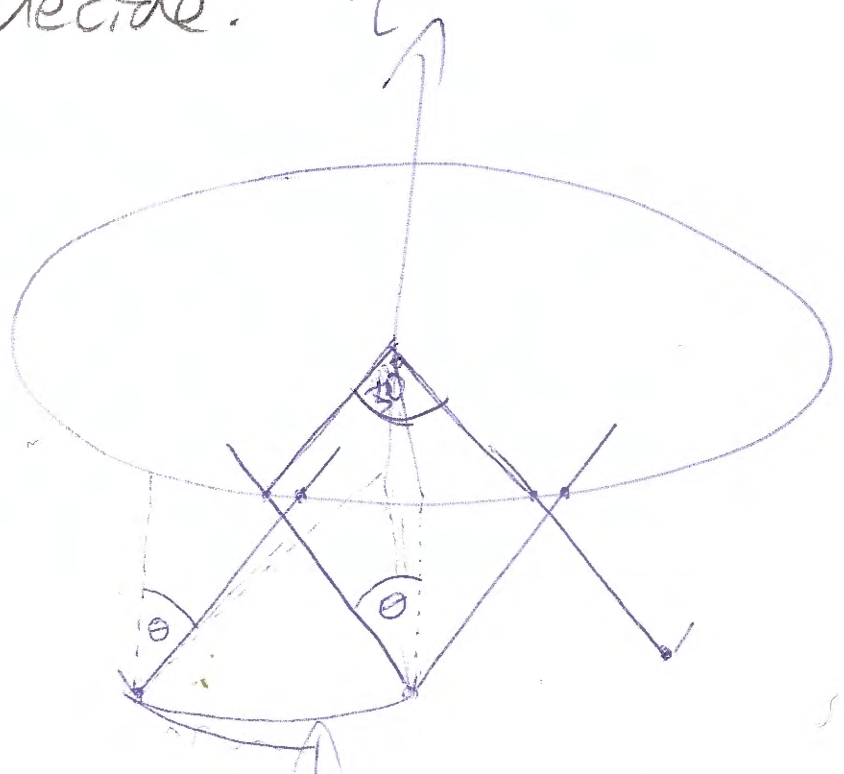
This is the real measured ~~distance~~ angle fun

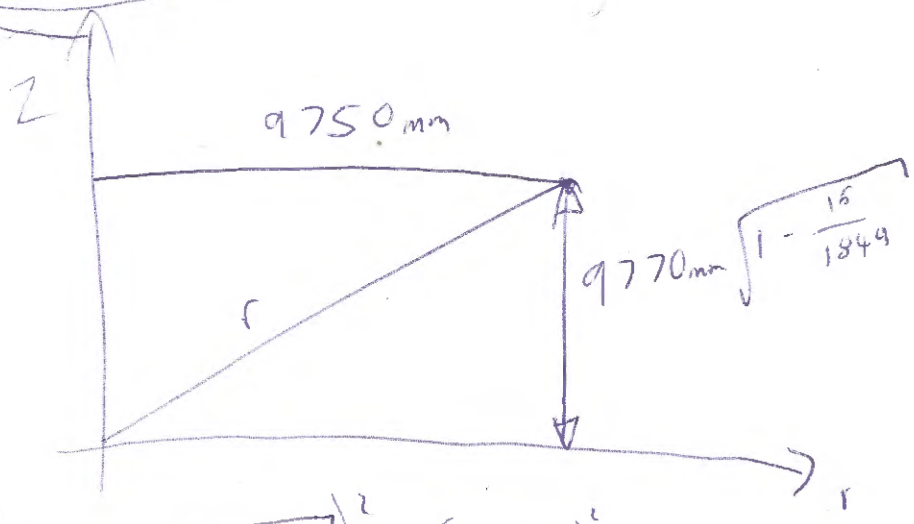
equiv

$$\boxed{\frac{\phi}{2\lambda c}}$$

Humph $\ddot{\frown}$

what if the stellorator and the tocomac are both non optimal, example of General Fusions 50 piston model is optimal? Only measurement and data collection accurate will decide.





$$r^2 = \left(9770\,\text{mm}\sqrt{1 - \frac{15}{1849}}\right)^2 + (9750\,\text{mm})^2$$

$$r = \sqrt{\left(9770\,\text{mm}\sqrt{1 - \frac{15}{1849}}\right)^2 + (9750\,\text{mm})^2}$$