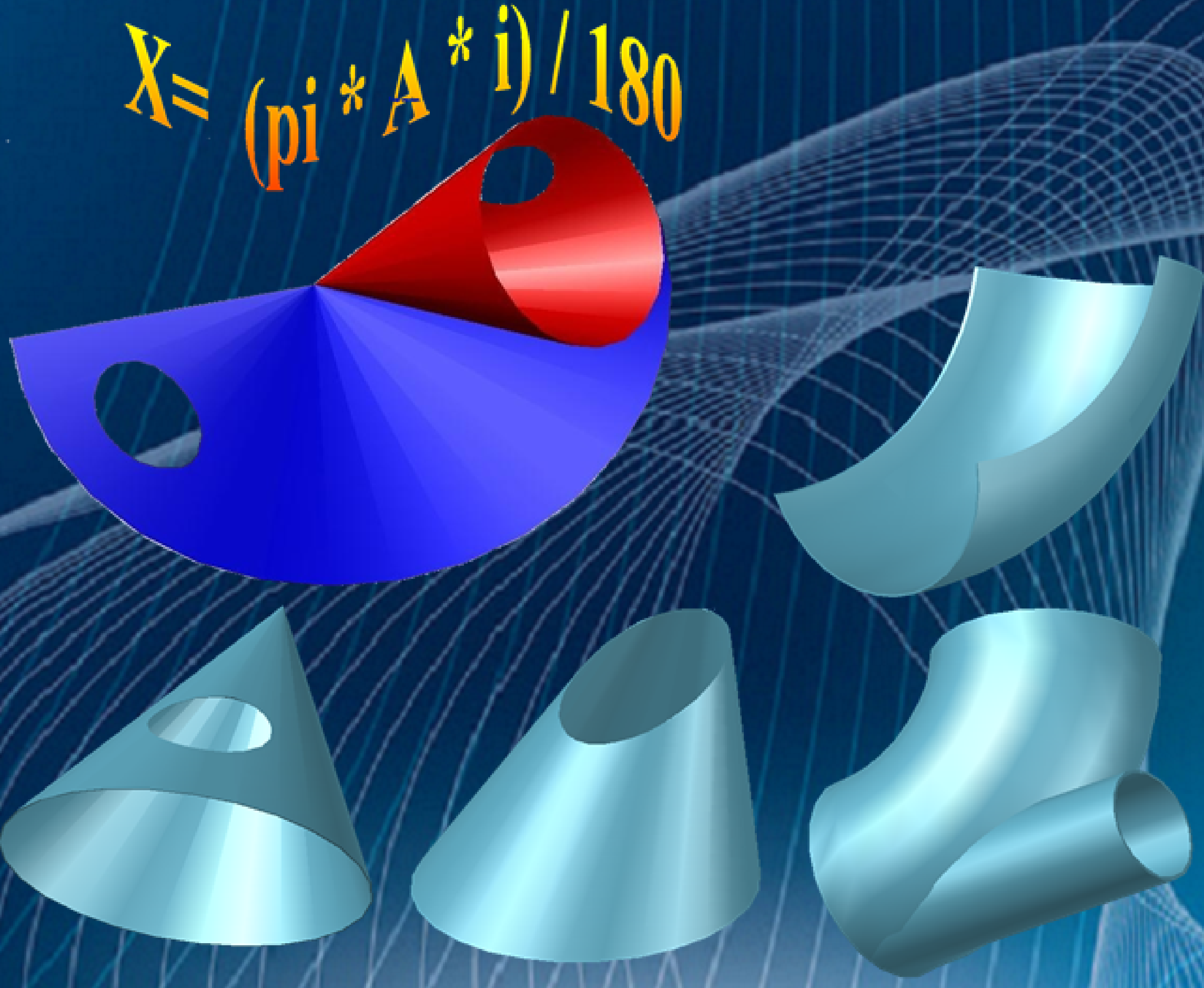
Development Engineering

Development of Surface of Objects

Applications by Mathematics Equations

First Edition



Hazem Albadry

DEVELOPMENT ENGINEERING

DEVELOPMENT OF SURFACE OF OBJECTS

Applications by Mathematics Equations

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Dedication

To whom shall i guide the way of life
to my dear Father
To whom satisfied me with her tenderness
to my tender mother
To whom i loved in all the meaning of love
to my beloved wife
To those who planted in all the meaning of a sweet life
to my beloved children
To those who advise me and support me after God Almighty in this world
to my dear brothers and sisters

Contents

FOREWORD

In industrial world, an engineer is frequently confronted with problems where the development of surfaces of an object has to be made to help him to go ahead with the design and manufacturing processes. For example, in sheet metal work, it plays a vital role, thus enabling a mechanic to cut proper size of the plate from the development and then to fold at proper places to form the desired objects, namely, boilers, boxes, buckets, packing boxes, chimneys, hoppers, air-conditioning ducts etc.

"**The development of surface of an object means the unrolling and unfolding of all surfaces of the object on a plane.**"
"If the surface of a solid is laid out on a plain surface, the shape thus obtained is called the development of that solid."

In other words, the development of a solid is the shape of a plain sheet that by proper folding could be converted into the shape of the concerned solid.

Importance of Development:

Knowledge of development is very useful in **sheet metal work**, **construction of storage vessels**, **chemical vessels**, **boilers**, and **chimneys**. Such vessels are manufactured from plates that are cut according to these developments and then properly bend into desired shaped. The joints are then **welded or riveted**.

Principle of Development:

Every line on the development should show the true length of the corresponding line on the surface which is developed.

Methods of Development:

(a) Parallel-line development

(b) Radial-line development

(c) Triangulation development

(d) Approximate development

Parallel-line Method:

It is used for developing prisms and single curved surfaces like cylinders, in which all the edges/generation of lateral surfaces are parallel in each other.

Radial-line Method:

It is employed for pyramids and single curved surfaces like cones in which the apex is taken as centre and the slant edge or generator as radius of its development.

Triangulation Method:

It is used for developing transition pieces.

Approximate Method:

It is employed for double curved surfaces like spheres, as they are theoretically not possible to develop. The surface of the sphere is developed by approximate method. When the surface is cut by a series of cutting planes, the cut surfaces is called a zone.

The new in this book is to rely on mathematical equations in the design of geometric shapes, which means the accuracy of the results and the speed of implementation and not to fall into the mistakes that will often be known after the manufacturing process, resulting in loss of cost and time.

In addition, an engineering program that gives digital and visual results has been done for all objects in this book.

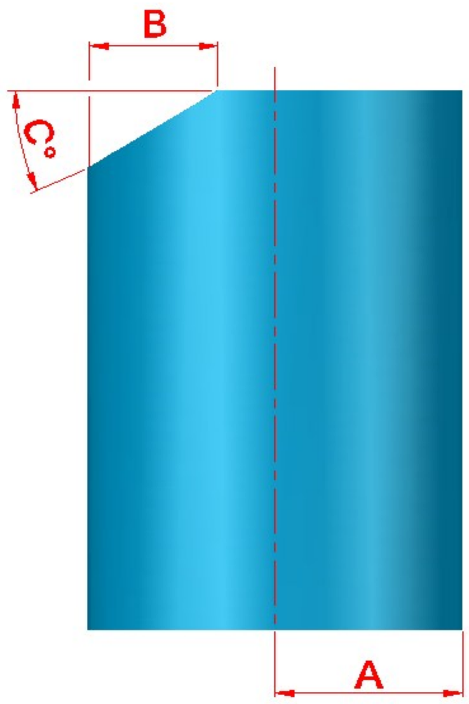
Hazem H. R.

Hazem Hameed Rashid Albadry

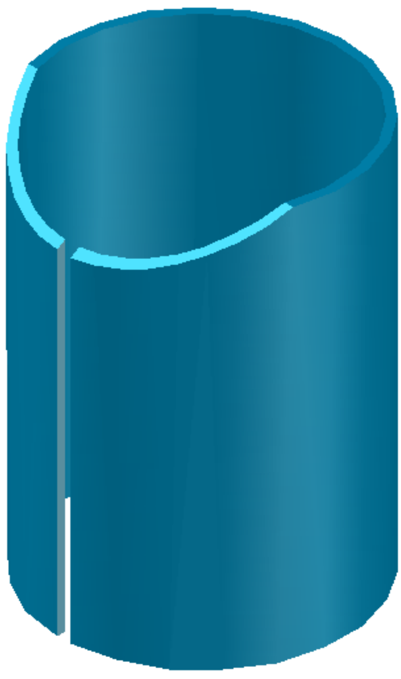
CHAPTER – 1

CYLINDER

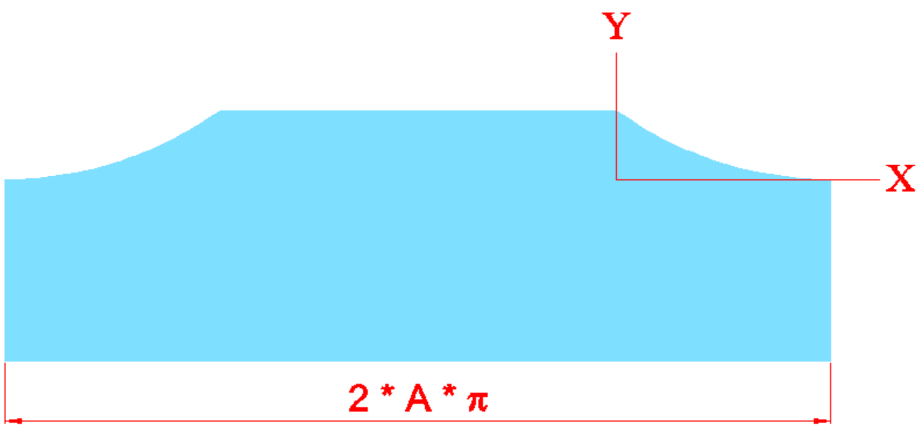
1-1 Cylinder cut
(In case B ≤ A)



Cylinder dimensions



Cylinder after rolling



Cylinder before rolling

$$s = 180 - \cos^{-1}(\frac{A-B}{A})$$

For i = s to 180

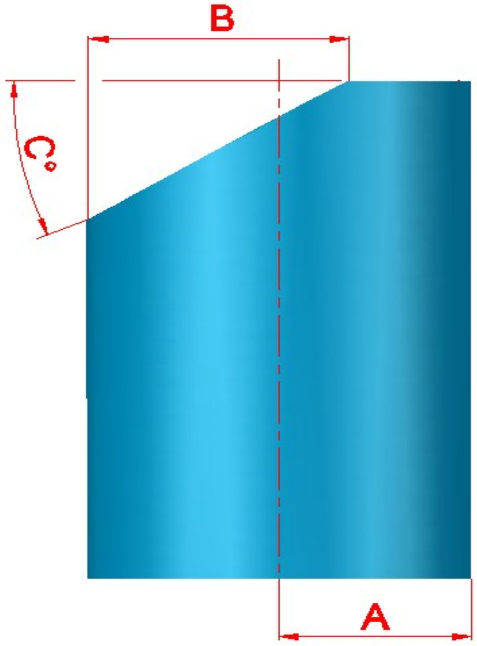
$$X = \frac{\pi * A * i}{180}$$

$$Y = \tan(C) * A * (1 - \cos(180 - i))$$

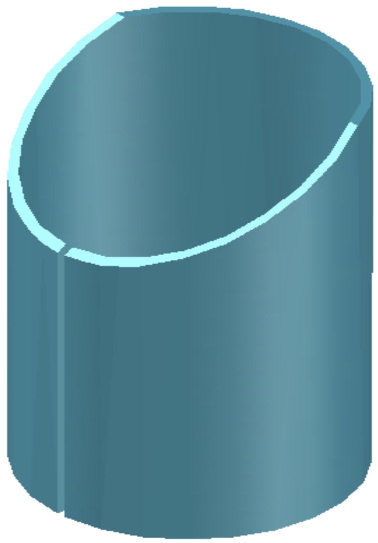
Notes:

- The length of cylinder is optional.
- The left curve is same as right curve.
- The steps of (i) are optionals.

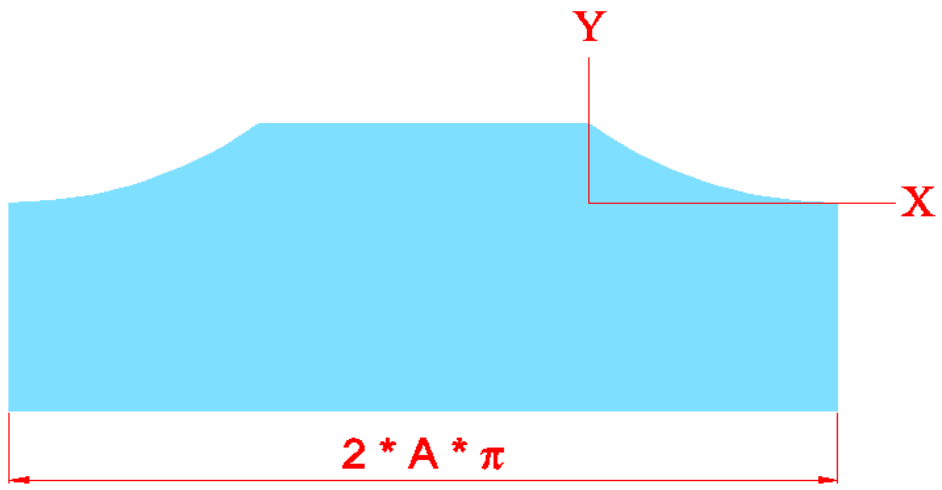
1-2 Cylinder cut
(In case B > A)



Cylinder dimensions



Cylinder after rolling



Cylinder before rolling

$$s = 180 - \cos^{-1}\left(\frac{B - A}{A}\right)$$

For i = s to 180

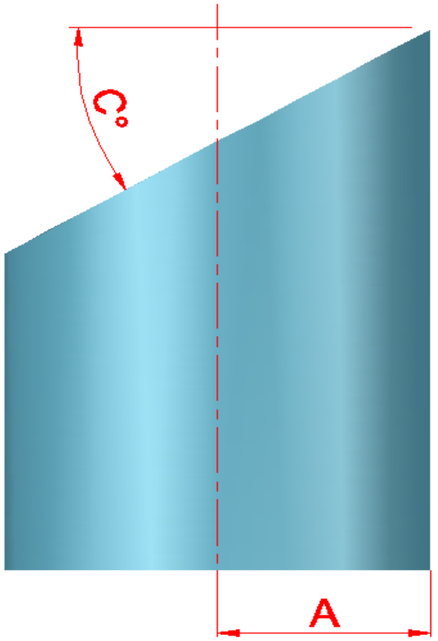
$$X = \frac{\pi * A * i}{180}$$

$$Y = \tan(C) * A * (1 + \cos i)$$

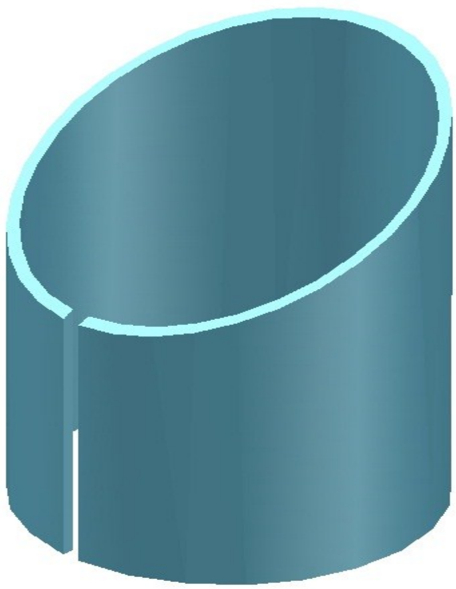
Notes:

- The length of cylinder is optional.
- The left curve is same as right curve.
- The steps of (i) are optionals.

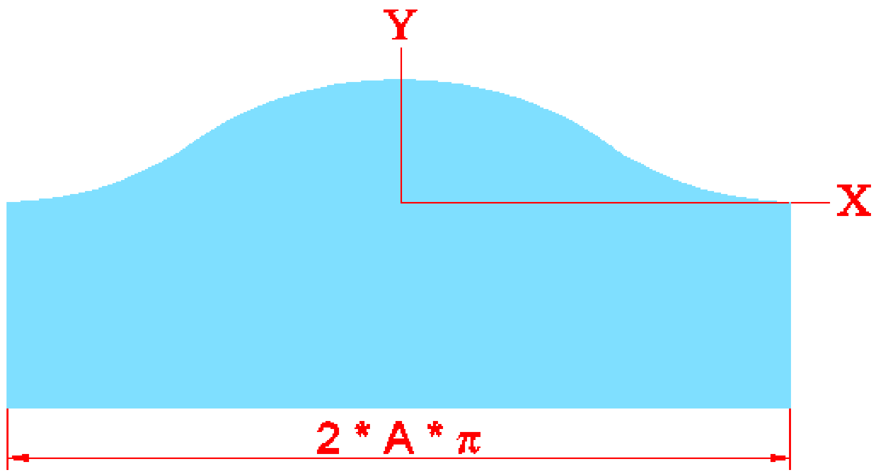
1-3 Cylinder cut
(In case full cut)



Cylinder dimensions



Cylinder after rolling



Cylinder before rolling

For i = 0 to 180

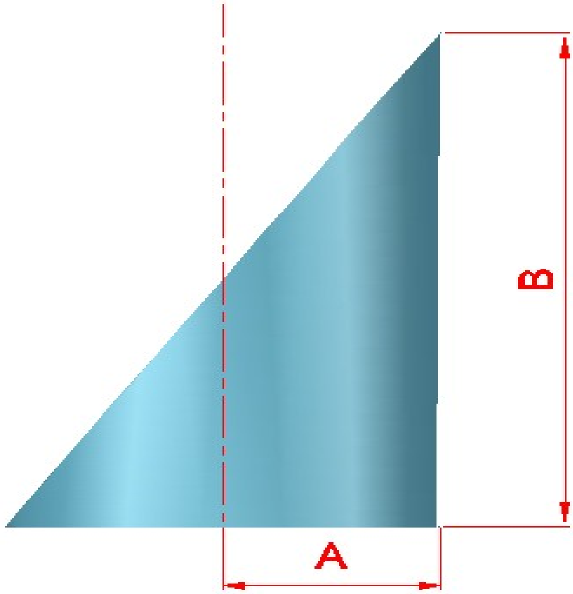
$$X = \frac{\pi * A * i}{180}$$

$$Y = \tan(C) * A * (1 + \cos i)$$

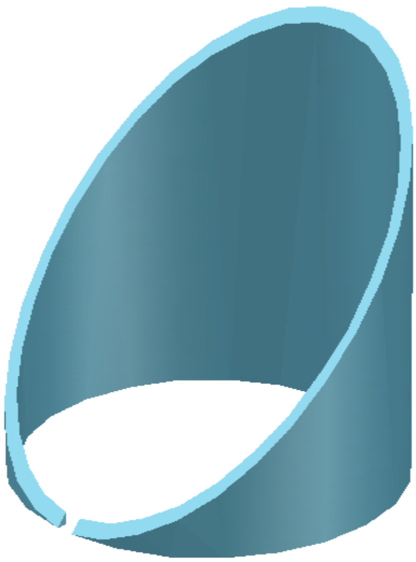
Notes:

- The length of cylinder is optional.
  The left curve is same as right curve.
- The steps of (i) are optionals.

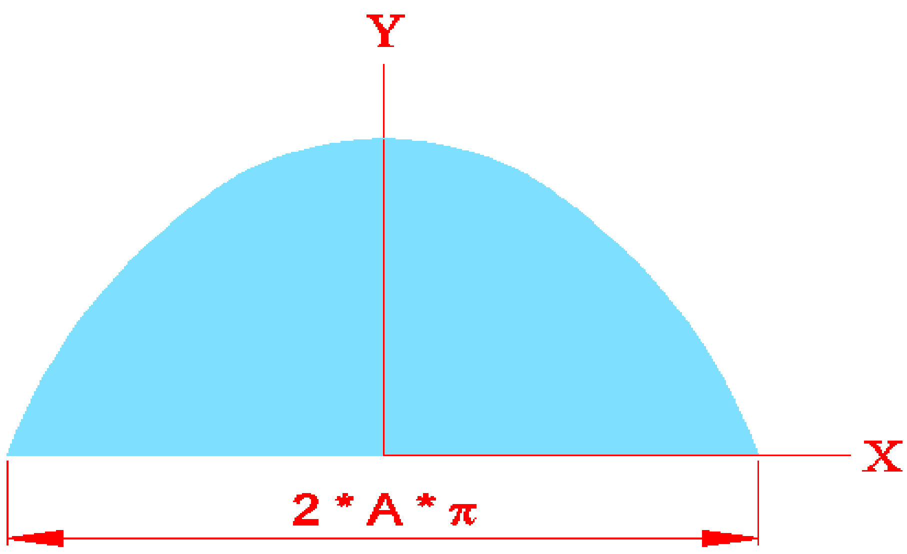
1-4 Cylinder cut
(In case full cut along)



Cylinder dimensions



Cylinder after rolling



Cylinder before rolling

For i = 0 to 90

$$X = \frac{\pi * A * i}{180}$$

$$Y = B * \cos i$$

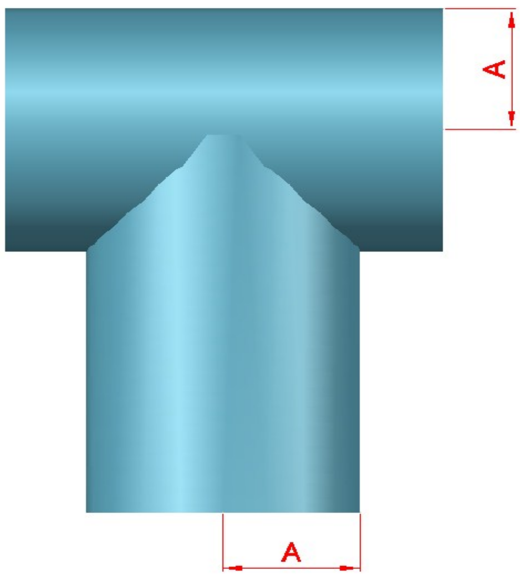
Notes:

- The length of cylinder is B.
- The left curve is same as right curve.
- The steps of (i) are optionals.

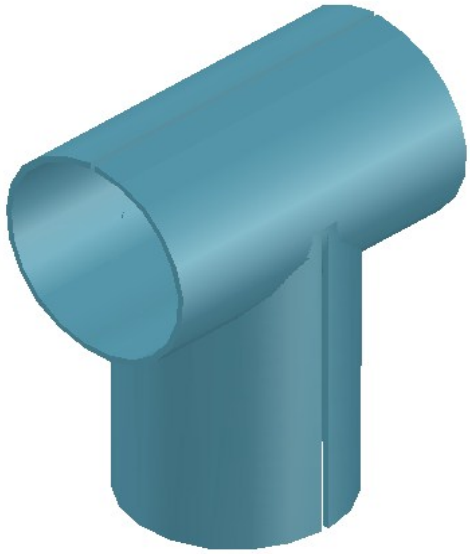
CHAPTER – 2

TWO CYLINDERS

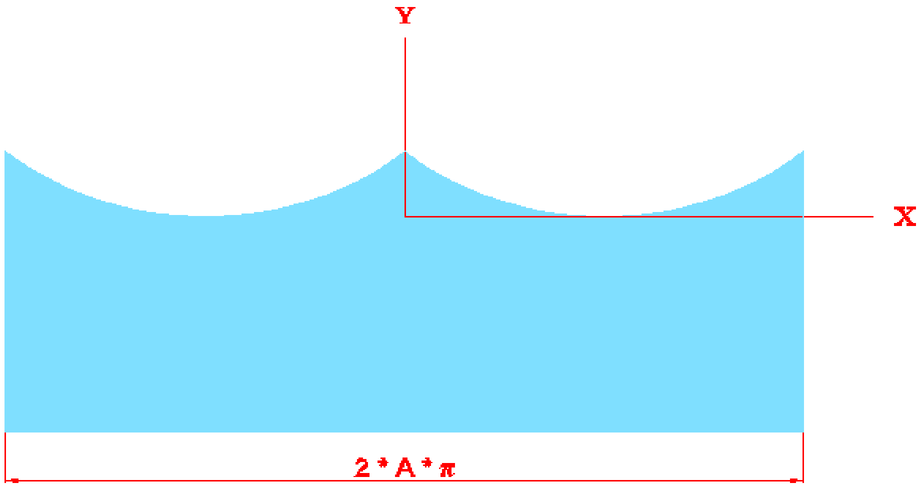
2-1 Two same cylinders orthogonals



Cylinders dimensions



Cylinders after rolling



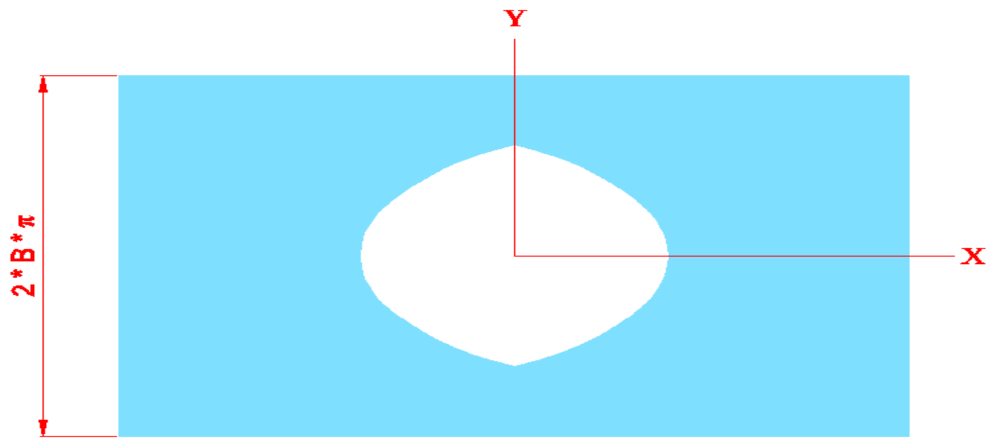
Vertical Cylinder before rolling

2-1-1 Vertical Cylinder

For i = 0 to 180

$$X = \frac{\pi * A * i}{180}$$

$$Y = A * (1 - \sin i)$$



Horizontal Cylinder before rolling

2-1-2 Horizontal Cylinder

For i = 0 to 90

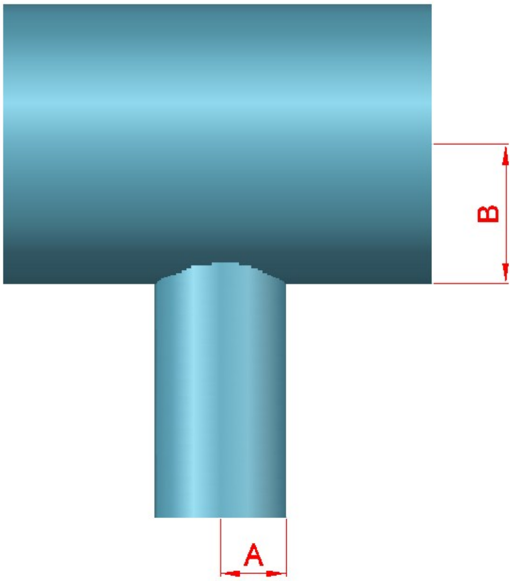
$$X = A * \cos i$$

$$Y = \frac{\pi * A * i}{180}$$

Notes:

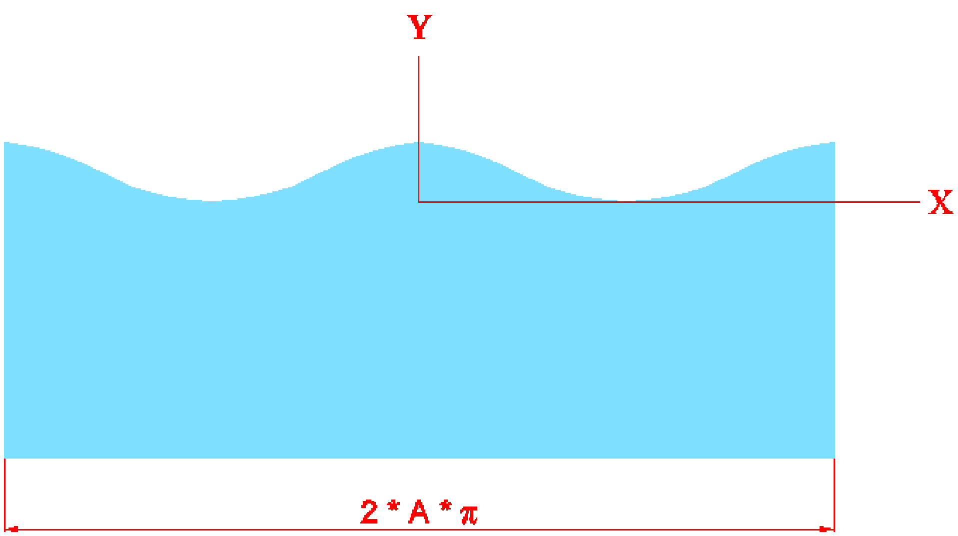
- The length of cylinder is optional.
- The left curve is same as right curve.
- The steps of (i) are optionals.

2-2 Two different cylinders orthogonals



Cylinders dimensions

Cylinders after rolling



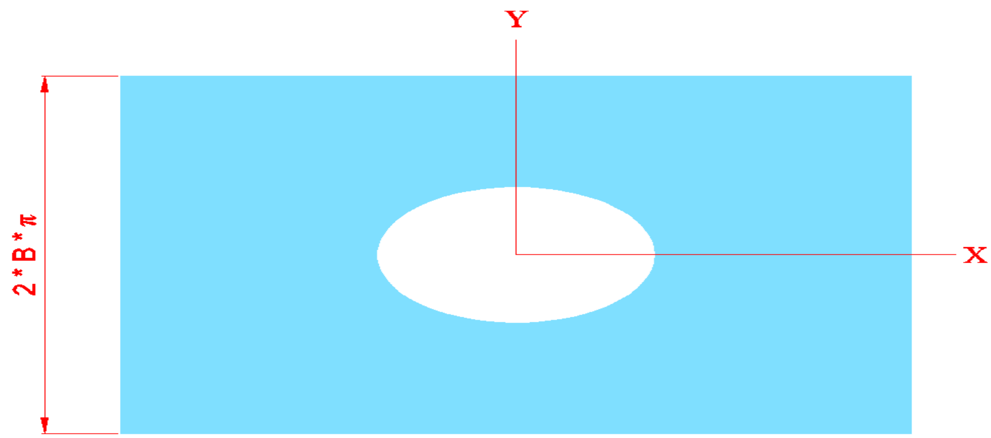
Vertical Cylinder before rolling

2-2-1 Vertical Cylinder

For i = 0 to 180

$$X = \frac{\pi * A * i}{180}$$

$$Y = B - \sqrt{B^2 - A^2 * (\text{Cos } i)^2}$$



Horizontal Cylinder before rolling

2-2-2 Horizontal Cylinder

For i = 0 to 90

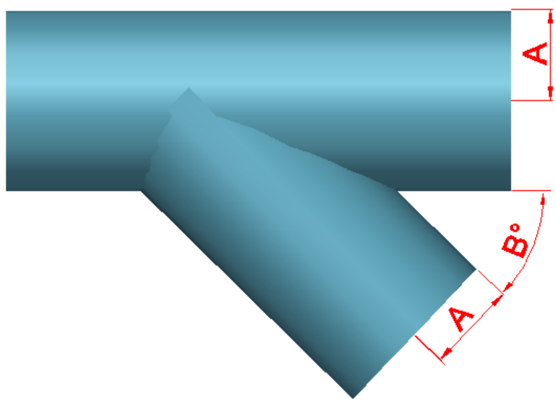
$$k = \sqrt{B^2 - A^2 * (\cos i)^2}$$

$$m = \tan^{-1}\left(\frac{A * \cos i}{k}\right) * \frac{\pi}{180}$$

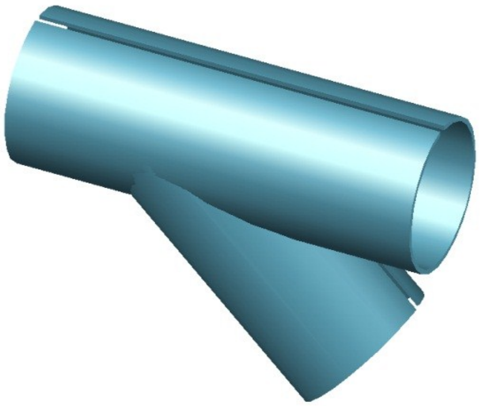
$$X = A * \sin i$$

$$Y = m * B$$

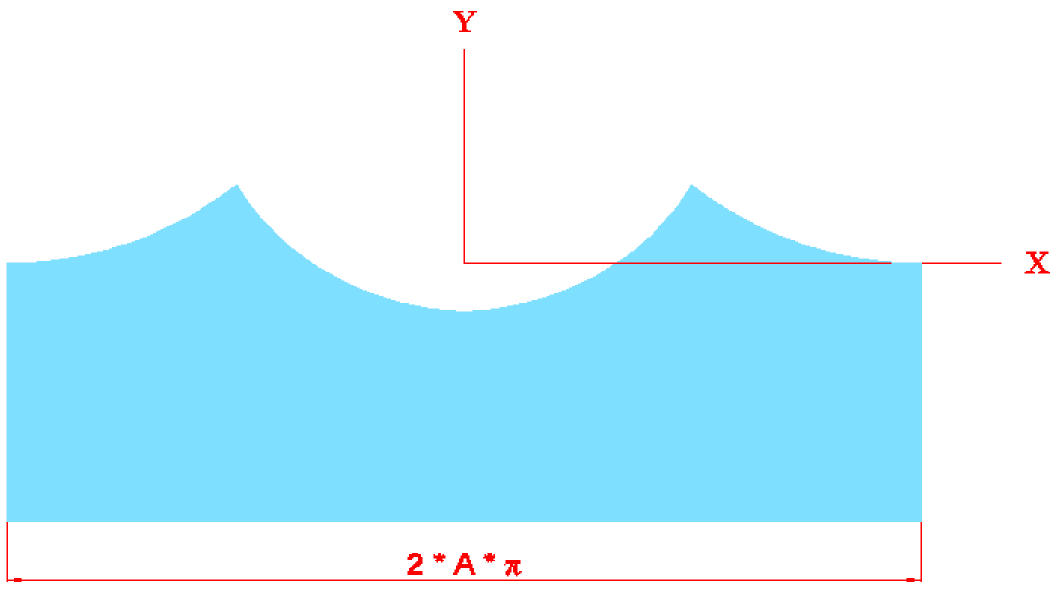
2-3 Two same cylinders not orthogonals



Cylinders dimensions



Cylinders after rolling



Diagonal Cylinder before rolling

2-3-1 Diagonal Cylinder

For i = 0 to 180

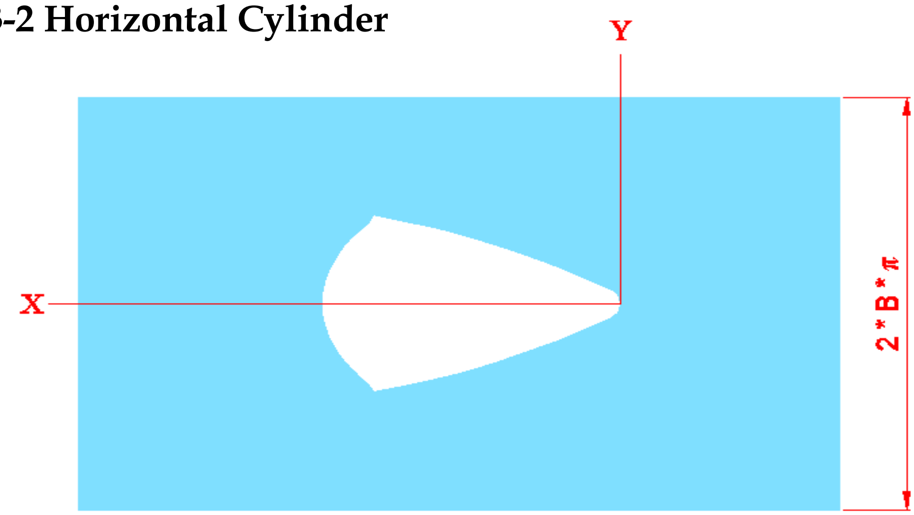
$$X = \frac{\pi * A * i}{180}$$

$$Y = A * [\{\frac{1 - Abs(Cos\ i)}{Sin\ B}\} + \{\frac{1 + Cos\ i}{tan\ B}\}]$$

Notes:

- The length of cylinder is optional.
- The left curve is same as right curve.
- The steps of (i) are optionals.

2-3-2 Horizontal Cylinder



Horizontal Cylinder before rolling

$$Y = \frac{\pi * A * i}{180}$$

1- The top right curve formula:
For i = 0 to 90 step R

$$X = -\frac{A * (1 - \cos i) * (1 + \cos B)}{\sin B}$$

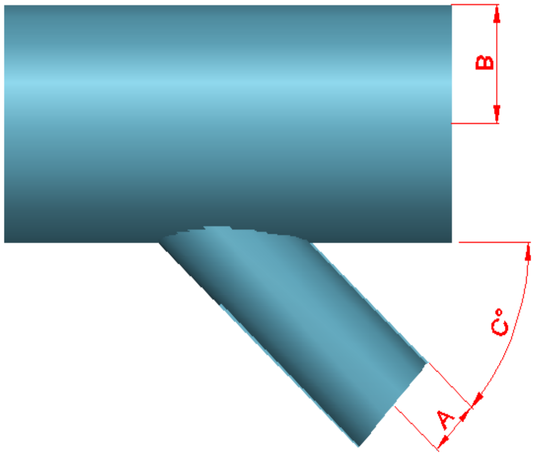
2- The top left curve formula:
For i = (90 - R) to 0 step -R

$$X = -\frac{2 * A - A * (1 - \cos i) * (1 - \cos B)}{\sin B}$$

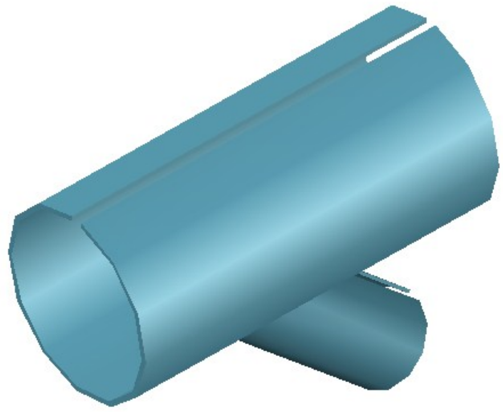
Notes:

- The length of cylinder is optional.
- The down curve is same as top curve.
- The steps (R) are optionals.

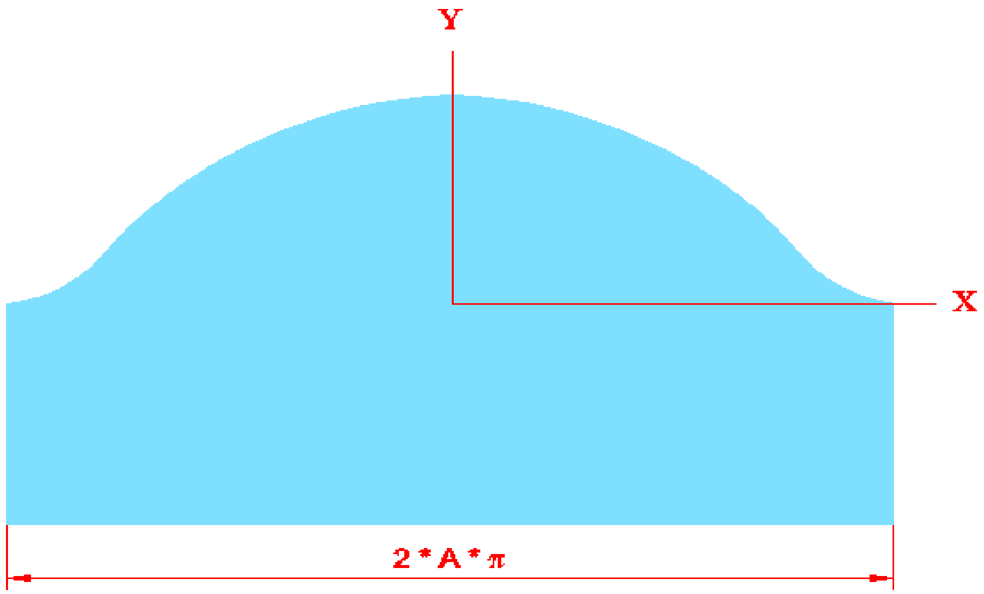
2-4 Two different cylinders not orthogonals



Cylinders dimensions



Cylinders after rolling



Diagonal Cylinder before rolling

2-4-1 Diagonal Cylinder

For i = 0 to 180

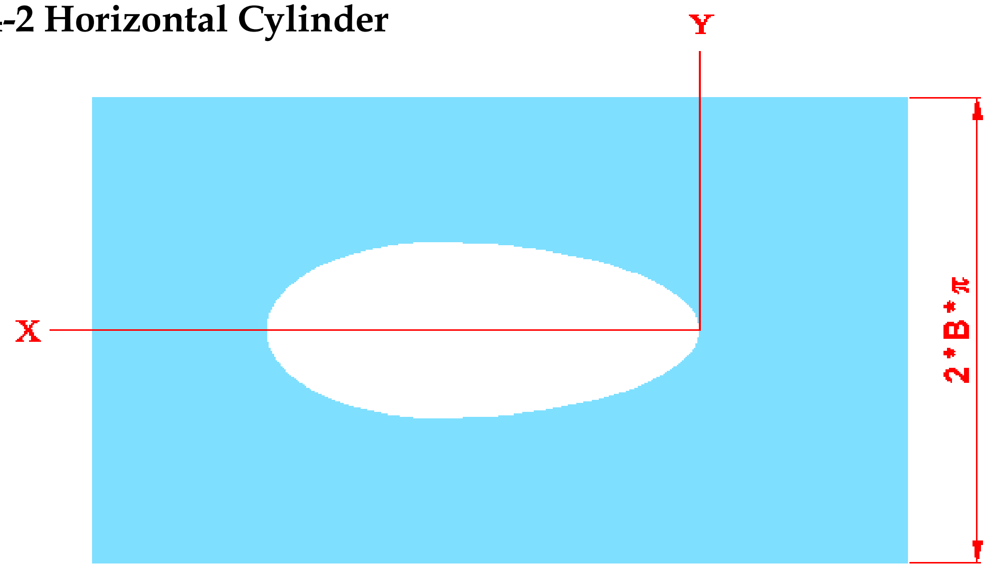
$$X = \frac{\pi * A * i}{180}$$

$$Y = \frac{B - \sqrt{B^2 - A^2 * (\sin i)^2}}{\sin C} + \frac{A * (1 + \cos i)}{\tan C}$$

Notes:

- The length of cylinder is optional.
- The left curve is same as right curve.
- The steps of (i) are optionals.

2-4-2 Horizontal Cylinder



Horizontal Cylinder before rolling

1- The top right curve formulas:

For i = 0 to 90 step R

$$m = B - \sqrt{B^2 - A^2 * (\sin i)^2}$$

$$X = -\frac{A * (1 - \text{Cos } i) * \cos(C) + m}{\tan C} + A * \sin(C) * (1 - \cos i)$$

$$Y = \frac{B * \pi}{180} * \tan^{-1}\left(\frac{A * \sin i}{\sqrt{B^2 - A^2 * (\sin i)^2}}\right)$$

Continue 2-4-2 Horizontal Cylinder

2- The top left curve formulas:

For i = (90 – R) to 0 step -R

$$m = B - \sqrt{B^2 - A^2 * (\sin i)^2}$$

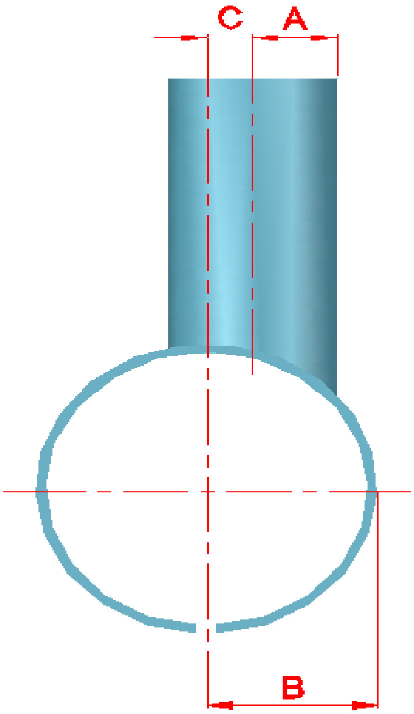
$$\mathbf{X = \frac{1}{\sin C} * \{2 * A - A * (1 - \cos i) + m * \cos C\}}$$

$$\mathbf{Y = B * \tan^{-1}\left(\frac{A * \sin i}{\sqrt{B^2 - A^2 * (\sin i)^2}}\right)}$$

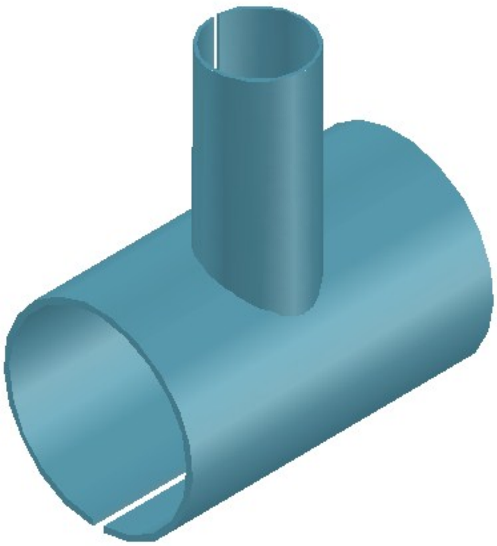
Notes:

- The length of cylinder is optional.
- The upper curve is same as lower curve.
- The steps (R) are optionals.

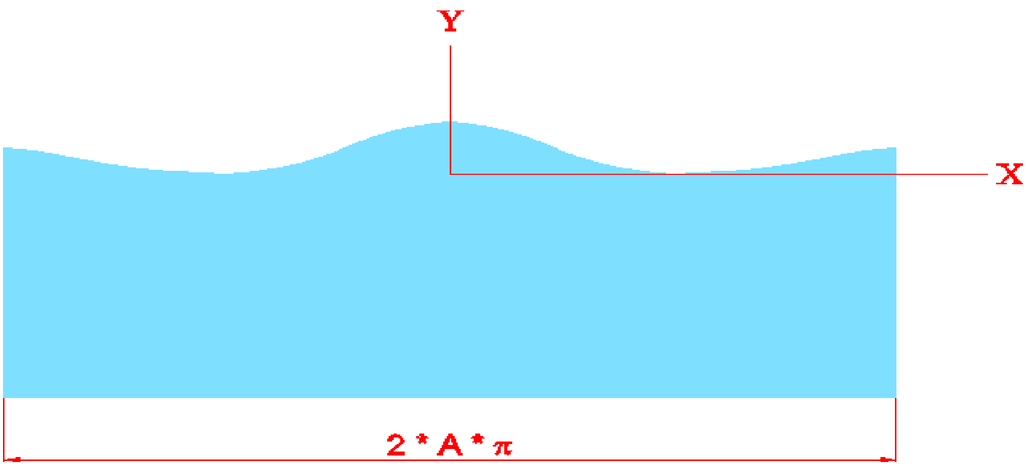
2-5 Two different cylinders orthogonals with shifting



Cylinders dimensions



Cylinders after rolling



Vertical Cylinder before rolling

2-5-1 Vertical Cylinder

For i = 0 to 180

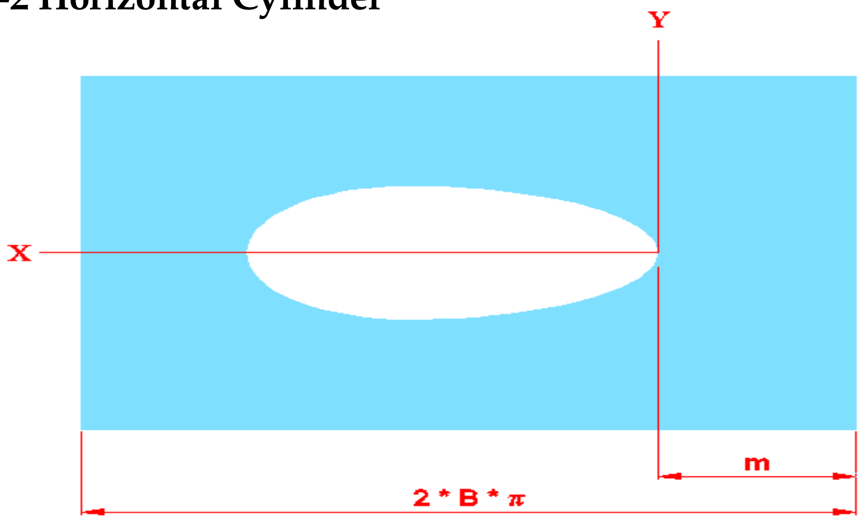
$$X = \frac{\pi * A * i}{180}$$

$$Y = B - \sqrt{B^2 - (A * \cos(i) + C)^2}$$

Notes:

- The length of cylinder is optional.
- The left curve is same as right curve.
- The steps of (i) are optionals.

2-5-2 Horizontal Cylinder



Horizontal Cylinderb efore rolling

For i = 0 to 180

$$f = \tan^{-1}\left(\frac{A + C}{\sqrt{B^2 - (A + C)^2}}\right)$$

$$k = \tan^{-1}\left(\frac{A * \cos(i) + C}{\sqrt{B^2 - (A * \cos(i) + C)^2}}\right)$$

$$m = B * \tan^{-1}\left(\frac{\sqrt{B^2 - (A + C)^2}}{A + C}\right)$$

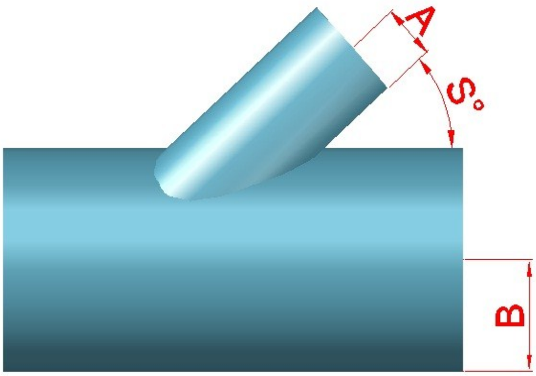
$$X = \frac{\pi * B * (f - k)}{180}$$

$$Y = A * \sin i$$

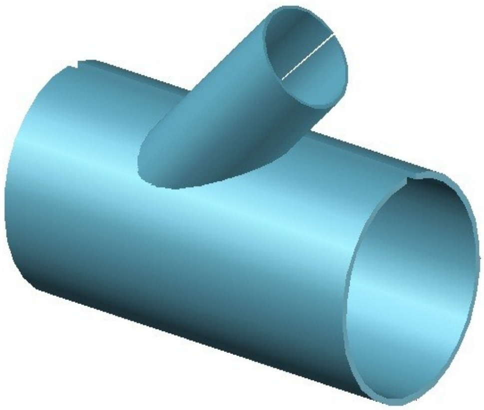
Notes:

- The length of cylinder is optional.
- The lower curve is same as upper curve.
- The steps of (i) are optionals.

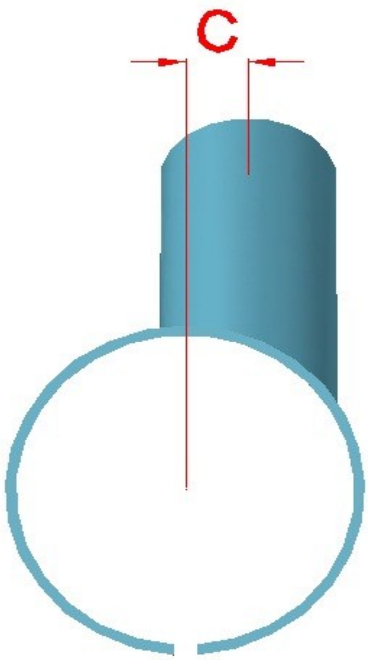
2-6 Two different cylinders non orthogonals with shifting



Cylinders dimensions

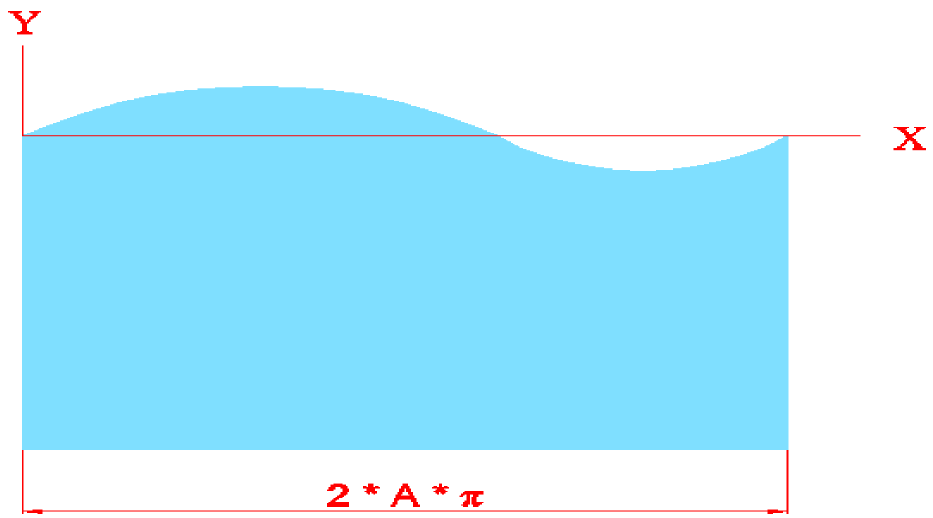


Cylinders after rolling



Cylinders dimensions

2-6-1 Diagonal Cylinder



Diagonal Cylinder before rolling

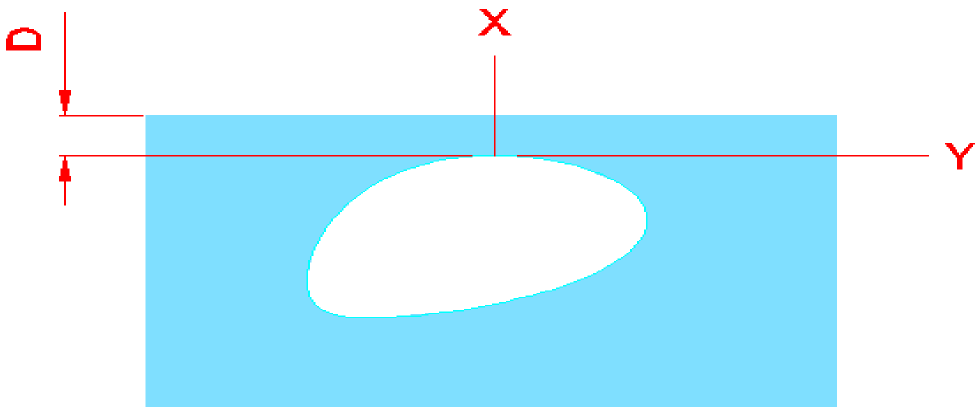
For i = 0 to 360

$$f = \sqrt{B^2 - (C - A)^2} - B * \cos S$$

$$X = \frac{\pi * A * i}{180}$$

$$Y = \frac{f}{\tan S} + \frac{A * \sin i}{\sin S}$$

2-6-2 Horizontal Cylinder



Big Cylinder before rolling

For i = 0 to 360

$$k = \tan^{-1}\left(\frac{C-A}{\sqrt{B^2-(C-A)^2}}\right)$$

$$t = \tan^{-1}\left(\frac{C-A*\cos(i)}{\sqrt{B^2-(C-A*\cos(i))^2}}\right)$$

$$f = \sqrt{B^2 - (C - A)^2} - B * \cos t$$

$$D = \frac{\pi * B * k}{180}$$

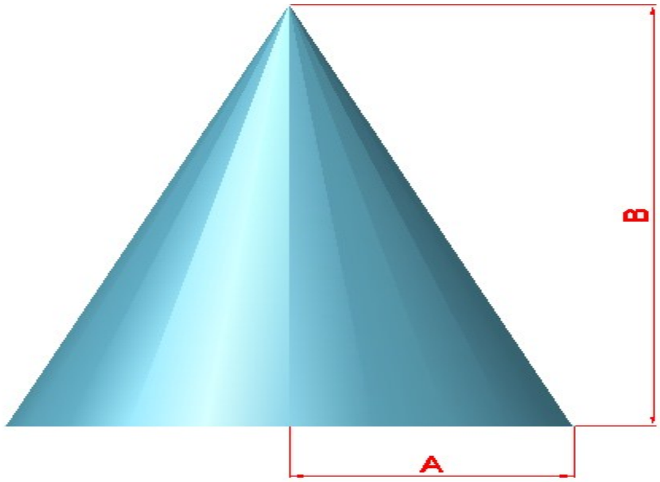
$$\mathbf{X = \frac{-f}{\tan S} - \frac{A * \sin i}{\sin S}}$$

$$\mathbf{Y = \frac{-\pi * b * (t - k)}{180}}$$

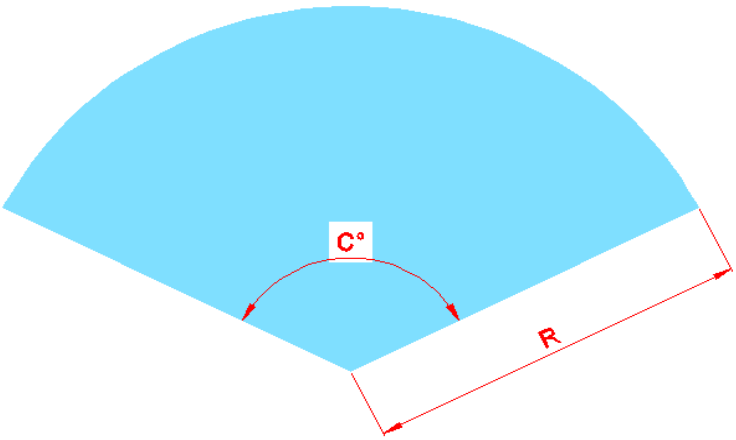
CHAPTER – 3

CONES

3-1 Right Circular Cone



Cone after rolling

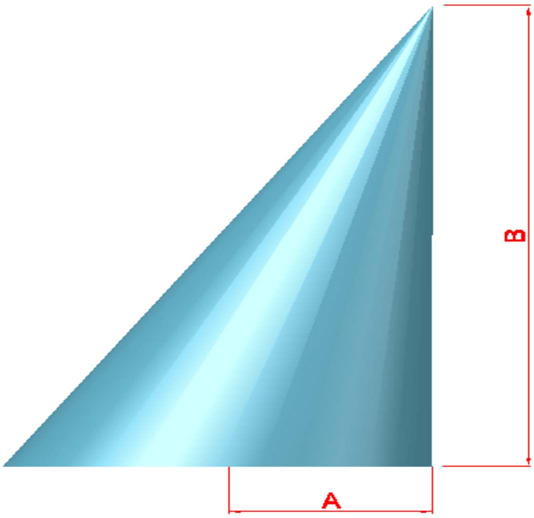


Cone before rolling

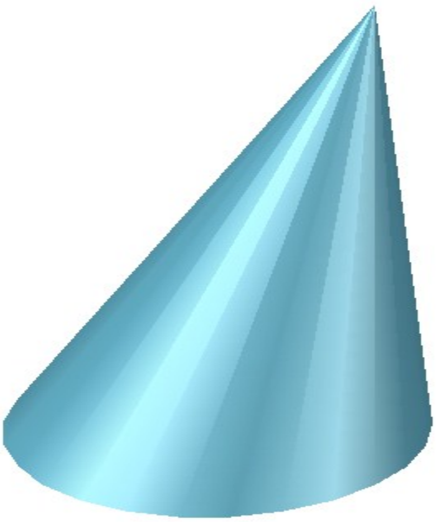
$$R = \sqrt{A^2 + B^2}$$

$$C = \frac{360 * A}{\sqrt{A^2 + B^2}}$$

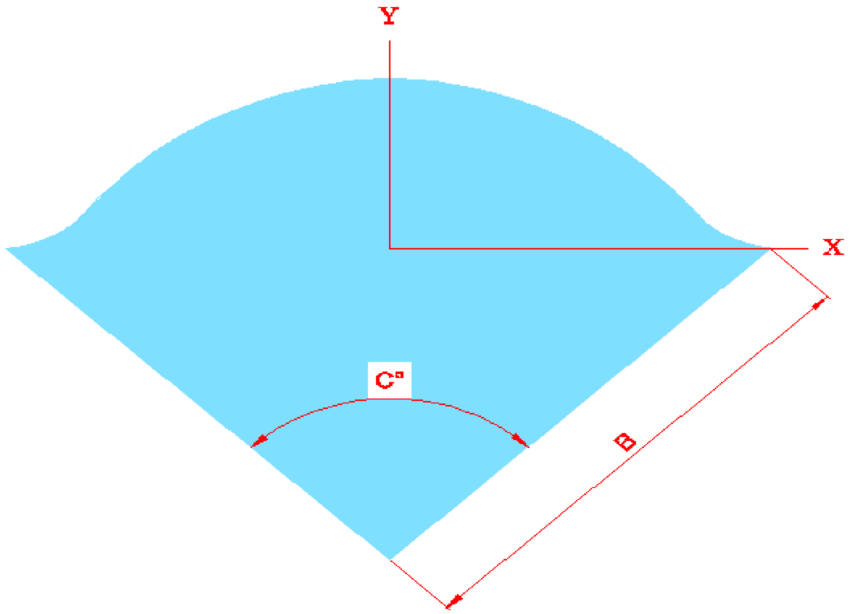
3-2 Oblique Cone



Cone dimensions



Cone after rolling



Cone before rolling

Continue 3-2

For i = 0 to 180 step s

$$k = \sqrt{B^2 + 4 * A^2 * (\cos\frac{i}{2})^2}$$

$$m = \sqrt{B^2 + 4 * A^2 * (\cos\frac{i}{2} + \frac{s}{2})^2}$$

$$z = k^2 + m^2 - 4 * A^2 * (\sin\frac{s}{2})^2$$

$$t = \tan^{-1}(\frac{\sqrt{4 * k^2 * m^2 - z^2}}{z})$$

$$f = \sum t$$

$$C^\circ = 2 * (f - t)$$

For w = 0 to 180 step s

$$k = \sqrt{B^2 + 4 * A^2 * (\cos\frac{w}{2})^2}$$

$$m = \sqrt{B^2 + 4 * A^2 * (\cos\frac{w}{2} + \frac{s}{2})^2}$$

$$z = k^2 + m^2 - 4 * A^2 * (\sin\frac{s}{2})^2$$

Continue 3-2

$$tt = \tan^{-1}\left(\frac{\sqrt{4 * k^2 * m^2 - z^2}}{z}\right)$$

$$ff = \sum tt$$

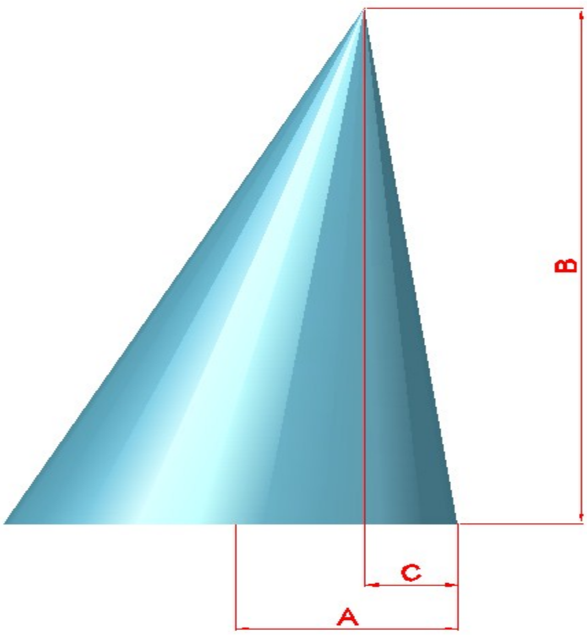
X = k * Sin(ff - tt)

Y = k * Cos(ff - tt) - B * Cos(f - t)

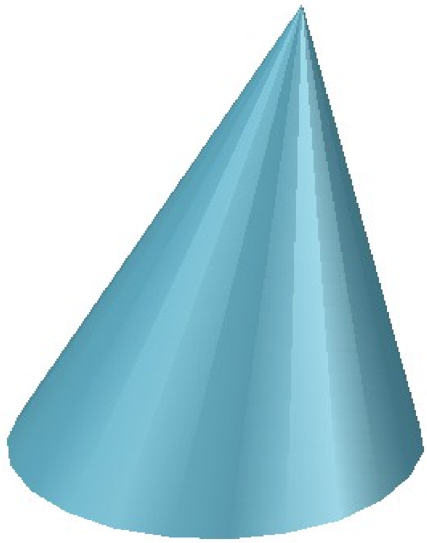
Notes:

- The values (f) and (t) in the last equation are when i = 180.
- The left curve is same as right curve.
- The steps of (i) and (w) are sames and optionals.

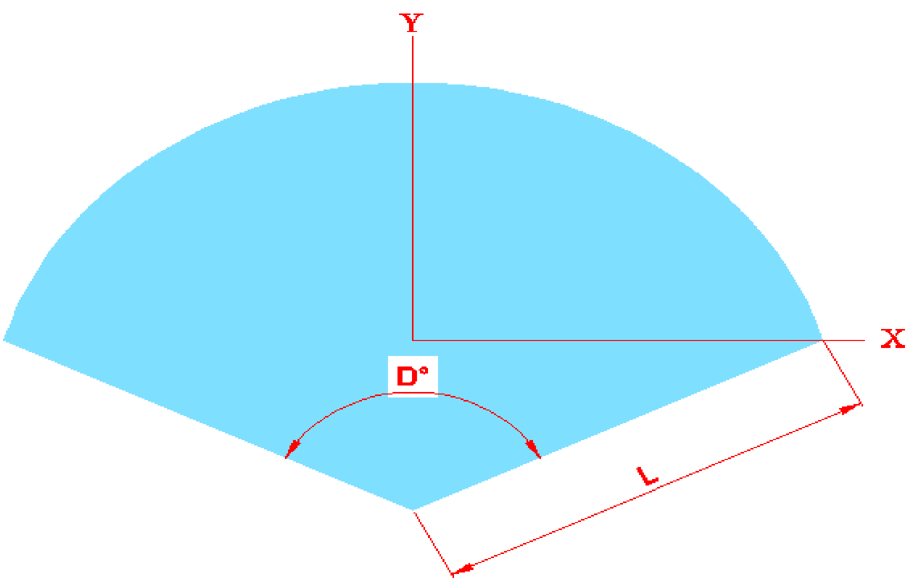
3-3 Scalene Cone



Cone dimensions



Cone after rolling



Cone before rolling

Continue 3-3

For i = 0 to 180 step s

$$k = \sqrt{B^2 + A^2 * (\sin i)^2 + (A * \cos(i) + A - C)^2}$$

$$m = \sqrt{B^2 + A^2 * (\sin(i + s))^2 + (A * \cos(i + s) + A - C)^2}$$

$$z = k^2 + m^2 - 4 * A^2 * (\sin\frac{s}{2})^2$$

$$t = \tan^{-1}\left(\frac{\sqrt{4 * k^2 * m^2 - z^2}}{z}\right)$$

$$f = \sum t$$

$$L = \sqrt{B^2 + C^2}$$

$$D^\circ = 2 * (f - t)$$

For w = 0 to 180 step s

$$k = \sqrt{B^2 + A^2 * (\sin w)^2 + (A * \cos(w) + A - C)^2}$$

$$m = \sqrt{B^2 + A^2 * (\sin(w + s))^2 + (A * \cos(i + s) + A - C)^2}$$

Continue 3-3

$$z = k^2 + m^2 - 4 * A^2 * (\sin\frac{s}{2})^2$$

$$tt = \tan^{-1}(\frac{\sqrt{4 * k^2 * m^2 - z^2}}{z})$$

$$ff = \sum tt$$

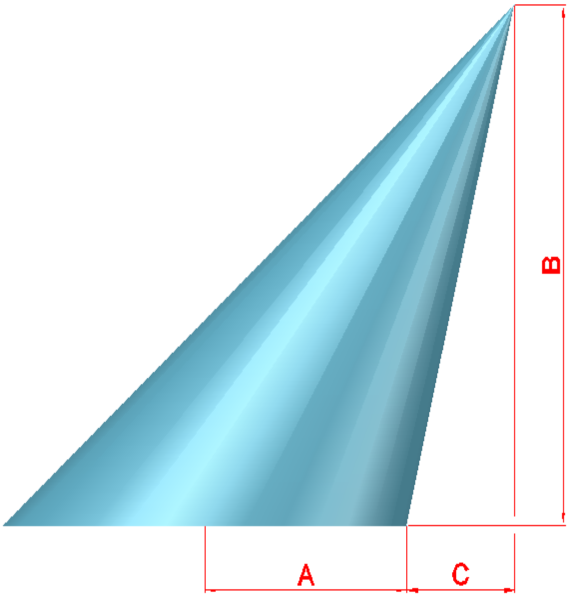
$$\mathbf{X = k * Sin(ff - tt)}$$

$$\mathbf{Y = k * Cos(ff - tt) - \sqrt{B^2 + C^2} * Cos(f - t)}$$

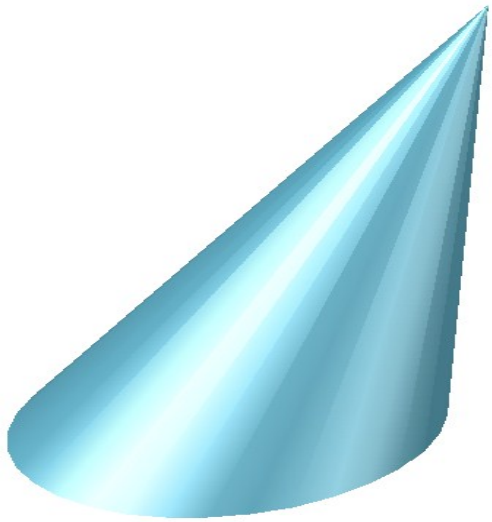
Notes:

- The values (f) and (t) in the last equation are when i = 180.
- The left curve is same as right curve.
- The steps of (i) and (w) are sames and optionals.

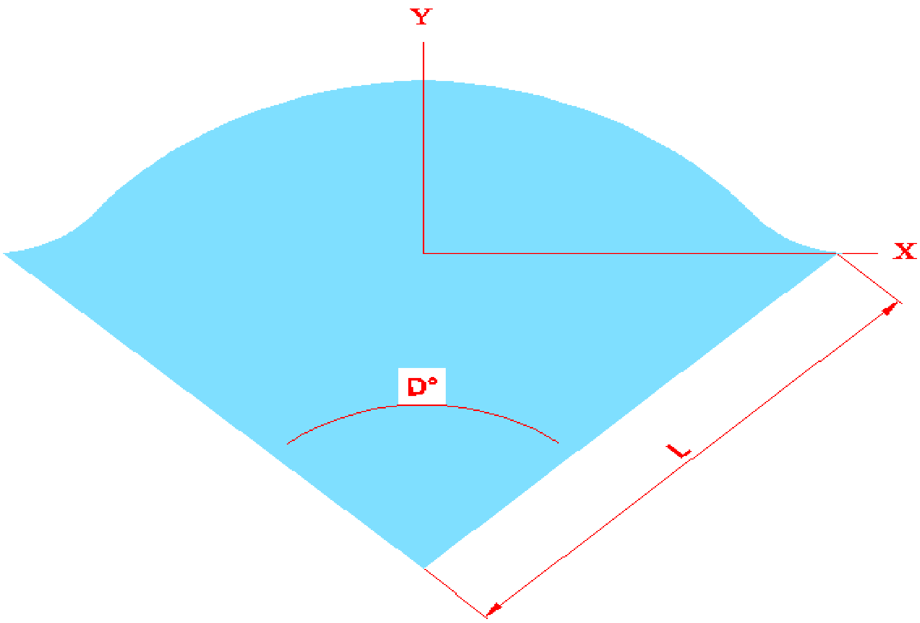
3-4 Obtuse Cone



Cone dimensions



Cone after rolling



Cone before rolling

Continue 3-4

For i = 0 to 180 step s

$$k = \sqrt{B^2 + A^2 * (\sin i)^2 + (A * \cos(i) + A + C)^2}$$

$$m = \sqrt{B^2 + A^2 * (\sin(i + s))^2 + (A * \cos(i + s) + A + C)^2}$$

$$z = k^2 + m^2 - 4 * A^2 * (\sin \frac{s}{2})^2$$

$$t = \tan^{-1}(\frac{\sqrt{4 * k^2 * m^2 - z^2}}{z})$$

$$f = \sum t$$

$$L = \sqrt{b^2 + c^2}$$

$$D^\circ = 2 * (f - t)$$

For w = 0 to 180 step s

$$k = \sqrt{B^2 + A * (\sin w)^2 + (A * \cos(w) + A + C)^2}$$

$$m = \sqrt{B^2 + A^2 * (\sin(w + s))^2 + (A * \cos(w + s) + A + C)^2}$$

$$z = k^2 + m^2 - 4 * A^2 * (\sin \frac{s}{2})^2$$

Continue 3-4

$$tt = \tan^{-1}\left(\frac{\sqrt{4 * k^2 * m^2 - z^2}}{z}\right)$$

$$ff = \sum tt$$

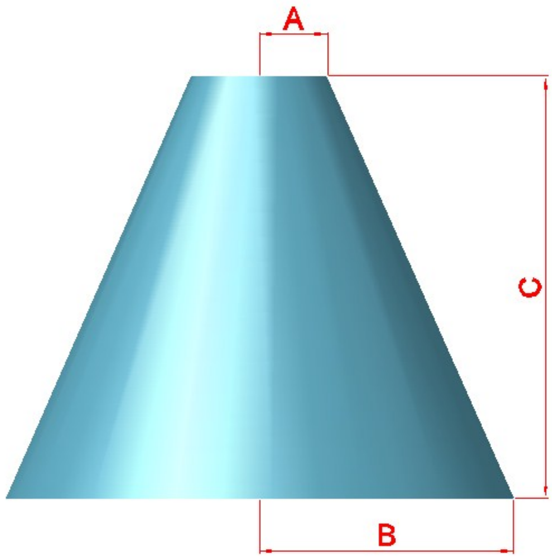
$$\mathbf{X = k * Sin(f - t)}$$

$$\mathbf{Y = k * Cos(ff - tt) - \sqrt{B^2 + C^2} * Cos(f - t)}$$

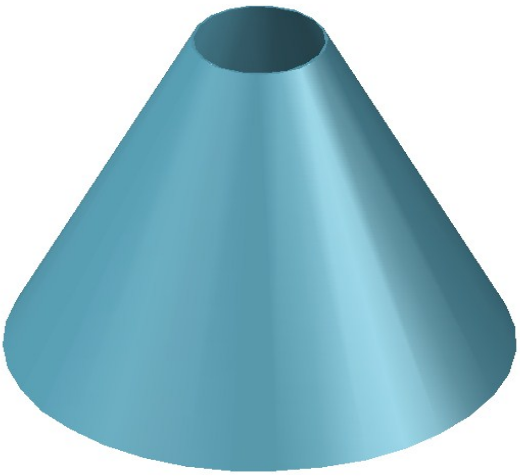
Notes:

- The values (f) and (t) in the last equation are when i = 180.
- The left curve is same as right curve.
- The steps of (i) and (w) are sames and optionals.

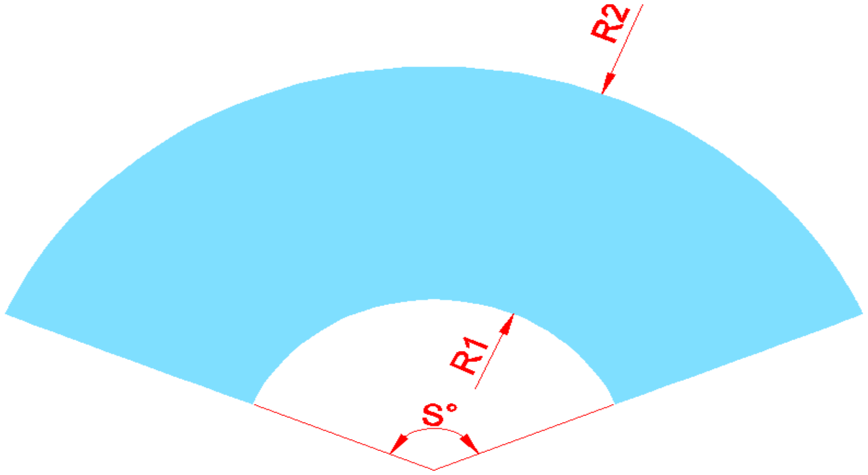
3-5 Truncated Cone



Dimensions



After rolling



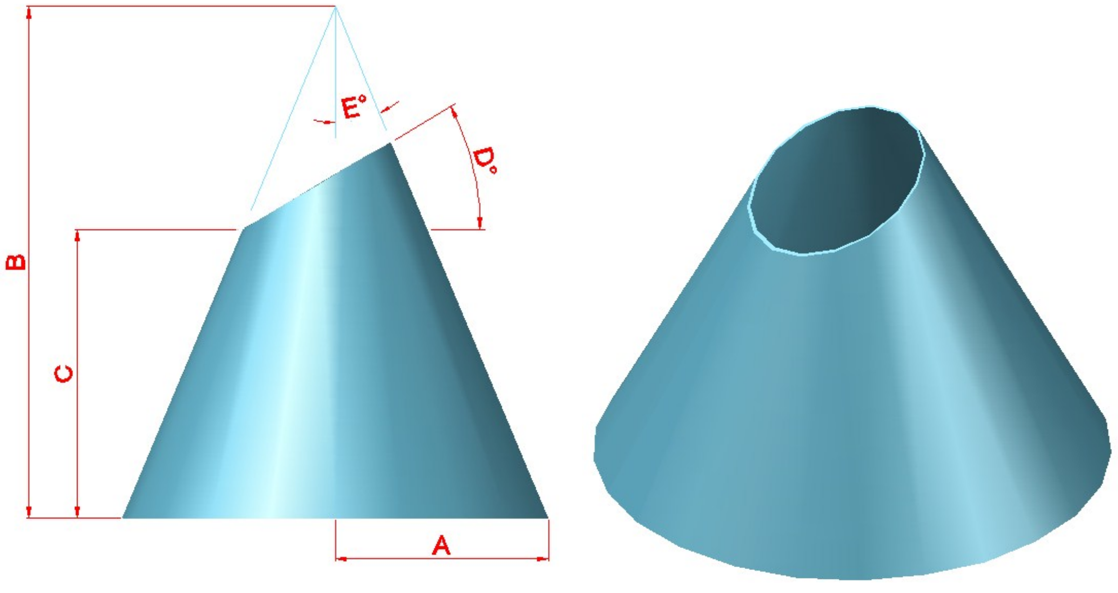
Before rolling

$$R1 = \sqrt{\left(\frac{A * C}{(B-A)}\right)^2 + A^2}$$

$$R2 = \sqrt{\left(\frac{B * C}{(B-A)}\right)^2 + B^2}$$

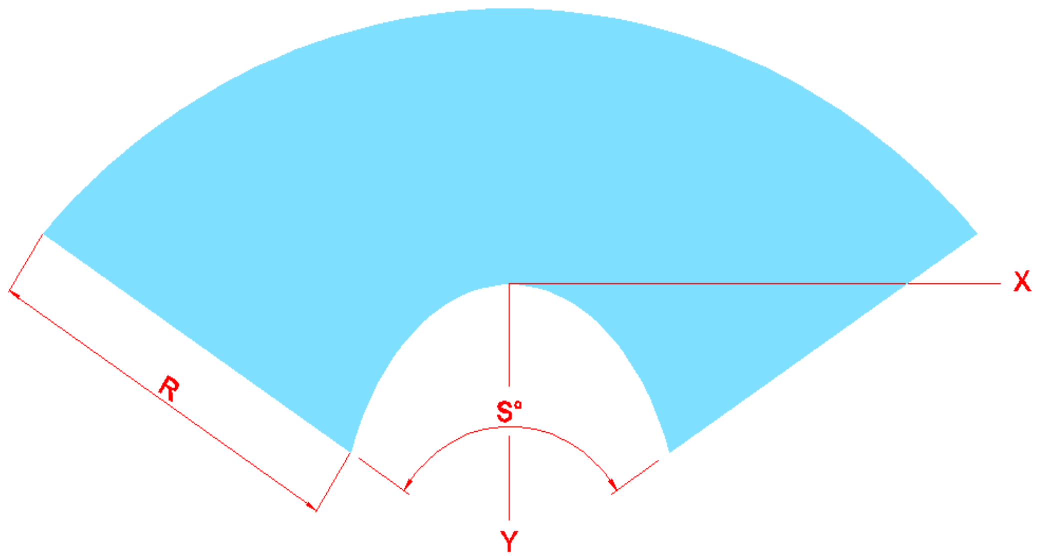
$$S = \frac{360 * B}{R2}$$

3-6 Right Circular Cone cut from top with angle



Dimensions   After rolling

3-6-1 Cone before rolling



Before rolling

Continue 3-6-1

$$R = \sqrt{A^2 + B^2}$$

$$S = \frac{360 * A}{R}$$

For i = 0 to 180 and i ≠ 90

$$m = \frac{(B - C) * (\cos(i) - 1)}{\tan(D) * \cos(i) - \frac{B}{A}}$$

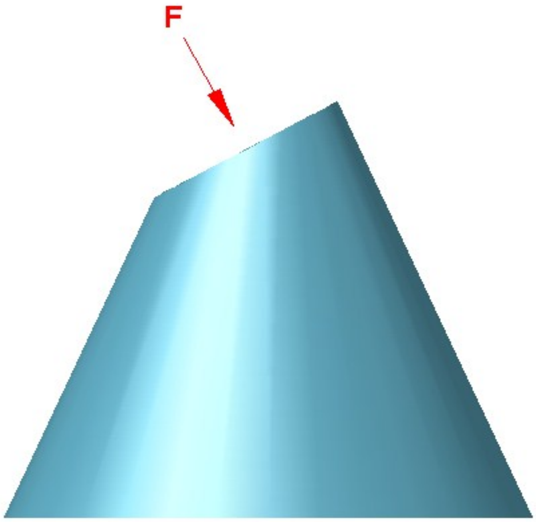
$$h = \frac{\left(A - \frac{C * A}{B} - m\right) * B}{A * \cos\ i}$$

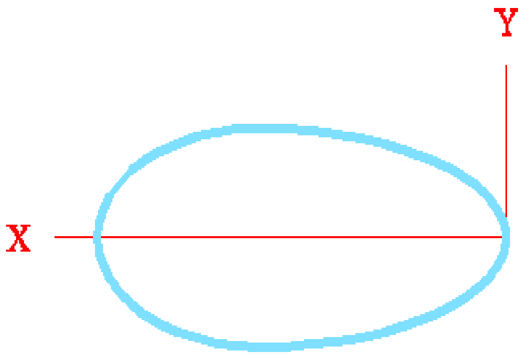
$$k = \frac{h * \sqrt{A^2 + B^2}}{B}$$

$$\mathbf{X = k * \sin(\frac{i * S}{360})}$$

$$\mathbf{Y = -\frac{(B - C) * \sqrt{A^2 + B^2}}{B} - k * \cos(\frac{i * S}{360})}$$

3-6-2 View-F





View - F

$$k = \frac{2 * A * (B - C)}{B * (\cos(D) + \sin(D) * \tan E)}$$

For i = 0 to k

m = tan (E) * [B – { i * sin(D) + C}]

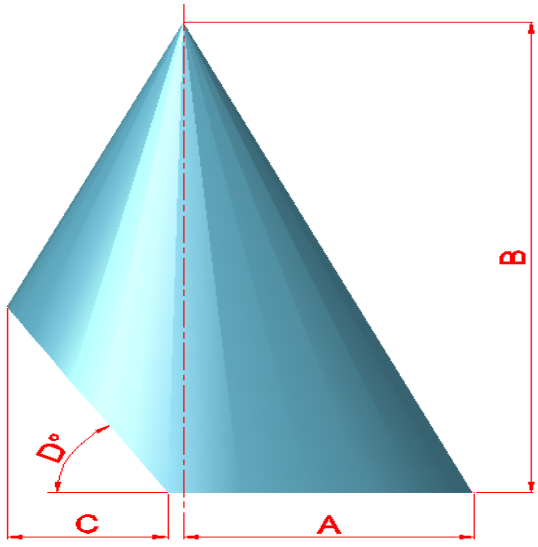
X = i

$$Y = \sqrt{m^2 - [A - \{ i * \cos(D) + C * \tan E\}]^2}$$

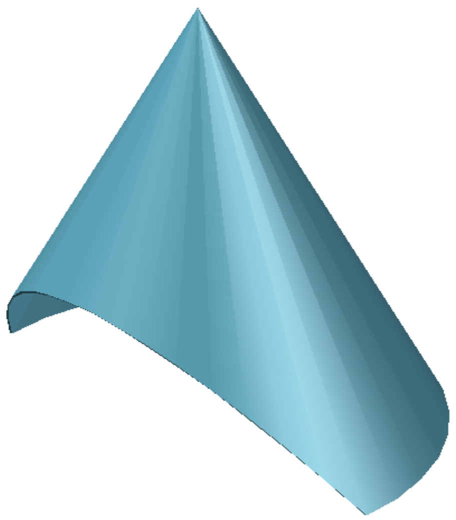
Notes:

- The bottom curve is same as top curve.
- The steps of (i) are optionals.

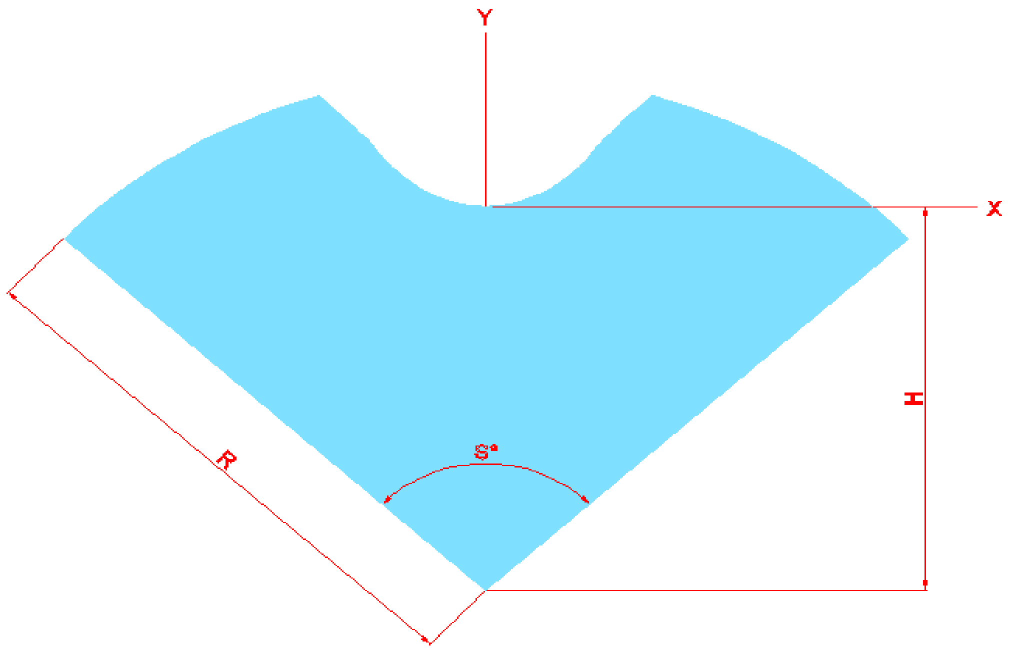
3-7 Right Circular Cone cut from side



Dimensions



After rolling



Before rolling

3-7-1 The Cone

$$R = \sqrt{A^2 + B^2}$$

$$S = \frac{360 * A}{\sqrt{A^2+B^2}}$$

3-7-2 The cut

If A > C Then

$$k = \tan^{-1}\left(\frac{\sqrt{A^2-(A-C)^2}}{A-C}\right)$$

If A = C Then

k = 90

If A < C Then

$$k = 90 + \tan^{-1}\frac{C-A}{\sqrt{A^2-(C-A)^2}}$$

For i = 0 to k

m = B * Cos (D) + A * Cos i * Sin D

f = B * Cos(D) + Sin(D) * (A - C)

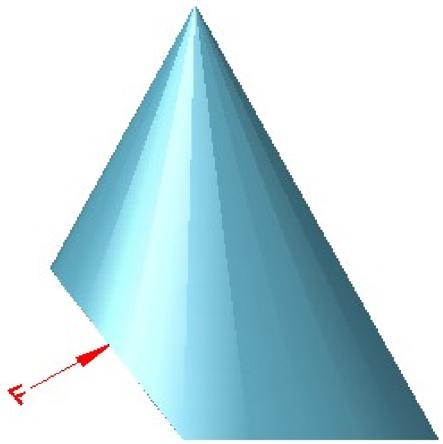
q = B * Cos(D) + A * Sin D

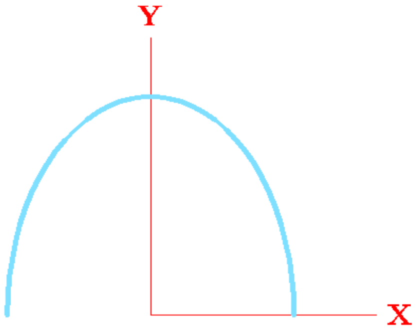
$$H = R * f / m$$

$$X = R * \frac{f}{m} * \sin\left(\frac{i * S}{360}\right)$$

$$Y = \frac{R * f}{m} * \cos\left(\frac{i * S}{360}\right) - \frac{R * f}{q}$$

3-7-3 View – F





View - F

For i = 0 to k

$$h = \frac{A * \cos(i) - A + C}{\frac{1}{\tan D} + \frac{A * \cos i}{B}}$$

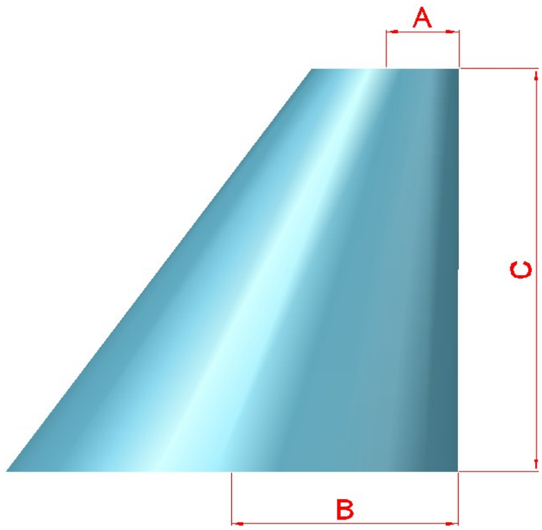
$$X = \left(A - \frac{A*h}{B}\right) * \sin i$$

$$Y = \frac{h}{\sin D}$$

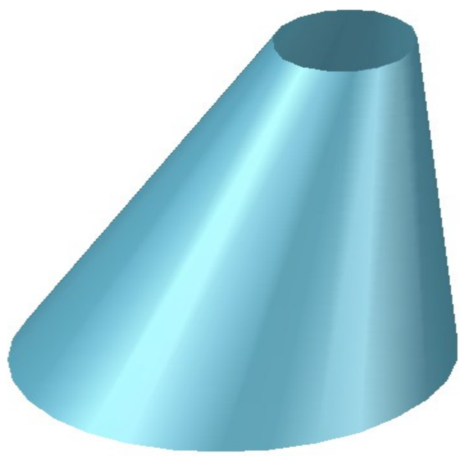
Notes:

- The left curve is same as right curve.
- The steps of (i) are optionals.

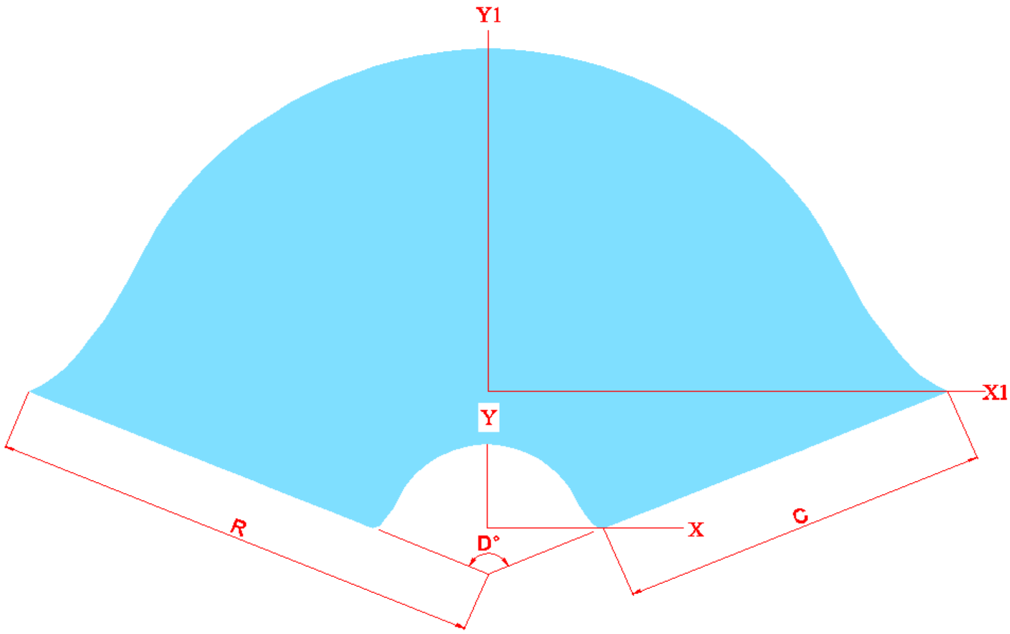
3-8 Oblique Cone cut from top



Dimensions



After rolling



Before rolling

3-8-1 The Base of Cone

For i = 0 to 180 step s

$$k = \sqrt{(\frac{B*C}{B-A})^2 + 4 * B^2 * (\cos\frac{i}{2})^2}$$

$$m = \sqrt{(\frac{B*C}{B-A})^2 + 4 * B^2 * (\cos\frac{i}{2} + \frac{s}{2})^2}$$

$$z = k^2 + m^2 - 4 * B^2 * (\sin\frac{s}{2})^2$$

$$t = \tan^{-1}(\frac{\sqrt{4 * k^2 * m^2 - z^2}}{z})$$

$$f = \sum t$$

For w = 0 to 180 step s

$$k = \sqrt{(\frac{B*C}{B-A})^2 + 4 * B^2 * (\cos\frac{w}{2})^2}$$

$$m = \sqrt{(\frac{B*C}{B-A})^2 + 4 * B^2 * (\cos\frac{w}{2} + \frac{s}{2})^2}$$

$$z = k^2 + m^2 - 4 * B^2 * (\sin\frac{s}{2})^2$$

$$tt = \tan^{-1}(\frac{\sqrt{4 * k^2 * m^2 - z^2}}{z})$$

$$ff = \sum tt$$

Continue 3-8-1

$$X = k * \sin(ff - tt)$$

$$Y = k * \cos(ff - tt) - \frac{B*C}{B-A} * \cos(f - t)$$

- The values (f) and (t) in the last equation are when i = 180.

3-8-2 The Top of Cone

For i = 0 to 180 step s

$$k = \sqrt{(\frac{A*C}{B-A})^2 + 4*A^2*(\cos\frac{i}{2})^2}$$

$$m = \sqrt{(\frac{A*C}{B-A})^2 + 4*A^2*(\cos\frac{i}{2} + \frac{s}{2})^2}$$

$$z = k^2 + m^2 - 4 * A^2 * (\sin\frac{s}{2})^2$$

$$t = \tan^{-1}(\frac{\sqrt{4*k^2*m^2-z^2}}{z})$$

$$f = \sum t$$

$$D^\circ = f$$

Continue 3-8-2

For w = 0 to 180 step s

$$k = \sqrt{(\frac{A * C}{B - A})^2 + 4 * A^2 * (\cos\frac{w}{2})^2}$$

$$m = \sqrt{(\frac{A * C}{B - A})^2 + 4 * A^2 * (\cos\frac{w}{2} + \frac{s}{2})^2}$$

$$z = k^2 + m^2 - 4 * A^2 * (\sin\frac{s}{2})^2$$

$$tt = \tan^{-1}(\frac{\sqrt{4 * k^2 * m^2 - z^2}}{z})$$

$$ff = \sum tt$$

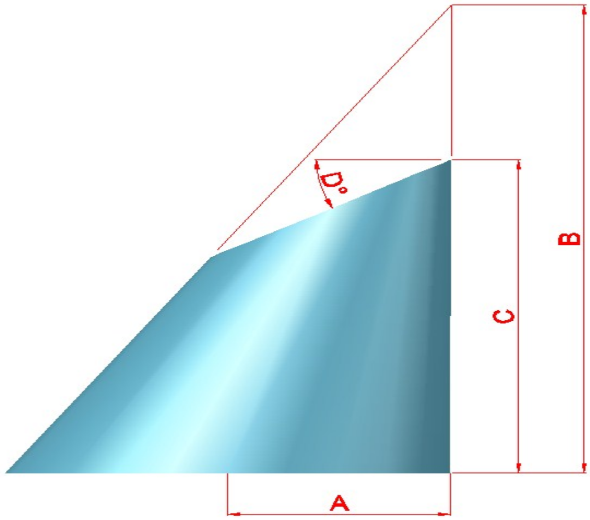
$$\mathbf{X = k * Sin(ff - tt)}$$

$$\mathbf{Y = k * cos(ff\text{-}tt) - \frac{A * C}{B - A} * cos(f - t)}$$

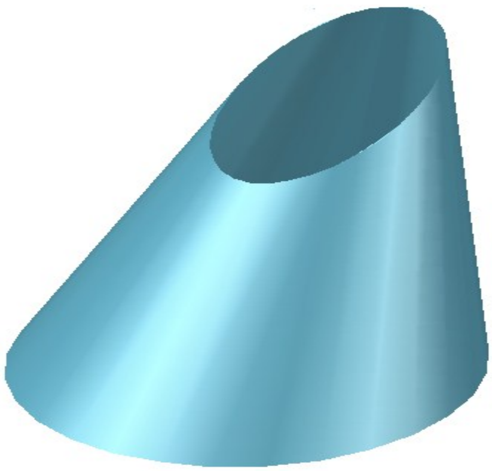
Notes:

- The values (f) and (t) in the last equation are when i = 180.
- The left curve is same as right curve.
- The steps of (i) and (w) are sames and optionals.

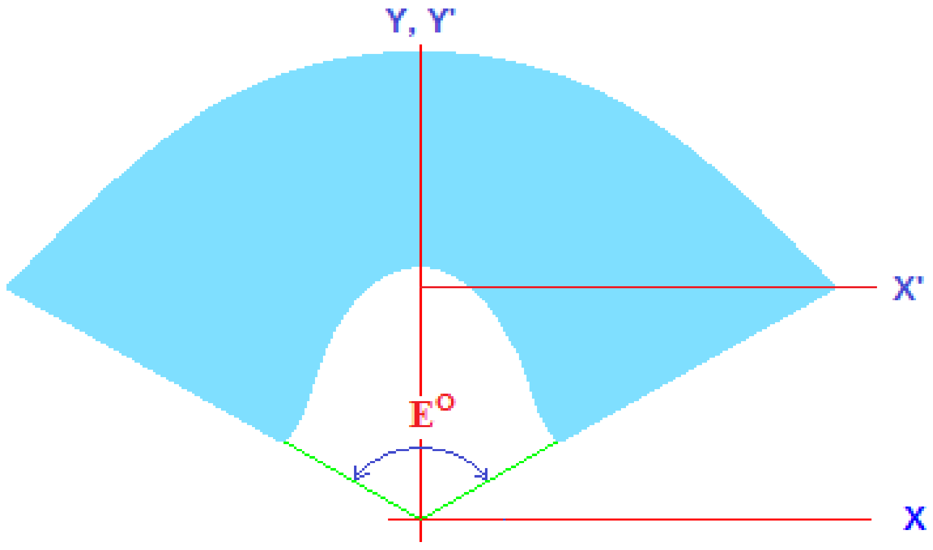
3-9 Oblique Cone cut from top with angle



Dimensions



After rolling



Before rolling

3-9-1 The Base of Cone

For i = 0 to 180 step s

$$k = \sqrt{B^2 + 4 * A^2 * (\cos\frac{i}{2})^2}$$

$$m = \sqrt{B^2 + 4 * A^2 * (\cos\frac{i}{2} + \frac{s}{2})^2}$$

$$z = k^2 + m^2 - 4 * A^2 * (\sin\frac{s}{2})^2$$

$$t = \tan^{-1}(\frac{\sqrt{4 * k^2 * m^2 - z^2}}{z})$$

$$f = \sum t$$

$$E^\circ = 2 * (f - t)$$

For w = 0 to 180 step s

$$k = \sqrt{B^2 + 4 * A^2 * (\cos\frac{w}{2})^2}$$

$$m = \sqrt{B^2 + 4 * A^2 * (\cos\frac{w}{2} + \frac{s}{2})^2}$$

$$z = k^2 + m^2 - 4 * A^2 * (\sin\frac{s}{2})^2$$

Continue 3-9-1

$$tt = \tan^{-1}\left(\frac{\sqrt{4 * k^2 * m^2 - z^2}}{z}\right)$$

$$ff = \sum tt$$

X′ = k * Sin(ff - tt)

Y′ = k * Cos(ff - tt) - B * Cos(f - t)

- The values (f) and (t) in the last equation are when i = 180.

3-9-2 The Top of Cone

For w = 0 to 180 step s

$$k = \sqrt{B^2 + 4 * A^2 * (\cos\frac{w}{2})^2}$$

$$m = \sqrt{B^2 + 4 * A^2 * (\cos\frac{w}{2} + \frac{s}{2})^2}$$

$$n = \frac{A * (B - C) * (1 + \cos w)}{B - (1 + \cos w) * A * \tan D}$$

Continue 3-9-2

If w = 180 then

z = B – C

Else

$$Z = \sqrt{\left(\frac{n}{\cos\frac{w}{2}}\right)^2 + (\, n * \tan(D) + (B - C))^2}$$

$$p = k^2 + m^2 - 4 * A^2 * (\sin \frac{s}{2})^2$$

$$t = \tan^{-1}(\frac{\sqrt{4 * k^2 * m^2 - p^2}}{p})$$

$$f = \sum t$$

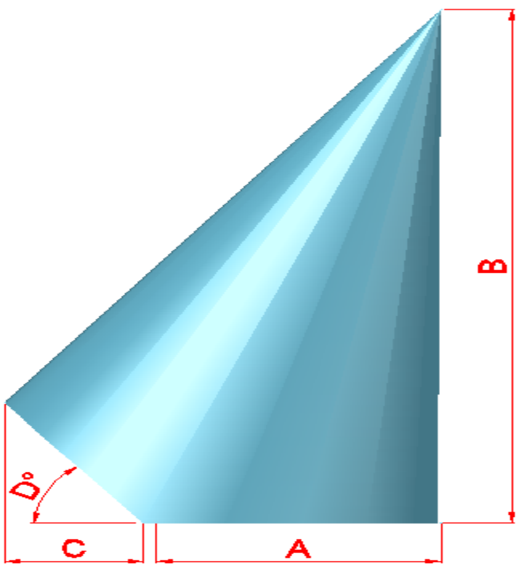
X = z * Sin(f - t)

Y = z * Cos(f - t)

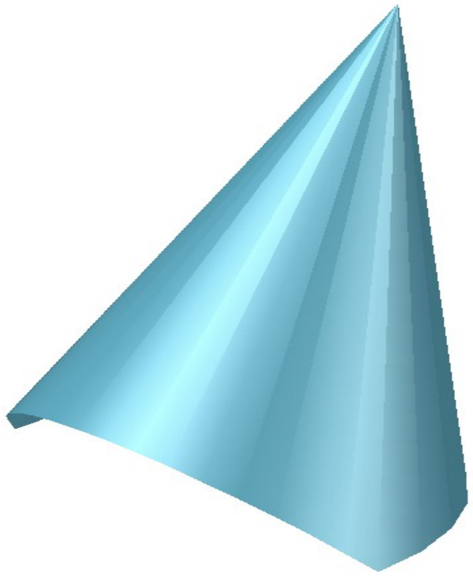
Notes:

- The values (f) and (t) in the last equation are when i = 180.
- The left curve is same as right curve.
- The steps of (i) and (w) are sames and optionals.

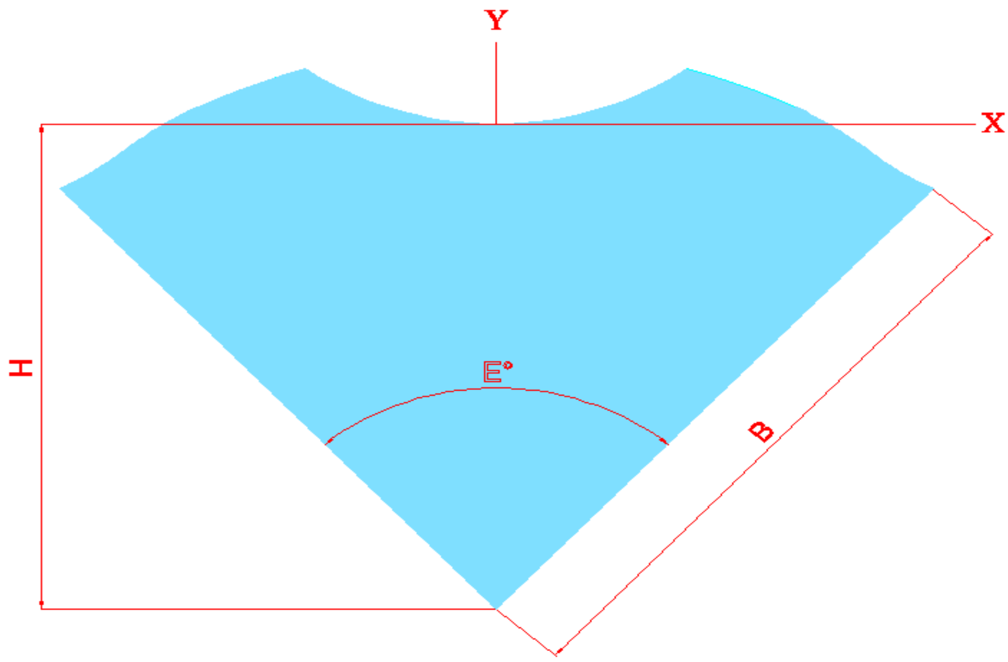
3-10 Oblique Cone cut from side



Cone dimensions



Cone after rolling



Cone before rolling

3-10-1 The Base of Cone

For i = 0 to 180 step s

$$k = \sqrt{B^2 + 4 * A^2 * (\cos\frac{i}{2})^2}$$

$$m = \sqrt{B^2 + 4 * A^2 * (\cos\frac{i}{2} + \frac{s}{2})^2}$$

$$z = k^2 + m^2 - 4 * A^2 * (\sin\frac{s}{2})^2$$

$$t = \tan^{-1}(\frac{\sqrt{4 * k^2 * m^2 - z^2}}{z})$$

$$f = \sum t$$

$$E = 2 * (f - t)$$

For w = 0 to 180 step s

$$k = \sqrt{B^2 + 4 * A^2 * (\cos\frac{w}{2})^2}$$

$$m = \sqrt{B^2 + 4 * A^2 * (\cos\frac{w}{2} + \frac{s}{2})^2}$$

Continue 3-10-1

$$z = k^2 + m^2 - 4 * A^2 * (\sin\frac{s}{2})^2$$

$$tt = \tan^{-1}(\frac{\sqrt{4 * k^2 * m^2 - z^2}}{z})$$

$$ff = \sum tt$$

X = k * Sin(ff - tt)

Y = k * Cos(ff - tt) - B * Cos(f - t)

- The values (f) and (t) in the last equation are when i = 180.

3-10-2 The Side of Cone

If A = C Then

g = 90

ElseIf C > A Then

$$g = 90 + \tan^{-1}(\frac{C - A}{\sqrt{A^2 - (C - A)^2}})$$

ElseIf A > C Then

$$g = \tan^{-1}(\frac{\sqrt{A^2 - (C - A)^2}}{A - C})$$

For i = 0 to g step p

Continue 3-10-2

$$k = \sqrt{B^2 + 4 * A^2 * \left(\cos(\frac{i}{2})\right)^2}$$

$$m = \sqrt{B^2 + 4 * A^2 * \left(\cos(\frac{i}{2} + \frac{s}{2})\right)^2}$$

$$q = \frac{A * (1 + \cos\ i) - (2 * A - C)}{A * \tan(D) * (\frac{1 + \cos\ i}{B} + 1)}$$

$$z = \sqrt{\left\{\frac{q - C + 2 * A}{\cos\left(\frac{i}{2}\right)}\right\}^2 + (B - q * \tan\ D)^2}$$

$$t = \sqrt{\left\{\frac{q - C + 2 * A}{\cos\left(\frac{i}{2} + \frac{s}{2}\right)}\right\}^2 + (B - q * \tan\ D)^2}$$

$$j = z^2 + t^2 - 4 * A^2 * (\sin s)^2$$

$$p1 = \tan^{-1}(\frac{\sqrt{4 * z^2 * t^2 - j^2}}{j})$$

Continue 3-10-2

$$p2 = \sum p1$$

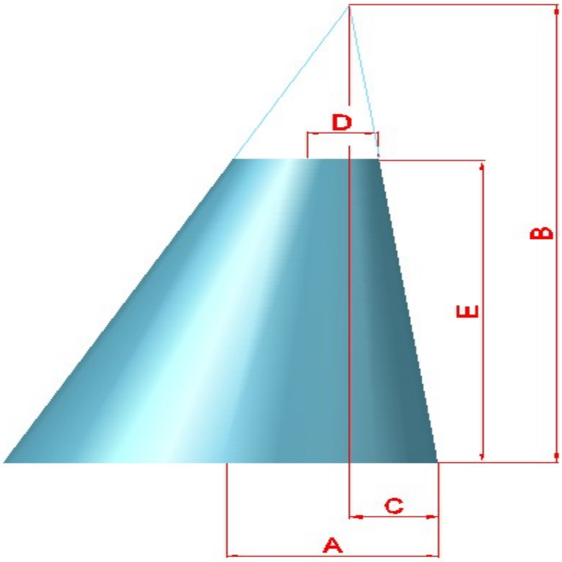
$$f = \frac{A * 2 - (2 * A - C)}{\frac{2 * A * \tan D}{B} + 1}$$

$$H = \sqrt{(f - C + 2 * A)^2 + (B - f * \tan D)^2}$$

X = t * Sin(p2 – p1)

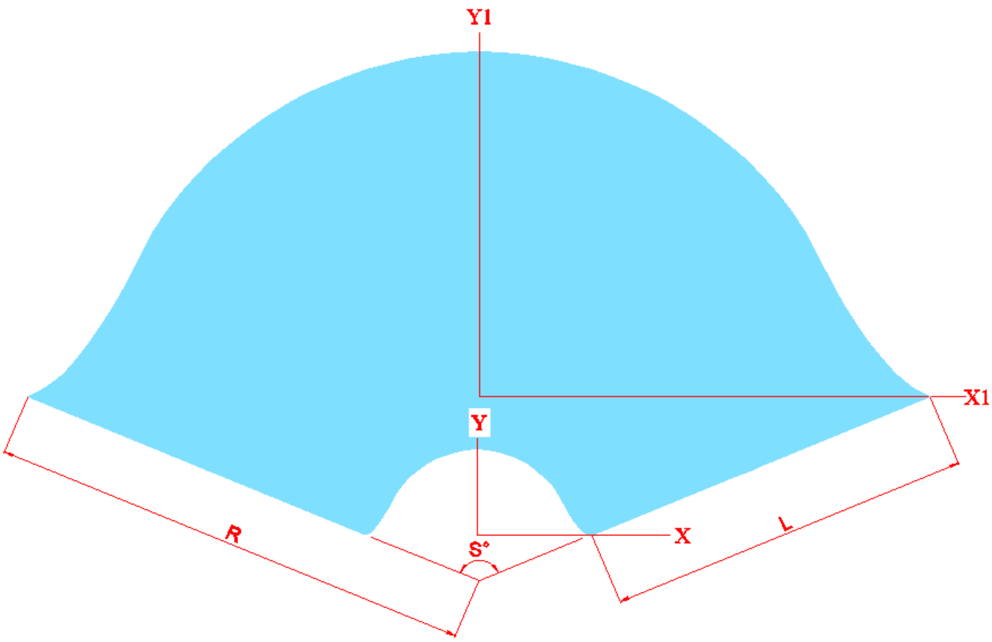
Y = t * Cos(p2 – p1)

3-11 Truncated Scalene Cone



Cone dimensions

Cone after rolling



Cone before rolling

3-11-1 The Base of Cone

For i = 0 to 180 step s

$$k = \sqrt{B^2 + A^2 * (\sin i)^2 + (A * \cos(i) + A - C)^2}$$

$$m = \sqrt{B^2 + A^2 * (\sin(i + s))^2 + (A * \cos(i + s) + A - C)^2}$$

$$z = k^2 + m^2 - 4 * A^2 * (\sin\frac{s}{2})^2$$

$$t = \tan^{-1}(\frac{\sqrt{4 * k^2 * m^2 - z^2}}{z})$$

$$f = \sum t$$

$$L = \sqrt{B^2 + C^2}$$

$$S^\circ = 2 * (f - t)$$

For w = 0 to 180 step s

$$k = \sqrt{B^2 + A^2 * (\sin w)^2 + (A * \cos(w) + A - C)^2}$$

$$m = \sqrt{B^2 + A^2 * (\sin(w + s))^2 + (A * \cos(i + s) + A - C)^2}$$

Continue 3-11-1

$z = k^2 + m^2 - 4 * A^2 * (\sin\frac{s}{2})^2$

$tt = \tan^{-1}(\frac{\sqrt{4 * k^2 * m^2 - z^2}}{z})$

$ff = \sum tt$

$$\mathbf{X1 = k * Sin(ff - tt)}$$

$$\mathbf{Y1 = k * Cos(ff - tt) - \sqrt{(B - E)^2 + C^2} * Cos(f - t)}$$

Notes:

- The values (f) and (t) in the last equation are when i = 180.
- The left curve is same as right curve.
- The steps of (i) and (w) are sames and optionasl.

3-11-2 The Top of Cone

For i = 0 to 180 step s

$k = \sqrt{(B - E)^2 + D^2 * (\sin i)^2 + (D * \cos(i) + D - C)^2}$

$m = \sqrt{(B - E)^2 + D^2 * (\sin(i + s))^2 + (D * \cos(i + s) + D - C)^2}$

$z = k^2 + m^2 - 4 * D^2 * (\sin\frac{s}{2})^2$

Continue 3-11-2

$$t = \tan^{-1}\left(\frac{\sqrt{4 * k^2 * m^2 - z^2}}{z}\right)$$

$$f = \sum t$$

For $w = 0$ to 180 step s

$$k = \sqrt{(B - E)^2 + D^2 * (\sin w)^2 + (D * \cos(w) + D - C)^2}$$

$$m = \sqrt{(B - E)^2 + D^2 * (\sin(w + s))^2 + (D * \cos(i + s) + D - C)^2}$$

$$z = k^2 + m^2 - 4 * D^2 * \left(\sin\frac{s}{2}\right)^2$$

$$tt = \tan^{-1}\left(\frac{\sqrt{4 * k^2 * m^2 - z^2}}{z}\right)$$

$$ff = \sum tt$$

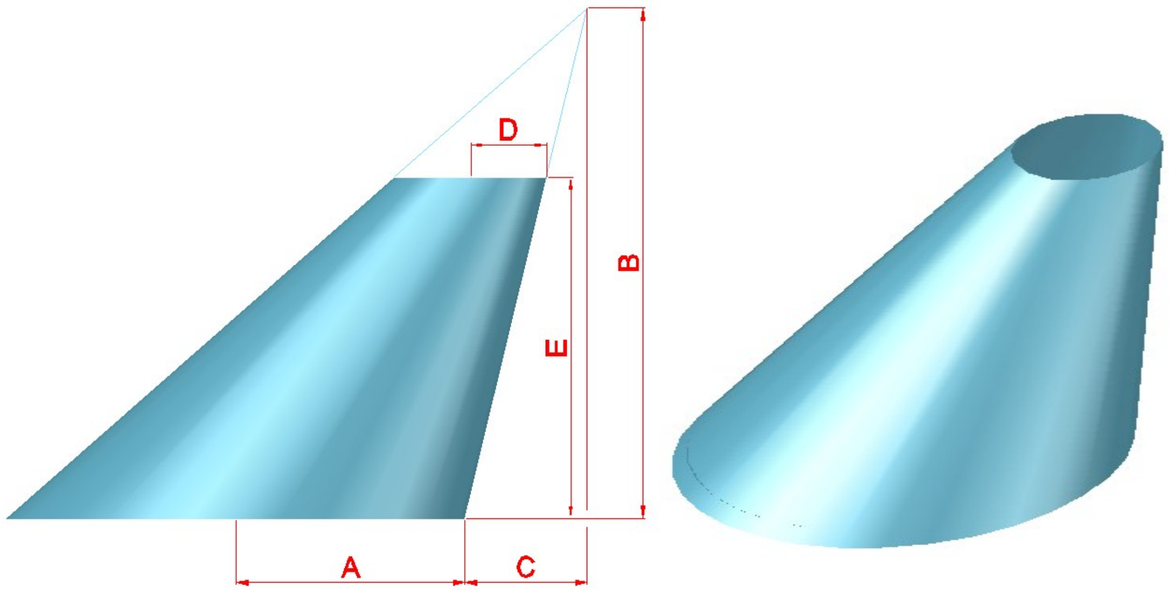
$$\mathbf{X = k * Sin(ff - tt)}$$

$$\mathbf{Y = k * Cos(ff - tt) - \sqrt{(B - E)^2 + C^2} * Cos(f - t)}$$

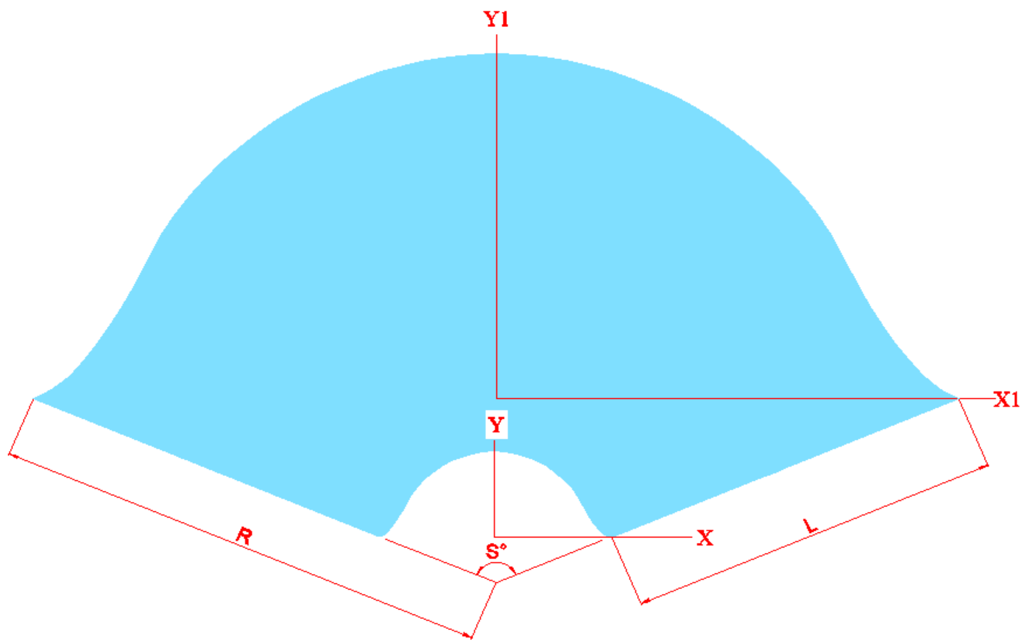
Notes:

- The values (f) and (t) in the last equation are when i = 180.
- The left curve is same as right curve.
- The steps of (i) and (w) are sames and optionals.

3-12 Truncated Obtuse Cone



Cone dimensions **Cone after rolling**



Cone before rolling

3-12-1 The Base of Cone

For i = 0 to 180 step s

$$k = \sqrt{B^2 + A^2 * (\sin i)^2 + (A * \cos(i) + A + C)^2}$$

$$m = \sqrt{B^2 + A^2 * (\sin(i + s))^2 + (A * \cos(i + s) + A + C)^2}$$

$$z = k^2 + m^2 - 4 * A^2 * (\sin \frac{s}{2})^2$$

$$t = \tan^{-1}(\frac{\sqrt{4 * k^2 * m^2 - z^2}}{z})$$

$$f = \sum t$$

$$L = \sqrt{b^2 + c^2}$$

$$S^\circ = 2 * (f - t)$$

For w = 0 to 180 step s

$$k = \sqrt{B^2 + A * (\sin w)^2 + (A * \cos(w) + A + C)^2}$$

$$m = \sqrt{B^2 + A^2 * (\sin(w + s))^2 + (A * \cos(w + s) + A + C)^2}$$

$$z = k^2 + m^2 - 4 * A^2 * (\sin \frac{s}{2})^2$$

Continue 3-12-1

$$tt = \tan^{-1}\left(\frac{\sqrt{4 * k^2 * m^2 - z^2}}{z}\right)$$

$$ff = \sum tt$$

$$X = k * \mathrm{Sin}(f - t)$$

$$Y = k * \mathrm{Cos}(ff - tt) - \sqrt{B^2 + C^2} * \mathrm{Cos}(f - t)$$

Notes:

- The values (f) and (t) in the last equation are when i = 180.
- The left curve is same as right curve.
- The steps of (i) and (w) are sames and optionals.

3-12-2 The Top of Cone

For i = 0 to 180 step s

$$k = \sqrt{(B - E)^2 + D^2 * (\sin i)^2 + (D * \cos(i) + D + C)^2}$$

$$m = \sqrt{(B - E)^2 + D^2 * (\sin(i + s))^2 + (D * \cos(i + s) + D + C)^2}$$

$$z = k^2 + m^2 - 4 * D^2 * (\sin\frac{s}{2})^2$$

Continue 3-12-2

$$t = \tan^{-1}\left(\frac{\sqrt{4 * k^2 * m^2 - z^2}}{z}\right)$$

$$f = \sum t$$

For w = 0 to 180 step s

$$k = \sqrt{B^2 + A * (\sin w)^2 + (A * \cos(w) + A + C)^2}$$

$$m = \sqrt{B^2 + A^2 * (\sin(w + s))^2 + (A * \cos(w + s) + A + C)^2}$$

$$z = k^2 + m^2 - 4 * A^2 * (\sin\frac{s}{2})^2$$

$$t = \tan^{-1}\left(\frac{\sqrt{4 * k^2 * m^2 - z^2}}{z}\right)$$

$$ff = \sum tt$$

$$\mathbf{X = k * Sin(f - t)}$$

$$\mathbf{Y = k * Cos(ff - tt) - \sqrt{B^2 + C^2} * Cos(f - t)}$$

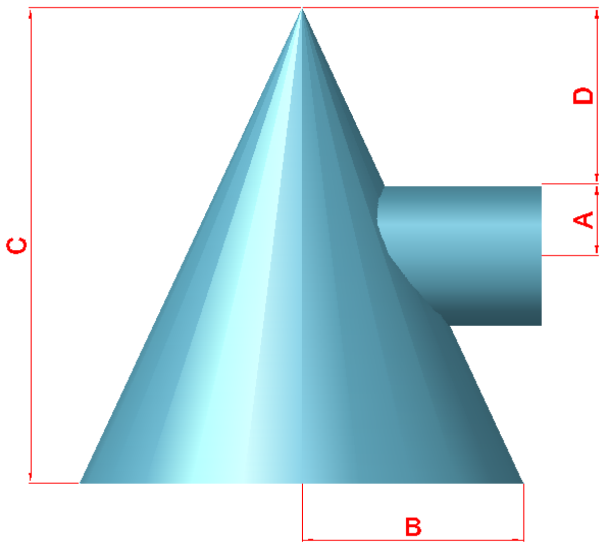
Notes:

- The values (f) and (t) in the last equation are when i = 180.
- The left curve is same as right curve.
- The steps of (i) and (w) are sames and optionals.

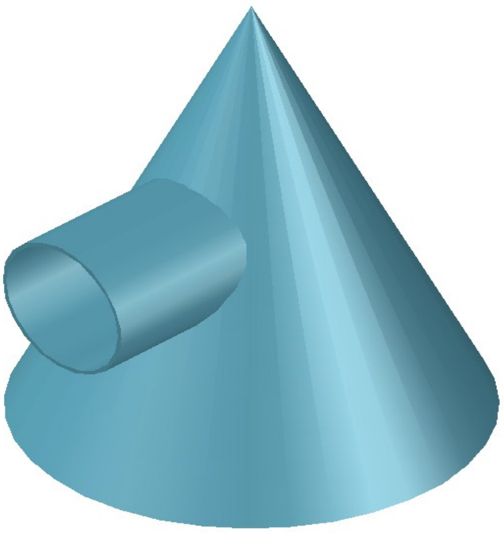
CHAPTER – 4

CONES WITH CYLINDERS

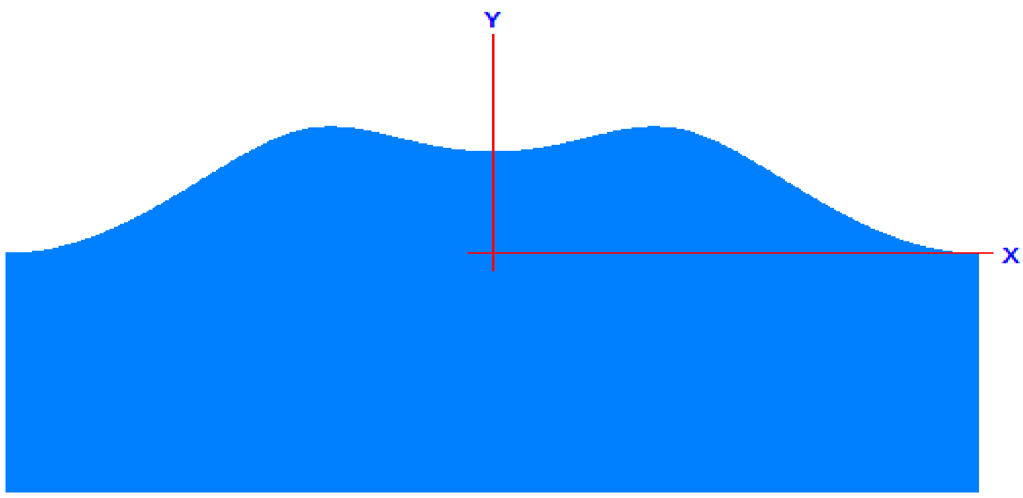
4-1 Right Circular Cone with horizontal cylinder



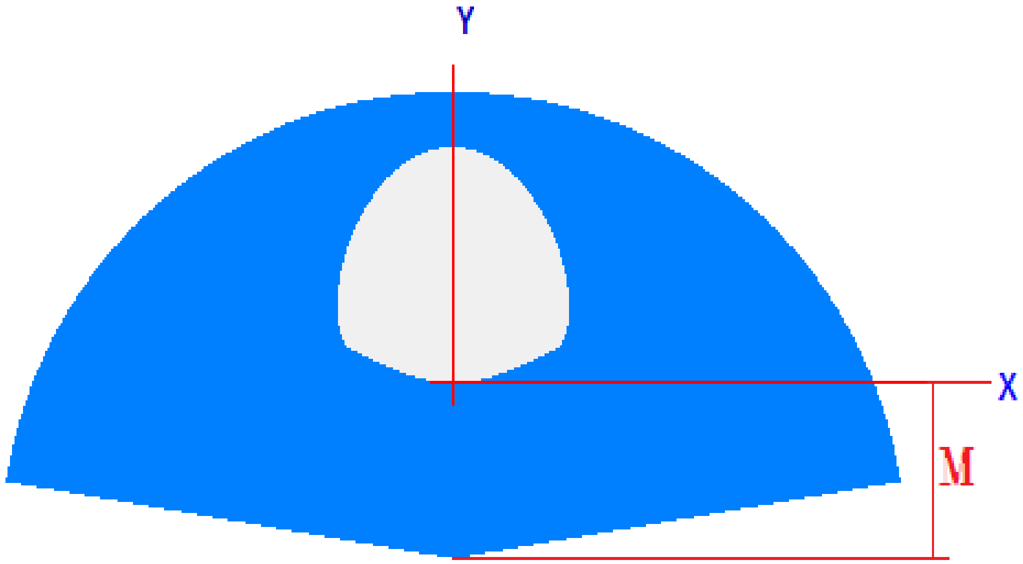
Assembly dimensions



Assembly after rolling



Cylinder before rolling



Cone before rolling

4-1-1 Horizontal Cylinder

For u = 0 to 180

$$t = \frac{B * \{D + A * (1 - \cos\ u)\}}{C}$$

$$\mathbf{X = \frac{A * \pi * u}{180}}$$

$$\mathbf{Y = t - \sqrt{t^2 - \{(A * \sin(u)\}^2} + \frac{A * B * (1+\cos\ u)}{C}}$$

4-1-2 Cone

For u = 0 to 180

$$q = \frac{B * \{D + A * (1 - \cos\ u)\}}{C}$$

$$t = \frac{360 * B}{\sqrt{(C^2 - B^2)}}$$

$$z = \frac{360 * t * \tan^{-1}(A * \sin u)}{\sqrt{q^2 - (A * \sin u)^{\ 2}}}$$

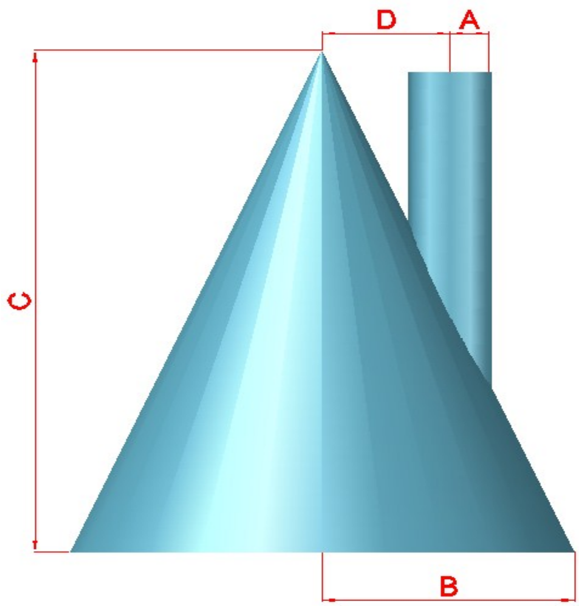
$$M = \frac{D * \sqrt{(B^2 + C^2}}{C}$$

$$k = \frac{\{D + A * (1 - \cos\ u)\} * \ \sqrt{(B^2 + C^2}}{C}$$

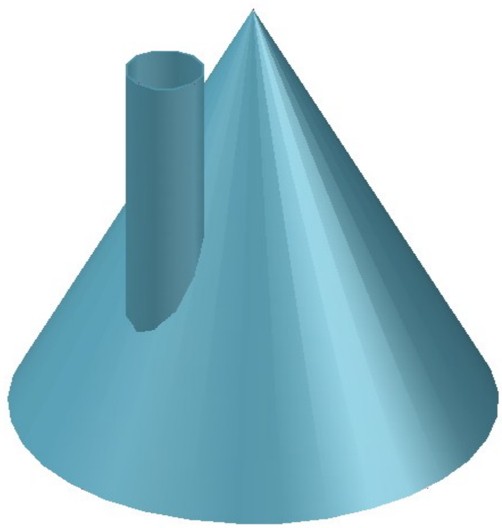
X = k * sin z

Y = k * Cos(z) - M

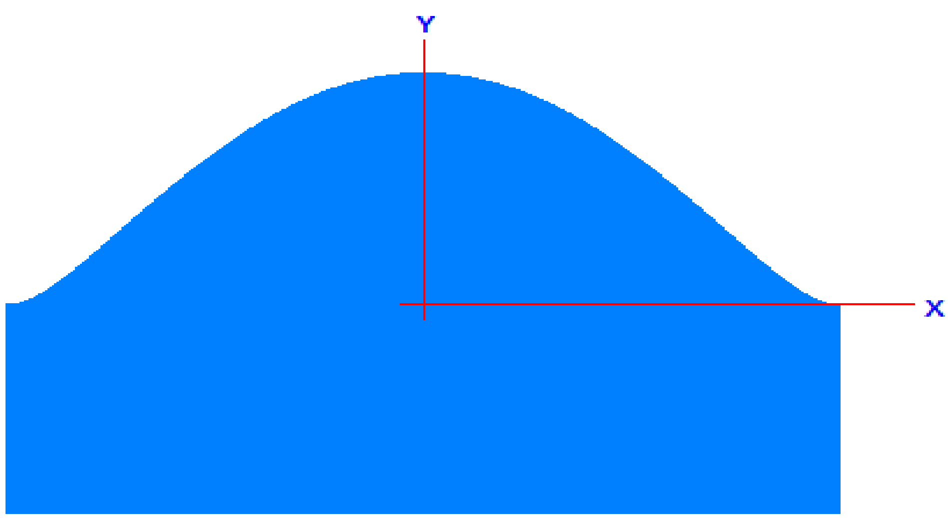
4-2 Right Circular Cone with vertical cylinder



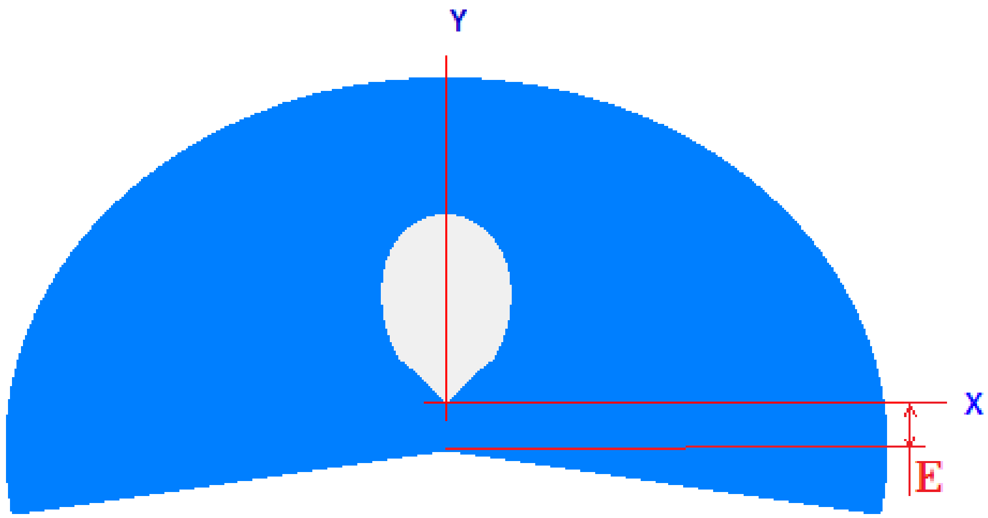
Assembly dimensions



Assembly after rolling



Cylinder before rolling



Cone before rolling

4-2-1 Vertical Cylinder

For u = 0 to 180

$$m = \sqrt{A^2 + D^2 + 2 * D * A * \cos u}$$

$$X = \frac{A * \pi * u}{180}$$

$$Y = \frac{C * (m + A - D)}{B}$$

4-2-2 Cone

For u = 0 to 180

$$m = \sqrt{A^2 + D^2 - 2 * D * A * \cos u}$$

$$t = \frac{360 * B}{\sqrt{(C^2 + B^2)}}$$

$$z = \frac{360 * t * \tan^{-1}(A * \sin u)}{\sqrt{m^2 - (A * \sin u)^2}}$$

$$k = \frac{(D - A) * \sqrt{B^2 + C^2}}{B}$$

$$j = \frac{m * \sqrt{B^2 + C^2}}{B}$$

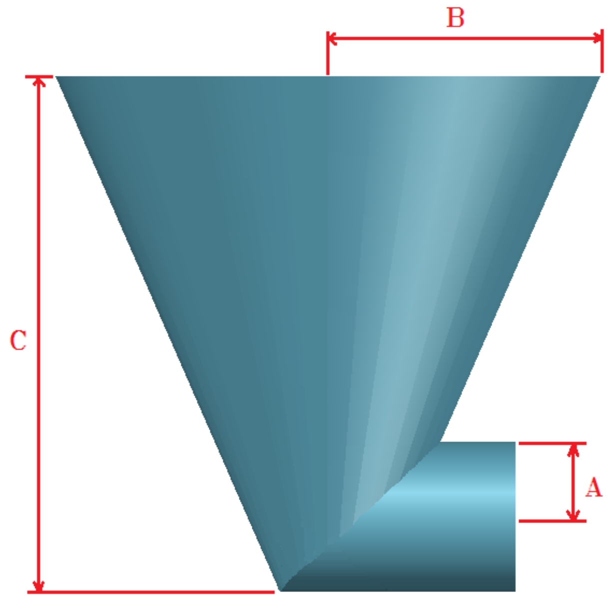
$$q = \frac{C * (D - A)}{B}$$

$$E = \sqrt{(D - A)^2 + q^2}$$

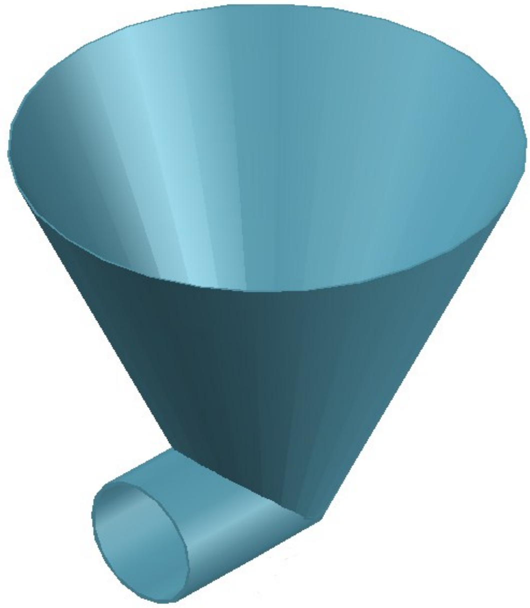
$$X = j * \sin z$$

$$Y = j * \cos(z) - k$$

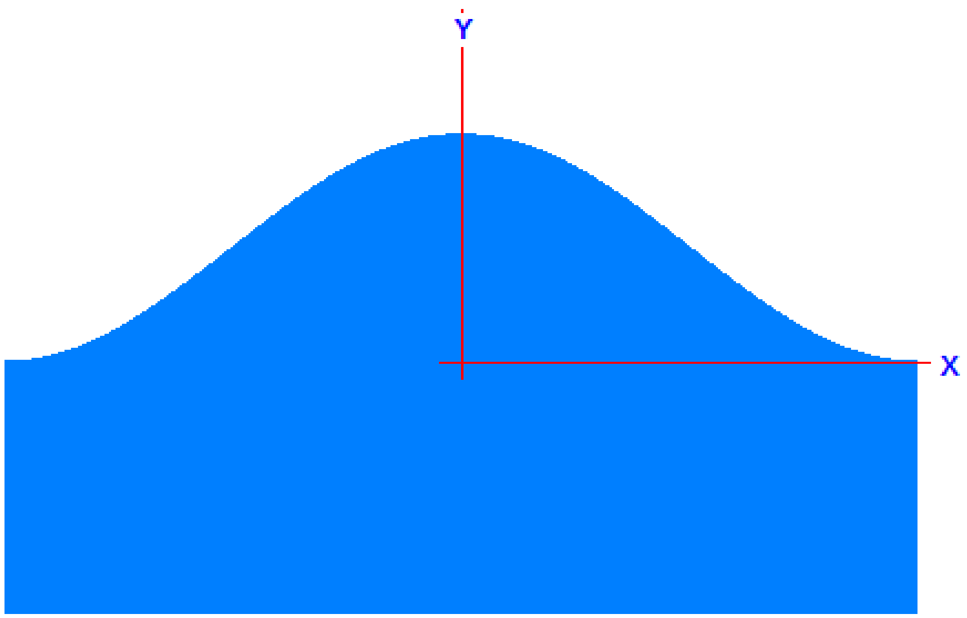
4-3 Inverted Right Circular Cone with Horizontal cylinder



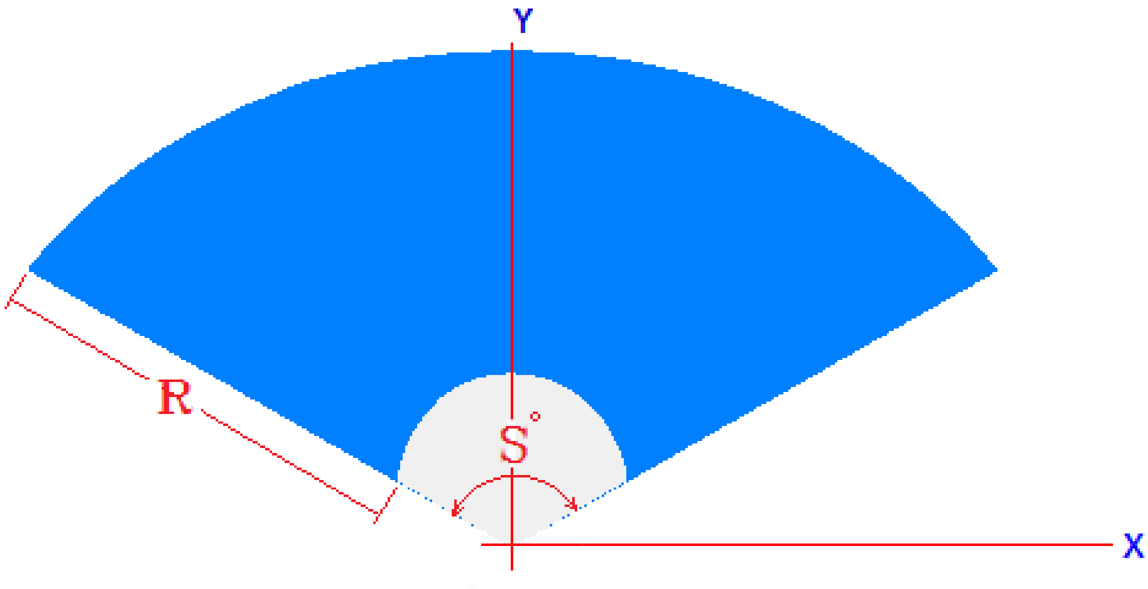
Assembly dimensions



Assembly after rolling



Cylinder before rolling



Cone before rolling

4-3-1 Pipe

$$k = 90 - \left[\tan^{-1}\left\{\frac{(C-A)}{B}\right\} + \tan^{-1}\left\{\frac{A}{\sqrt{B^2-A^2+(C-A)^2}}\right\}\right]$$

$$h = \frac{B}{\tan k}$$

$$z = 90 - k$$

Continue 4-3-1

For u = 0 to z

$$m = \frac{B * \{(h - C) + A * (1 - \cos u)\}}{h}$$

$$R = \sqrt{(h^2 + B^2}$$

$$S = \frac{360 * B}{\sqrt{(h^2 + B^2}}$$

$$\mathbf{X = \frac{A * \pi * u}{180}}$$

$$\mathbf{Y = m + \sqrt{m^2 - (A * \sin u)^2} + \frac{A * B * (1 + \cos u)}{C}}$$

For u = z to 180

$$\mathbf{Y = m - \sqrt{m^2 - (A * \sin u)^2} + \frac{A * B * (1 + \cos u)}{C}}$$

4-3-2 Cone

$$k = 90 - [\tan^{-1}\{\frac{(C-A)}{B}\} + \tan^{-1}\{\frac{A}{\sqrt{B^2-A^2+(C-A)^2}}\}]$$

$$h = \frac{B}{\tan k}$$

$$z = 90 - k$$

For u = 180 to z

$$m = \frac{B*\{(h-C)+A*(1-\cos u)\}}{h}$$

$$q = \frac{360*B}{\sqrt{h^2+B^2}}$$

$$j = q * \tan^{-1}(\frac{A*\sin u}{\sqrt{m^2-(A*\sin u)^2}})$$

$$f = [\frac{\{(h-C)+A*(1-\cos u)\}*\sqrt{h^2+B^2}}{h}]$$

X = f * sin j

Y = f * Cos j

Continue 4-3-2

For $u = z$ to 0

$$m = \frac{B * \{(h - C) + A * (1 - \cos u)\}}{h}$$

$$q = \frac{360 * B}{\sqrt{h^2 + B^2}}$$

$$g = \frac{q}{360} * \tan^{-1}\left(\frac{A * \sin u}{\sqrt{(m^2 + (A * \sin\ u)^2}}\right)$$

Note: the value of (j) below is when (u) = (z)

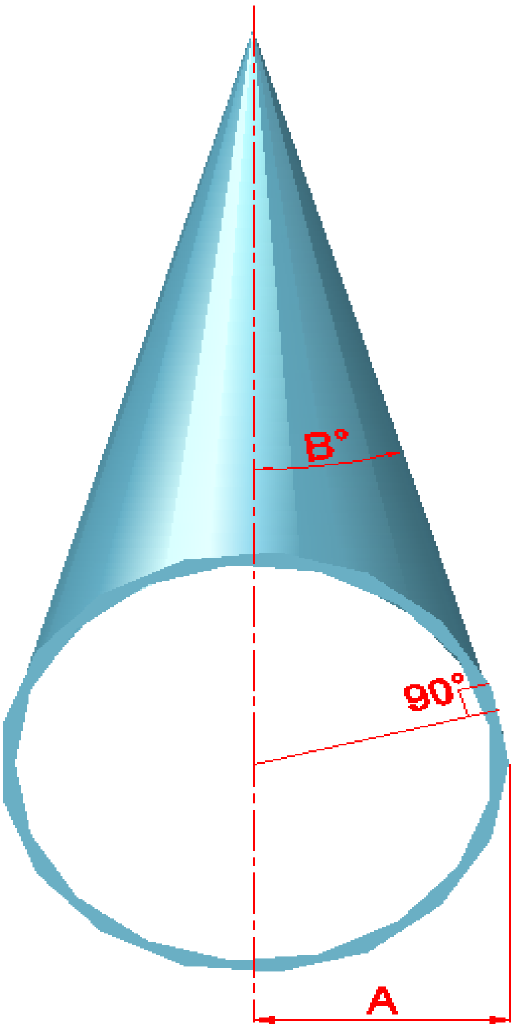
$$w = 2 * j - g$$

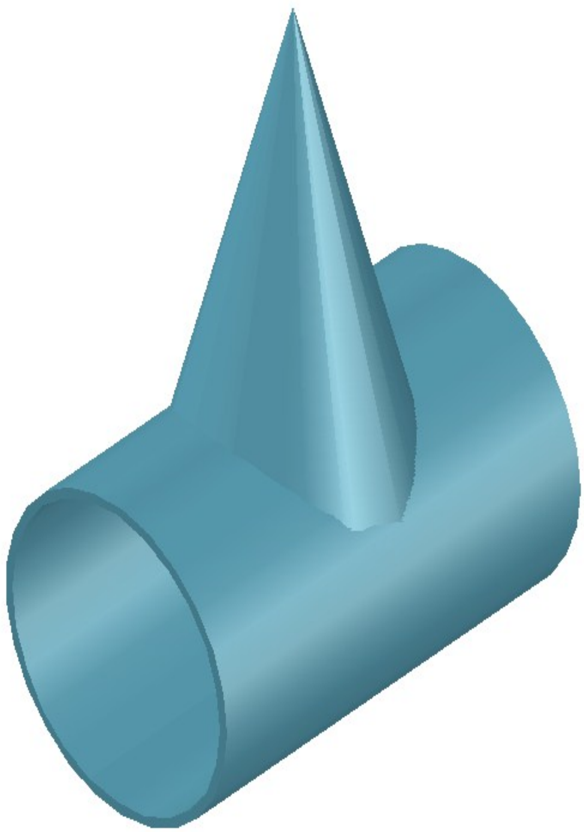
$$f = \left[\frac{\{(h - C) + A * (1 - \cos u)\} * \sqrt{h^2 + B^2}}{h}\right]$$

X = f * sin w

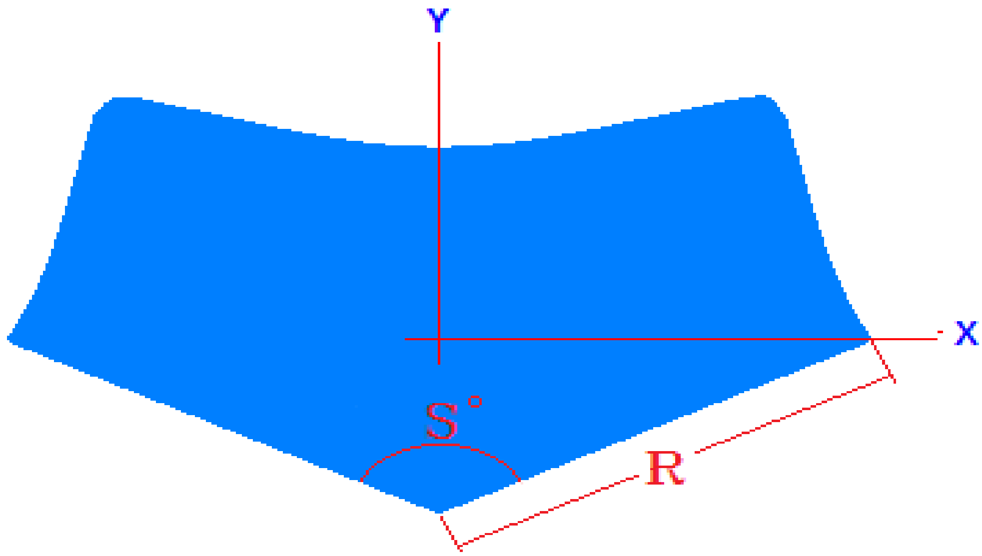
Y = f * Cos w

4-4 Horizontal cylinder with Right Circular Cone





Assembly dimensions **Assembly after rolling**



Cone before rolling

4-4-1 Cone

$$R = \frac{A}{\tan B}$$

$$S = \frac{360 * A}{R}$$

g = 360 * Sin B

For i = 0 to (90 – B – p) step p

$$f = A * \{\frac{1}{\cos B} - \mathrm{Cos}(i) * \mathrm{Tan}\ B\}$$

Continue 4-4-1

$$t = \tan^{-1}\left(\frac{A*\sin i}{\sqrt{(f^2 - (A*\sin i)^2}}\right)$$

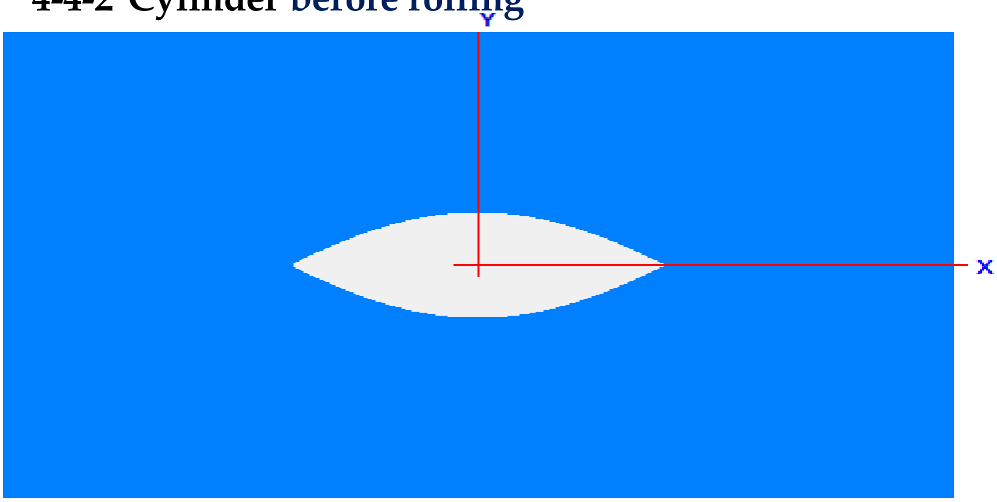
h = t * Sin B

$$r = \frac{f}{\sin B}$$

$$\mathbf{X = r * \sin h}$$

$$\mathbf{Y = r * \cos(h) - \frac{A * \cos\left(\frac{g}{2}\right) * \left(\frac{1}{\sin B} - 1\right)}{\cos B}}$$

4-4-2 Cylinder before rolling



Cylinder before rolling

Continue 4-4-2

For $i = 0$ to $(90 - B - p)$ step p

$$f = A * \{\frac{1}{\cos B} - \text{Cos}(i) * \text{Tan } B\}$$

$$X = \frac{A * \pi * i}{180}$$

$$Y = \sqrt{f^2 - A^2 * (\sin i)^2}$$

The last point should be as following:

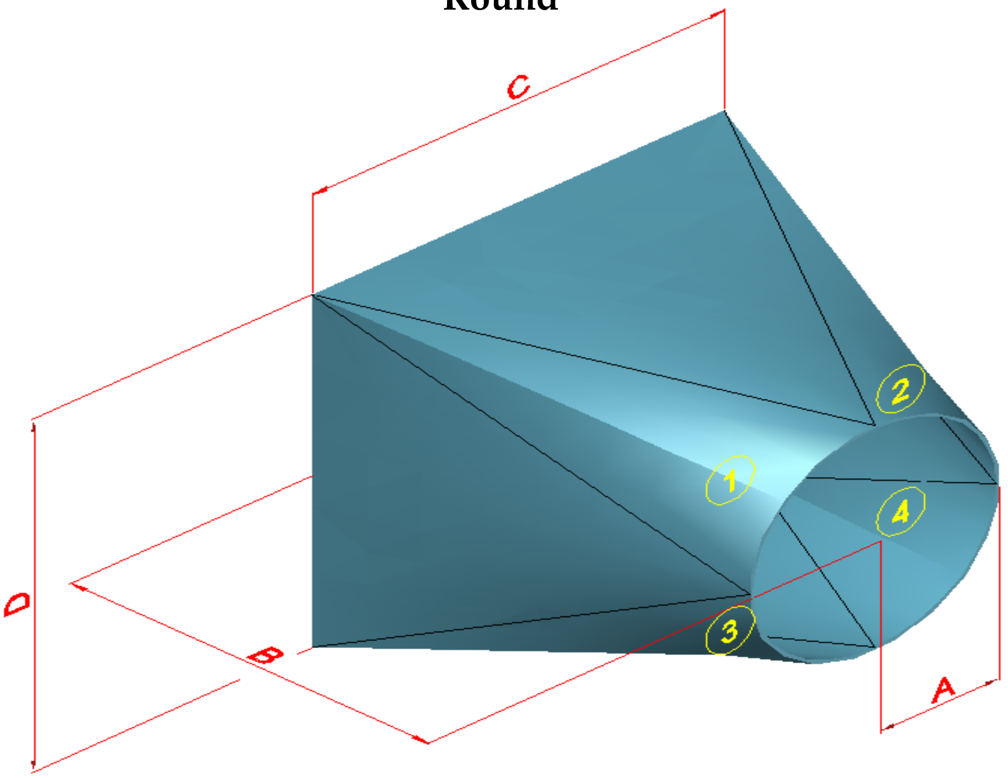
$$X = \frac{A * \pi * (90 - B)}{180}$$

$$Y = 0$$

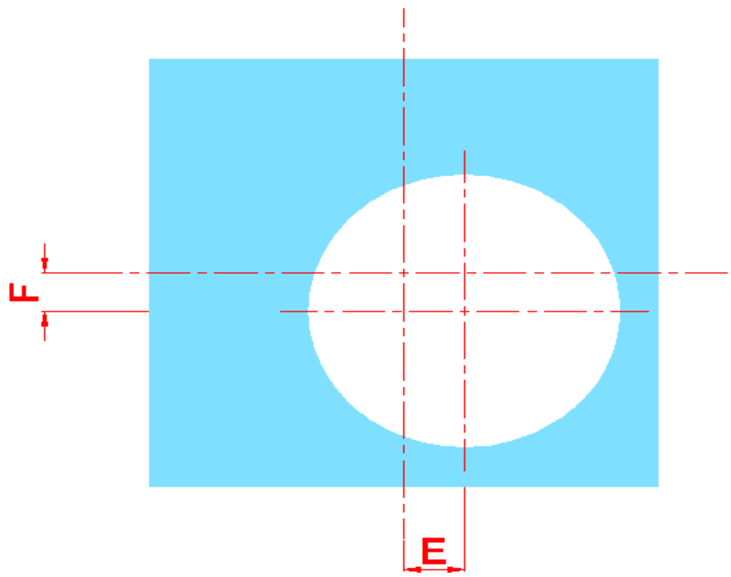
CHAPTER – 5

TRANSITIONS

5-1 Concentric and Eccentric Transition - Square or regtangular to Round

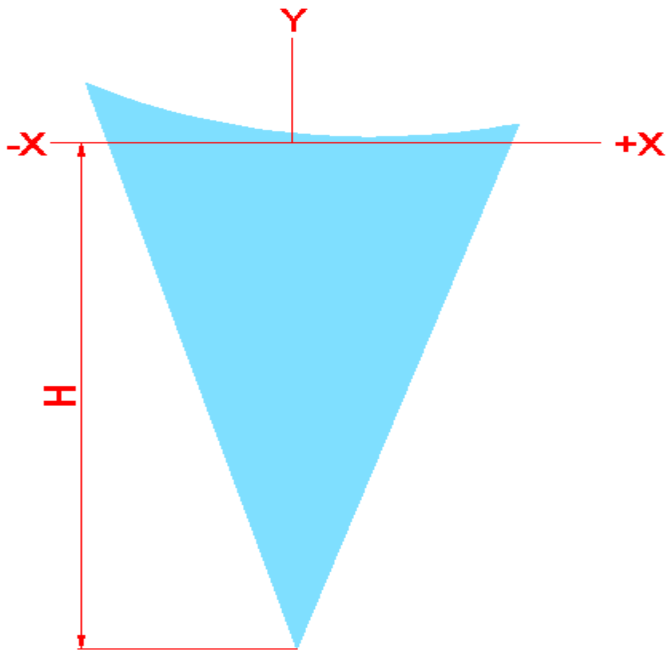


After assembly



Front View

Continue 5-1



The Four Corners before rolling

Note: if the assembly is concentric then E = 0 and F = 0

5-1 Corner no. 1

$$w = \sqrt{\left(\frac{C}{2} + E\right)^2 + \left(\frac{D}{2} + F\right)^2}$$

********** If w > A Then ***********

j = w – A

$$H = \sqrt{j^2 + B^2}$$

Continue 5-1

a- For Right curve (+X, Y)

$$m = \tan^{-1}\left(\frac{\frac{D}{2} - F}{\frac{C}{2} + E}\right)$$

b- For Left curve (-X, Y)

$$m = \tan^{-1}\left(\frac{\frac{C}{2} + E}{\frac{D}{2} - F}\right)$$

For i = 0 To m Step p

$$r = \sqrt{B^2 + A^2 * (\sin i)^2 + (A + j - A * \cos i)^2}$$

$$g = \sqrt{B^2 + A^2 * (\sin(i + p))^2 + (A + j - A * \cos(i + p))^2}$$

$$q = r^2 + g^2 - 4 * A^2 * (\mathrm{Sin}(\tfrac{p}{2}))^2$$

$$v = 2 * r * g$$

If q > v Then

Continue 5-1

$l = 0$

ElseIf v > q Then

$$l = \tan^{-1}\left(\frac{\sqrt{v^2 - q^2}}{q}\right)$$

$$k = \sum l$$

$$\mathbf{X = r * Sin(k - \mathit{l}\,)}$$

$$\mathbf{Y = r * Cos(k - \mathit{l}\,) - \sqrt{j^2 + B^2}}$$

Continue 5-1

********** If w = A Then ***********

$j = w - A$

$$H = \sqrt{j^2 + B^2}$$

a- For Right curve (+X, Y)

$$m = \tan^{-1}\left(\frac{\frac{D}{2} - F}{\frac{C}{2} + E}\right)$$

b- For Left curve (-X, Y)

$$m = \tan^{-1}\left(\frac{\frac{C}{2} + E}{\frac{D}{2} - F}\right)$$

For i = 0 To m Step p

$$r = \sqrt{B^2 + 4 * A^2 * (\sin\frac{i}{2})^2}$$

Continue 5-1

$$g = \sqrt{B^2 + 4 * A^2 * (\sin(\frac{i}{2} + \frac{p}{2}))^2}$$

$$q = r^2 + g^2 - 4 * A^2 * (\mathrm{Sin}(\frac{p}{2}))^2$$

$$v = 2 * r * g$$

If q > v Then

$l = 0$

ElseIf v > q Then

$$l = \tan^{-1}(\frac{\sqrt{v^2 - q^2}}{q})$$

$$k = \sum l$$

$X = r * \mathrm{Sin}(k - l)$

$Y = r * \mathrm{Cos}(k - l) - B$

Continue 5-1

********** If w < A Then ***********

j = A - w

$$H = \sqrt{j^2 + B^2}$$

a- For Right curve (+X, Y)

$$m = \tan^{-1}\left(\frac{\frac{D}{2} - F}{\frac{C}{2} + E}\right)$$

b- For Left curve (-X, Y)

$$m = \tan^{-1}\left(\frac{\frac{C}{2} + E}{\frac{D}{2} - F}\right)$$

For i = 0 To m Step p

$$r = \sqrt{B^2 + A^2 * (\sin i)^2 + (A + j - A * \cos\ i)^2}$$

$$g = \sqrt{B^2 + A^2 * (\sin(i + p))^2 + (j - A + A * \cos(i + p))^2}$$

$$q = r^2 + g^2 - 4 * A^2 * (\mathrm{Sin}(\tfrac{p}{2}))^2$$

Continue 5-1

v = 2 * r * g

If q > v Then

$l = 0$

ElseIf v > q Then

$$l = \tan^{-1}\left(\frac{\sqrt{v^2 - q^2}}{q}\right)$$

$$k = \sum l$$

$X = r * \mathrm{Sin}(k - l)$

$Y = r * \mathrm{Cos}(k - l) - \sqrt{j^2 + B^2}$

5-2 Corner no. 2

$$w = \sqrt{\left(\frac{C}{2} - E\right)^2 + \left(\frac{D}{2} + F\right)^2}$$

********** If w > A Then ***********

j = w – A

$$H = \sqrt{j^2 + B^2}$$

a- For Right curve (+X, Y)

$$m = \tan^{-1}\left(\frac{\frac{D}{2} + F}{\frac{C}{2} - E}\right)$$

b- For Left curve (-X, Y)

$$m = \tan^{-1}\left(\frac{\frac{C}{2} - E}{\frac{D}{2} + F}\right)$$

For i = 0 To m Step p

Continue 5-2

$$r = \sqrt{B^2 + A^2 * (\sin i)^2 + (A + j - A * \cos i)^2}$$

$$g = \sqrt{B^2 + A^2 * (\sin(i + p))^2 + (A + j - A * \cos(i + p))^2}$$

$q = r^2 + g^2 - 4 * A^2 * (\mathrm{Sin}(\frac{p}{2}))^2$

$v = 2 * r * g$

If $q > v$ Then

$l = 0$

ElseIf $v > q$ Then

$l = \tan^{-1}(\frac{\sqrt{v^2 - q^2}}{q})$

$k = \sum l$

$$X = r * \mathrm{Sin}(k - l)$$

$$Y = r * \mathrm{Cos}(k - l) - \sqrt{j^2 + B^2}$$

Continue 5-2

********** If w = A Then ***********

$j = w - A$

$$H = \sqrt{j^2 + B^2}$$

a- For Right curve (+X, Y)

$$m = \tan^{-1}\left(\frac{\frac{D}{2} - F}{\frac{C}{2} + E}\right)$$

b- For Left curve (-X, Y)

$$m = \tan^{-1}\left(\frac{\frac{C}{2} + E}{\frac{D}{2} - F}\right)$$

For i = 0 To m Step p

$$r = \sqrt{B^2 + 4 * A^2 * \left(\sin\frac{i}{2}\right)^2}$$

Continue 5-2

$$g = \sqrt{B^2 + 4 * A^2 * (\sin(\frac{i}{2} + \frac{p}{2}))^2}$$

$$q = r^2 + g^2 - 4 * A^2 * (\mathrm{Sin}(\frac{p}{2}))^2$$

$$v = 2 * r * g$$

If q > v Then

$$l = 0$$

ElseIf v > q Then

$$l = \tan^{-1}(\frac{\sqrt{v^2 - q^2}}{q})$$

$$k = \sum l$$

$$\mathbf{X = r * Sin(k - \mathit{l})}$$

$$\mathbf{Y = r * Cos(k - \mathit{l}) - B}$$

Continue 5-2

********** If w < A Then ***********

j = A - w

$$H = \sqrt{j^2 + B^2}$$

c- For Right curve (+X, Y)

$$m = \tan^{-1}\left(\frac{\frac{D}{2} + F}{\frac{C}{2} - E}\right)$$

d- For Left curve (-X, Y)

$$m = \tan^{-1}\left(\frac{\frac{C}{2} - E}{\frac{D}{2} + F}\right)$$

For i = 0 To m Step p

$$r = \sqrt{B^2 + A^2 * (\sin i)^2 + (A + j - A * \cos\ i)^2}$$

$$g = \sqrt{B^2 + A^2 * (\sin(i + p))^2 + (j - A + A * \cos(i + p))^2}$$

$$q = r^2 + g^2 - 4 * A^2 * (\mathrm{Sin}(\tfrac{p}{2}))^2$$

Continue 5-2

v = 2 * r * g

If q > v Then

$l = 0$

ElseIf v > q Then

$$l = \tan^{-1}\left(\frac{\sqrt{v^2 - q^2}}{q}\right)$$

$$k = \sum l$$

$X = r * \mathrm{Sin}(k - l)$

$Y = r * \mathrm{Cos}(k - l) - \sqrt{j^2 + B^2}$

5-3 Corner no. 3

$$w = \sqrt{\left(\frac{C}{2} + E\right)^2 + \left(\frac{D}{2} - F\right)^2}$$

********** If w > A Then ***********

j = w – A

$$H = \sqrt{j^2 + B^2}$$

a- For Right curve (+X, Y)

$$m = \tan^{-1}\left(\frac{\frac{D}{2} + F}{\frac{C}{2} + E}\right)$$

b- For Left curve (-X, Y)

$$m = \tan^{-1}\left(\frac{\frac{C}{2} + E}{\frac{D}{2} + F}\right)$$

For i = 0 To m Step p

Continue 5-3

$$r = \sqrt{B^2 + A^2 * (\sin i)^2 + (A + j - A * \cos i)^2}$$

$$g = \sqrt{B^2 + A^2 * (\sin(i + p))^2 + (A + j - A * \cos(i + p))^2}$$

$$q = r^2 + g^2 - 4 * A^2 * (\mathrm{Sin}(\frac{p}{2}))^2$$

$$v = 2 * r * g$$

If q > v Then

$l = 0$

ElseIf v > q Then

$$l = \tan^{-1}(\frac{\sqrt{v^2 - q^2}}{q})$$

$$k = \sum l$$

$$\mathbf{X = r * Sin(k - \mathit{l})}$$

$$\mathbf{Y = r * Cos(k - \mathit{l}) - \sqrt{j^2 + B^2}}$$

Continue 5-3

********** If w = A Then ***********

$j = w - A$

$$H = \sqrt{j^2 + B^2}$$

c- For Right curve (+X, Y)

$$m = \tan^{-1}\left(\frac{\frac{D}{2} + F}{\frac{C}{2} + E}\right)$$

d- For Left curve (-X, Y)

$$m = \tan^{-1}\left(\frac{\frac{C}{2} + E}{\frac{D}{2} - F}\right)$$

For i = 0 To m Step p

$$r = \sqrt{B^2 + 4 * A^2 * (\sin\frac{i}{2})^2}$$

Continue 5-3

$$g = \sqrt{B^2 + 4 * A^2 * (\sin(\frac{i}{2} + \frac{p}{2}))^2}$$

$$q = r^2 + g^2 - 4 * A^2 * (\mathrm{Sin}(\frac{p}{2}))^2$$

$$v = 2 * r * g$$

If q > v Then

$$l = 0$$

ElseIf v > q Then

$$l = \tan^{-1}(\frac{\sqrt{v^2 - q^2}}{q})$$

$$k = \sum l$$

$$\mathbf{X = r * Sin(k - \mathit{l}\,)}$$

$$\mathbf{Y = r * Cos(k - \mathit{l}\,) - B}$$

Continue 5-3

********** If w < A Then ***********

j = A - w

$$H = \sqrt{j^2 + B^2}$$

c- For Right curve (+X, Y)

$$m = \tan^{-1}\left(\frac{\frac{D}{2} + F}{\frac{C}{2} + E}\right)$$

d- For Left curve (-X, Y)

$$m = \tan^{-1}\left(\frac{\frac{C}{2} + E}{\frac{D}{2} + F}\right)$$

For i = 0 To m Step p

$$r = \sqrt{B^2 + A^2 * (\sin i)^2 + (A + j - A * \cos\ i)^2}$$

$$g = \sqrt{B^2 + A^2 * (\sin(i + p))^2 + (j - A + A * \cos(i + p))^2}$$

$$q = r^2 + g^2 - 4 * A^2 * (\mathrm{Sin}(\tfrac{p}{2}))^2$$

Continue 5-3

$v = 2 * r * g$

If q > v Then

$l = 0$

ElseIf v > q Then

$$l = \tan^{-1}\left(\frac{\sqrt{v^2 - q^2}}{q}\right)$$

$k = \sum l$

$X = r * \mathrm{Sin}(k - l)$

$Y = r * \mathrm{Cos}(k - l) - B$

5-4 Corner no. 4

$$w = \sqrt{\left(\frac{C}{2} - E\right)^2 + \left(\frac{D}{2} - F\right)^2}$$

********** If w > A Then ***********

j = w – A

$$H = \sqrt{j^2 + B^2}$$

c- For Right curve (+X, Y)

$$m = \tan^{-1}\left(\frac{\frac{D}{2} - F}{\frac{C}{2} - E}\right)$$

d- For Left curve (-X, Y)

$$m = \tan^{-1}\left(\frac{\frac{C}{2} - E}{\frac{D}{2} - F}\right)$$

For i = 0 To m Step p

Continue 5-4

$$r = \sqrt{B^2 + A^2 * (\sin i)^2 + (A + j - A * \cos i)^2}$$

$$g = \sqrt{B^2 + A^2 * (\sin(i + p))^2 + (A + j - A * \cos(i + p))^2}$$

$$q = r^2 + g^2 - 4 * A^2 * (\mathrm{Sin}(\frac{p}{2}))^2$$

$$v = 2 * r * g$$

If q > v Then

$$l = 0$$

ElseIf v > q Then

$$l = \tan^{-1}(\frac{\sqrt{v^2 - q^2}}{q})$$

$$k = \sum l$$

$$\mathbf{X = r * Sin(k - \mathit{l})}$$

$$\mathbf{Y = r * Cos(k - \mathit{l}) - \sqrt{j^2 + B^2}}$$

Continue 5-4

********** If w = A Then ***********

$j = w - A$

$$H = \sqrt{j^2 + B^2}$$

e- For Right curve (+X, Y)

$$m = \tan^{-1}\left(\frac{\frac{D}{2} - F}{\frac{C}{2} - E}\right)$$

f- For Left curve (-X, Y)

$$m = \tan^{-1}\left(\frac{\frac{C}{2} - E}{\frac{D}{2} - F}\right)$$

For i = 0 To m Step p

$$r = \sqrt{B^2 + 4 * A^2 * (\sin\frac{i}{2})^2}$$

Continue 5-4

$$g = \sqrt{B^2 + 4 * A^2 * (\sin(\frac{i}{2} + \frac{p}{2}))^2}$$

$$q = r^2 + g^2 - 4 * A^2 * (\sin(\frac{p}{2}))^2$$

$$v = 2 * r * g$$

If q > v Then

$$l = 0$$

ElseIf v > q Then

$$l = \tan^{-1}(\frac{\sqrt{v^2 - q^2}}{q})$$

$$k = \sum l$$

$$\mathbf{X = r * Sin(k - \mathit{l})}$$

$$\mathbf{Y = r * Cos(k - \mathit{l}) - B}$$

Continue 5-4

********** If w < A Then ***********

j = A - w

$$H = \sqrt{j^2 + B^2}$$

e- For Right curve (+X, Y)

$$m = \tan^{-1}\left(\frac{\frac{D}{2} - F}{\frac{C}{2} - E}\right)$$

f- For Left curve (-X, Y)

$$m = \tan^{-1}\left(\frac{\frac{C}{2} - E}{\frac{D}{2} - F}\right)$$

For i = 0 To m Step p

$$r = \sqrt{B^2 + A^2 * (\sin i\,)^2 + (A + j - A * \cos\ i)^2}$$

$$g = \sqrt{B^2 + A^2 * (\sin(i + p))^2 + (j - A + A * \cos(i + p))^2}$$

$$q = r^2 + g^2 - 4 * A^2 * (\text{Sin}(\tfrac{p}{2}))^2$$

Continue 5-4

$v = 2 * r * g$

If $q > v$ Then

$l = 0$

ElseIf $v > q$ Then

$$l = \tan^{-1}\left(\frac{\sqrt{v^2 - q^2}}{q}\right)$$

$$k = \sum l$$

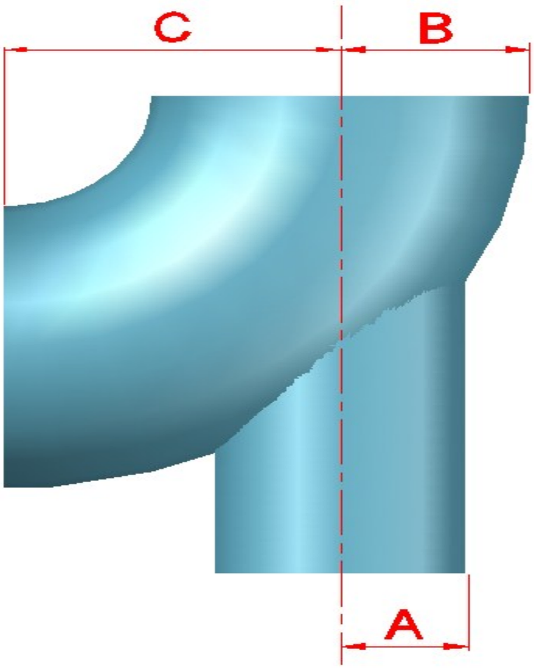
$$\mathbf{X = r * Sin(k - \mathit{l})}$$

$$\mathbf{Y = r * Cos(k - \mathit{l}) - \sqrt{j^2 + B^2}}$$

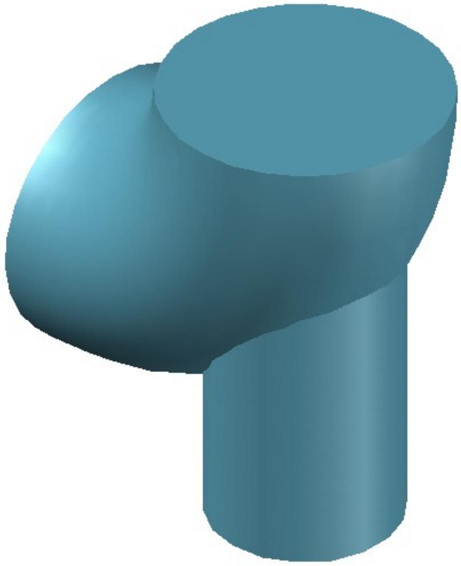
CHAPTER – 6

ELBOWS WITH CYLINDERS

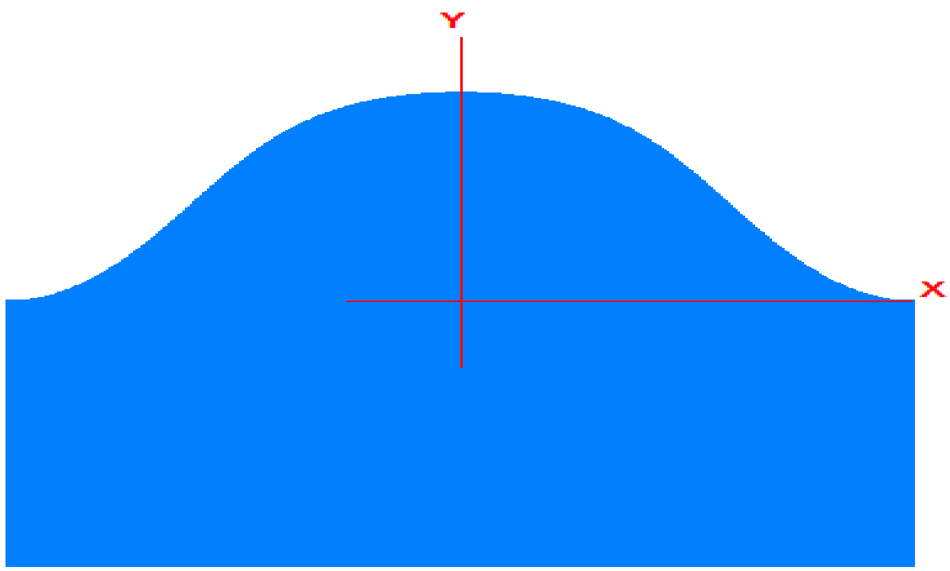
6-1 Elbow with Cylinder (Centered)



Assembly dimensions



Cylinder after rolling



Cylinder before rolling

Continue 6-1

For w = 0 To 180

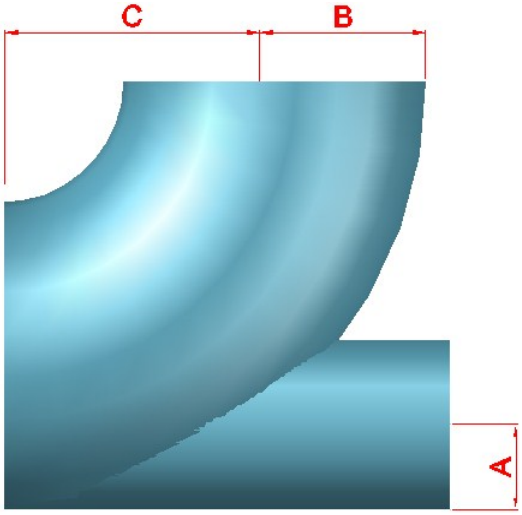
$$n = \sqrt{B^2 - A^2 * (\sin w)^2}$$

$$\mathbf{X = w * A * pi / 180}$$

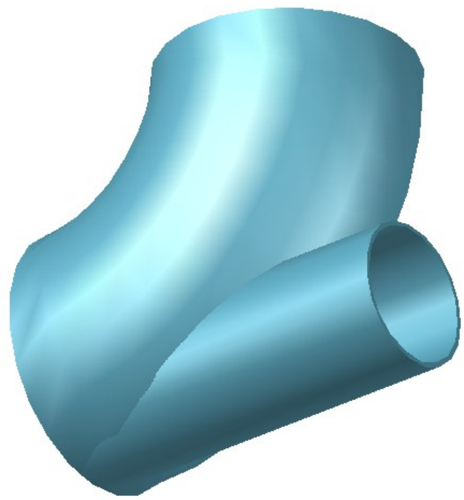
$$g = \sqrt{(C + n)^2 - (C + A * \cos\ w)^2}$$

$$\mathbf{Y = \sqrt{(C + B)^2 - (C - A)^2)}\ - g}$$

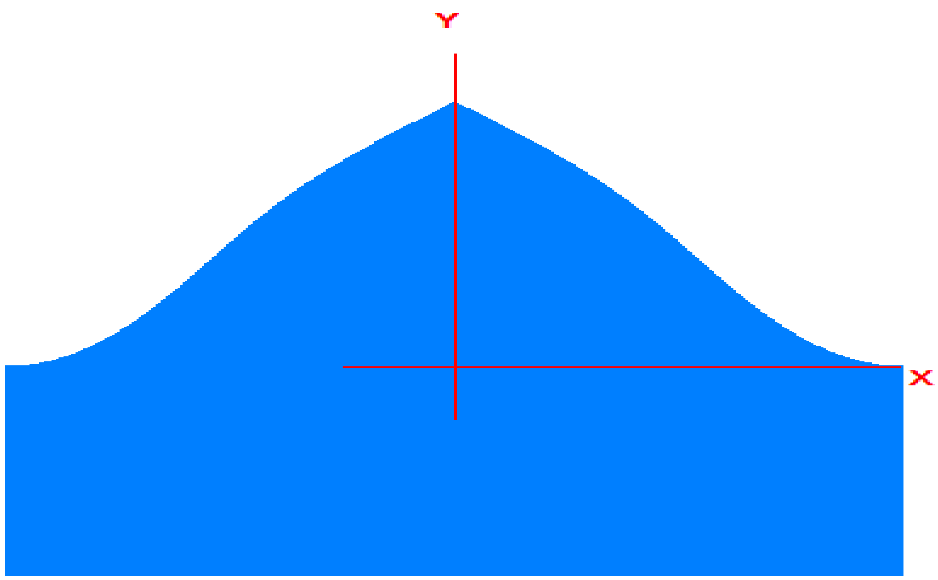
6-2 Elbow with Cylinder (Same bottom elevation)



Assembly dimensions



Cylinder after rolling



Cylinder before rolling

Continue 6-2

For w = 0 To 180

$$h = \sqrt{(C + B)^2 - (C + B - 2 * A)^2}$$

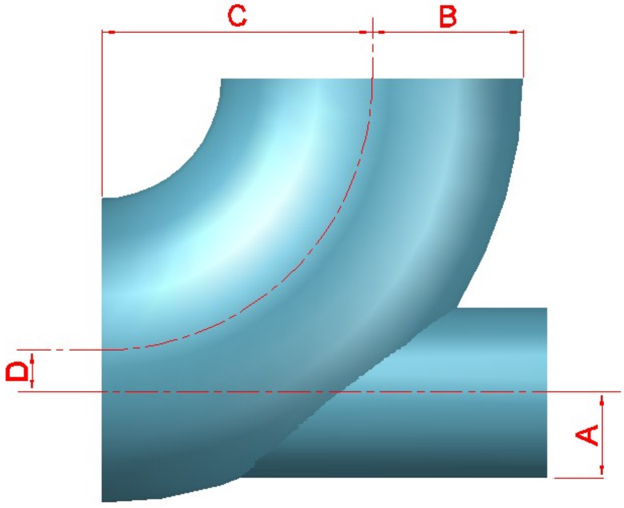
$$r = c + \sqrt{B^2 - A^2 * (\sin w)^2}$$

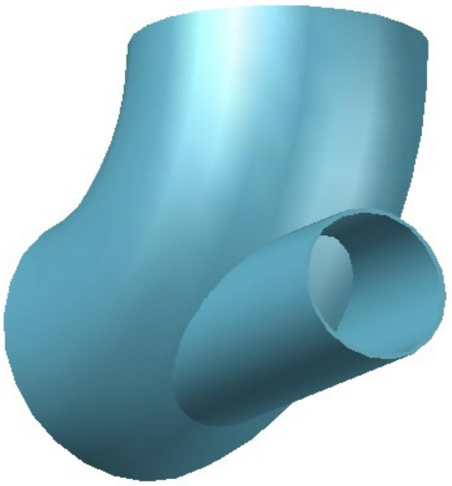
$$m = A * (1 - \cos\ w) - B + \sqrt{B^2 - A^2 * (\sin w)^2}$$

$$\mathbf{X = w * A * pi / 180}$$

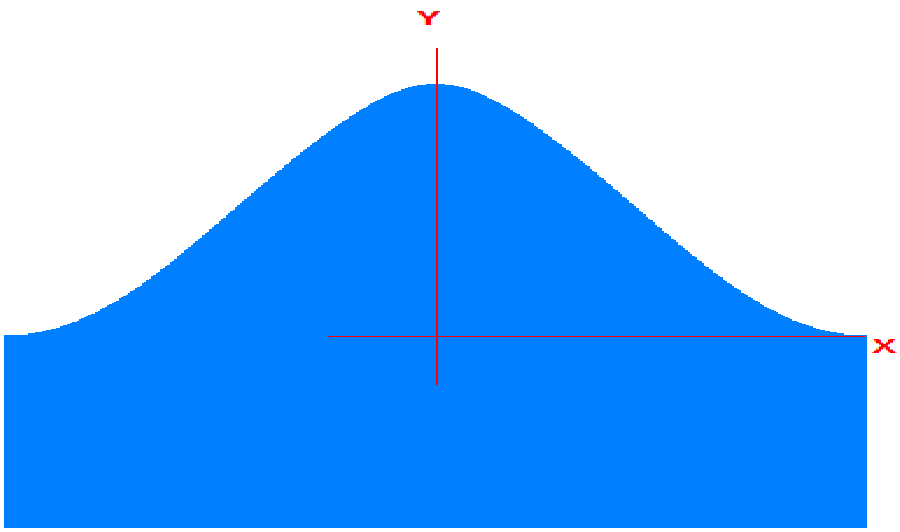
$$\mathbf{Y = h - \sqrt{r^2 - (r - m)^2}}$$

6-3 Elbow with Cylinder (Eccentric)





Assembly dimensions Cylinder after rolling



Cylinder before rolling

Continue 6-3

For w = 180 To 0

m = C + D - A * Cos w

$$r = c + \sqrt{B^2 - A^2 * (\sin w)^2}$$

$$k = r - \sqrt{r^2 - m^2}$$

$$f = C + B - \sqrt{(C + B)^2 - (C + D - A)^2}$$

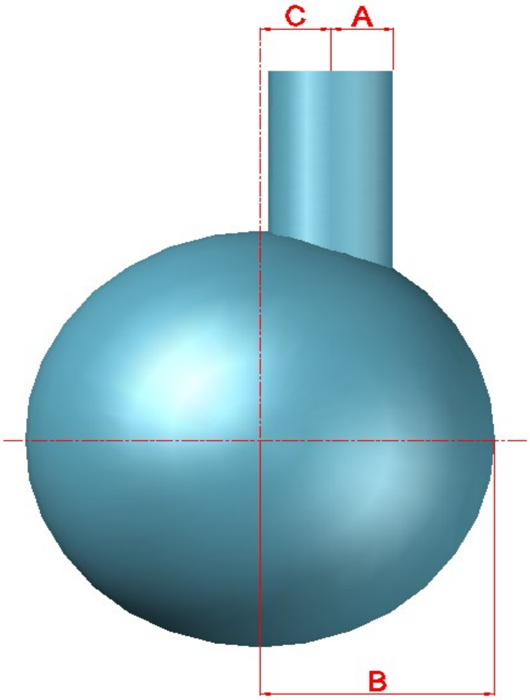
$$\mathbf{X = (180 - w) * A * \pi / 180}$$

$$\mathbf{Y = k + B - f - \sqrt{B^2 - A^2 * (\sin w)^2}}$$

CHAPTER – 7

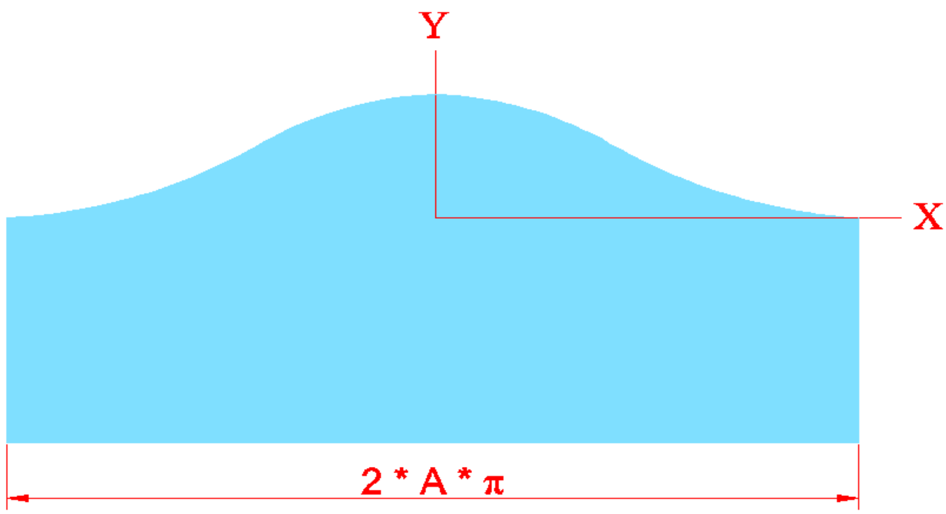
SPHARE WITH CYLINDER

7- 1 Sphare with Cylinder



Assembly dimensions

Cylinders after rolling



Cylinder before rolling

Continue 7-1

For i = 0 To 180

$$X = \frac{i * \pi * A}{180}$$

$$Y = \sqrt{B^2 - (C - A)^2} - \sqrt{B^2 - (A * \cos(i) + C)^2}$$

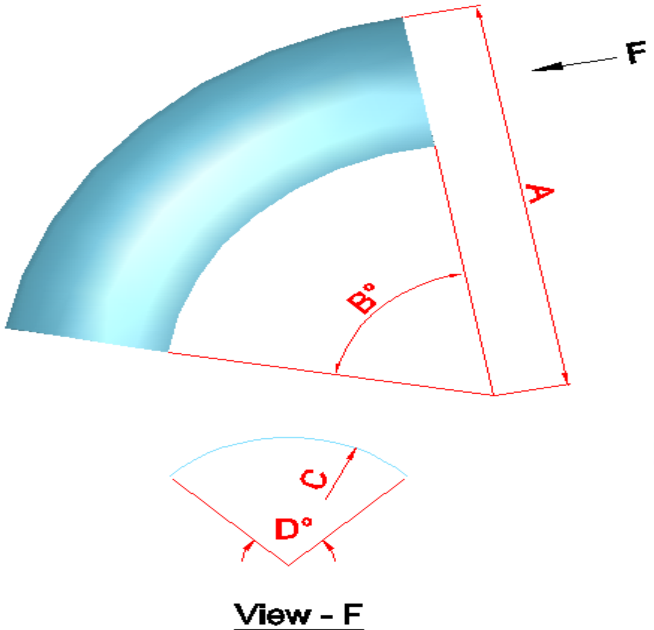
Notes:

- The length of cylinder is optional.
- The left curve is same as right curve.
- The steps of (i) are optionals.
- B > (C + A)

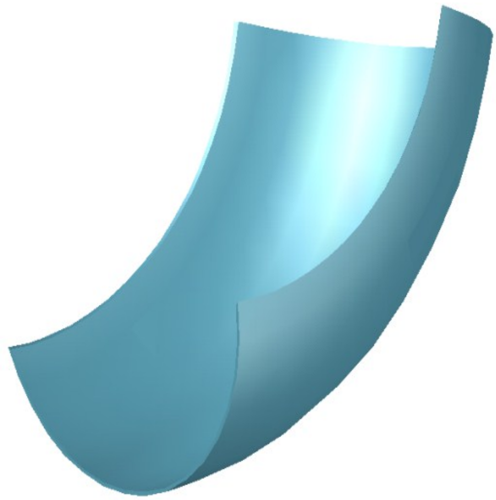
CHAPTER – 8

ELBOWS

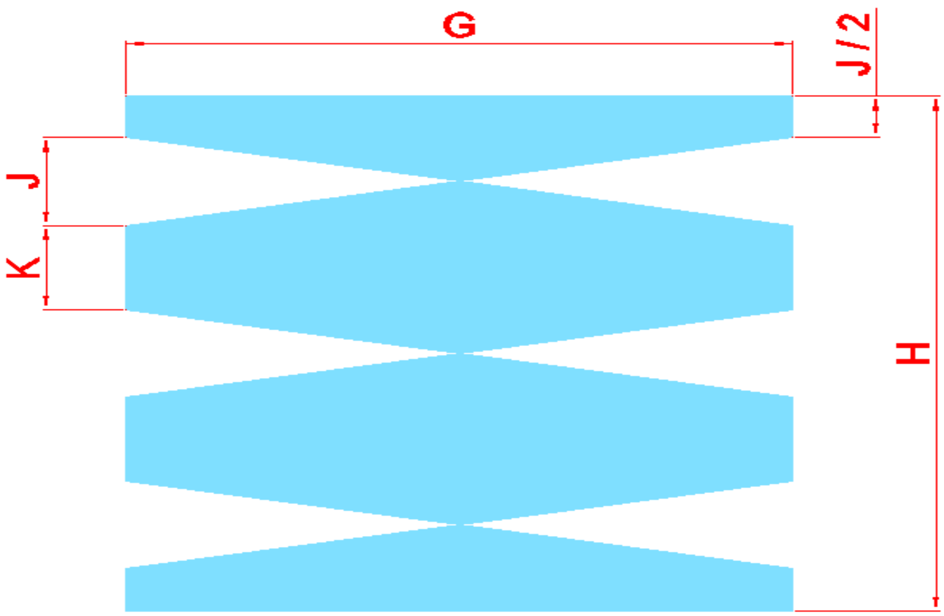
8-1 Part of Elbow



Dimensions



Part of Elbow after rolling



Part of Elbow before rolling

Continue 8-1

$$G = \frac{\pi * C * D}{180}$$

$$H = \frac{\pi * A * B}{180}$$

$$m = \frac{B * \pi * \{A - C * (1-\cos \frac{D}{2})\}}{180}$$

$$K = \frac{m}{E-1}$$

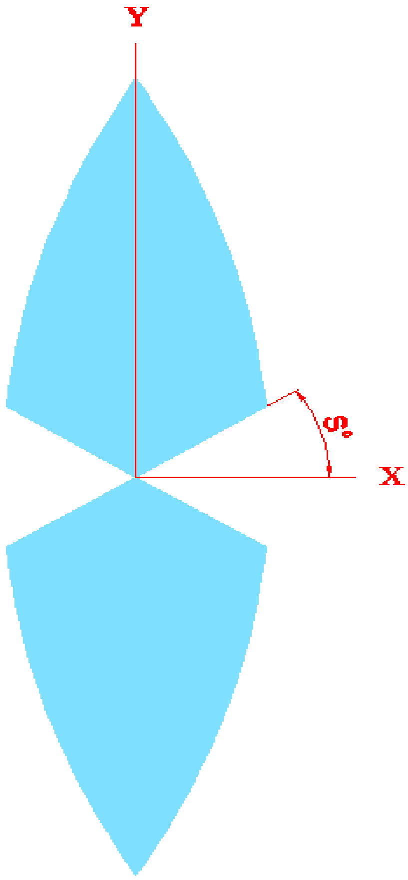
Note : E is the number of pieces required (for example the number of pieces in drawing above is 4.

$$J = \frac{H - m}{E-1}$$

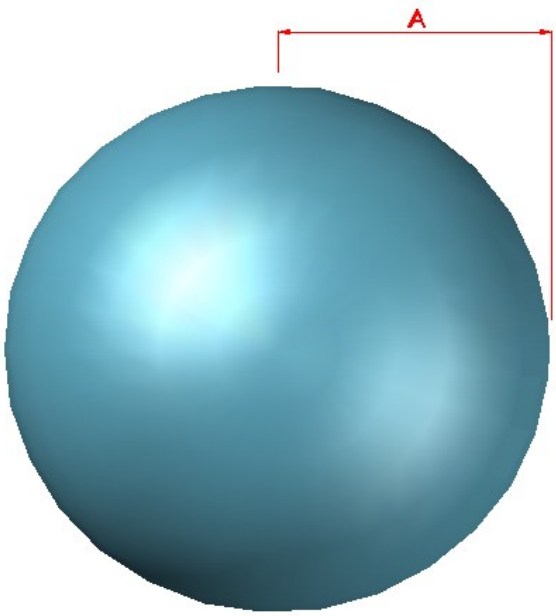
CHAPTER – 9

SPHARES

9-1 Sphare



Dimensions of one part



Sphare after rolling

Note : B is the number of pieces

$$r = B * A * \pi * \left(\frac{\frac{1}{B^2} + 0.25}{2}\right)$$

Continue 9-1

$$k = r * \tan^{-1}\left(\frac{A * \pi}{\sqrt{(4 * r^2 - A^2 * \pi^2)}}\right))$$

$$c = \left\{\frac{180 * \left(k - A * \frac{\pi}{2}\right)}{r * \pi}\right\}$$

$$S = \tan^{-1}\left\{\frac{\text{Sin } c}{\cos(c) - 1 + \frac{A * \pi}{B * r}}\right\}$$

$$w = \frac{A * \pi}{2}$$

For i = 0 To w

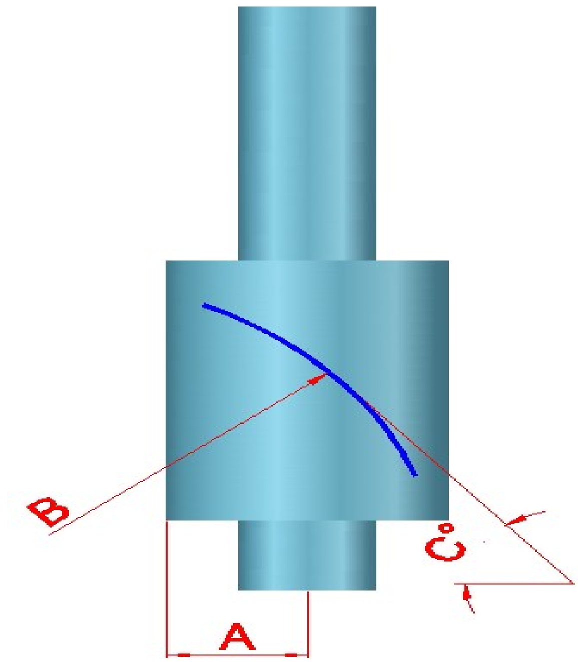
$$\mathbf{X} = \frac{\mathbf{A * \pi * \cos\left(\frac{180 * i}{A * \pi}\right)}}{\mathbf{B}}$$

Y = i

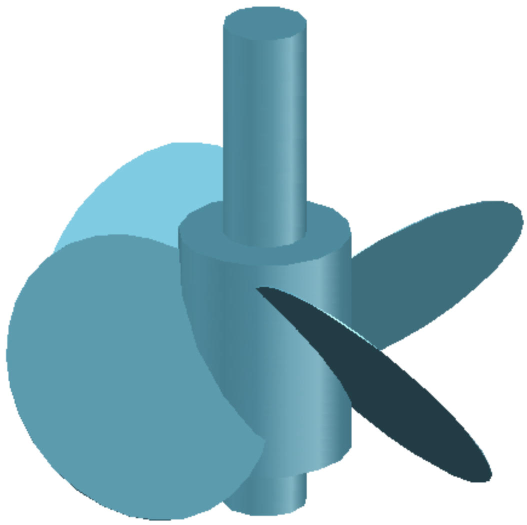
CHAPTER – 10

FANS

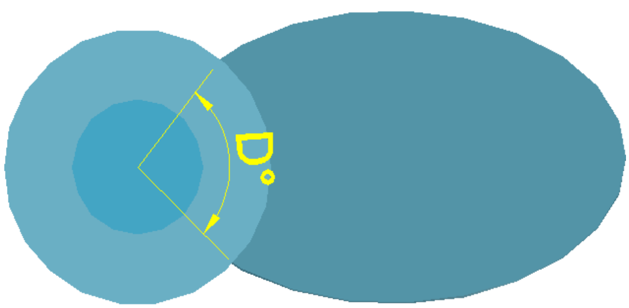
10-1 Fan



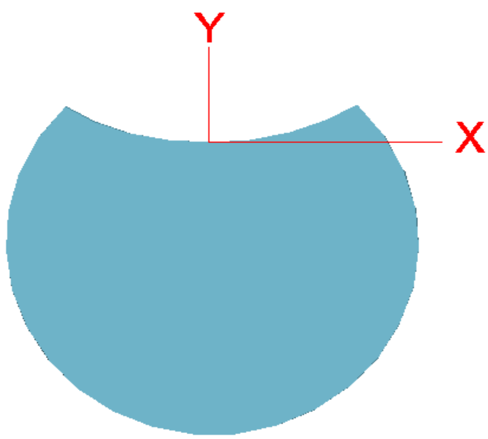
Dimensions



Fan after Connection



Fan Top view



Fan before installation

10-1 Left curve (From –X to 0 axis)

If B = 0 Then

B = 1000000

$$z = \sqrt{B^2 - \frac{A^2 * (\sin D)^2}{(\cos C)^2}}$$

k = z * Sin C

For u = $(90 - \frac{D}{2})$ to 90

$$Y = A * (1 - \sin u)$$

$$m = \tan^{-1}\left\{\frac{\sqrt{B^2 - z^2 * (\sin k)^2}}{z * \sin k}\right\}$$

$$n = \tan^{-1}\left\{\frac{\sqrt{B^2 - (A * \cos(u) + z * \sin k)^2}}{A * \cos(u) + z * \sin k}\right\}$$

$$X = \frac{\pi * B * (m - n)}{180}$$

10-2 Right curve (From 0 to +X axis)

For u = 90 to $(90 + \frac{D}{2})$

Y = A * (1 – Sin u)

$$m = \tan^{-1}\{\frac{\sqrt{B^2 - z^2 * (\sin k)^2}}{z * \sin k}\}$$

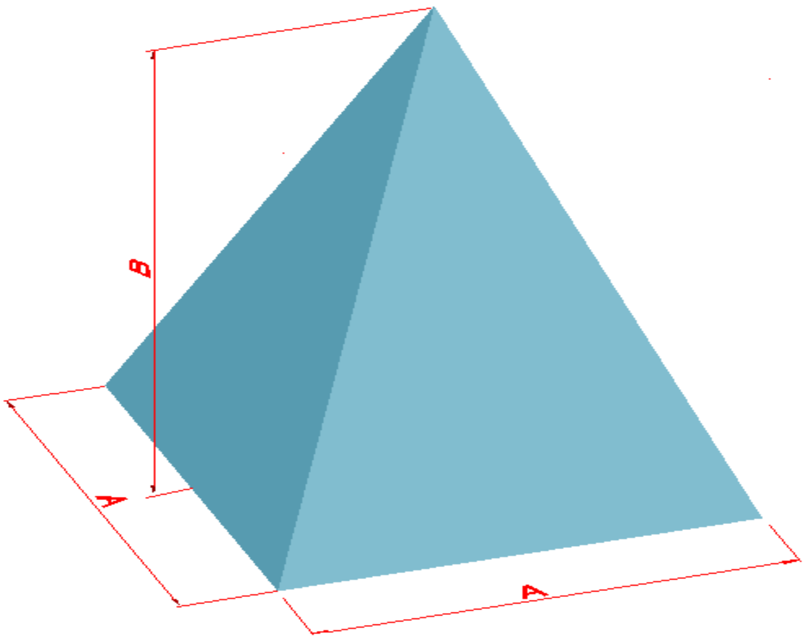
$$n = \tan^{-1}\{\frac{\sqrt{B^2 - (A * \cos(u) + z * \sin k)^2}}{A * \cos(u) + z * \sin k}\}$$

$$\boldsymbol{X = \frac{\pi * B * (n - m)}{180}}$$

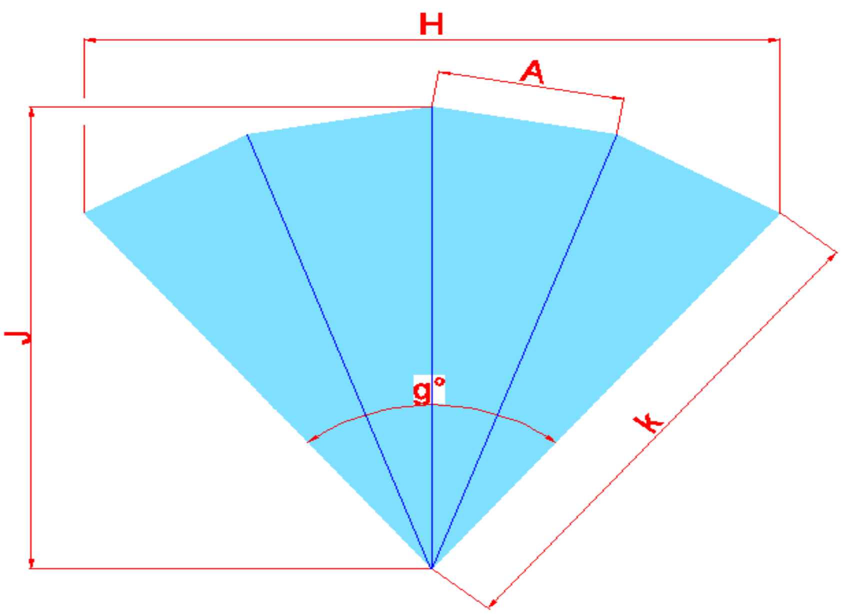
CHAPTER – 11

PYRAMIDS

11- 1 Pyramids



Pyramid after connection



Pyramid before assembly

Continue 11-1

Note: C is the number of sides required

$$k = \sqrt{B^2 + \{\frac{A}{2 * \sin(\frac{180}{C})}\}^2}$$

$$g = 2 * C * \tan^{-1}(\frac{A}{\sqrt{4 * k^2 - A^2}})$$

$$H = 2 * k * \cos(90 - \frac{g}{2})$$

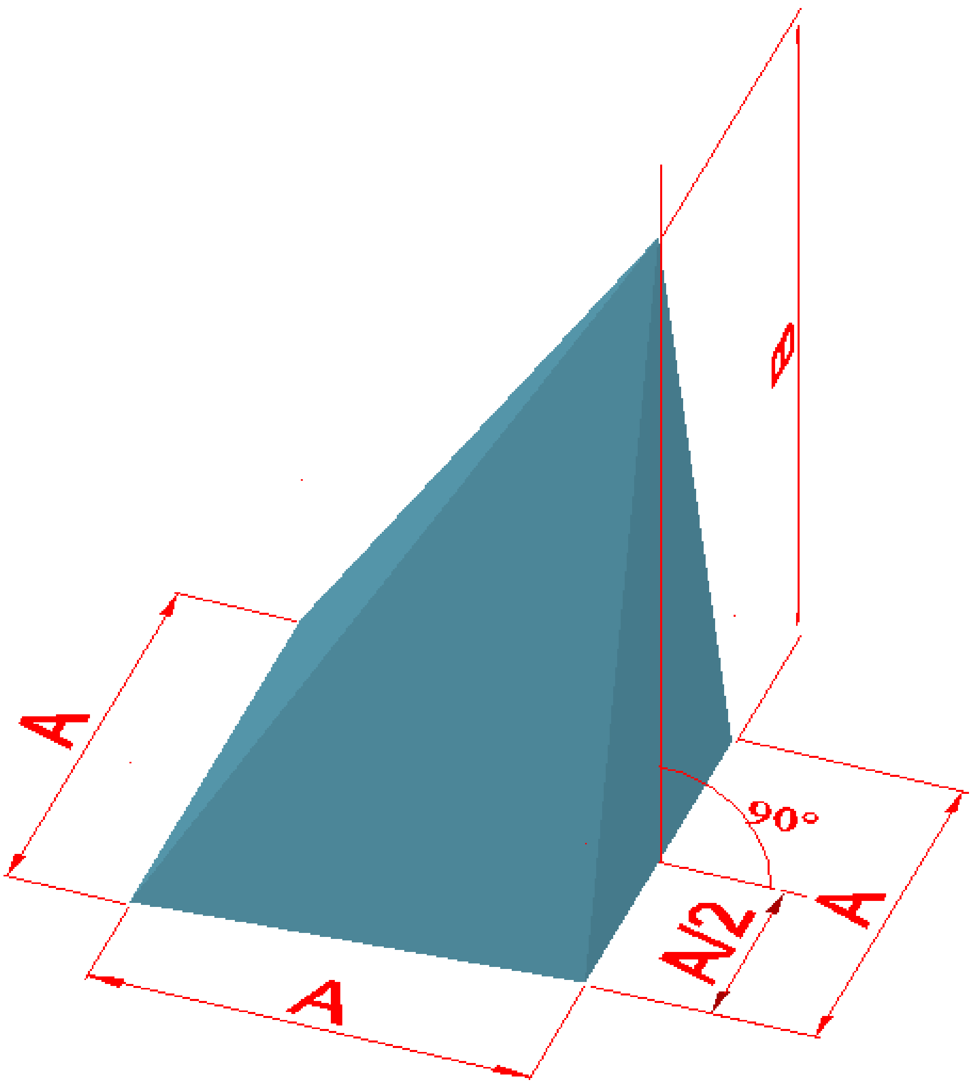
If C is even nember then

$$J = k$$

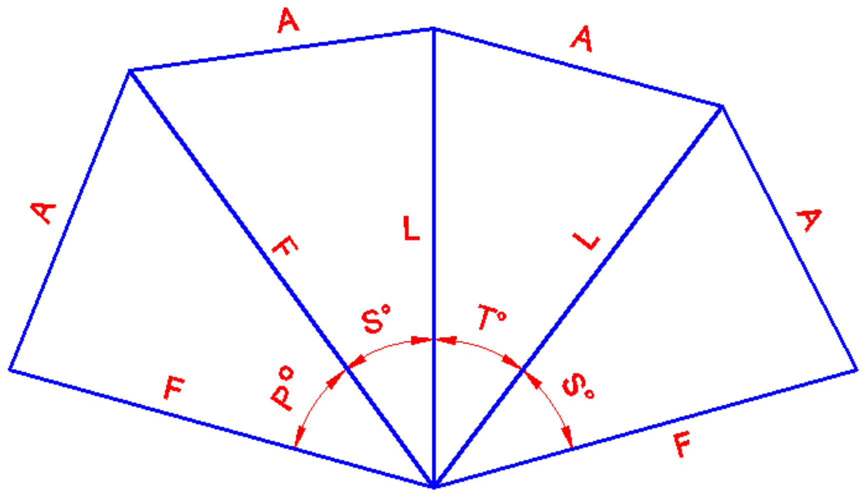
If C is odd number then

$$J = \sqrt{k^2 - (\frac{A}{2})^2}$$

11-2 Orthogonal Pyramid Four Sides



Continue 11-2



$$L = \sqrt{B^2 + \frac{A^2}{4}}$$

$$F = \sqrt{B^2 + \frac{5 * A^2}{4}}$$

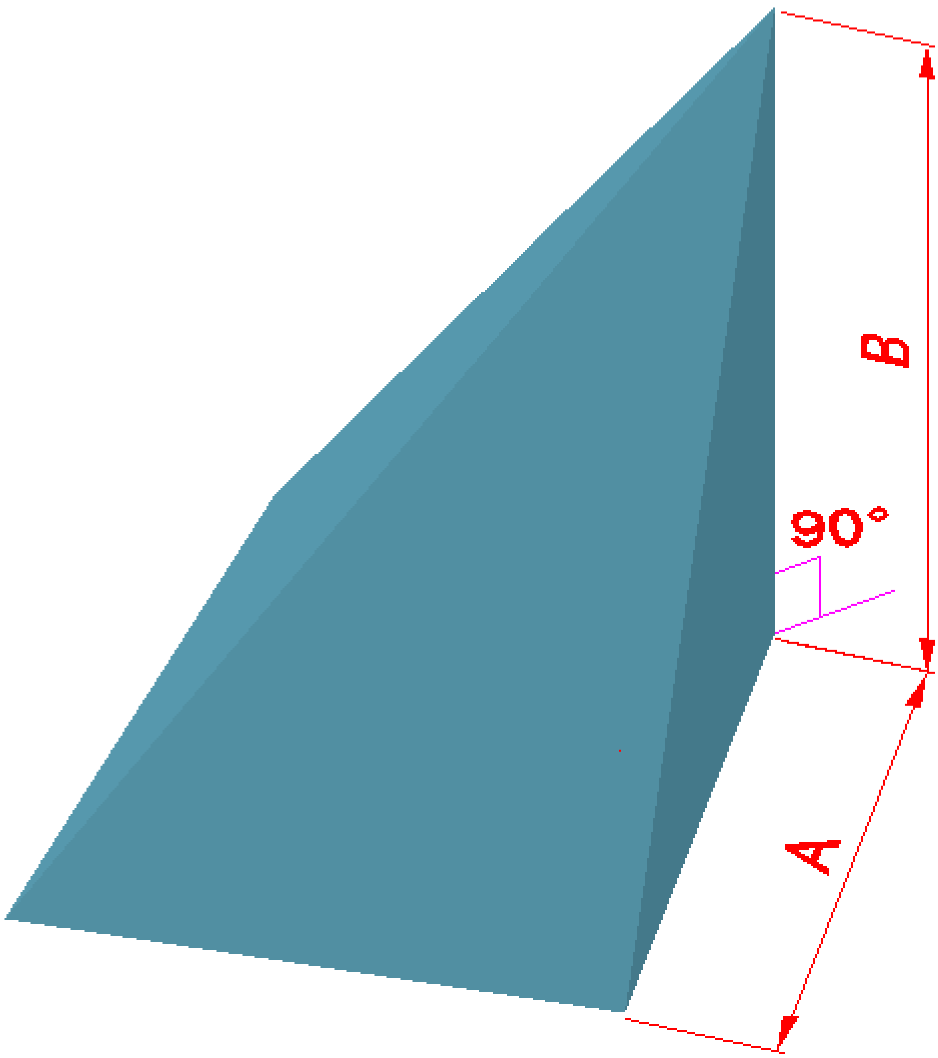
$$T^\circ = 2 * \tan^{-1}(\frac{A}{2 * B})$$

$$n = \frac{L^2 - A^2 + F^2}{2 * F}$$

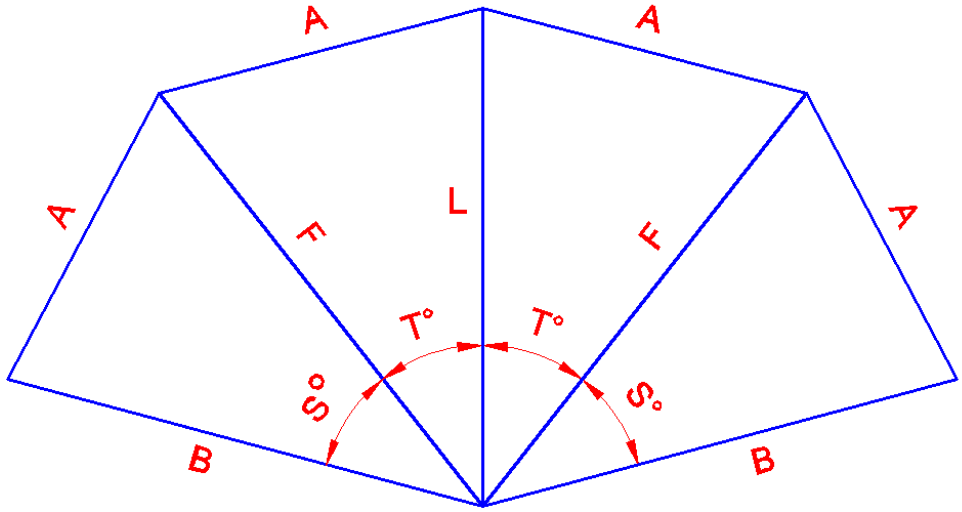
$$S^\circ = \cos^{-1}(\frac{n}{L})$$

$$P^\circ = 2 * \sin^{-1}(\frac{A}{2 * F})$$

11-3 Orthogonal Pyramid Four Sides



Continue 11-3



$$F = \sqrt{B^2 + A^2}$$

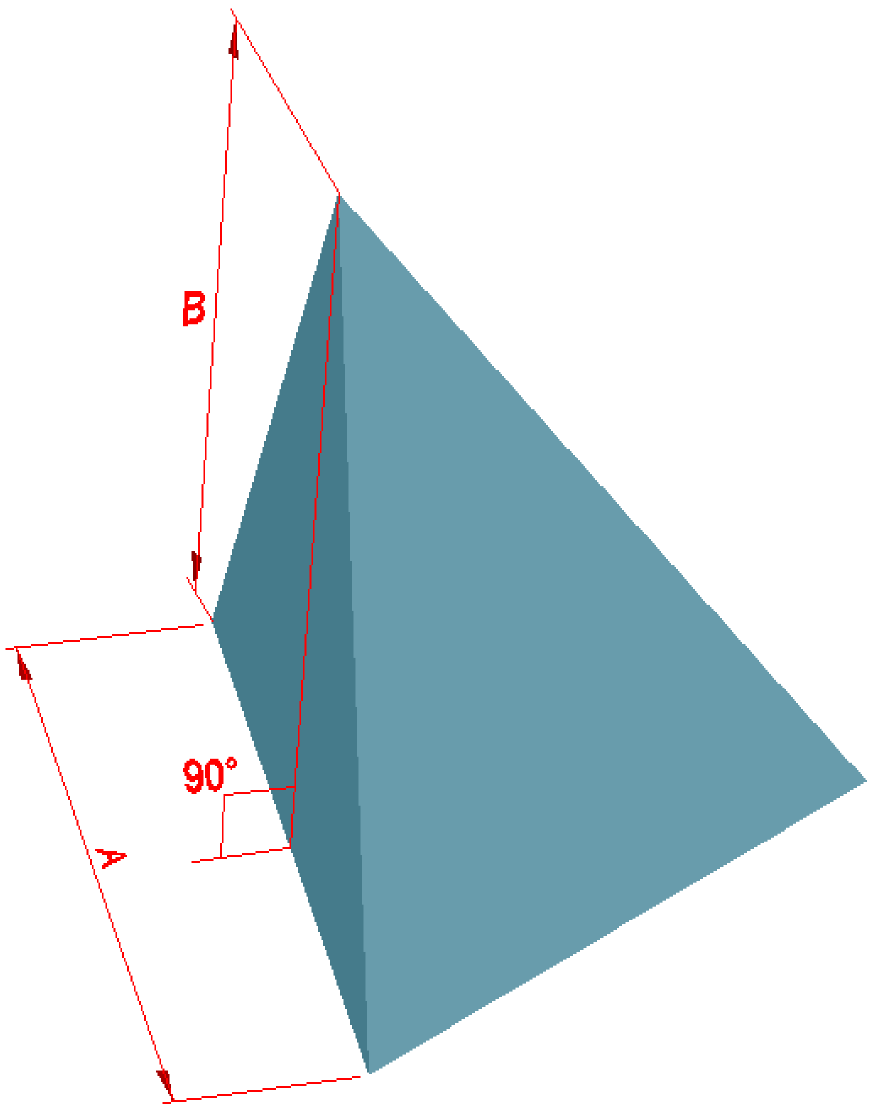
$$L = \sqrt{B^2 + 2 * A^2}$$

$$S^\circ = \tan^{-1}\left(\frac{A}{B}\right)$$

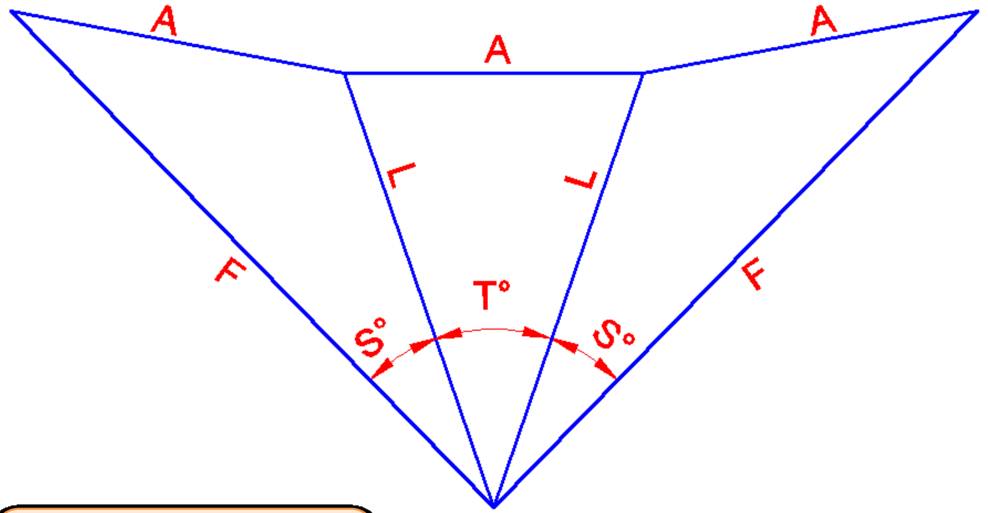
$$n = \frac{F^2 - A^2 + L^2}{2 * L}$$

$$T^\circ = \cos^{-1}\left(\frac{n}{F}\right)$$

11-4 Orthogonal Pyramid Three Sides



Continue 11-4



$$L = \sqrt{B^2 + (\frac{A}{B})^2}$$

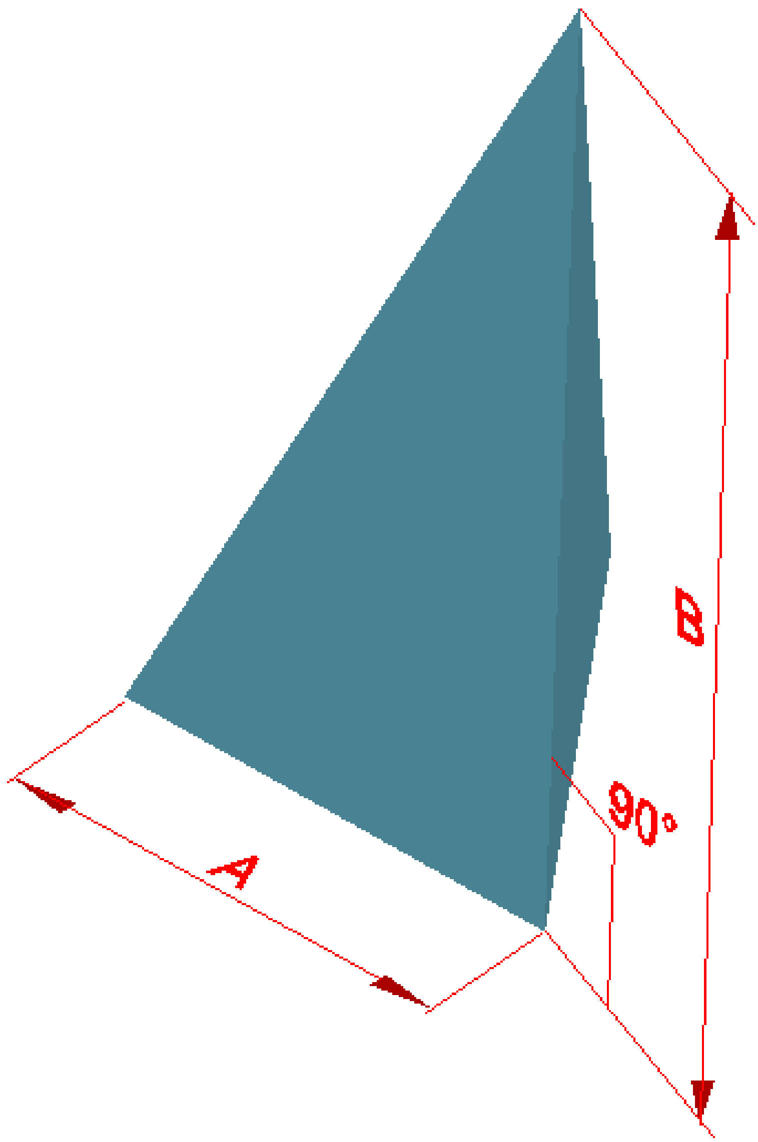
$$F = \sqrt{B^2 + \frac{3 * A^2}{4}}$$

$$T^\circ = 2 * \tan^{-1}(\frac{A}{2 * B})$$

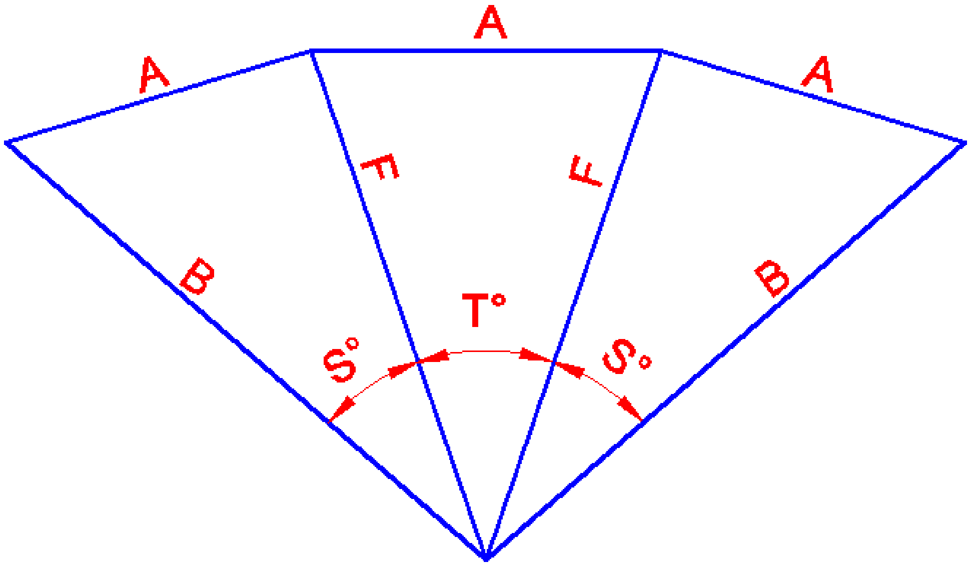
$$n = \frac{L^2 - A^2 + F^2}{2 * F}$$

$$S^\circ = \cos^{-1}(\frac{n}{L})$$

11-5 Orthogonal Pyramid Three Sides



Continue 11-5



$$F = \sqrt{B^2 + A^2}$$

$$S^\circ = \tan^{-1}(\frac{A}{B})$$

$$T^\circ = 2 * \sin^{-1}(\frac{A}{2 * F})$$