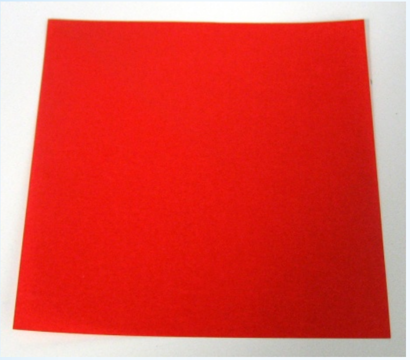
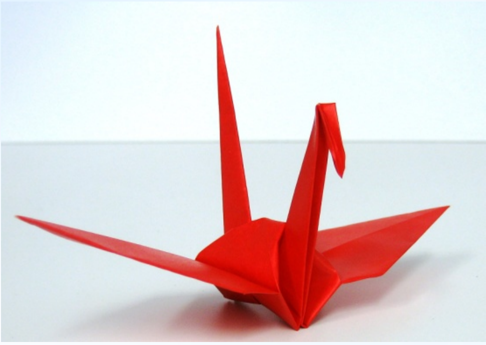
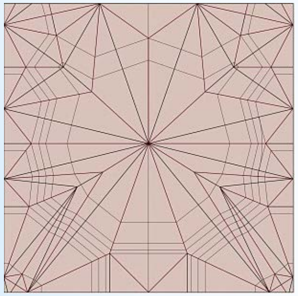
回転軸対称構造物の折り畳み

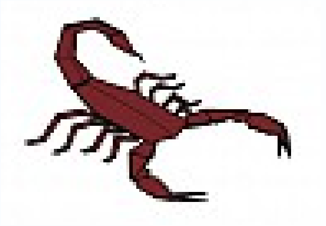
杉山 文子(京都大学)

はじめに

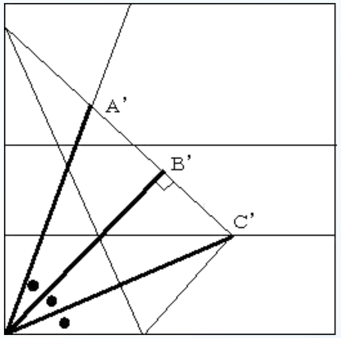








Robert. J. Lang



阿部恒

野島武敏

講演内容

(1)折り畳みの基本事項

(2)1本の線分を軸回転させたときにできる3次元構造体の折畳み
（円筒、円錐殻）

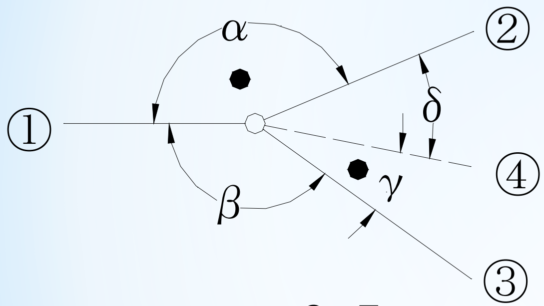
(3) 折れ線を軸回転させたときにできる3次元構造体の折畳み

(4)曲線を軸回転させたときにできる3次元構造体の折畳み
（球面、パラボラ面）

(5)球面の軸方向及び半径方向への同時折畳み

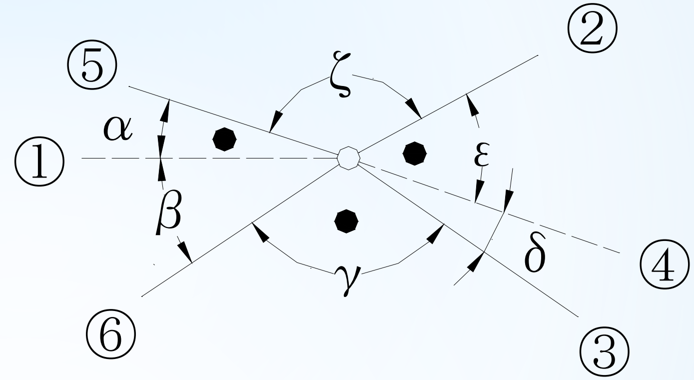
折り畳みの幾何学的基本事項

(a)



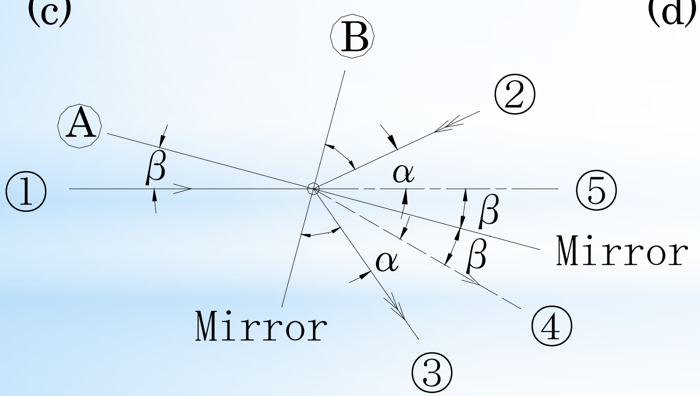
$\alpha+\gamma=\beta+\delta$

(b)



$\alpha+\gamma+\varepsilon=\beta+\delta+\zeta$

(c)



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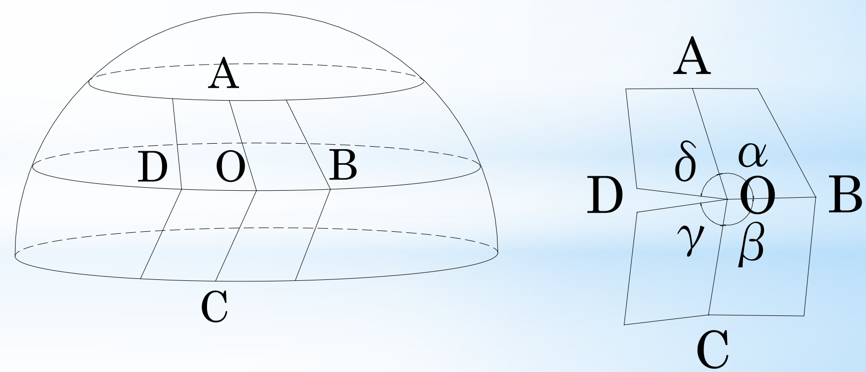


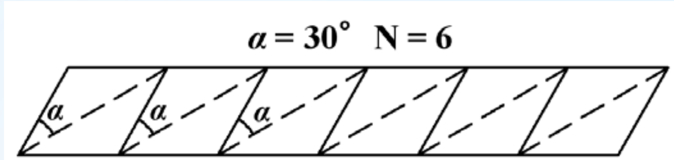
$\alpha+\gamma=\beta+\delta$

直交鏡面則

鏡面と考える直交する2本の直線の交点を節点として，この点でジグザグの折り線を交叉させると，自動的に折り畳み条件が成立つ．

1本の線分を軸周りに回転させた回転形状体の折畳み (円筒、円錐の折畳み)

α=2π/(2N)



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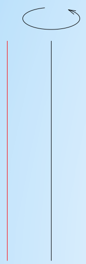

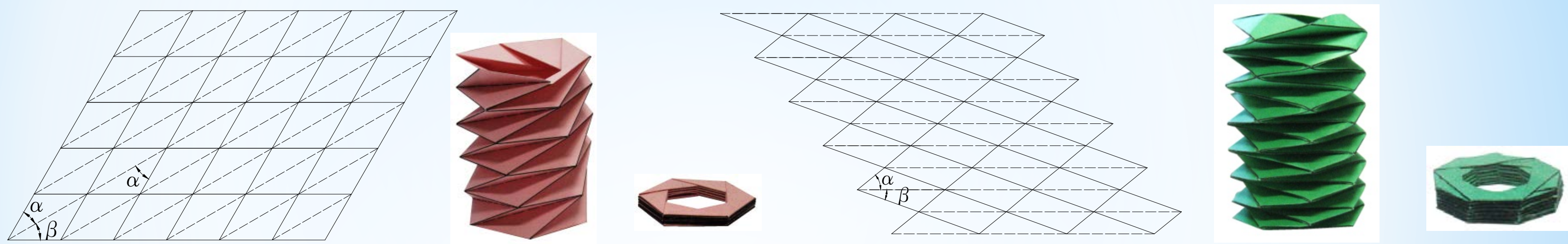

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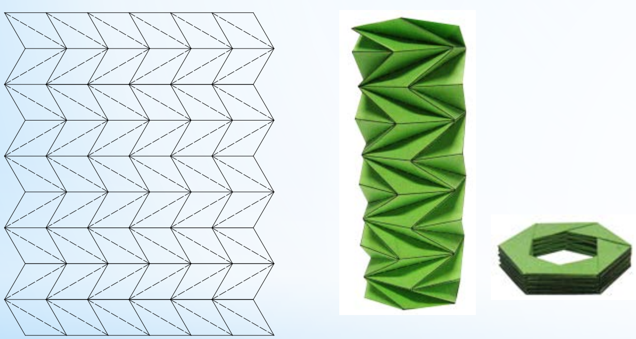

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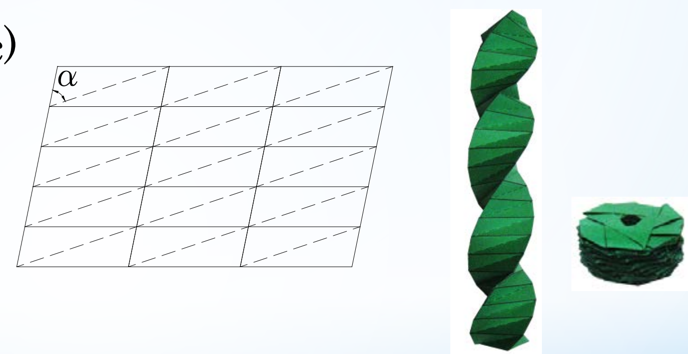

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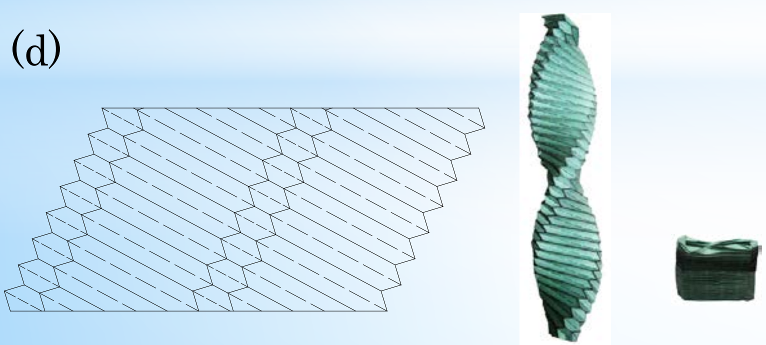

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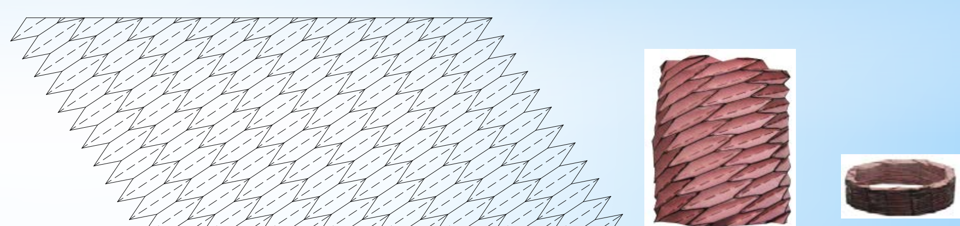

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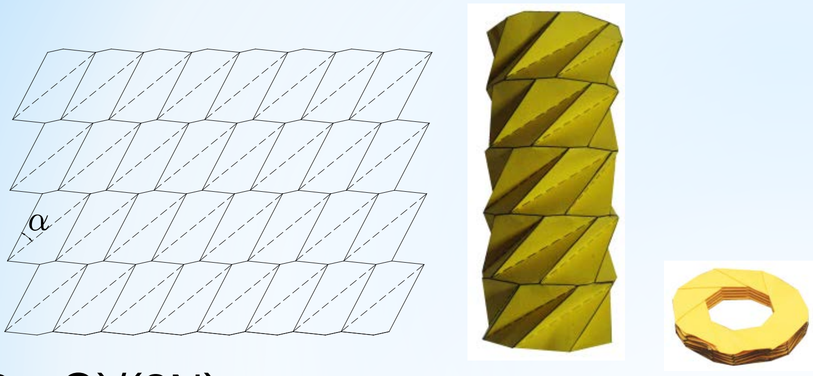
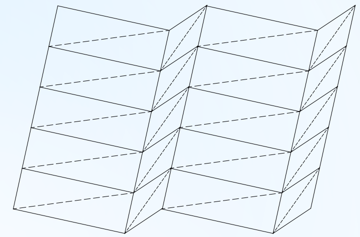
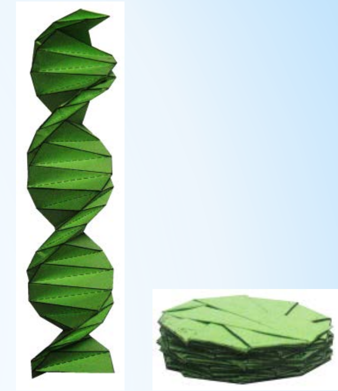


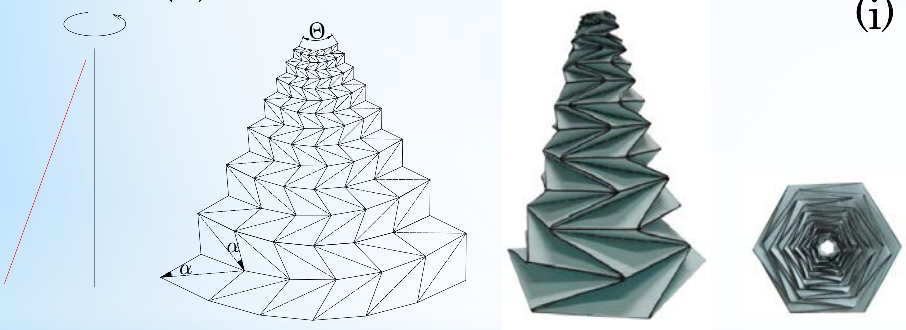
(g)



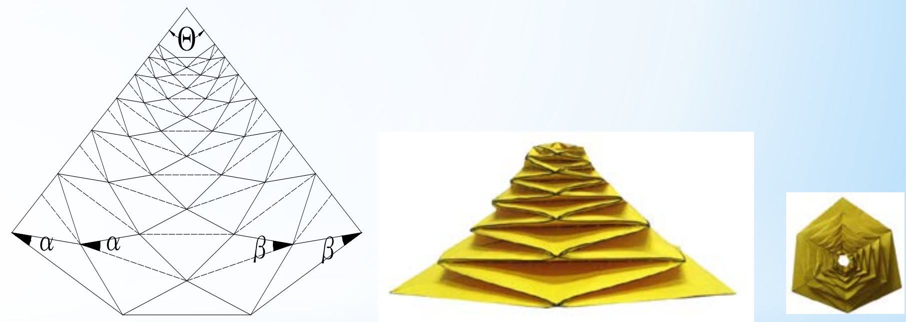


$\alpha = (2\pi - \Theta)/(2N)$

(h)



(i)



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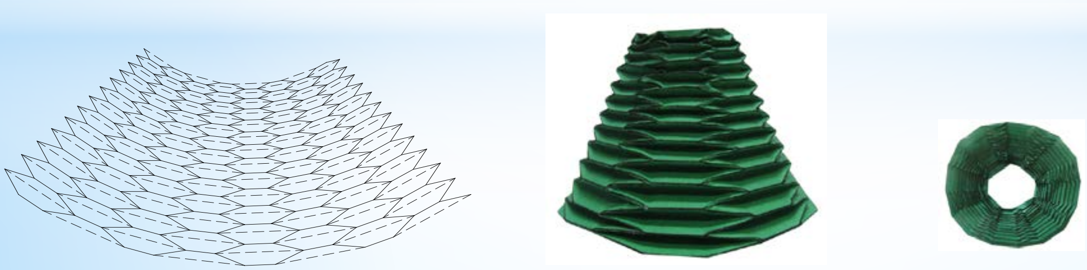
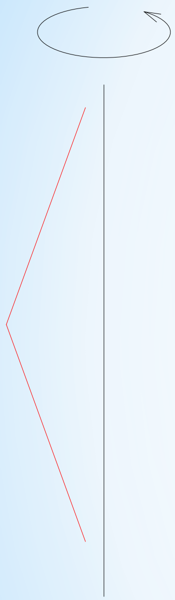
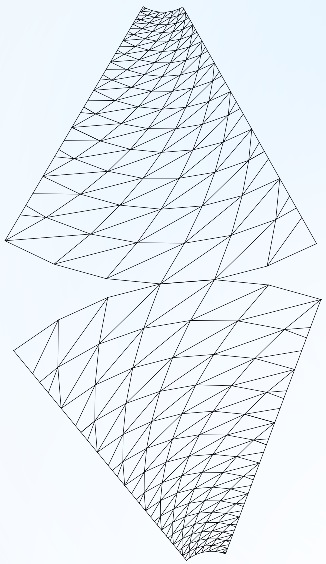
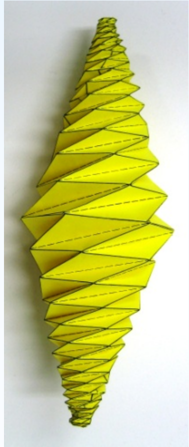
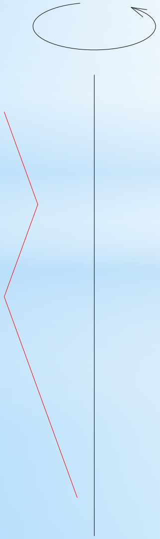
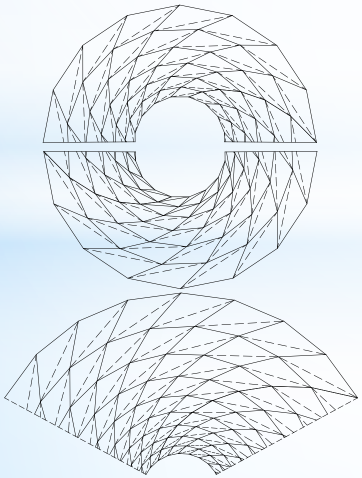


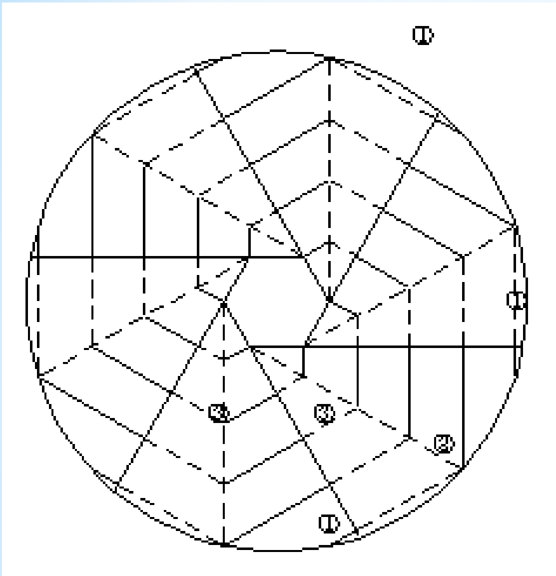
折れ線を軸周りに回転させてできる構造物の軸方向への折畳み

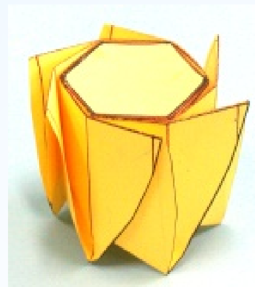



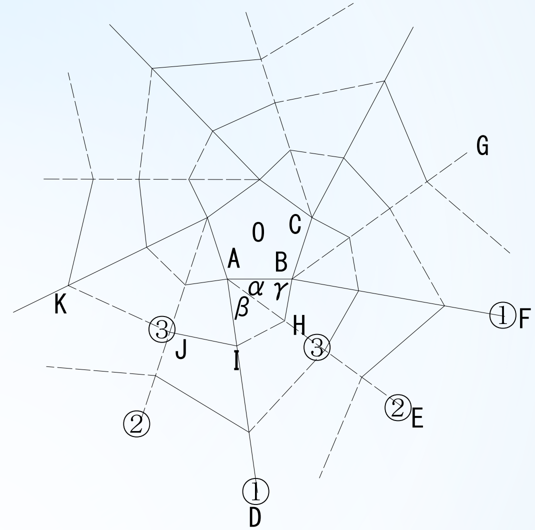



円錐台形状膜を軸周りに巻き取る方法(アルキメデスの螺旋状折線を用いる方法)

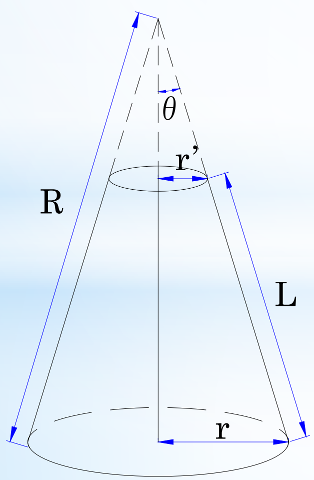




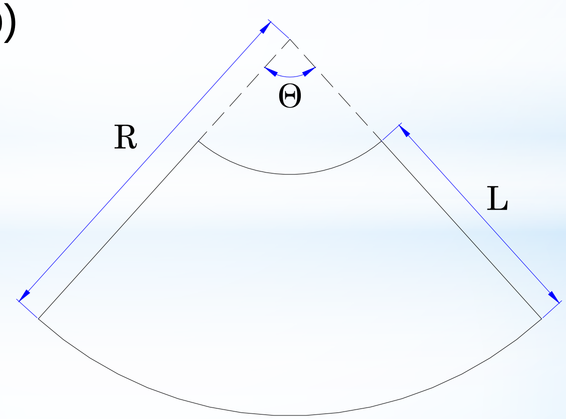


$\beta + \gamma = (\pi/2)(1+2/n)$

(a)



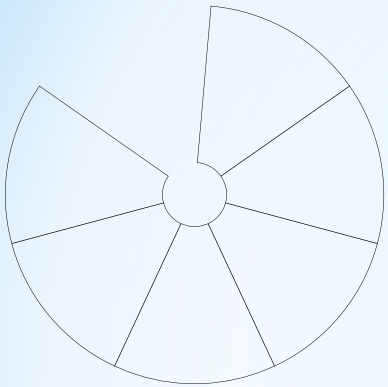
(b)



$$(R-L)\Theta = 2\pi r'$$

$$\Theta = 2\pi \sin\theta$$

(a)



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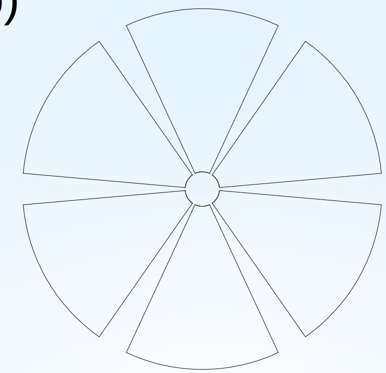

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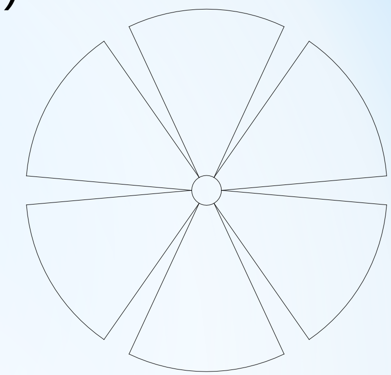

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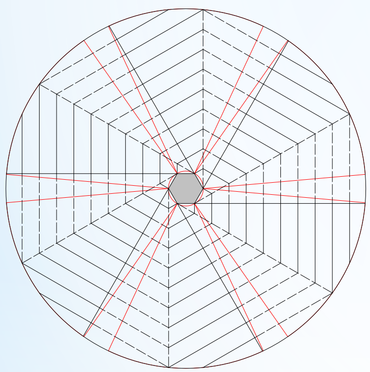

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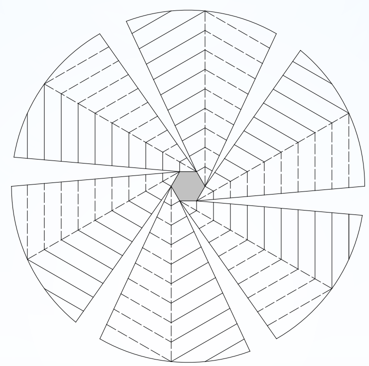

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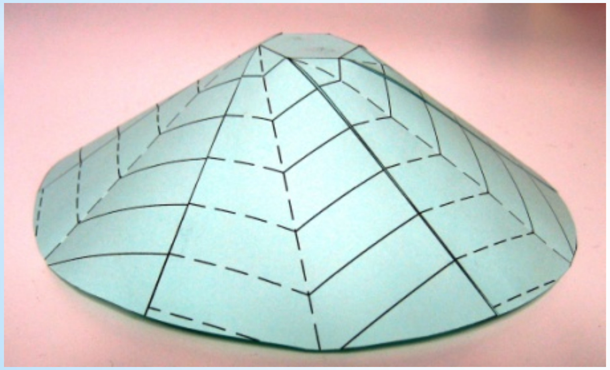
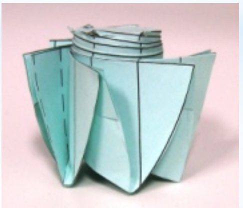
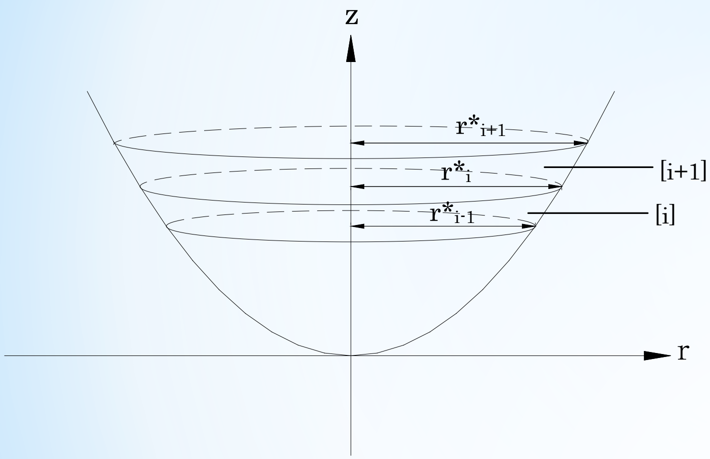


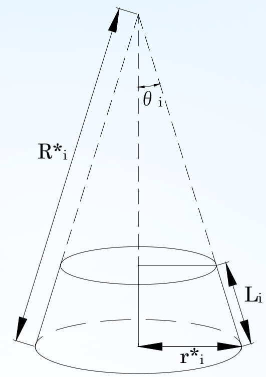
(g)

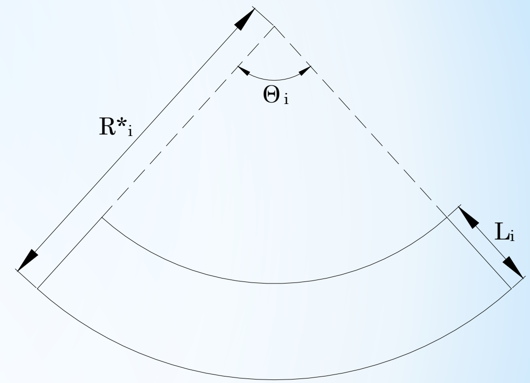


曲線を軸周りに回転させた回転形状膜の折畳み

パラボラ面の輪切り近似モデル

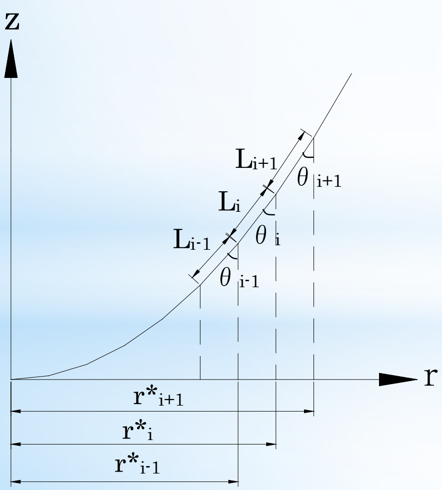


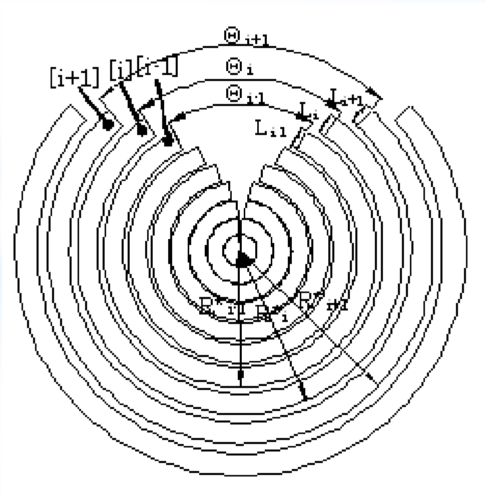




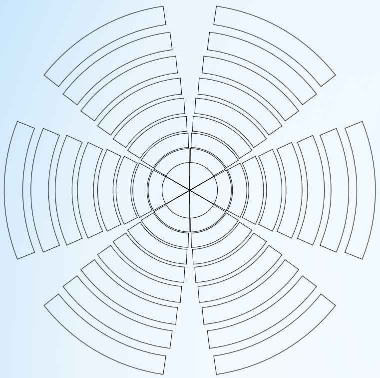
$$R^{*}{}_{i}\Theta_{i} = 2\pi r^{*}{}_{i}$$

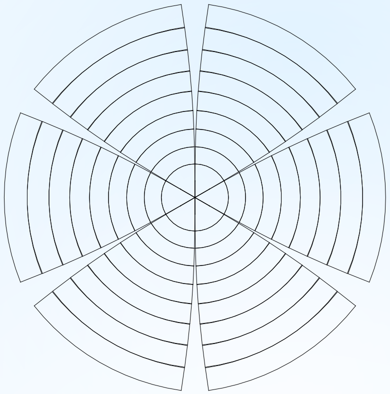
$$\Theta_{i} = 2\pi \sin\theta_{i}$$

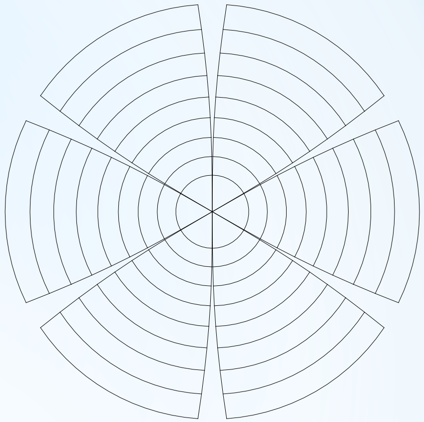


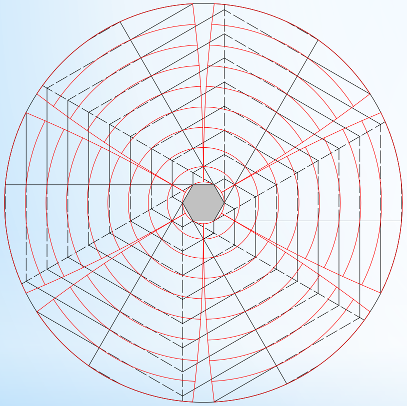


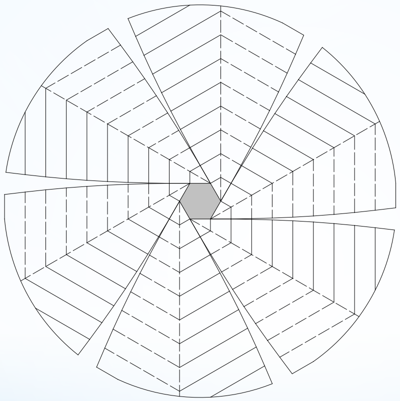
パラボラ面の巻取りモデル

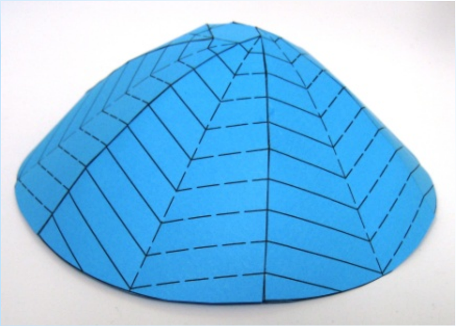


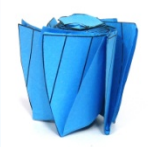


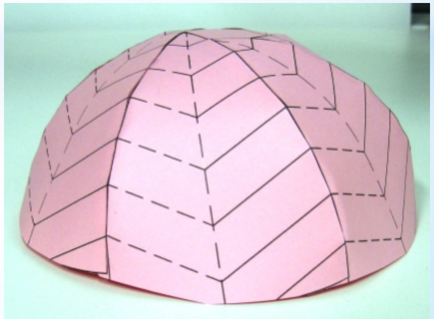






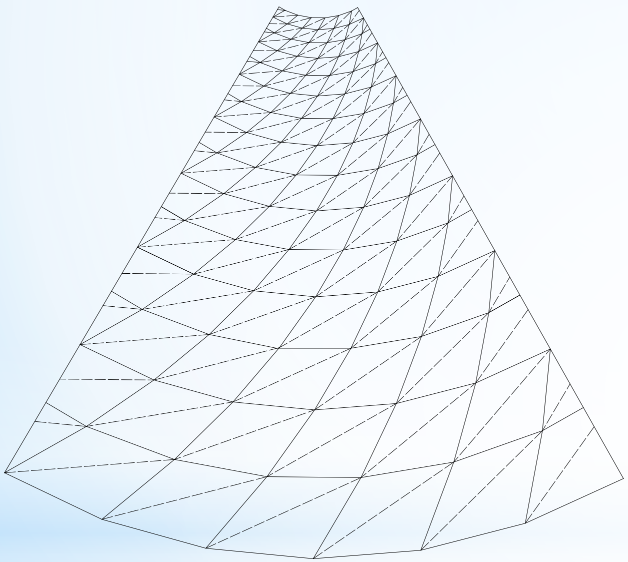






回転形状の膜構造の輪切りによる曲面の多面体近似と折り畳み

(a)



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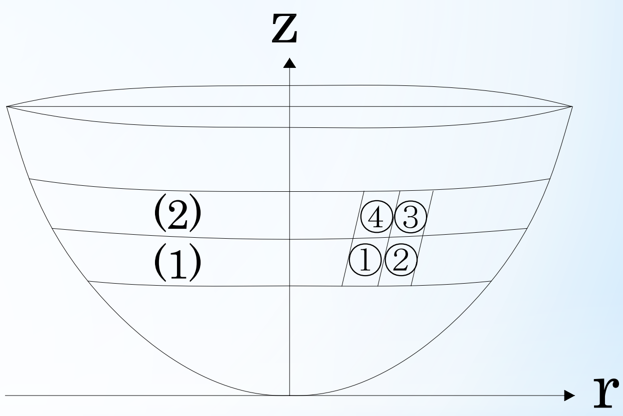


1節点 6折り線による展開図の折り畳み

$\alpha - \beta + \gamma = \delta - \varepsilon + \zeta$

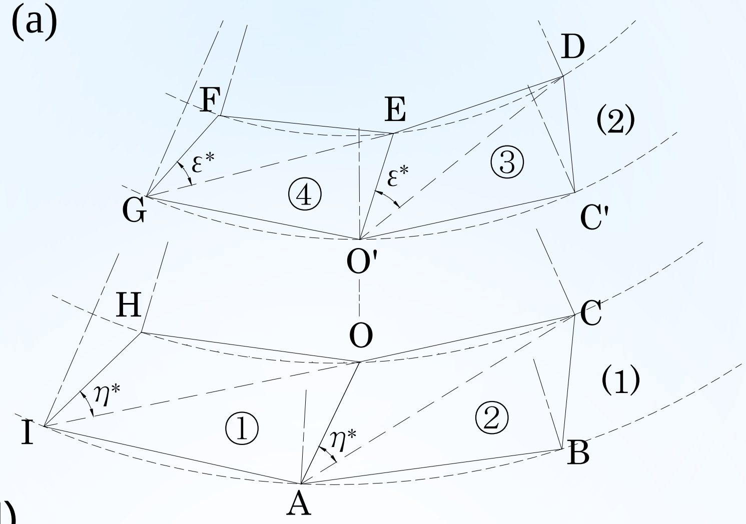
$\eta^* = (360^\circ - \Theta_1)/(2N)$
$\varepsilon^* = (360^\circ - \Theta_2)/(2N)$

$\beta = \eta^* + \Theta_1/N,\ \varepsilon = \varepsilon^*$

$\beta - \varepsilon = (\Theta_1 + \Theta_2)/(2N)$

$(\delta + \zeta) - (\alpha + \gamma) = -(\Theta_1 + \Theta_2)/(2N)$

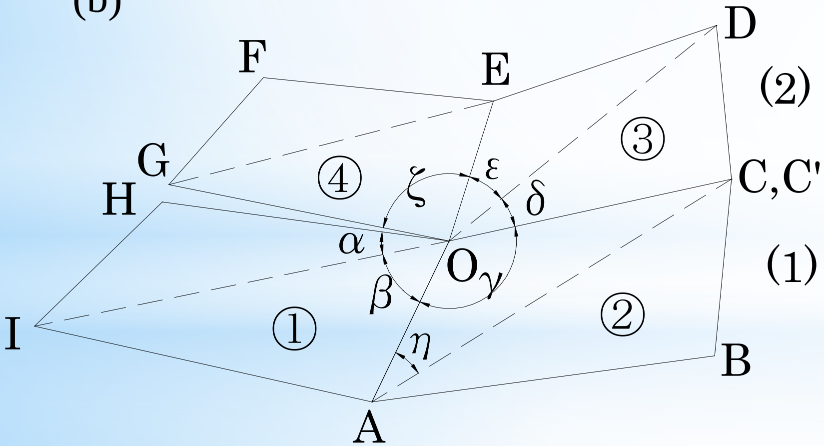
(a)



中心角: Θ_2

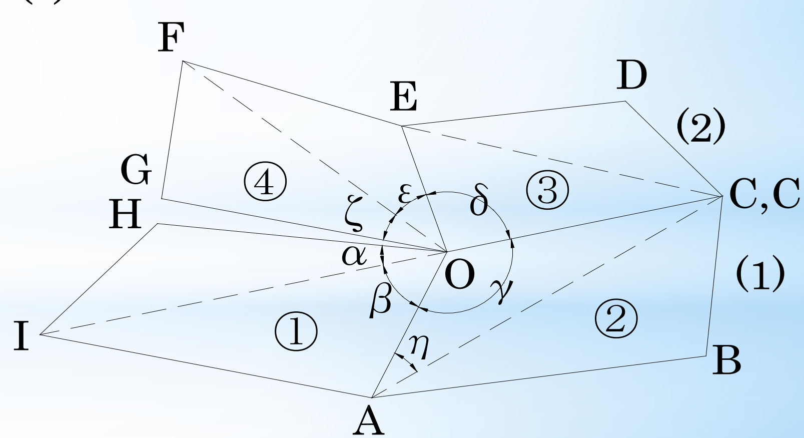
中心角: Θ_1

(b)



順螺旋型

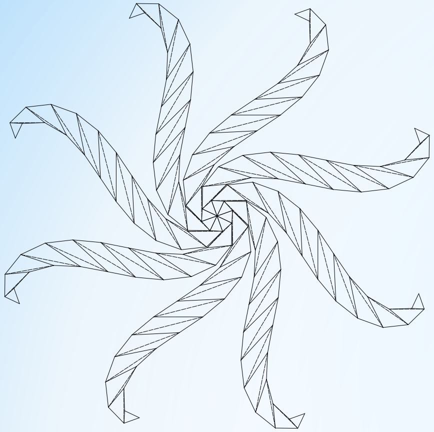
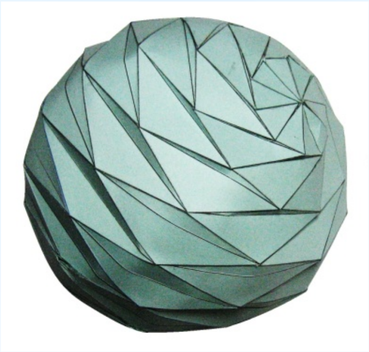
(c)



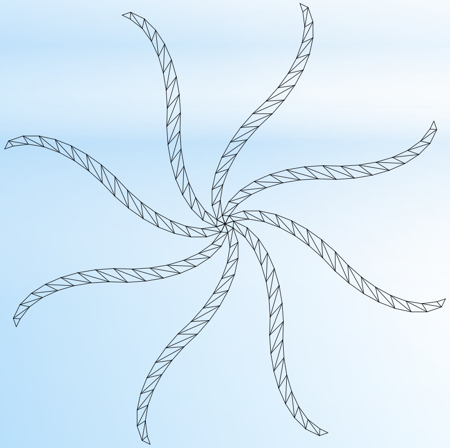
逆螺旋型

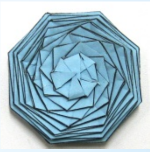
①, ②の内角の和より$\alpha + \beta + \gamma = \pi + \Theta_1/N$　　③, ④の内角の和より$\delta + \varepsilon + \zeta = \pi + \Theta_2/N$

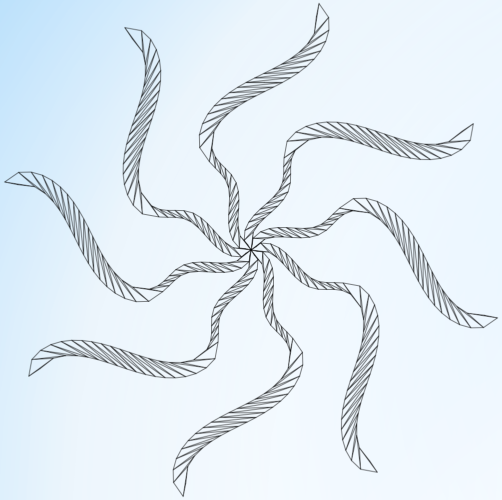
$(\delta + \zeta) - (\alpha + \gamma) = -(\Theta_1 + \Theta_2)/(2N)$

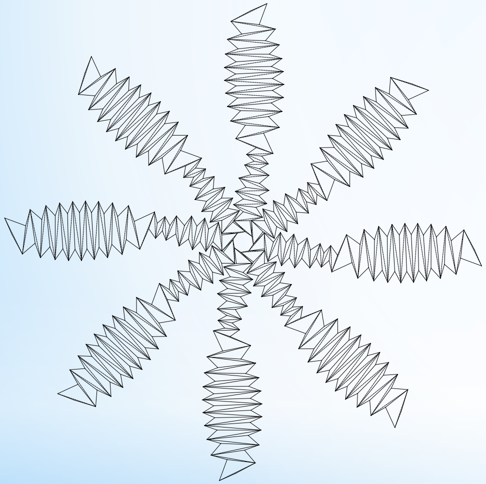



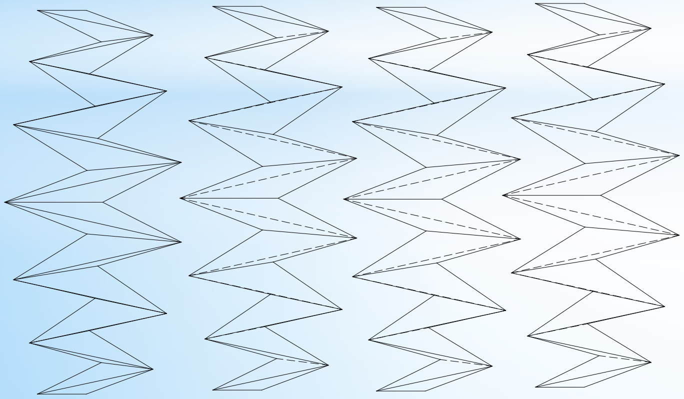






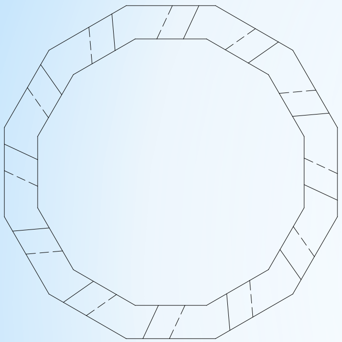



円形膜の折り畳み

円形膜を半径方向にその面内で平坦に折り畳む方法

(a)



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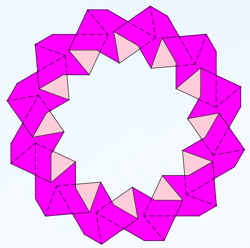
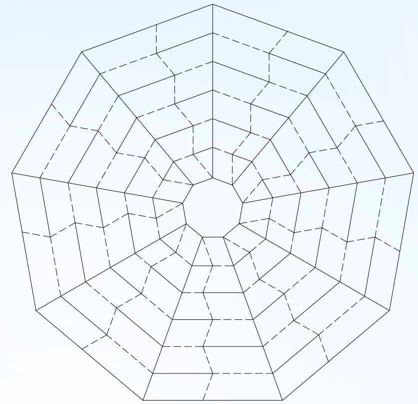


(c)



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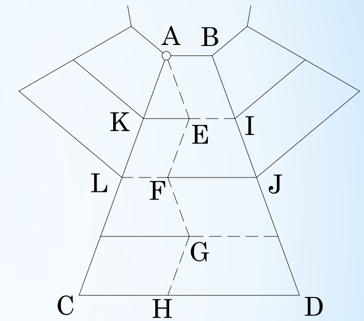

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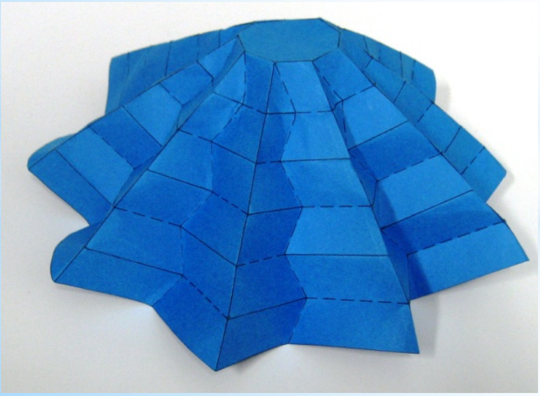


(f)

(g)

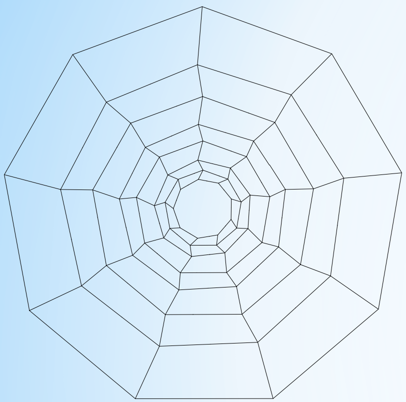
(h)







(a)



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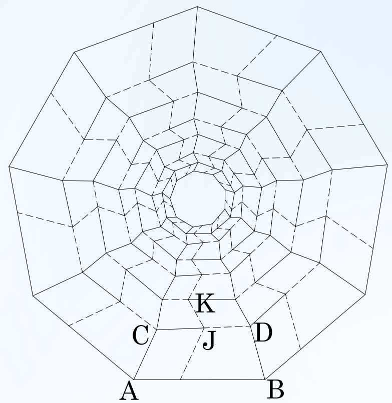

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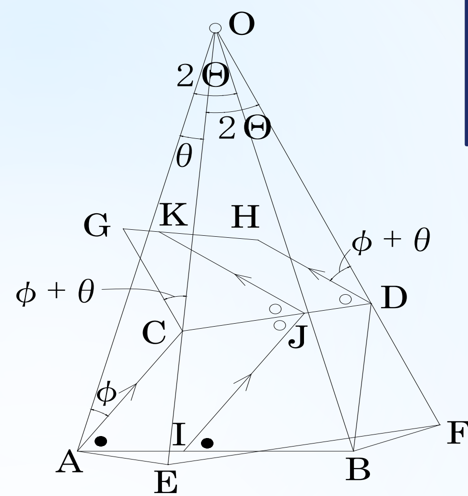


$\angle CAB = 90 - \Theta - \varphi$

⬇

$\angle IJC = 90 - \Theta - \varphi - \theta$

$\angle ODH = \varphi + \theta$

⬇

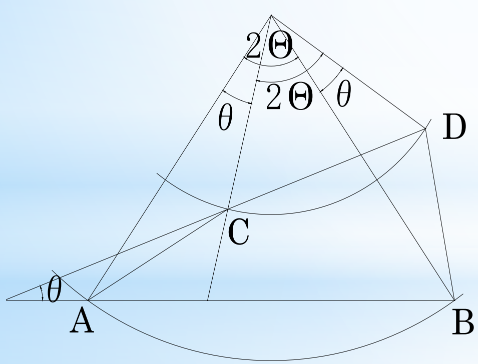
$\angle HDC = 90 - \Theta - (\varphi + \theta)$

⬇

$\angle KJC = 90 - \Theta - (\varphi + \theta)$

$\angle IJC = \angle KJC$

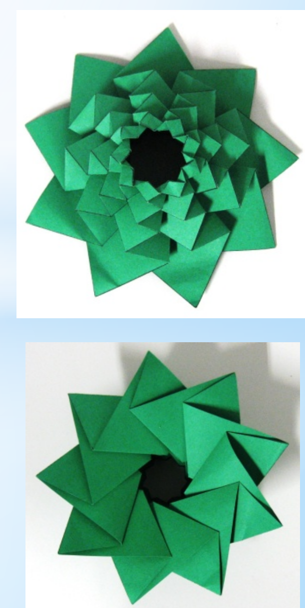
(d)



(e)

⇨

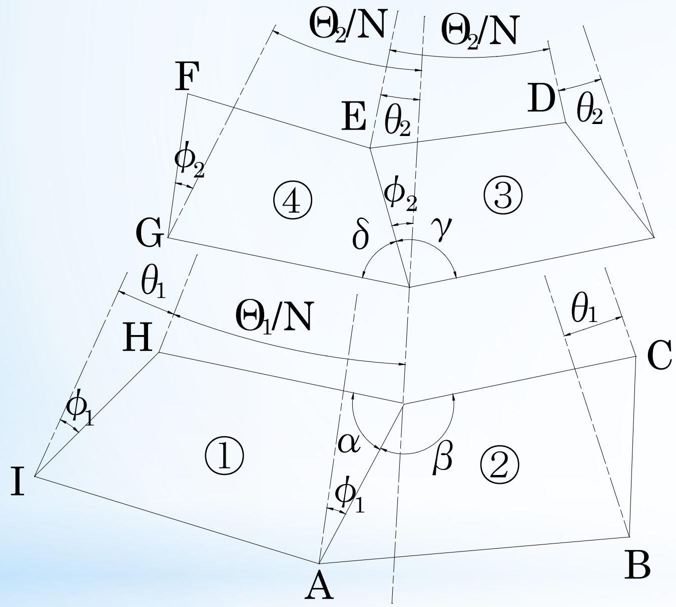
(f)



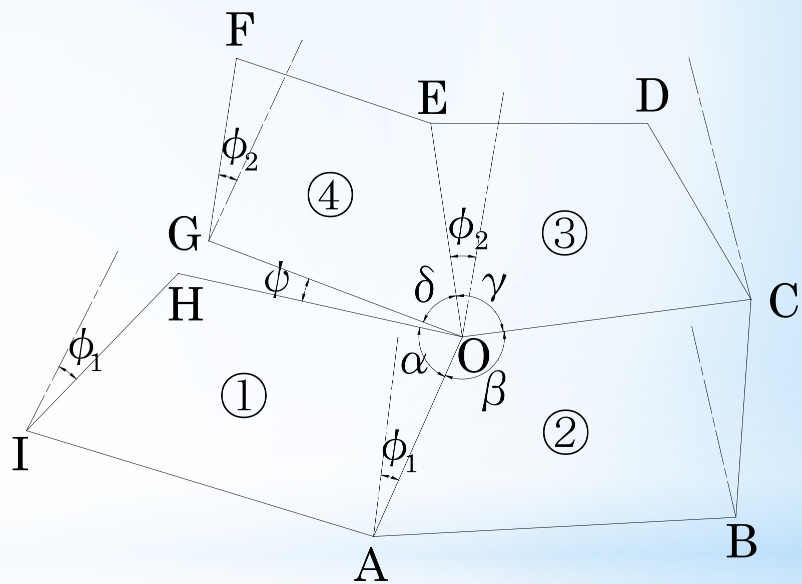
半径方向に折り畳む基本モデルの展開図でも平行に折り線を設けることで半径方向に収縮させながら平坦に折り畳むことができる。

1節点 4折り線による展開図の折り畳み

(a)



(b)



折り畳み条件： $\beta-\alpha=\gamma-\delta$

$\alpha=90+\Theta_1/N-(\theta_1+\varphi_1)$、　$\beta=90+\Theta_1/N+(\theta_1+\varphi_1)$、

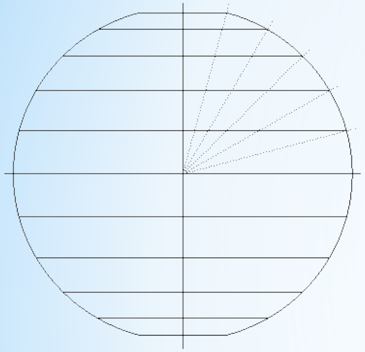
$\gamma=90+\Theta_2/N+\varphi_2$、　$\delta=90+\Theta_1/N-\varphi_2$

節点Oにおける折り畳み条件式、$\varphi_2=\varphi_1+\theta_1$

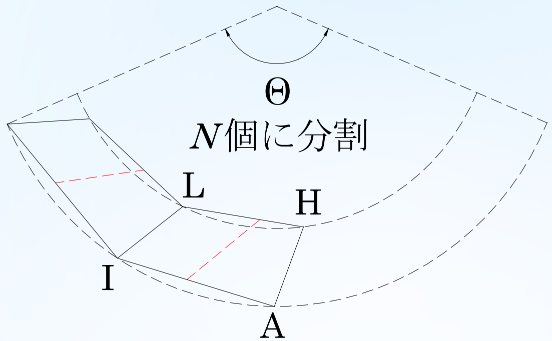
回転体においても、鏡面側が成立

半径及び軸方向に折り畳み可能な半球形状および球形状膜の設計

(a)



(b)



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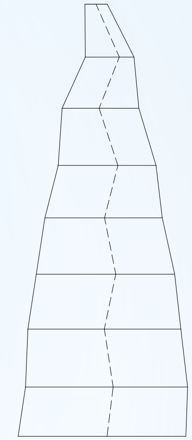

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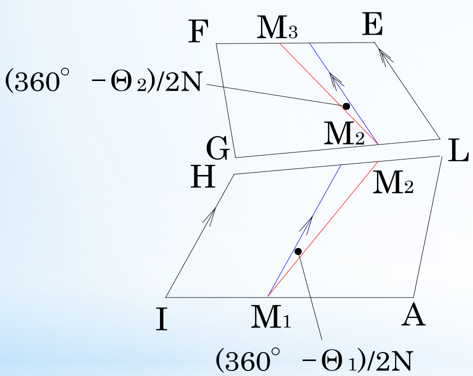
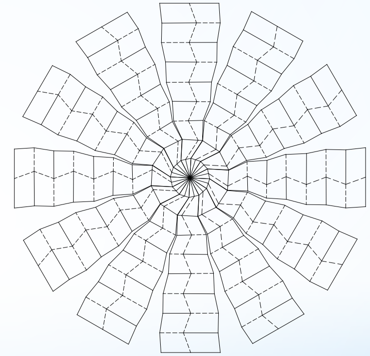


(e)

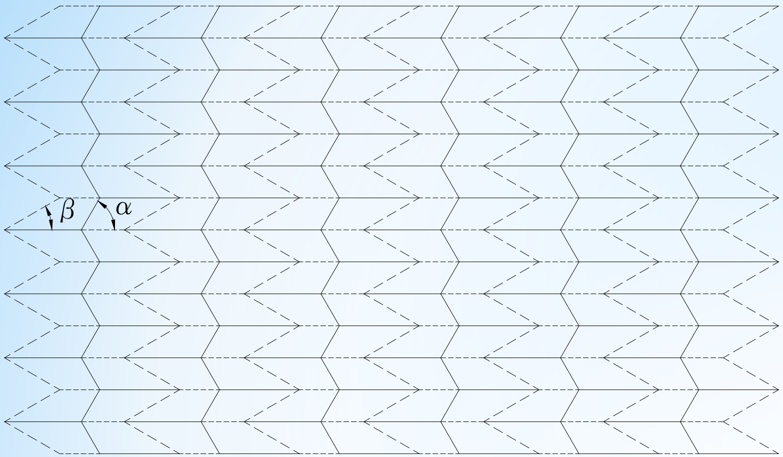


(f)

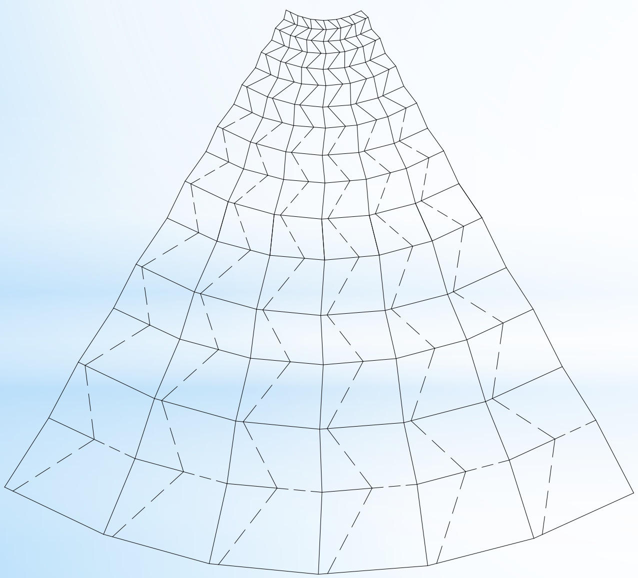
(g)

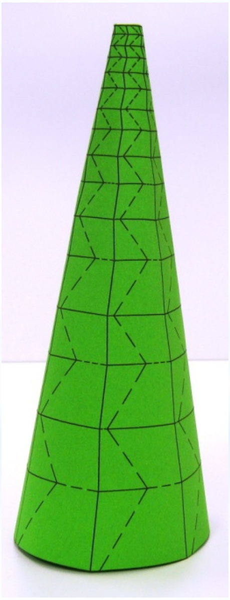
(h)

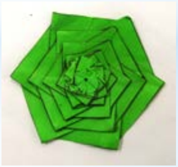
(i)



α-β=π/6







結　語

回転軸対称構造物の折り畳みについてまとめた。

1. 直線を軸回転させた構造物(円筒、円錐殻):節点の折り畳み条件および周方向に閉じる条件を満たすように設計する。

2. 曲線を回転させた構造物:円錐の折り畳みを応用する。

3. 軸方向に折り畳むと同時に半径方向に折り畳む方法:1節点4折線法に平行線を加えることによって実現できる。